Notices

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In This Document

Keysight EasyEXPERT software contains the application library which supports the characteristic measurements of CMOS devices, TFT, BJT, diode, resistor, capacitor, varactor, memory, nanotechnology devices such as CNT FET, and so on. The application library includes more than one hundred test definitions. And they are classified into the following categories.

- BJT
- CMOS
- Discrete
- GenericTest
- MCSMU_IV
- Memory
- MixedSignal
- NanoTech
- Organic
- PwrDevice
- Reliability
- Sample
- Solar Cell
- SPGU_PLSDIV
- Structure
- TFT
- Utility
- WGFMU
- WGFMU Utility
- WGFMU_IV
- GaN Diode
- GaN FET
- IGBT
- Interconnection
- MISCAP
- PowerBJT
- PowerDiode
- PowerMOSFET
- PMIC
- SiC
- GateCharge
- N1272A
- MultiHVSMU
- Thermal
- N1274A
- Advanced NVM
- Utility (NVM)
- Thyristor
What is described in the reference sections

Reference section contains detailed description of test definitions. The test definitions are listed in alphabetical order. Each entry explains one test definition and provides the information following to the next terms. Some sections may not follow to some terms and may follow to the terms not in this table.

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Brief explanation of the test definition.</td>
</tr>
<tr>
<td>Device Under Test</td>
<td>DUT name. The number of terminals, the connection information, and the other information may be included.</td>
</tr>
<tr>
<td>Required Modules and Accessories</td>
<td>Lists the required accessories, modules, and/or equipment. The connection information may be included.</td>
</tr>
<tr>
<td>Required Test Definition</td>
<td>Lists the test definitions if they are used in this test definition.</td>
</tr>
<tr>
<td>Device Parameters</td>
<td>Lists the parameters changeable in the Device Parameters area of the EasyEXPERT Application Test screen.</td>
</tr>
<tr>
<td>Test Parameters</td>
<td>Lists the parameters changeable in the Test Parameters area of the EasyEXPERT Application Test screen.</td>
</tr>
<tr>
<td>Extended Test Parameters</td>
<td>Lists the parameters changeable in the dialog box opened by clicking the Extended Setup button.</td>
</tr>
<tr>
<td>Measurement Parameters</td>
<td>Lists the parameters measured by this test definition.</td>
</tr>
<tr>
<td>User Function and Analysis Function</td>
<td>Lists the parameters used for the user function or the analysis function.</td>
</tr>
<tr>
<td>X-Y Plot or X-Y Graph</td>
<td>Lists the parameters to be displayed in the X-Y Graph Plot area, List Display area, or Parameters area on the Data Display window.</td>
</tr>
<tr>
<td>List Display</td>
<td></td>
</tr>
<tr>
<td>Parameters Display Area</td>
<td></td>
</tr>
<tr>
<td>Auto Analysis</td>
<td>Lists the parameters used for the auto analysis function.</td>
</tr>
<tr>
<td>Test Output: X-Y Graph</td>
<td>Lists the parameters defined in the Test Output tab screen of the Test Definition window. The parameters will be displayed in the X-Y Graph Plot area, List Display area, or Parameters area on the Data Display window.</td>
</tr>
<tr>
<td>Test Output: List Display</td>
<td></td>
</tr>
<tr>
<td>Test Output: Parameters</td>
<td></td>
</tr>
</tbody>
</table>
### Revision number

The test definitions are managed by using the revision number shown below.

<table>
<thead>
<tr>
<th>Revision Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.01.xx</td>
<td>Test definitions supported by EasyEXPERT A.01.xx and later.</td>
</tr>
<tr>
<td>A.01.20</td>
<td>Test definitions updated from A.01.xx or supported by EasyEXPERT A.02.00 and later.</td>
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<tr>
<td>A.02.00</td>
<td>This number is used by the Subsite move test definition only.</td>
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<td>A.03.00</td>
<td>Test definitions supported by EasyEXPERT A.03.00 and later.</td>
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<td>A.03.10</td>
<td>Test definitions supported by EasyEXPERT A.03.10 and later.</td>
</tr>
<tr>
<td>A.03.11</td>
<td>Test definitions supported by EasyEXPERT A.03.11 and later.</td>
</tr>
<tr>
<td>A.03.20</td>
<td>Test definitions supported by EasyEXPERT A.03.20 and later.</td>
</tr>
<tr>
<td>A.04.00</td>
<td>Test definitions supported by EasyEXPERT A.04.00 and later.</td>
</tr>
<tr>
<td>A.05.00</td>
<td>Test definitions supported by EasyEXPERT A.05.00 and later.</td>
</tr>
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<td>A.05.01</td>
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</tr>
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</tr>
<tr>
<td>A.05.50</td>
<td>Test definitions supported by EasyEXPERT A.05.50 and later.</td>
</tr>
<tr>
<td>A.06.00</td>
<td>Test definitions supported by EasyEXPERT A.06.00 and later.</td>
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<td>Test definitions supported by EasyEXPERT A.06.10 and later.</td>
</tr>
<tr>
<td>A.06.20</td>
<td>Test definitions supported by EasyEXPERT A.06.20 and later.</td>
</tr>
</tbody>
</table>

### Application Library

The application library is a set of test definitions effective for the EasyEXPERT application test execution mode. The application test can be performed by selecting a test definition and setting the test condition for the actual DUT (device under test). And the setup can be saved as the dedicated test setup for the DUT.

All test definitions are just sample. If the samples damage your devices, Keysight Technologies is NOT LIABLE for the damage.

### If you delete a test definition

Application library should be recovered. Import the test definition by using the Import Test Definition... function of the Library button. The original test definitions are stored in the following folders.

<program folder>\Agilent\B1500\EasyEXPERT\Application Tests
<program folder>\Agilent\B1500\EasyEXPERT\Contribution\Application Tests
# Supported Instrument and Required Equipment

Each test definition (Library) supports the following instrument, and requires the following accessories, modules, and/or equipment.

<table>
<thead>
<tr>
<th>Category</th>
<th>Test definition name</th>
<th>Supported instrument</th>
<th>Required equipment and quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BC Diode Fwd [2HL]</td>
<td>B2901A, B2902A, B2911A, B2912A</td>
<td>SMU×2. See Figure 2.</td>
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<td>BC diode Rev [2HL]</td>
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<td>BVcbo [2HL]</td>
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<td>BVceo [2HL]</td>
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<tr>
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<td>BVebo [2HL]</td>
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<td>B1500A</td>
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<td>Ctc-Vc</td>
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<td>MFCMU 1</td>
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<td>Ctc-Ve</td>
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<td>Cts</td>
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<td>MFCMU 1</td>
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<tr>
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<td>EB Diode Fwd [2HL]</td>
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<tr>
<td></td>
<td>G-Plot ConstVce Pulse</td>
<td>B1500A, E5260A, E5270B</td>
<td>SMU 4</td>
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<tr>
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<td>G-Plot ConstVce Pulse [2HL]</td>
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<td>SMU×2. See Figure 2.</td>
</tr>
<tr>
<td>Category</td>
<td>Test definition name</td>
<td>Supported instrument</td>
<td>Required equipment and quantity</td>
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<tr>
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<td>SMU×2. See Figure 2.</td>
<td></td>
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<tr>
<td>BJT G-Plot Vbc=0V Pulse</td>
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<tr>
<td>BJT G-Plot Vbc=0V Pulse [2HL]</td>
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<td>BJT G-Plot Vbc=0V [2HL]</td>
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<td>BJT hfe-Vbe ConstVce</td>
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<tr>
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<td>BJT Ic-Vc Pulse Ib</td>
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<tr>
<td>BJT Ic-Vc Pulse Ib [2HL]</td>
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<td>BJT Ic-Vc Pulse Vb</td>
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<tr>
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<td>BJT Rb</td>
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<td>BVdss</td>
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<td>Cgb-Vg HighVoltage</td>
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<td>Test definition name</td>
<td>Supported instrument</td>
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<td>Qg(High Vce Switching)</td>
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<td>N1272A, MPSMU 1, HVSMU 1</td>
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<td>[HCSMU 1 and SMU 1] or SMU 2</td>
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<td>Qg(High Ic + High Vce + JESD24-2)</td>
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<td>Qg(R Load High Ic + High Vce + JESD24-2)</td>
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<td>Qg(High Ic + High Vce)</td>
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<td>Qg(R Load High Ic + High Vce)</td>
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<td>Qg(R Load High Ic + JESD24-2)</td>
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<td>Qg(High Vce + JESD24-2)</td>
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<td>UHCU/HCSMU 1, MCSMU 2</td>
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<td>Qg(High Vce)</td>
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<td>Qg(JESD24-2 High Ic + JESD24-2 High Vce)</td>
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<td>Qg(High Id + High Vds + JESD24-2)</td>
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<td>Qg(R Load High Id + High Vds + JESD24-2)</td>
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<td>UHCU/HCSMU 1, MCSMU 2, HVSMU 1</td>
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<td>Qg(High Id + High Vds)</td>
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<td>Qg(R Load High Id + High Vds)</td>
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<td>Qg(High Id + JESD24-2)</td>
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<td>Qg(R Load High Id + JESD24-2)</td>
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<td>Qg(R Load High Id)</td>
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<td>Qg(High Vds + JESD24-2)</td>
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<td>Qg(JESD24-2 High Id + JESD24-2 High Vds)</td>
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a. This test definition cannot be executed individually. It is called from other test definitions.

**Note 1**
These test definitions belong to the categories PMIC, PowerMOSFET, and SiC.

**Note 2**
This test definition belongs to the categories IGBT, MISCAP, PMIC, PowerMOSFET, and SiC.
**Note 3**  
These test definitions belong to the categories IGBT and GateCharge.

**Note 4**  
These test definitions belong to the categories PowerMOSFET and GateCharge.

**Figure 1**  
DUT connections for using B2900 test definitions [1HL]

**Figure 2**  
DUT connections for using B2900 test definitions [2HL]
1 BJT
1. BC Diode Fwd: Base-Collector junction forward characteristics (A.01.20)
2. BC Diode Fwd [2HL]: Base-Collector junction forward characteristics (A.06.10)
3. BC diode Rev: Base-Collector junction reverse characteristics (A.01.20)
4. BC diode Rev [2HL]: Base-Collector junction reverse characteristics (A.06.10)
5. BVceo: Base-Collector junction breakdown voltage (A.01.20)
6. BVceo [2HL]: Base-Collector junction breakdown voltage (A.06.10)
7. BVcei: Emitter-Collector breakdown voltage (A.01.20)
8. BVceo: Emitter-Collector breakdown voltage, opened base (A.01.20)
9. BVceo [2HL]: Emitter-Collector breakdown voltage, opened base (A.06.10)
10. BVVebo: Emitter-Base breakdown voltage (A.01.20)
11. BVVebo [2HL]: Emitter-Base breakdown voltage (A.06.10)
12. CS Diode Fwd: Collector-Substrate junction forward characteristics (A.01.20)
13. CS Diode Fwd [2HL]: Collector-Substrate junction forward characteristics (A.06.10)
14. CS Diode Rev: Collector-Substrate junction reverse characteristics (A.01.20)
15. CS Diode Rev [2HL]: Collector-Substrate junction reverse characteristics (A.06.10)
16. Ctc-Freq Log: Ctc-f characteristics (A.01.20)
17. Ctc-Vc: Ctc-Vcb characteristics (A.01.20)
18. Cte-Ve: Cte-Veb characteristics (A.01.20)
19. Cts: Cts-Vsc characteristics (A.01.20)
20. EB Diode Fwd: Emitter-Base junction forward characteristics (A.01.20)
21. EB Diode Fwd [2HL]: Emitter-Base junction forward characteristics (A.06.10)
22. EB Diode Rev: Emitter-Base junction reverse characteristics (A.01.20)
23. EB Diode Rev [2HL]: Emitter-Base junction reverse characteristics (A.06.10)
24. G-Plot ConstVce Pulse: Ic-Vb characteristics, Vce=const, SMU Pulse (A.01.11)
25. G-Plot ConstVce Pulse [2HL]: Ic-Vb characteristics, Vce=const, SMU Pulse (A.06.10)
26. G-Plot ConstVce Pulse[3]: Ic-Vb characteristics, Vce=const, 3-terminal, SMU Pulse (A.01.11)
27. G-Plot ConstVc: Gummel characteristics, Vce=constant (A.01.20)
28. G-Plot ConstVc[3]: Gummel characteristics, Vce=constant, 3-terminal (A.01.20)
29. G-Plot ConstVc[2HL]: Gummel characteristics, Vce=constant (A.06.10)
30. G-Plot Vbc=0V Pulse: Ic-Vc characteristics, Vbc=0, SMU Pulse (A.01.11)
31. G-Plot Vbc=0V Pulse[3]: Ic-Vc characteristics, Vbc=0, 3-terminal, SMU Pulse (A.01.11)
32. G-Plot Vbc=0V (Vc=Vb) [2HL]: Gummel characteristics, Vbc=0V (Vc=Vb), SMU Pulse (A.06.10)
33. G-Plot Vbc=0V: Gummel characteristics, Vbc=0 (A.01.20)
34. G-Plot Vbc=0V[3]: Gummel characteristics, Vbc=0, 3-terminal (A.01.20)
35. G-Plot Vbc=0V (Vc=Vb) [2HL]: Gummel characteristics, Vbc=0V (Vc=Vb) (A.06.10)
36. hfe-Vbe ConstVce: hfe-Ic characteristics, Vce=constant (A.01.20)
37. hfe-Vbe Vbc=0V: hfe-Ic characteristics, Vbc=0, (A.01.20)
38. Ic-Vc Ib: Ic-Vc characteristics, Ib sweep (A.01.20)
39. Ic-Vc Ib[3]: Ic-Vc characteristics, 3-terminal, Ib sweep (A.01.20)
40. Ic-Vc Ib [2HL]: Ic-Vc characteristics, Ib sweep (A.06.10)
41. Ic-Vce Pulse Ib: Ic-Vc characteristics, Ib sweep, SMU Pulse (A.01.11)
42. Ic-Vce Pulse Ib[3]: Ic-Vc characteristics, 3-terminal, Ib sweep, SMU Pulse (A.01.11)
43. Ic-Vce Pulse Ib [2HL]: Ic-Vc characteristics, Ib sweep, SMU Pulse (A.06.10)
44. Ic-Vce Pulse Vb: Ic-Vc characteristics, Vb sweep, SMU Pulse (A.01.11)
45. Ic-Vce Pulse Vb[3]: Ic-Vc characteristics, 3-terminal, Vb sweep, SMU Pulse (A.01.11)
46. Ic-Vce Pulse Vb [2HL]: Ic-Vc characteristics, Vb sweep, SMU Pulse (A.06.10)
47. Ic-Vc Vb: Ic-Vc characteristics, Vb sweep (A.01.20)
48. Ic-Vc Vb[3]: Ic-Vc characteristics, 3-terminal, Vb sweep (A.01.20)
49. Ic-Vc Vb [2HL]: Ic-Vc characteristics, Vb sweep (A.06.10)
50. Rb: Base resistance (flyback method, 4-terminal) (A.01.20)
51. Rb [2HL]: Base resistance (flyback method, 4-terminal) (A.06.10)
52. Re+Rc: Collector resistance (including Emitter resistance, flyback method, 4-terminal) (A.01.20)
53. Re: Emitter resistance (flyback method, 4-terminal) (A.01.20)
54. Simple Gummel Plot: Evaluation of Gummel characteristics (Vce=const) (A.01.10)
55. Simple GummelPlot [2HL]: Evaluation of Gummel characteristics (Vce=const) (A.06.10)
56. Vbe-Le: hfe,Vbe-Le characteristics (A.01.20)
57. Vbe-We: hfe,Vbe-Le characteristics (A.01.20)
1 BJT

1.1 BC Diode Fwd: Base-Collector junction forward characteristics (A.01.20)

[Supported Analyzer]

[Description]
Measures the Base-Collector junction forward characteristics of BJT. Emitter and Substrate are opened.

[Device Under Test]
Bipolar transistor

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Lb: Base length
Wb: Base width
Temp: Temperature
Imax: Current compliance

[Test Parameters]
IntegTime: Integration time
Collector: SMU connected to Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcStep: Sweep step voltage for Collector terminal
Base: SMU connected to Base terminal, constant voltage output

[Extended Test Parameters]
Vb: Base voltage
HoldTime: Hold time
DelayTime: Delay time
BaseMinRng: Minimum range for the base current measurement
CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]
Collector current Icollector
Base current Ibase

[User Function]
IcPerArea=Icollector/Lb/Wb
IbPerArea=Ibase/Lb/Wb

[X-Y Plot]
X axis: Collector voltage Vcollector (LINEAR)
Y1 axis: Collector current Icollector (LOG)
Y2 axis: Collector current Icollector (LINEAR)
Y3 axis: Base current Ibase (LOG)
Y4 axis: Base current Ibase (LINEAR)
1.2 *BC Diode Fwd [2HL]: Base-Collector junction forward characteristics (A.06.10)*

[Supported Analyzer]
- B2901A, B2902A, B2911A, B2912A

[Description]
Measures the Base-Collector junction forward characteristics of BJT. Emitter and Substrate are opened.

[Device Under Test]
Bipolar transistor

[Device Parameters]
- Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
- Lb: Base length
- Wb: Base width
- Temp: Temperature
- Imax: Current compliance

[Test Parameters]
- IntegTime: Integration time
- Collector: SMU connected to Collector terminal, primary sweep voltage output
- VcStart: Sweep start voltage for Collector terminal
- VcStop: Sweep stop voltage for Collector terminal
- VcStep: Sweep step voltage for Collector terminal
- Base: SMU connected to Base terminal, constant voltage output

[Extended Test Parameters]
- Vb: Base voltage
- HoldTime: Hold time
- DelayTime: Delay time
- BaseMinRng: Minimum range for the base current measurement
- CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]
- Collector current Icollector
- Base current Ibase

[User Function]
- IcPerArea=Icollector/Lb/Wb
- IbPerArea=Ibase/Lb/Wb

[X-Y Plot]
- X axis: Collector voltage Vcollector (LINEAR)
- Y1 axis: Collector current Icollector (LOG)
- Y2 axis: Collector current Icollector (LINEAR)
- Y3 axis: Base current Ibase (LOG)
- Y4 axis: Base current Ibase (LINEAR)
1 BJT

1.3 BC diode Rev: Base-Collector junction reverse characteristics (A.01.20)

[Supported Analyzer]

[Description]
Measures the Base-Collector junction reverse characteristics of BJT. Emitter and Substrate are opened.

[Device Under Test]
Bipolar transistor

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Lb: Base length
Wb: Base width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Collector: SMU connected to Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcStep: Sweep step voltage for Collector terminal
IcLimit: Collector current compliance
Base: SMU connected to Base terminal, constant voltage output

[Extended Test Parameters]
Vb: Base voltage
HoldTime: Hold time
DelayTime: Delay time
BaseMinRng: Minimum range for the base current measurement
CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]
Collector current Icollector
Base current Ibase

[User Function]
IcPerArea=Icollector/Lb/Wb
IbPerArea=Ibase/Lb/Wb

[X-Y Plot]
X axis: Collector voltage Vcollector (LINEAR)
Y1 axis: Collector current Icollector (LOG)
Y2 axis: Base current Ibase (LOG)
1.4  BC diode Rev [2HL]: Base-Collector junction reverse characteristics (A.06.10)

[Supported Analyzer]
  B2901A, B2902A, B2911A, B2912A

[Description]
  Measures the Base-Collector junction reverse characteristics of BJT. Emitter and Substrate are opened.

[Device Under Test]
  Bipolar transistor

[Device Parameters]
  Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
  Lb: Base length
  Wb: Base width
  Temp: Temperature

[Test Parameters]
  IntegTime: Integration time
  Collector: SMU connected to Collector terminal, primary sweep voltage output
  VcStart: Sweep start voltage for Collector terminal
  VcStop: Sweep stop voltage for Collector terminal
  VcStep: Sweep step voltage for Collector terminal
  IcLimit: Collector current compliance
  Base: SMU connected to Base terminal, constant voltage output

[Extended Test Parameters]
  Vb: Base voltage
  HoldTime: Hold time
  DelayTime: Delay time
  BaseMinRng: Minimum range for the base current measurement
  CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]
  Collector current Icollector
  Base current Ibase

[User Function]
  IcPerArea=Icollector/Lb/Wb
  IbPerArea=Ibase/Lb/Wb

[X-Y Plot]
  X axis: Collector voltage Vcollector (LINEAR)
  Y1 axis: Collector current Icollector (LOG)
  Y2 axis: Base current Ibase (LOG)
1.5 **BV<sub>cbo</sub>: Base-Collector junction breakdown voltage (A.01.20)**

[Supported Analyzer]

[Description]
Measures the collector current vs collector voltage characteristics, and extracts the Base-Collector junction breakdown voltage (BV<sub>cbo</sub>). Emitter and Substrate are opened.

[Device Under Test]
- Bipolar transistor

[Device Parameters]
- Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
- L<sub>b</sub>: Base length
- W<sub>b</sub>: Base width
- Temp: Temperature

[Test Parameters]
- IntegTime: Integration time
- I<sub>c</sub>@BV<sub>cbo</sub>: Collector current to decide the breakdown
- Collector: SMU connected to Collector terminal, primary sweep voltage output
- V<sub>c</sub>Start: Sweep start voltage for Collector terminal
- V<sub>c</sub>Stop: Sweep stop voltage for Collector terminal
- V<sub>c</sub>Step: Sweep step voltage for Collector terminal
- Base: SMU connected to Base terminal, constant voltage output

[Extended Test Parameters]
- V<sub>b</sub>: Base voltage
- HoldTime: Hold time
- DelayTime: Delay time
- CollectorMinRng: Minimum range for the collector current measurement
- BaseMinRng: Minimum range for the base current measurement

[Measurement Parameters]
- Collector current I<sub>collector</sub>
- Base current I<sub>base</sub>
- For the all terminals, the SMU current compliance is set to I<sub>c</sub>@BV<sub>cbo</sub>*1.1.

[User Function]
- I<sub>c</sub>PerArea=I<sub>collector</sub>/L<sub>b</sub>/W<sub>b</sub>
- I<sub>b</sub>PerArea=I<sub>base</sub>/L<sub>b</sub>/W<sub>b</sub>

[Analysis Function]
- BV<sub>cbo</sub>=@L1X (X interrupt of Line1)

[X-Y Plot]
- X axis: Collector voltage V<sub>collector</sub> (LINEAR)
- Y1 axis: Collector current I<sub>collector</sub> (LOG)
- Y2 axis: Base current I<sub>base</sub> (LOG)

[Parameters Display Area]
- Base-Collector junction breakdown voltage BV<sub>cbo</sub>

[Auto Analysis]
- Line1: Vertical line through Y1 data at I<sub>collector</sub>=I<sub>c</sub>@BV<sub>cbo</sub>
1.6  \textit{BVcbo [2HL]: Base-Collector junction breakdown voltage (A.06.10)}

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the collector current vs collector voltage characteristics, and extracts the Base-Collector junction breakdown voltage (BVcbo). Emitter and Substrate are opened.

[Device Under Test]
Bipolar transistor

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Lb: Base length
Wb: Base width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Ic@BVcbo: Collector current to decide the breakdown Collector: SMU connected to Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcStep: Sweep step voltage for Collector terminal
Base: SMU connected to Base terminal, constant voltage output

[Extended Test Parameters]
Vb: Base voltage
HoldTime: Hold time
DelayTime: Delay time
CollectorMinRng: Minimum range for the collector current measurement
BaseMinRng: Minimum range for the base current measurement

[Measurement Parameters]
Collector current Icollector
Base current Ibase
For the all terminals, the SMU current compliance is set to Ic@BVcbo*1.1.

[User Function]
IcPerArea=Icollector/Lb/Wb
IbPerArea=Ibase/Lb/Wb

[Analysis Function]
BVcbo=@L1X (X interrupt of Line1)

[X-Y Plot]
X axis: Collector voltage Vcollector (LINEAR)
Y1 axis: Collector current Icollector (LOG)
Y2 axis: Base current Ibase (LOG)

[Parameters Display Area]
Base-Collector junction breakdown voltage BVcbo

[Auto Analysis]
Line1: Vertical line through Y1 data at Icollector=Ic@BVcbo
1.7 *BVcei: Emitter-Collector breakdown voltage (A.01.20)*

[Supported Analyzer]

[Description]
Measures the collector current vs collector voltage characteristics, and extracts the Emitter-Collector junction breakdown voltage (BVcei). Substrate is opened.

[Device Under Test]
Bipolar transistor

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Ic@BVcei: Collector current to decide the breakdown
Collector: SMU connected to Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcStep: Sweep step voltage for Collector terminal
Base: SMU connected to Base terminal, constant current output
Ib: Base current
VbLimit: Base voltage compliance
Emitter: SMU connected to Emitter terminal, constant voltage output

[Extended Test Parameters]
Ve: Emitter voltage
HoldTime: Hold time
DelayTime: Delay time
CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]
Collector current Icollector
Emitter current Iemitter
Base voltage Vbase
For the all terminals, the SMU current compliance is set to Ic@BVcei*1.1.

[User Function]
IcPerArea=Icollector/Le/We
IePerArea=Iemitter/Le/We

[Analysis Function]
BVcei=@L1X (X interrupt of Line1)

[X-Y Plot]
X axis: Collector voltage Vcollector (LINEAR)
Y1 axis: Collector current Icollector (LOG)
Y2 axis: Emitter current Iemitter (LOG)

[Parameters Display Area]
Emitter-Collector junction breakdown voltage BVcei

[Auto Analysis]
Line1: Vertical line through Y1 data at Icollector=Ic@BVcei
1.8 **BVceo: Emitter-Collector breakdown voltage, opened base (A.01.20)**

[Supported Analyzer]

[Description]
Measures the collector current vs collector voltage characteristics, and extracts the Emitter-Collector junction breakdown voltage (BVceo). Base and Substrate are opened.

[Device Under Test]
Bipolar transistor

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Ic@BVceo: Collector current to decide the breakdown
Collector: SMU connected to Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcStep: Sweep step voltage for Collector terminal
Emitter: SMU connected to Emitter terminal, constant voltage output

[Extended Test Parameters]
Ve: Emitter voltage
HoldTime: Hold time
DelayTime: Delay time
CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]
Collector current Icollector
Emitter current Iemitter
For the all terminals, the SMU current compliance is set to Ic@BVceo*1.1.

[User Function]
IcPerArea=Icollector/Le/We
IePerArea=Iemitter/Le/We

[Analysis Function]
BVceo=@L1X (X interrupt of Line1)

[X-Y Plot]
X axis: Collector voltage Vcollector (LINEAR)
Y1 axis: Collector current Icollector (LOG)
Y2 axis: Emitter current Iemitter (LOG)

[Parameters Display Area]
Emitter-Collector junction breakdown voltage BVceo

[Auto Analysis]
Line1: Vertical line through Y1 data at Icollector=Ic@BVceo
1 BJT

1.9 BVceo [2HL]: Emitter-Collector breakdown voltage, opened base (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the collector current vs collector voltage characteristics, and extracts the Emitter-Collector junction breakdown voltage (BVceo). Base and Substrate are opened.

[Device Under Test]
Bipolar transistor

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Ic@BVceo: Collector current to decide the breakdown
Collector: SMU connected to Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcStep: Sweep step voltage for Collector terminal
Emitter: SMU connected to Emitter terminal, constant voltage output

[Extended Test Parameters]
Ve: Emitter voltage
HoldTime: Hold time
DelayTime: Delay time
CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]
Collector current Icollector
Emitter current Iemitter
For the all terminals, the SMU current compliance is set to Ic@BVceo*1.1.

[User Function]
IcPerArea=Icollector/Le/We
IePerArea=Iemitter/Le/We

[Analysis Function]
BVceo=@L1X (X interrupt of Line1)

[X-Y Plot]
X axis: Collector voltage Vcollector (LINEAR)
Y1 axis: Collector current Icollector (LOG)
Y2 axis: Emitter current Iemitter (LOG)

[Parameters Display Area]
Emitter-Collector junction breakdown voltage BVceo

[Auto Analysis]
Line1: Vertical line through Y1 data at Icollector=Ic@BVceo
1.10 BVebo: Emitter-Base breakdown voltage (A.01.20)

[Supported Analyzer]

[Description]
Measures the emitter current vs emitter voltage characteristics, and extracts the Emitter-Base junction breakdown voltage (BVebo). Collector and Substrate are opened.

[Device Under Test]
- Bipolar transistor

[Device Parameters]
- Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
- Le: Emitter length
- We: Emitter width
- Temp: Temperature

[Test Parameters]
- IntegTime: Integration time
- Ie@BVebo: Emitter current to decide the breakdown
- Emitter: SMU connected to Emitter terminal, primary sweep voltage output
- VeStart: Sweep start voltage for Emitter terminal
- VeStop: Sweep stop voltage for Emitter terminal
- VeStep: Sweep step voltage for Emitter terminal
- Base: SMU connected to Base terminal, constant voltage output

[Extended Test Parameters]
- Vb: Base voltage
- HoldTime: Hold time
- DelayTime: Delay time
- EmitterMinRng: Minimum range for the emitter current measurement
- BaseMinRng: Minimum range for the base current measurement

[Measurement Parameters]
- Emitter current Iemitter
- Base current Ibase
For the all terminals, the SMU current compliance is set to Ie@BVebo*1.1.

[User Function]
- IePerArea=Iemitter/Le/We
- IbPerArea=Ibase/Le/We

[Analysis Function]
- BVebo=@L1X (X interrupt of Line1)

[X-Y Plot]
- X axis: Emitter voltage Vemitter (LINEAR)
- Y1 axis: Emitter current Iemitter (LOG)
- Y2 axis: Base current Ibase (LOG)

[Parameters Display Area]
- Emitter-Base junction breakdown voltage BVebo

[Auto Analysis]
- Line1: Vertical line through Y1 data at Iemitter=Ie@BVebo
1.11 BVebo [2HL]: Emitter-Base breakdown voltage (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the emitter current vs emitter voltage characteristics, and extracts the Emitter-Base junction breakdown voltage (BVebo). Collector and Substrate are opened.

[Device Under Test]
Bipolar transistor

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Ie@BVebo: Emitter current to decide the breakdown
Emitter: SMU connected to Emitter terminal, primary sweep voltage output
VeStart: Sweep start voltage for Emitter terminal
VeStop: Sweep stop voltage for Emitter terminal
VeStep: Sweep step voltage for Emitter terminal
Base: SMU connected to Base terminal, constant voltage output

[Extended Test Parameters]
Vb: Base voltage
HoldTime: Hold time
DelayTime: Delay time
EmitterMinRng: Minimum range for the emitter current measurement
BaseMinRng: Minimum range for the base current measurement

[Measurement Parameters]
Emitter current Iemitter
Base current Ibase
For the all terminals, the SMU current compliance is set to Ie@BVebo*1.1.

[User Function]
IePerArea=Iemitter/Le/We
IbPerArea=Ibase/Le/We

[Analysis Function]
BVebo=@L1X (X interrupt of Line1)

[X-Y Plot]
X axis: Emitter voltage Vemitter (LINEAR)
Y1 axis: Emitter current Iemitter (LOG)
Y2 axis: Base current Ibase (LOG)

[Parameters Display Area]
Emitter-Base junction breakdown voltage BVebo

[Auto Analysis]
Line1: Vertical line through Y1 data at Iemitter=Ie@BVebo
1.12 CS Diode Fwd: Collector-Substrate junction forward characteristics
(A.01.20)

[Supported Analyzer]

[Description]
Measures the Collector-Substrate junction forward characteristics of BJT. Base and Emitter are opened.

[Device Under Test]
Bipolar transistor, 4 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Lc: Collector length
Wc: Collector width
Temp: Temperature
Imax: Current compliance

[Test Parameters]
IntegTime: Integration time
Subs: SMU connected to Substrate, primary sweep voltage output
VsubsStart: Sweep start voltage for Substrate
VsubsStop: Sweep stop voltage for Substrate
VsubsStep: Sweep step voltage for Substrate
Collector: SMU connected to Collector terminal, constant voltage output

[Extended Test Parameters]
Vc: Collector voltage
HoldTime: Hold time
DelayTime: Delay time
CollectorMinRng: Minimum range for the collector current measurement
SubsMinRng: Minimum range for the substrate current measurement

[Measurement Parameters]
Substrate current Isubs
Collector current Icollector

[User Function]
IcPerArea=Icollector/Lc/Wc
IsubsPerArea=Isubs/Lc/Wc

[X-Y Plot]
X axis: Substrate voltage Vsubs (LINEAR)
Y1 axis: Substrate current Isubs (LINEAR)
Y2 axis: Substrate current Isubs (LOG)
Y3 axis: Collector current Icollector (LINEAR)
Y4 axis: Collector current Icollector (LOG)
1 BJT

1.13 CS Diode Fwd [2HL]: Collector-Substrate junction forward characteristics (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the Collector-Substrate junction forward characteristics of BJT. Base and Emitter are opened.

[Device Under Test]
Bipolar transistor, 4 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Lc: Collector length
WC: Collector width
Temp: Temperature
Imax: Current compliance

[Test Parameters]
IntegTime: Integration time
Subs: SMU connected to Substrate, primary sweep voltage output
VsubsStart: Sweep start voltage for Substrate
VsubsStop: Sweep stop voltage for Substrate
VsubsStep: Sweep step voltage for Substrate
Collector: SMU connected to Collector terminal, constant voltage output

[Extended Test Parameters]
Vc: Collector voltage
HoldTime: Hold time
DelayTime: Delay time
CollectorMinRng: Minimum range for the collector current measurement
SubsMinRng: Minimum range for the substrate current measurement

[Measurement Parameters]
Substrate current Isubs
Collector current Icollector

[User Function]
IcPerArea=Icollector/Lc/Wc
IsubsPerArea=Isubs/Lc/Wc

[X-Y Plot]
X axis: Substrate voltage Vsubs (LINEAR)
Y1 axis: Substrate current Isubs (LINEAR)
Y2 axis: Substrate current Isubs (LOG)
Y3 axis: Collector current Icollector (LINEAR)
Y4 axis: Collector current Icollector (LOG)
1.14 CS Diode Rev: Collector-Substrate junction reverse characteristics (A.01.20)

[Supported Analyzer]

[Description]
Measures the Collector-Substrate junction reverse characteristics of BJT. Base and Emitter are opened.

[Device Under Test]
Bipolar transistor, 4 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Lc: Collector length
Wc: Collector width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Subs: SMU connected to Substrate, primary sweep voltage output
VsubsStart: Sweep start voltage for Substrate
VsubsStop: Sweep stop voltage for Substrate
VsubsStep: Sweep step voltage for Substrate
IsubsLimit: Substrate current compliance
Collector: SMU connected to Collector terminal, constant voltage output

[Extended Test Parameters]
Vc: Collector voltage
HoldTime: Hold time
DelayTime: Delay time
CollectorMinRng: Minimum range for the collector current measurement
SubsMinRng: Minimum range for the substrate current measurement

[Measurement Parameters]
Substrate current Isubs
Collector current Icollector

[User Function]
IcPerArea=Icollector/Lc/Wc
IsubsPerArea=Isubs/Lc/Wc

[X-Y Plot]
X axis: Substrate voltage Vsubs (LINEAR)
Y1 axis: Substrate current Isubs (LOG)
Y2 axis: Collector current Icollector (LOG)
1.15 CS Diode Rev [2HL]: Collector-Substrate junction reverse characteristics (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the Collector-Substrate junction reverse characteristics of BJT. Base and Emitter are opened.

[Device Under Test]
Bipolar transistor, 4 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Lc: Collector length
Wc: Collector width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Subs: SMU connected to Substrate, primary sweep voltage output
VsubsStart: Sweep start voltage for Substrate
VsubsStop: Sweep stop voltage for Substrate
VsubsStep: Sweep step voltage for Substrate
IsubsLimit: Substrate current compliance
Collector: SMU connected to Collector terminal, constant voltage output

[Extended Test Parameters]
Vc: Collector voltage
HoldTime: Hold time
DelayTime: Delay time
CollectorMinRng: Minimum range for the collector current measurement
SubsMinRng: Minimum range for the substrate current measurement

[Measurement Parameters]
Substrate current Isubs
Collector current Icollector

[User Function]
IcPerArea=Icollector/Lc/Wc
IsubsPerArea=Isubs/Lc/Wc

[X-Y Plot]
X axis: Substrate voltage Vsubs (LINEAR)
Y1 axis: Substrate current Isubs (LOG)
Y2 axis: Collector current Icollector (LOG)
1.16 Ctc-Freq Log: Ctc-f characteristics (A.01.20)

[Supported Analyzer]
B1500A

[Description]
Measures BJT's characteristics of base-to-collector capacitance (Ctc, linear) vs frequency (f, log). The measurement frequency is 10 points per decade.
For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
Bipolar transistor, 4 terminals
Connect CMU High and CMU Low to the collector terminal and base terminal respectively. For the emitter and substrate, connect GNDU.

[Required Modules and Accessories]
Keysight B1520A MFCMU 1 unit

[Device Parameters]
Polarity: NPN (CMU forces the specified value) or PNP (CMU forces the negative specified value)
Le: Emitter length
We: Emitter width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Base: CMU connected between Base and Collector
FreqStart: Sweep start frequency
NoOfDecade: Number of decades for data collection
OscLevel: Measurement signal level
Vcb: Collector-Base voltage, constant voltage output

[Extended Test Parameters]
G_Min: Minimum transconductance value for graph
G_Max: Maximum transconductance value for graph
Cp_Min: Minimum capacitance value for graph
Cp_Max: Maximum capacitance value for graph

[Measurement Parameters]
Parallel capacitance Cp
Conductance G

[User Function]
Circular constant PI=3.141592653589
Frequency Frequency=Freq
Dissipation factor D=G/(2*PI*Freq*Cp)
1 BJT

Parallel resistance \( R_p = \frac{1}{G} \)
Series capacitance \( C_s = (1 + D^2)C_p \)
Reactance \( X = -\frac{1}{(2\pi Freq \cdot C_s)} \)
Series resistance \( R_s = D \cdot abs(X) \)
Impedance \( Z = \sqrt{R_s^2 + X^2} \)
Phase Theta = \( atan(X/R_s) \)

[X-Y Plot]
  X axis: Frequency Freq (LOG)
  Y1 axis: Base-Collector capacitance (parallel capacitance) \( C_p \) (LINEAR)
  Y2 axis: Conductance \( G \) (LINEAR)

[List Display]
  Frequency Freq
  Base-Collector capacitance (parallel capacitance) \( C_p \)
  Conductance \( G \)
  Series capacitance \( C_s \)
  Series resistance \( R_s \)
  Parallel resistance \( R_p \)
  Dissipation factor \( D \)
  Reactance \( X \)
  Impedance \( Z \)
  Phase Theta
  Collector voltage \( V_{c} \)

[Test Output: X-Y Graph]
  X axis: Frequency FreqList (LOG)
  Y1 axis: Base-Collector capacitance (parallel capacitance) \( C_pList \) (LINEAR)
  Y2 axis: Conductance \( GList \) (LINEAR)

[Test Output: List Display]
  Frequency FreqList
  Base-Collector capacitance (parallel capacitance) \( C_pList \)
  Conductance \( GList \)
  Series capacitance \( C_sList \)
  Series resistance \( R_sList \)
  Parallel resistance \( R_pList \)
  Dissipation factor \( DList \)
  Reactance \( XList \)
  Impedance \( ZList \)
  Phase ThetaList
  Collector voltage \( VcList \)
1.17 Ctc-Vc: Ctc-Vcb characteristics (A.01.20)

[Supported Analyzer]
B1500A

[Description]
Measures the Base-Collector capacitance (Ctc), and plots the Ctc-Vcb characteristics. For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M,
3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
Bipolar transistor
Connect Base to the CMU Low, Collector to the CMU High, and the other terminals to the GNDU.

[Device Parameters]
Polarity: NPN (CMU forces the specified value) or PNP (CMU forces the negative specified value).
Le: Emitter length
We: Emitter width
Lb: Base length
Wb: Base width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
FREQ: Measurement frequency
OscLevel: Measurement signal level
Base: CMU connected between Base and Collector (CV sweep measurement)
VcbStart: DC bias start voltage
VcbStop: DC bias stop voltage
VcbStep: DC bias step voltage

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Parallel capacitance Cp
Conductance G

[User Function]
PI=3.141592653589
D=G/(2*PI*FREQ*Cp)
Rp=1/G
Cs=(1+D^2)*Cp
X=-1/(2*PI*FREQ*Cs)
Rs=D*abs(X)
Z=sqrt(Rs^2+X^2)
Theta=atan(X/Rs)
Vcb=Vcollector
CtcPerArea=Cp/Lb/Wb

[Analysis Function]
Cj0=@L1Y1 (Y interrupt of Line1)

[X-Y Graph]
X axis: Base-Collector voltage Vcb (LINEAR)
Y1 axis: Base-Collector capacitance (parallel capacitance) Cp (LINEAR)
Y2 axis: Conductance G (LINEAR)

[List Display]
Base-Collector voltage Vcb
Base-Collector capacitance (parallel capacitance) Cp
Conductance G
Series capacitance Cs
Series resistance Rs
Parallel resistance Rp
Dissipation factor D
Reactance X
Impedance Z
Phase Theta

[Parameter Display Area]
Zero bias capacitance Cj0

[Auto Analysis]
Line1: Horizontal line through Y1 data at Vcb=0
1.18 Cte-Ve: Cte-Veb characteristics (A.01.20)

[Supported Analyzer]
B1500A

[Description]
Measures the Base-Emitter capacitance (Cte), and plots the Cte-Veb characteristics. For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement. If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
Bipolar transistor
Connect Base to the CMU Low, Emitter to the CMU High, and the other terminals to the GNDU.

[Device Parameters]
Polarity: NPN (CMU forces the specified value) or PNP (CMU forces the negative specified value). Le: Emitter length We: Emitter width Temp: Temperature

[Test Parameters]
HoldTime: Hold time DelayTime: Delay time IntegTime: Integration time FREQ: Measurement frequency OscLevel: Measurement signal level Base: CMU connected between Base and Emitter (CV sweep measurement) VebStart: DC bias start voltage VebStop: DC bias stop voltage VebStep: DC bias step voltage

[Measurement Parameters]
Parallel capacitance Cp Conductance G

[User Function]
\[ PI=3.141592653589 \]
\[ D=G/(2*PI*FREQ*Cp) \]
\[ Rp=1/G \]
\[ Cs=(1+D^2)*Cp \]
\[ X=\sqrt{1/(2*PI*FREQ*Cs)} \]
\[ Rs=D*abs(X) \]
\[ Z=\sqrt{Rs^2+X^2} \]
\[ Theta=atan(X/Rs) \]
\[ Veb=Vemitter \]
\[ CtePerArea=Cp/Le/We \]
1 BJT

[Analysis Function]
Cj0=L1Y1 (Y interrupt of Line1)

[X-Y Graph]
X axis: Base-Emitter voltage Veb (LINEAR)
Y1 axis: Base-Emitter capacitance (parallel capacitance) Cp (LINEAR)
Y2 axis: Conductance G (LINEAR)

[List Display]
Base-Emitter voltage Veb
Base-Emitter capacitance (parallel capacitance) Cp
Conductance G
Series capacitance Cs
Series resistance Rs
Parallel resistance Rp
Dissipation factor D
Reactance X
Impedance Z
Phase Theta

[Parameter Display Area]
Zero bias capacitance Cj0

[Auto Analysis]
Line1: Horizontal line through Y1 data at Veb=0
1.19 Cts: Cts-Vsc characteristics (A.01.20)

[Supported Analyzer]
B1500A

[Description]
Measures the Collector-Substrate capacitance (Cts), and plots the Cts-Vsc characteristics. For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement. If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
Bipolar transistor
Connect Collector to the CMU Low, Substrate to the CMU High, and the other terminals to the GNDU.

[Device Parameters]
Polarity: NPN (CMU forces the specified value) or PNP (CMU forces the negative specified value).
Le: Emitter length
We: Emitter width
Lc: Collector length
Wc: Collector width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
FREQ: Measurement frequency
OscLevel: Measurement signal level
Subs: CMU connected between Collector and Substrate (CV sweep measurement)
VscStart: DC bias start voltage
VscStop: DC bias stop voltage
VscStep: DC bias step voltage

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Parallel capacitance Cp
Conductance G

[User Function]
PI=3.141592653589
D=G/(2*PI*FREQ*Cp)
Rp=1/G
Cs=(1+D^2)*Cp
X=-1/(2*PI*FREQ*Cs)
Rs=D*abs(X)
Z=sqrt(Rs^2+X^2)
1 BJT

Theta=atan(X/Rs)
Vsc=Vsubs
CtsPerArea=Cp/Lc/Wc

[Analysis Function]
Cj0=@L1Y1 (Y interrupt of Line1)

[X-Y Graph]
X axis: Collector-Substrate voltage Vsc (LINEAR)
Y1 axis: Collector-Substrate capacitance (parallel capacitance) Cp (LINEAR)
Y2 axis: Conductance G (LINEAR)

[List Display]
Collector-Substrate voltage Vsc
Collector-Substrate capacitance (parallel capacitance) Cp
Conductance G
Series capacitance Cs
Series resistance Rs
Parallel resistance Rp
Dissipation factor D
Reactance X
Impedance Z
Phase Theta

[Parameter Display Area]
Zero bias capacitance Cj0

[Auto Analysis]
Line1: Horizontal line through Y1 data at Vsub(=Vsc)=0
1.20 EB Diode Fwd: Emitter-Base junction forward characteristics (A.01.20)

[Supported Analyzer]

[Description]
Measures the Emitter-Base junction forward characteristics of BJT. Collector and Substrate are opened.

[Device Under Test]
Bipolar transistor

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
Imax: Current compliance

[Test Parameters]
IntegTime: Integration time
Emitter: SMU connected to Emitter terminal, primary sweep voltage output
VeStart: Sweep start voltage for Emitter terminal
VeStop: Sweep stop voltage for Emitter terminal
VeStep: Sweep step voltage for Emitter terminal
Base: SMU connected to Base terminal, constant voltage output

[Extended Test Parameters]
Vb: Base voltage
HoldTime: Hold time
DelayTime: Delay time
EmitterMinRng: Minimum range for the emitter current measurement
BaseMinRng: Minimum range for the base current measurement

[Measurement Parameters]
Emitter current Iemitter
Base current Ibase

[User Function]
IePerArea=Iemitter/Le/We
IbPerArea=Ibase/Le/We

[X-Y Plot]
X axis: Emitter voltage Vemitter (LINEAR)
Y1 axis: Emitter current Iemitter (LINEAR)
Y2 axis: Emitter current Iemitter (LOG)
Y3 axis: Base current Ibase (LINEAR)
Y4 axis: Base current Ibase (LOG)
1 BJT

1.21 EB Diode Fwd [2HL]: Emitter-Base junction forward characteristics (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the Emitter-Base junction forward characteristics of BJT. Collector and Substrate are opened.

[Device Under Test]
Bipolar transistor

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
Imax: Current compliance

[Test Parameters]
IntegTime: Integration time
Emitter: SMU connected to Emitter terminal, primary sweep voltage output
VeStart: Sweep start voltage for Emitter terminal
VeStop: Sweep stop voltage for Emitter terminal
VeStep: Sweep step voltage for Emitter terminal
Base: SMU connected to Base terminal, constant voltage output

[Extended Test Parameters]
Vb: Base voltage
HoldTime: Hold time
DelayTime: Delay time
EmitterMinRng: Minimum range for the emitter current measurement
BaseMinRng: Minimum range for the base current measurement

[Measurement Parameters]
Emitter current Iemitter
Base current Ibase

[User Function]
IePerArea=Iemitter/Le/We
IbPerArea=Ibase/Le/We

[X-Y Plot]
X axis: Emitter voltage Vemitter (LINEAR)
Y1 axis: Emitter current Iemitter (LINEAR)
Y2 axis: Emitter current Iemitter (LOG)
Y3 axis: Base current Ibase (LINEAR)
Y4 axis: Base current Ibase (LOG)
### 1.22 EB Diode Rev: Emitter-Base junction reverse characteristics (A.01.20)

**[Supported Analyzer]**

**[Description]**
Measures the Emitter-Base junction reverse characteristics of BJT. Collector and Substrate are opened.

**[Device Under Test]**
- Bipolar transistor

**[Device Parameters]**
- Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
- Le: Emitter length
- We: Emitter width
- Temp: Temperature

**[Test Parameters]**
- IntegTime: Integration time
- Emitter: SMU connected to Emitter terminal, primary sweep voltage output
- VeStart: Sweep start voltage for Emitter terminal
- VeStop: Sweep stop voltage for Emitter terminal
- VeStep: Sweep step voltage for Emitter terminal
- IeLimit: Emitter current compliance
- Base: SMU connected to Base terminal, constant voltage output

**[Extended Test Parameters]**
- Vb: Base voltage
- HoldTime: Hold time
- DelayTime: Delay time
- EmitterMinRng: Minimum range for the emitter current measurement
- BaseMinRng: Minimum range for the base current measurement

**[Measurement Parameters]**
- Emitter current Iemitter
- Base current Ibase

**[User Function]**
- \[ IePerArea = \frac{Iemitter}{Le/We} \]
- \[ IbPerArea = \frac{Ibase}{Le/We} \]

**[X-Y Plot]**
- X axis: Emitter voltage Vemitter (LINEAR)
- Y1 axis: Emitter current Iemitter (LOG)
- Y2 axis: Base current Ibase (LOG)
1.23 **EB Diode Rev [2HL]: Emitter-Base junction reverse characteristics (A.06.10)**

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the Emitter-Base junction reverse characteristics of BJT. Collector and Substrate are opened.

[Device Under Test]
Bipolar transistor

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Emitter: SMU connected to Emitter terminal, primary sweep voltage output
VeStart: Sweep start voltage for Emitter terminal
VeStop: Sweep stop voltage for Emitter terminal
VeStep: Sweep step voltage for Emitter terminal
IeLimit: Emitter current compliance
Base: SMU connected to Base terminal, constant voltage output

[Extended Test Parameters]
Vb: Base voltage
HoldTime: Hold time
DelayTime: Delay time
EmitterMinRng: Minimum range for the emitter current measurement
BaseMinRng: Minimum range for the base current measurement

[Measurement Parameters]
Emitter current Iemitter
Base current Ibase

[User Function]
IePerArea=Iemitter/Le/We
IbPerArea=Ibase/Le/We

[X-Y Plot]
X axis: Emitter voltage Vemitter (LINEAR)
Y1 axis: Emitter current Iemitter (LOG)
Y2 axis: Base current Ibase (LOG)
1.24 G-Plot ConstVce Pulse: Ic-Vb characteristics, Vce=const, SMU Pulse (A.01.11)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the collector current vs base voltage characteristics. The SMU pulse is used for the Collector voltage output.

[Device Under Test]
Bipolar transistor, 4 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
Base: SMU connected to Base terminal, primary sweep voltage output
VbStart: Sweep start voltage for Base terminal
VbStop: Sweep stop voltage for Base terminal
VbStep: Sweep step voltage for Base terminal
Collector: SMU connected to Collector terminal, constant voltage output
Ve: Collector voltage
PulsePeriod: Pulse period
PulseWidth: Pulse width
BaseValue: Pulse base value
Emitter: SMU connected to Emitter terminal, constant voltage output
Subs: SMU connected to Substrate terminal, constant voltage output
Vsubs: Substrate voltage
IsubsLimit: Substrate current compliance

[Extended Test Parameters]
Ve: Emitter voltage
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Collector current Icollector

[User Function]
IcPerArea=Icollector/Le/We

[X-Y Plot]
X axis: Base voltage Vbase (LINEAR)
Y1 axis: Collector current Icollector (LINEAR)
1 BJT

1.25 G-Plot ConstVce Pulse [2HL]: Ic-Vb characteristics, Vce=const, SMU Pulse (A.06.10)

[SUPPORTED ANALYZER]
B2901A, B2902A, B2911A, B2912A

[DESCRIPTION]
Measures the collector current vs base voltage characteristics. The SMU pulse is used for the Collector voltage output.

[DEVICE UNDER TEST]
Bipolar transistor, 4 terminals

[DEVICE PARAMETERS]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[TEST PARAMETERS]
Base: SMU connected to Base terminal, primary sweep voltage output
VbStart: Sweep start voltage for Base terminal
VbStop: Sweep stop voltage for Base terminal
VbStep: Sweep step voltage for Base terminal
Collector: SMU connected to Collector terminal, constant voltage output
Vc: Collector voltage
PulsePeriod: Pulse period
PulseWidth: Pulse width
BaseValue: Pulse base value

[EXTENDED TEST PARAMETERS]
HoldTime: Hold time
DelayTime: Delay time

[MEASUREMENT PARAMETERS]
Collector current Icollector

[USER FUNCTION]
IcPerArea=Icollector/Le/We

[X-Y PLOT]
X axis: Base voltage Vbase (LINEAR)
Y1 axis: Collector current Icollector (LINEAR)
1.26 G-Plot ConstVce Pulse[3]: Ic-Vb characteristics, Vce=const, 3-terminal, SMU Pulse (A.01.11)

[Supported Analyzer]

[Description]
Measures the collector current vs base voltage characteristics. The SMU pulse is used for the Collector voltage output.

[Device Under Test]
Bipolar transistor, 3 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
Base: SMU connected to Base terminal, primary sweep voltage output
VbStart: Sweep start voltage for Base terminal
VbStop: Sweep stop voltage for Base terminal
VbStep: Sweep step voltage for Base terminal
Collector: SMU connected to Collector terminal, constant voltage output
Ve: Collector voltage
PulsePeriod: Pulse period
PulseWidth: Pulse width
BaseValue: Pulse base value
Emitter: SMU connected to Emitter terminal, constant voltage output

[Extended Test Parameters]
Ve: Emitter voltage
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Collector current Icollector

[User Function]
IcPerArea=Icollector/Le/We

[X-Y Plot]
X axis: Base voltage Vbase (LINEAR)
Y1 axis: Collector current Icollector (LINEAR)
1.27 G-Plot ConstVce: Gummel characteristics, Vce=constant (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the collector current vs base voltage characteristics and the base current vs base voltage characteristics, extracts the current amplification factor $h_{fe}$, and plots the gummel characteristics.

[Device Under Test]
Bipolar transistor, 4 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
IntegTime: Integration time
Base: SMU connected to Base terminal, primary sweep voltage output
VbStart: Sweep start voltage for Base terminal
VbStop: Sweep stop voltage for Base terminal
VbStep: Sweep step voltage for Base terminal
Collector: SMU connected to Collector terminal, constant voltage output
Vc: Collector voltage
Emitter: SMU connected to Emitter terminal, constant voltage output
Subs: SMU connected to Substrate terminal, constant voltage output
Vsubs: Substrate voltage
IsubsLimit: Substrate current compliance

[Extended Test Parameters]
Ve: Emitter voltage
HoldTime: Hold time
DelayTime: Delay time
BaseMinRng: Minimum range for the base current measurement
CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]
Collector current $I_{collector}$
Base current $I_{base}$

[User Function]
$I_{bPerArea}=I_{base}/Le/We$
$I_{cPerArea}=I_{collector}/Le/We$
$h_{fe}=I_{collector}/I_{base}$
$h_{feMax}=\max(h_{fe})$

[X-Y Plot]
X axis: Base voltage $V_{base}$ (LINEAR)
Y1 axis: Base current $I_{base}$ (LOG)
Y2 axis: Collector current $I_{collector}$ (LOG)
Y3 axis: Current amplification factor $h_{fe}$ (LINEAR)

[Parameters Display Area]
Current amplification factor maximum value $h_{feMax}$
1.28 G-Plot ConstVce[3]: Gummel characteristics, Vce=constant, 3-terminal (A.01.20)

[Supported Analyzer]

[Description]
Measures the collector current vs base voltage characteristics and the base current vs base voltage characteristics, extracts the current amplification factor hfe, and plots the gummel characteristics.

[Device Under Test]
Bipolar transistor, 3 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
IntegTime: Integration time
Base: SMU connected to Base terminal, primary sweep voltage output
VbStart: Sweep start voltage for Base terminal
VbStop: Sweep stop voltage for Base terminal
VbStep: Sweep step voltage for Base terminal
Collector: SMU connected to Collector terminal, constant voltage output
Vc: Collector voltage
Emitter: SMU connected to Emitter terminal, constant voltage output

[Extended Test Parameters]
Ve: Emitter voltage
HoldTime: Hold time
DelayTime: Delay time
BaseMinRng: Minimum range for the base current measurement
CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]
Collector current Icollector
Base current Ibase

[User Function]
IbPerArea=Ibase/Le/We
IcPerArea=Icollector/Le/We
hfe=Icollector/Ibase
hfeMax=max(hfe)

[X-Y Plot]
X axis: Base voltage Vbase (LINEAR)
Y1 axis: Base current Ibase (LOG)
Y2 axis: Collector current Icollector (LOG)
Y3 axis: Current amplification factor hfe (LINEAR)

[Parameters Display Area]
Current amplification factor maximum value hfeMax
1.29 G-Plot ConstVce [2HL]: Gummel characteristics, Vce=constant (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the collector current vs base voltage characteristics and the base current vs base voltage characteristics, extracts the current amplification factor hfe, and plots the gummel characteristics.

[Device Under Test]
Bipolar transistor, 4 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
IntegTime: Integration time
Base: SMU connected to Base terminal, primary sweep voltage output
VbStart: Sweep start voltage for Base terminal
VbStop: Sweep stop voltage for Base terminal
VbStep: Sweep step voltage for Base terminal
Collector: SMU connected to Collector terminal, constant voltage output
Vc: Collector voltage

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
BaseMinRng: Minimum range for the base current measurement
CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]
Collector current Icollector
Base current Ibase

[User Function]
IbPerArea=Ibase/Le/We
IcPerArea=Icollector/Le/We
hfe=Icollector/Ibase
hfeMax=max(hfe)

[X-Y Plot]
X axis: Base voltage Vbase (LINEAR)
Y1 axis: Base current Ibase (LOG)
Y2 axis: Collector current Icollector (LOG)
Y3 axis: Current amplification factor hfe (LINEAR)

[Parameters Display Area]
Current amplification factor maximum value hfeMax
1.30 G-Plot Vbc=0V Pulse: Ic-Ve characteristics, Vbc=0, SMU Pulse (A.01.11)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the collector current vs emitter voltage characteristics. The SMU pulse is used for the Emitter voltage output.

[Device Under Test]
Bipolar transistor, 4 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
Base: SMU connected to Base terminal, constant voltage output
Collector: SMU connected to Collector terminal, constant voltage output
Emitter: SMU connected to Emitter terminal, primary sweep voltage output
VeStart: Sweep start voltage for Emitter terminal
VeStop: Sweep stop voltage for Emitter terminal
VeStep: Sweep step voltage for Emitter terminal
PulsePeriod: Pulse period
PulseWidth: Pulse width
Subs: SMU connected to Substrate terminal, constant voltage output
Vsubs: Substrate voltage
IsubsLimit: Substrate current compliance

[Extended Test Parameters]
BaseValue: Pulse base value
Vb: Base voltage
Vc: Collector voltage
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Collector current Icollector

[User Function]
IcPerArea=Icollector/Le/We

[X-Y Plot]
X axis: Emitter voltage Vemitter (LINEAR)
Y1 axis: Collector current Icollector (LINEAR)
1.31 G-Plot $V_{bc}=0V$ Pulse[3]: $Ic$-$Ve$ characteristics, $V_{bc}=0$, 3-terminal, SMU Pulse (A.01.11)

[Supported Analyzer]

[Description]
Measures the collector current vs emitter voltage characteristics. The SMU pulse is used for the Emitter voltage output.

[Device Under Test]
Bipolar transistor, 3 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
Base: SMU connected to Base terminal, constant voltage output
Collector: SMU connected to Collector terminal, constant voltage output
Emitter: SMU connected to Emitter terminal, primary sweep voltage output
VeStart: Sweep start voltage for Emitter terminal
VeStop: Sweep stop voltage for Emitter terminal
VeStep: Sweep step voltage for Emitter terminal
PulsePeriod: Pulse period
PulseWidth: Pulse width

[Extended Test Parameters]
BaseValue: Pulse base value
Vb: Base voltage
Vc: Collector voltage
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Collector current $Ic_{collector}$

[User Function]
$IcPerArea=Ic_{collector}/Le/We$

[X-Y Plot]
X axis: Emitter voltage $V_{emitter}$ (LINEAR)
Y1 axis: Collector current $Ic_{collector}$ (LINEAR)
1.32 G-Plot Vbc=0V (Vc=Vb) [2HL]: Gummel characteristics, Vbc=0V (Vc=Vb), SMU Pulse (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the collector current vs collector voltage characteristics and the base current vs base voltage characteristics with same collector/base voltage, extracts the current amplification factor hfe, and plots the gummel characteristics.

[Device Under Test]
Bipolar transistor, 4 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
Collector: SMU connected to Collector terminal, primary sweep voltage output
Base: SMU connected to Base terminal, primary sweep voltage output
VbStart: Sweep start voltage for Base terminal
VbStop: Sweep stop voltage for Base terminal
VbStep: Sweep step voltage for Base terminal
PulsePeriod: Pulse period
PulseWidth: Pulse width

[Extended Test Parameters]
hfeYMax: Maximum Y axis value for hfe
Vc: Collector voltage
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Collector current Icollector
Base current Ibase

[User Function]
IbPerArea=Ibase/Le/We
IcPerArea=Icollector/Le/We
hfe=Icollector/Ibase
hfeMax=max(hfe)

[X-Y Plot]
X axis: Base voltage Vbase (LINEAR)
Y1 axis: Collector current Icollector (LOG)
Y2 axis: Base current Ibase (LOG)
Y3 axis: Current amplification factor hfe (LINEAR)

[Parameters Display Area]
Current amplification factor maximum value hfeMax
1.33 G-Plot Vbc=0V: Gummel characteristics, Vbc=0 (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the collector current vs emitter voltage characteristics and the base current vs emitter voltage characteristics, extracts the current amplification factor \( h_{fe} \), and plots the gummel characteristics.

[Device Under Test]
Bipolar transistor, 4 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
IntegTime: Integration time
Base: SMU connected to Base terminal, constant voltage output
Collector: SMU connected to Collector terminal, constant voltage output
Emitter: SMU connected to Emitter terminal, primary sweep voltage output
VeStart: Sweep start voltage for Emitter terminal
VeStop: Sweep stop voltage for Emitter terminal
VeStep: Sweep step voltage for Emitter terminal
Subs: SMU connected to Substrate terminal, constant voltage output
Vsubs: Substrate voltage
IsubsLimit: Substrate current compliance

[Extended Test Parameters]
Vb: Base voltage
Vc: Collector voltage
HoldTime: Hold time
DelayTime: Delay time
BaseMinRng: Minimum range for the base current measurement
CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]
Collector current \( I_{collector} \)
Base current \( I_{base} \)

[User Function]
\( I_{bPerArea}=I_{base}/Le/We \)
\( I_{cPerArea}=I_{collector}/Le/We \)
\( h_{fe}=I_{collector}/I_{base} \)
\( h_{feMax}=\max(h_{fe}) \)

[X-Y Plot]
X axis: Emitter voltage \( V_{emitter} \) (LINEAR)
Y1 axis: Base current \( I_{base} \) (LOG)
Y2 axis: Collector current \( I_{collector} \) (LOG)
Y3 axis: Current amplification factor \( h_{fe} \) (LINEAR)

[Parameters Display Area]
Current amplification factor maximum value \( h_{feMax} \)
1.34 *G-Plot Vbc=0V[3]: Gummel characteristics, Vbc=0, 3-terminal (A.01.20)*

[Supported Analyzer]

[Description]
Measures the collector current vs emitter voltage characteristics and the base current vs emitter voltage characteristics, extracts the current amplification factor $h_{fe}$, and plots the gummel characteristics.

[Device Under Test]
Bipolar transistor, 3 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
IntegTime: Integration time
Base: SMU connected to Base terminal, constant voltage output
Collector: SMU connected to Collector terminal, constant voltage output
Emitter: SMU connected to Emitter terminal, primary sweep voltage output
VeStart: Sweep start voltage for Emitter terminal
VeStop: Sweep stop voltage for Emitter terminal
VeStep: Sweep step voltage for Emitter terminal

[Extended Test Parameters]
Vb: Base voltage
Vc: Collector voltage
HoldTime: Hold time
DelayTime: Delay time
BaseMinRng: Minimum range for the base current measurement
CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]
Collector current $I_{collector}$
Base current $I_{base}$
Emitter current $I_{emitter}$

[User Function]
$I_{bPerArea}=I_{base}/Le/We$
$I_{cPerArea}=I_{collector}/Le/We$
$h_{fe}=I_{collector}/I_{base}$
$h_{feMax}=\max(h_{fe})$

[X-Y Plot]
X axis: Emitter voltage $V_{emitter}$ (LINEAR)
Y1 axis: Base current $I_{base}$ (LOG)
Y2 axis: Collector current $I_{collector}$ (LOG)
Y3 axis: Current amplification factor $h_{fe}$ (LINEAR)

[Parameters Display Area]
Current amplification factor maximum value $h_{feMax}$
1.35 G-Plot Vbc=0V (Vc=Vb) [2HL]: Gummel characteristics, Vbc=0V (Vc=Vb) (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the collector current vs collector voltage characteristics and the base current vs base voltage characteristics with same collector/base voltage, extracts the current amplification factor hfe, and plots the gummel characteristics.

[Device Under Test]
Bipolar transistor, 4 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
IntegTime: Integration time
Collector: SMU connected to Collector terminal, primary sweep voltage output
Base: SMU connected to Base terminal, primary sweep voltage output
VbStart: Sweep start voltage for Base terminal
VbStop: Sweep stop voltage for Base terminal
VbStep: Sweep step voltage for Base terminal

[Extended Test Parameters]
Vc: Collector voltage
HoldTime: Hold time
DelayTime: Delay time
CollectorMinRng: Minimum range for the collector and base current measurement

[Measurement Parameters]
Collector current Icollector
Base current Ibase

[User Function]
IbPerArea=Ibase/Le/We
IcPerArea=Icollector/Le/We
hfe=Icollector/Ibase
hfeMax=max(hfe)

[X-Y Plot]
X axis: Base voltage Vbase (LINEAR)
Y1 axis: Collector current Icollector (LOG)
Y2 axis: Base current Ibase (LOG)
Y3 axis: Current amplification factor hfe (LINEAR)

[Parameters Display Area]
Current amplification factor maximum value hfeMax
### 1.36 hfe-Vbe ConstVce: hfe-Ic characteristics, Vce=constant (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the collector current vs base voltage characteristics and the base current vs base voltage characteristics, extracts the current amplification factor hfe, and plots the hfe-Ic characteristics.

[Device Under Test]
Bipolar transistor, 4 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
IntegTime: Integration time
Base: SMU connected to Base terminal, primary sweep voltage output
VbStart: Sweep start voltage for Base terminal
VbStop: Sweep stop voltage for Base terminal
VbStep: Sweep step voltage for Base terminal
Collector: SMU connected to Collector terminal, constant voltage output
Ve: Collector voltage
Emitter: SMU connected to Emitter terminal, constant voltage output
Subs: SMU connected to Substrate terminal, constant voltage output
Vsubs: Substrate voltage
IsubsLimit: Substrate current compliance

[Extended Test Parameters]
Ve: Emitter voltage
HoldTime: Hold time
DelayTime: Delay time
BaseMinRng: Minimum range for the base current measurement
CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]
Collector current Icollector
Base current Ibase

[User Function]
IbPerArea=Ibase/Le/We
IcPerArea=Icollector/Le/We
hfe=Icollector/Ibase
hfeMax=max(hfe)

[Analysis Function]
Ic@hfeMax=@L1X (X intercept of Line1)

[X-Y Plot]
X axis: Collector current Icollector (LOG)
Y1 axis: Current amplification factor hfe (LINEAR)

[Parameters Display Area]
Current amplification factor maximum value hfeMax
Collector current at hfeMax Ic@hfeMax

[Auto Analysis]
Line1: Vertical line through Y1 data at hfe=hfeMax
1.37 \text{hfe-Vbe Vbc=0V: hfe-Ic characteristics, Vbc=0 (A.01.20)}

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the collector current vs emitter voltage characteristics and the base current vs emitter voltage characteristics, extracts the current amplification factor hfe, and plots the hfe-Ic characteristics.

[Device Under Test]
Bipolar transistor, 4 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
IntegTime: Integration time
Base: SMU connected to Base terminal, constant voltage output
Collector: SMU connected to Collector terminal, constant voltage output
Emitter: SMU connected to Emitter terminal, primary sweep voltage output
VeStart: Sweep start voltage for Emitter terminal
VeStop: Sweep stop voltage for Emitter terminal
VeStep: Sweep step voltage for Emitter terminal
Subs: SMU connected to Substrate terminal, constant voltage output
Vsubs: Substrate voltage
IsubsLimit: Substrate current compliance

[Extended Test Parameters]
Vb: Base voltage
Vc: Collector voltage
HoldTime: Hold time
DelayTime: Delay time
BaseMinRng: Minimum range for the base current measurement
CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]
Collector current Icollector
Base current Ibase

[User Function]
IbPerArea=Ibase/Le/We
IcPerArea=Icollector/Le/We
hfe=Icollector/Ibase
hfeMax=max(hfe)

[Analysis Function]
Ic@hfeMax=@L1X (X intercept of Line1)

[X-Y Plot]
X axis: Collector current Icollector (LOG)
Y1 axis: Current amplification factor hfe (LINEAR)

[Parameters Display Area]
Current amplification factor maximum value hfeMax
Collector current at hfeMax Ic@hfeMax

[Auto Analysis]
Line1: Vertical line through Y1 data at hfe=hfeMax
### 1.38 Ic-Vc Ib: Ic-Vc characteristics, Ib sweep (A.01.20)

**[Supported Analyzer]**
- B1500A, E5260A, E5270B

**[Description]**
Measures the collector current vs collector voltage characteristics.

**[Device Under Test]**
- Bipolar transistor, 4 terminals

**[Device Parameters]**
- Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
- Le: Emitter length
- We: Emitter width
- Temp: Temperature
- IcMax: Collector current compliance

**[Test Parameters]**
- IntegTime: Integration time
- Collector: SMU connected to Collector terminal, primary sweep voltage output
- VcStart: Sweep start voltage for Collector terminal
- VcStop: Sweep stop voltage for Collector terminal
- VcStep: Sweep step voltage for Collector terminal
- Base: SMU connected to Base terminal, secondary sweep voltage output
- IbStart: Sweep start current for Base terminal
- IbStop: Sweep stop current for Base terminal
- IbStep: Sweep step current for Base terminal
- Emitter: SMU connected to Emitter terminal, constant voltage output
- Subs: SMU connected to Substrate terminal, constant voltage output
- Vsubs: Substrate voltage
- IsubsLimit: Substrate current compliance

**[Extended Test Parameters]**
- Ve: Emitter voltage
- VbLimit: Base voltage compliance
- HoldTime: Hold time
- DelayTime: Delay time
- CollectorMinRng: Minimum range for the collector current measurement
- SubsMinRng: Minimum range for the substrate current measurement

**[Measurement Parameters]**
- Collector current Icollector
- Base voltage Vbase
- Substrate current Isubs

**[User Function]**
- IbPerArea=Ibase/Le/We
- IcPerArea=Icollector/Le/We
- hfe=Icollector/Ibase
- VA=Icollector*diff(Vcollector,Icollector)-Vcollector

**[X-Y Plot]**
- X axis: Collector voltage Vcollector (LINEAR)
- Y1 axis: Collector current Icollector (LINEAR)
1.39 Ic-Vc Ib[3]: Ic-Vc characteristics, 3-terminal, Ib sweep (A.01.20)

[Supported Analyzer]

[Description]
Measures the collector current vs collector voltage characteristics.

[Device Under Test]
Bipolar transistor, 3 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
IntegTime: Integration time
Collector: SMU connected to Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcStep: Sweep step voltage for Collector terminal
Base: SMU connected to Base terminal, secondary sweep voltage output
IbStart: Sweep start current for Base terminal
IbStop: Sweep stop current for Base terminal
IbStep: Sweep step current for Base terminal
Emitter: SMU connected to Emitter terminal, constant voltage output

[Extended Test Parameters]
Ve: Emitter voltage
VbLimit: Base voltage compliance
HoldTime: Hold time
DelayTime: Delay time
CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]
Collector current Icollector
Base voltage Vbase

[User Function]
IbPerArea=Ibase/Le/We
IcPerArea=Icollector/Le/We
hfe=Icollector/Ibase
VA=Icollector*diff(Vcollector,Icollector)-Vcollector

[X-Y Plot]
X axis: Collector voltage Vcollector (LINEAR)
Y1 axis: Collector current Icollector (LINEAR)
1.40 Ic-Vc Ib [2HL]: Ic-Vc characteristics, Ib sweep (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the collector current vs collector voltage characteristics.

[Device Under Test]
Bipolar transistor, 4 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
IntegTime: Integration time
Collector: SMU connected to Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcStep: Sweep step voltage for Collector terminal
Base: SMU connected to Base terminal, secondary sweep voltage output
IbStart: Sweep start current for Base terminal
IbStop: Sweep stop current for Base terminal
IbStep: Sweep step current for Base terminal

[Extended Test Parameters]
VbLimit: Base voltage compliance
HoldTime: Hold time
DelayTime: Delay time
CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]
Collector current Icollector
Base voltage Vbase

[User Function]
IbPerArea=Ibase/Le/We
IcPerArea=Icollector/Le/We
hfe=Icollector/Ibase
VA=Icollector*diff(Vcollector,Icollector)-Vcollector

[X-Y Plot]
X axis: Collector voltage Vcollector (LINEAR)
Y1 axis: Collector current Icollector (LINEAR)
1 BJT

1.41 Ic-Vc Pulse Ib: Ic-Vc characteristics, Ib sweep, SMU Pulse (A.01.11)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the collector current vs collector voltage characteristics. The SMU pulse is used for the collector voltage output.

[Device Under Test]
Bipolar transistor, 4 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
Collector: SMU connected to Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcStep: Sweep step voltage for Collector terminal
PulsePeriod: Pulse period
PulseWidth: Pulse width
Base: SMU connected to Base terminal, secondary sweep voltage output
IbStart: Sweep start current for Base terminal
IbStop: Sweep stop current for Base terminal
IbStep: Sweep step current for Base terminal
Emitter: SMU connected to Emitter terminal, constant voltage output
Subs: SMU connected to Substrate terminal, constant voltage output
Vsubs: Substrate voltage
IsubsLimit: Substrate current compliance

[Extended Test Parameters]
Ve: Emitter voltage
BaseValue: Pulse base value
VbLimit: Base voltage compliance
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Collector current Icollector

[User Function]
IcPerArea=Icollector/Le/We
VA=Icollector*diff(Vcollector,Icollector)-Vcollector

[X-Y Plot]
X axis: Collector voltage Vcollector (LINEAR)
Y1 axis: Collector current Icollector (LINEAR)
1.42 Ic-Vc Pulse Ib[3]: Ic-Vc characteristics, 3-terminal, Ib sweep, SMU Pulse (A.01.11)

[Supported Analyzer]

[Description]
Measures the collector current vs collector voltage characteristics. The SMU pulse is used for the collector voltage output.

[Device Under Test]
Bipolar transistor, 3 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
Collector: SMU connected to Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcStep: Sweep step voltage for Collector terminal
PulsePeriod: Pulse period
PulseWidth: Pulse width
Base: SMU connected to Base terminal, secondary sweep voltage output
IbStart: Sweep start current for Base terminal
IbStop: Sweep stop current for Base terminal
IbStep: Sweep step current for Base terminal
Emitter: SMU connected to Emitter terminal, constant voltage output

[Extended Test Parameters]
Ve: Emitter voltage
BaseValue: Pulse base value
VbLimit: Base voltage compliance
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Collector current Icollector

[User Function]
IcPerArea=Icollector/Le/We
VA=Icollector*diff(Vcollector,Icollector)-Vcollector

[X-Y Plot]
X axis: Collector voltage Vcollector (LINEAR)
Y1 axis: Collector current Icollector (LINEAR)
1.43 Ic-Vc Pulse Ib [2HL]: Ic-Vc characteristics, Ib sweep, SMU Pulse (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the collector current vs collector voltage characteristics. The SMU pulse is used for the collector voltage output.

[Device Under Test]
Bipolar transistor, 4 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
Collector: SMU connected to Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcStep: Sweep step voltage for Collector terminal
PulsePeriod: Pulse period
PulseWidth: Pulse width
Base: SMU connected to Base terminal, secondary sweep voltage output
IbStart: Sweep start current for Base terminal
IbStop: Sweep stop current for Base terminal
IbStep: Sweep step current for Base terminal

[Extended Test Parameters]
BaseValue: Pulse base value
VbLimit: Base voltage compliance
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Collector current Icollector

[User Function]
IcPerArea=Icollector/Le/We
VA=Icollector*diff(Vcollector,Icollector)-Vcollector

[X-Y Plot]
X axis: Collector voltage Vcollector (LINEAR)
Y1 axis: Collector current Icollector (LINEAR)
1.44 Ic-Vc Pulse Vb: Ic-Vc characteristics, Vb sweep, SMU Pulse (A.01.11)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the collector current vs collector voltage characteristics. The SMU pulse is used for the collector voltage output.

[Device Under Test]
Bipolar transistor, 4 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
Collector: SMU connected to Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcStep: Sweep step voltage for Collector terminal
PulsePeriod: Pulse period
PulseWidth: Pulse width
Base: SMU connected to Base terminal, secondary sweep voltage output
VbStart: Sweep start voltage for Base terminal
VbStop: Sweep stop voltage for Base terminal
VbStep: Sweep step voltage for Base terminal
Emitter: SMU connected to Emitter terminal, constant voltage output
Subs: SMU connected to Substrate terminal, constant voltage output
Vsubs: Substrate voltage
IsubsLimit: Substrate current compliance

[Extended Test Parameters]
Ve: Emitter voltage
BaseValue: Pulse base value
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Collector current Icollector

[User Function]
IcPerArea=Icollector/Le/We
VA=Icollector*diff(Vcollector,Icollector)-Vcollector

[X-Y Plot]
X axis: Collector voltage Vcollector (LINEAR)
Y1 axis: Collector current Icollector (LINEAR)
1.45 *Ic-Vc Pulse Vb[3]*: *Ic-Vc characteristics, 3-terminal, Vb sweep, SMU Pulse (A.01.11)

[Supported Analyzer]

[Description]
Measures the collector current vs collector voltage characteristics. The SMU pulse is used for the collector voltage output.

[Device Under Test]
Bipolar transistor, 3 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
Collector: SMU connected to Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcStep: Sweep step voltage for Collector terminal
PulsePeriod: Pulse period
PulseWidth: Pulse width
Base: SMU connected to Base terminal, secondary sweep voltage output
VbStart: Sweep start voltage for Base terminal
VbStop: Sweep stop voltage for Base terminal
VbStep: Sweep step voltage for Base terminal
Emitter: SMU connected to Emitter terminal, constant voltage output

[Extended Test Parameters]
Ve: Emitter voltage
BaseValue: Pulse base value
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Collector current Icollector

[User Function]
IcPerArea=Icollector/Le/We
VA=Icollector*diff(Vcollector,Icollector)-Vcollector

[X-Y Plot]
X axis: Collector voltage Vcollector (LINEAR)
Y1 axis: Collector current Icollector (LINEAR)
1.46 Ic-Vc Pulse Vb [2HL]: Ic-Vc characteristics, Vb sweep, SMU Pulse (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the collector current vs collector voltage characteristics. The SMU pulse is used for the collector voltage output.

[Device Under Test]
Bipolar transistor, 4 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
Collector: SMU connected to Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcStep: Sweep step voltage for Collector terminal
PulsePeriod: Pulse period
PulseWidth: Pulse width
Base: SMU connected to Base terminal, secondary sweep voltage output
VbStart: Sweep start voltage for Base terminal
VbStop: Sweep stop voltage for Base terminal
VbStep: Sweep step voltage for Base terminal

[Extended Test Parameters]
BaseValue: Pulse base value
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Collector current Icollector

[User Function]
IcPerArea=Icollector/Le/We
VA=Icollector*diff(Vcollector,Icollector)-Vcollector

[X-Y Plot]
X axis: Collector voltage Vcollector (LINEAR)
Y1 axis: Collector current Icollector (LINEAR)
1 BJT

1.47 Ic-Vc Vb: Ic-Vc characteristics, Vb sweep (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the collector current vs collector voltage characteristics.

[Device Under Test]
Bipolar transistor, 4 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
IntegTime: Integration time
Collector: SMU connected to Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcStep: Sweep step voltage for Collector terminal
Base: SMU connected to Base terminal, secondary sweep voltage output
VbStart: Sweep start voltage for Base terminal
VbStop: Sweep stop voltage for Base terminal
VbStep: Sweep step voltage for Base terminal
Emitter: SMU connected to Emitter terminal, constant voltage output
Subs: SMU connected to Substrate terminal, constant voltage output
Vsubs: Substrate voltage
IsubsLimit: Substrate current compliance

[Extended Test Parameters]
Ve: Emitter voltage
HoldTime: Hold time
DelayTime: Delay time
CollectorMinRng: Minimum range for the collector current measurement
BaseMinRng: Minimum range for the base current measurement
SubsMinRng: Minimum range for the substrate current measurement

[Measurement Parameters]
Collector current Icollector
Base current Ibase

[User Function]
IbPerArea=Ibase/Le/We
IcPerArea=Icollector/Le/We
hfe=Icollector/Ibase
VA=Icollector*diff(Vcollector,Icollector)-Vcollector

[X-Y Plot]
X axis: Collector voltage Vcollector (LINEAR)
Y1 axis: Collector current Icollector (LINEAR)
1.48 Ic-Vc Vb[3]: Ic-Vc characteristics, 3-terminal, Vb sweep (A.01.20)

[Supported Analyzer]

[Description]
Measures the collector current vs collector voltage characteristics.

[Device Under Test]
Bipolar transistor, 3 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
IntegTime: Integration time
Collector: SMU connected to Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcStep: Sweep step voltage for Collector terminal
Base: SMU connected to Base terminal, secondary sweep voltage output
VbStart: Sweep start voltage for Base terminal
VbStop: Sweep stop voltage for Base terminal
VbStep: Sweep step voltage for Base terminal
Emitter: SMU connected to Emitter terminal, constant voltage output

[Extended Test Parameters]
Ve: Emitter voltage
HoldTime: Hold time
DelayTime: Delay time
CollectorMinRng: Minimum range for the collector current measurement
BaseMinRng: Minimum range for the base current measurement

[Measurement Parameters]
Collector current Icollector
Base current Ibase

[User Function]
IbPerArea=Ibase/Le/We
IcPerArea=Icollector/Le/We
hfe=Icollector/Ibase
VA=Icollector*diff(Vcollector,Icollector)-Vcollector

[X-Y Plot]
X axis: Collector voltage Vcollector (LINEAR)
Y1 axis: Collector current Icollector (LINEAR)
1 BJT

1.49 Ic-Vc Vb [2HL]: Ic-Vc characteristics, Vb sweep (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the collector current vs collector voltage characteristics.

[Device Under Test]
Bipolar transistor, 4 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
IntegTime: Integration time
Collector: SMU connected to Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcStep: Sweep step voltage for Collector terminal
Base: SMU connected to Base terminal, secondary sweep voltage output
VbStart: Sweep start voltage for Base terminal
VbStop: Sweep stop voltage for Base terminal
VbStep: Sweep step voltage for Base terminal

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
CollectorMinRng: Minimum range for the collector current measurement
BaseMinRng: Minimum range for the base current measurement

[Measurement Parameters]
Collector current Icollector
Base current Ibase

[User Function]
IbPerArea=Ibase/Le/We
IcPerArea=Icollector/Le/We
hfe=Icollector/Ibase
VA=Icollector*diff(Vcollector,Icollector)-Vcollector

[X-Y Plot]
X axis: Collector voltage Vcollector (LINEAR)
Y1 axis: Collector current Icollector (LINEAR)
### 1.50 Rb: Base resistance (flyback method, 4-terminal) (A.01.20)

[Supported Analyzer]
- B1500A, E5260A, E5270B

[Description]
Measures the base voltage, collector voltage vs base current characteristics, and extracts the Base resistance in the high current region. Uses the flyback method.

[Device Under Test]
- Bipolar transistor, 4 terminals

[Device Parameters]
- Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
- Le: Emitter length
- We: Emitter width
- Temp: Temperature

[Test Parameters]
- IntegTime: Integration time
- Base: SMU connected to Base terminal, primary sweep current output
- IbStart: Sweep start current for Base terminal
- IbStop: Sweep stop current for Base terminal
- IbStep: Sweep step current for Base terminal
- VbLimit: Base voltage compliance
- Collector: SMU connected to Collector terminal, constant current output
- VcLimit: Collector voltage compliance
- Emitter: SMU connected to Emitter terminal, constant voltage output
- Subs: SMU connected to Substrate, constant voltage output
- Vsubs: Substrate voltage
- IsubsLimit: Substrate current compliance

[Extended Test Parameters]
- Ve: Emitter voltage
- Ic: Collector current
- HoldTime: Hold time
- DelayTime: Delay time

[Measurement Parameters]
- Base voltage Vbase
- Collector voltage Vcollector

[User Function]
- \( R_b = \frac{(V_{base} - V_{collector})}{I_{base}} \)
- \( \text{Inv}_{-}I_{base} = \frac{1}{I_{base}} \)

[X-Y Plot]
- X axis: Inversed Base current Inv_{-}I_{base} (LINEAR)
- Y1 axis: Base resistance Re (LINEAR)
- Y2 axis: Base current I_{base} (LINEAR)
1 BJT

1.51 Rb [2HL]: Base resistance (flyback method, 4-terminal) (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the base voltage, collector voltage vs base current characteristics, and extracts the Base resistance in the high current region. Uses the flyback method.

[Device Under Test]
Bipolar transistor, 4 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Base: SMU connected to Base terminal, primary sweep current output
IbStart: Sweep start current for Base terminal
IbStop: Sweep stop current for Base terminal
IbStep: Sweep step current for Base terminal
VbLimit: Base voltage compliance
Collector: SMU connected to Collector terminal, constant current output
VcLimit: Collector voltage compliance

[Extended Test Parameters]
Ic: Collector current
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Base voltage Vbase
Collector voltage Vcollector

[User Function]
Rb=(Vbase-Vcollector)/Ibase
Inv_Ibase=1/Ibase

[X-Y Plot]
X axis: Inversed Base current Inv_Ibase (LINEAR)
Y1 axis: Base resistance Re (LINEAR)
Y2 axis: Base current Ib (LINEAR)
1.52 Re+Rc: Collector resistance (including Emitter resistance, flyback method, 4-terminal) (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the collector voltage vs collector current characteristics, and extracts the combined resistance of the collector resistance and the emitter resistance. Uses the flyback method.

[Device Under Test]
Bipolar transistor, 4 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Collector: SMU connected to Collector terminal, primary sweep current output
IcStart: Sweep start current for Collector terminal
IcStop: Sweep stop current for Collector terminal
IcStep: Sweep step current for Collector terminal
VcLimit: Collector voltage compliance
Base: SMU connected to Base terminal, constant current output
Ib: Base current
Emitter: SMU connected to Emitter terminal, constant voltage output
Subs: SMU connected to Substrate, constant voltage output
Vsubs: Substrate voltage
IsubsLimit: Substrate current compliance

[Extended Test Parameters]
Ve: Emitter voltage
VbLimit: Base voltage compliance
HoldTime: Hold time
DelayTime: Delay time
EmitterMinRng: Minimum range for the emitter current measurement
SubsMinRng: Minimum range for the substrate current measurement

[Measurement Parameters]
Collector voltage Vcollector

[User Function]
IePerArea=Iemitter/Le/We
IbPerArea=Ibase/Le/We
IsPerArea=Isubs/Le/We
Rc_Re=diff(Vcollector,Icollector)

[X-Y Plot]
X axis: Collector current Icollector (LINEAR)
Y1 axis: Collector voltage Vcollector (LINEAR)
Y2 axis: Combined resistance of Collector resistance and Emitter resistance
1.53 Re: Emitter resistance (flyback method, 4-terminal) (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the collector voltage vs base current characteristics, and extracts the Emitter resistance. Uses the flyback method.

[Device Under Test]
Bipolar transistor, 4 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Base: SMU connected to Base terminal, primary sweep current output
IbStart: Sweep start current for Base terminal
IbStop: Sweep stop current for Base terminal
IbStep: Sweep step current for Base terminal
VbLimit: Base voltage compliance
Collector: SMU connected to Collector terminal, constant current output
Ic: Collector current
VcLimit: Collector voltage compliance
Emitter: SMU connected to Emitter terminal, constant voltage output
Subs: SMU connected to Substrate, constant voltage output
Vsubs: Substrate voltage
IsubsLimit: Substrate current compliance

[Extended Test Parameters]
Ve: Emitter voltage
HoldTime: Hold time
DelayTime: Delay time
EmitterMinRng: Minimum range for the emitter current measurement
SubsMinRng: Minimum range for the substrate current measurement

[Measurement Parameters]
Collector voltage Vcollector

[User Function]
Emitter current per emitter unit area IePerArea=Iemitter/Le/We
Base current per emitter unit area IbPerArea=Ibase/Le/We
Substrate current per emitter unit area IsPerArea=Isubs/Le/We
Emitter resistance Re=diff(Vcollector,Ibase)

[X-Y Plot]
X axis: Base current Ib (LINEAR)
Y1 axis: Collector voltage Vcollector (LINEAR)
Y2 axis: Emitter resistance Re (LINEAR)
1.54 Simple Gummel Plot: Evaluation of Gummel characteristics (Vce=const) (A.01.10)

[Supported Analyzer]

[Application]
This application evaluates the Gummel characteristics of a NPN BJT with three terminals.

[Device Measured]
Single NPN device with three terminals.

[Parameter Setting]
Test parameters are specified for NPN device under test.

[Description of Measurement]
Base and Collector voltage, referenced to emitter voltage (0 V), sweeps synchronously in accordance with the test parameter setting.
Currents flowing in base and collector terminals are measured while the synchronized voltages sweep.

[Plot Display]
Collector and base currents in log scale, as well as the current amplification factor (Beta) in linear scale, are plotted versus base voltage on the linear horizontal axis.
1.55 Simple GummelPlot [2HL] : Evaluation of Gummel characteristics (Vce=const) (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Application]
This application evaluates the Gummel characteristics of a NPN BJT with three terminals.

[Device Measured]
Single NPN device with three terminals.

[Parameter Setting]
Test parameters are specified for NPN device under test.

[Description of Measurement]
Base and Collector voltage, referenced to emitter voltage (0 V), sweeps synchronously in accordance with the test parameter setting.
Currents flowing in base and collector terminals are measured while the synchronized voltages sweep.

[Plot Display]
Collector and base currents in log scale, as well as the current amplification factor (Beta) in linear scale, are plotted versus base voltage on the linear horizontal axis.
1.56 Vbe-Le: hfe,Vbe-Le characteristics (A.01.20)

[Supported Analyzer]
   B1500A, E5260A, E5270B

[Description]
   Measures \( hfe \) (current amplification factor)-Vbe (voltage between base and emitter) characteristics of BJT with different \( Le \) (emitter length) and plots \( hfe \) and Vbe's dependency on \( Le \).

[Device Under Test]
   Bipolar transistor, 4 terminals

[Required Modules and Accessories]
   Keysight B2200A or B2201A switching matrix 1 unit
   GPIB cable

   Connect B2200A/B2201A to B1500A with measurement cables and GPIB cable.
   Set information on B1500A SMU channel's connection to the B2200A/B2201A input port properly on the Switching Matrix tab screen of the Configuration window.
   Set the output channel number of B2200A/B2201A connected to each terminal of a device under test properly in the B#/C#/E#/Sb# field (\( # \) is an integer from 1 to 12) of Test Parameters area.
   The maximum number of devices connected at once depends on the number of matrix modules mounted on B2200A/B2201A. Maximum three devices can be connected to one module at once.

[Setting of Le#/B#/C#/E#/Sb# field (\( # \) is an integer from 1 to 12)]
   Set one device for Le#(emitter length)/B#(base)/C#(collector)/E#(emitter)/Sb#(substrate).
   Le1<Le2<Le3... must be satisfied. Enter zero for a field with no device.

[Device Parameters]
   Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value)
   Temp: Temperature
   IcMax: Collector current compliance

[Test Parameters]
   IntegTime: Integration time
   BaseSMU: SMU connected to Base terminal, constant voltage output
   CollectorSMU: SMU connected to Collector terminal, constant voltage output
   SbSMU: SMU connected to Substrate terminal, constant voltage output
   EmitterSMU: SMU connected to Emitter terminal, primary sweep voltage output
   VeStart: Sweep start voltage for Emitter terminal
   VeStop: Sweep stop voltage for Emitter terminal
   VeStep: Sweep step voltage for Emitter terminal
   Vsubs: Substrate voltage
   Ic@hfe: Collector current determining the hfe (Calculates hfe on a particular Ic)
   Ie@Vbe: Emitter current determining the Vbe voltage (Calculates Vbe on a particular Ie)
   We: Emitter width
   Le1 - Le12: Emitter length
   B1 - B12: SWM Pin Assign setting for Base of devices
   C1 - C12: SWM Pin Assign setting for Collector of devices
   E1 - E12: SWM Pin Assign setting for Emitter of devices
   Sb1 - Sb12: SWM Pin Assign setting for Subs of devices

[Extended Test Parameters]
   Vb: Base voltage
1 BJT

Vc: Collector voltage
IsubSLimit: Substrate current compliance
HoldTime: Hold time
DelayTime: Delay time
hfe_MIN: Minimum hfe value for graph scale
hfe_MAX: Maximum hfe value for graph scale
BaseMinRng: Minimum range for base current measurement
CollectorMinRng: Minimum range for collector current measurement
EmitterMinRng: Minimum range for emitter current measurement

[Measurement Parameters]
Collector current Icollector
Base current Ibase
Emitter current Iemitter

[User Function]
hfe=Icollector/Ibase

[Analysis Function]
Ic@hfeVal= aerL1X (X intercept of Line1)
Ie@VbeVal= aerL2X (X intercept of Line2)

[Auto Analysis]
Line1: Vertical line for Y1 at hfe=Ic@hfe*Ratio
Line2: Vertical line for Y2 at Vemitter=Ie@Vbe*Ratio

[X-Y Plot]
X axis: Emitter voltage Vemitter (LINEAR)
Y1 axis: Base current Ibase (LOG)
Y2 axis: Current amplification factor hfe (LINEAR)
Y3 axis: Collector current Icollector (LOG)
Y4 axis: Emitter current Iemitter (LOG)

[List Display]
Emitter voltage Vemitter
Collector current Icollector
Emitter current Iemitter
Base current Ibase
Current amplification factor hfe

[Parameters Display Area]
Collector current determining the hfe (Calculates hfe on a particular Ic) Ic@hfeVal
Emitter current determining the Vbe voltage (Calculates Vbe on a particular Ie) Ie@VbeVal

[Test Output: X-Y Graph]
X axis: Emitter length (Le size) LeList (LINEAR)
Y1 axis: Current amplification factor at Ic@hfe Ic@hfeList (LINEAR)
Y2 axis: Emitter voltage at Ic@Vbe Ic@VbeList (LINEAR)

[Test Output: List Display]
Emitter length (Le size) LeList
Current amplification factor Ic@hfeList
Emitter voltage Ic@VbeList
1.57 Vbe-We: hfe, Vbe-Le characteristics (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the hfe (current amplification factor) vs Vbe (voltage between base and emitter) characteristics of BJT with different We (emitter width) and plots hfe and Vbe's dependency on We.

[Device Under Test]
Bipolar transistor, 4 terminals

[Required Modules and Accessories]
Keysight B2200A or B2201A switching matrix 1 unit
GPIB cable

Connect B2200A/B2201A to B1500A with a measuring cable and GPIB cable.
Set information on B1500A SMU channel's connection to the B2200A/B2201A input port properly on the Switching Matrix tab screen of the Configuration window.
Set the output channel number of B2200A/B2201A connected to each terminal of a device under test properly in the B#/C#/E#/Sb# field (# is an integer from 1 to 12) of Test Parameters area.
The maximum number of devices connected at once depends on the number of matrix modules mounted on B2200A/B2201A. Maximum three devices can be connected to one module at once.

[Setting of We#/B#/C#/E#/Sb# field (# is an integer from 1 to 12)]
Set one device for We#(emitter width)/B#(base)/C#(collector)/E#(emitter)/Sb#(substrate).
We1<&lt;We2<&lt;We3... must be satisfied. Enter zero for a field with no device.

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value)
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
IntegTime: Integration time
BaseSMU: SMU connected to Base terminal, constant voltage output
CollectorSMU: SMU connected to Collector terminal, constant voltage output
SbSMU: SMU connected to Substrate terminal, constant voltage output
EmitterSMU: SMU connected to Emitter terminal, primary sweep voltage output
VeStart: Sweep start voltage for Emitter terminal
VeStop: Sweep stop voltage for Emitter terminal
VeStep: Sweep step voltage for Emitter terminal
Vsubs: Substrate voltage
Ic@hfe: Collector current determining the hfe (Calculates hfe on a particular Ic)
Ie@Vbe: Emitter current determining the Vbe voltage (Calculates Vbe on a particular Ie)
Le: Emitter length
We1 - We12: Emitter width
B1 - B12: SWM Pin Assign setting for Base of devices
C1 - C12: SWM Pin Assign setting for Collector of devices
E1 - E12: SWM Pin Assign setting for Emitter of devices
Sb1 - Sb12: SWM Pin Assign setting for Subs of devices

[Extended Test Parameters]
Vb: Base voltage
1 BJT

Vc: Collector voltage
IsubsLimit: Substrate current compliance
HoldTime: Hold time
DelayTime: Delay time
hfe_MIN: Minimum hfe value for graph scale
hfe_MAX: Maximum hfe value for graph scale
BaseMinRng: Minimum range for base current measurement
CollectorMinRng: Minimum range for collector current measurement
EmitterMinRng: Minimum range for emitter current measurement

[Measurement Parameters]
Collector current Icollector
Base current Ibase
Emitter current Iemitter

[User Function]
hfe=Icollector/Ibase

[Analysis Function]
Ic@hfeVal=@L1X (X intercept of Line1)
Ie@VbeVal=@L2X (X intercept of Line2)

[Auto Analysis]
Line1: Vertical line for Y1 at hfe=Ic@hfe*Ratio
Line2: Vertical line for Y2 at Vemitter=Ie@Vbe*Ratio

[X-Y Plot]
X axis: Emitter voltage Vemitter (LINEAR)
Y1 axis: Base current Ibase (LOG)
Y2 axis: Current amplification factor hfe (LINEAR)
Y3 axis: Collector current Icollector (LOG)
Y4 axis: Emitter current Iemitter (LOG)

[List Display]
Emitter voltage Vemitter
Collector current Icollector
Emitter current Iemitter
Base current Ibase
Current amplification factor hfe

[Parameters Display Area]
Collector current determining the hfe (Calculates hfe on a particular Ic) Ic@hfeVal
Emitter current determining the Vbe voltage (Calculates Vbe on a particular Ie) Ie@VbeVal

[Test Output: X-Y Graph]
X axis: Emitter width (We size) WeList (LINEAR)
Y1 axis: Current amplification factor at Ic@hfe Ic@hfeList (LINEAR)
Y2 axis: Emitter voltage at Ic@Vbe Ic@VbeList (LINEAR)

[Test Output: List Display]
Emitter width (We size) WeList
Current amplification factor Ic@hfeList
Emitter voltage Ic@VbeList
2 CMOS
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2.1 BVdss: Breakdown voltage between source and drain (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the breakdown voltage between source and drain of MOSFET.

[Device Under Test]
MOSFET, 4 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Is@BVdss: Source current to decide the breakdown
Drain: SMU connected to Drain, primary sweep voltage output
VdStart: Sweep start voltage for Drain
VdStop: Sweep stop voltage for Drain
VdStep: Sweep step voltage for Drain
Gate: SMU connected to Gate, constant voltage output
Subs: SMU connected to Substrate, constant voltage output
Source: SMU connected to Source, constant voltage output

[Extended Test Parameters]
Vg: Gate voltage
Vs: Source voltage
Vssubs: Substrate voltage
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for the drain current measurement
GateMinRng: Minimum range for the gate current measurement
SubsMinRng: Minimum range for the substrate current measurement

[Measurement Parameters]
Drain current Idrain
Source current Isource
Gate current Igate
Substrate current Isubs
For the source terminal, the SMU current compliance is set to Is@BVdss*1.1.

[User Function]
Source current per unit gate width IsourcePerWg=Isource/Wg
Drain current per unit gate width IdrainPerWg=Idrain/Wg

[Analysis Function]
BVdss=@L1X (X intercept of Line1)

[X-Y Plot]
X axis: Drain voltage Vdrain (LINEAR)
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Y1 axis: Drain current Idrain (LOG)
Y2 axis: Source current Isource (LOG)

[List Display]
Gate current Igate
Substrate current Isubs

[Parameters Display Area]
Breakdown voltage between source and drain BVdss

[Auto Analysis]
Line1: Vertical line through Y2 data at Isource=Is@BVdss
2.2 BVdss [2HL]: Breakdown voltage between source and drain (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the breakdown voltage between source and drain of MOSFET.

[Device Under Test]
MOSFET, 4 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Is@BVdss: Source current to decide the breakdown
Drain: SMU connected to Drain, primary sweep voltage output
VdStart: Sweep start voltage for Drain
VdStop: Sweep stop voltage for Drain
VdStep: Sweep step voltage for Drain
Source: SMU connected to Source, constant voltage output

[Extended Test Parameters]
Vs: Source voltage
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
Drain current Idrain
Source current Isource
For the source terminal, the SMU current compliance is set to Is@BVdss*1.1.

[User Function]
Source current per unit gate width IsourcePerWg=Isource/Wg
Drain current per unit gate width IdrainPerWg=Idrain/Wg

[Analysis Function]
BVdss=@L1X (X intercept of Line1)

[X-Y Plot]
X axis: Drain voltage Vdrain (LINEAR)
Y1 axis: Drain current Idrain (LOG)
Y2 axis: Source current Isource (LOG)

[Parameters Display Area]
Breakdown voltage between source and drain BVdss

[Auto Analysis]
Line1: Vertical line through Y2 data at Isource=Is@BVdss
2.3 BVgso: Breakdown voltage between gate and source (A.01.20)

[Supported Analyzer]

[Description]
Measures the breakdown voltage between gate and source of MOSFET when drain is opened.

[Device Under Test]
MOSFET, 4 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Is@BVgso: Source current to decide the breakdown
Gate: SMU connected to Gate, primary sweep voltage output
VgStart: Sweep start voltage for Gate
VgStop: Sweep stop voltage for Gate
VgStep: Sweep step voltage for Gate
Subs: SMU connected to Substrate, constant voltage output
Source: SMU connected to Source, constant voltage output

[Extended Test Parameters]
Vsubs: Substrate voltage
Vs: Source voltage
HoldTime: Hold time
DelayTime: Delay time
GateMinRng: Minimum range for the gate current measurement
SourceMinRng: Minimum range for the source current measurement
SubsMinRng: Minimum range for the substrate current measurement

[Measurement Parameters]
Source current Isource
Gate current Igate
Substrate current Isubs

For the all terminals, the SMU current compliance is set to Is@BVgso*1.1.

[User Function]
Gate current per Gate unit area IgatePerGateArea=Igate/Lg/Wg

[Analysis Function]
BVgso=@L1X (X intercept of Line1)

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Source current Isource (LOG)
Y2 axis: Gate current Igate (LOG)

[List Display]
Substrate current Isubs

[Parameters Display Area]
Breakdown voltage between gate and source BVgso

[Auto Analysis]
Line1: Vertical line through Y1 data at Isource=Is@BVgso
2.4 BVgso [2HL]: Breakdown voltage between gate and source (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the breakdown voltage between gate and source of MOSFET when drain is opened.

[Device Under Test]
MOSFET, 4 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Is@BVgso: Source current to decide the breakdown
Gate: SMU connected to Gate, primary sweep voltage output
VgStart: Sweep start voltage for Gate
VgStop: Sweep stop voltage for Gate
VgStep: Sweep step voltage for Gate
Source: SMU connected to Source, constant voltage output

[Extended Test Parameters]
Vs: Source voltage
HoldTime: Hold time
DelayTime: Delay time
GateMinRng: Minimum range for the gate current measurement
SourceMinRng: Minimum range for the source current measurement

[Measurement Parameters]
Source current Isource
Gate current Igate
For the all terminals, the SMU current compliance is set to Is@BVgso*1.1.

[User Function]
Gate current per Gate unit area IgatePerGateArea=Igate/Lg/Wg

[Analysis Function]
BVgso=@L1X (X intercept of Line1)

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Source current Isource (LOG)
Y2 axis: Gate current Igate (LOG)

[Parameters Display Area]
Breakdown voltage between gate and source BVgso

[Auto Analysis]
Line1: Vertical line through Y1 data at Isource=Is@BVgso
2.5 Cgb-AC Level: Cgb-Vosc characteristics (A.01.11)

[Supported Analyzer]
B1500A

[Description]
Measures the Gate-Substrate capacitance (Cgs), and plots the Cgs-Vosc characteristics.
DC bias output is fixed at -Vgs. Oscillator level (Vosc) is changed from -OscStart to -OscStop in -OscStep steps. The CMU performs spot measurement of the parallel capacitance (Cp) and conductance (G) at each oscillator level.
For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
MOSFET, 4 terminals
Connect Gate to the CMU Low and Substrate to the CMU High. And connect Drain and Source to the specified SMU.

[Device Parameters]
Polarity: Nch (CMU/SMU forces the specified value) or Pch (CMU/SMU forces the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
OscStart: Oscillator level (Vosc) start voltage
OscStop: Vosc stop voltage
OscStep: Vosc step voltage
FREQ: Measurement frequency
Gate: CMU connected between Gate and Substrate (CV spot measurement)
Vgs: DC bias. Gate-Substrate voltage.
Source: SMU connected to Source terminal (constant voltage output)

[Extended Test Parameters]
Vs: Source voltage
IsLimit: Source current compliance
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Parallel capacitance cp
Conductance g

[User Function]
\[ PI=3.141592653589 \]
\[ d=g/(2*PI*FREQ*cp) \]
\[ \begin{align*}
    \rho_p &= 1/g \\
    c_s &= (1+d^2) \cdot c_p \\
    x &= -1/(2 \pi FREQ \cdot c_s) \\
    r_s &= d \cdot \text{abs}(x) \\
    z &= \sqrt{r_s^2 + x^2} \\
    \theta &= \text{atan}(x/r_s) \\
    V_{gs} &= -V_{subs} \\
    \text{osclevel} &= \text{OscLevel} \\
\end{align*} \]

[Display Setup: X-Y Graph]
- X axis: Oscillator level Vosc (LINEAR)
- Y1 axis: Gate-Substrate capacitance (parallel capacitance) c_p (LINEAR)
- Y2 axis: Conductance g (LINEAR)

[Display Setup: List Display]
- Oscillator level osclevel
- Oscillator level Vosc
- Gate-Substrate capacitance (parallel capacitance) c_p
- Conductance g
- Gate-Substrate voltage V_{gs}

[Test Output: X-Y Graph]
- X axis: Oscillator level OSCLEVEL (LINEAR)
- Y1 axis: Gate-Substrate capacitance (parallel capacitance) C_p (LINEAR)
- Y2 axis: Conductance G (LINEAR)

[Test Output: List Display]
- Oscillator level OSCLEVEL
- Parallel capacitance C_p
- Conductance G
- Series capacitance C_s
- Series resistance R_s
- Parallel resistance R_p
- Dissipation factor D
- Reactance X
- Impedance Z
- Phase \theta

Keysight EasyEXPERT Application Library Reference
2.6 Cgb-Freq Log: Cgb-f characteristics (A.01.20)

[Supported Analyzer]
B1500A

[Description]
Measures MOSFET's characteristics of gate-to-substrate capacitance (Cgb, linear) vs frequency (f, log). The measurement frequency is 10 points per decade.
For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
MOSFET, 4 terminals
Connect Gate to the CMU Low and Substrate to the CMU High. And connect Drain and Source to the GNDU.

[Required Modules and Accessories]
Keysight B1520A MFCMU 1 unit

[Device Parameters]
Polarity: Nch (CMU forces the specified value) or Pch (CMU forces the negative specified value)
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Gate: CMU connected to Gate terminal, CV sweep measurement
Source: SMU connected to Source terminal, constant voltage output
FreqStart: Sweep start frequency
NoOfDecade: Number of decades for data collection
OscLevel: Measurement signal level
Vgs: Voltage for Gate terminal, constant voltage output

[Extended Test Parameters]
G_Min: Minimum transconductance value for graph
G_Max: Maximum transconductance value for graph
Cp_Min: Minimum capacitance value for graph
Cp_Max: Maximum capacitance value for graph
Vs: Voltage for Source terminal
IsLimit: Source current compliance

[Measurement Parameters]
Parallel capacitance Cp
Conductance G

[User Function]
Circular constant PI=3.141592653589
Frequency Frequency=Freq
Dissipation factor D=G/(2*PI*Freq*Cp)
Parallel resistance Rp=1/G
Series capacitance Cs=(1+D^2)*Cp
Reactance X=-1/(2*PI*Freq*Cs)
Series resistance Rs=D*abs(X)
Impedance Z=sqrt(Rs^2+X^2)
Phase Theta=atan(X/Rs)

[X-Y Plot]
X axis: Frequency Freq (LOG)
Y1 axis: Gate-Substrate capacitance (parallel capacitance) Cp (LINEAR)
Y2 axis: Conductance G (LINEAR)

[List Display]
Frequency Freq
Gate-Substrate capacitance Cp
Series capacitance Cs
Series resistance Rs
Parallel resistance Rp
Dissipation factor D
Reactance X
Impedance Z
Phase Theta
Substrate voltage Vsubs
Conductance G

[Test Output: X-Y Graph]
X axis: Frequency list FreqList (LOG)
Y1 axis: Gate-Substrate capacitance (parallel capacitance) list CpList (LINEAR)
Y2 axis: Conductance list GList (LINEAR)

[Test Output: List Display]
Frequency FreqList
Gate-Substrate capacitance (parallel capacitance) CpList
Conductance GList
Series capacitance CsList
Series resistance RsList
Parallel resistance RpList
Dissipation factor DList
Reactance XList
Impedance ZList
Phase ThetaList
Substrate voltage VsubsList
2.7 Cgb-Vg High Voltage: Cgb-Vg characteristics using SCUU (A.01.11)

[Supported Analyzer]
B1500A

[Description]
Measures the Gate-Substrate capacitance (Cgs), and plots the Cgs-Vg characteristics.
DC bias output is performed from -VgsStart to -VgsStop in -VgsStep steps. The CMU performs spot
measurement of the parallel capacitance (Cp) and conductance (G) at each bias output. SCUU enables the
maximum 100 V DC bias.
For a more accurate measurement, perform correction data measurement at the measurement frequency before
starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced
Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU
Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M,
3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
MOSFET, 4 terminals
Connect Gate and Substrate to the SCUU. And connect Drain and Source to the specified SMU.

[Required Modules and Accessories]
One MFCMU module, three SMU modules, and a set of SCUU/GSWU are required.
SCUU connections: Output1: Substrate, Output2: Gate
Connection wire must be connected between the GSWU and the DUT interface High/Low guard lines.

[Device Parameters]
Polarity: Nch (CMU/SMU forces the specified value) or Pch (CMU/SMU forces the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
FREQ: Measurement frequency
OscLevel: Measurement signal level
Gate: CMU connected between Gate and Substrate (CV spot measurement)
VgsStart: DC bias start voltage
VgsStop: DC bias stop voltage
VgsStep: DC bias step voltage
Source: SMU connected to Source terminal (constant voltage output)

[Extended Test Parameters]
IsLimit: Source current compliance
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Parallel capacitance Cp
Conductance G
[User Function]
PI=3.141592653589
D=G/(2*PI*FREQ*Cp)
Rp=1/G
Cs=(1+D^2)*Cp
X=-1/(2*PI*FREQ*Cs)
Rs=D*abs(X)
Z=sqrt(Rs^2+X^2)
Theta=atan(X/Rs)
Subs=Vstart*Polarity

[Display Setup: X-Y Graph]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Gate-Substrate capacitance (parallel capacitance) Cp (LINEAR)
Y2 axis: Conductance G (LINEAR)

[Display Setup: List Display]
Substrate voltage Subs
Gate voltage Vgate
Gate-Substrate capacitance (parallel capacitance) Cp

[Test Output: X-Y Graph]
X axis: Gate voltage VgList (LINEAR)
Y1 axis: Gate-Substrate capacitance (parallel capacitance) CpList (LINEAR)
Y2 axis: Conductance GList (LINEAR)

[Test Output: List Display]
Gate voltage VgList
Gate-Substrate capacitance (parallel capacitance) CpList
Conductance GList
Series capacitance CsList
Series resistance RsList
Parallel resistance RpList
Dissipation factor DList
Reactance XList
Impedance ZList
Phase ThetaList
2.8 Cgb-Vg: Cgb-Vg characteristics (A.01.11)

[Supported Analyzer]
B1500A

[Description]
Measures the Gate-Substrate capacitance (Cgs), and plots the Cgs-Vg characteristics. DC bias output is performed from -VgsStart to -VgsStop in -VgsStep steps. The CMU performs spot measurement of the parallel capacitance (Cp) and conductance (G) at each bias output. For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement. If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
MOSFET, 4 terminals
Connect Gate to the CMU Low, and Substrate to the CMU High. And connect Drain and Source to the specified SMU.

[Device Parameters]
Polarity: Nch (CMU/SMU forces the specified value) or Pch (CMU/SMU forces the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
FREQ: Measurement frequency
OscLevel: Measurement signal level
Gate: CMU connected between Gate and substrate (CV spot measurement)
VgsStart: DC bias start voltage
VgsStop: DC bias stop voltage
VgsStep: DC bias step voltage
Source: SMU connected to Source terminal (constant voltage output)

[Extended Test Parameters]
Vs: Source voltage
IsLimit: Source current compliance
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Parallel capacitance Cp
Conductance G

[User Function]
\[ PI=3.141592653589 \]
\[ D=G/(2*PI*FREQ*Cp) \]
\[ Rp=1/G \]
Cs = (1 + D^2) * Cp
X = 1 / (2 * PI * FREQ * Cs)
Rs = D * abs(X)
Z = sqrt(Rs^2 + X^2)
Theta = atan(X / Rs)
Vsubs = Vstart * Polarity

[Display Setup: X-Y Graph]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Gate-Substrate capacitance (parallel capacitance) Cp (LINEAR)
Y2 axis: Conductance G (LINEAR)

[Display Setup: List Display]
Substrate voltage Vsubs
Source voltage Vsource
Gate-Substrate capacitance (parallel capacitance) Cp

[Test Output: X-Y Graph]
X axis: Gate voltage VgList (LINEAR)
Y1 axis: Gate-Substrate capacitance (parallel capacitance) CpList (LINEAR)
Y2 axis: Conductance GList (LINEAR)

[Test Output: List Display]
Gate voltage VgList
Gate-Substrate capacitance (parallel capacitance) CpList
Conductance GList
Series capacitance CsList
Series resistance RsList
Parallel resistance RpList
Dissipation factor DList
Reactance XList
Impedance ZList
Phase ThetaList
2.9 Cgc-Freq Log: Cgc-f characteristics (A.01.20)

[Supported Analyzer]
B1500A

[Description]
Measures MOSFET's characteristics of gate-to-channel capacitance (Cgc, linear) vs frequency (f, log). The measurement frequency is 10 points per decade.
For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
MOSFET, 4 terminals
Connect Gate to the CMU Low, and Drain-Source to the CMU High. And connect Substrate to the GNDU.

[Required Modules and Accessories]
Keysight B1520A MFCMU 1 unit

[Device Parameters]
Polarity: Nch (CMU forces the specified value) or Pch (CMU forces the negative specified value)
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Gate: CMU connected to Gate terminal, CV sweep measurement
Subs: SMU connected to Substrate terminal, constant voltage output
FreqStart: Sweep start frequency
NoOfDecade: Number of decades for data collection
OscLevel: Measurement signal level
Vgs: Voltage for Gate terminal, constant voltage output

[Extended Test Parameters]
Vsubs: Voltage for Substrate terminal
IsubsLimit: Substrate current compliance
G_Mi_n: Minimum transconductance value for graph
G_Ma_x: Maximum transconductance value for graph
Cp_Mi_n: Minimum capacitance value for graph
Cp_Ma_x: Maximum capacitance value for graph

[Measurement Parameters]
Parallel capacitance Cp
Conductance G

[User Function]
Circular constant PI=3.141592653589
Frequency $F_{\text{Freq}} = Freq$
Dissipation factor $D = G/(2\pi F_{\text{Freq}} C_{\text{p}})$
Parallel resistance $R_{\text{p}} = 1/G$
Series capacitance $C_{\text{s}} = (1 + D^2) C_{\text{p}}$
Reactance $X = -1/(2\pi F_{\text{Freq}} C_{\text{s}})$
Series resistance $R_{\text{s}} = D \times \text{abs}(X)$
Impedance $Z = \sqrt{R_{\text{s}}^2 + X^2}$
Phase $\Theta = \text{atan}(X/R_{\text{s}})$

[X-Y Plot]
X axis: Frequency $F_{\text{Freq}}$ (LOG)
Y1 axis: Gate-Channel capacitance (parallel capacitance) $C_{\text{p}}$ (LINEAR)
Y2 axis: Conductance $G$ (LINEAR)

[List Display]
Frequency $F_{\text{Freq}}$
Gate-Channel capacitance $C_{\text{p}}$
Gate voltage $G$
Series capacitance $C_{\text{s}}$
Series resistance $R_{\text{s}}$
Parallel resistance $R_{\text{p}}$
Dissipation factor $D$
Reactance $X$
Impedance $Z$
Phase $\Theta$
Source voltage $V_{\text{source}}$

[Test Output: X-Y Graph]
X axis: Frequency list $F_{\text{FreqList}}$ (LOG)
Y1 axis: Gate-Channel capacitance (parallel capacitance) list $C_{\text{pList}}$ (LINEAR)
Y2 axis: Conductance list $G_{\text{List}}$ (LINEAR)

[Test Output: List Display]
Frequency $F_{\text{FreqList}}$
Gate-Channel capacitance (parallel capacitance) $C_{\text{pList}}$
Conductance $G_{\text{List}}$
Series capacitance $C_{\text{sList}}$
Series resistance $R_{\text{sList}}$
Parallel resistance $R_{\text{pList}}$
Dissipation factor $D_{\text{List}}$
Reactance $X_{\text{List}}$
Impedance $Z_{\text{List}}$
Phase $\Theta_{\text{List}}$
Source voltage $V_{\text{sourceList}}$
2 CMOS

2.10  \textit{Cgc-Vg: Cgc-Vg characteristics (A.01.11)}

[Supported Analyzer]
B1500A

[Description]
Measures the Gate-Channel capacitance (Cgc), and plots the Cgc-Vg characteristics.
DC bias output is performed from \(-Vgs\text{Start}\) to \(-Vgs\text{Stop}\) in \(-Vgs\text{Step}\) steps. The CMU performs spot measurement of the parallel capacitance (Cp) and conductance (G) at each bias output. The substrate voltage is changed simultaneously with the DC bias output to keep the Channel-Substrate voltage constant. The SMU works as the constant voltage source and realizes the secondary sweep by repeating the output change every DC bias sweep.
For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
MOSFET, 4 terminals
Connect Gate to the CMU Low, and Drain-Source to the CMU High. And connect Substrate to the specified SMU.

[Device Parameters]
Polarity: Nch (CMU/SMU forces the specified value) or Pch (CMU/SMU forces the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
FREQ: Measurement frequency
OscLevel: Measurement signal level
Gate: CMU connected between Gate and channel (CV spot measurement)
VgsStart: DC bias start voltage (primary sweep)
VgsStop: DC bias stop voltage (primary sweep)
VgsStep: DC bias step voltage (primary sweep)
Subs: SMU connected to Substrate terminal (constant voltage output)
VbsStart: Substrate start voltage (secondary sweep)
VbsStop: Substrate stop voltage (secondary sweep)
VbsStep: Substrate step voltage (secondary sweep)
IsubsLimit: Substrate current compliance

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Parallel capacitance Cp
Conductance G
[User Function]
PI=3.141592653589
D=G/(2*PI*FREQ*Cp)
Rp=1/G
Cs=(1+D^2)*Cp
X=-1/(2*PI*FREQ*Cs)
Rs=D*abs(X)
Z=sqrt(Rs^2+X^2)
Theta=atan(X/Rs)
Vgate=-Vsource

[Display Setup: X-Y Graph]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Gate-Channel capacitance (parallel capacitance) Cp (LINEAR)
Y2 axis: Conductance G (LINEAR)

[Display Setup: List Display]
Gate voltage Vgate
Substrate voltage Vsubs
Gate-Channel capacitance (parallel capacitance) Cp
Conductance G

[Test Output: X-Y Graph]
X axis: Gate voltage VgList (LINEAR)
Y1 axis: Gate-Channel capacitance (parallel capacitance) CpList (LINEAR)
Y2 axis: Conductance GList (LINEAR)

[Test Output: List Display]
Gate voltage VgList
Channel-Substrate voltage VbsList
Gate-Channel capacitance (parallel capacitance) CpList
Conductance GList
Series capacitance CsList
Series resistance RsList
Parallel resistance RpList
Dissipation factor DList
Reactance XList
Impedance ZList
Phase ThetaList
2.11 Cgg-Freq Linear: Cgg-f characteristics (A.01.20)

[Supported Analyzer]
B1500A

[Description]
Measures the gate capacitance (Cgg, linear) vs frequency (f, linear) characteristics of MOSFET.
For a more accurate measurement, perform correction data measurement at the measurement frequency before
starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced
Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU
Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M,
3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
MOSFET, 4 terminals
Connect Gate to the CMU Low, and Drain-Source-Substrate to the CMU High.

[Required Modules and Accessories]
Keysight B1520A MFCMU 1 unit

[Device Parameters]
Polarity: Nch (CMU forces the specified value) or Pch (CMU forces the negative specified value)
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
FreqStart: Sweep start frequency
NoOfPoint: Number of measurement points
OscLevel: Measurement signal level
Gate: CMU connected to Gate terminal, CV sweep measurement
Vgs: Voltage for Gate terminal, constant voltage output

[Extended Test Parameters]
G_Min: Minimum transconductance value for graph
G_Max: Maximum transconductance value for graph
Cp_Min: Minimum capacitance value for graph
Cp_Max: Maximum capacitance value for graph

[Measurement Parameters]
Parallel capacitance Cp
Conductance G

[User Function]
Circular constant PI=3.141592653589
Frequency Frequency=Freq
Dissipation factor D=G/(2*PI*Freq*Cp)
Parallel resistance Rp=1/G
Series capacitance Cs=(1+D^2)*Cp
Reactance \( X = -1/(2\pi Freq \times Cs) \)
Series resistance \( Rs = D \times \text{abs}(X) \)
Impedance \( Z = \sqrt{Rs^2 + X^2} \)
Phase \( \theta = \text{atan}(X/Rs) \)

[X-Y Plot]
- X axis: Frequency \( Freq \) (LINEAR)
- Y1 axis: Gate capacitance (parallel capacitance) \( Cp \) (LINEAR)
- Y2 axis: Conductance \( G \) (LINEAR)

[List Display]
- Frequency \( Freq \)
- Gate capacitance (parallel capacitance) \( Cp \)
- Conductance \( G \)
- Series capacitance \( Cs \)
- Series resistance \( Rs \)
- Parallel resistance \( Rp \)
- Dissipation factor \( D \)
- Reactance \( X \)
- Impedance \( Z \)
- Phase \( \theta \)
- Substrate voltage \( Vsubs \)

[Test Output: X-Y Graph]
- X axis: Frequency list \( FreqList \) (LINEAR)
- Y1 axis: Gate capacitance (parallel capacitance) list \( CpList \) (LINEAR)
- Y2 axis: Conductance list \( GList \) (LINEAR)

[Test Output: List Display]
- Frequency \( FreqList \)
- Gate capacitance (parallel capacitance) \( CpList \)
- Conductance \( GList \)
- Series capacitance \( CsList \)
- Series resistance \( RsList \)
- Parallel resistance \( RpList \)
- Dissipation factor \( DList \)
- Reactance \( XList \)
- Impedance \( ZList \)
- Phase \( \thetaList \)
- Substrate voltage \( VsubsList \)
2.12  *Cgg-Freq Log: Cgg-f characteristics (A.01.20)*

[Supported Analyzer]
B1500A

[Description]
Measures the gate capacitance (Cgg, linear) vs frequency (f, log) characteristics of MOSFET. The measurement frequency is 10 points per decade.
For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
MOSFET, 4 terminals
Connect Gate to the CMU Low, and Drain-Source-Substrate to the CMU High.

[Required Modules and Accessories]
Keysight B1520A MFCMU 1 unit

[Device Parameters]
Polarity: Nch (CMU forces the specified value) or Pch (CMU forces the negative specified value)
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
FreqStart: Sweep start frequency
NoOfDecade: Number of decades for data collection
OscLevel: Measurement signal level
Gate: CMU connected to Gate terminal, CV sweep measurement
Vgs: Voltage for Gate terminal, constant voltage output

[Extended Test Parameters]
G_Min: Minimum transconductance value for graph
G_Max: Maximum transconductance value for graph
Cp_Min: Minimum capacitance value for graph
Cp_Max: Maximum capacitance value for graph

[Measurement Parameters]
Parallel capacitance Cp
Conductance G

[User Function]
Circular constant PI=3.141592653589
Frequency Frequency=Freq
Dissipation factor D=G/(2*PI*Freq*Cp)
Parallel resistance Rp=1/G
Series capacitance $C_s = (1 + D^2) * C_p$
Reactance $X = -1/(2\pi Freq * C_s)$
Series resistance $R_s = D * \text{abs}(X)$
Impedance $Z = \sqrt{R_s^2 + X^2}$
Phase Theta = \text{atan}(X/R_s)

[X-Y Plot]
X axis: Frequency Freq (LOG)
Y1 axis: Gate capacitance (parallel capacitance) $C_p$ (LINEAR)
Y2 axis: Conductance $G$ (LINEAR)

[List Display]
Frequency Freq
Gate capacitance (parallel capacitance) $C_p$
Conductance $G$
Series capacitance $C_s$
Series resistance $R_s$
Parallel resistance $R_p$
Dissipation factor $D$
Reactance $X$
Impedance $Z$
Phase Theta
Substrate voltage $V_{subs}$

[Test Output: X-Y Graph]
X axis: Frequency measurement list $FreqList$ (LOG)
Y1 axis: Gate capacitance (parallel capacitance) list $C_pList$ (LINEAR)
Y2 axis: Conductance list $GList$ (LINEAR)

[Test Output: List Display]
Frequency $FreqList$
Gate capacitance (parallel capacitance) list $C_pList$
Conductance $GList$
Series capacitance $C_sList$
Series resistance $R_sList$
Parallel resistance $R_pList$
Dissipation factor $DList$
Reactance $XList$
Impedance $ZList$
Phase ThetaList
Substrate voltage $V_{subsList}$
2.13  Cgg-Vg 2Freq: Cgg-Vg characteristics, 2-frequency method (A.01.11)

[Supported Analyzer]
B1500A

[Description]
Measures the Gate capacitance (Cgg), and plots the Cgg-Vg characteristics. The Cgg value is given by the following formula. Then C1 and C2 are capacitance, D1 and D2 are dissipation factor measured at the frequency (f1 and f2).

\[ C_{gg} = \frac{f_1^2*C_1*(1+D_1^2)-f_2^2*C_2*(1+D_2^2)}{f_2^2-f_1^2} \]

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement. If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
MOSFET, 4 terminals
Connect Gate to the CMU Low, and the other terminals to the CMU High.

[Device Parameters]
Polarity: Nch (CMU forces the specified value) or Pch (CMU forces the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
OscLevel: Measurement signal level
FREQ1: Measurement frequency
FREQ2: Measurement frequency
Gate: CMU connected to Gate terminal (CV sweep measurement)
VgsStart: DC bias start voltage
VgsStop: DC bias stop voltage
VgsStep: DC bias step voltage

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Parallel capacitance Cp
Dissipation factor D

[User Function]
Vgs=-Vsubs

[Display Setup: X-Y Graph]
X axis: Gate voltage Vgs (LINEAR)
Y1 axis: Gate capacitance (parallel capacitance) Cp (LINEAR)
Y2 axis: Dissipation factor D (LINEAR)

[Display Setup: List Display]
Gate voltage Vgs
Gate capacitance (parallel capacitance) Cp
Dissipation factor D

[Test Output: X-Y Graph]
X axis: Gate voltage VGS (LINEAR)
Y1 axis: Gate capacitance (parallel capacitance) Cgg (LINEAR)
Y2 axis: Gate capacitance (parallel capacitance) Cp_FREQ1 (LINEAR)
Y3 axis: Gate capacitance (parallel capacitance) Cp_FREQ2 (LINEAR)

[Test Output: List Display]
Gate voltage VGS
Gate capacitance (parallel capacitance) Cgg
Gate capacitance (parallel capacitance) Cp_FREQ1
Gate capacitance (parallel capacitance) Cp_FREQ2
Dissipation factor D_FREQ1
Dissipation factor D_FREQ2
2.14 *Cgg-Vg: Cgg-Vg characteristics (A.01.11)*

[Supported Analyzer]
B1500A

[Description]
Measures the Gate capacitance (Cgg), and plots the Cgg-Vg characteristics.
For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
MOSFET, 4 terminals
Connect Gate to the CMU Low, and the other terminals to the CMU High.

[Device Parameters]
Polarity: Nch (CMU forces the specified value) or Pch (CMU forces the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
FREQ: Measurement frequency
OscLevel: Measurement signal level
Gate: CMU connected to Gate terminal (CV sweep measurement)
VgsStart: DC bias start voltage
VgsStop: DC bias stop voltage
VgsStep: DC bias step voltage

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Parallel capacitance Cp
Conductance G

[User Function]
PI=3.141592653589
Dval=Gval/(2*PI*FREQ*Cpval)
Rpval=1/Gval
Csval=(1+Dval^2)*Cpval
Xval=-1/(2*PI*FREQ*Csval)
Rsval=Dval*abs(Xval)
Zval=sqrt(Rsval^2+Xval^2)
Thetaval=atan(Xval/Rsval)
Vgateval=-Vsubs
[X-Y Graph]
X axis: Gate voltage Vgateval (LINEAR)
Y1 axis: Gate capacitance (parallel capacitance) Cpval (LINEAR)
Y2 axis: Conductance Gval (LINEAR)

[List Display]
Gate voltage Vgateval
Gate capacitance (parallel capacitance) Cpval
Conductance Gval
Series capacitance Csval
Series resistance Rsval
Parallel resistance Rpval
Dissipation factor Dval
Reactance Xval
Impedance Zval
Phase Thetaval
2.15  \textit{IdRdsGds: Drain resistance/conductance (A.01.20)}

[Supported Analyzer]
- B1500A, E5260A, E5270B

[Description]
Extracts the early voltage, drain resistance, and drain conductance from the drain current vs drain voltage characteristics of MOSFET.

[Device Under Test]
MOSFET, 4 terminals

[Device Parameters]
- Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
- Lg: Gate length
- Wg: Gate width
- Temp: Temperature
- IdMax: Drain current compliance

[Test Parameters]
- IntegTime: Integration time
- Drain: SMU connected to Drain terminal, primary sweep voltage output
- VdStart: Sweep start voltage for Drain terminal
- VdStop: Sweep stop voltage for Drain terminal
- VdStep: Sweep step voltage for Drain terminal
- Gate: SMU connected to Gate terminal, secondary sweep voltage output
- VgStart: Sweep start voltage for Gate terminal
- VgStop: Sweep stop voltage for Gate terminal
- VgStep: Sweep step voltage for Gate terminal
- Subs: SMU connected to Substrate, constant voltage output
- Vsubs: Substrate voltage
- Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]
- Vs: Source voltage
- IgLimit: Gate current compliance
- IsubsLimit: Substrate current compliance
- HoldTime: Hold time
- DelayTime: Delay time
- DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
- Drain current Idrain
- Drain resistance Rds
- Early voltage VA
- Drain conductance gds

[User Function]
- \(gds = \text{diff}(Idrain, Vdrain)\)
- \(Rds = 1/gds\)
- \(VA = Rds*\text{abs}(Idrain) - \text{abs}(Vdrain)\)

[X-Y Plot]
- X axis: Drain voltage Vdrain (LINEAR)
- Y1 axis: Drain current Idrain (LINEAR)
- Y2 axis: Drain resistance Rds (LOG)
- Y3 axis: Early voltage VA (LINEAR)

[List Display]
- Drain conductance gds
2.16  \textit{IdRdsGds [2HL]: Drain resistance/conductance (A.06.10)}

[Supported Analyzer]
  B2901A, B2902A, B2911A, B2912A

[Description]
  Extracts the early voltage, drain resistance, and drain conductance from the drain current vs drain voltage characteristics of MOSFET.

[Device Under Test]
  MOSFET, 4 terminals

[Device Parameters]
  Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
  Lg: Gate length
  Wg: Gate width
  Temp: Temperature
  IdMax: Drain current compliance

[Test Parameters]
  IntegTime: Integration time
  Drain: SMU connected to Drain terminal, primary sweep voltage output
  VdStart: Sweep start voltage for Drain terminal
  VdStop: Sweep stop voltage for Drain terminal
  VdStep: Sweep step voltage for Drain terminal
  Gate: SMU connected to Gate terminal, secondary sweep voltage output
  VgStart: Sweep start voltage for Gate terminal
  VgStop: Sweep stop voltage for Gate terminal
  VgStep: Sweep step voltage for Gate terminal

[Extended Test Parameters]
  IgLimit: Gate current compliance
  HoldTime: Hold time
  DelayTime: Delay time
  DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
  Drain current Idrain
  Drain resistance Rds
  Early voltage VA
  Drain conductance gds

[User Function]
  \( gds = \text{diff}(Idrain, Vdrain) \)
  \( Rds = 1 / gds \)
  \( VA = Rds \times \text{abs}(Idrain) - \text{abs}(Vdrain) \)

[X-Y Plot]
  X axis: Drain voltage Vdrain (LINEAR)
  Y1 axis: Drain current Idrain (LINEAR)
  Y2 axis: Drain resistance Rds (LOG)
  Y3 axis: Early voltage VA (LINEAR)

[List Display]
  Drain conductance gds
2.17  
**Id-Vd pulse: Id-Vd characteristics, SMU Pulse (A.01.11)**

[Supported Analyzer]

B1500A, E5260A, E5270B

[Description]

Measures the drain current vs drain voltage characteristics of MOSFET. SMU pulse output is used for applying the drain voltage.

[Device Under Test]

MOSFET, 4 terminals

[Device Parameters]

Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]

Drain: SMU connected to Drain terminal, primary sweep voltage output
VdStart: Sweep start voltage for Drain terminal
VdStop: Sweep stop voltage for Drain terminal
VdStep: Sweep step voltage for Drain terminal
PulsePeriod: Pulse period
PulseWidth: Pulse width
Gate: SMU connected to Gate terminal, secondary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
IgLimit: Gate current compliance
Subs: SMU connected to Substrate, constant voltage output
Vsubs: Substrate voltage
IsubsLimit: Substrate current compliance
Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]

Vs: Source voltage
BaseValue: Pulse base voltage
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]

Drain current Idrain

[User Function]

IdrainPerWg: Drain current per unit gate width IdrainPerWg=Idrain/Wg

[X-Y Plot]

X axis: Drain voltage Vdrain (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)

[List Display]

Drain current per unit gate width IdrainPerWg
2.18  Id-Vd pulse[3] : Id-Vd characteristics (3-terminal), SMU Pulse (A.01.11)

[Supported Analyzer]

[Description]
Measures the drain current vs drain voltage characteristics of MOSFET. SMU pulse is used for the drain voltage output.

[Device Under Test]
MOSFET, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Drain: SMU connected to Drain terminal, primary sweep voltage output
VdStart: Sweep start voltage for Drain terminal
VdStop: Sweep stop voltage for Drain terminal
VdStep: Sweep step voltage for Drain terminal
PulsePeriod: Pulse period
PulseWidth: Pulse width
Gate: SMU connected to Gate terminal, secondary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
IgLimit: Gate current compliance
Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]
Vs: Source voltage
BaseValue: Pulse base voltage
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Drain current Idrain

[User Function]
IdrainPerWg: Drain current per unit gate width IdrainPerWg=Idrain/Wg

[X-Y Plot]
X axis: Drain voltage Vdrain (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)

[List Display]
Drain current per unit gate width IdrainPerWg
2.19  *Id-Vd pulse [2HL]: Id-Vd characteristics, SMU Pulse (A.06.10)*

[Supported Analyzer]
  B2901A, B2902A, B2911A, B2912A

[Description]
  Measures the drain current vs drain voltage characteristics of MOSFET. SMU pulse output is used for
  applying the drain voltage.

[Device Under Test]
  MOSFET, 4 terminals

[Device Parameters]
  Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
  Lg: Gate length
  Wg: Gate width
  Temp: Temperature
  IdMax: Drain current compliance

[Test Parameters]
  Drain: SMU connected to Drain terminal, primary sweep voltage output
  VdStart: Sweep start voltage for Drain terminal
  VdStop: Sweep stop voltage for Drain terminal
  VdStep: Sweep step voltage for Drain terminal
  PulsePeriod: Pulse period
  PulseWidth: Pulse width
  Gate: SMU connected to Gate terminal, secondary sweep voltage output
  VgStart: Sweep start voltage for Gate terminal
  VgStop: Sweep stop voltage for Gate terminal
  VgStep: Sweep step voltage for Gate terminal
  IgLimit: Gate current compliance

[Extended Test Parameters]
  BaseValue: Pulse base voltage
  HoldTime: Hold time
  DelayTime: Delay time

[Measurement Parameters]
  Drain current Idrain

[User Function]
  IdrainPerWg: Drain current per unit gate width IdrainPerWg=Idrain/Wg

[X-Y Plot]
  X axis: Drain voltage Vdrain (LINEAR)
  Y1 axis: Drain current Idrain (LINEAR)

[List Display]
  Drain current per unit gate width IdrainPerWg
2.20  **Id-Vd: Id-Vd Characteristics (A.01.20)**

[Supported Analyzer]
- B1500A, E5260A, E5270B

[Description]
Measures the drain current vs drain voltage characteristics of MOSFET.

[Device Under Test]
- MOSFET, 4 terminals

[Device Parameters]
- Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
- Lg: Gate length
- Wg: Gate width
- Temp: Temperature
- IdMax: Drain current compliance

[Test Parameters]
- Drain: SMU connected to Drain terminal, primary sweep voltage output
- VdStart: Sweep start voltage for Drain terminal
- VdStop: Sweep stop voltage for Drain terminal
- VdStep: Sweep step voltage for Drain terminal
- Gate: SMU connected to Gate terminal, secondary sweep voltage output
- VgStart: Sweep start voltage for Gate terminal
- VgStop: Sweep stop voltage for Gate terminal
- VgStep: Sweep step voltage for Gate terminal
- Subs: SMU connected to Substrate, constant voltage output
- Vsubs: Substrate voltage
- Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]
- Vs: Source voltage
- IgLimit: Gate current compliance
- IsubsLimit: Substrate current compliance
- IntegTime: Integration time
- HoldTime: Hold time
- DelayTime: Delay time
- DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
- Drain current Idrain

[User Function]
- IdrainPerWg: Drain current per unit gate width IdrainPerWg=Idrain/Wg

[X-Y Plot]
- X axis: Drain voltage Vdrain (LINEAR)
- Y1 axis: Drain current Idrain (LINEAR)

[List Display]
- Drain current per unit gate width IdrainPerWg
2.21  Id-Vd[3]: Id-Vd Characteristics (3-terminal) (A.01.20)

[Supported Analyzer]

[Description]
Measures the drain current vs drain voltage characteristics of MOSFET.

[Device Under Test]
MOSFET, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Drain: SMU connected to Drain terminal, primary sweep voltage output
VdStart: Sweep start voltage for Drain terminal
VdStop: Sweep stop voltage for Drain terminal
VdStep: Sweep step voltage for Drain terminal
Gate: SMU connected to Gate terminal, secondary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]
Vs: Source voltage
IgLimit: Gate current compliance
IntegTime: Integration time
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
Drain current Idrain

[User Function]
IdrainPerWg: Drain current per unit gate width IdrainPerWg=Idrain/Wg

[X-Y Plot]
X axis: Drain voltage Vdrain (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)

[List Display]
Drain current per unit gate width IdrainPerWg
2.22  *Id-Vd [2HL]: Id-Vd Characteristics (A.06.10)*

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the drain current vs drain voltage characteristics of MOSFET.

[Device Under Test]
MOSFET, 4 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Drain: SMU connected to Drain terminal, primary sweep voltage output
VdStart: Sweep start voltage for Drain terminal
VdStop: Sweep stop voltage for Drain terminal
VdStep: Sweep step voltage for Drain terminal
Gate: SMU connected to Gate terminal, secondary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal

[Extended Test Parameters]
IgLimit: Gate current compliance
IntegTime: Integration time
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
Drain current Idrain

[User Function]
IdrainPerWg: Drain current per unit gate width IdrainPerWg=Idrain/Wg

[X-Y Plot]
X axis: Drain voltage Vdrain (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)

[List Display]
Drain current per unit gate width IdrainPerWg
2.23  *Id-Vg pulse: Id-Vg characteristics, SMU Pulse (A.01.12)*

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the drain current vs gate voltage characteristics of MOSFET by using SMU pulse.

[Device Under Test]
MOSFET, 4 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Drain: SMU connected to Drain terminal, constant voltage output
Vd: Drain voltage
PulsePeriod: Pulse period
PulseWidth: Pulse width
Subs: SMU connected to Substrate, secondary sweep voltage output
VsubsStart: Sweep start voltage for Substrate terminal
VsubsStop: Sweep stop voltage for Substrate terminal
VsubsStep: Sweep step voltage for Substrate terminal
Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]
Vs: Source voltage
BaseValue: Pulse base voltage
IgLimit: Gate current compliance
IsubsLimit: Substrate current compliance
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Drain current Idrain

[User Function]
IdrainPerWg: Drain current per unit gate width IdrainPerWg=Idrain/Wg
gm: Transconductance gm=diff(Idrain,Vgate)
gmPerWg: Transconductance per unit gate width gmPerWg=diff(IdrainPerWg,Vgate)

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Transconductance gm (LINEAR)

[List Display]
Drain current per unit gate width IdrainPerWg
Transconductance per unit gate width gmPerWg
2.24  Id-Vg Vpulse[3]: Id-Vg characteristics (3-terminal), SMU Pulse (A.01.11)

[Supported Analyzer]

[Description]
   Measures the drain current vs gate voltage characteristics of MOSFET.

[Device Under Test]
   MOSFET, 3 terminals

[Device Parameters]
   Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
   Lg: Gate length
   Wg: Gate width
   Temp: Temperature
   IdMax: Drain current compliance

[Test Parameters]
   Gate: SMU connected to Gate terminal, primary sweep voltage output
   VgStart: Sweep start voltage for Gate terminal
   VgStop: Sweep stop voltage for Gate terminal
   VgStep: Sweep step voltage for Gate terminal
   Drain: SMU connected to Drain terminal, secondary sweep voltage output
   VdStart: Sweep start voltage for Drain terminal
   VdStop: Sweep stop voltage for Drain terminal
   VdStep: Sweep step voltage for Drain terminal
   PulsePeriod: Pulse period
   PulseWidth: Pulse width
   Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]
   Vs: Source voltage
   BaseValue: Pulse base voltage
   IgLimit: Gate current compliance
   HoldTime: Hold time
   DelayTime: Delay time

[Measurement Parameters]
   Drain current Idrain

[User Function]
   IdrainPerWg: Drain current per unit gate width IdrainPerWg=Idrain/Wg
   gm: Transconductance gm=diff(Idrain,Vgate)
   gmPerWg: Transconductance per unit gate width gmPerWg=diff(IdrainPerWg,Vgate)

[X-Y Plot]
   X axis: Gate voltage Vgate (LINEAR)
   Y1 axis: Drain current Idrain (LINEAR)
   Y2 axis: Transconductance gm (LINEAR)

[List Display]
   Drain current per unit gate width IdrainPerWg
   Transconductance per unit gate width gmPerWg
2.25  Id-Vg: Id-Vg Characteristics (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the drain current vs gate voltage characteristics of MOSFET.

[Device Under Test]
MOSFET, 4 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
Gate: SMU connected to Gate terminal, primary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Drain: SMU connected to Drain terminal, constant voltage output
Vd: Drain voltage
Subs: SMU connected to Substrate, secondary sweep voltage output
VsubsStart: Sweep start voltage for Substrate terminal
VsubsStop: Sweep stop voltage for Substrate terminal
VsubsStep: Sweep step voltage for Substrate terminal
Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]
Vs: Source voltage
IgLimit: Gate current compliance
IsubsLimit: Substrate current compliance
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Measurement minimum range of drain current
SubsMinRng: Measurement minimum range of substrate current

[Measurement Parameters]
Drain current Idrain
Substrate current Isubs

[User Function]
IdrainPerWg: Drain current per unit gate width IdrainPerWg=Idrain/Wg
IsubsPerWg: Substrate current per unit gate width IsubsPerWg=Isubs/Wg
gm: Transconductance gm=diff(Idrain,Vgate)
gmPerWg: Transconductance per unit gate width gmPerWg=diff(IdrainPerWg,Vgate)

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)
Y3 axis: Substrate current Isubs (LINEAR)
Y4 axis: Substrate current Isubs (LOG)

[List Display]
Drain current per unit gate width IdrainPerWg
Substrate current per unit gate width IsubsPerWg
Transconductance gm
Transconductance per unit gate width gmPerWg
2.26  Id-Vg[3]: Id-Vg Characteristics (3-terminal) (A.01.20)

[Supported Analyzer]

[Description]
   Measures the drain current vs gate voltage characteristics of MOSFET.

[Device Under Test]
   MOSFET, 3 terminals

[Device Parameters]
   Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
   Lg: Gate length
   Wg: Gate width
   Temp: Temperature
   IdMax: Drain current compliance

[Test Parameters]
   IntegTime: Integration time
   Gate: SMU connected to Gate terminal, primary sweep voltage output
   VgStart: Sweep start voltage for Gate terminal
   VgStop: Sweep stop voltage for Gate terminal
   VgStep: Sweep step voltage for Gate terminal
   Drain: SMU connected to Drain terminal, secondary sweep voltage output
   VdStart: Sweep start voltage for Drain terminal
   VdStop: Sweep stop voltage for Drain terminal
   VdStep: Sweep step voltage for Drain terminal
   Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]
   Vs: Source voltage
   IgLimit: Gate current compliance
   HoldTime: Hold time
   DelayTime: Delay time
   DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
   Drain current Idrain

[User Function]
   IdrainPerWg: Drain current per unit gate width IdrainPerWg=Idrain/Wg
   gm: Transconductance gm=diff(Idrain,Vgate)
   gmPerWg: Transconductance per unit gate width gmPerWg=diff(IdrainPerWg,Vgate)

[X-Y Plot]
   X axis: Gate voltage Vgate (LINEAR)
   Y1 axis: Drain current Idrain (LINEAR)
   Y2 axis: Drain current Idrain (LOG)

[List Display]
   Drain current per unit gate width IdrainPerWg
   Transconductance gm
   Transconductance per unit gate width gmPerWg
2.27 IonIoffSlope: On current, off current, and subthreshold slope (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Extracts the on current, off current, and subthreshold slope from the Id-Vg characteristics.

[Device Under Test]
MOSFET, 4 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
Gate: SMU connected to Gate terminal, primary sweep voltage output
VgStart: Sweep start voltage for Gate terminal, VgStart < 0
VgStop: Sweep stop voltage for Gate terminal, VgStop=Vd
VgStep: Sweep step voltage for Gate terminal
Drain: SMU connected to Drain terminal, constant voltage output
Vd: Drain voltage
Subs: SMU connected to Substrate, constant voltage output
Vsubs: Substrate voltage
Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]
Vs: Source voltage
IgLimit: Gate current compliance
IsubsLimit: Substrate current compliance
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
Drain current Idrain

[User Function]
Slope=1/diff(lgt(Idrain),Vgate)
SlopeMin=min(abs(Slope))

[Analysis Function]
Ion=@L1Y1 (Y1 intercept of Line1)
Ioff=@L2Y1 (Y1 intercept of Line2)

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LOG)
Y2 axis: Slope (LINEAR)
2 CMOS

[Parameters Display Area]
SlopeMin: minimum Slope value
Ion: on current (drain current at Vg=VgStop)
Ioff: off current (drain current at Vg=0)

[Auto Analysis]
Line1: Horizontal line through the Y1 data at Vgate=Vd(=VgStop)
Line2: Horizontal line through the Y1 data at Vgate=0
Marker: Point of Slope=SlopeMin
2.28 IonIoffSlope [2HL]: On current, off current, and subthreshold slope (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Extracts the on current, off current, and subthreshold slope from the Id-Vg characteristics.

[Device Under Test]
MOSFET, 4 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
Gate: SMU connected to Gate terminal, primary sweep voltage output
VgStart: Sweep start voltage for Gate terminal, VgStart < 0
VgStop: Sweep stop voltage for Gate terminal, VgStop=Vd
VgStep: Sweep step voltage for Gate terminal
Drain: SMU connected to Drain terminal, constant voltage output
Vd: Drain voltage

[Extended Test Parameters]
IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
Drain current Idrain

[User Function]
Slope=1/diff(lgt(Idrain),Vgate)
SlopeMin=min(abs(Slope))

[Analysis Function]
Ion=@L1Y1 (Y1 intercept of Line1)
Ioff=@L2Y1 (Y1 intercept of Line2)

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LOG)
Y2 axis: Slope (LINEAR)

[Parameters Display Area]
SlopeMin: minimum Slope value
2 CMOS

Ion: on current (drain current at Vg=VgStop)
Ioff: off current (drain current at Vg=0)

[Auto Analysis]
Line1: Horizontal line through the Y1 data at Vgate=Vd(=VgStop)
Line2: Horizontal line through the Y1 data at Vgate=0
Marker: Point of Slope=SlopeMin
2.29 Isub-Vg: Isub-Lg characteristics (A.01.20)

[Supported Analyzer]
   B1500A, E5260A, E5270B

[Description]
Measures the substrate current vs gate voltage characteristics of MOSFET.

[Device Under Test]
MOSFET, 4 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value)
Lg: Gate length
Wg: Gate width
Temp: Temperature (deg C)

[Test Parameters]
IntegTime: Integration time (SHORT, MEDIUM, LONG) default: MEDIUM
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, secondary sweep voltage output
Subs: SMU connected to Substrate terminal, constant voltage output
Source: SMU connected to Source terminal, constant voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
VdStart: Sweep start voltage for Drain terminal
VdStop: Sweep stop voltage for Drain terminal
VdStep: Sweep step voltage for Drain terminal

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
Vsubs: Substrate terminal voltage
IgLimit: Gate current compliance
IdLimit: Drain current compliance
IsubsLimit: Substrate current compliance
Vs: Source terminal voltage
DrainMinRng: Minimum range for drain current measurement
SubsMinRng: Minimum range for substrate current measurement
GateMinRng: Minimum range for gate current measurement

[Measurement Parameters]
Substrate current Isubs

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Substrate current Isubs (LOG)

[List Display]
Gate voltage Vgate
Substrate current Isubs
Drain current Idrain
Gate current Igate
2.30  QSCV[4]: C-Vg, Ig-Vg (4-terminal) (A.03.00)

[Supported Analyzer]
B1500A, B1505A

[Description]
Measures the oxide film capacitance of a MOSFET by using the quasi-static CV method, and plots the C-V characteristics.
To obtain the measurement data after the capacitance offset cancel, perform the QSCV C Offset Meas application test before this test.

[Device Under Test]
MOSFET, 4 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force negative specified value)
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
Source: SMU connected to Source terminal, constant voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Gate: SMU connected to Gate terminal, primary sweep (QSCV) voltage output
Subs: SMU connected to Substrate terminal, constant voltage output
IMeasSMU: SMU to measure current and capacitance, connected to Gate terminal or Substrate terminal
Vstart: Sweep start voltage
Vstop: Sweep stop voltage
Vstep: Sweep step voltage
QSCVM measV: QSCV measurement voltage
I_Comp: Current compliance
LeakCompen: Leakage current compensation on/off
MeasRange: Current measurement range used for the QSCV measurement, fixed range
Integ_C: Integration time for the capacitance measurement
Integ_L: Integration time for the leakage current measurement
HoldTime: Hold time
DelayTime: Delay time
IOffsetCancel: QSCV smart operation enable/disable
IOffsetSink: SMU to perform QSCV smart operation, connected to terminal which connected to IMeasSMU

QSCV smart operation is effective for QSCV measurements with a large leakage current. The SMU set as the IOffsetSink performs the current force operation to minimize the measurement error caused by an offset current.

[Extended Test Parameters]
StepDelay: Step delay time
OutputRange: Ranging type for voltage output
SwpMode: Sweep mode
VCompSinkSMU: Voltage compliance of SMU for QSCV smart operation
Cmin: Minimum capacitance value for graph
Cmax: Maximum capacitance value for graph
IgMin: Minimum leakage current value for graph
IgMax: Maximum leakage current value for graph

[Measurement parameters]
Capacitance C
Leakage current IgLeak

[X-Y Graph]
X axis: Gate Voltage Vg (LINEAR)
Y1 axis: Capacitance C (LINEAR)
Y2 axis: Leakage current Ig (LINEAR)

[List Display]
Gate voltage Vg
Capacitance C
Leakage current Ig
2.31 QSCV C Offset Meas: Offset capacitance measurement (A.03.00)

[Supported Analyzer]
B1500A, B1505A

[Description]
Measures the offset capacitance of the cables and DUT interface by using the QSCV method when measurement terminals are open.

[Device Under Test]
MOS capacitance, 2 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force negative specified value)
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IMeasSMU: SMU to measure current and capacitance, connected to Gate terminal or Substrate terminal
MeasRange: Current measurement range used for the QSCV measurement, fixed range
Integ_C: Integration time for the capacitance measurement
Integ_L: Integration time for the leakage current measurement
HoldTime: Hold time
DelayTime: Delay time

[Extended Test Parameters]
StepDelay: Step delay time

[Measurement parameters]
Capacitance C

[List Display]
Capacitance C
2.32 Simple Cgb : Evaluation of gate-substrate capacitance versus gate voltage (A.01.10)

[Supported Analyzer]
B1500A

[Application]
This application evaluates the gate-substrate capacitance of an Nch MOSFET.
For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Measured]
Single device with four terminals.

[Parameter Setting]
Test parameters are specified for NMOS device under test.
Swept bias voltage parameters are specified by the gate voltage referenced to the source voltage (Vgs).

[Description of Measurement]
Gate voltage (Vgs) sweeps in accordance with the test parameter setting.
Gate capacitances are measured with Cp-G model applied while the bias voltage sweeps.

[Plot Display]
Measured gate capacitances in linear scale are plotted versus substrate voltage on the linear horizontal axis.
2.33  **Simple Vth : Evaluation of Threshold Voltage (Vth) (A.01.20)**

[Supported Analyzer]
   B1500A, E5260A, E5270B

[Application]
   This application evaluates the threshold voltage (Vth) of a Nch MOSFET.

[Device Measured]
   Single device with four terminals.

[Parameter Setting]
   Test parameters are specified for NMOS device under test.
   Swept bias voltage parameters are specified by the gate voltage referenced to the source voltage (Vg).

[Description of Measurement]
   Gate voltage (Vg) sweeps in accordance with the test parameter setting.
   Currents flowing in drain terminal are measured while the gate voltage sweeps.

[Plot Display]
   Measured drain currents and transconductance in linear scale are plotted versus gate voltage on the linear horizontal axis.
   Maximum transconductance value (Gmmax) and threshold voltage (Vth) are extracted from the measurement data, then displayed in the parameters display area.
2.34 **Simple Vth [2HL]: Evaluation of Threshold Voltage (Vth) (A.06.10)**

[Supported Analyzer]
- B2901A, B2902A, B2911A, B2912A

[Application]
- This application evaluates the threshold voltage (Vth) of a N-ch MOSFET.

[Device Measured]
- Single device with four terminals.

[Parameter Setting]
- Test parameters are specified for NMOS device under test.
  - Swept bias voltage parameters are specified by the gate voltage referenced to the source voltage (Vgs).

[Description of Measurement]
- Gate voltage (Vg) sweeps in accordance with the test parameter setting.
  - Currents flowing in drain terminal are measured while the gate voltage sweeps.

[Plot Display]
- Measured drain currents and transconductance in linear scale are plotted versus gate voltage on the linear horizontal axis.
  - Maximum transconductance value (Gmmax) and threshold voltage (Vth) are extracted from the measurement data, then displayed in the parameters display area.
2.35  \textit{Vth Const Id: Constant current Vth (A.01.20)}

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the drain current vs gate voltage characteristics, and extracts the threshold voltage (Vth) by using the constant current method.

[Device Under Test]
MOSFET, 4 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
Id@Vth: Drain current to decide the Vth
Gate: SMU connected to Gate terminal, primary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Drain: SMU connected to Drain terminal, constant voltage output
Vd: Drain voltage
Subs: SMU connected to Substrate, constant voltage output
Vsubs: Substrate voltage
Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]
Vs: Source voltage
IgLimit: Gate current compliance
IsubsLimit: Substrate current compliance
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
Drain current Idrain

[User Function]
gm=\text{diff}(Idrain,Vgate)

[Analysis Function]
Vth=@L1X (X intercept of Line1)

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)

[List Display]
Transconductance gm

[Parameters Display Area]
Threshold voltage Vth

[Auto Analysis]
Line1: Vertical line for Y1 at Idrain=Id@Vth
2.36  *Vth Const Id [2HL]: Constant current Vth (A.06.10)*

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the drain current vs gate voltage characteristics, and extracts the threshold voltage (Vth) by using the constant current method.

[Device Under Test]
MOSFET, 4 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
Id@Vth: Drain current to decide the Vth
Gate: SMU connected to Gate terminal, primary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Drain: SMU connected to Drain terminal, constant voltage output
Vd: Drain voltage

[Extended Test Parameters]
IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
Drain current Idrain

[User Function]
gm=diff(Idrain,Vgate)

[Analysis Function]
Vth=@L1X (X intercept of Line1)

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)

[List Display]
Transconductance gm

[Parameters Display Area]
Threshold voltage Vth

[Auto Analysis]
Line1: Vertical line for Y1 at Idrain=Id@Vth
2.37 \textit{Vth gmMax : Linear region Vth (A.01.20)}

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Extracts the threshold voltage (Vth) by using the extrapolation method for the linear region of the drain current vs gate voltage characteristics.

[Device Under Test]
MOSFET, 4 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
Gate: SMU connected to Gate terminal, primary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Drain: SMU connected to Drain terminal, constant voltage output
Vd: Drain voltage
Subs: SMU connected to Substrate, constant voltage output
Vsubs: Substrate voltage
Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]
Vs: Source voltage
IgLimit: Gate current compliance
IsubsLimit: Substrate current compliance
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
Drain current Idrain

[User Function]
gm=diff(Idrain,Vgate)

[Analysis Function]
gmMax=max(gm)
Von=@L1X (X intercept of Line1)
Vth=Von-Vd/2

Vth is given by the following formula.
Vth=Vg(gmMax)-Id(gmMax)/gmMax
Vd/2 is necessary to compensate the secondary term of Vd in theory.
[X-Y Plot]
  X axis: Gate voltage Vgate (LINEAR)
  Y1 axis: Drain current Idrain (LINEAR)
  Y2 axis: Transconductance gm (LINEAR)
  Y3 axis: Drain current Idrain (LOG)

[Parameters Display Area]
  Threshold voltage Vth
  Maximum gm value gmMax

[Auto Analysis]
  Line1: Tangent line for Y1 at gm=gmMax
2.38  \( V_{th \, gmMax \, [2HL]}: \text{Linear region } V_{th} \) \((A.06.10)\)

[Supported Analyzer]
  B2901A, B2902A, B2911A, B2912A

[Description]
  Extracts the threshold voltage (\(V_{th}\)) by using the extrapolation method for the linear region of the drain current vs gate voltage characteristics.

[Device Under Test]
  MOSFET, 4 terminals

[Device Parameters]
  Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
  \(L_g\): Gate length
  \(W_g\): Gate width
  \(T_{em}\): Temperature
  \(I_{d,Max}\): Drain current compliance

[Test Parameters]
  \(I_{n}\text{ntegTime}\): Integration time
  Gate: SMU connected to Gate terminal, primary sweep voltage output
  \(V_{g,Start}\): Sweep start voltage for Gate terminal
  \(V_{g,Stop}\): Sweep stop voltage for Gate terminal
  \(V_{g,Step}\): Sweep step voltage for Gate terminal
  Drain: SMU connected to Drain terminal, constant voltage output
  \(V_d\): Drain voltage

[Extended Test Parameters]
  \(I_{g,Limit}\): Gate current compliance
  \(H_{oldTime}\): Hold time
  \(D_{elayTime}\): Delay time
  \(D_{rainMinRng}\): Minimum range for the drain current measurement

[Measurement Parameters]
  Drain current \(I_{drain}\)

[User Function]
  \(gm=\text{diff}(I_{drain},V_{gate})\)

[Analysis Function]
  \(gm_{Max}=\text{max}(gm)\)
  \(V_{on}=\text{@L1X}(X\text{ intercept of Line1})\)
  \(V_{th}=V_{on}-V_{d}/2\)

  \(V_{th}\) is given by the following formula.
  \(V_{th}=V_g(gm_{Max})-I_d(gm_{Max})/gm_{Max}\)
  \(V_d/2\) is necessary to compensate the secondary term of \(V_d\) in theory.

[X-Y Plot]
  X axis: Gate voltage \(V_{gate}\) (LINEAR)
  Y1 axis: Drain current \(I_{drain}\) (LINEAR)
  Y2 axis: Transconductance \(gm\) (LINEAR)
  Y3 axis: Drain current \(I_{drain}\) (LOG)
[Parameters Display Area]
  Threshold voltage Vth
  Maximum gm value gmMax

[Auto Analysis]
  Line1: Tangent line for Y1 at gm=gmMax
2.39 \textit{VthAndCgg-Vg ASU: Cgg-Vg, Id-Vg, using ASU (A.01.20)}

[Supported Analyzer]
B1500A

[Description]
Measures the gate capacitance vs gate voltage characteristics, the drain current vs gate voltage measurement by using one MFCMU, two sets of HRSMU/ASU, and one SMU.
For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
MOSFET, 4 terminals

[Required Modules and Accessories]
One MFCMU module, two sets of HRSMU/ASU, and one SMU module are required.
ASU#1 connections: Output: Gate, SMU: HRSMU, AUX: MFCMU Low
ASU#2 connections for Cgg-Vg: Output: other 3 terminals, SMU: HRSMU, AUX: MFCMU High
ASU#2 connections for Id-Vg: Output: Source and Substrate, SMU: HRSMU, AUX: MFCMU High
Connection wire must be connected between the CMU Return terminals of ASUs.
Setting of ASU I/O Path, ASU tab, Configuration window: AUX

[Device Parameters]
Polarity: Nch (CMU/SMU forces the specified value) or Pch (CMU/SMU forces the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
GateAC: CMU connected to Gate terminal (CV sweep measurement)
GateDC: SMU connected to Gate terminal (primary sweep, voltage output)
SourceDC: SMU connected to Source and Substrate terminal (constant voltage output)
Drain: SMU connected to Drain terminal (constant voltage output)
IntegTime: Integration time
IgLimit: Gate current compliance
IdLimit: Drain current compliance
IsubsLimit: Substrate current compliance
HoldTime: Hold time
DelayTime: Delay time
VgsBiasStart: Cgg-Vg measurement start voltage
VgsBiasStop: Cgg-Vg measurement stop voltage
VgsBiasStep: Cgg-Vg measurement step voltage
OscLevel: Cgg-Vg measurement signal level
FREQ: Cgg-Vg measurement frequency
VgsStartDC: Id-Vg measurement start voltage
VgsStopDC: Id-Vg measurement stop voltage
VgsStepDC: Id-Vg measurement step voltage
Vd: Drain current

[Extended Test Parameters]
- DrainMinRng: Minimum range for the drain current measurement
- GateMinRng: Minimum range for the gate current measurement

[Cgg-Vg: Measurement Parameters]
- Parallel capacitance Cp
- Conductance G

[Cgg-Vg: User Function]
- PI=3.141592653589
- D=G/(2*PI*FREQ*Cp)
- Rp=1/G
- Cs=(1+D^2)*Cp
- X=-1/(2*PI*FREQ*Cs)
- Rs=D*abs(X)
- Z=sqrt(Rs^2+X^2)
- Vgate=-Vsource
- Cp_S=Cp/Lg/Wg
- Cp_W=Cp/Wg

[Cgg-Vg: X-Y Graph]
- X axis: Gate voltage Vgate (LINEAR)
- Y1 axis: Gate capacitance (parallel capacitance) Cp (LINEAR)
- Y2 axis: Conductance G (LINEAR)

[Cgg-Vg: List Display]
- Gate voltage Vgate
- Parallel capacitance Cp
- Conductance G
- Series capacitance Cs
- Series resistance Rs
- Parallel resistance Rp
- Dissipation factor D
- Reactance X
- Impedance Z
- Phase Theta

[Id-Vg: Measurement Parameters]
- Drain current Idrain

[Id-Vg: User Function]
- gm=delta(Idrain)/delta(Vgate)
- gmMax=max(gm)

[Id-Vg: Analysis Function]
- Vth=@L1X (X intercept of Line1)

[Id-Vg: X-Y Plot]
- X axis: Gate voltage Vgate (LINEAR)
- Y1 axis: Drain current Idrain (LINEAR)
- Y2 axis: Transconductance gm (LINEAR)
2 CMOS

[Id-Vg: List Display]
Gate current Igate

[Id-Vg: Parameters Display Area]
Maximum gm value gmMax
Threshold voltage Vth

[Id-Vg: Auto Analysis]
Line1: Tangent line for Y1 at gm=gmMax
2.40 \textit{VthAndCgg-Vg SCUU: Cgg-Vg, Id-Vg, using SCUU (A.01.20)}

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the gate capacitance vs gate voltage characteristics, the drain current vs gate voltage measurement by using one MFCMU, three SMUs, and a set of SCUU/GSWU.
For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
MOSFET, 4 terminals

[Required Modules and Accessories]
One MFCMU module, three SMU modules, and a set of SCUU/GSWU are required.
SCUU connections (Cgg-Vg): Output1: terminals other than Gate, Output2: Gate
SCUU connections (Id-Vg): Output1: Source and Substrate, Output2: Gate
Connection wire must be connected between the GSWU and the DUT interface High/Low guard lines for the capacitance measurements.

[Device Parameters]
Polarity: Nch (CMU/SMU forces the specified value) or Pch (CMU/SMU forces the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
GateAC: CMU connected to Gate terminal (CV sweep measurement)
GateDC: SMU connected to Gate terminal (primary sweep, voltage output)
SourceDC: SMU connected to Source and Substrate terminal (constant voltage output)
Drain: SMU connected to Drain terminal (constant voltage output)
Vd: Drain current
IntegTime: Integration time
IgLimit: Gate current compliance
IdLimit: Drain current compliance
IsLimit: Source current compliance
HoldTime: Hold time
DelayTime: Delay time
VgsBiasStart: Cgg-Vg measurement start voltage
VgsBiasStop: Cgg-Vg measurement stop voltage
VgsBiasStep: Cgg-Vg measurement step voltage
OscLevel: Cgg-Vg measurement signal level
FREQ: Cgg-Vg measurement frequency
VgsStartDC: Id-Vg measurement start voltage
VgsStopDC: Id-Vg measurement stop voltage
VgsStepDC: Id-Vg measurement step voltage
[Extended Test Parameters]
DrainMinRng: Minimum range for the drain current measurement
GateMinRng: Minimum range for the gate current measurement

[Cgg-Vg: Measurement Parameters]
Parallel capacitance Cp
Conductance G

[Cgg-Vg: User Function]
PI=3.141592653589
D=G/(2*PI*FREQ*Cp)
Rp=1/G
Cs=(1+D^2)*Cp
X=-1/(2*PI*FREQ*Cs)
Rs=D*abs(X)
Z=sqrt(Rs^2+X^2)
Theta=atan(X/Rs)
Vgate=-Vsource
Cp_S=Cp/Lg/Wg
Cp_W=Cp/Wg

[Cgg-Vg: X-Y Graph]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Gate capacitance (parallel capacitance) Cp (LINEAR)
Y2 axis: Conductance G (LINEAR)

[Cgg-Vg: List Display]
Gate voltage Vgate
Parallel capacitance Cp
Conductance G
Series capacitance Cs
Series resistance Rs
Parallel resistance Rp
Dissipation factor D
Reactance X
Impedance Z
Phase Theta

[Id-Vg: Measurement Parameters]
Drain current Idrain

[Id-Vg: User Function]
\[ gm = \frac{\text{delta}(Idrain)}{\text{delta}(Vgate)} \]
\[ gmMax = \text{max}(gm) \]

[Id-Vg: Analysis Function]
\[ Vth = @L1X \text{ (X intercept of Line1)} \]

[Id-Vg: X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Transconductance gm (LINEAR)

[Id-Vg: List Display]
Gate current $I_{\text{gate}}$

[Id-Vg: Parameters Display Area]
Maximum $g_m$ value $g_m^{\text{Max}}$
Threshold voltage $V_{\text{th}}$

[Id-Vg: Auto Analysis]
Line1: Tangent line for $Y_1$ at $g_m=g_m^{\text{Max}}$
2.41 \( V_{th-Lg}: V_{th-Lg} \) characteristics \((A.01.20)\)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the \( I_d-V_{g} \) characteristics of MOSFET with different \( L_g \) (gate length) and plots the \( V_{th} \)'s dependency on \( L_g \) (threshold voltage).

[Device Under Test]
MOSFET, 4 terminals

[Required Modules and Accessories]
Keysight B2200A or B2201A switching matrix 1 unit
GPIB cable

Connect B2200A/B2201A to B1500A with a measuring cable and GPIB cable. Set information on B1500A SMU channel's connection to the B2200A/B2201A input port properly on the Switching Matrix tab screen of the Configuration window.

Set the output channel number of B2200A/B2201A connected to each terminal of a device under test properly in the \( G##/D##/E##/S##/Sb## \) field (\( # \) is an integer from 1 to 12) of Test Parameters area.

The maximum number of devices connected at once depends on the number of matrix modules mounted on B2200A/B2201A. Maximum three devices can be connected to one module at once.

[Setting of \( Lg##/G##/D##/E##/S##/Sb## \) field (\( # \) is an integer from 1 to 12)]
Set one device for \( Lg##(gate length)/G##(gate)/D##(drain)/S##(source)/Sb##(substrate) \). \( Lg1<\ Lg2<\ Lg3\ldots \) must be satisfied. Enter zero for a field with no device.

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value)
Temp: Temperature (deg C)
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
GateSMU: SMU connected to Gate terminal, primary sweep voltage output
DrainSMU: SMU connected to Drain terminal, constant voltage output
SbSMU: SMU connected to Substrate, constant voltage output
SourceSMU: SMU connected to Source terminal, constant voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Vd: Drain voltage, ideally at around 100mV
Vssubs: Substrate voltage
Wg: Gate width
Lg1 - Lg12: Gate length for MOSFETs
G1 - G12: SWM Pin Assign setting for Gate of devices
D1 - D12: SWM Pin Assign setting for Drain of devices
S1 - S12: SWM Pin Assign setting for Source of devices
Sb1 - Sb12: SWM Pin Assign setting for Subs of devices

[Extended Test Parameters]
Vs: Source voltage
IgLimit: Gate current compliance
IsubsLimit: Substrate current compliance
HoldTime: Hold time
DelayTime: Delay time
Vth_Min: Minimum Vth value for graph scale
Vth_Max: Maximum Vth value for graph scale
gmMax_Min: Minimum gmMax value for graph scale
gmMax_Max: Maximum gmMax value for graph scale
DrainMinRng: Minimum range for drain current measurement

[Measurement Parameters]
Idrain: Drain current

[User Function]
gm=diff(Idrain,Vgate)

[Analysis Function]
gmMax=max(gm)
Von=@L1X (X intercept of Line1)
Vth=Von-Vd/2

Vth is given by the following formula.
Vth=Vg(gmMax)-Id(gmMax)/gmMax
Vd/2 is for compensation of the secondary term of Vd in the theoretical formula.

[Auto Analysis]
Line1: Tangent line for Y1 at gm=gmMax

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Transconductance gm (LINEAR)
Y3 axis: Drain current Idrain (LOG)

[List Display]
Gate voltage Vgate
Source voltage Vsource
Drain voltage Vdrain
Substrate voltage Vsubs
Drain current Idrain
Transconductance gm

[Parameters Display Area]
Threshold voltage Vth
Maximum transconductance value gmMax

[Test Output: X-Y Graph]
X axis: Gate length LgList (LINEAR)
Y1 axis: Threshold voltage VthList (LINEAR)
Y2 axis: Maximum transconductance value gmMaxList (LINEAR)

[Test Output: List Display]
Gate length LgList
Threshold voltage VthList
Maximum transconductance value gmMaxList
2.42 \( V_{th-Wg} \): \( V_{th-Wg} \) characteristics (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the \( I_d-V_{g} \) characteristics of MOSFET with different \( W_{g} \) (gate width) and plots the \( V_{th} \)'s dependency on \( W_{g} \) (threshold voltage).

[Device Under Test]
MOSFET, 4 terminals

[Required Modules and Accessories]
Keysight B2200A or B2201A switching matrix 1 unit
GPIB cable

Connect B2200A/B2201A to B1500A with a measuring cable and GPIB cable.
Set information on B1500A SMU channel's connection to the B2200A/B2201A input port properly on the Switching Matrix tab screen of the Configuration window.
Set the output channel number of B2200A/B2201A connected to each terminal of a device under test properly in the \#/#/#/#/#/# field (# is an integer from 1 to 12) of Test Parameters area.
The maximum number of devices connected at once depends on the number of matrix modules mounted on B2200A/B2201A. Maximum three devices can be connected to one module at once.

[Setting of \( W_{g}/G/#/D/#/S/#/Sb# \) field (# is an integer from 1 to 12)]
Set one device for \( W_{g}/(gate width)/G/(gate)/D/(drain)/S/(source)/Sb/(substrate) \). \( W_{g1}<W_{g2}<W_{g3} \ldots \) must be satisfied. Enter zero for a field with no device.

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value)
Temp: Temperature (deg C)
\( I_{d\text{Max}} \): Drain current compliance

[Test Parameters]
\( I_{\text{IntegTime}} \): Integration time
\( G_{\text{GateSMU}} \): SMU connected to Gate terminal, primary sweep voltage output
\( D_{\text{DrainSMU}} \): SMU connected to Drain terminal, constant voltage output
\( S_{\text{SbSMU}} \): SMU connected to Substrate, constant voltage output
\( S_{\text{SourceSMU}} \): SMU connected to Source terminal, constant voltage output
\( V_{\text{gStart}} \): Sweep start voltage for Gate terminal
\( V_{\text{gStop}} \): Sweep stop voltage for Gate terminal
\( V_{\text{gStep}} \): Sweep step voltage for Gate terminal
\( V_{d} \): Drain voltage, ideally at around 100mV
\( V_{subs} \): Substrate voltage
\( L_{g} \): Gate length
\( W_{g1} - W_{g12} \): Gate width for MOSFETs
\( G_{1} - G_{12} \): SWM Pin Assign setting for Gate of devices
\( D_{1} - D_{12} \): SWM Pin Assign setting for Drain of devices
\( S_{1} - S_{12} \): SWM Pin Assign setting for Source of devices
\( S_{b1} - S_{b12} \): SWM Pin Assign setting for Subs of devices

[Extended Test Parameters]
\( V_{s} \): Source voltage
\( I_{g\text{Limit}} \): Gate current compliance
IsubsLimit: Substrate current compliance
HoldTime: Hold time
DelayTime: Delay time
Vth_Min: Minimum Vth value for graph scale
Vth_Max: Maximum Vth value for graph scale
gmMax_Min: Minimum gmMax value for graph scale
gmMax_Max: Maximum gmMax value for graph scale
DrainMinRng: Minimum range for drain current measurement

[Measurement Parameters]
Idrain: Drain current

[User Function]
gm=diff(Idrain,Vgate)

[Analysis Function]
gmMax=max(gm)
Von=@L1X (X intercept of Line1)
Vth=Von-Vd/2

Vth is given by the following formula.
Vth=Vg(gmMax)-Id(gmMax)/gmMax
Vd/2 is for compensation of the secondary term of Vd in the theoretical formula.

[Auto Analysis]
Line1: Tangent line for Y1 at gm=gmMax

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Transconductance gm (LINEAR)
Y3 axis: Drain current Idrain (LOG)

[List Display]
Gate voltage Vgate
Source voltage Vsource
Drain voltage Vdrain
Substrate voltage Vsubs
Drain current Idrain
Transconductance gm

[Parameters Display Area]
Threshold voltage Vth
Maximum transconductance value gmMax

[Test Output: X-Y Graph]
X axis: Gate width WgList (LINEAR)
Y1 axis: Threshold voltage VthList (LINEAR)
Y2 axis: Maximum transconductance value gmMaxList (LINEAR)

[Test Output: List Display]
Gate width WgList
Threshold voltage VthList
Maximum transconductance value gmMaxList
3 Discrete
3 Discrete

1. BJT GummelPlot: Bipolar transistor gummel characteristics (A.01.20)
2. BJT Ic-Vc Ib: Bipolar transistor Ic-Vc characteristics (A.01.20)
3. BJT Ic-Vc Ib [2HL]: Bipolar transistor Ic-Vc characteristics (A.06.10)
4. Diode IV Fwd: Diode forward bias characteristics (A.01.20)
5. Diode IV Fwd [1HL]: Diode forward bias characteristics (A.06.10)
6. Diode IV Rev: Diode reverse bias characteristics (A.01.20)
7. Diode IV Rev [1HL]: Diode reverse bias characteristics (A.06.10)
8. FET Id-Vd: MOSFET Id-Vd characteristics (A.01.20)
9. FET Id-Vd [2HL]: MOSFET Id-Vd characteristics (A.06.10)
10. FET Id-Vg: MOSFET Id-Vg characteristics (A.01.20)
11. FET Id-Vg [2HL]: MOSFET Id-Vg characteristics (A.06.10)
3.1 BJT GummelPlot: Bipolar transistor gummel characteristics (A.01.20)

[Supported Analyzer]

[Description]
Measures the gummel characteristics of bipolar transistor.

[Device Under Test]
Bipolar junction transistor

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IeMax: Collector current compliance
Pmax: Power compliance

[Test Parameters]
IntegTime: Integration time
Base: SMU connected to Base terminal, primary sweep voltage output
VbStart: Sweep start voltage for Base terminal
VbStop: Sweep stop voltage for Base terminal
VbStep: Sweep step voltage for Base terminal
Collector: SMU connected to Collector terminal, constant voltage output
Vc: Collector voltage
Emitter: SMU connected to Emitter terminal, constant voltage output

[Extended Test Parameters]
Ve: Emitter voltage
HoldTime: Hold time
DelayTime: Delay time
BaseMinRng: Minimum range for the base current measurement
CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]
Base current Ibase
Collector current Icurrent

[User Function]
IePerArea=Iemitter/Le/We
IbPerArea=Ibase/Le/We
IcPerArea=Icollector/Le/We
hfe=Icollector/Ibase

[Analysis Function]
hfemax=max(hfe)

[X-Y Plot]
X axis: Base voltage Vbase (LINEAR)
Y1 axis: Base current Ibase (LOG)
Y2 axis: Collector current Icollector (LOG)
Y3 axis: Current amplification factor hfe (LINEAR)

[User Function]
Emitter current per unit area of Emitter IePerArea
Base current per unit area of Emitter IbPerArea
Collector current per unit area of Emitter IcPerArea

[Parameters Display Area]
hfe maximum value hfemax
3.2 **BJT Ic-Vc Ib : Bipolar transistor Ic-Vc characteristics (A.01.20)**

[Supported Analyzer]

[Description]
Measures the collector current vs collector voltage characteristics of bipolar transistor.

[Device Under Test]
Bipolar junction transistor

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Temp: Temperature
IcMax: Collector current compliance
Pmax: Power compliance

[Test Parameters]
IntegTime: Integration time
Collector: SMU connected to Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcStep: Sweep step voltage for Collector terminal
Base: SMU connected to Base terminal, secondary sweep voltage output
IbStart: Sweep start current for Base terminal
IbStop: Sweep stop current for Base terminal
IbStep: Sweep step current for Base terminal
VbLimit: Base voltage compliance
Emitter: SMU connected to Emitter terminal, constant voltage output

[Extended Test Parameters]
Ve: Emitter voltage
HoldTime: Hold time
DelayTime: Delay time
CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]
Collector current Icollector
Base current Ibase

[User Function]
hfe=Icollector/Ibase
VA=Icollector*diff(Vcollector,Icollector)-Vcollector

[X-Y Plot]
X axis: Collector voltage Vcollector (LINEAR)
Y1 axis: Collector current Icollector (LINEAR)

[User Function]
Current amplifier factor hfe
Early voltage VA

[List Display]
Base current Ibase
3.3 BJT Ic-Vc Ib [2HL]: Bipolar transistor Ic-Vc characteristics (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the collector current vs collector voltage characteristics of bipolar transistor.

[Device Under Test]
Bipolar junction transistor

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Temp: Temperature
IcMax: Collector current compliance
Pmax: Power compliance

[Test Parameters]
IntegTime: Integration time
Collector: SMU connected to Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcStep: Sweep step voltage for Collector terminal
Base: SMU connected to Base terminal, secondary sweep voltage output
IbStart: Sweep start current for Base terminal
IbStop: Sweep stop current for Base terminal
IbStep: Sweep step current for Base terminal
VbLimit: Base voltage compliance

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]
Collector current Icollector
Base current Ib

[User Function]
hfe=Icollector/Ibase
VA=Icollector*diff(Vcollector,Icollector)-Vcollector

[X-Y Plot]
X axis: Collector voltage Vcollector (LINEAR)
Y1 axis: Collector current Icollector (LINEAR)

[List Display]
Base current Ib
3.4 Diode IV Fwd: Diode forward bias characteristics (A.01.20)

[Supported Analyzer]

[Description]
Measures the forward bias anode voltage vs anode current characteristics.

[Device Under Test]
Diode

[Device Parameters]
- Temp: Temperature
- Imax: Current compliance

[Test Parameters]
- IntegTime: Integration time
- Anode: SMU connected to Anode terminal, primary sweep voltage output
- VanodeStart: Sweep start voltage for Anode terminal
- VanodeStop: Sweep stop voltage for Anode terminal
- VanodeStep: Sweep step voltage for Anode terminal
- Cathode: SMU connected to Cathode terminal, constant voltage output

[Extended Test Parameters]
- Vcathode: Cathode voltage
- HoldTime: Hold time
- DelayTime: Delay time
- AnodeMinRng: Minimum range for the anode current measurement

[Measurement Parameters]
- Anode current Ianode

[X-Y Plot]
- X axis: Anode voltage Vanode (LINEAR)
- Y1 axis: Anode current Ianode (LINEAR)
- Y2 axis: Anode current Ianode (LOG)
3.5 Diode IV Fwd [IHL]: Diode forward bias characteristics (A.06.10)

[Supported Analyzer]
   B2901A, B2902A, B2911A, B2912A

[Description]
   Measures the forward bias anode voltage vs anode current characteristics.

[Device Under Test]
   Diode

[Device Parameters]
   Temp: Temperature
   Imax: Current compliance

[Test Parameters]
   IntegTime: Integration time
   Anode: SMU connected to Anode terminal, primary sweep voltage output
   VanodeStart: Sweep start voltage for Anode terminal
   VanodeStop: Sweep stop voltage for Anode terminal
   VanodeStep: Sweep step voltage for Anode terminal

[Extended Test Parameters]
   HoldTime: Hold time
   DelayTime: Delay time
   AnodeMinRng: Minimum range for the anode current measurement

[Measurement Parameters]
   Anode current Ianode

[X-Y Plot]
   X axis: Anode voltage Vanode (LINEAR)
   Y1 axis: Anode current Ianode (LINEAR)
   Y2 axis: Anode current Ianode (LOG)
3.6 Diode IV Rev: Diode reverse bias characteristics (A.01.20)

[Supported Analyzer]

[Description]
Measures the reverse bias anode voltage vs anode current characteristics.

[Device Under Test]
Diode

[Device Parameters]
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Anode: SMU connected to Anode terminal, primary sweep voltage output
VanodeStart: Sweep start voltage for Anode terminal
VanodeStop: Sweep stop voltage for Anode terminal
VanodeStep: Sweep step voltage for Anode terminal
IanodeLimit: Anode current compliance
Cathode: SMU connected to Cathode terminal, constant voltage output

[Extended Test Parameters]
Vcathode: Cathode voltage
HoldTime: Hold time
DelayTime: Delay time
AnodeMinRng: Minimum range for the anode current measurement

[Measurement Parameters]
Anode current Ianode

[X-Y Plot]
X axis: Anode voltage Vanode (LINEAR)
Y1 axis: Anode current Ianode (LOG)
3.7  Diode IV Rev [1HL]: Diode reverse bias characteristics (A.06.10)

[Supported Analyzer]
   B2901A, B2902A, B2911A, B2912A

[Description]
   Measures the reverse bias anode voltage vs anode current characteristics.

[Device Under Test]
   Diode

[Device Parameters]
   Temp: Temperature

[Test Parameters]
   IntegTime: Integration time
   Anode: SMU connected to Anode terminal, primary sweep voltage output
   VanodeStart: Sweep start voltage for Anode terminal
   VanodeStop: Sweep stop voltage for Anode terminal
   VanodeStep: Sweep step voltage for Anode terminal
   IanodeLimit: Anode current compliance

[Extended Test Parameters]
   HoldTime: Hold time
   DelayTime: Delay time
   AnodeMinRng: Minimum range for the anode current measurement

[Measurement Parameters]
   Anode current Ianode

[X-Y Plot]
   X axis: Anode voltage Vanode (LINEAR)
   Y1 axis: Anode current Ianode (LOG)
3 Discrete

3.8 *FET Id-Vd: MOSFET Id-Vd characteristics (A.01.20)*

[Supported Analyzer]

[Description]
Measures the drain current vs drain voltage characteristics of MOSFET.

[Device Under Test]
MOSFET, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
Drain: SMU connected to Drain terminal, primary sweep voltage output
VdStart: Sweep start voltage for Drain terminal
VdStop: Sweep stop voltage for Drain terminal
VdStep: Sweep step voltage for Drain terminal
Gate: SMU connected to Gate terminal, secondary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
IgLimit: Gate current compliance
Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]
Vs: Source voltage
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
Drain current Idrain

[X-Y Plot]
X axis: Drain voltage Vdrain (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
3.9 **FET Id-Vd [2HL]: MOSFET Id-Vd characteristics (A.06.10)**

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the drain current vs drain voltage characteristics of MOSFET.

[Device Under Test]
MOSFET, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
Drain: SMU connected to Drain terminal, primary sweep voltage output
VdStart: Sweep start voltage for Drain terminal
VdStop: Sweep stop voltage for Drain terminal
VdStep: Sweep step voltage for Drain terminal
Gate: SMU connected to Gate terminal, secondary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
IgLimit: Gate current compliance

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
Drain current Idrain

[X-Y Plot]
X axis: Drain voltage Vdrain (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
3.10 FET Id-Vg : MOSFET Id-Vg characteristics (A.01.20)

[Supported Analyzer]

[Description]
Measures the drain current vs gate voltage characteristics of MOSFET.

[Device Under Test]
MOSFET, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
Gate: SMU connected to Gate terminal, primary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
IgLimit: Gate current compliance
Drain: SMU connected to Drain terminal, secondary sweep voltage output
VdStart: Sweep start voltage for Drain terminal
VdStop: Sweep stop voltage for Drain terminal
VdStep: Sweep step voltage for Drain terminal
Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]
Vs: Source voltage
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
Drain current Idrain

[User Function]
gm: Transconductance gm=diff(Idrain,Vgate)

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)
Y3 axis: Transconductance gm (LINEAR)
3.11 FET Id-Vg [2HL]: MOSFET Id-Vg characteristics (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the drain current vs gate voltage characteristics of MOSFET.

[Device Under Test]
MOSFET, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
Gate: SMU connected to Gate terminal, primary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
IgLimit: Gate current compliance
Drain: SMU connected to Drain terminal, secondary sweep voltage output
VdStart: Sweep start voltage for Drain terminal
VdStop: Sweep stop voltage for Drain terminal
VdStep: Sweep step voltage for Drain terminal

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
Drain current Idrain

[User Function]
gm: Transconductance gm=diff(Idrain,Vgate)

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)
Y3 axis: Transconductance gm (LINEAR)
3 Discrete
4 GenericTest
1. Generic C-f  C-f characteristics of capacitor (2 terminals) (A.03.00)
2. Generic C-t  C-t characteristics of capacitor (2 terminals) (A.03.00)
4.1 Generic C-f: C-f characteristics of capacitor (2 terminals) (A.03.00)

[Supported Analyzer]
B1500A, B1505A, B1506A

[Description]
Measures the capacitance and conductance vs frequency characteristics. For a more accurate measurement, perform Open/Short/Load correction at the measurement frequency before starting the capacitance measurement. If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
Capacitor, 2 terminals
For a more accurate measurement, connect CMU High to device’s Low and CMU Low to device’s High.

[Required Modules and Accessories]
Keysight B1520A MFCMU 1 unit

[Test Parameters]
Port1: CMU connected between capacitance
Vbias: DC bias voltage
FreqStart: Sweep start frequency
FreqStop: Sweep stop frequency
NoOfSteps: Number of measurements
OscLevel: Measurement signal level
Single_Double: Sweep direction (Single/Double)
Linear_Log: Frequency scale (Linear/Log)
OnAbnormalStatus: Auto abort function set up
IntegTime: Integration time

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
Range: Measurement range
G Мин: Minimum transconductance value for graph
G Max: Maximum transconductance value for graph
Cp Мин: Minimum capacitance value for graph
Cp Max: Maximum capacitance value for graph

[Measurement parameters]
Susceptance B
Conductance G
DC bias monitor data DeMon
AC level monitor data AcMon
Frequency Freq

[User Function]
Circular constant PI=3.141592653589
Parallel capacitance Cp=B/(2*PI*Freq)
Parallel resistance Rp=1/G
Dissipation factor D=G/abs(B)
Series resistance Rs=G/(G^2+B^2)
Reactance X=-B/(G^2+B^2)
Series capacitance Cs=-1/(2*PI*Freq*X)
Impedance Z=sqrt(Rs^2+X^2)
Phase Theta=atan(X/Rs)

[X-Y Plot]
X axis: Frequency Freq (LINEAR/LOG)
Y1 axis: Parallel capacitance Cp (LINEAR)
Y2 axis: Conductance G (LINEAR)

[List Display]
Frequency Freq
Parallel capacitance Cp
Conductance G
DC bias voltage Vbias
Series capacitance Cs
Series resistance Rs
Parallel resistance Rp
Dissipation factor D
Reactance X
Impedance Z
Phase Theta
DC bias monitor data DcMon
AC level monitor data AcMon
4.2 Generic C-t: C-t characteristics of capacitor (2 terminals) (A.03.00)

[Supported Analyzer]
B1500A, B1505A, B1506A

[Description]
Measures the capacitance and conductance vs time characteristics.
For a more accurate measurement, perform Open/Short/Load correction at the measurement frequency before starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
Capacitor, 2 terminals
For a more accurate measurement, connect CMU High to device’s Low and CMU Low to device’s High.

[Required Modules and Accessories]
Keysight B1520A MFCMU 1 unit

[Test Parameters]
Port1: CMU connected between capacitance
Vbias: Bias voltage
Vbase: Voltage before measurement
Freq: Measurement frequency
OscLevel: Measurement signal level
IntegTime: Integration time
BiasHoldTime: Vbias hold time
BaseHoldTime: Vbase hold time
Interval: Sampling interval time
NoOfSampling: Number of sampling steps
OnAbnormalStatus: Auto abort function set up
Range: Measurement range

[Extended Test Parameters]
G_Min: Minimum transconductance value for graph
G_Max: Maximum transconductance value for graph
Cp_Min: Minimum capacitance value for graph
Cp_Max: Maximum capacitance value for graph
InitialVoltage: Initial voltage before Vbase

[Measurement parameters]
Susceptance B
Conductance G
DC bias monitor data DcMon
AC level monitor data AcMon

[User Function]
Circular constant PI=3.141592653589
4 GenericTest

Parallel capacitance \( Cp = \frac{B}{2\pi Freq} \)
Parallel resistance \( Rp = \frac{1}{G} \)
Dissipation factor \( D = \frac{G}{\text{abs}(B)} \)
Series resistance \( Rs = \frac{G}{(G^2 + B^2)} \)
Reactance \( X = \frac{-B}{(G^2 + B^2)} \)
Series capacitance \( Cs = -\frac{1}{(2\pi Freq X)} \)
Impedance \( Z = \sqrt{Rs^2 + X^2} \)
Phase Theta = \( \text{atan}(X/Rs) \)

[X-Y Plot]
X axis: Time (LINEAR)
Y1 axis: Parallel capacitance \( Cp \) (LINEAR)
Y2 axis: Conductance \( G \) (LINEAR)

[List Display]
Time Time
Parallel capacitance \( Cp \)
Conductance \( G \)
Frequency \( Freq \)
Series capacitance \( Cs \)
Series resistance \( Rs \)
Parallel resistance \( Rp \)
Dissipation factor \( D \)
Reactance \( X \)
Impedance \( Z \)
Phase Theta
DC bias monitor data \( DcMon \)
AC level monitor data \( AcMon \)
| 5 | MCSMU_IV |
1. Id-Vds MCSMU: Id-Vds characteristics, SMU Pulse (A.05.50_2013.04.10.1)
2. Id-Vgs MCSMU: Id-Vgs characteristics, MCSMU Pulse (A.05.50_2013.04.10.1)
3. Id-Vgs MCSMU 2-stage: Id-Vgs characteristics, MCSMU Pulse (A.05.50_2013.04.10.1)
5.1 Id-Vds MCSMU: Id-Vds characteristics, SMU Pulse (A.05.50_2013.04.10.1)

[Supported Analyzer]
B1500A

[Description]
Measures Drain current vs Drain voltage characteristics. SMU pulses are used for the Drain-Source and Gate-Source voltage output.

[Device Under Test]
Power MOSFET, 3 terminals and Subs terminal

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memor
Scale: Scale of sweep, LINEAR, LOG10, LOG25, or LOG50

Gate: SMU connection to Gate terminal, secondary sweep voltage output
VgStart: Sweep start voltage for gate terminal
VgStop: Sweep stop voltage for gate terminal
VgStep: Sweep step voltage for gate terminal
GatePulseWidth: Gate pulse width
GateDelay: Gate pulse delay (Effective only for MCSMU)

Source: COMMON connected to source terminal, 0 V voltage output

Drain: SMU connected to drain terminal, primary sweep voltage output
VdStart: Sweep start voltage for drain terminal
VdStop: Sweep stop voltage for drain terminal
VdLinearStep: Sweep step voltage for drain terminal, effective if Scale=LINEAR
IdLimit: Drain current compliance
DrainPulseWidth: Drain pulse width
PdLimit: Drain power compliance

EnableSubs: Enable or Disable Subs terminal assignment
Subs: SMU connected to Subs terminal, constant voltage output
VsSubs: Constant voltage for Subs terminal

PulsePeriodMode: Pulse period mode (AUTO or MANUAL)
ManualPulsePeriod: Manual pulse period
MeasurementTime: Measurement time

[Extended Test Parameters]
HoldTime: Hold time
PulseAvgCnt: Pulse averaging count
GatePulseBase: Gate pulse base voltage
IgLimit: Gate current compliance
DrainPulseBase: Drain pulse base voltage
IdZero: Y axis (Id) minimum value
5 MCSMU_IV

[Measurement Parameters]
Drain current Idrain

[User Function]
Ta: Temperature Ta=Temp

[X-Y Plot]
For Scale=LINEAR:
X axis: Drain voltage Vdrain (LINEAR)
Y axis: Drain current Idrain (LINEAR)

For Scale=LOG10, LOG25, or LOG50:
X axis: Drain voltage Vdrain (LOG)
Y axis: Drain current Idrain (LOG)

[List Display]
Drain voltage Vdrain
Drain current Idrain
Gate voltage Vgate

[Parameter Display Area]
Temperature Ta=Temp
5.2 Id-Vgs MCSMU: Id-Vgs characteristics, MCSMU Pulse
(A.05.50_2013.04.10.1)

[Supported Analyzer]
B1500A

[Description]
Measures Drain current vs Gate voltage characteristics. SMU pulses are used for the Drain-Source and gate-Source voltage output.

[Device Under Test]
Power MOSFET, 3 terminals and Subs terminal

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature
YAxisgfsMin: Y axis (gfs) minimum value
YAxisgfsMax: Y axis (gfs) maximum value

[Test Parameters]
Memo: Memo
Gate: SMU connected to gate terminal, primary sweep voltage output
VgStart: Sweep start voltage for gate terminal
VgStop: Sweep stop voltage for gate terminal
VgStep: Sweep step voltage for gate terminal
GatePulseWidth: Gate pulse width
GateDelay: Gate pulse delay (Effective only for MCSMU)

Source: COMMON connected to source terminal, 0 V voltage output

Drain: SMU connected to drain terminal, secondary sweep voltage output
VdStart: Sweep start voltage for drain terminal
VdStop: Sweep stop voltage for drain terminal
VdPoint: Sweep step point for drain terminal
IdLimit: Drain current compliance
DrainPulseWidth: Drain pulse width
EnableSubs: Enable or Disable Subs terminal assignment
Subs: SMU connected to Subs terminal, constant voltage output
Vsubs: Constant voltage for Subs terminal

PulsePeriodMode: Pulse period mode (AUTO or MANUAL)
ManualPulsePeriod: Manual pulse period
MeasurementTime: Measurement time

[Extended Test Parameters]
HoldTime: Hold time
PulseAvgCnt: Pulse averaging count
GatePulseBase: Gate pulse base voltage
IgLimit: Gate current compliance
DrainPulseBase: Drain pulse base voltage
YAxisIdMin: Y axis (Log Idrain) minimum value
5 MCSMU_IV

[Measurement Parameters]
Drain current Idrain

[User Function]
gfs: Forward transconductance gfs=diff(Idrain,Vgate)
Ta: Temperature Ta=Temp

[Analysis Function]
gfsMax=max(gfs)
Vth=@L1X (X intercept of Line1)

[Auto Analysis]
Line1: Tangent for Y2 data at the point of gfs=gfsMax

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Forward transconductance gfs (LINEAR)
Y2 axis: Drain current Idrain (LINEAR)
Y3 axis: Drain current Idrain (LOG)

[List Display]
Drain voltage Vdrain
Drain current Idrain
Gate voltage Vgate
Forward transconductance gfs

[Parameter Display Area]
Temperature Ta=Temp
Maximum value of forward transconductance gfsMax
Threshold voltage Vth
5.3 *Id-Vgs MCSMU 2-stage: Id-Vgs characteristics, MCSMU Pulse*  
*(A.05.50_2013.04.10.1)*

[Supported Analyzer]
B1500A

[Description]
Measures Drain current vs Gate voltage characteristics. SMU pulses are used for the Drain-Source and gate-Source voltage output.
Measurement is performed twice with lower compliance for low current region, higher compliance for high current region, then merge two curves.

[Device Under Test]
Power MOSFET, 3 terminals and Subs terminal

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature
YAxisgfsMin: Y axis (gfs) minimum value
YAxisgfsMax: Y axis (gfs) maximum value

[Test Parameters]
Memo: Memo

Gate: SMU connected to gate terminal, primary sweep voltage output
VgStart: Sweep start voltage for gate terminal
VgStop: Sweep stop voltage for gate terminal
VgStep: Sweep step voltage for gate terminal
GatePulseWidth: Gate pulse width
GateDelay: Gate pulse delay (Effective only for MCSMU)
GatePulseWidth2: Gate pulse width for lower current measurement
GateDelay2: Gate Pulse delay for lower current measurement (Effective only for MCSMU)

Source: COMMON connected to source terminal, 0 V voltage output

Drain: SMU connected to drain terminal, secondary sweep voltage output
VdStart: Sweep start voltage for drain terminal
VdStop: Sweep stop voltage for drain terminal
VdPoint: Sweep step point for drain terminal
IdLimit: Drain current compliance
DrainPulseWidth: Drain pulse width
IdLimit2: Drain current compliance for lower current measurement
DrainPulseWidth2: Drain pulse width for lower current measurement

EnableSubs: Enable or Disable Subs terminal assignment
Subs: SMU connected to Subs terminal, constant voltage output
Vsubs: Constant voltage for Subs terminal

PulsePeriodMode: Pulse period mode (AUTO or MANUAL)
ManualPulsePeriod: Manual pulse period
MeasurementTime: Measurement time
MeasurementTime2: Measurement time for lower current measurement
5 MCSMU_IV

[Extended Test Parameters]
HoldTime: Hold time
PulseAvgCnt: Pulse averaging count
GatePulseBase: Gate pulse base voltage
IgLimit: Gate current compliance
DrainPulseBase: Drain pulse base voltage
YAxisIdMin: Minimum value of Y-axis: Log Id
RecordRawData: Switch if to save the raw sweep data

[Measurement Parameters]
Drain current Idrain

[User Function]
gfs: Forward transconductance gfs=diff(Idrain,Vgate)
Ta: Temperature Ta=Temp

[Analysis Function]
gfsMax=\text{max}(gfs)
Vth=\text{@L1X} (X intercept of Line1)

[Auto Analysis]
Line1: Tangent for Y2 data at the point of gfs=gfsMax

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Forward transconductance gfs (LINEAR)
Y2 axis: Drain current Idrain (LINEAR)
Y3 axis: Drain current Idrain (LOG)

[List Display]
Drain voltage Vdrain
Drain current Idrain
Gate voltage Vgate
Forward transconductance gfs

[Parameter Display Area]
Temperature Ta=Temp
Maximum value of forward transconductance gfsMax
Threshold voltage Vth
6 Memory
1. Flash Ccf-V: Flash memory cell Control Gate to Floating Gate capacitance (A.01.11)
2. Flash Cfb-V: Flash memory cell Floating Gate-Substrate capacitance (A.01.11)
3. Flash Cgg-Vcg: Flash memory cell Gate capacitance (A.01.11)
4. NandFlash2 Endurance 3devices: Repeatedly tests write/erase on a NAND-type flash memory cell, simultaneously using three devices (A.01.20).
5. NandFlash2 Endurance: NAND flash memory cell endurance test (A.01.20)
6. NandFlash2 IV-Erase-IV: NAND flash memory cell Id-Vg, Erase, Id-Vg (A.01.20)
7. NandFlash2 IV-Write-IV: NAND flash memory cell Id-Vg, Write, Id-Vg (A.01.20)
8. NandFlash2 Retention(ErasedCell): NAND flash memory cell Data retention test after Erase (A.01.20)
9. NandFlash2 Retention(WrittenCell): NAND flash memory cell Data retention test after Write (A.01.20)
10. NandFlash2 Vth(ErasingTimeDependence): NAND flash memory cell erasing time dependence test (A.01.20)
11. NandFlash2 Vth(WritingTimeDependence): NAND flash memory cell writing time dependence test (A.01.20)
12. NandFlash2 WordDisturb(ErasedCell): NAND flash memory cell erase-disturb test (A.01.20)
13. NandFlash2 WordDisturb(WrittenCell): NAND flash memory cell read-disturb test (A.01.20)
14. NandFlash3 Endurance: NAND flash memory cell endurance test (A.03.10)
15. NandFlash3 IV-Erase-IV: NAND flash memory cell Id-Vg, Erase, Id-Vg (A.03.10)
16. NandFlash3 IV-Write-IV: NAND flash memory cell Id-Vg, Write, Id-Vg (A.03.10)
17. NandFlash3 Retention(ErasedCell): NAND flash memory cell Data retention test after Erase (A.03.10)
18. NandFlash3 Retention(WrittenCell): NAND flash memory cell Data retention test after Write (A.03.10)
19. NandFlash3 Vth(ErasingTimeDependence): NAND flash memory cell erasing time dependence test (A.03.10)
20. NandFlash3 Vth(WritingTimeDependence): NAND flash memory cell writing time dependence test (A.03.10)
21. NandFlash3 WordDisturb(ErasedCell): NAND flash memory cell erase-disturb test (A.03.10)
22. NandFlash3 WordDisturb(WrittenCell): NAND flash memory cell read-disturb test (A.03.10)
23. NorFlash Endurance: NOR flash memory cell endurance test (A.03.10)
24. NorFlash IV-Erase-IV: NOR flash memory cell Id-Vg, Erase, Id-Vg (A.03.10)
25. NorFlash IV-Write-IV: NOR flash memory cell Id-Vg, Write, Id-Vg (A.03.10)
26. NorFlash Retention(ErasedCell): NOR flash memory cell Data retention test after Erase (A.03.10)
27. NorFlash Retention(WrittenCell): NOR flash memory cell Data retention test after Write (A.03.10)
28. NorFlash Vth(ErasingTimeDependence): NOR flash memory cell erasing time dependence test (A.03.10)
29. NorFlash Vth(WritingTimeDependence): NOR flash memory cell writing time dependence test (A.03.10)
30. NorFlash WordDisturb(ErasedCell): NOR flash memory cell word disturb test after Erase (A.03.10)
31. NorFlash WordDisturb(WrittenCell): NOR flash memory cell word disturb test after Write (A.03.10)
32. NorFlash DataDisturb(ErasedCell): NOR flash memory cell data disturb test after Erase (A.03.10)
33. NorFlash DataDisturb(WrittenCell):
   NOR flash memory cell data disturb test after Write (A.03.10)
6 Memory

6.1 *Flash Ccf-V: Flash memory cell Control Gate to Floating Gate capacitance (A.01.11)*

[Supported Analyzer]
B1500A

[Description]
Measures the Control Gate to Floating Gate capacitance (Ccf), and plots the Ccf-V characteristics. For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
Flash memory cell
Connect the Control Gate to CMU High and the Floating Gate to CMU Low.
Connect the other terminals to the ground unit (GNDU).

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
M: Number of cells connected in parallel. M=1 for the single cell.

[Test Parameters]
IntegTime: Integration time
FREQ: Measurement frequency
OscLevel: Measurement signal level
ControlGate: CMU connected between Control Gate and Floating Gate (CV sweep measurement)
VcfStart: DC bias start voltage
VcfStop: DC bias stop voltage
VcfStep: DC bias step voltage

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Parallel capacitance C_p
Conductance G

[User Function]
PI=3.141592653589
D=G/(2*PI*FREQ*C_p)
R_p=1/G
C_s=(1+D^2)*C_p
X=-1/(2*PI*FREQ*C_s)
R_s=D*abs(X)
Z = sqrt(Rs^2 + X^2)
Theta = atan(X/Rs)
CsPerCell = Cs/M
CpPerCell = Cp/M

[X-Y Graph]
  X axis: DC bias Vcontrolgate (LINEAR)
  Y1 axis: Control Gate to Floating Gate capacitance (parallel capacitance) Cp (LINEAR)
  Y2 axis: Dissipation factor D (LINEAR)
  Y3 axis: Conductance G (LINEAR)

[List Display]
  Measurement frequency Freq
  DC bias Vcontrolgate
  Control Gate to Floating Gate capacitance (parallel capacitance) Cp
  Conductance G
  Series capacitance Cs
  Series resistance Rs
  Parallel resistance Rp
  Dissipation factor D
  Reactance X
  Impedance Z
  Phase Theta
  Series capacitance per cell CsPerCell
  Parallel capacitance per cell CpPerCell
6 Memory

6.2 Flash Cfb-V: Flash memory cell Floating Gate-Substrate capacitance (A.01.11)

[Supported Analyzer]
B1500A

[Description]
Measures the Floating Gate-Substrate capacitance (Ccf), and plots the Cfb-V characteristics.
DC bias output is performed from -VfbStart to -VfbStop in -VfbStep steps.
For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
Flash memory cell
Connect the Control Gate to ground unit (GNDU), the Floating Gate to CMU Low, and the other terminals to CMU High.

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
M: Number of cells connected in parallel. M=1 for the single cell.

[Test Parameters]
IntegTime: Integration time
FREQ: Measurement frequency
OscLevel: Measurement signal level
FloatingGate: CMU connected between Floating Gate and Substrate (CV sweep measurement)
VfbStart: DC bias start voltage
VfbStop: DC bias stop voltage
VfbStep: DC bias step voltage

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Parallel capacitance Cp
Conductance G

[User Function]
PI=3.141592653589
D=G/(2*PI*FREQ*Cp)
Rp=1/G
Cs=(1+D^2)*Cp
X=-1/(2*PI*FREQ*Cs)
Rs=D*abs(X)
Z=sqrt(Rs^2+X^2)
Theta=atan(X/Rs)
CsPerCell=Cs/M
CpPerCell=Cp/M
Vfb=-Vsubs

[X-Y Graph]
  X axis: DC bias Vfb (LINEAR)
  Y1 axis: Floating Gate-Substrate capacitance (parallel capacitance) Cp (LINEAR)
  Y2 axis: Dissipation factor D (LINEAR)
  Y3 axis: Conductance G (LINEAR)

[List Display]
  Measurement frequency Freq
  DC bias Vfb
  Floating Gate-Substrate capacitance (parallel capacitance) Cp
  Conductance G
  Series capacitance Cs
  Series resistance Rs
  Parallel resistance Rp
  Dissipation factor D
  Reactance X
  Impedance Z
  Phase Theta
  Series capacitance per cell CsPerCell
  Parallel capacitance per cell CpPerCell
6 Memory

6.3 Flash Cgg-Vcg: Flash memory cell Gate capacitance (A.01.11)

[Supported Analyzer]
B1500A

[Description]
Measures the Gate capacitance (Cgg), and plots the Cgg-Vcs characteristics.
DC bias output is performed from -VcsStart to -VcsStop in -VcsStep steps.
For a more accurate measurement, perform correction data measurement at the measurement frequency before
starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced
Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU
Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M,
3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
Flash memory cell
Open the Floating Gate, and connect the Control Gate to CMU Low and the other terminals to CMU High.

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
M: Number of cells connected in parallel. M=1 for the single cell.

[Test Parameters]
IntegTime: Integration time
FREQ: Measurement frequency
OscLevel: Measurement signal level
ControlGate: CMU connected between Control Gate and Substrate (CV sweep measurement)
VcsStart: DC bias start voltage
VcsStop: DC bias stop voltage
VcsStep: DC bias step voltage

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Parallel capacitance Cp
Conductance G

[User Function]
\[ PI=3.141592653589 \]
\[ D=G/(2*PI*FREQ*Cp) \]
\[ Rp=1/G \]
\[ Cs=(1+D^2)*Cp \]
\[ X=-1/(2*PI*FREQ*Cs) \]
\[ Rs=D*abs(X) \]
\[ Z=sqrt(Rs^2+X^2) \]
\[ Theta=atan(X/Rs) \]
CsPerCell = Cs/M
CpPerCell = Cp/M
Vcs = -Vsubs

[X-Y Graph]
X axis: DC bias Vcs (LINEAR)
Y1 axis: Gate capacitance (parallel capacitance) Cp (LINEAR)
Y2 axis: Dissipation factor D (LINEAR)
Y3 axis: Conductance G (LINEAR)

[List Display]
Measurement frequency Freq
DC bias Vcs
Gate capacitance (parallel capacitance) Cp
Conductance G
Series capacitance Cs
Series resistance Rs
Parallel resistance Rp
Dissipation factor D
Reactance X
Impedance Z
Phase Theta
Series capacitance per cell CsPerCell
Parallel capacitance per cell CpPerCell
6.4 NandFlash2 Endurance 3devices: Repeatedly tests write/erase on a NAND-type flash memory cell, simultaneously using three devices (A.01.20)

[Supported Analyzer]
B1500A

[Description]
Repeatedly tests write/erase on a NAND-type flash memory cell. Plots the number of writes/erases vs threshold voltage characteristic. Maximum three devices can be measured at once.

[Device Under Test]
NAND-type flash memory cell, 4 terminals x 3 devices
When some device is destroyed during write/erase, a desired voltage may not be applied to other devices.

[Required Modules and Accessories]
Keysight B2200A or B2201A switching matrix 1 unit
Keysight 81110A pulse generator (2-output, PGU1 and PGU2) 1 unit
GPIB cable

Connect 81110A, B2200A/B2201A and B1500A with measurement cables and GPIB cables.
Set information on B1500A SMU channel's connection to the B2200A/B2201A input port properly on the Switching Matrix tab screen of the Configuration window.
Set information on 81110A output channel's connection to B2200A/B2201A input port properly in the PulseGate and PulseDrain fields of the Test Parameters area. Set B2200A/B2201A input ports connected to the output channel of a gate pulse and drain pulse in these fields.
Set the output channel number of B2200A/B2201A connected to each terminal of a measured device properly in the Tr#Gate/Tr#Drain/Tr#Source/Tr#Subs field (# is an integer from 1 to 3) of the Test Parameters area.

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature (deg C)
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
TotalWriteAndEraseCycles: Number of write/erase cycles
Tr1Gate - Tr3Gate: SWM Pin Assign setting for Gate of devices
Tr1Drain - Tr3Drain: SWM Pin Assign setting for Drain of devices
Tr1Source - Tr3Source: SWM Pin Assign setting for Source of devices
Tr1Subs - Tr3Subs: SWM Pin Assign setting for Subs of devices
PgAdd: GPIB address of pulse generator
PulseGate: B2200A/B2201A input port for Gate pulse
PulseDrain: B2200A/B2201A input port for Drain pulse
ErasePeriod: Write/Erase pulse period
EraseDelay: Write/Erase pulse delay
EraseWidth: Write/Erase pulse width
EraseLeadTime: Pulse leading edge transition time
EraseTrailTime: Pulse trailing edge transition time
Verase: Pulse voltage output level, High
BaseValue: Pulse voltage output level, Low
[Test Parameters for Vth Acquisition]
- MeasGate: SMU connected to Gate terminal
- MeasDrain: SMU connected to Drain terminal
- MeasSource: SMU connected to Source terminal
- VgStart: Sweep start voltage for Gate terminal
- VgStop: Sweep stop voltage for Gate terminal
- VgStep: Sweep step voltage for Gate terminal
- Vd: Drain voltage
- IgLimit: Gate current compliance
- Id@Vth: Current determining the threshold voltage

[Extended Test Parameters for Vth Acquisition]
- Vs: Source voltage
- HoldTime: Hold time
- DelayTime: Delay time
- Vth_Min: Minimum Vth value for graph scale
- Vth_Max: Maximum Vth value for graph scale
- DrainMinRng1: Minimum range for drain current measurement on device 1
- DrainMinRng2: Minimum range for drain current measurement on device 2
- DrainMinRng3: Minimum range for drain current measurement on device 3

[Measurement Parameters]
- [Measurement Parameters for Vth Acquisition after Write Operation]
  - Drain current: Idrain

- [Measurement Parameters for Vth Acquisition after Erase Operation]
  - Drain current: Idrain

[Analysis Function]
- [Analysis Function for Vth Acquisition after Write Operation]
  - Vth@Id=@L1X (X intercept of Line1)

- [Analysis Function for Vth Acquisition after Erase Operation]
  - Vth@Id=@L1X (X intercept of Line1)

[Auto Analysis]
- [Auto Analysis for Vth Acquisition after Write Operation]
  - Line1: Idrain=X intercept of Id@Vth

- [Auto Analysis for Vth Acquisition after Erase Operation]
  - Line1: Idrain=X intercept of Id@Vth

[X-Y Plot]
- [X-Y Plot for Vth Acquisition after Write Operation]
  - X axis: Gate voltage Vgate (LINEAR)
  - Y1 axis: Drain current Idrain (LOG)

- [X-Y Plot for Vth Acquisition after Erase Operation]
  - X axis: Gate voltage Vgate (LINEAR)
  - Y1 axis: Drain current Idrain (LOG)

[List Display]
- [List Display for Vth Acquisition after Write Operation]
  - Gate voltage Vgate
  - Drain current Idrain
6 Memory

[List Display for Vth Acquisition after Erase Operation]
Gate voltage Vgate
Drain current Idrain

[Test Output: X-Y Graph]
  X axis: Number of write/erase cycles CycleList (LOG)
  Y1 axis: Vth value after write operation on device 1 Dev1_VthWrittenList (LINEAR)
  Y2 axis: Vth value after write operation on device 2 Dev2_VthWrittenList (LINEAR)
  Y3 axis: Vth value after write operation on device 3 Dev3_VthWrittenList (LINEAR)
  Y4 axis: Vth value after erase operation on device 1 Dev1_VthErasedList (LINEAR)
  Y5 axis: Vth value after erase operation on device 2 Dev2_VthErasedList (LINEAR)
  Y6 axis: Vth value after erase operation on device 3 Dev3_VthErasedList (LINEAR)

[Test Output: List Display]
  Number of write/erase cycles CycleList
  Vth value after write operation on device 1 Dev1_VthWrittenList
  Vth value after write operation on device 2 Dev2_VthWrittenList
  Vth value after write operation on device 3 Dev3_VthWrittenList
  Vth value after erase operation on device 1 Dev1_VthErasedList
  Vth value after erase operation on device 2 Dev2_VthErasedList
  Vth value after erase operation on device 3 Dev3_VthErasedList

[Test Setup Details]
  Refer to "NandFlash2 IV-Write-IV" and "NandFlash2 IV-Erase-IV."
6.5 *NandFlash2 Endurance: NAND flash memory cell endurance test (A.01.20)*

[Supported Analyzer]
B1500A

[Description]
Performs the endurance test for the NAND type flash memory cell and plots the number of write/erase operation vs threshold voltage characteristics.

[Device Under Test]
NAND-type flash memory cell
Connect the Control Gate to the ASU1 Output, and the Drain to the ASU2 Output.
Open the Floating Gate, and connect the other terminals to the ASU3 Output.

[Required Modules and Accessories]
Keysight 81110A pulse generator (2-output, PGU1 and PGU2) 1 unit
HRSMU/ASU 3 sets (ASU1, ASU2, and ASU3)

ASU1 connections: Output: Control Gate, SMU: HRSMU, AUX: PGU1
ASU2 connections: Output: Drain, SMU: HRSMU, AUX: PGU2
ASU3 connections: Output: Source and Substrate, SMU: HRSMU, AUX: PGU2
Setting of ASU I/O Path, ASU tab, Configuration window: AUX

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source and Substrate terminals, constant voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Vd: Drain voltage
Id@Vth: Drain current to decide the Vth
IntegTime: Integration time
TotalWriteAndEraseCycles: Total number of write/erase operation
WritePulsePeriod: Write pulse period
WritePulseDelay: Write pulse delay
WritePulseWidth: Write pulse width
WriteLeadingTime: Write pulse leading edge transition time
WriteTrailingTime: Write pulse trailing edge transition time
Vwrite: Write pulse output level
ErasePulsePeriod: Erase pulse period
ErasePulseDelay: Erase pulse delay
ErasePulseWidth: Erase pulse width
EraseLeadingTime: Erase pulse leading edge transition time
EraseTrailingTime: Erase pulse trailing edge transition time
Verase: Erase pulse output level

[Extended Test Parameters]
6 Memory

Vs: Source voltage
IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
PgAdd: GPIB address of pulse generator
BaseValue: Pulse base value
NoOfPulse: Number of output pulses

[Test Output: X-Y Graph]
X axis: Number of write/erase operation (LOG)
Y1 axis: Threshold voltage after write VthWrittenList (LINEAR)
Y2 axis: Threshold voltage after erase VthErasedList (LINEAR)

[Test Setup Details]
See NandFlash2 IV-Write-IV and NandFlash2 IV-Erase-IV.
6.6  **NandFlash2 IV-Erase-IV: NAND flash memory cell Id-Vg, Erase, Id-Vg (A.01.20)**

[Supported Analyzer]
B1500A

[Description]
Measures the Id-Vg characteristics of NAND-type flash memory cell, performs the data erase operation, measures the Id-Vg characteristics again, and plots the both Id-Vg characteristics on a graph. Uses pulse generator (2-output) 1 unit and HRSMU/ASU 2 sets.
Before the Id-Vg measurements, the initial pulse will be applied to the device under test.

[Device Under Test]
NAND-type flash memory cell
Connect the Control Gate to a SMU and the Drain to the ASU1 Output.
Open the Floating Gate. And connect the other terminals to the ASU2 Output.

[Required Modules and Accessories]
Keysight 81110A pulse generator (2-output, PGU1 and PGU2) 1 unit
HRSMU/ASU 2 sets (ASU1 and ASU2)

ASU1 connections: Output: Drain, SMU: HRSMU, AUX: PGU1
ASU2 connections: Output: Source and Substrate, SMU: HRSMU, AUX: PGU1
Setting of ASU I/O Path, ASU tab, Configuration window: AUX

PGU1 is connected to keep the setup for the data write operation.

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Vd: Drain voltage
Id@Vth: Drain current to decide the Vth
Source: SMU connected to Source and Substrate terminals, constant voltage output
PulsePeriod: Erase pulse period
PulseDelay: Erase pulse delay
PulseWidth: Erase pulse width
LeadingTime: Pulse leading edge transition time
TrailingTime: Pulse trailing edge transition time
Verase: Erase pulse output level

[Extended Test Parameters]
IgLimit: Gate current compliance
HoldTime: Hold time
6 Memory

DelayTime: Delay time
BaseValue: Erase pulse base value
PgAdd: GPIB address of pulse generator
NoOfPulse: Number of output pulses for the erase operation

[Initial pulse setup parameters]
  Pulse period Period2=50 s
  Pulse delay Delay2=0 s
  Pulse duty cycle Dcyc2=50 %
  Pulse output level Level2=0 V
  Pulse base value Base2=200 mV
  Number of output pulses TrigCount=1
The parameters are defined in the ForcePG2 setup of the Test Contents, and can be changed by using the Test
Definition editor.

[Measurement Parameters]
  Drain current Idrain (defined in Id-Vg_Initial and Id-Vg_Erased setup)

[User Function]
  IdrainPerWg=Idrain/Wg (defined in Id-Vg_Initial and Id-Vg_Erased setup)

[Analysis Function]
  VthBefore=@L1X (X intercept of Line1, defined in Id-Vg_Initial setup)
  VthAfter=@L1X (X intercept of Line1, defined in Id-Vg_Erased setup)

[Auto Analysis]
  Line1: Vertical line for Y1 at Idrain=Id@Vth

[Test Output: X-Y Graph]
  X axis: Gate voltage VgateList (LINEAR)
  Y1 axis: Drain current before Erase operation IdInitialList (LOG)
  Y2 axis: Drain current after Erase operation IdErasedList (LOG)

[Test Output: Parameters]
  Threshold voltage before Erase operation VthInitial
  Threshold voltage after Erase operation VthErased
6.7  NandFlash2 IV-Write-IV: NAND flash memory cell Id-Vg, Write, Id-Vg (A.01.20)

[Supported Analyzer]
B1500A

[Description]
Measures the Id-Vg characteristics of NAND-type flash memory cell, performs the data write operation, measures the Id-Vg characteristics again, and plots the both Id-Vg characteristics on a graph. Uses pulse generator (2-output) 1 unit and HRSMU/ASU 1 set.
Before the Id-Vg measurements, the initial pulse will be applied to the device under test.

[Device Under Test]
NAND-type flash memory cell
Connect the Control Gate to the ASU Output, and the Drain to a SMU.
Open the Floating Gate. And connect the other terminals to a SMU.

[Required Modules and Accessories]
Keysight 81110A pulse generator (2-output, PGU1 and PGU2) 1 unit
HRSMU/ASU 1 set

ASU connections: Output: Control Gate, SMU: HRSMU, AUX: PGU1
Setting of ASU I/O Path, ASU tab, Configuration window: AUX

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Vd: Drain voltage
Id@Vth: Drain current to decide the Vth
Source: SMU connected to Source and Substrate terminals, constant voltage output
PulsePeriod: Write pulse period
PulseDelay: Write pulse delay
PulseWidth: Write pulse width
LeadingTime: Pulse leading edge transition time
TrailingTime: Pulse trailing edge transition time
Vwrite: Write pulse output level

[Extended Test Parameters]
IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
BaseValue: Write pulse base value
PgAdd: GPIB address of pulse generator
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NoOfPulse: Number of output pulses for the write operation

[Initial pulse setup parameters]
Pulse period Period2=50 s
Pulse delay Delay2=0 s
Pulse duty cycle Dcyc2=50 %
Pulse output level Level2=0 V
Pulse base value Base2=200 mV
Number of output pulses TrigCount=1
The parameters are defined in the ForcePG2 setup of the Test Contents, and can be changed by using the Test Definition editor.

[Measurement Parameters]
Drain current Idrain (defined in Id-Vg_Initial and Id-Vg_Written setup)

[User Function]
IdrainPerWg=Idrain/Wg (defined in Id-Vg_Initial and Id-Vg_Written setup)

[Analysis Function]
VthBefore=@L1X (X intercept of Line1, defined in Id-Vg_Initial setup)
VthAfter=@L1X (X intercept of Line1, defined in Id-Vg_Written setup)

[Auto Analysis]
Line1: Vertical line for Y1 at Idrain=Id@Vth

[Test Output: X-Y Graph]
X axis: Gate voltage VgateList (LINEAR)
Y1 axis: Drain current before Write operation IdInitialList (LOG)
Y2 axis: Drain current after Write operation IdWrittenList (LOG)

[Test Output: Parameters]
Threshold voltage before Write operation VthInitial
Threshold voltage after Write operation VthWritten
6.8 NandFlash2 Retention(ErasedCell): NAND flash memory cell Data retention test after Erase (A.01.20)

[Supported Analyzer]
B1500A

[Description]
Performs the data retention test for the NAND type flash memory cell after the erase operation, and plots the accumulated time vs threshold voltage characteristics. The test is performed as follows.

1. Applies the erase pulse.
2. Measures the Id-Vg characteristics, and extracts the threshold voltage (Vth).
3. If the accumulated time is 100 seconds or less:
   Performs the drain current sampling measurement, 10 seconds in 1 second step.
   After the sampling measurement, measures the Id-Vg characteristics and extracts Vth.
4. If the accumulated time is more than 100 seconds:
   Performs the drain current sampling measurement, 100 seconds in 10 seconds step.
   After the sampling measurement, measures the Id-Vg characteristics and extracts Vth.
5. Repeats 3 or 4 until that the accumulated time over the specified TotalRetentionTime.
   The available TotalRetentionTime value is 10 to 10000 seconds.

[Device Under Test]
NAND-type flash memory cell
Connect the Source and Substrate to the ASU1 Output, and the Drain to the ASU2 Output.
Open the Floating Gate, and connect the other terminals to the PGU2 output terminal.

[Required Modules and Accessories]
Keysight 81110A pulse generator (2-output, PGU1 and PGU2) 1 unit
HRSMU/ASU 2 sets (ASU1 and ASU2)

ASU1 connections: Output: Source and Substrate, SMU: HRSMU, AUX: PGU1
ASU2 connections: Output: Drain, SMU: HRSMU, AUX: PGU1
Setting of ASU I/O Path, ASU tab, Configuration window: AUX
PGU1 is connected to keep the setup for the data write operation.

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source and Substrate terminals, constant voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Vd: Drain voltage
Id@Vth: Drain current to decide the Vth
IntegTime: Integration time
PulsePeriod: Erase pulse period
PulseDelay: Erase pulse delay
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PulseWidth: Erase pulse width
Verase: Erase pulse output level
LeadingTime: Pulse leading edge transition time
TrailingTime: Pulse trailing edge transition time
TotalRetentionTime: Time to continue the test. 10 to 10000 seconds.

[Extended Test Parameters]
IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
BaseValue: Erase pulse base value
PgAdd: GPIB address of pulse generator
NoOfPulse: Number of output pulses for the erase operation

[Test Output: X-Y Graph]
X axis: Time TimeList (LOG)
Y1 axis: Threshold voltage VthList (LINEAR)

[Test Setup Details]
See NandFlash2 IV-Erase-IV.
6.9 **NandFlash2 Retention(WrittenCell): NAND flash memory cell Data retention test after Write (A.01.20)**

[Supported Analyzer]
B1500A

[Description]
Performs the data retention test for the NAND type flash memory cell after the write operation, and plots the accumulated time vs threshold voltage characteristics. The test is performed as follows.

1. Applies the write pulse.
2. Measures the Id-Vg characteristics, and extracts the threshold voltage (Vth).
3. If the accumulated time is 100 seconds or less:
   - Performs the drain current sampling measurement, 10 seconds in 1 second step.
   - After the sampling measurement, measures the Id-Vg characteristics and extracts Vth.
4. If the accumulated time is more than 100 seconds:
   - Performs the drain current sampling measurement, 100 seconds in 10 seconds step.
   - After the sampling measurement, measures the Id-Vg characteristics and extracts Vth.
5. Repeats 3 or 4 until that the accumulated time overs the specified TotalRetentionTime.
   - The available TotalRetentionTime value is 10 to 10000 seconds.

[Device Under Test]
NAND-type flash memory cell
Connect the Control Gate to the ASU Output, and the Drain to a SMU.
Open the Floating Gate, and connect the other terminals to a SMU.

[Required Modules and Accessories]
Keysight 81110A pulse generator (2-output, PGU1 and PGU2) 1 unit
HRSMU/ASU 1 set

ASU connections: Output: Control Gate, SMU: HRSMU, AUX: PGU1
Setting of ASU I/O Path, ASU tab, Configuration window: AUX

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source and Substrate terminals, constant voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Vd: Drain voltage
Id@Vth: Drain current to decide the Vth
IntegTime: Integration time
PulsePeriod: Write pulse period
PulseDelay: Write pulse delay
PulseWidth: Write pulse width
Vwrite: Write pulse output level
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LeadingTime: Pulse leading edge transition time
TrailingTime: Pulse trailing edge transition time
TotalRetentionTime: Time to continue the test. 10 to 10000 seconds.

[Extended Test Parameters]
IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
PgAdd: GPIB address of pulse generator
BaseValue: Write pulse base value
NoOfPulse: Number of output pulses for the write operation

[Test Output: X-Y Graph]
X axis: Time TimeList (LOG)
Y1 axis: Threshold voltage VthList (LINEAR)

[Test Setup Details]
See NandFlash2 IV-Write-IV.
6.10 NandFlash2 Vth(ErasingTimeDependence): NAND flash memory cell erasing time dependence test (A.01.20)

[Supported Analyzer]
B1500A

[Description]
Performs the erasing time dependence test of the NAND-type flash memory cell, and plots the accumulated erasing time (accumulated pulse width) vs threshold voltage characteristics.

[Device Under Test]
NAND-type flash memory cell
Connect the Control Gate to a SMU, and the Drain to the ASU2 Output.
Open the Floating Gate, and connect the other terminals to the ASU1 Output.

[Required Modules and Accessories]
Keysight 81110A pulse generator (2-output, PGU1 and PGU2) 1 unit
HRSMU/ASU 2 sets (ASU1 and ASU2)

ASU1 connections: Output: Source and Substrate, SMU: HRSMU, AUX: PGU1
ASU2 connections: Output: Drain, SMU: HRSMU, AUX: PGU1
Setting of ASU I/O Path, ASU tab, Configuration window: AUX

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source terminal, constant voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Vd: Drain voltage
Vs: Source voltage
Id@Vth: Drain current to decide the Vth
IntegTime: Integration time
PulsePeriod: Erase pulse period
PulseDelay: Erase pulse delay
PulseWidth: Total accumulated pulse width
CheckNoOfTimes: Number of Vth measurement operation
Verase: Erase pulse output level
LeadingTime: Pulse leading edge transition time
TrailingTime: Pulse trailing edge transition time

[Extended Test Parameter]
IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
BaseValue: Erase pulse base value
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PgAdd: GPIB address of pulse generator
NoOfPulse: Number of output pulses for the erase operation

[Measurement Parameters]
Drain current Idrain

[Analysis Function]
Vth=@L1X (X intercept of Line1)

[Auto Analysis]
Line1: Vertical line for Y1 at Idrain=Id@Vth

[Test Output: X-Y Graph]
X axis: Accumulated erasing pulse width EraseTimeList (LOG)
Y1 axis: Threshold voltage Vth (LINEAR)
6.11 NandFlash2 Vth(WritingTimeDependence): NAND flash memory cell writing time dependence test (A.01.20)

[Supported Analyzer]
B1500A

[Description]
Performs the writing time dependence test of the NAND-type flash memory cell, and plots the accumulated writing time (accumulated pulse width) vs threshold voltage characteristics.

[Device Under Test]
NAND-type flash memory cell
Connect the Control Gate to the ASU Output, and the Drain to a SMU.
Open the Floating Gate, and connect the other terminals to a SMU.

[Required Modules and Accessories]
Keysight 81110A pulse generator (2-output, PGU1 and PGU2) 1 unit
HRSMU/ASU 1 set

ASU connections: Output: Control Gate, SMU: HRSMU, AUX: PGU1
Setting of ASU I/O Path, ASU tab, Configuration window: AUX

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source terminal, constant voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Vd: Drain voltage
Vs: Source voltage
Id@Vth: Drain current to decide the Vth
IntegTime: Integration time
PulsePeriod: Write pulse period
PulseDelay: Write pulse delay
PulseWidth: Total accumulated pulse width
CheckNoOfTimes: Number of Vth measurement operation
Vwrite: Write pulse output level
LeadingTime: Pulse leading edge transition time
TrailingTime: Pulse trailing edge transition time

[Extended Test Parameter]
IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
BaseValue: Write pulse base value
PgAdd: GPIB address of pulse generator
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NoOfPulse: Number of output pulses for the write operation

[Measurement Parameters]
Drain current I\text{drain}

[Analysis Function]
V\text{th}=\text{L1X} (X intercept of Line1)

[Auto Analysis]
Line1: Vertical line for Y1 at I\text{drain}=I\text{d@Vth}

[Test Output: X-Y Graph]
X axis: Accumulated writing pulse width WriteTimeList (LOG)
Y1 axis: Threshold voltage V\text{th} (LINEAR)
6.12 NandFlash2 WordDisturb(ErasedCell): NAND flash memory cell erase-disturb test (A.01.20)

[Supported Analyzer]
B1500A

[Description]
Performs the erase-disturb test of the NAND-type flash memory cell, and plots the accumulated stress time vs threshold voltage characteristics.

[Device Under Test]
NAND-type flash memory cell
Connect the Control Gate to the ASU1 Output, and the Drain to the ASU2 Output.
Open the Floating Gate, and connect the other terminals to the ASU3 Output.

[Required Modules and Accessories]
Keysight 81110A pulse generator (2-output, PGU1 and PGU2) 1 unit
HRSMU/ASU 3 sets (ASU1, ASU2, and ASU3)

ASU1 connections: Output: Control Gate, SMU: HRSMU, AUX: PGU1
ASU2 connections: Output: Drain, SMU: HRSMU, AUX: PGU2
ASU3 connections: Output: Source and Substrate, SMU: HRSMU, AUX: PGU2
Setting of ASU I/O Path, ASU tab, Configuration window: AUX

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source terminal, constant voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
VgStress: Stress voltage for Gate terminal
Vd: Drain voltage
Vs: Source voltage
Id@Vth: Drain current to decide the Vth
IntegTime: Integration time
TotalStressTime: Total accumulated stress time
CheckNoOfTimes: Number of Vth measurement operation
PulsePeriod: Erase pulse period
PulseDelay: Erase pulse delay
PulseWidth: Erase pulse width
Verase: Erase pulse output level
LeadingTime: Pulse leading edge transition time
TrailingTime: Pulse trailing edge transition time

[Extended Test Parameter]
6 Memory

IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
BaseValue: Erase pulse base value
PgAdd: GPIB address of pulse generator
NoOfPulse: Number of output pulses for the erase operation

[Measurement Parameters]
Drain current Idrain

[Analysis Function]
Vth=@L1X (X intercept of Line1)

[Auto Analysis]
Line1: Vertical line for Y1 at Idrain=Id@Vth

[Test Output: X-Y Graph]
X axis: Accumulated stress time StressTimeList (LOG)
Y1 axis: Threshold voltage Vth (LINEAR)
6.13 **NandFlash2 WordDisturb(WrittenCell): NAND flash memory cell read-disturb test (A.01.20)**

[Supported Analyzer]
B1500A

[Description]
Performs the read-disturb test of the NAND-type flash memory cell, and plots the accumulated stress time vs threshold voltage characteristics.

[Device Under Test]
NAND-type flash memory cell
Connect the Control Gate to the ASU Output, and the Drain to a SMU. Open the Floating Gate, and connect the other terminals to a SMU.

[Required Modules and Accessories]
Keysight 81110A pulse generator (2-output, PGU1 and PGU2) 1 unit
HRSMU/ASU 1 set

ASU connections: Output: Control Gate, SMU: HRSMU, AUX: PGU1
Setting of ASU I/O Path, ASU tab, Configuration window: AUX

[Device Parameters]
- Lg: Gate length
- Wg: Gate width
- Temp: Temperature
- IdMax: Drain current compliance

[Test Parameters]
- Gate: SMU connected to Gate terminal, primary sweep voltage output
- Drain: SMU connected to Drain terminal, constant voltage output
- Source: SMU connected to Source terminal, constant voltage output
- VgStart: Sweep start voltage for Gate terminal
- VgStop: Sweep stop voltage for Gate terminal
- VgStep: Sweep step voltage for Gate terminal
- VgStress: Stress voltage for Gate terminal
- Vd: Drain voltage
- Vs: Source voltage
- Id@Vth: Drain current to decide the Vth
- IntegTime: Integration time
- TotalStressTime: Total accumulated stress time
- CheckNoOfTimes: Number of Vth measurement operation
- PulsePeriod: Write pulse period
- PulseDelay: Write pulse delay
- PulseWidth: Write pulse width
- Vwrite: Write pulse output level
- LeadingTime: Pulse leading edge transition time
- TrailingTime: Pulse trailing edge transition time

[Extended Test Parameter]
- IgLimit: Gate current compliance
- HoldTime: Hold time
- DelayTime: Delay time
6 Memory

- BaseValue: Write pulse base value
- PgAdd: GPIB address of pulse generator
- NoOfPulse: Number of output pulses for the write operation

[Measurement Parameters]
- Drain current Idrain

[Analysis Function]
- Vth=@L1X (X intercept of Line1)

[Auto Analysis]
- Line1: Vertical line for Y1 at Idrain=Id@Vth

[Test Output: X-Y Graph]
- X axis: Accumulated stress time StressTimeList (LOG)
- Y1 axis: Threshold voltage Vth (LINEAR)
6.14 NandFlash3 Endurance: NAND flash memory cell endurance test (A.03.10)

[Supported Analyzer]
B1500A

[Description]
Performs the endurance test for the NAND type flash memory cell and plots the number of write/erase operation vs threshold voltage characteristics.

[Device Under Test]
NAND-type flash memory cell

[Required Modules and Accessories]
Keysight B1525A SPGU 1 unit
Selector (16440A/16445A 2 sets or HRSMU/ASU 3 sets)

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source and Substrate terminals, constant voltage output
Pgate: SPGU channel connected to Gate terminal via Selector
Psource: SPGU channel connected to Drain, Source, and Substrate via Selector
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Vd: Drain voltage
Id@Vth: Drain current to decide the Vth
IntegTime: Integration time
TotalWriteAndEraseCycles: Total number of write/erase operation
WritePulsePeriod: Write pulse period
WritePulseDelay: Write pulse delay
WritePulseWidth: Write pulse width
WriteLeadingTime: Write pulse leading edge transition time
WriteTrailingTime: Write pulse trailing edge transition time
Vwrite: Write pulse output level
ErasePulsePeriod: Erase pulse period
ErasePulseDelay: Erase pulse delay
ErasePulseWidth: Erase pulse width
EraseLeadingTime: Erase pulse leading edge transition time
EraseTrailingTime: Erase pulse trailing edge transition time
Verase: Erase pulse output level
MeasTiming: Timing to perform Vth measurement

[Extended Test Parameters]
Vs: Source voltage
IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
6 Memory

BaseValue: Write pulse base value
DrainMinRng: Minimum range of drain current measurement

[Measurement Parameters]
Drain current Idrain

[Analysis Function]
Vth@Id=Id@L1X (X intercept of Line1)

[Auto Analysis]
Line1: Vertical line for Y1 at Idrain=Id@Vth

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LOG)

[List Display]
Gate voltage Vgate
Drain current Idrain

[Test Output: X-Y Graph]
X axis: Number of write/erase cycles CycleList (LOG)
Y1 axis: Threshold voltage after write VthWrittenList (LINEAR)
Y2 axis: Threshold voltage after erase VthErasedList (LINEAR)

[Test Output: List Display]
Number of write/erase cycles CycleList
Threshold voltage after write VthWrittenList
Threshold voltage after erase VthErasedList

[Test Setup Details]
See NandFlash3 IV-Write-IV and NandFlash3 IV-Erase-IV.
TotalWriteAndEraseCycles should be 10, 100, 1000, 10000, 100000, or 1000000.
6.15 NandFlash3 IV-Erase-IV: NAND flash memory cell Id-Vg, Erase, Id-Vg (A.03.10)

[Supported Analyzer]
B1500A

[Description]
Measures the Id-Vg characteristics of NAND-type flash memory cell, performs the data erase operation, measures the Id-Vg characteristics again, and plots the both Id-Vg characteristics on a graph. Before the Id-Vg measurements, the initial pulse will be applied to the device under test.

[Device Under Test]
NAND-type flash memory cell

[Required Modules and Accessories]
Keysight B1525A SPGU 1 unit
Selector (16440A/16445A 1 set or HRSMU/ASU 2 sets)

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source and Substrate terminals, constant voltage output
PSource: SPGU channel connected to Drain and Source via Selector
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Vd: Drain voltage
Id@Vth: Drain current to decide the Vth
IntegTime: Integration time
PulsePeriod: Erase pulse period
PulseDelay: Erase pulse delay
PulseWidth: Erase pulse width
Verase: Erase pulse output level
LeadingTime: Pulse leading edge transition time
TrailingTime: Pulse trailing edge transition time

[Extended Test Parameters]
Vs: Source voltage
IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
BaseValue: Erase pulse base value
NoOfPulse: Number of output pulses for the erase operation
DrainMinRng: Minimum range of drain current measurement
6 Memory

[Measurement Parameters]
Drain current Idrain

[User Function]
IdrainPerWg=Idrain/Wg

[Analysis Function]
VthAfter=@L1X (X intercept of Line1)

[Auto Analysis]
Line1: Vertical line for Y1 at Idrain=Id@Vth

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)

[List Display]
Gate voltage Vgate
Drain voltage Vdrain
Drain current Idrain

[Test Output: X-Y Graph]
X axis: Gate voltage VgateList (LINEAR)
Y1 axis: Drain current before Erase operation IdInitialList (LOG)
Y2 axis: Drain current after Erase operation IdErasedList (LOG)

[Test Output: List Display]
Gate voltage VgateList
Drain current before Erase operation IdInitialList
Drain current after Erase operation IdErasedList

[Test Output: Parameters]
Threshold voltage before Erase operation VthInitial
Threshold voltage after Erase operation VthErased
6.16 *NandFlash3 IV-Write-IV: NAND flash memory cell Id-Vg, Write, Id-Vg (A.03.10)*

[Supported Analyzer]
B1500A

[Description]
Measures the Id-Vg characteristics of NAND-type flash memory cell, performs the data write operation, measures the Id-Vg characteristics again, and plots the both Id-Vg characteristics on a graph. Before the Id-Vg measurements, the initial pulse will be applied to the device under test.

[Device Under Test]
NAND-type flash memory cell

[Required Modules and Accessories]
Keysight B1525A SPGU 1 unit
Selector (16440A/16445A 1 set or HRSMU/ASU 1 sets)

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source and Substrate terminals, constant voltage output
Pgate: SPGU channel connected to Gate terminal via Selector
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Vd: Drain voltage
Id@Vth: Drain current to decide the Vth
IntegTime: Integration time
PulsePeriod: Write pulse period
PulseDelay: Write pulse delay
PulseWidth: Write pulse width
Vwrite: Write pulse output level
LeadingTime: Pulse leading edge transition time
TrailingTime: Pulse trailing edge transition time

[Extended Test Parameters]
Vs: Source voltage
IgLImi: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
BaseValue: Write pulse base value
NoOfPulse: Number of output pulses for the write operation
DrainMinRng: Minimum range of drain current measurement
6 Memory

[Measurement Parameters]
  Drain current Idrain

[User Function]
  IdrainPerWg = Idrain/Wg

[Analysis Function]
  VthAfter = @L1x (X intercept of Line1)

[Auto Analysis]
  Line1: Vertical line for Y1 at Idrain=Id@Vth

[X-Y Plot]
  X axis: Gate voltage Vgate (LINEAR)
  Y1 axis: Drain current Idrain (LINEAR)
  Y2 axis: Drain current Idrain (LOG)

[List Display]
  Gate voltage Vgate
  Drain voltage Vdrain
  Drain current Idrain

[Test Output: X-Y Graph]
  X axis: Gate voltage VgateList (LINEAR)
  Y1 axis: Drain current before Write operation IdInitialList (LOG)
  Y2 axis: Drain current after Write operation IdWrittenList (LOG)

[Test Output: List Display]
  Gate voltage VgateList
  Drain current before Write operation IdInitialList
  Drain current after Write operation IdWrittenList

[Test Output: Parameters]
  Threshold voltage before Write operation VthInitial
  Threshold voltage after Write operation VthWritten
6.17 NandFlash3 Retention(ErasedCell): NAND flash memory cell Data retention test after Erase (A.03.10)

[Supported Analyzer]
B1500A

[Description]
Performs the data retention test for the NAND type flash memory cell after the erase operation, and plots the accumulated time vs threshold voltage characteristics.

[Device Under Test]
NAND-type flash memory cell

[Required Modules and Accessories]
Keysight B1525A SPGU 1 unit
Selector (16440A/16445A 1 set or HRSMU/ASU 2 sets)

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source and Substrate terminals, constant voltage output
Psource: SPGU channel connected to Drain, Source, and Substrate via Selector
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Vd: Drain voltage
Id@Vth: Drain current to decide the Vth
IntegTime: Integration time
PulsePeriod: Erase pulse period
PulseDelay: Erase pulse delay
PulseWidth: Erase pulse width
Verase: Erase pulse output level
LeadingTime: Pulse leading edge transition time
TrailingTime: Pulse trailing edge transition time
TotalRetentionTime: Time to continue the test. 10 to 10000 seconds
MeasTiming: Timing to perform Vth measurement

[Extended Test Parameters]
Vs: Source voltage
IgLImit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
BaseValue: Erase pulse base value
NoOfPulse: Number of output pulses for the erase operation
DrainMinRng: Minimum range of drain current measurement

[Measurement Parameters]
6 Memory

Drain current $I_{drain}$

[User Function]
$I_{drain\text{PerWg}} = I_{drain}/Wg$

[Analysis Function]
$V_{th}@I_{d}=@L1X$ (X intercept of Line1)

[Auto Analysis]
Line1: Vertical line for Y1 at $I_{drain}=I_{d}@V_{th}$

[X-Y Plot]
X axis: Gate voltage $V_{gate}$ (LINEAR)
Y1 axis: Drain current $I_{drain}$ (LINEAR)
Y2 axis: Drain current $I_{drain}$ (LOG)

[List Display]
Gate voltage $V_{gate}$
Drain voltage $V_{drain}$
Drain current $I_{drain}$

[Test Output: X-Y Graph]
X axis: Time $TimeList$ (LOG)
Y1 axis: Threshold voltage $V_{thList}$ (LINEAR)

[Test Output: List Display]
Time $TimeList$
Threshold voltage $V_{thList}$

[Test Setup Details]
See NandFlash3 IV-Erase-IV.
6.18 NandFlash3 Retention(WrittenCell): NAND flash memory cell Data retention test after Write (A.03.10)

[Supported Analyzer]
B1500A

[Description]
Performs the data retention test for the NAND type flash memory cell after the write operation, and plots the accumulated time vs threshold voltage characteristics.

[Device Under Test]
NAND-type flash memory cell

[Required Modules and Accessories]
Keysight B1525A SPGU 1 unit
Selector (16440A/16445A 1 set or HRSMU/ASU 1 set)

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source and Substrate terminals, constant voltage output
Pgate: SPGU channel connected to Gate terminal via Selector
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Vd: Drain voltage
Id@Vth: Drain current to decide the Vth
IntegTime: Integration time
PulsePeriod: Write pulse period
PulseDelay: Write pulse delay
PulseWidth: Write pulse width
Vwrite: Write pulse output level
LeadingTime: Pulse leading edge transition time
TrailingTime: Pulse trailing edge transition time
TotalRetentionTime: Time to continue the test. 10 to 10000 seconds
MeasTiming: Timing to perform Vth measurement

[Extended Test Parameters]
Vs: Source voltage
IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
BaseValue: Write pulse base value
NoOfPulse: Number of output pulses for the write operation
DrainMinRng: Minimum range of drain current measurement

[Measurement Parameters]
6 Memory

Drain current Idrain

[User Function]
IdrainPerWg=Idrain/Wg

[Analysis Function]
Vth@Id=@L1X (X intercept of Line1)

[Auto Analysis]
Line1: Vertical line for Y1 at Idrain=Id@Vth

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)

[List Display]
Gate voltage Vgate
Drain voltage Vdrain
Drain current Idrain

[Test Output: X-Y Graph]
X axis: Time TimeList (LOG)
Y1 axis: Threshold voltage VthList (LINEAR)

[Test Output: List Display]
Time TimeList
Threshold voltage VthList

[Test Setup Details]
See NandFlash3 IV-Write-IV.
6.19 NandFlash3 Vth(ErasingTimeDependence): NAND flash memory cell erasing time dependence test (A.03.10)

[Supported Analyzer]
B1500A

[Description]
Performs the erasing time dependence test of the NAND-type flash memory cell, and plots the accumulated erasing time (accumulated pulse width) vs threshold voltage characteristics. The test is performed as follows.

1. Applies the erase pulse with pulse width specified by the first element of the PulseWidth parameter.
2. Measures the Id-Vg characteristics, and extracts the threshold voltage (Vth).
3. Applies the erase pulse with pulse width specified by the next element of the PulseWidth parameter.
4. Measures the Id-Vg characteristics, and extracts the threshold voltage (Vth).
5. Repeats 3 and 4 until that the pulse width becomes StopPulseWidth.

[Device Under Test]
NAND-type flash memory cell

[Required Modules and Accessories]
Keysight B1525A SPGU 1 unit
Selector (16440A/16445A 1 set or HRSMU/ASU 2 set)

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source terminal, constant voltage output
Psource: SPGU channel connected to Drain, Source, and Substrate via Selector
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Vd: Drain voltage
Id@Vth: Drain current to decide the Vth
IntegTime: Integration time
PulseDelay: Erase pulse delay
PulseWidth: List of erase pulse width
StopPulseWidth: Pulse width to stop testing
Verase: Erase pulse output level
LeadingTime: Pulse leading edge transition time
TrailingTime: Pulse trailing edge transition time

[Extended Test Parameters]
Vs: Source voltage
IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
BaseValue: Erase pulse base value
6 Memory

DrainMinRng: Minimum range of drain current measurement

[Measurement Parameters]
Drain current Idrain

[Analysis Function]
Vth@Ild=@L1X (X intercept of Line1)

[Auto Analysis]
Line1: Vertical line for Y1 at Idrain=Id@Vth

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)

[List Display]
Gate voltage Vgate
Drain voltage Vdrain
Drain current Idrain

[Test Output: X-Y Graph]
X axis: Accumulated erasing pulse width EraseTimeList (LOG)
Y1 axis: Threshold voltage VthList (LINEAR)

[Test Output: List Display]
Accumulated erasing pulse width EraseTimeList
Threshold voltage VthList
6.20 NandFlash3 Vth(WritingTimeDependence): NAND flash memory cell writing time dependence test (A.03.10)

[Supported Analyzer]
B1500A

[Description]
Performs the writing time dependence test of the NAND-type flash memory cell, and plots the accumulated writing time (accumulated pulse width) vs threshold voltage characteristics. The test is performed as follows.

1. Applies the write pulse with pulse width specified by the first element of the PulseWidth parameter.
2. Measures the Id-Vg characteristics, and extracts the threshold voltage (Vth).
3. Applies the write pulse with pulse width specified by the next element of the PulseWidth parameter.
4. Measures the Id-Vg characteristics, and extracts the threshold voltage (Vth).
5. Repeats 3 and 4 until that the pulse width becomes StopPulseWidth.

[Device Under Test]
NAND-type flash memory cell

[Required Modules and Accessories]
Keysight B1525A SPGU 1 unit
Selector (16440A/16445A 1 set or HRSMU/ASU 1 set)

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source terminal, constant voltage output
Pgate: SPGU channel connected to Gate terminal via Selector
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Vd: Drain voltage
Id@Vth: Drain current to decide the Vth
IntegTime: Integration time
PulseDelay: Write pulse delay
PulseWidth: List of write pulse width
StopPulseWidth: Pulse width to stop testing
Vwrite: Write pulse output level
LeadingTime: Pulse leading edge transition time
TrailingTime: Pulse trailing edge transition time

[Extended Test Parameters]
Vs: Source voltage
IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
6 Memory

BaseValue: Write pulse base value
DrainMinRng: Minimum range of drain current measurement

[Measurement Parameters]
Drain current Idrain

[Analysis Function]
Vth@Id=@L1X (X intercept of Line1)

[Auto Analysis]
Line1: Vertical line for Y1 at Idrain=Id@Vth

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)

[List Display]
Gate voltage Vgate
Drain voltage Vdrain
Drain current Idrain

[Test Output: X-Y Graph]
X axis: Accumulated writing pulse width WriteTimeList (LOG)
Y1 axis: Threshold voltage VthList (LINEAR)

[Test Output: List Display]
Accumulated writing pulse width WriteTimeList
Threshold voltage VthList
6.21 NandFlash3 WordDisturb(ErasedCell): NAND flash memory cell erase-disturb test (A.03.10)

[Supported Analyzer]
B1500A

[Description]
Performs the erase-disturb test of the NAND-type flash memory cell, and plots the accumulated stress time vs threshold voltage characteristics.

[Device Under Test]
NAND-type flash memory cell

[Required Modules and Accessories]
Keysight B1525A SPGU 1 unit
Selector (16440A/16445A 2 set or HRSMU/ASU 3 set)

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source terminal, constant voltage output
Pgate: SPGU channel connected to Gate terminal via Selector
Psource: SPGU channel connected to Drain, Source, and Substrate via Selector
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
VgStress: Stress voltage for Gate terminal
Vd: Drain voltage
Id@Vth: Drain current to decide the Vth
IntegTime: Integration time
TotalStressTime: Total accumulated stress time
CheckNoOfTimes: Number of Vth measurement operation
PulsePeriod: Erase pulse period
PulseDelay: Erase pulse delay
PulseWidth: Erase pulse width
Verase: Erase pulse output level
LeadingTime: Pulse leading edge transition time
TrailingTime: Pulse trailing edge transition time

[Extended Test Parameter]
Vs: Source voltage
IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
BaseValue: Erase pulse base value
NoOfPulse: Number of output pulses for the erase operation
DrainMinRng: Minimum range of drain current measurement
6 Memory

[Measurement Parameters]
Drain current Idrain

[Analysis Function]
Vth@Id=@L1X (X intercept of Line1)

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)

[List Display]
Gate voltage Vgate
Drain voltage Vdrain
Drain current Idrain

[Test Contents: Auto Analysis]
Line1: Vertical line for Y1 at Idrain=Id@Vth

[Test Output: X-Y Graph]
X axis: Accumulated erasing pulse width EraseTimeList (LOG)
Y1 axis: Threshold voltage VthList (LINEAR)

[Test Output: List Display]
Accumulated erasing pulse width EraseTimeList
Threshold voltage VthList
6.22 NandFlash3 WordDisturb(WrittenCell): NAND flash memory cell read-disturb test (A.03.10)

[Supported Analyzer]
B1500A

[Description]
Performs the read-disturb test of the NAND-type flash memory cell, and plots the accumulated stress time vs threshold voltage characteristics.

[Device Under Test]
NAND-type flash memory cell

[Required Modules and Accessories]
Keysight B1525A SPGU 1 unit
Selector (16440A/16445A 1 set or HRSMU/ASU 1 set)

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source terminal, constant voltage output
Pgate: SPGU channel connected to Gate terminal via Selector
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
VgStress: Stress voltage for Gate terminal
Vd: Drain voltage
Id@Vth: Drain current to decide the Vth
IntegTime: Integration time
TotalStressTime: Total accumulated stress time
CheckNoOfTimes: Number of Vth measurement operation
PulsePeriod: Write pulse period
PulseDelay: Write pulse delay
PulseWidth: Total accumulated pulse width
Vwrite: Write pulse output level
LeadingTime: Pulse leading edge transition time
TrailingTime: Pulse trailing edge transition time

[Extended Test Parameters]
Vs: Source voltage
IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
BaseValue: Write pulse base value
NoOfPulse: Number of output pulses for the erase operation
DrainMinRng: Minimum range of drain current measurement
6 Memory

[Measurement Parameters]
Drain current Idrain

[Analysis Function]
Vth@Id=@L1X (X intercept of Line1)

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)

[List Display]
Gate voltage Vgate
Drain voltage Vdrain
Drain current Idrain

[Test Contents: Auto Analysis]
Line1: Vertical line for Y1 at Idrain=Id@Vth

[Test Output: X-Y Graph]
X axis: Accumulated writing pulse width WriteTimeList (LOG)
Y1 axis: Threshold voltage Vth (LINEAR)

[Test Output: List Display]
Accumulated writing pulse width WriteTimeList
Threshold voltage VthList
6.23 NorFlash Endurance: NOR flash memory cell endurance test (A.03.10)

[Supported Analyzer]
B1500A

[Description]
Performs the endurance test for the NOR type flash memory cell and plots the number of write/erase operation
vs threshold voltage characteristics.

[Device Under Test]
NOR-type flash memory cell

[Required Modules and Accessories]
Keysight B1525A SPGU 2 units
Selector (16440A/16445A 2 sets or HRSMU/ASU 3 sets)

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source terminal, constant voltage output
Subs: SMU connected to Substrate terminal, constant voltage output
Pgate: SPGU channel connected to Gate terminal via Selector
Pdrain: SPGU channel connected to Drain terminal via Selector
Psource: SPGU channel connected to Source terminal via Selector
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Vd: Drain voltage
Id@Vth: Drain current to decide the Vth
IntegTime: Integration time
TotalWriteAndEraseCycles: Total number of write/erase operation
WritePeriod: Write pulse period
WriteGateDelay: Gate write pulse delay
WriteGateWidth: Gate write pulse width
WriteGateVwrite: Gate write pulse output level
WriteGateLeadingTime: Gate write pulse leading edge transition time
WriteGateTrailingTime: Gate write pulse trailing edge transition time
WriteDrainDelay: Drain write pulse delay
WriteDrainWidth: Drain write pulse width
WriteDrainVwrite: Drain write pulse output level
WriteDrainLeadingTime: Drain write pulse leading edge transition time
WriteDrainTrailingTime: Drain write pulse trailing edge transition time
ErasePeriod: Erase pulse period
EraseGateDelay: Gate erase pulse delay
EraseGateWidth: Gate erase pulse width
EraseGateVerase: Gate erase pulse output level
EraseGateLeadingTime: Gate erase pulse leading edge transition time
6 Memory

EraseGateTrailingTime: Gate erase pulse trailing edge transition time
EraseSourceDelay: Source erase pulse delay
EraseSourceWidth: Source erase pulse width
EraseSourceVerase: Source erase pulse output level
EraseSourceLeadingTime: Source erase pulse leading edge transition time
EraseSourceTrailingTime: Source erase pulse trailing edge transition time

MeasTiming: Timing to perform Vth measurement

[Extended Test Parameters]
Vs: Source voltage
Vsub: Substrate voltage
IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
BaseValue: Pulse base value
DrainMinRng: Minimum range of drain current measurement

[Measurement Parameters]
Drain current Idrain

[Analysis Function]
Vth@Id=Id@L1X (X intercept of Line1)

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LOG)

[List Display]
Gate voltage Vgate
Drain current Idrain

[Test Contents: Auto Analysis]
Line1: Vertical line for Y1 at Idrain=Id@Vth

[Test Output: X-Y Graph]
X axis: Number of write/erase cycles CycleList (LOG)
Y1 axis: Threshold voltage after write VthWrittenList (LINEAR)
Y2 axis: Threshold voltage after erase VthErasedList (LINEAR)

[Test Output: List Display]
Number of write/erase cycles CycleList
Threshold voltage after write VthWrittenList
Threshold voltage after erase VthErasedList

[Test Setup Details]
See NorFlash IV-Write-IV and NorFlash IV-Erase-IV.
TotalWriteAndEraseCycles should be 10, 100, 1000, 10000, 100000, or 1000000.
6.24 NorFlash IV-Erase-IV: NOR flash memory cell Id-Vg, Erase, Id-Vg (A.03.10)

[Supported Analyzer]
B1500A

[Description]
Measures the Id-Vg characteristics of NOR-type flash memory cell, performs the data erase operation, measures the Id-Vg characteristics again, and plots the both Id-Vg characteristics on a graph.
Before the Id-Vg measurements, the initial pulse will be applied to the device under test.

[Device Under Test]
NOR-type flash memory cell

[Required Modules and Accessories]
Keysight B1525A SPGU 1 unit
Selector (16440A/16445A 1 set or HRSMU/ASU 2 sets)

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source terminal, constant voltage output
Subs: SMU connected to Substrate terminal, constant voltage output
Pgate: SPGU channel connected to Gate terminal via Selector
Psource: SPGU channel connected to Source terminal via Selector
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Vd: Drain voltage
Id@Vth: Drain current to decide the Vth
IntegTime: Integration time
PulsePeriod: Erase pulse period
GateDelay: Gate erase pulse delay
GateWidth: Gate erase pulse width
GateVerase: Gate erase pulse output level
GateLeadingTime: Gate pulse leading edge transition time
GateTrailingTime: Gate pulse trailing edge transition time
SourceDelay: Source erase pulse delay
SourceWidth: Source erase pulse width
SourceVerase: Source erase pulse output level
SourceLeadingTime: Source pulse leading edge transition time
SourceTrailingTime: Source pulse trailing edge transition time

[Extended Test Parameters]
Vs: Source voltage
Vsubs: Substrate voltage
IgLimit: Gate current compliance
6 Memory

HoldTime: Hold time
DelayTime: Delay time
BaseValue: Pulse base value
NoOfPulse: Number of output pulses for the erase operation
DrainMinRng: Minimum range of drain current measurement

[Measurement Parameters]
Drain current Idrain

[User Function]
IdrainPerWg = Idrain/Wg

[Analysis Function]
VthAfter = @L1X (X intercept of Line1)

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)

[List Display]
Gate voltage Vgate
Drain voltage Vdrain
Drain current Idrain

[Test Contents: Auto Analysis]
Line1: Vertical line for Y1 at Idrain=Id@Vth

[Test Output: X-Y Graph]
X axis: Gate voltage VgateList (LINEAR)
Y1 axis: Drain current before Erase operation IdInitialList (LOG)
Y2 axis: Drain current after Erase operation IdErasedList (LOG)

[Test Output: List Display]
Gate voltage VgateList
Drain current before Erase operation IdInitialList
Drain current after Erase operation IdErasedList

[Test Output: Parameters]
Threshold voltage before Erase operation VthInitial
Threshold voltage after Erase operation VthErased
6.25 NorFlash IV-Write-IV: NOR flash memory cell Id-Vg, Write, Id-Vg
(A.03.10)

[Supported Analyzer]
B1500A

[Description]
Measures the Id-Vg characteristics of NOR-type flash memory cell, performs the data write operation,
measures the Id-Vg characteristics again, and plots the both Id-Vg characteristics on a graph.
Before the Id-Vg measurements, the initial pulse will be applied to the device under test.

[Device Under Test]
NOR-type flash memory cell

[Required Modules and Accessories]
Keysight B1525A SPGU 1 unit
Selector (16440A/16445A 1 set or HRSMU/ASU 2 sets)

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source terminal, constant voltage output
Subs: SMU connected to Substrater terminal, constant voltage output
Pgare: SPGU channel connected to Gate terminal via Selector
Pdrain: SPGU channel connected to Drain terminal via Selector
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Vd: Drain voltage
Id@Vth: Drain current to decide the Vth
IntegTime: Integration time
PulsePeriod: Write pulse period
GateDelay: Gate write pulse delay
GateWidth: Gate write pulse width
GateVwrite: Gate write pulse output level
GateLeadingTime: Gate pulse leading edge transition time
GateTrailingTime: Gate pulse trailing edge transition time
DrainDelay: Drain write pulse delay
DrainWidth: Drain write pulse width
DrainVwrite: Drain write pulse output level
DrainLeadingTime: Drain pulse leading edge transition time
DrainTrailingTime: Drain pulse trailing edge transition time

[Extended Test Parameters]
Vs: Source voltage
Vsubs: Substrate voltage
IgLimit: Gate current compliance
6 Memory

HoldTime: Hold time
DelayTime: Delay time
BaseValue: Pulse base value
NoOfPulse: Number of output pulses for the write operation
DrainMinRng: Minimum range of drain current measurement

[Measurement Parameters]
Drain current Idrain

[User Function]
IdrainPerWg=Idrain/Wg

[Analysis Function]
VthAfter=@L1X (X intercept of Line1)

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)

[List Display]
Gate voltage Vgate
Drain voltage Vdrain
Drain current Idrain

[Test Contents: Auto Analysis]
Line1: Vertical line for Y1 at Idrain=Id@Vth

[Test Output: X-Y Graph]
X axis: Gate voltage VgateList (LINEAR)
Y1 axis: Drain current before Write operation IdInitialList (LOG)
Y2 axis: Drain current after Write operation IdWrittenList (LOG)

[Test Output: List Display]
Gate voltage VgateList
Drain current before Write operation IdInitialList
Drain current after Write operation IdWrittenList

[Test Output: Parameters]
Threshold voltage before Write operation VthInitial
Threshold voltage after Write operation VthWritten
6.26 NorFlash Retention(ErasedCell): NOR flash memory cell Data retention test after Erase (A.03.10)

[Supported Analyzer]
B1500A

[Description]
Performs the data retention test for the NOR type flash memory cell after the erase operation, and plots the accumulated time vs threshold voltage characteristics.

[Device Under Test]
NOR-type flash memory cell

[Required Modules and Accessories]
Keysight B1525A SPGU 1 unit
Selector (16440A/16445A 1 set or HRSMU/ASU 2 sets)

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source terminal, constant voltage output
Subs: SMU connected to Substrate terminal, constant voltage output
Pgate: SPGU channel connected to Gate terminal via Selector
Psource: SPGU channel connected to Source terminal via Selector
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Vd: Drain voltage
Id@Vth: Drain current to decide the Vth
IntegTime: Integration time
PulsePeriod: Erase pulse period
GateDelay: Gate erase pulse delay
GateWidth: Gate erase pulse width
GateVerase: Gate erase pulse output level
GateLeadingTime: Gate pulse leading edge transition time
GateTrailingTime: Gate pulse trailing edge transition time
SourceDelay: Source erase pulse delay
SourceWidth: Source erase pulse width
SourceVerase: Source erase pulse output level
SourceLeadingTime: Source pulse leading edge transition time
SourceTrailingTime: Source pulse trailing edge transition time
TotalRetentionTime: Time to continue the test. 10 to 10000 seconds.
MeasTiming: Timing to perform Vth measurement

[Extended Test Parameters]
Vs: Source voltage
Vsubs: Substrate voltage
6 Memory

IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
BaseValue: Pulse base value
NoOfPulse: Number of output pulses for the erase operation
DrainMinRng: Minimum range of drain current measurement

[Measurement Parameters]
Drain current I\textsubscript{drain}

[User Function]
I\textsubscript{drainPerWg}=I\textsubscript{drain}/Wg

[Analysis Function]
V\textsubscript{th}@I\textsubscript{d}=@L1X (X intercept of Line1)

[X-Y Plot]
X axis: Gate voltage V\textsubscript{gate} (LINEAR)
Y1 axis: Drain current I\textsubscript{drain} (LINEAR)
Y2 axis: Drain current I\textsubscript{drain} (LOG)

[List Display]
Gate voltage V\textsubscript{gate}
Drain voltage V\textsubscript{drain}
Drain current I\textsubscript{drain}

[Test Contents: Auto Analysis]
Line1: Vertical line for Y1 at I\textsubscript{drain}=I\textsubscript{d}@V\textsubscript{th}

[Test Output: X-Y Graph]
X axis: Time TimeList (LOG)
Y1 axis: Threshold voltage V\textsubscript{thList} (LINEAR)

[Test Output: List Display]
Time TimeList
Threshold voltage V\textsubscript{thList}

[Test Setup Details]
See NorFlash IV-Erase-IV.
6.27 NorFlash Retention(WrittenCell): NOR flash memory cell Data retention test after Write (A.03.10)

[Supported Analyzer]
B1500A

[Description]
Performs the data retention test for the NOR type flash memory cell after the write operation, and plots the accumulated time vs threshold voltage characteristics.

[Device Under Test]
NOR-type flash memory cell

[Required Modules and Accessories]
Keysight B1525A SPGU 1 unit
Selector (16440A/16445A 1 set or HRSMU/ASU 2 set)

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source terminal, constant voltage output
Subs: SMU connected to Substrate terminal, constant voltage output
Pgate: SPGU channel connected to Gate terminal via Selector
Pdrain: SPGU channel connected to Drain terminal via Selector
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Vd: Drain voltage
Id@Vth: Drain current to decide the Vth
IntegTime: Integration time
PulsePeriod: Write pulse period
GateDelay: Gate write pulse delay
GateWidth: Gate write pulse width
GateVwrite: Gate write pulse output level
GateLeadingTime: Gate pulse leading edge transition time
GateTrailingTime: Gate pulse trailing edge transition time
DrainDelay: Drain write pulse delay
DrainWidth: Drain write pulse width
DrainVwrite: Drain write pulse output level
DrainLeadingTime: Drain pulse leading edge transition time
DrainTrailingTime: Drain pulse trailing edge transition time
TotalRetentionTime: Time to continue the test. 10 to 10000 seconds.
MeasTiming: Timing to perform Vth measurement

[Extended Test Parameters]
Vs: Source voltage
Vsubs: Substrate voltage
6 Memory

IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
BaseValue: Pulse base value
NoOfPulse: Number of output pulses for the write operation
DrainMinRng: Minimum range of drain current measurement

[Measurement Parameters]
  Drain current Idrain

[User Function]
  IdrainPerWg=Idrain/Wg

[Analysis Function]
  Vth@Id=@L1X (X intercept of Line1)

[X-Y Plot]
  X axis: Gate voltage Vgate (LINEAR)
  Y1 axis: Drain current Idrain (LINEAR)
  Y2 axis: Drain current Idrain (LOG)

[List Display]
  Gate voltage Vgate
  Drain voltage Vdrain
  Drain current Idrain

[Test Contents: Auto Analysis]
  Line1: Vertical line for Y1 at Idrain=Id@Vth

[Test Output: X-Y Graph]
  X axis: Time TimeList (LOG)
  Y1 axis: Threshold voltage VthList (LINEAR)

[Test Output: List Display]
  Time TimeList
  Threshold voltage VthList

[Test Setup Details]
  See NorFlash IV-Write-IV.
6.28 NorFlash Vth(ErasingTimeDependence): NOR flash memory cell erasing
time dependence test (A.03.10)

[Supported Analyzer]
B1500A

[Description]
Performs the erasing time dependence test of the NOR-type flash memory cell, and plots the accumulated erasing time (accumulated pulse width) vs threshold voltage characteristics. The test is performed as follows.

1. Applies the erase pulse with pulse width specified by the first element of the SourceWidth parameter.
2. Measures the Id-Vg characteristics, and extracts the threshold voltage (Vth).
3. Applies the erase pulse with pulse width specified by the next element of the SourceWidth parameter.
4. Measures the Id-Vg characteristics, and extracts the threshold voltage (Vth).
5. Repeats 3 and 4 until that the pulse width becomes StopPulseWidth.

[Device Under Test]
NOR-type flash memory cell

[Required Modules and Accessories]
Keysight B1525A SPGU 1 unit
Selector (16440A/16445A 1 set or HRSMU/ASU 2 set)

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source terminal, constant voltage output
Subs: SMU connected to Substrate terminal, constant voltage output
Pgate: SPGU channel connected to Gate terminal via Selector
Psource: SPGU channel connected to Source terminal via Selector
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Vd: Drain voltage
Id@Vth: Drain current to decide the Vth
IntegTime: Integration time
GateWidthOffset: Gate erase pulse width offset
GateVerase: Gate erase pulse output level
GateLeadingTime: Gate pulse leading edge transition time
GateTrailingTime: Gate pulse trailing edge transition time
SourceDelay: Source erase pulse delay
SourceWidth: List of source erase pulse width
StopPulseWidth: Source erase pulse width to stop testing
SourceVerase: Source erase pulse output level
SourceLeadingTime: Source pulse leading edge transition time
SourceTrailingTime: Source pulse trailing edge transition time
6 Memory

[Extended Test Parameters]
Vs: Source voltage
Vsubs: Substrate voltage
IgL: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
BaseValue: Pulse base value
DrainMinRng: Minimum range of drain current measurement

[Measurement Parameters]
Drain current Idrain

[Analysis Function]
Vth@Id=0 (X intercept of Line1)

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)

[List Display]
Gate voltage Vgate
Drain voltage Vdrain
Drain current Idrain

[Test Contents: Auto Analysis]
Line1: Vertical line for Y1 at Idrain=Id@Vth

[Test Output: X-Y Graph]
X axis: Accumulated erasing pulse width EraseTimeList (LOG)
Y1 axis: Threshold voltage VthList (LINEAR)

[Test Output: List Display]
Accumulated erasing pulse width EraseTimeList
Threshold voltage VthList
6.29 NorFlash Vth(WritingTimeDependence): NOR flash memory cell writing time dependence test (A.03.10)

[Supported Analyzer]
B1500A

[Description]
Performs the writing time dependence test of the NOR-type flash memory cell, and plots the accumulated writing time (accumulated pulse width) vs threshold voltage characteristics. The test is performed as follows.

1. Applies the write pulse with pulse width specified by the first element of the DrainWidth parameter.
2. Measures the Id-Vg characteristics, and extracts the threshold voltage (Vth).
3. Applies the write pulse with pulse width specified by the next element of the DrainWidth parameter.
4. Measures the Id-Vg characteristics, and extracts the threshold voltage (Vth).
5. Repeats 3 and 4 until that the pulse width becomes StopPulseWidth.

[Device Under Test]
NOR-type flash memory cell

[Required Modules and Accessories]
Keysight B1525A SPGU 1 unit
Selector (16440A/16445A 1 set or HRSMU/ASU 2 set)

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source terminal, constant voltage output
Subs: SMU connected to Substrate terminal, constant voltage output
Pgate: SPGU channel connected to Gate terminal via Selector
Pdrain: SPGU channel connected to Drain terminal via Selector
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Vd: Drain voltage
Id@Vth: Drain current to decide the Vth
IntegTime: Integration time
GateWidthOffset: Gate write pulse width offset
GateVwrite: Gate write pulse output level
GateLeadingTime: Gate pulse leading edge transition time
GateTrailingTime: Gate pulse trailing edge transition time
DrainDelay: Drain write pulse delay
DrainWidth: List of drain write pulse width
StopPulseWidth: Drain write pulse width to stop testing
DrainVwrite: Drain write pulse output level
DrainLeadingTime: Drain pulse leading edge transition time
DrainTrailingTime: Drain pulse trailing edge transition time
6 Memory

[Extended Test Parameters]
Vs: Source voltage
Vsubs: Substrate voltage
IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
BaseValue: Pulse base value
DrainMinRng: Minimum range of drain current measurement

[Measurement Parameters]
Drain current Idrain

[Analysis Function]
Vth@Id=⇒L1X (X intercept of Line1)

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)

[List Display]
Gate voltage Vgate
Drain voltage Vdrain
Drain current Idrain

[Test Contents: Auto Analysis]
Line1: Vertical line for Y1 at Idrain=Id@Vth

[Test Output: X-Y Graph]
X axis: Accumulated writing pulse width WriteTimeList (LOG)
Y1 axis: Threshold voltage VthList (LINEAR)

[Test Output: List Display]
Accumulated writing pulse width WriteTimeList
Threshold voltage VthList
6.30 NorFlash WordDisturb(ErasedCell): NOR flash memory cell Word disturb test after Erase (A.03.10)

[Supported Analyzer]
B1500A

[Description]
Performs the word disturb test of the NOR-type flash memory cell after the erase operation, and plots the accumulated stress time vs threshold voltage characteristics.

[Device Under Test]
NOR-type flash memory cell

[Required Modules and Accessories]
Keysight B1525A SPGU 1 unit
Selector (16440A/16445A 1 set or HRSMU/ASU 2 set)

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source terminal, constant voltage output
Subs: SMU connected to Substrate terminal, constant voltage output
Pgate: SPGU channel connected to Gate terminal via Selector
Psource: SPGU channel connected to Source terminal via Selector
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
VgStress: Stress voltage for Gate terminal
Vd: Drain voltage
Id@Vth: Drain current to decide the Vth
IntegTime: Integration time
PulsePeriod: Erase pulse period
GateDelay: Gate erase pulse delay
GateWidth: Gate erase pulse width
GateVerase: Gate erase pulse output level
GateLeadingTime: Gate pulse leading edge transition time
GateTrailingTime: Gate pulse trailing edge transition time
SourceDelay: Source erase pulse delay
SourceWidth: Source erase pulse width
SourceVerase: Source erase pulse output level
SourceLeadingTime: Source pulse leading edge transition time
SourceTrailingTime: Source pulse trailing edge transition time
TotalStressTime: Total accumulated stress time
CheckNoOfTimes: Number of Vth measurement operation

[Extended Test Parameters]
Vs: Source voltage
6 Memory

Vsubs: Substrate voltage
IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
BaseValue: Pulse base value
NoOfPulse: Number of output pulses for the erase operation
DrainMinRng: Minimum range of drain current measurement

[Measurement Parameters]
Drain current Idrain

[Analysis Function]
Vth@Id=@L1X (X intercept of Line1)

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)

[List Display]
Gate voltage Vgate
Drain voltage Vdrain
Drain current Idrain

[Test Contents: Auto Analysis]
Line1: Vertical line for Y1 at Idrain=Id@Vth

[Test Output: X-Y Graph]
X axis: Accumulated erasing pulse width EraseTimeList (LOG)
Y1 axis: Threshold voltage VthList (LINEAR)

[Test Output: List Display]
Accumulated erasing pulse width EraseTimeList
Threshold voltage VthList
6.31 *NorFlash WordDisturb(WrittenCell): NOR flash memory cell Word disturb test after Write (A.03.10)*

[Supported Analyzer]
B1500A

[Description]
Performs the word disturb test of the NOR-type flash memory cell after the write operation, and plots the accumulated stress time vs threshold voltage characteristics.

[Device Under Test]
NOR-type flash memory cell

[Required Modules and Accessories]
Keysight B1525A SPGU 1 unit
Selector (16440A/16445A 1 set or HRSMU/ASU 2 set)

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source terminal, constant voltage output
Subs: SMU connected to Substrate terminal, constant voltage output
Pgate: SPGU channel connected to Gate terminal via Selector
Pdrain: SPGU channel connected to Drain terminal via Selector
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
VgStress: Stress voltage for Gate terminal
Vd: Drain voltage
Id@Vth: Drain current to decide the Vth
IntegTime: Integration time
PulsePeriod: Write pulse period
GateDelay: Gate write pulse delay
GateWidth: Gate write pulse width
GateVwrite: Gate write pulse output level
GateLeadingTime: Gate pulse leading edge transition time
GateTrailingTime: Gate pulse trailing edge transition time
DrainDelay: Drain write pulse delay
DrainWidth: Drain write pulse width
DrainVwrite: Drain write pulse output level
DrainLeadingTime: Drain pulse leading edge transition time
DrainTrailingTime: Drain pulse trailing edge transition time
TotalStressTime: Total accumulated stress time
CheckNoOfTimes: Number of Vth measurement operation

[Extended Test Parameters]
Vs: Source voltage
6 Memory

Vsubs: Substrate voltage
IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
BaseValue: Pulse base value
NoOfPulse: Number of output pulses for the write operation
DrainMinRng: Minimum range of drain current measurement

[Measurement Parameters]
Drain current Idrain

[Analysis Function]
Vth@Id=1@L1X (X intercept of Line1)

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)

[List Display]
Gate voltage Vgate
Drain voltage Vdrain
Drain current Idrain

[Test Contents: Auto Analysis]
Line1: Vertical line for Y1 at Idrain=Id@Vth

[Test Output: X-Y Graph]
X axis: Accumulated writing pulse width WriteTimeList (LOG)
Y1 axis: Threshold voltage Vth (LINEAR)

[Test Output: List Display]
Accumulated writing pulse width WriteTimeList
Threshold voltage VthList
6.32 NorFlash DataDisturb(ErasedCell): NOR flash memory cell Data disturb test after Erase (A.03.10)

[Supported Analyzer]
B1500A

[Description]
Performs the data disturb test of the NOR-type flash memory cell after the erase operation, and plots the accumulated stress time vs threshold voltage characteristics.

[Device Under Test]
NOR-type flash memory cell

[Required Modules and Accessories]
Keysight B1525A SPGU 2 unit
Selector (16440A/16445A 2 set or HRSMU/ASU 3 set)

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source terminal, constant voltage output
Subs: SMU connected to Substrate terminal, constant voltage output
Pgate: SPGU channel connected to Gate terminal via Selector
Psource: SPGU channel connected to Source terminal via Selector
Pdrain: SPGU channel connected to Drain terminal via Selector
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
VdStress: Stress voltage for Drain terminal
Vd: Drain voltage
Id@Vth: Drain current to decide the Vth
IntegTime: Integration time
PulsePeriod: Erase pulse period
GateDelay: Gate erase pulse delay
GateWidth: Gate erase pulse width
GateVerase: Gate erase pulse output level
GateLeadingTime: Gate pulse leading edge transition time
GateTrailingTime: Gate pulse trailing edge transition time
SourceDelay: Source erase pulse delay
SourceWidth: Source erase pulse width
SourceVerase: Source erase pulse output level
SourceLeadingTime: Source pulse leading edge transition time
SourceTrailingTime: Source pulse trailing edge transition time
DrainDelay: Drain stress pulse delay
DrainLeadingTime: Drain pulse leading edge transition time
DrainTrailingTime: Drain pulse trailing edge transition time
TotalStressTime: Total accumulated stress time
6 Memory

CheckNoOfTimes: Number of Vth measurement operation

[Extended Test Parameters]
Vs: Source voltage
Vsubs: Substrate voltage
IgLmit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
BaseValue: Pulse base value
NoOfPulse: Number of output pulses for the erase operation
DrainMinRng: Minimum range of drain current measurement

[Measurement Parameters]
Drain current Idrain

[Analysis Function]
Vth@Id= @L1X (X intercept of Line1)

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)

[List Display]
Gate voltage Vgate
Drain voltage Vdrain
Drain current Idrain

[Test Contents: Auto Analysis]
Line1: Vertical line for Y1 at Idrain=Id@V

[Test Output: X-Y Graph]
X axis: Accumulated erasing pulse width EraseTimeList (LOG)
Y1 axis: Threshold voltage VthList (LINEAR)

[Test Output: List Display]
Accumulated erasing pulse width EraseTimeList
Threshold voltage VthList
6.33 NorFlash DataDisturb(WrittenCell): NOR flash memory cell Data disturb test after Write (A.03.10)

[Supported Analyzer]
B1500A

[Description]
Performs the data disturb test of the NOR-type flash memory cell after the write operation, and plots the accumulated stress time vs threshold voltage characteristics.

[Device Under Test]
NOR-type flash memory cell

[Required Modules and Accessories]
Keysight B1525A SPGU 1 unit
Selector (16440A/16445A 1 set or HRSMU/ASU 2 set)

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source terminal, constant voltage output
Subs: SMU connected to Substrate terminal, constant voltage output
Pgate: SPGU channel connected to Gate terminal via Selector
Pdrain: SPGU channel connected to Drain terminal via Selector
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
VdStress: Stress voltage for Drain terminal
Vd: Drain voltage
Id@Vth: Drain current to decide the Vth
IntegTime: Integration time
PulsePeriod: Write pulse period
GateDelay: Gate write pulse delay
GateWidth: Gate write pulse width
GateVwrite: Gate write pulse output level
GateLeadingTime: Gate pulse leading edge transition time
GateTrailingTime: Gate pulse trailing edge transition time
DrainDelay: Drain write pulse delay
DrainWidth: Drain write pulse width
DrainVwrite: Drain write pulse output level
DrainLeadingTime: Drain pulse leading edge transition time
DrainTrailingTime: Drain pulse trailing edge transition time
TotalStressTime: Total accumulated stress time
CheckNoOfTimes: Number of Vth measurement operation

[Extended Test Parameters]
Vs: Source voltage
6 Memory

Vsubs: Substrate voltage
IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
BaseValue: Pulse base value
NoOfPulse: Number of output pulses for the write operation
DrainMinRng: Minimum range of drain current measurement

[Measurement Parameters]
Drain current Idrain

[Analysis Function]
Vth@Id=@L1X (X intercept of Line1)

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)

[List Display]
Gate voltage Vgate
Drain voltage Vdrain
Drain current Idrain

[Test Contents: Auto Analysis]
Line1: Vertical line for Y1 at Idrain=Id@Vth

[Test Output: X-Y Graph]
X axis: Accumulated writing pulse width WriteTimeList (LOG)
Y1 axis: Threshold voltage Vth (LINEAR)

[Test Output: List Display]
Accumulated writing pulse width WriteTimeList
Threshold voltage VthList
7 MixedSignal
1. BJT Varactor CV Mismatch:  BJT Varactor capacitance CV characteristics mismatch (A.01.11)
2. Diff-R Mismatch:  Diffusion resistor R-I characteristics mismatch, Kelvin conneciton (A.01.11)
3. Diode IV Fwd Mismatch:  Diode forward bias characteristics mismatch (A.01.20)
4. Diode IV Rev Mismatch:  Diode reverse bias characteristics mismatch (A.01.20)
5. G-Plot ConstVce Mismatch:  Gummel characteristics mismatch, Vce=Const (A.01.20)
6. G-Plot ConstVce Mismatch[3]:  Gummel characteristics mismatch, Vce=Const, 3-terminal (A.01.20)
7. G-Plot Vbc=0V Mismatch:  Gummel characteristics mismatch, Vbc=0 V (A.01.20)
8. G-Plot Vbc=0V Mismatch[3]:  Gummel characteristics mismatch, Vbc=0, 3-terminal (A.01.20)
9. Ic-Vc Ib Mismatch:  Ic-Vce characteristics mismatch, Ib sweep (A.01.20)
10. Ic-Vc Ib Mismatch[3]:  Ic-Vce characteristics mismatch, Ib sweep, 3-terminal (A.01.20)
11. Ic-Vc Vb Mismatch:  Ic-Vce characteristics mismatch, Vb sweep (A.01.20)
12. Ic-Vc Vb Mismatch[3]:  Ic-Vce characteristics mismatch, Vb sweep, 3-terminal (A.01.20)
13. Id-Vd Mismatch:  Id-Vd characteristics mismatch (A.01.20)
14. Id-Vd Mismatch[3]:  Id-Vd characteristics mismatch, 3-terminal (A.01.20)
15. Id-Vg Mismatch:  Id-Vg characteristics mismatch (A.01.20)
16. Id-Vg Mismatch[3]:  Id-Vg characteristics mismatch, 3-terminal (A.01.20)
17. MIM CV Mismatch:  MIM capacitor C-V characteristics mismatch (A.01.11)
18. MOS Varactor CV Mismatch:  MOS Varactor capacitance CV characteristics mismatch (A.01.11)
19. Poly-R Mismatch:  Resistor R-I characteristics mismatch, Kelvin connection (A.01.11)
7.1 BJT Varactor CV Mismatch: BJT Varactor capacitance CV characteristics mismatch (A.01.11)

[Supported Analyzer]
B1500A

[Description]
Measures the BJT varactor capacitance (C-Vce characteristics) of device A, and measures the C-Vce characteristics of device B. After that, calculates the differences between capacitance values by using the following formula, and plots the results.

\[
\text{DeltaCp} = \frac{(C_{pBList} - C_{pAList})}{C_{pAList}} \times 100 \quad \text{for parallel capacitance}
\]
\[
\text{DeltaCs} = \frac{(C_{sBList} - C_{sAList})}{C_{sAList}} \times 100 \quad \text{for series capacitance}
\]

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
Bipolar junction transistor, 4 terminals, 2 ea.
Connect Base to the CMU Low, Collector to the CMU High, and the other terminals to the GNDU.

[Device Parameters]
Polarity: NPN (CMU forces the specified value) or PNP (CMU forces the negative specified value).
Lb: Base length
Wb: Base width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
FREQ: Measurement frequency
OscLevel: Measurement signal level
Collector: CMU connected between Collector and Base (CV sweep measurement)
VcbStart: DC bias start voltage
VcbStop: DC bias stop voltage
VcbStep: DC bias step voltage

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Parallel capacitance Cp
Conductance G

[User Function]
To specify the device, A or B is added to the actual variable names.
MixedSignal

\[ \pi = 3.141592653589 \]
\[ Dval = Gval/(2*\pi*FREQ*Cpval) \]
\[ Rpval = 1/Gval \]
\[ Csval = (1+Dval^2)*Cpval \]
\[ Xval = -1/(2*\pi*FREQ*Csval) \]
\[ Rsval = Dval*abs(Xval) \]
\[ Zval = \sqrt{Rsval^2+Xval^2} \]
\[ Thetaval = \text{atan}(Xval/Rsval) \]
\[ Vceval = Vcollector \]

[X-Y Graph]
To specify the device, A or B is added to the actual variable names.
X axis: Collector-Emitter voltage Vceval (LINEAR)
Y1 axis: Collector capacitance (parallel capacitance) Cpval (LINEAR)
Y2 axis: Conductance Gval (LINEAR)

[List Display]
To specify the device, A or B is added to the actual variable names.
Collector-Emitter voltage Vceval
Parallel capacitance Cpval
Conductance Gval
Series capacitance Csval
Series resistance Rsval
Parallel resistance Rpval
Dissipation factor Dval
Reactance Xval
Impedance Zval
Phase Thetaval

[Test Output: X-Y Graph]
X axis: Collector-Emitter voltage VceList (LINEAR)
Y1 axis: Collector capacitance (parallel capacitance) CpAList (LINEAR)
Y2 axis: Collector capacitance (parallel capacitance) CpBList (LINEAR)
Y3 axis: Differences between Cp DeltaCp (LINEAR)
7.2 **Diff-R Mismatch: Diffusion resistor R-I characteristics mismatch, Kelvin connection (A.01.11)**

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the resistance vs input current characteristics of diffusion resistors, and plots the differences between the devices.

[Device Under Test]
Resistor, 2 terminals, 2 ea.
with substrate

[Device Parameters]
Polarity: Ntype (SMUs force the specified value) or Ptype (SMUs force the negative specified value).
L: Resistor length
W: Resistor width
Temp: Temperature

[Test Parameters]
IntegTime: Integration Time
Port1: SMU connected to device A high terminal, primary sweep current output
Port2: SMU connected to device B high terminal, synchronous sweep current output
I1Start: Port1/Port2 sweep start current
I1Stop: Port1/Port2 sweep stop current
I1Step: Port1/Port2 sweep step current
Port3: SMU connected to device A/B low terminal, constant voltage output
Subs: SMU connected to Substrate, constant voltage output
VM1: SMU connected to device A high terminal, constant current output
VM2: SMU connected to device A low terminal, constant current output
VM3: SMU connected to device B high terminal, constant current output
VM4: SMU connected to device B low terminal, constant current output

[Extended Test Parameters]
IM1: VM1 output current
IM2: VM2 output current
IM3: VM3 output current
IM4: VM4 output current
V3: Port3 output voltage
Vsubs: Substrate voltage
V1Limit: Port1 voltage compliance
VM1Limit: VM1 voltage compliance
I3Limit: Port3 current compliance
IsubsLimit: Substrate current compliance
HoldTime: Hold time
DelayTime: Deley time

[Measurement Parameters]
Device A input current Iport1
Device B input current Iport2
Device A terminal voltage Vvm1, Vvm2
Device B terminal voltage Vvm3, Vvm4
[User Function]
DeltaV_A = Vvm1-Vvm2
DeltaV_B = Vvm3-Vvm4
R_A = DeltaV_A / Iport1
R_B = DeltaV_B / Iport2
Rsheet_A = R_A / (W/L)
Rsheet_B = R_B / (W/L)
Delta_R = (R_A - R_B) / R_A * 100

[X-Y Plot]
X axis: Device input current Iport1 (LINEAR)
Y1 axis: Device A voltage between terminals DeltaV_A (LINEAR)
Y2 axis: Device B voltage between terminals DeltaV_B (LINEAR)
Y3 axis: Device A resistance R_A (LINEAR)
Y4 axis: Device A resistance R_B (LINEAR)
Y5 axis: Rate-of-change between R_A and R_B Delta_R (LINEAR)
7.3 **Diode IV Fwd Mismatch: Diode forward bias characteristics mismatch (A.01.20)**

[Supported Analyzer]

[Description]
Measures the forward bias anode voltage vs anode current characteristics, and plots the differences between the devices.

[Device Under Test]
Diode, 2 ea.

[Device Parameters]
L: Junction length
W: Junction width
Temp: Temperature
IMax: Current compliance

[Test Parameters]
IntegTime: Integration time
AnodeA: SMU connected to the device A Anode terminal, primary sweep voltage output
AnodeB: SMU connected to the device B Anode terminal, synchronous sweep voltage output
VanodeStart: Sweep start voltage for Anode terminal
VanodeStop: Sweep stop voltage for Anode terminal
VanodeStep: Sweep step voltage for Anode terminal
Cathode: SMU connected to Cathode terminal, constant voltage output

[Extended Test Parameters]
Vcathode: Cathode voltage
HoldTime: Hold time
DelayTime: Delay time
AnodeMinRng: Minimum range for the anode current measurement

[Measurement Parameters]
Anode current IanodeA, IanodeB

[User Function]
Delta_Ianode=(IanodeA-IanodeB)/IanodeA*100

[X-Y Plot]
X axis: Anode voltage VanodeA (LINEAR)
Y1 axis: Anode current IanodeA (LINEAR)
Y2 axis: Anode current IanodeB (LINEAR)
Y3 axis: Differences between anode current Delta_Ianode (LINEAR)
7.4 **Diode IV Rev Mismatch: Diode reverse bias characteristics mismatch (A.01.20)**

[Supported Analyzer]

[Description]
Measures the reverse bias anode voltage vs anode current characteristics, and plots the differences between the devices.

[Device Under Test]
Diode, 2 ea.

[Device Parameters]
- L: Junction length
- W: Junction width
- Temp: Temperature

[Test Parameters]
- IntegTime: Integration time
- AnodeA: SMU connected to the device A Anode terminal, primary sweep voltage output
- AnodeB: SMU connected to the device B Anode terminal, synchronous sweep voltage output
- VanodeStart: Sweep start voltage for Anode terminal
- VanodeStop: Sweep stop voltage for Anode terminal
- VanodeStep: Sweep step voltage for Anode terminal
- IanodeLimit: Anode current compliance
- Cathode: SMU connected to Cathode terminal, constant voltage output

[Extended Test Parameters]
- Vcathode: Cathode voltage
- HoldTime: Hold time
- DelayTime: Delay time
- AnodeMinRng: Minimum range for the anode current measurement

[Measurement Parameters]
- Anode current IanodeA, IanodeB

[User Function]
\[ \text{Delta}_\text{Ianode} = (\text{IanodeA} - \text{IanodeB})/\text{IanodeA} \times 100 \]

[X-Y Plot]
- X axis: Anode voltage VanodeA (LINEAR)
- Y1 axis: Anode current IanodeA (LINEAR)
- Y2 axis: Anode current IanodeB (LINEAR)
- Y3 axis: Differences between anode current Delta_Ianode (LINEAR)
7.5  **G-Plot ConstVce Mismatch: Gummel characteristics mismatch, Vce=Const (A.01.20)**

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the collector current vs base voltage characteristics and the base current vs base voltage characteristics, extracts the current amplification factor $h_{fe}$, and plots the gummel characteristics.

[Device Under Test]
Bipolar transistor, 4 terminals, 2 ea.

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
IntegTime: Integration time
BaseA: SMU connected to Device A Base terminal, primary sweep voltage output
BaseB: SMU connected to Device B Base terminal, synchronous sweep voltage output
VbStart: Sweep start voltage for Base terminal
VbStop: Sweep stop voltage for Base terminal
VbStep: Sweep step voltage for Base terminal
Emitter: SMU connected to Emitter terminal, constant voltage output
CollectorA: SMU connected to Device A Collector terminal, constant voltage output
CollectorB: SMU connected to Device B Collector terminal, constant voltage output
Ve: Collector voltage
Subs: SMU connected to Substrate, constant voltage output
Isubs: Substrate voltage
IsubsLimit: Substrate current compliance

[Extended Test Parameters]
Ve: Emitter voltage
HoldTime: Hold time
DelayTime: Delay time
BaseMinRng: Minimum range for the base current measurement
CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]
Collector current $I_{collectorA}$
Collector current $I_{collectorB}$
Base current $I_{baseA}$
Base current $I_{baseB}$

[User Function]
hfe\_A=$I_{collectorA}/I_{baseA}$
hfe\_B=$I_{collectorB}/I_{baseB}$
$\Delta h_{fe}=(hfe\_A-hfe\_B)/hfe\_A*100$
$\Delta I_{collector}=(I_{collectorA}-I_{collectorB})/I_{collectorA}*100$
7 MixedSignal

Vbe=VbaseA

[X-Y Plot]
X axis: Base-Emitter voltage Vbe (LINEAR)
Y1 axis: Collector current IcollectorA (LOG)
Y2 axis: Base current IbaseA (LOG)
Y3 axis: Collector current IcollectorB (LOG)
Y4 axis: Base current IbaseB (LOG)
Y5 axis: Current amplification factor $hfe_A$ (LINEAR)
Y6 axis: Current amplification factor $hfe_B$ (LINEAR)
Y7 axis: Differences of $hfe$ Delta_hfe (LINEAR)
7.6  **G-Plot ConstVce Mismatch[3]: Gummel characteristics mismatch, Vce=Const, 3-terminal (A.01.20)**

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the collector current vs base voltage characteristics and the base current vs base voltage characteristics, extracts the current amplification factor hfe, and plots the gummel characteristics.

[Device Under Test]
Bipolar transistor, 3 terminals, 2 ea.

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
IntegTime: Integration time
BaseA: SMU connected to Device A Base terminal, primary sweep voltage output
BaseB: SMU connected to Device B Base terminal, synchronous sweep voltage output
VbStart: Sweep start voltage for Base terminal
VbStop: Sweep stop voltage for Base terminal
VbStep: Sweep step voltage for Base terminal
Emitter: SMU connected to Emitter terminal, constant voltage output
CollectorA: SMU connected to Device A Collector terminal, constant voltage output
CollectorB: SMU connected to Device B Collector terminal, constant voltage output
Vc: Collector voltage

[Extended Test Parameters]
Ve: Emitter voltage
HoldTime: Hold time
DelayTime: Delay time
BaseMinRng: Minimum range for the base current measurement
CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]
Collector current IcollectorA
Collector current IcollectorB
Base current IbaseA
Base current IbaseB

[User Function]
hfe_A=IcollectorA/IbaseA
hfe_B=IcollectorB/IbaseB
Delta_hfe=(hfe_A-hfe_B)/hfe_A*100
Delta_Impl=(IcollectorA-IcollectorB)/IcollectorA*100
Vbe=VbaseA

[X-Y Plot]
7 MixedSignal

X axis: Base-Emitter voltage Vbe (LINEAR)
Y1 axis: Collector current IcollectorA (LOG)
Y2 axis: Base current IbaseA (LOG)
Y3 axis: Collector current IcollectorB (LOG)
Y4 axis: Base current IbaseB (LOG)
Y5 axis: Current amplification factor hfe_A (LINEAR)
Y6 axis: Current amplification factor hfe_B (LINEAR)
Y7 axis: Differences of hfe Delta_hfe (LINEAR)
7.7 **G-Plot Vbc=0V Mismatch: Gummel characteristics mismatch, Vbc=0 V** *(A.01.20)*

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the collector current vs emitter voltage characteristics and the base current vs emitter voltage characteristics, extracts the current amplification factor hfe, and plots the gummel characteristics.

[Device Under Test]
Bipolar transistor, 4 terminals, 2 ea.

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
IntegTime: Integration time
Emitter: SMU connected to Emitter terminal, primary sweep voltage output
VeStart: Sweep start voltage for Emitter terminal
VeStop: Sweep stop voltage for Emitter terminal
VeStep: Sweep step voltage for Emitter terminal
BaseA: SMU connected to Device A Base terminal, constant voltage output
BaseB: SMU connected to Device B Base terminal, constant voltage output
CollectorA: SMU connected to Device A Collector terminal, constant voltage output
CollectorB: SMU connected to Device B Collector terminal, constant voltage output
Ve: Collector voltage
Subs: SMU connected to Substrate, constant voltage output
IsubsLimit: Substrate current compliance

[Extended Test Parameters]
Vb: Base voltage
HoldTime: Hold time
DelayTime: Delay time
BaseMinRng: Minimum range for the base current measurement
CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]
Collector current IcollectorA
Collector current IcollectorB
Base current IbaseA
Base current IbaseB

[User Function]
hfe_A=IcollectorA/IbaseA
hfe_B=IcollectorB/IbaseB
Delta_hfe=((hfe_A-hfe_B)/hfe_A)*100
Delta_Icollector=((IcollectorA-IcollectorB)/IcollectorA)*100
MixedSignal

Vbe=-Vemitter

[X-Y Plot]
X axis: Base-Emitter voltage Vbe (LINEAR)
Y1 axis: Collector current IcollectorA (LOG)
Y2 axis: Base current IbaseA (LOG)
Y3 axis: Collector current IcollectorB (LOG)
Y4 axis: Base current IbaseB (LOG)
Y5 axis: Current amplification factor hfe_A (LINEAR)
Y6 axis: Current amplification factor hfe_B (LINEAR)
Y7 axis: Differences of hfe Delta_hfe (LINEAR)
7.8  G-Plot Vbc=0V Mismatch[3]: Gummel characteristics mismatch, Vbc=0, 3-terminal (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the collector current vs emitter voltage characteristics and the base current vs emitter voltage characteristics, extracts the current amplification factor hfe, and plots the gummel characteristics.

[Device Under Test]
Bipolar transistor, 3 terminals, 2 ea.

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
IntegTime: Integration time
Emitter: SMU connected to Emitter terminal, primary sweep voltage output
VeStart: Sweep start voltage for Emitter terminal
VeStop: Sweep stop voltage for Emitter terminal
VeStep: Sweep step voltage for Emitter terminal
BaseA: SMU connected to Device A Base terminal, constant voltage output
BaseB: SMU connected to Device B Base terminal, constant voltage output
CollectorA: SMU connected to Device A Collector terminal, constant voltage output
CollectorB: SMU connected to Device B Collector terminal, constant voltage output

[Extended Test Parameters]
Vb: Base voltage
Vc: Collector voltage
HoldTime: Hold time
DelayTime: Delay time
BaseMinRng: Minimum range for the base current measurement
CollectorMinRng: Minimum range for the collector current measurement

[Measurement Parameters]
Collector current IcollectorA
Collector current IcollectorB
Base current IbaseA
Base current IbaseB

[User Function]
hfe_A=IcollectorA/IbaseA
hfe_B=IcollectorB/IbaseB
Delta_hf=(hfe_A-hfe_B)/hfe_A*100
Delta_Icollector=(IcollectorA-IcollectorB)/IcollectorA*100
Vbe=-Vemitter

[X-Y Plot]
7 MixedSignal

X axis: Base-Emitter voltage Vbe (LINEAR)
Y1 axis: Collector current IcollectorA (LOG)
Y2 axis: Base current IbaseA (LOG)
Y3 axis: Collector current IcollectorB (LOG)
Y4 axis: Base current IbaseB (LOG)
Y5 axis: Current amplification factor hfe_A (LINEAR)
Y6 axis: Current amplification factor hfe_B (LINEAR)
Y7 axis: Differences of hfe Delta_hfe (LINEAR)
### 7.9 Ic-Vc Ib Mismatch: Ic-Vce characteristics mismatch, Ib sweep (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the collector current vs collector voltage (Ic-Ice) characteristics of device A, and measures the Ic-Ice characteristics of device B. After that, calculates the differences between Ic values by using the following formula, and plots the results.

\[ \text{Delta}_Ic = \frac{\text{I}_{\text{collector A}} - \text{I}_{\text{collector B}}}{\text{I}_{\text{collector A}}} \times 100 \]

[Device Under Test]
Bipolar transistor, 4 terminals, 2 ea.

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
IntegTime: Integration time
CollectorA: SMU connected to Device A Collector terminal, primary sweep voltage output
CollectorB: SMU connected to Device B Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcStep: Sweep step voltage for Collector terminal
BaseA: SMU connected to Device A Base terminal, secondary sweep current output
BaseB: SMU connected to Device B Base terminal, secondary sweep current output
IbStart: Sweep start current for Base terminal
IbStop: Sweep stop current for Base terminal
IbStep: Sweep step current for Base terminal
VbLimit: Base voltage compliance
Emitter: SMU connected to Emitter terminal, constant voltage output
Subs: SMU connected to Substrate, constant voltage output
Vsubs: Substrate voltage
IsubsLimit: Substrate current compliance

[Extended Test Parameters]
Ve: Emitter voltage
HoldTime: Hold time
DelayTime: Delay time
CollectorMinRng: Minimum range for the collector current measurement

[Device A: Measurement Parameters]
Collector current IcollectorA

[Device A: User Function]
hfe_A = IcollectorA/IbaseA

[Device A: X-Y Plot]
X axis: Collector voltage VcollectorA (LINEAR)
Y1 axis: Collector current IcollectorA (LINEAR)
7 MixedSignal

[Device B: Measurement Parameters]
Collector current IcollectorB

[Device B: User Function]
hfe_B=IcollectorB/IbaseB

[Device B: X-Y Plot]
X axis: Collector voltage VcollectorB (LINEAR)
Y1 axis: Collector current IcollectorB (LINEAR)

[Test Output: X-Y Graph]
X axis: Collector-Emitter voltage Vce (LINEAR)
Y1 axis: Collector current Icollector_A (LINEAR)
Y2 axis: Collector current Icollector_B (LINEAR)
Y3 axis: Differences between Ic Delta_Ic (LINEAR)
7.10 Ic-Vc Ib Mismatch[3]: Ic-Vce characteristics mismatch, Ib sweep, 3-terminal (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the collector current vs collector voltage (Ic-Ice) characteristics of device A, and measures the Ic-Ice characteristics of device B. After that, calculates the differences between Ic values by using the following formula, and plots the results.

\[ \text{Delta}_Ic = \frac{(I_{collector_A} - I_{collector_B})}{I_{collector_A}} \times 100 \]

[Device Under Test]
Bipolar transistor, 3 terminals, 2 ea.

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
IntegTime: Integration time
CollectorA: SMU connected to Device A Collector terminal, primary sweep voltage output
CollectorB: SMU connected to Device B Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcStep: Sweep step voltage for Collector terminal
BaseA: SMU connected to Device A Base terminal, secondary sweep current output
BaseB: SMU connected to Device B Base terminal, secondary sweep current output
IbStart: Sweep start current for Base terminal
IbStop: Sweep stop current for Base terminal
IbStep: Sweep step current for Base terminal
VbLimit: Base voltage compliance
Emitter: SMU connected to Emitter terminal, constant voltage output

[Extended Test Parameters]
Ve: Emitter voltage
HoldTime: Hold time
DelayTime: Delay time
CollectorMinRng: Minimum range for the collector current measurement

[Device A: Measurement Parameters]
Collector current IcollectorA

[Device A: User Function]
hfe_A = IcollectorA/IbaseA

[Device A: X-Y Plot]
X axis: Collector voltage VcollectorA (LINEAR)
Y1 axis: Collector current IcollectorA (LINEAR)
7 MixedSignal

[Device B: Measurement Parameters]
Collector current IcollectorB

[Device B: User Function]
hfe_B=IcollectorB/IbaseB

[Device B: X-Y Plot]
X axis: Collector voltage VcollectorB (LINEAR)
Y1 axis: Collector current IcollectorB (LINEAR)

[Test Output: X-Y Graph]
X axis: Collector-Emitter voltage Vce (LINEAR)
Y1 axis: Collector current Icollector_A (LINEAR)
Y2 axis: Collector current Icollector_B (LINEAR)
Y3 axis: Differences between Ic Delta_Ic (LINEAR)
7.11 Ic-Vc Vb Mismatch: Ic-Vce characteristics mismatch, Vb sweep (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the collector current vs collector voltage (Ic-Ice) characteristics of device A, and measures the Ic-Ice characteristics of device B. After that, calculates the differences between Ic values by using the following formula, and plots the results.
\[
\text{Delta}_Ic = \frac{I_{\text{collector A}} - I_{\text{collector B}}}{I_{\text{collector A}}} \times 100
\]

[Device Under Test]
Bipolar transistor, 4 terminals, 2 ea.

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
IntegTime: Integration time
CollectorA: SMU connected to Device A Collector terminal, primary sweep voltage output
CollectorB: SMU connected to Device B Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcStep: Sweep step voltage for Collector terminal
BaseA: SMU connected to Device A Base terminal, secondary sweep voltage output
BaseB: SMU connected to Device B Base terminal, secondary sweep voltage output
VbStart: Sweep start voltage for Base terminal
VbStop: Sweep stop voltage for Base terminal
VbStep: Sweep step voltage for Base terminal
Emitter: SMU connected to Emitter terminal, constant voltage output
Subs: SMU connected to Substrate, constant voltage output
Vsubs: Substrate voltage
IsubsLimit: Substrate current compliance

[Extended Test Parameters]
Ve: Emitter voltage
HoldTime: Hold time
DelayTime: Delay time
BaseMinRng: Minimum range for the base current measurement
CollectorMinRng: Minimum range for the collector current measurement

[Device A: Measurement Parameters]
Collector current IcollectorA
Base current IbaseA

[Device A: User Function]
hfe_A = IcollectorA/IbaseA

[Device A: X-Y Plot]
X axis: Collector voltage VcollectorA (LINEAR)
[Device B: Measurement Parameters]
Collector current IcollectorB
Base current IbaseB

[Device B: User Function]
hfe_B=IcollectorB/IbaseB

[Device B: X-Y Plot]
X axis: Collector voltage VcollectorB (LINEAR)
Y1 axis: Collector current IcollectorB (LINEAR)

[Test Output: X-Y Graph]
X axis: Collector-Emitter voltage Vce (LINEAR)
Y1 axis: Collector current Icollector_A (LINEAR)
Y2 axis: Collector current Icollector_B (LINEAR)
Y3 axis: Differences between Ic Delta_Ic (LINEAR)
7.12 Ic-Vc Vb Mismatch[3]: Ic-Vce characteristics mismatch, Vb sweep, 3-terminal (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the collector current vs collector voltage (Ic-Ice) characteristics of device A, and measures the Ic-Ice characteristics of device B. After that, calculates the differences between Ic values by using the following formula, and plots the results.
\[ \text{Delta}\_Ic=\left(\text{Icollector}\_A-\text{Icollector}\_B\right)/\text{Icollector}\_A*100 \]

[Device Under Test]
Bipolar transistor, 3 terminals, 2 ea.

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Le: Emitter length
We: Emitter width
Temp: Temperature
IcMax: Collector current compliance

[Test Parameters]
IntegTime: Integration time
CollectorA: SMU connected to Device A Collector terminal, primary sweep voltage output
CollectorB: SMU connected to Device B Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcStep: Sweep step voltage for Collector terminal
BaseA: SMU connected to Device A Base terminal, secondary sweep voltage output
BaseB: SMU connected to Device B Base terminal, secondary sweep voltage output
VbStart: Sweep start voltage for Base terminal
VbStop: Sweep stop voltage for Base terminal
VbStep: Sweep step voltage for Base terminal
Emitter: SMU connected to Emitter terminal, constant voltage output

[Extended Test Parameters]
Ve: Emitter voltage
HoldTime: Hold time
DelayTime: Delay time
BaseMinRng: Minimum range for the base current meausrement
CollectorMinRng: Minimum range for the collector current measurement

[Device A: Measurement Parameters]
Collector current IcollectorA
Base current IbaseA

[Device A: User Function]
hfe\_A=IcollectorA/IbaseA

[Device A: X-Y Plot]
X axis: Collector voltage VcollectorA (LINEAR)
Y1 axis: Collector current IcollectorA (LINEAR)
[Device B: Measurement Parameters]
  Collector current IcollectorB
  Base current IbaseB

[Device B: User Function]
  hfe_B=IcollectorB/IbaseB

[Device B: X-Y Plot]
  X axis: Collector voltage VcollectorB (LINEAR)
  Y1 axis: Collector current IcollectorB (LINEAR)

[Test Output: X-Y Graph]
  X axis: Collector-Emitter voltage Vce (LINEAR)
  Y1 axis: Collector current Icollector_A (LINEAR)
  Y2 axis: Collector current Icollector_B (LINEAR)
  Y3 axis: Differences between Ic Delta_Ic (LINEAR)
7.13 Id-Vd Mismatch: Id-Vd characteristics mismatch (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the drain current vs drain voltage characteristics of two MOSFETs, and plots the differences of them.

[Device Under Test]
MOSFET, 4 terminals, 2 ea.

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
DrainA: SMU connected to the device A Drain terminal, primary sweep voltage output
DrainB: SMU connected to the device B Drain terminal, synchronous sweep voltage output
VdStart: Sweep start voltage for Drain terminal
VdStop: Sweep stop voltage for Drain terminal
VdStep: Sweep step voltage for Drain terminal
Gate: SMU connected to Gate terminal, secondary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
IgLimit: Gate current compliance
Subs: SMU connected to Substrate, constant voltage output
Vsubs: Substrate voltage
IsubsLimit: Substrate current compliance
Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]
Vs: Source voltage
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for the drain current measurement
SubsMinRng: Minimum range for the substrate current measurement

[Measurement Parameters]
Device A Drain current IdrainA
Device B Drain current IdrainB
Substrate current Isubs
Source current Isource

[User Function]
Drain conductance gds_A=diff(IdrainA,VdrainA)
Drain conductance gds_B=diff(IdrainB,VdrainB)
Drain resistance Rds_A=1/gds_A
Drain resistance Rds_B=1/gds_B
Delta_Ids=(IdrainA-IdrainB)/IdrainA*100
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\[ \text{Delta}_{\text{gds}} = \frac{(\text{gds}_A - \text{gds}_B)}{\text{gds}_A} \times 100 \]
\[ \text{Delta}_{\text{Rds}} = \frac{(\text{Rds}_A - \text{Rds}_B)}{\text{Rds}_A} \times 100 \]

[X-Y Graph]
X axis: Drain voltage $V_{\text{drain}A}$ (LINEAR)
Y1 axis: Device A Drain current $I_{\text{drain}A}$ (LINEAR)
Y2 axis: Device B Drain current $I_{\text{drain}B}$ (LINEAR)
Y3 axis: Difference of Drain current $\Delta I_{\text{drain}}$ (LINEAR)

[List Display]
Drain voltage $V_{\text{drain}A}$
Gate voltage $V_{\text{gate}}$
Device A Drain current $I_{\text{drain}A}$
Device B Drain current $I_{\text{drain}B}$
Differences of Drain current $\Delta I_{\text{drain}}$
Substrate current $I_{\text{subs}}$
Source current $I_{\text{source}}$
7.14 Id-Vd Mismatch[3]: Id-Vd characteristics mismatch, 3-terminal (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the drain current vs drain voltage characteristics of two MOSFETs, and plots the differences of them.

[Device Under Test]
MOSFET, 3 terminals, 2 ea.

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
DrainA: SMU connected to the device A Drain terminal, primary sweep voltage output
DrainB: SMU connected to the device B Drain terminal, synchronous sweep voltage output
Gate: SMU connected to Gate terminal, secondary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
IgLimit: Gate current compliance
Source: SMU connected to Source terminal, constant voltage output
VdStart: Sweep start voltage for Drain terminal
VdStop: Sweep stop voltage for Drain terminal
VdStep: Sweep step voltage for Drain terminal

[Extended Test Parameters]
Vs: Source voltage
 HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
Device A Drain current IdrainA
Device B Drain current IdrainB

[User Function]
Drain conductance gds_A=diff(IdrainA,VdrainA)
Drain conductance gds_B=diff(IdrainB,VdrainB)
Drain resistance Rds_A=1/gds_A
Drain resistance Rds_B=1/gds_B
Delta_Id=(IdrainA-IdrainB)/IdrainA*100
Delta_gds=(gds_A-gds_B)/gds_A*100
Delta_Rds=(Rds_A-Rds_B)/Rds_A*100

[X-Y Graph]
X axis: Drain voltage VdrainA (LINEAR)
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Y1 axis: Device A Drain current IdrainA (LINEAR)
Y2 axis: Device B Drain current IdrainB (LINEAR)
Y3 axis: Difference of Drain current Delta_Ids (LINEAR)

[List Display]
Drain voltage VdrainA
Gate voltage Vgate
Device A Drain current IdrainA
Device B Drain current IdrainB
Differences of Drain current Delta_Ids
7.15 Id-Vg Mismatch: Id-Vg characteristics mismatch (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the drain current vs gate voltage characteristics of two MOSFETs, and plots the differences of them.

[Device Under Test]
MOSFET, 4 terminals, 2 ea.

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
Gate: SMU connected to Gate terminal, primary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
IgLimit: Gate current compliance
DrainA: SMU connected to the device A Drain terminal, constant voltage output
DrainB: SMU connected to the device B Drain terminal, constant voltage output
Vd: Drain voltage
Subs: SMU connected to Substrate, secondary sweep voltage output
VsubsStart: Sweep start voltage for Substrate terminal
VsubsStop: Sweep stop voltage for Substrate terminal
VsubsStep: Sweep step voltage for Substrate terminal
IsubsLimit: Substrate current compliance
Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]
Vs: Source voltage
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for the drain current measurement
GateMinRng: Minimum range for the gate current measurement
SubsMinRng: Minimum range for the Substrate current measurement

[Measurement Parameters]
Device A Drain current IdrainA
Device B Drain current IdrainB
Gate current Igate
Substrate current Isubs

[User Function]
gm_A=diff(IdrainA,Vgate)
gm_B=diff(IdrainB,Vgate)
Delta_Id=(IdrainA-IdrainB)/IdrainA*100
Delta_gm=(gm_A-gm_B)/gm_A*100
[X-Y Graph]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Device A Drain current IdrainA (LINEAR)
Y2 axis: Device B Drain current IdrainB (LINEAR)
Y3 axis: Difference of Drain current Delta_Id (LINEAR)

[List Display]
Gate voltage Vgate
Drain voltage VdrainA
Device A Drain current IdrainA
Device B Drain current IdrainB
Differences of Drain current Delta_Id
Gate current Igate
Substrate current Isubs
### 7.16 Id-Vd Mismatch[3]: Id-Vd characteristics mismatch, 3-terminal (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the drain current vs drain voltage characteristics of two MOSFETs, and plots the differences of them.

[Device Under Test]
MOSFET, 3 terminals, 2 ea.

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
DrainA: SMU connected to the device A Drain terminal, primary sweep voltage output
DrainB: SMU connected to the device B Drain terminal, synchronous sweep voltage output
Gate: SMU connected to Gate terminal, secondary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
IgLimit: Gate current compliance
Source: SMU connected to Source terminal, constant voltage output
Vd: Drain voltage

[Extended Test Parameters]
Vs: Source voltage
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
Device A Drain current IdrainA
Device B Drain current IdrainB

[User Function]
Drain conductance gds_A=diff(IdrainA,VdrainA)
Drain conductance gds_B=diff(IdrainB,VdrainB)
Drain resistance Rds_A=1/gds_A
Drain resistance Rds_B=1/gds_B
Delta_Ids=(IdrainA-IdrainB)/IdrainA*100
Delta_gds=(gds_A-gds_B)/gds_A*100
Delta_Rds=(Rds_A-Rds_B)/Rds_A*100

[X-Y Graph]
X axis: Drain voltage VdrainA (LINEAR)
Y1 axis: Device A Drain current IdrainA (LINEAR)
Y2 axis: Device B Drain current IdrainB (LINEAR)
Y3 axis: Difference of Drain current Delta_Ids (LINEAR)
[List Display]
Drain voltage VdrainA
Gate voltage Vgate
Device A Drain current IdrainA
Device B Drain current IdrainB
Differences of Drain current Delta_Ids
7.17 MIM CV Mismatch: MIM capacitor C-V characteristics mismatch (A.01.11)

[Supported Analyzer]
B1500A

[Description]
Measures the MIM capacitance (C-V characteristics) of device A, and measures the C-V characteristics of device B. After that, calculates the differences between capacitance values by using the following formula, and plots the results.

\[
\text{DeltaCp} = \frac{\text{CpBList} - \text{CpAList}}{\text{CpAList}} \times 100 \quad \text{for parallel capacitance}
\]
\[
\text{DeltaCs} = \frac{\text{CsBList} - \text{CsAList}}{\text{CsAList}} \times 100 \quad \text{for series capacitance}
\]

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
MIM capacitor, 2 terminals, 2 ea.

[Device Parameters]
Lg: Device length
Wg: Device width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
FREQ: Measurement frequency
OscLevel: Measurement signal level
Port1: CMU connected to the device (CV sweep measurement)
V1Start: DC bias start voltage
V1Stop: DC bias stop voltage
V1Step: DC bias step voltage

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Parallel capacitance Cp
Conductance G

[User Function]
To specify the device, A or B is added to the actual variable names.
\[ PI = 3.141592653589 \]
\[ Dval = Gval/(2*PI*FREQ*Cpval) \]
\[ Rpval = 1/Gval \]
\[ Csva = (1+Dval^2)*Cpval \]
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\[ X_{val} = \frac{-1}{(2\pi FREQ \cdot Csval)} \]
\[ R_{val} = Dval \cdot \text{abs}(X_{val}) \]
\[ Z_{val} = \sqrt{R_{val}^2 + X_{val}^2} \]
\[ \text{Thetav}_{al} = \text{atan}(X_{val}/R_{val}) \]

[X-Y Graph]
To specify the device, A or B is added to the actual variable names.
X axis: DC bias Vport1 (LINEAR)
Y1 axis: MIM capacitance (parallel capacitance) Cpval (LINEAR)
Y2 axis: Conductance Gval (LINEAR)

[List Display]
To specify the device, A or B is added to the actual variable names.
DC bias Vport1
Parallel capacitance Cpval
Conductance Gval
Series capacitance Csval
Series resistance Rsval
Parallel resistance Rpval
Dissipation factor Dval
Reactance Xval
Impedance Zval
Phase Thetav{

[Test Output: X-Y Graph]
X axis: DC bias Vport1List (LINEAR)
Y1 axis: MIM capacitance (parallel capacitance) CpAList (LINEAR)
Y2 axis: MIM capacitance (parallel capacitance) CpBList (LINEAR)
Y3 axis: Differences between Cp DeltaCp (LINEAR)
7.18 MOS Varactor CV Mismatch: MOS Varactor capacitance CV characteristics mismatch (A.01.11)

[Supported Analyzer]
B1500A

[Description]
Measures the MOS varactor capacitance (C-Vg characteristics) of device A, and measures the C-Vg characteristics of device B. After that, calculates the differences between capacitance values by using the following formula, and plots the results.

\[
\text{DeltaCp} = \frac{C_{pBList} - C_{pAList}}{C_{pAList}} \times 100 \quad \text{for parallel capacitance} \\
\text{DeltaCs} = \frac{C_{sBList} - C_{sAList}}{C_{sAList}} \times 100 \quad \text{for series capacitance}
\]

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
MOSFET, 4 terminals, 2 ea.
Connect Gate to the CMU Low, and the other terminals to the CMU High.

[Device Parameters]
Polarity: Nch (CMU forces the specified value) or Pch (CMU forces the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
FREQ: Measurement frequency
OscLevel: Measurement signal level
Gate: CMU connected to Gate terminal (CV sweep measurement)
VgsStart: DC bias start voltage
VgsStop: DC bias stop voltage
VgsStep: DC bias step voltage

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Parallel capacitance Cp
Conductance G

[User Function]
To specify the device, A or B is added to the actual variable names.
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\[ \pi = 3.141592653589 \]

\[ D_{val} = \frac{G_{val}}{(2\pi FREQ \cdot C_{pval})} \]

\[ R_{pval} = \frac{1}{G_{val}} \]

\[ C_{val} = \frac{(1 + D_{val}^2) \cdot C_{pval}}{C_{pval}} \]

\[ X_{val} = -\frac{1}{(2\pi FREQ \cdot C_{sval})} \]

\[ R_{sval} = D_{val} \cdot \text{abs}(X_{val}) \]

\[ Z_{val} = \sqrt{R_{sval}^2 + X_{val}^2} \]

\[ \Theta_{val} = \text{atan}(X_{val}/R_{sval}) \]

\[ V_{gateval} = -V_{subs} \]

[X-Y Graph]
To specify the device, A or B is added to the actual variable names.

X axis: Gate voltage \( V_{gateval} \) (LINEAR)
Y1 axis: Gate capacitance (parallel capacitance) \( C_{pval} \) (LINEAR)
Y2 axis: Conductance \( G_{val} \) (LINEAR)

[List Display]
To specify the device, A or B is added to the actual variable names.
Gate voltage \( V_{gateval} \)
Parallel capacitance \( C_{pval} \)
Conductance \( G_{val} \)
Series capacitance \( C_{sval} \)
Series resistance \( R_{sval} \)
Parallel resistance \( R_{pval} \)
Dissipation factor \( D_{val} \)
Reactance \( X_{val} \)
Impedance \( Z_{val} \)
Phase \( \Theta_{val} \)

[Test Output: X-Y Graph]
X axis: Gate voltage \( V_{List} \) (LINEAR)
Y1 axis: Gate capacitance (parallel capacitance) \( C_{pAList} \) (LINEAR)
Y2 axis: Gate capacitance (parallel capacitance) \( C_{pBList} \) (LINEAR)
Y3 axis: Differences between \( C_{p} \) \( \Delta C_{p} \) (LINEAR)
7.19 Poly-R Mismatch: Resistor R-I characteristics mismatch, Kelvin connection (A.01.11)

[Supported Analyzer]

[Description]
Measures the resistance vs input current characteristics of resistors, and plots the differences between the devices.

[Device Under Test]
Resistor, 2 terminals, 2 ea.

[Device Parameters]
L: Resistor length
W: Resistor width
Temp: Temperature

[Test Parameters]
IntegTime: Integration Time
Port1: SMU connected to device A high terminal, primary sweep current output
Port2: SMU connected to device B high terminal, synchronous sweep current output
I1Start: Port1/Port2 sweep start current
I1Stop: Port1/Port2 sweep stop current
I1Step: Port1/Port2 sweep step current
V1Limit: Maximum voltage
Port3: SMU connected to device A/B low terminal, constant voltage output
VM1: SMU connected to device A high terminal, constant current output
VM2: SMU connected to device A high terminal, constant current output
VM3: SMU connected to device B high terminal, constant current output
VM4: SMU connected to device B high terminal, constant current output

[Extended Test Parameters]
V3: Port3 output voltage
IM1: VM1 output current
IM2: VM2 output current
IM3: VM3 output current
IM4: VM4 output current
HoldTime: Hold time
DelayTime: Deley time

[Measurement Parameters]
Device A input current Iport1
Device B input current Iport2
Device A terminal voltage Vvm1, Vvm2
Device B terminal voltage Vvm3, Vvm4

[User Function]
DeltaV_A = Vvm1-Vvm2
DeltaV_B = Vvm3-Vvm4
R_A = DeltaV_A / Iport1
R_B = DeltaV_B / Iport2
Rsheet_A = R_A / (W/L)
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\[ R_{\text{sheet} B} = R_B / (W/L) \]
\[ \text{Delta}_R = (R_A - R_B) / R_A * 100 \]

[X-Y Plot]
X axis: Device A input current Iport1 (LINEAR)
Y1 axis: Device A resistance \( R_A \) (LINEAR)
Y2 axis: Device B resistance \( R_B \) (LINEAR)
Y3 axis: Rate-of-change between \( R_A \) and \( R_B \) \( \text{Delta}_R \) (LINEAR)
Y4 axis: Device A voltage between terminals \( \text{Delta}V_A \) (LINEAR)
Y5 axis: Device B voltage between terminals \( \text{Delta}V_B \) (LINEAR)
1. CNT Differential R[AC]: CNT Differential R-V characteristics (A.01.20)
2. CNT Gate Leak: CNT FET Ig-Vg characteristics (A.01.20)
3. CNT Gate Leak [1HL]: CNT FET Ig-Vg characteristics (A.06.10)
4. CNT Id-Time: CNT FET Id-Time Characteristic (A.01.20)
5. CNT Id-Time [2HL]: CNT FET Id-Time Characteristic (A.06.10)
6. CNT Id-Vd: CNT FET Id-Vd characteristics (A.01.20)
7. CNT Id-Vd [2HL]: CNT FET Id-Vd characteristics (A.06.10)
8. CNT Id-Vg: Carbon Nano Tube FET Id-Vg characteristics (A.01.20)
9. CNT Id_Vg [2HL]: Carbon Nano Tube FET Id-Vg characteristics (A.06.10)
10. CNT Id-Vg-Time: CNT FET Ig-Vg characteristics (A.01.20)
11. CNT Id-Vg-time [2HL]: CNT FET Id-Vg-Time characteristics (A.06.10)
12. CNT IV Sweep: CNT Differential I-V characteristics (A.01.20)
13. CNT IV Sweep [1HL]: CNT I-V characteristics (A.06.10)
14. CNT R-I Kelvin 2SMU: CNT R-I characteristics, Kelvin connection (A.01.20)
15. CNT R-V Kelvin 2SMU: CNT R-V characteristics, Kelvin connection (A.01.20)
16. CNT Vth gmMax: CNT FET linear region Vth (A.01.20)
17. CNT Vth gmMax [2HL]: CNT FET linear region Vth (A.06.10)
8.1 CNT Differential R[AC]: CNT Differential R-V characteristics (A.01.20)

[Supported Analyzer]
B1500A

[Description]
Measures the conductance of a CNT 2-terminal device and plots differential R-V (resistance vs voltage) characteristics. This test is designed to calculate resistance as the inverse of conductance. Additionally, the level of a measurement signal is specified by a peak-to-peak value (normally effective value).
For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
Carbon Nano Tube FET, 2 terminals

[Required Modules and Accessories]
Keysight B1520A MFCMU 1 unit

[Device Parameters]
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Port1: CMU connected to device under test, CV sweep measurement
V1Start: Sweep output start voltage
V1Stop: Sweep output stop voltage
V1Step: Sweep output step voltage
FREQ: Measurement frequency
Meas_Vpp: Measurement signal level, Peak to Peak value of oscillation

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
AxisY_RMin: Minimum Y axis (resistance) value
AxisY_RMax: Maximum Y axis (resistance) value

[Measurement Parameters]
Conductance G

[User Function]
Differential resistance R=1/G

[X-Y Plot]
X axis: Port1 input voltage Vport1 (LINEAR)
Y1 axis: Differential resistance R (LINEAR)

[List Display]
Port1 input voltage Vport1
Differential resistance R
Conductance G
8.2 CNT Gate Leak: CNT FET Ig-Vg characteristics (A.01.20)

[Supported Analyzer]

[Description]
Measures the gate current vs gate voltage (Ig-Vg) characteristics of CNT FET. Measures Ig before and after applying Vg by using the primary sweep SMU that forces the start and stop voltages only, and extracts the Ig-Vg characteristics by altering the stop value repeatedly.

[Device Under Test]
Carbon Nano Tube FET capacitor, 2 terminals
Connect SMU to the back gate and side gate and make the source and drain open.

[Device Parameters]
Polarity: Forward (SMUs force the specified value) or Reverse (SMUs force the negative specified value)
L: CNT length
D: CNT diameter
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
BackGate: SMU connected to Back Gate terminal, primary sweep voltage output
SideGate: SMU connected to Side Gate terminal, constant voltage output
VbgStart: Pulse peak start (sweep start) voltage for Back Gate terminal
VbgStop: Pulse peak stop (sweep stop) voltage for Back Gate terminal
VbgStep: Pulse peak step (sweep step) voltage for Back Gate terminal
VbgLow: Pulse base voltage (primary sweep start voltage)

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
Vsg: Side Gate terminal voltage
IbgLimit: Back Gate current compliance
BackGateMinRng: Minimum range for Back Gate current measurement
SideGateMinRng: Minimum range for Side Gate current measurement

[Measurement Parameters]
Ibackgate: Back Gate current

[X-Y Plot]
X axis: Back Gate voltage Vbackgate (LINEAR)
Y1 axis: Back Gate current Ibackgate (LOG)

[List Display]
Vbackgate: Back Gate voltage
Ibackgate: Back Gate current

[Test Output: X-Y Graph]
X axis: Back Gate voltage Vbackgate (LINEAR)
Y1 axis: Back Gate current Ibackgate (LOG)
Y2 axis: Back Gate current with pulse base voltage applied Ibackgate@LowVbg (LOG)

[Test Output: List Display]
V_backgate: Back Gate voltage
I_backgate: Back Gate current
I_backgate@LowVbg: Back Gate current with pulse base voltage applied

[Test Output: Parameters]
V_backgate: Back Gate voltage
I_backgate: Back Gate current
I_backgate@LowVbg: Back Gate current with pulse base voltage applied
8.3 CNT Gate Leak [1HL]: CNT FET Ig-Vg characteristics (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the gate current vs gate voltage (Ig-Vg) characteristics of CNT FET. Measures Ig before and after applying Vg by using the primary sweep SMU that forces the start and stop voltages only, and extracts the Ig-Vg characteristics by altering the stop value repeatedly.

[Device Under Test]
Carbon Nano Tube FET capacitor, 2 terminals
Connect SMU to the back gate and side gate and make the source and drain open.

[Device Parameters]
Polarity: Forward (SMUs force the specified value) or Reverse (SMUs force the negative specified value)
L: CNT length
D: CNT diameter
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
BackGate: SMU connected to Back Gate terminal, primary sweep voltage output
VbgStart: Pulse peak start (sweep start) voltage for Back Gate terminal
VbgStop: Pulse peak stop (sweep stop) voltage for Back Gate terminal
VbgStep: Pulse peak step (sweep step) voltage for Back Gate terminal
VbgLow: Pulse base voltage (primary sweep start voltage)

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
IbgLimit: Back Gate current compliance
BackGateMinRng: Minimum range for Back Gate current measurement

[Measurement Parameters]
Ibackgate: Back Gate current

[X-Y Plot]
X axis: Back Gate voltage Vbackgate (LINEAR)
Y1 axis: Back Gate current Ibackgate (LOG)

[List Display]
Vbackgate: Back Gate voltage
Ibackgate: Back Gate current

[Test Output: X-Y Graph]
X axis: Back Gate voltage Vbackgate (LINEAR)
Y1 axis: Back Gate current Ibackgate (LOG)
Y2 axis: Back Gate current with pulse base voltage applied Ibackgate@LowVbg (LOG)

[Test Output: List Display]
V_backgate: Back Gate voltage
I_backgate: Back Gate current
I_backgate@LowVbg: Back Gate current with pulse base voltage applied

[Test Output: Parameters]
V_backgate: Back Gate voltage
I_backgate: Back Gate current
I_backgate@LowVbg: Back Gate current with pulse base voltage applied
8.4 CNT Id-Time: CNT FET Id-Time Characteristic (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
This Algorithm evaluates the drain current with drain voltage for the gate condition change which is used as the DNA or the antibody sensor.
The IV curves between drain and source is measured with the gate condition change which indicate amount of the DNA or the antibody on the gate surface as a sensor.
The Algorithm is applied the time dependent measurement.

[Device Under Test]
CNT FET, 4 terminals

[Device Parameters]
Polarity: Forward (SMUs force the specified value) or Reverse (SMUs force the negative specified value).
L: CNT length
D: CNT diameter
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
BackGate: SMU connected to Backgate terminal, secondary sweep voltage output
Source: SMU connected to Source terminal, constant voltage output
Drain: SMU connected to Drain terminal, primary sweep voltage output
SideGate: SMU connected to Sidegate, constant voltage output
VbgStart: Sweep start voltage for Backgate terminal
VbgStop: Sweep stop voltage for Backgate terminal
VbgStep: Sweep step voltage for Backgate terminal
VdStart: Sweep start voltage for Drain terminal
VdStop: Sweep stop voltage for Drain terminal
VdStep: Sweep step voltage for Drain terminal
Vsg: Sidegate voltage
IntegTime: Integration time
T1Stop: T1 stop time
T1Step: T1 step time
T2Stop: T2 stop time
T2Step: T2 step time

[Extended Test Parameters]
Vs: Source voltage
IgLimit: Backgate current compliance
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
Drain current Idrain
Time ACC_TIME

ACC_TIME shows total time of T1Step or T2Step and measured time.
ACC_TIME = ACC_TIME + T1Step or T2Step + Measured time of Idrain-Vd

[X-Y Plot]
X axis: Drain voltage Vdrain (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
8.5  CNT Id-Time [2HL]: CNT FET Id-Time Characteristic (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
This Algorithm evaluates the drain current with drain voltage for the gate condition change which is used as the DNA or the antibody sensor.

The IV curves between drain and source is measured with the gate condition change which indicate amount of the DNA or the antibody on the gate surface as a sensor.

The Algorithm is applied the time dependent measurement.

[Device Under Test]
CNT FET, 4 terminals

[Device Parameters]
Polarity: Forward (SMUs force the specified value) or Reverse (SMUs force the negative specified value).
L: CNT length
D: CNT diameter
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
BackGate: SMU connected to Backgate terminal, secondary sweep voltage output
Drain: SMU connected to Drain terminal, primary sweep voltage output
VbgStart: Sweep start voltage for Backgate terminal
VbgStop: Sweep stop voltage for Backgate terminal
VbgStep: Sweep step voltage for Backgate terminal
VdStart: Sweep start voltage for Drain terminal
VdStop: Sweep stop voltage for Drain terminal
VdStep: Sweep step voltage for Drain terminal
IntegTime: Integration time
T1Stop: T1 stop time
T1Step: T1 step time
T2Stop: T2 stop time
T2Step: T2 step time

[Extended Test Parameters]
IgLimit: Backgate current compliance
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
Drain current Idrain
Time ACC_TIME
ACC_TIME shows total time of T1Step or T2Step and measured time.
ACC_TIME = ACC_TIME + T1Step or T2Step + Measured time of Id-Vd

[User Function]
ACC_TIME: Elapsed time
MaxTS: Maximum time stamp value

[Analysis Function]

[X-Y Plot]
X axis: Drain voltage Vdrain (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)

[Parameters Display Area]

[Auto Analysis]
8.6 CNT Id-Vd: CNT FET Id-Vd characteristics (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the drain current vs drain voltage characteristics of Carbon Nano Tube FET.

[Device Under Test]
Carbon Nano Tube FET, 4 terminals

[Device Parameters]
Polarity: Forward (SMUs force the specified value) or Reverse (SMUs force the negative specified value).
L: CNT length
D: CNT diameter
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
Drain: SMU connected to Drain, primary sweep voltage output
VdStart: Sweep start voltage for Drain
VdStop: Sweep stop voltage for Drain
VdStep: Sweep step voltage for Drain
BackGate: SMU connected to Backgate, secondary sweep voltage output
VbgStart: Sweep start voltage for Backgate
VbgStop: Sweep stop voltage for Backgate
VbgStep: Sweep step voltage for Backgate
IgLimit: Backgate current compliance
SideGate: SMU connected to Sidegate, constant voltage output
Source: SMU connected to Source, constant voltage output

[Extended Test Parameters]
Vsg: Sidegate voltage
Vs: Source voltage
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
Drain current Idrain

[X-Y Plot]
X axis: Drain voltage Vdrain (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
8.7  CNT Id_Vd [2HL]: CNT FET Id-Vd characteristics (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the drain current vs drain voltage characteristics of Carbon Nano Tube FET.

[Device Under Test]
Carbon Nano Tube FET, 4 terminals

[Device Parameters]
Polarity: Forward (SMUs force the specified value) or Reverse (SMUs force the negative specified value).
L: CNT length
D: CNT diameter
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
Drain: SMU connected to Drain, primary sweep voltage output
VdStart: Sweep start voltage for Drain
VdStop: Sweep stop voltage for Drain
VdStep: Sweep step voltage for Drain
BackGate: SMU connected to Backgate, secondary sweep voltage output
VbgStart: Sweep start voltage for Backgate
VbgStop: Sweep stop voltage for Backgate
VbgStep: Sweep step voltage for Backgate
IgLimit: Backgate current compliance

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
Drain current Idrain

[X-Y Plot]
X axis: Drain voltage Vdrain (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
8.8  CNT Id_Vg: Carbon Nano Tube FET Id-Vg characteristics (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the drain current vs gate voltage characteristics of Carbon Nano Tube FET.

[Device Under Test]
Carbon Nano Tube FET, 4 terminals

[Device Parameters]
Polarity: Forward (SMUs force the specified value) or Reverse (SMUs force the negative specified value).
L: CNT length
D: CNT diameter
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
BackGate: SMU connected to Backgate, primary sweep voltage output
VbgStart: Sweep start voltage for Backgate
VbgStop: Sweep stop voltage for Backgate
VbgStep: Sweep step voltage for Backgate
IgLimit: Backgate current compliance
Drain: SMU connected to Drain, secondary sweep voltage output
VdStart: Sweep start voltage for Drain
VdStop: Sweep stop voltage for Drain
VdStep: Sweep step voltage for Drain
SideGate: SMU connected to Sidegate, constant voltage output
Source: SMU connected to Source, constant voltage output

[Extended Test Parameters]
Vsg: Sidegate voltage
Vs: Source voltage
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
Drain current Idrain

[X-Y Plot]
X axis: Backgate voltage Vbackgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)
8.9  CNT Id_Vg [2HL]: Carbon Nano Tube FET Id-Vg characteristics (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the drain current vs gate voltage characteristics of Carbon Nano Tube FET.

[Device Under Test]
Carbon Nano Tube FET, 4 terminals

[Device Parameters]
Polarity: Forward (SMUs force the specified value) or Reverse (SMUs force the negative specified value).
L: CNT length
D: CNT diameter
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
BackGate: SMU connected to Backgate, primary sweep voltage output
VbgStart: Sweep start voltage for Backgate
VbgStop: Sweep stop voltage for Backgate
VbgStep: Sweep step voltage for Backgate
IgLimit: Backgate current compliance
Drain: SMU connected to Drain, secondary sweep voltage output
VdStart: Sweep start voltage for Drain
VdStop: Sweep stop voltage for Drain
VdStep: Sweep step voltage for Drain

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
Drain current Idrain

[X-Y Plot]
X axis: Backgate voltage Vbackgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)
8.10 CNT Id-Vg-Time: CNT FET Ig-Vg characteristics (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the Id-Vg characteristics of CNT FET repeatedly at a specified interval until specified time elapses. This test is designed to use a gate electrode as a sensor and consider the adsorption of DNA and antibody to the gate electrode as a change in Ids. Used for evaluation of a time change in characteristics.

[Device Under Test]
Carbon Nano Tube FET, 4 terminals

[Device Parameters]
Polarity: Forward (SMUs force the specified value) or Reverse (SMUs force the negative specified value)
L: CNT length
D: CNT diameter
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
Drain: SMU connected to Drain, primary sweep voltage output
VdStart: Sweep start voltage for Drain
VdStop: Sweep stop voltage for Drain
VdStep: Sweep step voltage for Drain
BackGate: SMU connected to Back Gate, secondary sweep voltage output
VbgStart: Sweep start voltage for Back Gate
VbgStop: Sweep stop voltage for Back Gate
VbgStep: Sweep step voltage for Back Gate
SideGate: SMU connected to Side Gate, constant voltage output
Vsg: Side Gate voltage
Source: SMU connected to Source, constant voltage output
T1Stop: T1 stop time
T1Step: T1 step time
T2Stop: T2 stop time
T2Step: T2 step time

[Extended Test Parameters]
Vs: Source voltage
IbgLimit: Back Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for drain current measurement

[Measurement Parameters]
Drain current Idrain
Time ACC_TIME

ACC_TIME is displayed after adding the sum of T1Step (or T2Step) and the actual measurement time.
ACC_TIME = ACC_TIME + T1Step (or T2Step) + Id-Vg measurement time

[User Function]
ACC_TIME: Elapsed time
MaxTS: Maximum time stamp value

[X-Y Plot]
X axis: Back Gate voltage Vbackgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)

[List Display]
Vbackgate: Back Gate voltage
Idrain: Drain current
Vsidegate: Side Gate voltage
ACC_TIME: Elapsed time

[Test Setup Details]
Refer to "CNT Id_Vg."
8.11 CNT Id-Vg-time [2HL]: CNT FET Id-Vg-Time characteristics (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the Id-Vg characteristics of CNT FET repeatedly at a specified interval until specified time elapses. This test is designed to use a gate electrode as a sensor and consider the adsorption of DNA and antibody to the gate electrode as a change in Ids. Used for evaluation of a time change in characteristics.

[Device Under Test]
Carbon Nano Tube FET, 4 terminals

[Device Parameters]
Polarity: Forward (SMUs force the specified value) or Reverse (SMUs force the negative specified value)
L: CNT length
D: CNT diameter
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
Drain: SMU connected to Drain, primary sweep voltage output
VdStart: Sweep start voltage for Drain
VdStop: Sweep stop voltage for Drain
VdStep: Sweep step voltage for Drain
BackGate: SMU connected to Back Gate, secondary sweep voltage output
VbgStart: Sweep start voltage for Back Gate
VbgStop: Sweep stop voltage for Back Gate
VbgStep: Sweep step voltage for Back Gate
T1Stop: T1 stop time
T1Step: T1 step time
T2Stop: T2 stop time
T2Step: T2 step time

[Extended Test Parameters]
IbgLimit: Back Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for drain current measurement

[Measurement Parameters]
Drain current Idrain
Time ACC_TIME
ACC_TIME is displayed after adding the sum of T1Step (or T2Step) and the actual measurement time.

\[ \text{ACC\_TIME} = \text{ACC\_TIME} + \text{T1Step (or T2Step)} + \text{Id-Vg measurement time} \]

[User Function]
- ACC_TIME: Elapsed time
- MaxTS: Maximum time stamp value

[X-Y Plot]
- X axis: Back Gate voltage Vbackgate (LINEAR)
- Y1 axis: Drain current Idrain (LINEAR)

[List Display]
- Vbackgate: Back Gate voltage
- Idrain: Drain current
- ACC_TIME: Elapsed time

[Test Setup Details]
- Refer to "CNT Id_Vg."
8.12 CNT IV Sweep: CNT Differential I-V characteristics (A.01.20)

[Supported Analyzer]

[Description]
Measures the I-V (current vs voltage) characteristics of a CNT 2-terminal device. This test definition allows one to select the direction of a sweep from "Single" and "Double." When the sweep start/stop value is not 0 V, outputs a sweep from 0 V to the start value or from the stop value to 0 V to protect a device.

[Device Under Test]
Carbon Nano Tube FET, 2 terminals

[Device Parameters]
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Port1: SMU connected to device under test, primary sweep voltage output
Port2: SMU connected to device under test, constant voltage output
V1Start: Sweep output start voltage
V1Stop: Sweep output stop voltage
V1Step: Sweep output step voltage
I1Limit: Port1 current compliance
SweepDirection: Sweep direction

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
V2: Port2 voltage
Y_Min: Minimum Y axis value
Y_Max: Maximum Y axis value
R_Max: Maximum Y axis resistance value
Port1MinRng: Minimum range for Port1 current measurement

[Measurement Parameters]
Iport1: Port1 current

[User Function]
Resistor terminal voltage DeltaV=Vport1-Vport2
Resistance R=DeltaV/Iport1

[X-Y Plot]
X axis: Voltage DeltaV (LINEAR)
Y1 axis: Measured current Iport1 (LINEAR)
Y2 axis: Resistance R (LINEAR)

[List Display]
DeltaV: Voltage
Iport1: Measured current
R: Resistance value
8.13 CNT IV Sweep [1HL]: CNT I-V characteristics (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the I-V (current vs voltage) characteristics of a CNT 2-terminal device. This test definition allows one to select the direction of a sweep from "Single" and "Double." When the sweep start/stop value is not 0 V, outputs a sweep from 0 V to the start value or from the stop value to 0 V to protect a device.

[Device Under Test]
Carbon Nano Tube FET, 2 terminals

[Device Parameters]
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Port1: SMU connected to device under test, primary sweep voltage output
V1Start: Sweep output start voltage
V1Stop: Sweep output stop voltage
V1Step: Sweep output step voltage
SweepDirection: Sweep direction

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
I1Limit: Port1 current compliance
Y_Min: Minimum Y axis value
Y_Max: Maximum Y axis value
R_Max: Maximum Y axis resistance value
Port1MinRng: Minimum range for Port1 current measurement

[Measurement Parameters]
Iport1: Port1 current

[User Function]
Resistor terminal voltage DeltaV=Vport1
Resistance R=DeltaV/Iport1

[X-Y Plot]
X axis: Voltage Vport1 or DeltaV (LINEAR)
Y1 axis: Measured current Iport1 (LINEAR)
Y2 axis: Resistance R (LINEAR)

[List Display]
DeltaV: Voltage
Iport1: Measured current
R: Resistance value
8.14 CNT R-I Kelvin 2SMU: CNT R-I characteristics, Kelvin connection (A.01.20)

[Supported Analyzer]

[Description]
Measures the electric resistance of a CNT 2-terminal device and plots R-I (resistance vs current) characteristics. This test is designed to apply a current between terminals of devices, measure a voltage and calculate resistance. Kelvin connection is used for connecting SMU to a device.

[Device Under Test]
Carbon Nano Tube FET, 2 terminals

[Device Parameters]
L: CNT length
D: CNT diameter
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Port1: SMU connected to resistor, primary sweep current output
I1Start: Sweep output start current
I1Stop: Sweep output stop current
I1Step: Sweep output step current
V1Limit: Port1 voltage compliance
Port2: SMU connected to resistor, constant voltage output

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
V2: Port2 voltage

[Measurement Parameters]
Vport1: Port1 voltage

[User Function]
Circular constant PI=3.141592653589
Resistor terminal voltage DeltaV=Vport1-Vport2
Resistance R=DeltaV/Iport1
Sheet resistance Rsheet=R*((PI*D)/L)

[X-Y Plot]
X axis: Current Iport1 (LINEAR)
Y1 axis: Resistance R (LINEAR)
Y2 axis: Measured voltage DeltaV (LINEAR)

[List Display]
Iport1: Input current
R: Resistance value
DeltaV: Resistor terminal voltage
Rsheet: Sheet resistance
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8.15 CNT R-V Kelvin 2SMU: CNT R-V characteristics, Kelvin connection (A.01.20)

[Supported Analyzer]

[Description]
Measures the electric resistance of a CNT 2-terminal device and plots R-V (resistance vs voltage) characteristics. This test is designed to apply a voltage between terminals of devices, measure a current and calculate the resistance. Kelvin connection is used for connecting SMU to a device.

[Device Under Test]
Carbon Nano Tube FET, 2 terminals

[Device Parameters]
L: CNT length
D: CNT diameter
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Port1: SMU connected to resistor, primary sweep voltage output
V1Start: Sweep output start voltage
V1Stop: Sweep output stop voltage
V1Step: Sweep output step voltage
I1Limit: Port1 current compliance
Port2: SMU connected to resistor, constant voltage output
V2: Port2 voltage

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
Port1MinRng: Minimum range for Port1 current measurement

[Measurement Parameters]
Iport1: Port1 current

[User Function]
Circular constant PI=3.141592653589
Resistor terminal voltage \Delta V=Vport1-Vport2
Resistance R=\Delta V/Iport1
Sheet resistance R_{sheet}=R*((PI*D)/L)

[X-Y Plot]
X axis: Voltage \Delta V (LINEAR)
Y1 axis: Measured current Iport1 (LINEAR)
Y2 axis: Resistance R (LINEAR)

[List Display]
\Delta V: Input voltage
Iport1: Measured current
R: Resistance value
R_{sheet}: Sheet resistance
8.16 CNT Vth gmMax: CNT FET linear region Vth (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Extracts the threshold voltage (Vth) from linear region data by using the extrapolation method for the measurement of CNT FET Id-Vg characteristics.

[Device Under Test]
Carbon Nano Tube FET, 4 terminals

[Device Parameters]
Polarity: Forward (SMUs force the specified value) or Reverse (SMUs force the negative specified value)
L: CNT length
D: CNT diameter
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
BackGate: SMU connected to Back Gate, primary sweep voltage output
VbgStart: Sweep start voltage for Back Gate
VbgStop: Sweep stop voltage for Back Gate
VbgStep: Sweep step voltage for Back Gate
Drain: SMU connected to Drain, constant voltage output
Vd: Drain voltage, ideally at around 100mV
SideGate: SMU connected to Side Gate, constant voltage output
Source: SMU connected to Source, constant voltage output

[Extended Test Parameters]
Vsg: Side Gate voltage
Vs: Source voltage
IbgLimit: Back Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
gm_Min: Minimum transconductance value for Y axis
gm_Max: Maximum transconductance value for Y axis
DrainMinRng: Minimum range for drain current measurement

[Measurement Parameters]
Drain current Idrain

[User Function]
gm=diff(Idrain,Vbackgate)

[Analysis Function]
gmMax=max(gm)
Von=@L1X (X intercept of Line1)
Vth=Von-Vd/2

Vth is given by the following formula.
Vth=Vg(gmMax)-Id(gmMax)/gmMax
Vd/2 is for compensation of the secondary term of Vd in the theoretical formula.
[Auto Analysis]
   Line1: Tangent line for Y1 at gm=gmMax

[X-Y Plot]
   X axis: Back Gate voltage Vbackgate (LINEAR)
   Y1 axis: Drain current Idrain (LINEAR)
   Y2 axis: Transconductance gm (LINEAR)
   Y3 axis: Drain current Idrain (LOG)

[List Display]
   Vbackgate: Back Gate voltage
   Vsource: Source voltage
   Vdrain: Drain voltage
   Vsidegate: Side Gate voltage
   Idrain: Drain current
   gm: Transconductance

[Parameters Display Area]
   Threshold voltage Vth
   Maximum transconductance value gmMax
8.17 CNT Vth gmMax [2HL]: CNT FET linear region Vth (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Extracts the threshold voltage (Vth) from linear region data by using the extrapolation method for the measurement of CNT FET Id-Vg characteristics.

[Device Under Test]
Carbon Nano Tube FET, 4 terminals

[Device Parameters]
Polarity: Forward (SMUs force the specified value) or Reverse (SMUs force the negative specified value)
L: CNT length
D: CNT diameter
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
BackGate: SMU connected to Back Gate, primary sweep voltage output
VbgStart: Sweep start voltage for Back Gate
VbgStop: Sweep stop voltage for Back Gate
VbgStep: Sweep step voltage for Back Gate
Drain: SMU connected to Drain, constant voltage output
Vd: Drain voltage, ideally at around 100mV

[Extended Test Parameters]
lbgLimit: Back Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
gm_Min: Minimum transconductance value for Y axis
gm_Max: Maximum transconductance value for Y axis
DrainMinRng: Minimum range for drain current measurement

[Measurement Parameters]
Drain current Idrain

[User Function]
gm=diff(Idrain,Vbackgate)

[Analysis Function]
gmMax=max(gm)
Von=@L1X (X intercept of Line1)
Vth= Von-Vd/2

Vth is given by the following formula.
Vth=Vg(gmMax)-Id(gmMax)/gmMax
Vd/2 is for compensation of the secondary term of Vd in the theoretical formula.

[Auto Analysis]
  Line1: Tangent line for Y1 at gm=gmMax

[X-Y Plot]
  X axis: Back Gate voltage Vbackgate (LINEAR)
  Y1 axis: Drain current Idrain (LINEAR)
  Y2 axis: Transconductance gm (LINEAR)
  Y3 axis: Drain current Idrain (LOG)

[List Display]
  Vbackgate: Back Gate voltage
  Vdrain: Drain voltage
  Idrain: Drain current
  gm: Transconductance

[Parameters Display Area]
  Threshold voltage Vth
  Maximum transconductance value gmMax
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1. 2-terminal dual IV sweep  2-terminal dual IV sweep (A.05.03.2013.0124_2013.01.28.1)
2. 2-terminal dual V sweep [1HL] (A.06.10)
9.1 2-terminal dual IV sweep (A.05.03.2013.0124_2013.01.28.1)

[Supported Analyzer]
B1500A

[Description]
Measures the voltage vs. current characteristics of 2-terminal device by sweeping as follows.
Vstart =(with Vstep1) => Vstop1 =(with Vstep1) => Vstart =(with Vstep2) => Vstop2=(with Vstep2) => Vstart

[Device Under Test]
2-terminal device

[Device Parameters]
Temp: Temperature

[Test Parameters]
Port1: SMU for terminal1, sweep voltage output
Port2: SMU/GNDU for terminal2, 0 V output
Vstart: Sweep start voltage
Vstop1: Sweep stop1 voltage
Vstep1: Sweep step1 voltage
Vstop2: Sweep step2 voltage
Vstep2: Sweep step2 voltage
IntegTime: Integration time
HoldTime: Hold time
DelayTime: Delay time
Compliance: Port1 current compliance

[Extended Test Parameters]
N/A

[Measurement Parameters]
Port1 measurement current I1

[User Function]
N/A

[Analysis Function]
N/A

[X-Y Plot]
X axis: V1: Port1 output voltage(LINEAR)
Y1 axis: I1: Port1 measurement current (LINEAR)

[List Display]
V1: Port1 output voltage
I1: Port1 measurement current

[Parameters Display Area]
N/A

[Auto Analysis]
N/A

[Note]
This measurement merges two double I/V sweep classic tests.
Vstart voltage holes between each tests by Bias Hold function.
9.2 2-terminal dual Vsweep [IHL] (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the voltage vs. current characteristics of 2-terminal device by sweeping as follows.
Vstart = (with Vstep1) = &gt; Vstop1 = (with Vstep1) = &gt; Vstart = (with Vstep2) = &gt; Vstop2 = (with Vstep2) = &gt; Vstart

[Device Under Test]
2-terminal device

[Device Parameters]
Temp: Temperature

[Test Parameters]
Port1: SMU for terminal1, sweep voltage output
Vstart: Sweep start voltage
Vstop1: Sweep stop1 voltage
Vstep1: Sweep step1 voltage
Vstop2: Sweep stop2 voltage
Vstep2: Sweep step2 voltage
IntegTime: Integration time
HoldTime: Hold time
DelayTime: Delay time
Compliance: Port1 current compliance
MinRange: Minimum range for the port1 current measurement

[Extended Test Parameters]
N/A

[Measurement Parameters]
Port1 measurement current I1

[User Function]
N/A

[Analysis Function]
N/A

[X-Y Plot]
X axis: V1: Port1 output voltage (LINEAR)
Y1 axis: I1: Port1 measurement current (LINEAR)

[List Display]
V1: Port1 output voltage
I1: Port1 measurement current

[Parameters Display Area]
N/A

[Auto Analysis]
N/A

[Note]
This measurement merges two double I/V sweep classic tests. Vstart voltage holes between each tests by Bias Hold function.
10 PwrDevice

1. **BVdss[3] PwrDevice**: Breakdown voltage between source and drain (A.01.20)
2. **BVgso[3] PwrDevice**: Breakdown voltage between gate and source (A.01.20)
3. **Id-Vd pulse[3] PwrDevice**: Id-Vd characteristics (3-terminal), SMU Pulse (A.01.20)
4. **Id-Vd[3] PwrDevice**: Id-Vd Characteristics (3-terminal) (A.01.20)
5. **Id-Vg pulse[3] PwrDevice**: Id-Vg characteristics (3-terminal), SMU Pulse (A.01.20)
6. **Id-Vg[3] PwrDevice**: Id-Vg Characteristics (3-terminal) (A.01.20)
7. **Vth Const Id[3] PwrDevice**: Constant current Vth (A.01.20)
8. **Vth gmMax[3] PwrDevice**: Linear region Vth (A.01.20)
10.1 BVdss[3] PwrDevice: Breakdown voltage between source and drain (A.01.20)

[Supported Analyzer]

[Description]
Measures the breakdown voltage between source and drain of a power MOSFET. Forces drain sweep voltage in the direction of FET on, and monitors breakdown.

[Device Under Test]
Power MOSFET, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Is@BVdss: Source current deemed to be a breakdown
Drain: SMU connected to Drain, primary sweep voltage output
VdStart: Sweep start voltage for Drain
VdStop: Sweep stop voltage for Drain
VdStep: Sweep step voltage for Drain
Gate: SMU connected to Gate, constant voltage output
Vg: Gate voltage
Source: SMU connected to Source, constant voltage output
BaseOffsetV: Base offset voltage

Base offset voltage is added to the specified voltage. For example, the gate start voltage will be VgStart+BaseOffsetV.

[Extended Test Parameters]
Vs: Source voltage
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for drain current measurement
GateMinRng: Minimum range for gate current measurement
IgLimit: Gate current compliance

[Measurement Parameters]
Drain current Idrain
Source current Isource

For the Source terminal, the SMU current compliance is set to Is@BVdss*1.1.

[User Function]
IsourcePerWg=Isource/Wg: Source current per unit gate width
IdrainPerWg=Idrain/Wg: Drain current per unit gate width

[Analysis Function]
10 PwrDevice

BVdss=\@L1X (X intercept of Line1)

[Auto Analysis]
Line1: Vertical line for Y2 at Isource=Is@BVdss

[X-Y Plot]
  X axis: Drain voltage Vdrain (LINEAR)
  Y1 axis: Drain current Idrain (LOG)
  Y2 axis: Source current Isource (LOG)

[List Display]
  Drain voltage Vdrain
  Drain current Idrain
  Source current Isource
  Gate current Igate
  Gate voltage Vgate
  Source voltage Vsource

[Parameters Display Area]
  Source-Drain breakdown voltage BVdss
10.2 BVgso[3] PwrDevice: Breakdown voltage between gate and source (A.01.20)

[Supported Analyzer]

[Description]
Measures the breakdown voltage between gate and source of a power MOSFET when drain is opened. Forces gate sweep voltage in the direction of FET off, and monitors breakdown.

[Device Under Test]
Power MOSFET, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Is@BVgso: Source current deemed to be a breakdown
Gate: SMU connected to Gate, primary sweep voltage output
VgStart: Sweep start voltage for Gate
VgStop: Sweep stop voltage for Gate
VgStep: Sweep step voltage for Gate
Source: SMU connected to Source, constant voltage output
BaseOffsetV: Base offset voltage

Base offset voltage is added to the specified voltage. For example, the gate start voltage will be VgStart+BaseOffsetV.

[Extended Test Parameters]
Vs: Source voltage
HoldTime: Hold time
DelayTime: Delay time
GateMinRng: Minimum range for gate current measurement
SourceMinRng: Minimum range for source current measurement

[Measurement Parameters]
Source current Isource
Gate current Igate

For the terminals, the SMU current compliance is set to Is@BVgso*1.1.

[User Function]
IgatePerGateArea=Igate/Lg/Wg: Gate current per unit gate area

[Analysis Function]
BVgso=@L1X (X intercept of Line1)

[Auto Analysis]
Line1: Vertical line for Y1 at Isource=Is@BVgso

[X-Y Plot]
10 PwrDevice

X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Source current Isource (LOG)
Y2 axis: Gate current Igate (LOG)

[List Display]
Gate voltage Vgate
Source current Isource
Gate current Igate
Source voltage Vsource

[Parameters Display Area]
Gate-Source breakdown voltage BVgso
10.3 Id-Vd pulse[3] PwrDevice: Id-Vd characteristics (3-terminal), SMU Pulse (A.01.20)

[Supported Analyzer]

[Description]
Measures the drain current vs drain voltage characteristics of a power MOSFET.

[Device Under Test]
Power MOSFET, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
Drain: SMU connected to Drain terminal, primary sweep voltage output
VdStart: Sweep start voltage for Drain terminal
VdStop: Sweep stop voltage for Drain terminal
VdStep: Sweep step voltage for Drain terminal
PulsePeriod: Pulse period
PulseWidth: Pulse width
Gate: SMU connected to Gate terminal, secondary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Source: SMU connected to Source terminal, constant voltage output
BaseOffsetV: Base offset voltage
Base offset voltage is added to the specified voltage. For example, the gate start voltage will be VgStart+BaseOffsetV.

[Extended Test Parameters]
Vs: Source voltage
IgLimit: Gate current compliance
BaseValue: Pulse base voltage
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Drain current Idrain

[User Function]
IdrainPerWg=Idrain/Wg: Drain current per unit gate width

[X-Y Plot]
X axis: Drain voltage Vdrain (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
List Display
Drain voltage Vdrain
Drain current Idrain
Source voltage Vs
Gate voltage Vgate
Drain current per unit gate width IdrainPerWg
10.4 *Id-Vd[3] PwrDevice: Id-Vd Characteristics (3-terminal) (A.01.20)*

[Supported Analyzer]

[Description]
Measures the drain current vs drain voltage characteristics of a power MOSFET.

[Device Under Test]
Power MOSFET, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
Drain: SMU connected to Drain terminal, primary sweep voltage output
VdStart: Sweep start voltage for Drain terminal
VdStop: Sweep stop voltage for Drain terminal
VdStep: Sweep step voltage for Drain terminal
Gate: SMU connected to Gate terminal, secondary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Source: SMU connected to Source terminal, constant voltage output
BaseOffsetV: Base offset voltage

Base offset voltage is added to the specified voltage. For example, the gate start voltage will be VgStart+BaseOffsetV.

[Extended Test Parameters]
Vs: Source voltage
IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for drain current measurement

[Measurement Parameters]
Drain current Idrain

[User Function]
IdrainPerWg=Idrain/Wg: Drain current per unit gate width

[X-Y Plot]
X axis: Drain voltage Vdrain (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)

[List Display]
Drain voltage Vdrain
Drain current Idrain
Gate voltage Vgate
Source voltage Vsource
Drain current per unit gate width IdrainPerWg
10.5 Id-Vg pulse[3] PwrDevice: Id-Vg characteristics (3-terminal), SMU Pulse (A.01.20)

[Supported Analyzer]

[Description]
Measures the drain current vs gate voltage characteristics of a power MOSFET.

[Device Under Test]
Power MOSFET, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
Gate: SMU connected to Gate terminal, primary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Drain: SMU connected to Drain terminal, secondary sweep voltage output
VdStart: Sweep start voltage for Drain terminal
VdStop: Sweep stop voltage for Drain terminal
VdStep: Sweep step voltage for Drain terminal
PulsePeriod: Pulse period
PulseWidth: Pulse width
Source: SMU connected to Source terminal, constant voltage output
BaseOffsetV: Base offset voltage

Base offset voltage is added to the specified voltage. For example, the gate start voltage will be VgStart+BaseOffsetV.

[Extended Test Parameters]
Vs: Source voltage
BaseValue: Pulse base voltage
IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Drain current Idrain

[User Function]
IdrainPerWg=Idrain/Wg: Drain current per unit gate width
gm=diff(Idrain,Vgate): gm: Transconductance
gmPerWg=diff(IdrainPerWg,Vgate): Transconductance per unit gate width

[X-Y Plot]
10 PwrDevice

X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)

[List Display]
Gate voltage Vgate
Source voltage Vsource
Drain voltage Vdrain
Drain current Idrain
Transconductance gm
Drain current per unit gate width IdrainPerWg
Transconductance per unit gate width gmPerWg
10.6 Id-Vg[3] PwrDevice: Id-Vg Characteristics (3-terminal) (A.01.20)

[Supported Analyzer]

[Description]
Measures the drain current vs gate voltage characteristics of a power MOSFET.

[Device Under Test]
Power MOSFET, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
Gate: SMU connected to Gate terminal, primary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Drain: SMU connected to Drain terminal, secondary sweep voltage output
VdStart: Sweep start voltage for Drain terminal
VdStop: Sweep stop voltage for Drain terminal
VdStep: Sweep step voltage for Drain terminal
Source: SMU connected to Source terminal, constant voltage output
BaseOffsetV: Base offset voltage

Base offset voltage is added to the specified voltage. For example, the gate start voltage will be VgStart+BaseOffsetV.

[Extended Test Parameters]
Vs: Source voltage
IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for drain current measurement

[Measurement Parameters]
Drain current Idrain

[User Function]
IdrainPerWg=Idrain/Wg: Drain current per unit gate width
gm=diff(Idrain,Vgate): gm: Transconductance
gmPerWg=diff(IdrainPerWg,Vgate): Transconductance per unit gate width

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)
10 PwrDevice

[List Display]
Gate voltage Vgate
Source voltage Vsource
Drain voltage Vdrain
Drain current Idrain
Transconductance gm
Drain current per unit gate width IdrainPerWg
Transconductance per unit gate width gmPerWg
10.7 Vth Const Id[3] PwrDevice: Constant current Vth (A.01.20)

[Supported Analyzer]

[Description]
   Measures the drain current vs gate voltage characteristics, and extracts the threshold voltage (Vth) by using the
   constant current method.

[Device Under Test]
   Power MOSFET, 3 terminals

[Device Parameters]
   Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
   Lg: Gate length
   Wg: Gate width
   Temp: Temperature
   IdMax: Drain current compliance

[Test Parameters]
   IntegTime: Integration time
   Id@Vth: Drain current to decide the Vth
   Gate: SMU connected to Gate terminal, primary sweep voltage output
   VgStart: Sweep start voltage for Gate terminal
   VgStop: Sweep stop voltage for Gate terminal
   VgStep: Sweep step voltage for Gate terminal
   Drain: SMU connected to Drain terminal, constant voltage output
   Vd: Drain voltage
   Source: SMU connected to Source terminal, constant voltage output
   BaseOffsetV: Base offset voltage

   Base offset voltage is added to the specified voltage. For example, the gate start voltage will be
   VgStart+BaseOffsetV.

[Extended Test Parameters]
   Vs: Source voltage
   IgLimit: Gate current compliance
   HoldTime: Hold time
   DelayTime: Delay time
   DrainMinRng: Minimum range for drain current measurement

[Measurement Parameters]
   Drain current Idrain

[User Function]
   gm=diff(Idrain,Vgate)

[Analysis Function]
   Vth=@L1X (X intercept of Line1)

[Auto Analysis]
   Line1: Vertical line for Y1 at Idrain=Id@Vth

[X-Y Plot]
10 PwrDevice

X axis: Gate voltage $V_{gate}$ (LINEAR)
Y1 axis: Drain current $I_{drain}$ (LINEAR)
Y2 axis: Drain current $I_{drain}$ (LOG)

[List Display]
Gate voltage $V_{gate}$
Drain current $I_{drain}$
Source voltage $V_{source}$
Drain voltage $V_{drain}$
Transconductance $g_m$

[Parameters Display Area]
Threshold voltage $V_{th}$
10.8 \textit{Vth gmMax[3]} \textit{PwrDevice: Linear region Vth (A.01.20)}

[Supported Analyzer]

[Description]
Extracts the threshold voltage (Vth) by using the extrapolation method for the linear region of the drain current vs gate voltage characteristics.

[Device Under Test]
Power MOSFET, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
Gate: SMU connected to Gate terminal, primary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Drain: SMU connected to Drain terminal, constant voltage output
Vd: Drain voltage, ideally at around 100mV
Source: SMU connected to Source terminal, constant voltage output
BaseOffsetV: Base offset voltage

Base offset voltage is added to the specified voltage. For example, the gate start voltage will be VgStart+BaseOffsetV.

[Extended Test Parameters]
Vs: Source voltage
IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
gm\_Min: Minimum gm value for graph scale
gm\_Max: Maximum gm value for graph scale
DrainMinRng: Minimum range for drain current measurement

[Measurement Parameters]
Drain current Idrain

[User Function]
gm=diff(Idrain,Vgate)

[Analysis Function]
gmMax=max(gm)
Von=@L1X (X intercept of Line1)
Vth=Von-Vd/2

Vth is given by the following formula.
Vth = Vg(gmMax) - Id(gmMax)/gmMax
Vd/2 is for compensation of the secondary term of Vd in the theoretical formula.

[Auto Analysis]
Line1: Tangent line for Y1 at gm=gmMax

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Transconductance gm (LINEAR)
Y3 axis: Drain current Idrain (LOG)

[List Display]
Gate voltage Vgate
Source voltage Vsource
Drain voltage Vdrain
Drain current Idrain
Transconductance gm

[Parameters Display Area]
Threshold voltage Vth
Maximum transconductance value gmMax
11 Reliability
11 Reliability

1. BJT EB RevStress 3devices:  
   Emitter-Base junction Reverse bias Stress test, 4 terminals, 3 devices (A.01.20)
2. BJT EB RevStress 3devices\[3\]:  
   Emitter-Base junction Reverse bias Stress test, 3 terminals, 3 devices (A.01.20)
3. BJT EB RevStress:  
   Emitter-Base junction Reverse bias Stress test, 4 terminals (A.01.20)
4. BJT EB RevStress2:  
   Emitter-Base junction Reverse bias Stress test, 4 terminals (A.03.10)
5. BJT EB RevStress[3]:  
   Emitter-Base junction Reverse bias Stress test, 3 terminals (A.01.20)
6. BJT EB RevStress2[3]:  
   Emitter-Base junction Reverse bias Stress test, 3 terminals (A.01.20)
7. BTI 3devices:  
   Bias Temperature Instability test, 4 terminals, 3 devices (A.01.20)
8. BTI 3devices[3]:  
   Bias Temperature Instability test, 3 terminals, 3 devices (A.01.20)
9. BTI:  
   Bias Temperature Instability test, 4 terminals (A.01.20)
10. BTI2:  
    Bias Temperature Instability test, 4 terminals (A.03.10)
11. BTI[3]:  
    Bias Temperature Instability test, 3 terminals (A.01.20)
12. BTI2[3]:  
    Bias Temperature Instability test, 3 terminals (A.03.10)
13. Charge Pumping:  
    Evaluation of the interface state using charge pumping method (A.01.20)
14. Charge Pumping2:  
    Evaluation of the interface state using charge pumping method (A.03.10)
15. EM Istress:  
    Electromigration test, current stressed, 4 SMUs (A.01.20)
16. EM Istress2:  
    Electromigration test, current stressed, 4 SMUs (A.03.10)
17. EM Istress[2]:  
    Electromigration test, current stressed, 2 SMUs (A.01.20)
18. EM Istress2[2]:  
    Electromigration test, current stressed, 2 SMUs (A.03.10)
19. EM Istress[6]:  
    Electromigration test, current stressed, 6 SMUs (A.01.20)
20. EM Istress2[6]:  
    Electromigration test, current stressed, 6 SMUs (A.03.10)
21. EM Vstress:  
    Electromigration test, voltage stressed, 4 SMUs (A.01.20)
22. EM Vstress2:  
    Electromigration test, voltage stressed, 4 SMUs (A.03.10)
23. EM Vstress[2]:  
    Electromigration test, voltage stressed, 2 SMUs (A.01.20)
24. EM Vstress2[2]:  
    Electromigration test, voltage stressed, 2 SMUs (A.03.10)
25. EM Vstress[6]:  
    Electromigration test, voltage stressed, 6 SMUs (A.01.20)
26. EM Vstress2[6]:  
    Electromigration test, voltage stressed, 6 SMUs (A.03.10)
27. HCI 3devices:  
    Hot Carrier Injection test, 4 terminals, 3 devices (A.01.20)
28. HCI:  
    Hot Carrier Injection test, 4 terminals (A.01.20)
29. HCI2:  
    Hot Carrier Injection test, 4 terminals (A.03.10)
30. J-Ramp:  
    Insulator lifetime evaluation, current stressed (A.01.20)
31. TDDB Istress 3devices:  
    TDDB Test, current stressed, 3 devices (A.01.20)
32. TDDB Istress2 3devices:  
    TDDB Test, current stressed, 3 devices (A.03.10)
33. TDDB Istress:  
    TDDB Test, current stressed (A.01.20)
34. TDDB Istress2:  
    TDDB Test, current stressed (A.03.10)
35. TDDB Vstress 3devices:  
    TDDB Test, voltage stressed, 3 devices (A.01.20)
36. TDDB Vstress2 3devices:  
    TDDB Test, voltage stressed, 3 devices (A.03.10)
37. TDDB Vstress:  
    TDDB Test, voltage stressed (A.01.20)
38. TDDB Vstress2:  
    TDDB Test, voltage stressed (A.03.10)
39. Timing On-the-fly NBTI  
    Timing On-the-fly NBTI Test (A.03.11)
40. Timing On-the-fly NBTI –Mch  
    Negative Bias Temperature Instability Test (A.05.03)
41. TZDB:  
    TZDB Test of oxide layer (A.01.20)
42. V-Ramp:  
    Insulator lifetime evaluation, voltage stressed (A.01.20)
11.1 BJT EB RevStress 3devices: Emitter-Base junction Reverse bias Stress test, 4 terminals, 3 devices (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Performs the bipolar transistor Emitter-Base junction reverse bias stress test, and plots the accumulated stress time vs collector current/base current/current amplification factor characteristics. Maximum three devices can be measured by a test execution. This test is performed as follows.
1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

[Device Under Test]
Bipolar transistor, 4 terminals, 3 devices

[Required Accessories]
Keysight B2200A or B2201A switching matrix 1 unit
GPIB cable

Connect B2200A/B2201A to B1500A with a measuring cable and GPIB cable.
Set information on B1500A SMU channel's connection to the B2200A/B2201A input port properly on the Switching Matrix tab screen of the Configuration window.
Set the output channel number of B2200A/B2201A connected to each terminal of a device under test properly in the Tr#Base/Tr#Collector/Tr#Emitter/Tr#Subs field (# is an integer from 1 to 3) of Test Parameters area.

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value)
Le: Emitter length
We: Emitter width
Temp: Temperature (deg C)
IcMax: Maximum collector current value

[Test Parameters]
IntegTime: Integration time (SHORT, MEDIUM, LONG)
Tr#Base: SWM Pin Assign setting for Base of devices
Tr#Collector: SWM Pin Assign setting for Collector of devices
Tr#Emitter: SWM Pin Assign setting for Emitter of devices
Tr#Subs: SWM Pin Assign setting for Subs of devices
where, # is an integer from 1 to 3.

[Test Parameters for Sampling_Stress]
TotalStrsTime: Total stress time
Tr#StrsEmitter: SMU connected to Emitter terminal of devices, constant voltage output
StrsBase: SMU connected to Base terminal, constant voltage output
StrsCollector: SMU connected to Collector terminal, constant voltage output
StrsSubs: SMU connected to Substrate terminal, constant voltage output
Tr#VeStrs: Stress voltage for Emitter terminal of devices
where, # is an integer from 1 to 3.
11 Reliability

[Test Parameters for IvSweep_hfe]
MeasCollector: SMU connected to Collector terminal, constant voltage output
MeasBase: SMU connected to Base terminal, voltage output
MeasEmitter: SMU connected to Emitter terminal, primary sweep constant voltage output
MeasSubs: SMU connected to Substrate terminal, constant voltage output
VbStart: Sweep start voltage for Base terminal
VbStop: Sweep stop voltage for Base terminal
VbStep: Sweep step voltage for Base terminal
Ic@hfe: Collector current determining the hfe
Vc: Collector voltage

[Extended Test Parameters]
[Extended Test Parameters for Sampling_Stress]
VbStrs: Stress voltage for Base terminal
VcStrs: Stress voltage for Collector terminal
VsubsStrs: Stress voltage for Substrate terminal
IeStrsLimit: Emitter current compliance

[Extended Test Parameters for IvSweep_hfe]
IsubsLimit: Substrate current compliance
Ve: Emitter voltage
Vsubs: Substrate voltage
hfe_Min: Minimum hfe value for graph scale
hfe_Max: Maximum hfe value for graph scale
HoldTime: Hold time
DelayTime: Delay time
BaseMinRng1: Minimum range for base current measurement on device 1
BaseMinRng2: Minimum range for base current measurement on device 2
BaseMinRng3: Minimum range for base current measurement on device 3
CollectorMinRng1: Minimum range for collector current measurement on device 1
CollectorMinRng2: Minimum range for collector current measurement on device 2
CollectorMinRng3: Minimum range for collector current measurement on device 3

[User Function]
[User Function for Sampling_Stress]
Maximum elapsed time value MaxTime=max(Time)
Stress time StressTime=AccTime+Time

[User Function for IvSweep_hfe]
Current amplification factor hfe=Icollector/Ibase

[Analysis Function]
[Analysis Function for IvSweep_hfe]
Ib@Ic=@L1X (X intercept of Line1)
hfe@Ic=@L2Y3 (X intercept of Line2)

[Auto Analysis]
[Auto Analysis for IvSweep_hfe]
Line1: Horizontal line for Y1 at Icollector=Ic@hfe
Line2: Horizontal line for Y3 at Icollector=Ic@hfe

[Test Output: X-Y Graph]
X axis: Accumulated stress time TimeList (LOG)
Y1 axis: Collector current for device 1 Dev1_IcList (LINEAR)
Y2 axis: Collector current for device 2 Dev2_IcList (LINEAR)
Y3 axis: Collector current for device 3 Dev3_IcList (LINEAR)
Y4 axis: Y3 accumulation data at Icollector=Ic@hfe for device 1 Dev1_hfe@IcList (LINEAR)
Y5 axis: Y3 accumulation data at Icollector=Ic@hfe for device 2 Dev2_hfe@IcList (LINEAR)
Y6 axis: Y3 accumulation data at Icollector=Ic@hfe for device 3 Dev3_hfe@IcList (LINEAR)

[Test Output: List Display]
  TimeList: Accumulated stress time
  Dev1_IcList: Collector current for device 1
  Dev2_IcList: Collector current for device 2
  Dev3_IcList: Collector current for device 3
  Dev1_hfe@IcList: Y3 accumulation data at Icollector=Ic@hfe for device 1
  Dev2_hfe@IcList: Y3 accumulation data at Icollector=Ic@hfe for device 2
  Dev3_hfe@IcList: Y3 accumulation data at Icollector=Ic@hfe for device 3
  Dev1_Ib@IcList: Y1 accumulation data at Icollector=Ic@hfe for device 1
  Dev2_Ib@IcList: Y1 accumulation data at Icollector=Ic@hfe for device 2
  Dev3_Ib@IcList: Y1 accumulation data at Icollector=Ic@hfe for device 3
11.2 BJT EB RevStress 3devices[3]: Emitter-Base junction Reverse bias Stress test, 3 terminals, 3 devices (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Performs the bipolar transistor Emitter-Base junction reverse bias stress test, and plots the accumulated stress time vs collector current/base current/current amplification factor characteristics.
This test is performed as follows.
1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

[Device Under Test]
Bipolar transistor, 3 terminals, 3 devices

[Required Accessories]
Keysight B2200A or B2201A switching matrix 1 unit
GPIB cable

Connect B2200A/B2201A to B1500A with a measuring cable and GPIB cable.
Set information on B1500A SMU channel's connection to the B2200A/B2201A input port properly on the Switching Matrix tab screen of the Configuration window.
Set the output channel number of B2200A/B2201A connected to each terminal of a device under test properly in the Tr#Base/Tr#Collector/Tr#Emitter field (# is an integer from 1 to 3) of Test Parameters area.

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value)
Le: Emitter length
We: Emitter width
Temp: Temperature (deg C)
IcMax: Maximum collector current value

[Test Parameters]
IntegTime: Integration time (SHORT, MEDIUM, LONG)
Tr#Base: SWM Pin Assign setting for Base of devices
Tr#Collector: SWM Pin Assign setting for Collector of devices
Tr#Emitter: SWM Pin Assign setting for Emitter of devices
where, # is an integer from 1 to 3.

[Test Parameters for Sampling_Stress]
TotalStrsTime: Total stress time
Tr#StrsEmitter: SMU connected to Emitter terminal of devices, constant voltage output
StrsBase: SMU connected to Base terminal, constant voltage output
StrsCollector: SMU connected to Collector terminal, constant voltage output
Tr#VeStrs: Stress voltage for Emitter terminal of devices
where, # is an integer from 1 to 3.

[Test Parameters for IvSweep_hfe]
MeasCollector: SMU connected to Collector terminal, constant voltage output
MeasBase: SMU connected to Base terminal, voltage output
MeasEmitter: SMU connected to Emitter terminal, primary sweep constant voltage output
VbStart: Sweep start voltage for Base terminal
VbStop: Sweep stop voltage for Base terminal
VbStep: Sweep step voltage for Base terminal
Ic@hfe: Collector current determining the hfe
Vc: Collector voltage

[Extended Test Parameters]
[Extended Test Parameters for Sampling_Stress]
VbStrs: Stress voltage for Base terminal
VcStrs: Stress voltage for Collector terminal
IeStrsLimit: Emitter current compliance

[Extended Test Parameters for IvSweep_hfe]
Ve: Emitter voltage
hfe_Min: Minimum hfe value for graph scale
hfe_Max: Maximum hfe value for graph scale
HoldTime: Hold time
DelayTime: Delay time
BaseMinRng1: Minimum range for base current measurement on device 1
BaseMinRng2: Minimum range for base current measurement on device 2
BaseMinRng3: Minimum range for base current measurement on device 3
CollectorMinRng1: Minimum range for collector current measurement on device 1
CollectorMinRng2: Minimum range for collector current measurement on device 2
CollectorMinRng3: Minimum range for collector current measurement on device 3

[User Function]
[User Function for Sampling_Stress]
Maximum elapsed time value MaxTime=max(Time)
Stress time StressTime=AccTime+Time

[User Function for IvSweep_hfe]
Current amplification factor hfe=Icollector/Ibase

[Analysis Function]
[Analysis Function for IvSweep_hfe]
Ib@Ic=−L1X (X intercept of Line1)
hfe@Ic=−L2Y3 (X intercept of Line2)

[Auto Analysis]
[Auto Analysis for IvSweep_hfe]
Line1: Horizontal line for Y1 at Icollector=Ic@hfe
Line2: Horizontal line for Y3 at Icollector=Ic@hfe

[Test Output: X-Y Graph]
X axis: Accumulated stress time TimeList (LOG)
Y1 axis: Collector current for device 1 Dev1_IcList (LINEAR)
Y2 axis: Collector current for device 2 Dev2_IcList (LINEAR)
Y3 axis: Collector current for device 3 Dev3_IcList (LINEAR)
Y4 axis: Y3 accumulation data at Icollector=Ic@hfe for device 1 Dev1_hfe@IcList (LINEAR)
Y5 axis: Y3 accumulation data at Icollector=Ic@hfe for device 2 Dev2_hfe@IcList (LINEAR)
Y6 axis: Y3 accumulation data at Icollector=Ic@hfe for device 3 Dev3_hfe@IcList (LINEAR)
11 Reliability

[Test Output: List Display]
TimeList: Accumulated stress time
Dev1_IcList: Collector current for device 1
Dev2_IcList: Collector current for device 2
Dev3_IcList: Collector current for device 3
Dev1_hfe@IcList: Y3 accumulation data at Icollector=Ic@hfe for device 1
Dev2_hfe@IcList: Y3 accumulation data at Icollector=Ic@hfe for device 2
Dev3_hfe@IcList: Y3 accumulation data at Icollector=Ic@hfe for device 3
Dev1_Ib@IcList: Y1 accumulation data at Icollector=Ic@hfe for device 1
Dev2_Ib@IcList: Y1 accumulation data at Icollector=Ic@hfe for device 2
Dev3_Ib@IcList: Y1 accumulation data at Icollector=Ic@hfe for device 3
11.3 **BJT EB RevStress: Emitter-Base junction Reverse bias Stress test, 4 terminals (A.01.20)**

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Performs the bipolar transistor Emitter-Base junction reverse bias stress test, and plots the accumulated stress time vs collector current/base current/current amplification factor characteristics.
This test is performed as follows.
1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

[Device Under Test]
Bipolar transistor, 4 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value)
Le: Emitter length
We: Emitter width
Temp: Temperature (deg C)
IcMax: Maximum collector current value

[Test Parameters]
IntegTime: Integration time (SHORT, MEDIUM, LONG)
TotalStressTime: Total stress time
Collector: SMU connected to Collector terminal, constant voltage output
Base: SMU connected to Base terminal, constant voltage output
Emitter: SMU connected to Emitter terminal, primary sweep voltage output
Subs: SMU connected to Substrate terminal, constant voltage output

[Test Parameters for Sampling_Stress]
VeStress: Stress voltage for Emitter terminal

[Test Parameters for IvSweep_hfe]
Ic@hfe: Collector current determining the hfe
VbStart: Sweep start voltage for Base terminal
VbStop: Sweep stop voltage for Base terminal
VbStep: Sweep step voltage for Base terminal
Vc: Collector voltage

[Extended Test Parameters]
[Extended Test Parameters for Sampling_Stress]
IeStressLimit: Emitter current compliance
VbStress: Stress voltage for Base terminal
VcStress: Stress voltage for Collector terminal
VsubsStress: Stress voltage for Substrate terminal
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[Extended Test Parameters for IvSweep_hfe]
HoldTime: Hold time
DelayTime: Delay time
IsubsLimit: Substrate current compliance
BaseMinRng: Minimum range for base current measurement
CollectorMinRng: Minimum range for collector current measurement
Ve: Emitter voltage
Vsubs: Substrate voltage
hfe_Min: Minimum hfe value for graph scale
hfe_Max: Maximum hfe value for graph scale

[User Function]
[User Function for Sampling_Stress]
Maximum elapsed time value MaxTime=max(Time)
Stress time StressTime=AccTime+Time

[User Function for IvSweep_hfe]
Current amplification factor hfe=Icollector/Ibase

[Analysis Function]
[Analysis Function for IvSweep_hfe]
Ib@Ic=@L1X (X intercept of Line1)
hfe@Ic=@L2Y3 (X intercept of Line2)

[Auto Analysis]
[Auto Analysis for IvSweep_hfe]
Line1: Horizontal line for Y1 at Icollector=Ic@hfe
Line2: Horizontal line for Y3 at Icollector=Ic@hfe

[Test Output: X-Y Graph]
X axis: Accumulated stress time TimeList (LOG)
Y1 axis: Collector current IcList (LOG)
Y2 axis: Y1 accumulation data at Icollector=Ic@hfe  Ib@IcList (LOG)
Y3 axis: Y3 accumulation data at Icollector=Ic@hfe  hfe@IcList (LINEAR)

[Test Output: List Display]
Accumulated stresss time TimeList
Collector current IcList
Y1 accumulation data at Icollector=Ic@hfe  Ib@IcList
Y3 accumulation data at Icollector=Ic@hfe  hfe@IcList
11.4 BJT EB RevStress2: Emitter-Base junction Reverse bias Stress test, 4 terminals (A.03.10)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Performs the bipolar transistor Emitter-Base junction reverse bias stress test, and plots the accumulated stress time vs collector current/base current/current amplification factor characteristics.
This test is performed as follows.
1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

[Device Under Test]
Bipolar transistor, 4 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value)
Le: Emitter length
We: Emitter width
Temp: Temperature (deg C)
IcMax: Maximum collector current value

[Test Parameters]
IntegTime: Integration time (SHORT, MEDIUM, LONG)
TotalStressTime: Total stress time
Collector: SMU connected to Collector terminal, constant voltage output
Base: SMU connected to Base terminal, constant voltage output
Emitter: SMU connected to Emitter terminal, primary sweep voltage output
Subs: SMU connected to Substrate terminal, constant voltage output
MeasTiming: Timing to measure device parameter
hfeStopRate: Hfe change rate to stop measurement

[Test Parameters for Sampling_Stress]
VeStress: Stress voltage for Emitter terminal
VbStress: Stress voltage for Base terminal
VcStress: Stress voltage for Collector terminal
VsubsStress: Stress voltage for Substrate terminal
IeStressLimit: Emitter current compliance

[Test Parameters for IvSweep_hfe]
Ic@hfe: Collector current determining the hfe
VbStart: Sweep start voltage for Base terminal
VbStop: Sweep stop voltage for Base terminal
VbStep: Sweep step voltage for Base terminal
Vc: Collector voltage

[Extended Test Parameters]
StoringRuntimeData: Data save during stress output, Yes or No
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[Extended Test Parameters for IvSweep_hfe]
HoldTime: Hold time
DelayTime: Delay time
IsubsLimit: Substrate current compliance
BaseMinRng: Minimum range for base current measurement
CollectorMinRng: Minimum range for collector current measurement
Ve: Emitter voltage
Vsubs: Substrate voltage
hfe_Min: Minimum hfe value for graph scale
hfe_Max: Maximum hfe value for graph scale

[Measurement Parameters]
[Measurement Parameters by Sampling_Stress]
Emitter current Iemitter

[Measurement Parameters by IvSweep_hfe]
Base current Ibase
Collector current Icollector

[User Function]
[User Function for IvSweep_hfe]
Current amplification factor hfe=Icollector/Ibase

[Analysis Function]
[Analysis Function for IvSweep_hfe]
Ib@Ic=@L1X (X intercept of Line1)
hfe@Ic=@L2Y3 (X intercept of Line2)

[Auto Analysis]
[Auto Analysis for IvSweep_hfe]
Line1: Horizontal line for Y1 at Icollector=Ic@hfe
Line2: Horizontal line for Y3 at Icollector=Ic@hfe

[X-Y Graph]
[X-Y Graph for Sampling_Stress]
X axis: Stress time StressTime (LINEAR)
Y1 axis: Emitter current Iemitter (LOG)

[X-Y Graph for IvSweep_hfe]
X axis: Base voltage Vbase (LINEAR)
Y1 axis: Base current Ibase (LOG)
Y2 axis: Collector current Icollector (LOG)
Y3 axis: Current amplification factor hfe (LINEAR)

[List Display]
[List Display for Sampling_Stress]
Stress time StressTime
Elapsed time Time
Emitter voltage Vemitter
Emitter current Iemitter
Base current Ibase

[List Display for IvSweep_hfe]
Emitter voltage Vemitter
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Base voltage $V_{\text{base}}$
Collector voltage $V_{\text{collector}}$
Base current $I_{\text{base}}$
Collector current $I_{\text{collector}}$
Current amplification factor $h_{\text{fe}}$

[Parameters]
[Parameters for IvSweep_hfe]
Base current $I_b$ at $I_c@h_{\text{fe}}$ $I_b@I_c$
Current amplification factor $h_{\text{fe}}$ at $I_c@h_{\text{fe}}$ $h_{\text{fe}}@I_c$

[Test Output: X-Y Graph]
X axis: Accumulated stress time $\text{TimeList (LOG)}$
Y1 axis: Collector current $I_{\text{cList (LINEAR)}}$
Y2 axis: Y1 accumulation data at $I_{\text{collector}=I_c@h_{\text{fe}}}$ $I_b@I_{\text{cList (LOG)}}$
Y3 axis: Y3 accumulation data at $I_{\text{collector}=I_c@h_{\text{fe}}}$ $h_{\text{fe}}@I_{\text{cList (LINEAR)}}$

[Test Output: List Display]
Accumulated stresss time $\text{TimeList}$
Collector current $I_{\text{cList}}$
Y1 accumulation data at $I_{\text{collector}=I_c@h_{\text{fe}}}$ $I_b@I_{\text{cList}}$
Y3 accumulation data at $I_{\text{collector}=I_c@h_{\text{fe}}}$ $h_{\text{fe}}@I_{\text{cList}}$
11 Reliability

11.5 BJT EB RevStress[3]: Emitter-Base junction Reverse bias Stress test, 3 terminals (A.01.20)

[Supported Analyzer]

[Description]
Performs the bipolar transistor Emitter-Base junction reverse bias stress test, and plots the accumulated stress time vs collector current/base current/current amplification factor characteristics.
This test is performed as follows.
1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

[Device Under Test]
Bipolar transistor, 3 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value)
Le: Emitter length
We: Emitter width
Temp: Temperature (deg C)
IcMax: Maximum collector current value

[Test Parameters]
IntegTime: Integration time (SHORT, MEDIUM, LONG)
TotalStressTime: Total stress time
Collector: SMU connected to Collector terminal, constant voltage output
Base: SMU connected to Base terminal, constant voltage output
Emitter: SMU connected to Emitter terminal, primary sweep voltage output

[Test Parameters for Sampling_Stress]
VeStress: Stress voltage for Emitter terminal

[Test Parameters for IvSweep_hfe]
Ic@hfe: Collector current determining the hfe
VbStart: Sweep start voltage for Base terminal
VbStop: Sweep stop voltage for Base terminal
VbStep: Sweep step voltage for Base terminal
Vc: Collector voltage

[Extended Test Parameters]
[Extended Test Parameters for Sampling_Stress]
IeStressLimit: Emitter current compliance
VBStress: Stress voltage for Base terminal
VCStress: Stress voltage for Collector terminal

[Extended Test Parameters for IvSweep_hfe]
HoldTime: Hold time
DelayTime: Delay time
BaseMinRng: Minimum range for base current measurement
CollectorMinRng: Minimum range for collector current measurement
Ve: Emitter voltage
hfe Min: Minimum hfe value for graph scale
hfe Max: Maximum hfe value for graph scale

[User Function]
[User Function for Sampling_Stress]
Maximum elapsed time value MaxTime=max(Time)
Stress time StressTime=AccTime+Time

[User Function for IvSweep_hfe]
hfe=Icollector/Ibase

[Analysis Function]
[Analysis Function for IvSweep_hfe]
Ib@Ic=@L1X (X intercept of Line1)
hfe@Ic=@L2Y3 (X intercept of Line2)

[Auto Analysis]
[Auto Analysis for IvSweep_hfe]
Line1: Horizontal line for Y1 at Icollector=Ic@hfe
Line2: Horizontal line for Y3 at Icollector=Ic@hfe

[Test Output: X-Y Graph]
X axis: Accumulated stress time TimeList (LOG)
Y1 axis: Collector current IcList (LOG)
Y2 axis: Y1 accumulation data at Icollector=Ic@hfe  Ib@IcList (LOG)
Y3 axis: Y3 accumulation data at Icollector=Ic@hfe  Ihfe@IcList (LINEAR)

[Test Output: List Display]
Accumulated stresss time TimeList
Collector current IcList
Y1 accumulation data at Icollector=Ic@hfe  Ib@IcList
Y3 accumulation data at Icollector=Ic@hfe  hfe@IcList
11 Reliability

11.6 BJT EB RevStress2[3]: Emitter-Base junction Reverse bias Stress test, 3 terminals (A.03.10)

[Supported Analyzer]

[Description]
Performs the bipolar transistor Emitter-Base junction reverse bias stress test, and plots the accumulated stress time vs collector current/base current/current amplification factor characteristics. This test is performed as follows.
1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

[Device Under Test]
Bipolar transistor, 3 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value)
Le: Emitter length
We: Emitter width
Temp: Temperature (deg C)
IcMax: Maximum collector current value

[Test Parameters]
IntegTime: Integration time (SHORT, MEDIUM, LONG)
TotalStressTime: Total stress time
Collector: SMU connected to Collector terminal, constant voltage output
Base: SMU connected to Base terminal, constant voltage output
Emitter: SMU connected to Emitter terminal, primary sweep voltage output
MeasTiming: Timing to measure device parameter
hfeStopRate: Hfe change rate to stop measurement

[Test Parameters for Sampling_Stress]
VeStress: Stress voltage for Emitter terminal
VbStress: Stress voltage for Base terminal
VcStress: Stress voltage for Collector terminal
IeStressLimit: Emitter current compliance

[Test Parameters for IvSweep_hfe]
Ic@hfe: Collector current determining the hfe
VbStart: Sweep start voltage for Base terminal
VbStop: Sweep stop voltage for Base terminal
VbStep: Sweep step voltage for Base terminal
Vc: Collector voltage

[Extended Test Parameters]
StoringRuntimeData: Data save during stress output, Yes or No

[Extended Test Parameters for IvSweep_hfe]
Ve: Emitter voltage
HoldTime: Hold time
DelayTime: Delay time
BaseMinRng: Minimum range for base current measurement
CollectorMinRng: Minimum range for collector current measurement
hfe_Min: Minimum hfe value for graph scale
hfe_Max: Maximum hfe value for graph scale

[Measurement Parameters]
[Measurement Parameters by Sampling_Stress]
Emitter current Iemitter

[Measurement Parameters by IvSweep_hfe]
Base current Ibase
Collector current Icollector

[User Function]
[User Function for IvSweep_hfe]
hfe=Icollector/Ibase

[Analysis Function]
[Analysis Function for IvSweep_hfe]
Ib@Ic=@L1X (X intercept of Line1)
hfe@Ic=@L2Y3 (X intercept of Line2)

[Auto Analysis]
[Auto Analysis for IvSweep_hfe]
Line1: Horizontal line for Y1 at Icollector=Ic@hfe
Line2: Horizontal line for Y3 at Icollector=Ic@hfe

[X-Y Graph]
[X-Y Graph for Sampling_Stress]
X axis: Stress time StressTime (LINEAR)
Y1 axis: Emitter current Iemitter (LOG)

[X-Y Graph for IvSweep_hfe]
X axis: Base voltage Vbase (LINEAR)
Y1 axis: Base current Ibase (LOG)
Y2 axis: Collector current Icollector (LOG)
Y3 axis: Current amplification factor hfe (LINEAR)

[List Display]
[List Display for Sampling_Stress]
Stress time StressTime
Elapsed time Time
Emitter voltage Vemitter
Emitter current Iemitter
Base current Ibase

[List Display for IvSweep_hfe]
Emitter voltage Vemitter
Base voltage Vbase
Collector voltage Vcollector
Base current Ibase
Collector current Icollector
Current amplification factor hfe
11 Reliability

[Parameters]
[Parameters for IvSweep_hfe]
Base current Ib at Ic@hfe Ib@Ic
Current amplification factor hfe at Ic@hfe hfe@Ic

[Test Output: X-Y Graph]
X axis: Accumulated stress time TimeList (LOG)
Y1 axis: Collector current IcList (LINEAR)
Y2 axis: Y1 accumulation data at Icollector=Ic@hfe Ib@IcList (LOG)
Y3 axis: Y3 accumulation data at Icollector=Ic@hfe hfe@IcList (LINEAR)

[Test Output: List Display]
Accumulated stresss time TimeList
Collector current IcList
Y1 accumulation data at Icollector=Ic@hfe Ib@IcList
Y3 accumulation data at Icollector=Ic@hfe hfe@IcList
11.7 BTI 3devices: Bias Temperature Instability test, 4 terminals, 3 devices (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Performs the bias temperature instability test, and plots the accumulated stress time vs threshold voltage/drain current characteristics. Maximum three devices can be measured by a test execution. This test is performed as follows.
1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

[Device Under Test]
MOSFET, 4 terminals, 3 devices

[Required Accessories]
Keysight B2200A or B2201A switching matrix 1 unit
GPIB cable

Connect B2200A/B2201A to B1500A with a measuring cable and GPIB cable.
Set information on B1500A SMU channel's connection to the B2200A/B2201A input port properly on the Switching Matrix tab screen of the Configuration window.
Set the output channel number of B2200A/B2201A connected to each terminal of a device under test properly in the Tr#Gate/Tr#Drain/Tr#Source/Tr#Subs field (# is an integer from 1 to 3) of Test Parameters area.

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value)
Lg: Gate length
Wg: Gate width
Temp: Temperature (deg C)

[Test Parameters]
IntegTime: Integration time (SHORT, MEDIUM, LONG)
Tr#Gate: SWM Pin Assign settings for Gate terminal of devices
Tr#Drain: SWM Pin Assign settings for Drain terminal of devices
Tr#Source: SWM Pin Assign settings for Source terminal of devices
Tr#Subs: SWM Pin Assign settings for Substrate terminal of devices
where, # is an integer from 1 to 3.

[Test Parameters for Sampling_Stress]
TotalStrsTime: Total stress time
Tr#StrsGate: SMU connected to Gate terminal of devices, constant voltage output
StrsSource: SMU connected to Gate terminal of devices, constant voltage output (drain/subs short)
Tr#VgStrs: Gate terminal stress voltage for the devices
VsStrs: Source terminal stress voltage
where, # is an integer from 1 to 3.
11 Reliability

[Test Parameters for IvSweep_ConstId]
MeasGate: SMU connected to the basic characteristics acquisition Gate terminal, primary sweep voltage output
MeasDrain: SMU connected to the basic characteristics acquisition Drain terminal, constant voltage output
MeasSource: SMU connected to the basic characteristics acquisition Source terminal, constant voltage output
Id@Vth: Drain current to decide the Vth, per unit area
VgStart1: Sweep start voltage for Gate terminal
VgStop1: Sweep stop voltage for Gate terminal
VgStep1: Sweep step voltage for Gate terminal
Vd1: Drain terminal voltage, constant value

[Test Parameters for IvSweep_gmmax]
MeasGate: SMU connected to the basic characteristics acquisition Gate terminal, primary sweep voltage output
MeasDrain: SMU connected to the basic characteristics acquisition Drain terminal, constant voltage output
MeasSource: SMU connected to the basic characteristics acquisition Source terminal, constant voltage output
VgStart2: Sweep start voltage for Gate terminal
VgStop2: Sweep stop voltage for Gate terminal
VgStep2: Sweep step voltage for Gate terminal
Vd2: Drain voltage

[Test Parameters for Sampling_Ids]
MeasGate: SMU connected to the basic characteristics acquisition Gate terminal, primary sweep voltage output
MeasDrain: SMU connected to the basic characteristics acquisition Drain terminal, constant voltage output
MeasSource: SMU connected to the basic characteristics acquisition Source terminal, constant voltage output
Vg3: Gate terminal voltage
Vd3: Drain terminal voltage

[Extended Test Parameters]
[Extended Test Parameters for IvSweep_ConstId]
HoldTime: Hold time
DelayTime: Delay time
Vs: Source terminal voltage, constant voltage
IgLimit: Gate current compliance
IdLimit: Drain current compliance
DrainMinRng1: Minimum range for drain current measurement on device 1
DrainMinRng2: Minimum range for drain current measurement on device 1
DrainMinRng3: Minimum range for drain current measurement on device 1

[Extended Test Parameters for IvSweep_gmmax]
HoldTime: Hold time
DelayTime: Delay time
Vs: Source terminal voltage, constant voltage
IgLimit: Gate current compliance
IdLimit: Drain current compliance
Vth_Min: Minimum Vth value for graph scale
Vth_Max: Maximum Vth value for graph scale
gmMax_Min: Minimum gmMax value for graph scale
gmMax_Max: Maximum gmMax value for graph scale
DrainMinRng1: Minimum range for drain current measurement on device 1
DrainMinRng2: Minimum range for drain current measurement on device 1
DrainMinRng3: Minimum range for drain current measurement on device 1
[Extended Test Parameters for Sampling_Ids]
Vs: Source terminal voltage, constant voltage
IgLimit: Gate current compliance
IdLimit: Drain current compliance
DrainMinRng1: Minimum range for drain current measurement on device 1
DrainMinRng2: Minimum range for drain current measurement on device 1
DrainMinRng3: Minimum range for drain current measurement on device 1

[User Function]
[User Function for Sampling_Stress]
Maximum elapsed time value MaxTime=max(Time)
Stress time StressTime=AccTime+Time

[User Function for IvSweep_ConstId]
Maximum drain current value IdMax=max(abs(Idrain))  (For initial measurement only)

[User Function for IvSweep_gmmax]
Transconductance gm=diff(Idrain,Vgate)
Maximum transconductance value gmax=max(gm)
Maximum drain current value IdMax=max(abs(Idrain))  (For initial measurement only)

[Analysis Function]
[Analysis Function for IvSweep_ConstId]
Vth@Id=@L1X (X intercept of Line1)

[Analysis Function for IvSweep_gmmax]
Vth@Gm=@L1X (X intercept of Line1)

[Auto Analysis]
[Auto Analysis for IvSweep_ConstId]
Line1: Vertical line for Y1 at Idrain=Id@Vth
[Auto Analysis for IvSweep_gmmax]
Line1: Tangent line for Y1 at gm=gmax

[Test Output: X-Y Graph]
X axis: Elapsed time TimeList (LOG)
Y1 axis: Drain current for device 1 Dev1_IdsList (LOG)
Y2 axis: Drain current for device 2 Dev2_IdsList (LOG)
Y3 axis: Drain current for device 3 Dev3_IdsList (LOG)
Y4 axis: Maximum transconductance value for device 1 Dev1_GmMaxList (LINEAR)
Y5 axis: Maximum transconductance value for device 2 Dev2_GmMaxList (LINEAR)
Y6 axis: Maximum transconductance value for device 3 Dev3_GmMaxList (LINEAR)

[Test Output: List Display]
TimeList: Elapsed time
Dev1_IdsList: Drain current for device 1
Dev2_IdsList: Drain current for device 2
Dev3_IdsList: Drain current for device 3
Dev1_VthIdList: Vth for device 1, determined by constant current method
Dev2_VthIdList: Vth for device 2, determined by constant current method
Dev3_VthIdList: Vth for device 3, determined by constant current method
Dev1_VthGmList: Vth for device 1, determined by extrapolation method
Dev2_VthGmList: Vth for device 2, determined by extrapolation method
Dev3_VthGmList: Vth for device 3, determined by extrapolation method
Dev1_GmMaxList: Maximum transconductance value for device 1
Dev2_GmMaxList: Maximum transconductance value for device 2
Dev3_GmMaxList: Maximum transconductance value for device 3
11.8 BTI 3devices[3]: Bias Temperature Instability test, 3 terminals, 3 devices (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Performs the bias temperature instability test, and plots the accumulated stress time vs threshold voltage/drain current characteristics. Maximum three devices can be measured by a test execution. This test is performed as follows.
1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

[Device Under Test]
MOSFET, 3 terminals, 3 devices

[Required Accessories]
Keysight B2200A or B2201A switching matrix 1 unit
GPIB cable
Connect B2200A/B2201A to B1500A with a measuring cable and GPIB cable.
Set information on B1500A SMU channel's connection to the B2200A/B2201A input port properly on the Switching Matrix tab screen of the Configuration window.
Set the output channel number of B2200A/B2201A connected to each terminal of a device under test properly in the Tr#Gate/Tr#Drain/Tr#Source field (# is an integer from 1 to 3) of Test Parameters area.

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value)
Lg: Gate length
Wg: Gate width
Temp: Temperature (deg C)

[Test Parameters]
IntegTime: Integration time (SHORT, MEDIUM, LONG)
Tr#Gate: SWM Pin Assign settings for Gate terminal of devices
Tr#Drain: SWM Pin Assign settings for Drain terminal of devices
Tr#Source: SWM Pin Assign settings for Source terminal of devices
where, # is an integer from 1 to 3.

[Test Parameters for Sampling_Stress]
TotalStrsTime: Total stress time
Tr#StrsGate: SMU connected to Gate terminal of devices, constant voltage output
StrsSource: SMU connected to Gate terminal of devices, constant voltage output (drain/subs short)
Tr#VgStrs: Gate terminal stress voltage for the devices
VsStrs: Source terminal stress voltage
where, # is an integer from 1 to 3.

[Test Parameters for IvSweep_ConstId]
MeasGate: SMU connected to the basic characteristics acquisition Gate terminal, primary sweep voltage output
MeasDrain: SMU connected to the basic characteristics acquisition Drain terminal, constant voltage output
MeasSource: SMU connected to the basic characteristics acquisition Source terminal, constant voltage output
Id@Vth: Drain current to decide the Vth, per unit area
VgStart1: Sweep start voltage for Gate terminal
VgStop1: Sweep stop voltage for Gate terminal
VgStep1: Sweep step voltage for Gate terminal
Vd1: Drain terminal voltage, constant value

[Test Parameters for IvSweep_gmmax]
MeasGate: SMU connected to the basic characteristics acquisition Gate terminal, primary sweep voltage output
MeasDrain: SMU connected to the basic characteristics acquisition Drain terminal, constant voltage output
MeasSource: SMU connected to the basic characteristics acquisition Source terminal, constant voltage output
VgStart2: Sweep start voltage for Gate terminal
VgStop2: Sweep stop voltage for Gate terminal
VgStep2: Sweep step voltage for Gate terminal
Vd2: Drain voltage

[Test Parameters for Sampling_Ids]
MeasGate: SMU connected to the basic characteristics acquisition Gate terminal, primary sweep voltage output
MeasDrain: SMU connected to the basic characteristics acquisition Drain terminal, constant voltage output
MeasSource: SMU connected to the basic characteristics acquisition Source terminal, constant voltage output
Vg3: Gate terminal voltage
Vd3: Drain terminal voltage

[Extended Test Parameters]
[Extended Test Parameters for IvSweep_ConstId]
HoldTime: Hold time
DelayTime: Delay time
Vs: Source terminal voltage, constant voltage
IgLimit: Gate current compliance
IdLimit: Drain current compliance
DrainMinRng1: Minimum range for drain current measurement on device 1
DrainMinRng2: Minimum range for drain current measurement on device 2
DrainMinRng3: Minimum range for drain current measurement on device 3

[Extended Test Parameters for IvSweep_gmmax]
HoldTime: Hold time
DelayTime: Delay time
Vs: Source terminal voltage, constant voltage
IgLimit: Gate current compliance
IdLimit: Drain current compliance
Vth_Min: Minimum Vth value for graph scale
Vth_Max: Maximum Vth value for graph scale
gmMax_Min: Minimum gmMax value for graph scale
gmMax_Max: Maximum gmMax value for graph scale
DrainMinRng1: Minimum range for drain current measurement on device 1
DrainMinRng2: Minimum range for drain current measurement on device 2
DrainMinRng3: Minimum range for drain current measurement on device 3

[Extended Test Parameters for Sampling_Ids]
Vs: Source terminal voltage, constant voltage
IgLimit: Gate current compliance
IdLimit: Drain current compliance
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DrainMinRng1: Minimum range for drain current measurement on device 1
DrainMinRng2: Minimum range for drain current measurement on device 2
DrainMinRng3: Minimum range for drain current measurement on device 3

[User Function]
[User Function for Sampling_Stress]
Maximum elapsed time value MaxTime=max(Time)
Stress time StressTime=AccTime+Time

[User Function for IvSweep_ConstId]
Maximum drain current value IdMax=max(abs(Idrain)) (For initial measurement only)

[User Function for IvSweep_gmmax]
Transconductance gm=diff(Idrain,Vgate)
Maximum transconductance value gmmax=max(gm)
Maximum drain current value IdMax=max(abs(Idrain)) (For initial measurement only)

[Analysis Function]
[Analysis Function for IvSweep_ConstId]
Vth@Id=@L1X (X intercept of Line1)

[Analysis Function for IvSweep_gmmax]
Vth@Gm=@L1X (X intercept of Line1)

[Auto Analysis]
[Auto Analysis for IvSweep_ConstId]
Line1: Vertical line for Y1 at Idrain=Id@Vth

[Auto Analysis for IvSweep_gmmax]
Line1: Tangent line for Y1 at gm=gmMax

[Test Output: X-Y Graph]
X axis: Elapsed time TimeList (LOG)
Y1 axis: Drain current for device 1 Dev1_IdsList (LOG)
Y2 axis: Drain current for device 2 Dev2_IdsList (LOG)
Y3 axis: Drain current for device 3 Dev3_IdsList (LOG)
Y4 axis: Maximum transconductance value for device 1 Dev1_GmMaxList (LINEAR)
Y5 axis: Maximum transconductance value for device 2 Dev2_GmMaxList (LINEAR)
Y6 axis: Maximum transconductance value for device 3 Dev3_GmMaxList (LINEAR)

[Test Output: List Display]
TimeList: Elapsed time
Dev1_IdsList: Drain current for device 1
Dev2_IdsList: Drain current for device 2
Dev3_IdsList: Drain current for device 3
Dev1_VthIdList: Vth for device 1, determined by constant current method
Dev2_VthIdList: Vth for device 2, determined by constant current method
Dev3_VthIdList: Vth for device 3, determined by constant current method
Dev1_VthGmList: Vth for device 1, determined by extrapolation method
Dev2_VthGmList: Vth for device 2, determined by extrapolation method
Dev3_VthGmList: Vth for device 3, determined by extrapolation method
Dev1_GmMaxList: Maximum transconductance value for device 1
Dev2_GmMaxList: Maximum transconductance value for device 2
Dev3_GmMaxList: Maximum transconductance value for device 3
11.9 BTI: Bias Temperature Instability test, 4 terminals (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Performs the bias temperature instability test, and plots the accumulated stress time vs threshold voltage/drain current characteristics.
This test is performed as follows.
1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

[Device Under Test]
MOSFET, 4 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value)
Lg: Gate length
Wg: Gate width
Temp: Temperature (deg C)

[Test Parameters]
IntegTime: Integration time (SHORT, MEDIUM, LONG)
TotalStressTime: Total stress time
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Subs: SMU connected to Substrate terminal, constant voltage output
Source: SMU connected to Source terminal, constant voltage output
VgStress: Gate terminal stress voltage

[Test Parameters for IvSweep_ConstId]
Id@Vth: Drain current to decide the Vth, per unit area
VgStart1: Sweep start voltage for Gate terminal
VgStop1: Sweep stop voltage for Gate terminal
VgStep1: Sweep step voltage for Gate terminal
Vd1: Drain terminal voltage, constant value

[Test Parameters for IvSweep_gmmax]
VgStart2: Sweep start voltage for Gate terminal
VgStop2: Sweep stop voltage for Gate terminal
VgStep2: Sweep step voltage for Gate terminal
Vd2: Drain voltage

[Test Parameters for Sampling_Ids]
Vg3: Gate terminal voltage
Vd3: Drain terminal voltage

[Extended Test Parameters]
[Extended Test Parameters for Sampling_Stress]
Vd: Drain terminal voltage, constant voltage
Vs: Source terminal voltage, constant voltage
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Vsubs: Substrate terminal voltage, constant voltage
IgLimit: Gate current compliance

[Extended Test Parameters for IvSweep_ConstId]
HoldTime: Hold time
DelayTime: Delay time
IdLimit: Drain current compliance
IsubsLimit: Substrate current compliance
Vs: Source terminal voltage, constant voltage
Vsubs: Substrate terminal voltage, constant voltage
DrainMinRng: Minimum range for drain current measurement

[Extended Test Parameters for IvSweep_gmmax]
HoldTime: Hold time
DelayTime: Delay time
IgLimit: Gate current compliance
IdLimit: Drain current compliance
IsubsLimit: Substrate current compliance
Vs: Source terminal voltage, constant voltage
Vsubs: Substrate terminal voltage, constant voltage
DrainMinRng: Minimum range for drain current measurement
Vth_Min: Minimum Vth value for graph scale
Vth_Max: Maximum Vth value for graph scale

[Extended Test Parameters for Sampling_Ids]
IgLimit: Gate current compliance
IdLimit: Drain current compliance
IsubsLimit: Substrate current compliance
Vs: Source terminal voltage, constant voltage
Vsubs: Substrate terminal voltage, constant voltage
DrainMinRng: Minimum range for drain current measurement

[User Function]
[User Function for Sampling_Stress]
Maximum elapsed time value MaxTime=max(Time)
Stress time StressTime=AccTime+Time

[User Function for IvSweep_ConstId]
Maximum drain current value IdMax=max(abs(Idrain)) (For initial measurement only)

[User Function for IvSweep_gmmax]
Maximum drain current value IdMax=max(abs(Idrain)) (For initial measurement only)
Transconductance gm=diff(Idrain,Vgate)
Maximum transconductance value gmMax=max(gm)

[Analysis Function]
[Analysis Function for IvSweep_ConstId]
Vth@Id=@L1X (X intercept of Line1)

[Analysis Function for IvSweep_gmmax]
Vth@Gm=@L1X (X intercept of Line1)

[Auto Analysis]
[Auto Analysis for IvSweep_ConstId]
Line1: Vertical line for Y1 at Idrain=Id@Vth
[Auto Analysis for IvSweep_gmmax]
Line1: Tangent line for Y1 at \( gm=gm\max \)

[Test Output: X-Y Graph]
X axis: Elapsed time TimeList (LOG)
Y1 axis: Maximum transconductance value gmMaxList (LINEAR)
Y2 axis: Vth by constant current method VthIdList (LINEAR)
Y3 axis: Vth by extrapolation method VthGmList (LINEAR)
Y4 axis: Drain current IdsList (LOG)

[Test Output: List Display]
Elapsed time TimeList
Vth by constant current method VthIdList
Vth by extrapolation method VthGmList
Drain current IdsList
Maximum transconductance value gmMaxList
11 Reliability

11.10 BTI2: Bias Temperature Instability test, 4 terminals (A.03.10)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Performs the bias temperature instability test, and plots the accumulated stress time vs threshold voltage/drain current characteristics.
This test is performed as follows.
1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

[Device Under Test]
MOSFET, 4 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value)
Lg: Gate length
Wg: Gate width
Temp: Temperature (deg C)

[Test Parameters]
IntegTime: Integration time (SHORT, MEDIUM, LONG)
TotalStressTime: Total stress time
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Subs: SMU connected to Substrate terminal, constant voltage output
Source: SMU connected to Source terminal, constant voltage output
VgStress: Gate terminal stress voltage
MeasConstId: Measurement by constant current method, Yes or No
MeasGmmax: Measurement by extrapolation method, Yes or No
MeasIds: Drain current measurement, Yes or No
MeasTiming: Timing to measure device parameter

[Test Parameters for IvSweep_ConstId]
Id@Vth: Drain current to decide the Vth, per unit area
VgStart1: Sweep start voltage for Gate terminal
VgStop1: Sweep stop voltage for Gate terminal
VgStep1: Sweep step voltage for Gate terminal
Vd1: Drain terminal voltage, constant value
VthStopRate: Vth_ConstId change rate to stop testing

[Test Parameters for IvSweep_gmmax]
VgStart2: Sweep start voltage for Gate terminal
VgStop2: Sweep stop voltage for Gate terminal
VgStep2: Sweep step voltage for Gate terminal
Vd2: Drain voltage
GmStopRate: Vth_GmMax change rate to stop testing

[Test Parameters for Sampling_Ids]
Vg3: Gate terminal voltage
Vd3: Drain terminal voltage
IdsStopRate: Ids change rate to stop testing

[Extended Test Parameters]
StoringRuntimeData: Data save during stress output, Yes or No

[Extended Test Parameters for Sampling_Stress]
Vd: Drain terminal voltage, constant voltage
Vs: Source terminal voltage, constant voltage
Vsubs: Substrate terminal voltage, constant voltage
IgLimit: Gate current compliance

[Extended Test Parameters for IvSweep_ConstId]
HoldTime: Hold time
DelayTime: Delay time
IdLimit: Drain current compliance
IsubsLimit: Substrate current compliance
Vs: Source terminal voltage, constant voltage
Vsubs: Substrate terminal voltage, constant voltage
DrainMinRng: Minimum range for drain current measurement

[Extended Test Parameters for IvSweep_gmmax]
HoldTime: Hold time
DelayTime: Delay time
IgLimit: Gate current compliance
IdLimit: Drain current compliance
IsubsLimit: Substrate current compliance
Vs: Source terminal voltage, constant voltage
Vsubs: Substrate terminal voltage, constant voltage
Vth_Min: Minimum Vth value for graph scale
Vth_Max: Maximum Vth value for graph scale
gmMax_Min: Minimum gmMax value for graph scale
gmMax_Max: Maximum gmMax value for graph scale
DrainMinRng: Minimum range for drain current measurement
DrainMinRng: Minimum range for drain current measurement

[Extended Test Parameters for Sampling_Ids]
IgLimit: Gate current compliance
IdLimit: Drain current compliance
IsubsLimit: Substrate current compliance
Vs: Source terminal voltage, constant voltage
Vsubs: Substrate terminal voltage, constant voltage
DrainMinRng: Minimum range for drain current measurement

[Measurement Parameters]
[Measurement Parameters by Sampling_Stress]
Gate current Igate

[Measurement Parameters by IvSweep_ConstId]
Drain current Idrain

[Measurement Parameters by IvSweep_gmmax]
Drain current Idrain
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[Measurement Parameters by IvSweep_Ids]
Drain current Idrain

[User Function]
[User Function for IvSweep_ConstId]
Maximum drain current value IdMax=max(abs(Idrain)) (For initial measurement only)

[User Function for IvSweep_gmmax]
Maximum drain current value IdMax=max(abs(Idrain)) (For initial measurement only)
Transconductance gm=diff(Idrain,Vgate)
Maximum transconductance value gmMax=max(gm)

[Analysis Function]
[Analysis Function for IvSweep_ConstId]
Vth@Id=@L1X (X intercept of Line1)

[Analysis Function for IvSweep_gmmax]
Vth@Gm=@L1X (X intercept of Line1)

[Auto Analysis]
[Auto Analysis for IvSweep_ConstId]
Line1: Vertical line for Y1 at Idrain=Id@Vth

[Auto Analysis for IvSweep_gmmax]
Line1: Tangent line for Y1 at gm=gmMax

[X-Y Graph]
[X-Y Graph for Sampling_Stress]
X axis: Stress time StressTime (LINEAR)
Y1 axis: Gate current Igate (LOG)

[X-Y Graph for IvSweep_ConstId]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)

[X-Y Graph for IvSweep_gmmax]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Transconductance gm (LINEAR)

[X-Y Graph for Sampling_Ids]
X axis: Elapsed time Time (LINEAR)
Y1 axis: Drain current Idrain (LOG)

[List Display]
[List Display for Sampling_Stress]
Stress time StressTime
Elapsed time Time
Gate voltage Vgate
Drain voltage Vdrain
Gate current Igate

[List Display for IvSweep_ConstId]
Gate voltage Vgate
Drain voltage V_{drain}
Drain current I_{drain}

[List Display for IvSweep_gmmax]
Gate voltage V_{gate}
Drain voltage V_{drain}
Drain current I_{drain}
Transconductance g_m

[List Display for Sampling_Ids]
Elapsed time Time
Drain current I_{drain}

[Test Output: X-Y Graph]
X axis: Elapsed time TimeList (LOG)
Y1 axis: Maximum transconductance value gmMaxList (LINEAR)
Y2 axis: V_{th} by constant current method V_{thIdList} (LINEAR)
Y3 axis: V_{th} by extrapolation method V_{thGmList} (LINEAR)
Y4 axis: Drain current I_{dsList} (LOG)

[Test Output: List Display]
Elapsed time TimeList
V_{th} by constant current method V_{thIdList}
V_{th} by extrapolation method V_{thGmList}
Drain current I_{dsList}
Maximum transconductance value gmMaxList
11 Reliability

11.11 BTI[3]: Bias Temperature Instability test, 3 terminals (A.01.20)

[Supported Analyzer]

[Description]
Performs the bias temperature instability test, and plots the accumulated stress time vs threshold voltage/drain current characteristics.
This test is performed as follows.
1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

[Device Under Test]
MOSFET, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value)
Lg: Gate length
Wg: Gate width
Temp: Temperature (deg C)

[Test Parameters]
IntegTime: Integration time (SHORT, MEDIUM, LONG)
TotalStressTime: Total stress time
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source terminal, constant voltage output
VgStress: Gate terminal stress voltage

[Test Parameters for IvSweep_ConstId]
Id@Vth: Drain current to decide the Vth, per unit area
VgStart1: Sweep start voltage for Gate terminal
VgStop1: Sweep stop voltage for Gate terminal
VgStep1: Sweep step voltage for Gate terminal
Vd1: Drain terminal voltage, constant value

[Test Parameters for IvSweep_gmmax]
VgStart2: Sweep start voltage for Gate terminal
VgStop2: Sweep stop voltage for Gate terminal
VgStep2: Sweep step voltage for Gate terminal
Vd2: Drain voltage

[Test Parameters for Sampling_Ids]
Vg3: Gate terminal voltage
Vd3: Drain terminal voltage

[Extended Test Parameters]
[Extended Test Parameters for Sampling_Stress]
Vd: Drain terminal voltage, constant voltage
Vs: Source terminal voltage, constant voltage
IgLimit: Gate current compliance
[Extended Test Parameters for IvSweep_ConstId]
HoldTime: Hold time
DelayTime: Delay time
IdLimit: Drain current compliance
Vs: Source terminal voltage, constant voltage
DrainMinRng: Minimum range for drain current measurement

[Extended Test Parameters for IvSweep_gmmax]
HoldTime: Hold time
DelayTime: Delay time
IgLimit: Gate current compliance
IdLimit: Drain current compliance
Vs: Source terminal voltage, constant voltage
DrainMinRng: Minimum range for drain current measurement
Vth_Min: Minimum Vth value for graph scale
Vth_Max: Maximum Vth value for graph scale

[Extended Test Parameters for Sampling_Ids]
IgLimit: Gate current compliance
IdLimit: Drain current compliance
Vs: Source terminal voltage, constant voltage
DrainMinRng: Minimum range for drain current measurement

[User Function]
[User Function for Sampling_Stress]
Maximum elapsed time value MaxTime=max(Time)
Stress time StressTime=AccTime+Time

[User Function for IvSweep_ConstId]
Maximum drain current value IdMax=max(abs(Idrain)) (For initial measurement only)

[User Function for IvSweep_gmmax]
Maximum drain current value IdMax=max(abs(Idrain)) (For initial measurement only)
Transconductance gm=diff(Idrain,Vgate)
Maximum transconductance value gmMax=max(gm)

[Analysis Function]
[Analysis Function for IvSweep_ConstId]
Vth@Id=@L1X (X intercept of Line1)

[Analysis Function for IvSweep_gmmax]
Vth@Gm=@L1X (X intercept of Line1)

[Auto Analysis]
[Auto Analysis for IvSweep_ConstId]
Line1: Vertical line for Y1 at Idrain=Id@Vth

[Auto Analysis for IvSweep_gmmax]
Line1: Tangent line for Y1 at gm=gmMax

[Test Output: X-Y Graph]
X axis: Elapsed time TimeList (LOG)
Y1 axis: Maximum transconductance value gmMaxList (LINEAR)
Y2 axis: Vth by constant current method VthIdList (LINEAR)
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Y3 axis: Vth by extrapolation method VthGmList (LINEAR)
Y4 axis: Drain current IdsList (LOG)

[Test Output: List Display]
Elapsed time TimeList
Vth by constant current method VthIdList
Vth by extrapolation method VthGmList
Drain current IdsList
Maximum transconductance value gmMaxList
11.12 BTI2[3]: Bias Temperature Instability test, 3 terminals (A.03.10)

[Supported Analyzer]

[Description]
Performs the bias temperature instability test, and plots the accumulated stress time vs threshold voltage/drain current characteristics.
This test is performed as follows.
1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

[Device Under Test]
MOSFET, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value)
Lg: Gate length
Wg: Gate width
Temp: Temperature (deg C)

[Test Parameters]
IntegTime: Integration time (SHORT, MEDIUM, LONG)
TotalStressTime: Total stress time
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Source: SMU connected to Source terminal, constant voltage output
VgStress: Gate terminal stress voltage
IdLimit: Drain current compliance
MeasConstId: Measurement by constant current method, Yes or No
MeasGmmax: Measurement by extrapolation method, Yes or No
MeasIds: Drain current measurement, Yes or No
MeasTiming: Timing to measure device parameter

[Test Parameters for IvSweep_ConstId]
Id@Vth: Drain current to decide the Vth, per unit area
VgStart1: Sweep start voltage for Gate terminal
VgStop1: Sweep stop voltage for Gate terminal
VgStep1: Sweep step voltage for Gate terminal
Vd1: Drain terminal voltage, constant value
VthStopRate: Vth_ConstId change rate to stop testing

[Test Parameters for IvSweep_gmmax]
VgStart2: Sweep start voltage for Gate terminal
VgStop2: Sweep stop voltage for Gate terminal
VgStep2: Sweep step voltage for Gate terminal
Vd2: Drain voltage
GmStopRate: Vth_GmMax change rate to stop testing

[Test Parameters for Sampling_Ids]
Vg3: Gate terminal voltage
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Vd3: Drain terminal voltage
IdsStopRate: Ids change rate to stop testing

[Extended Test Parameters]
StoringRuntimeData: Data save during stress output, Yes or No

[Extended Test Parameters for Sampling_Stress]
Vd: Drain terminal voltage, constant voltage
Vs: Source terminal voltage, constant voltage
IgLimit: Gate current compliance

[Extended Test Parameters for IvSweep_ConstId]
HoldTime: Hold time
DelayTime: Delay time
Vs: Source terminal voltage, constant voltage
DrainMinRng: Minimum range for drain current measurement

[Extended Test Parameters for IvSweep_gmmax]
HoldTime: Hold time
DelayTime: Delay time
IgLimit: Gate current compliance
Vs: Source terminal voltage, constant voltage
DrainMinRng: Minimum range for drain current measurement

[Extended Test Parameters for Sampling_Id]
IgLimit: Gate current compliance
Vs: Source terminal voltage, constant voltage
DrainMinRng: Minimum range for drain current measurement

[Measurement Parameters]
[Measurement Parameters by Sampling_Stress]
Gate current Igate

[Measurement Parameters by IvSweep_ConstId]
Drain current Idrain

[Measurement Parameters by IvSweep_gmmax]
Drain current Idrain

[Measurement Parameters by IvSweep_Id]
Drain current Idrain

[User Function]
[User Function for IvSweep_ConstId]
Maximum drain current value IdMax=max(abs(Idrain)) (For initial measurement only)

[User Function for IvSweep_gmmax]
Maximum drain current value IdMax=max(abs(Idrain)) (For initial measurement only)
Transconductance gm=diff(Idrain,Vgate)
Maximum transconductance value gmMax=max(gm)

[Analysis Function]
[Analysis Function for IvSweep_ConstId]
Vth@Id=@L1X (X intercept of Line1)
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[Analysis Function for IvSweep_gmmax]
Vth@Gm=JL1X (X intercept of Line1)

[Auto Analysis]
[Auto Analysis for IvSweep_ConstId]
Line1: Vertical line for Y1 at IdRAIN=Id@Vth

[Auto Analysis for IvSweep_gmmax]
Line1: Tangent line for Y1 at gm=gmMax

[X-Y Graph]
[X-Y Graph for Sampling_Stress]
X axis: Stress time StressTime (LINEAR)
Y1 axis: Gate current Igate (LOG)

[X-Y Graph for IvSweep_ConstId]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)

[X-Y Graph for IvSweep_gmmax]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Transconductance gm (LINEAR)

[X-Y Graph for Sampling_Ids]
X axis: Elapsed time Time (LINEAR)
Y1 axis: Drain current Idrain (LOG)

[List Display]
[List Display for Sampling_Stress]
Stress time StressTime
Elapsed time Time
Gate voltage Vgate
Drain voltage Vdrain
Gate current Igate

[List Display for IvSweep_ConstId]
Gate voltage Vgate
Drain voltage Vdrain
Drain current Idrain

[List Display for IvSweep_gmmax]
Gate voltage Vgate
Drain voltage Vdrain
Drain current Idrain
Transconductance gm

[List Display for Sampling_Ids]
Elapsed time Time
Drain current Idrain

[Test Output: X-Y Graph]
X axis: Elapsed time TimeList (LOG)
Y1 axis: Maximum transconductance value gmMaxList (LINEAR)
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Y2 axis: Vth by constant current method VthIdList (LINEAR)
Y3 axis: Vth by extrapolation method VthGmList (LINEAR)
Y4 axis: Drain current IdsList (LOG)

[Test Output: List Display]
Elapsed time TimeList
Vth by constant current method VthIdList
Vth by extrapolation method VthGmList
Drain current IdsList
Maximum transconductance value gmMaxList
11.13 Charge Pumping: Evaluation of the interface state using charge pumping method (A.01.20)

[Supported Analyzer]
B1500A

[Description]
Measures the Substrate current vs Gate pulse base voltage characteristics, and extracts the interface state density (Nss). This test uses the Keysight 81110A pulse generator.

[Test Setup used in this test definition]
ForcePGC: Used to apply Gate pulse
I/V-t Sampling: Used to perform the Substrate current measurement
ResetPG: Used to reset the pulse generator

[Device Under Test]
MOSFET, 3 terminals or 4 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Source: SMU connected to Source, constant voltage output
Vs: Source voltage
IsLimit: Source current compliance
Subs: SMU connected to Substrate, constant voltage output
Vsubs: Substrate voltage
IsubsLimit: Substrate current compliance

[Extended Test Parameters]
SubsMinRng: Minimum range for the substrate current measurement

[Test Parameters for Gate Pulse]
PulseLevel: Pulse output level
VbaseStart: Sweep start value of Gate pulse base voltage
VbaseStop: Sweep stop value of Gate pulse base voltage
VbaseStep: Sweep step value of Gate pulse base voltage
PulsePeriod: Pulse period
PulseDelay: Pulse delay
DutyCycle: Duty cycle
LeadingTime: Leading transition time
TrailingTime: Trailing transition time
PgAdd: GPIB address of Keysight 81110A

[Test Output: X-Y Graph]
X axis: Gate pulse base voltage VbaseList (LINEAR)
Y1 axis: Substrate current IcpList (LOG)

[Test Output: Parameters]
Interface state density Nss

[Nss calculation]
\[ Nss = \frac{I_{cp\max}}{q \times \text{PulsePeriod} / \text{Lg} \times \text{Wg}} \]
11 Reliability

11.14 Charge Pumping2: Evaluation of the interface state using charge pumping method (A.03.10)

[Supported Analyzer]
B1500A

[Description]
Measures the Substrate current vs Gate pulse base voltage characteristics, and extracts the interface state density (Nss).

[Required Modules and Accessories]
Keysight B1525A SPGU 1 unit

[Device Under Test]
MOSFET, 3 terminals or 4 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
Source: SMU connected to Source, constant voltage output
Subs: SMU connected to Substrate, constant voltage output
Gate: SPGU connected to Gate, pulse voltage output
PulsePeriod: Pulse period
PulseDelay: Pulse delay
DutyCycle: Duty cycle
PulseLevel: Pulse output level
LeadingTime: Leading transition time
TrailingTime: Trailing transition time
VbaseStart: Sweep start value of Gate pulse base voltage
VbaseStop: Sweep stop value of Gate pulse base voltage
VbaseStep: Sweep step value of Gate pulse base voltage
Vs: Source voltage
IsubsLimit: Substrate current compliance
IntegTime: Integration time
Vsubs: Substrate voltage
IsLimit: Source current compliance

[Extended Test Parameters]
SubsMinRng: Minimum range for the substrate current measurement

[Measurement Parameters]
Isubs Substrate current

[X-Y Graph]
X axis: Elapsed time Time (LINEAR)
Y1 axis: Substrate current Isubs (LOG)
11 Reliability

[List Display]
Elapsed time Time
Substrate current Isubs

[Test Output: X-Y Graph]
X axis: Gate pulse base voltage VbaseList (LINEAR)
Y1 axis: Substrate current IcpList (LOG)

[Test Output: List Display]
Gate pulse base voltage VbaseList
Substrate current IcpList

[Test Output: Parameters]
Maximum substrate current IcpMax
Interface state density Nss

[Nss calculation]
Nss=IcpMax/q*PulsePeriod/Lg/Wg
11 Reliability

11.15 EM Istress: Electromigration test, current stressed, 4 SMUs (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Performs the Electromigration (EM) test, and plots the stress time vs resistance characteristics. This test is performed by the sampling measurement mode.

[Device Under Test]
Wiring (resistor), 4 terminals

[Device Parameters]
L: Length of pattern
W: Width of pattern
Temp: Temperature

[Test Parameters]
Port1: SMU for Port1 stress force
Port2: SMU for Port2 stress force
VM1: SMU for Port1 voltage monitor
VM2: SMU for Port2 voltage monitor
TotalStressTime: Total stress time,
StopCondition: Measurement stop condition (% changes of wire resistance)
I1Stress: Port1 stress current
IntegTime: Integration time

[Extended Test Parameters]
V2: Port2 terminal voltage
V1Limit: Port1 voltage compliance
I2Limit: Port2 current compliance
HoldTime: Hold time

[User Function]
IPort1PerArea (A/cm²) Port1 terminal current per unit area
IPort2PerArea (A/cm²) Port2 terminal current per unit area
R (ohm) Resistance of wiring
DeltaR (%) Difference from initial resistance

[X-Y Plot]
X axis: Stress time TimeList (LOG)
Y1 axis: Port1 terminal voltage Vport1List (LOG)
Y2 axis: Resistance RList (LINEAR)
Y3 axis: Difference from initial resistance DeltaRList (LINEAR)
11.16 EM Istress2: Electromigration test, current stressed, 4 SMUs (A.03.10)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Performs the Electromigration (EM) test, and plots the stress time vs resistance characteristics. This test is performed by the sampling measurement mode.

[Device Under Test]
Wiring (resistor), 4 terminals

[Device Parameters]
L: Length of pattern
W: Width of pattern
Temp: Temperature

[Test Parameters]
Port1: SMU for Port1 stress force
Port2: SMU for Port2 stress force
VM1: SMU for Port1 voltage monitor
VM2: SMU for Port2 voltage monitor
TotalStressTime: Total stress time.
V1Limit: Port1 voltage compliance
FailureCondition: Measurement stop condition (% changes of wire resistance)
I1Stress: Port1 stress current
NoOfSamples: Number of samples
IntegTime: Integration time
PointPerDecade: Number of samples in 1 decade
Interval: Sampling interval

[Extended Test Parameters]
V2: Port2 terminal voltage
I2Limit: Port2 current compliance
HoldTime: Hold time
R_Max: Y axis maximum value for resistance
StoringRuntimeData: Data save during stress output, Yes or No

[Measurement Parameters]
Port1 current Ipport1

[User Function]
DeltaV Voltage between terminals of wiring device
R Resistance of wiring device
MaxTime Maximum elapsed time

[X-Y Graph]
X axis: Stress time Time (LOG)
Y1 axis: Voltage between terminals of wiring device DeltaV (LINEAR)
Y2 axis: Resistance of wiring device R (LINEAR)
11 Reliability

[List Display]
  Stress time Time
  Voltage between terminals of wiring device DeltaV
  Resistance of wiring device R

[Test Output: X-Y Graph]
  X axis: Accumulated stress time TimeList (LOG)
  Y1 axis: Voltage between terminals of wiring device DeltaVList (LINEAR)
  Y2 axis: Resistance of wiring device RList (LINEAR)
  Y3 axis: Difference from initial resistance DeltaRList (LINEAR)

[Test Output: List Display]
  Accumulated stress time TimeList
  Voltage between terminals of wiring device DeltaVList
  Resistance of wiring device RList
  Difference from initial resistance DeltaRList

[Test Output: Parameters]
  Time to failure FailureTime
11.17 EM Istress[2]: Electromigration test, current stressed, 2 SMUs (A.01.20)

[Supported Analyzer]

[Description]
Performs the Electromigration (EM) test, and plots the stress time vs resistance characteristics. This test is performed by the sampling measurement mode as shown below.
1. applies stress current
2. performs measurement and saves measurement data
3. calculates the device failure time

[Device Under Test]
Wiring device, 2 terminals

[Device Parameters]
D: Wiring pattern length
W: Wiring pattern width
Temp: Temperature (deg C)

[Test Parameters]
IntegTime: Integration time
TotalStressTime: Total stress time
StopCondition: Measurement stop condition (%changes of wire resistance)
Port1: SMU connected to Port1, constant current output
Port2: SMU connected to Port2, constant voltage output
I1Stress: Port1 stress current

[Extended Test Parameters]
V2: Port2 voltage
V1Limit: Port1 voltage compliance
I2Limit: Port2 current compliance
HoldTime: Hold time
DelayTime: Delay time

[User Function]
Wiring resistance value \( R = \frac{V_{\text{port1}}}{I_{\text{port1}}} \)

[Test Output: X-Y Graph]
X axis: Accumulated stress time TimeList
Y1 axis: Port1 voltage Vport1List
Y2 axis: Wiring resistance value RLList
Y3 axis: Offset from initial resistance value DeltaRLList

[Test Output: List Display]
Accumulated stress time TimeList
Port1 voltage Vport1List
Wiring resistance value RLList
Offset from initial resistance value DeltaRLList

[Test Output: Parameters]
FailureTime: Time to failure
11 Reliability

11.18 EM Istress2[2]: Electromigration test, current stressed, 2 SMUs (A.03.10)

[Supported Analyzer]

[Description]
Performs the Electromigration (EM) test, and plots the stress time vs resistance characteristics. This test is performed by the sampling measurement mode as shown below.
1. applies stress current
2. performs measurement and saves measurement data
3. calculates the device failure time

[Device Under Test]
Wiring (resistor), 2 terminals

[Device Parameters]
D: Length of pattern
W: Width of pattern
Temp: Temperature

[Test Parameters]
Port1: SMU connected to Port1, constant current output
Port2: SMU connected to Port2, constant voltage output
TotalStressTime: Total stress time.
FailureCondition: Measurement stop condition (%changes of wire resistance)
I1Stress: Port1 stress current
V1Limit: Port1 voltage compliance
IntegTime: Integration time
PointPerDecade: Number of samples in 1 decade
Interval: Sampling interval

[Extended Test Parameters]
V2: Port2 terminal voltage
I2Limit: Port2 current compliance
HoldTime: Hold time
R_Max: Y axis maximum value for resistance
StoringRuntimeData: Data save during stress output, Yes or No

[Measurement Parameters]
Port1 voltage Vport1
Port1 current Iport1

[User Function]
Resistance of wiring device R=Vport1/Iport1

[X-Y Graph]
X axis: Stress time Time (LOG)
Y1 axis: Port1 voltage Vport1 (LINEAR)
Y2 axis: Resistance of wiring device R (LINEAR)

[List Display]
Stress time Time
Port1 voltage Vport1
Resistance of wiring device R
[Test Output: X-Y Graph]
  X axis: Accumulated stress time TimeList (LOG)
  Y1 axis: Port1 voltage Vport1List (LINEAR)
  Y2 axis: Resistance of wiring device RList (LINEAR)
  Y3 axis: Difference from initial resistance DeltaRList (LINEAR)

[Test Output: List Display]
  Accumulated stress time TimeList
  Port1 voltage Vport1List
  Resistance of wiring device RList
  Difference from initial resistance DeltaRList

[Test Output: Parameters]
  Time to failure FailureTime
11 Reliability

11.19 EM Istress[6]: Electromigration test, current stressed, 6 SMUs (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Performs the Electromigration (EM) test for a wiring device with extrusion lines, and plots the stress time vs resistance characteristics. This test is performed by the sampling measurement mode as shown below.
1. applies stress current
2. performs measurement and saves measurement data
3. calculates the device failure time

[Device Under Test]
Wiring device with extrusion lines, 6 terminals

[Device Parameters]
D: Wiring pattern length
W: Wiring pattern width
Temp: Temperature (deg C)

[Test Parameters]
IntegTime: Integration time
TotalStressTime: Total stress time
StopCondition: Measurement stop condition 1 (%changes of wire resistance)
ExtCondition: Measurement stop condition 2 (current to extrusion line)
Port1: SMU connected to Port1, constant current output
Port2: SMU connected to Port2, constant voltage output
Port3: SMU connected to Extrusion Line, constant voltage output
Port4: SMU connected to Extrusion Line, constant voltage output
VM1: SMU for Port1 voltage monitoring, constant voltage output
VM2: SMU for Port2 voltage monitoring, constant voltage output
I1Stress: Port1 stress current
V1Limit: Port1 voltage compliance

[Extended Test Parameters]
V2: Port2 voltage
V3: Port3 voltage
V4: Port4 voltage
I2Limit: Port2 current compliance
I3Limit: Port3 current compliance
I4Limit: Port4 current compliance
HoldTime: Hold time
Port2MinRng: Minimum range for Port2 current measurement
Port3MinRng: Minimum range for Port3 current measurement
Port4MinRng: Minimum range for Port4 current measurement
R_Max: Y axis maximum value for resistance

[User Function]
Potential difference between lines DeltaV=Vm1-Vm2
Wiring resistance value R=DeltaV/Iport1

[Test Output: X-Y Graph]
X axis: Accumulated stresss time TimeList
Y1 axis: Wiring resistance value RLis
11 Reliability

Y2 axis: Offset from initial resistance value DeltaRList
Y3 axis: Port2 current Iport2List
Y4 axis: Port3 current Iport3List
Y5 axis: Port4 current Iport4List

[Test Output: List Display]
  Accumulated stresss time TimeList
  Wiring resistance value RList
  Offset from initial resistance value DeltaRList
  Port2 current Iport2List
  Port3 current Iport3List
  Port4 current Iport4List

[Test Output: Parameters]
  Time to failure given by rate of resistance change R_FailureTime
  Time to failure given by monitoring extrusion lines E_FailureTime
11 Reliability

11.20 EM Istress2[6]: Electromigration test, current stressed, 6 SMUs (A.03.10)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Performs the Electromigration (EM) test for a wiring device with extrusion lines, and plots the stress time vs resistance characteristics. This test is performed by the sampling measurement mode as shown below.
1. applies stress current
2. performs measurement and saves measurement data
3. calculates the device failure time

[Device Under Test]
Wiring device with extrusion lines, 6 terminals

[Device Parameters]
L: Length of pattern
W: Width of pattern
Temp: Temperature

[Test Parameters]
Port1: SMU connected to Port1, constant current output
Port2: SMU connected to Port2, constant voltage output
Port3: SMU connected to Extrusion Line, constant voltage output
Port4: SMU connected to Extrusion Line, constant voltage output
VM1: SMU for Port1 voltage monitoring, constant voltage output
VM2: SMU for Port2 voltage monitoring, constant voltage output
TotalStressTime: Total stress time.
FailureCondition: Measurement stop condition 1 (%changes of wire resistance)
ExtCondition: Measurement stop condition 2 (current to extrusion line)
I1Stress: Port1 stress current
IntegTime: Integration time
V1Limit: Port1 voltage compliance
I3Limit: Port3 current compliance
I4Limit: Port4 current compliance
PointPerDecade: Number of samples in 1 decade
Interval: Sampling interval

[Extended Test Parameters]
V2: Port2 voltage
V3: Port3 voltage
V4: Port4 voltage
I2Limit: Port2 current compliance
HoldTime: Hold time
Port2MinRng: Minimum range for Port2 current measurement
Port3MinRng: Minimum range for Port3 current measurement
Port4MinRng: Minimum range for Port4 current measurement
R_Max: Y axis maximum value for resistance
StoreOfRuntimeData: Data save during stress output, Yes or No

[Measurement Parameters]
Port1 voltage Vm1
Port2 voltage Vm2
Port2 current Iport2
Port3 current Iport3
Port4 current Iport4

[User Function]
Voltage between terminals of wiring device \( \Delta V = V_{m1} - V_{m2} \)
Resistance of wiring device \( R = V_{port1}/I_{port2} \)

[X-Y Graph]
X axis: Stress time Time (LOG)
Y1 axis: Resistance of wiring device R (LINEAR)
Y2 axis: Voltage between terminals of wiring device \( \Delta V \) (LINEAR)
Y3 axis: Port3 current Iport3 (LOG)
Y4 axis: Port4 current Iport4 (LOG)

[List Display]
Stress time Time
Resistance of wiring device R
Voltage between terminals of wiring device \( \Delta V \)
Port2 current Iport2
Port3 current Iport3
Port4 current Iport4

[Test Output: X-Y Graph]
X axis: Accumulated stress time TimeList (LOG)
Y1 axis: Resistance of wiring device RList (LINEAR)
Y2 axis: Difference from initial resistance DeltaRList (LINEAR)
Y3 axis: Port2 current Iport2List (LOG)
Y4 axis: Port3 current Iport3List (LOG)
Y5 axis: Port4 current Iport4List (LOG)

[Test Output: List Display]
Accumulated stress time TimeList
Resistance of wiring device RList
Difference from initial resistance DeltaRList
Port2 current Iport2List
Port3 current Iport3List
Port4 current Iport4List

[Test Output: Parameters]
Time to failure given by rate of resistance change \( R_{\text{FailureTime}} \)
Time to failure given by monitoring extrusion lines \( E_{\text{FailureTime}} \)
11.21 EM Vstress: Electromigration test, voltage stressed, 4 SMUs (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Performs the Electromigration (EM) test, and plots the stress time vs resistance characteristics. This test is performed by the sampling measurement mode.

[Device Under Test]
Wiring (resistor), 4 terminals

[Device Parameters]
L: Length of pattern
W: Width of pattern
Temp: Temperature

[Test Parameters]
Port1: SMU for Port1 stress force
Port2: SMU for Port2 stress force
VM1: SMU for Port1 voltage monitor
VM2: SMU for Port2 voltage monitor
TotalStressTime: Total stress time.
StopCondition: Measurement stop condition (%changes of wire resistance)
V1Stress: Port1 stress voltage
NoOfSamples: Number of samples
IntegTime: Integration time

[Extended Test Parameters]
V2: Port2 terminal voltage
I1Limit: Port1 current compliance
HoldTime: Hold time
Port1MinRng: Minimum range for the port1 current measurement

[User Function]
IPort1PerArea (A/cm2) Port1 terminal current per unit area
IPort2PerArea (A/cm2) Port2 terminal current per unit area
R (ohm) Resistance of wiring
DeltaR (%) Difference from initial resistance

[X-Y Plot]
X axis: Stress time TimeList (LOG)
Y1 axis: Port1 terminal current Iport1List (LOG)
Y2 axis: Resistance RList (LINEAR)
Y3 axis: Difference from initial resistance DeltaRList (LINEAR)
11.22 EM Vstress2: Electromigration test, voltage stressed, 4 SMUs (A.03.10)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Performs the Electromigration (EM) test, and plots the stress time vs resistance characteristics. This test is performed by the sampling measurement mode.

[Device Under Test]
Wiring (resistor), 4 terminals

[Device Parameters]
L: Length of pattern
W: Width of pattern
Temp: Temperature

[Test Parameters]
Port1: SMU for Port1 stress force
Port2: SMU for Port2 stress force
VM1: SMU for Port1 voltage monitor
VM2: SMU for Port2 voltage monitor
TotalStressTime: Total stress time.
FailureCondition: Measurement stop condition (%changes of wire resistance)
V1Stress: Port1 stress voltage
I1Limit: Port1 current compliance
IntegTime: Integration time
PointPerDecade: Number of samples in 1 decade
Interval: Sampling interval

[Extended Test Parameters]
V2: Port2 terminal voltage
HoldTime: Hold time
Port1MinRng: Minimum range for the port1 current measurement
R_Max: Y axis maximum value for resistance
StoringRuntimeData: Data save during stress output, Yes or No

[Measurement Parameters]
Port1 current Iport1
Port2 current Iport2

[User Function]
IPort1PerArea (A/cm²) Port1 terminal current per unit area
IPort2PerArea (A/cm²) Port2 terminal current per unit area
R Resistance of wiring device
DeltaV Voltage between terminals of wiring device
MaxTime Maximum elapsed time

[X-Y Graph]
X axis: Stress time Time (LOG)
Y1 axis: Port1 current Iport1 (LINEAR)
Y2 axis: Voltage between terminals of wiring device DeltaV (LINEAR)
Y3 axis: Resistance of wiring device R (LINEAR)
11 Reliability

[List Display]
- Stress time Time
- Port1 current Iport1
- Voltage between terminals of wiring device DeltaV
- Resistance of wiring device R

[Test Output: X-Y Graph]
- X axis: Accumulated stress time TimeList (LOG)
- Y1 axis: Port1 current Iport1List (LINEAR)
- Y2 axis: Resistance of wiring device RList (LINEAR)
- Y3 axis: Difference from initial resistance DeltaRList (LINEAR)

[Test Output: List Display]
- Accumulated stress time TimeList
- Port1 current Iport1List
- Resistance of wiring device RList
- Difference from initial resistance DeltaRList

[Test Output: Parameters]
- Time to failure FailureTime
11.23 EM Vstress[2]: Electromigration test, voltage stressed, 2 SMUs (A.01.20)

[Supported Analyzer]

[Description]
Performs the Electromigration (EM) test, and plots the stress time vs resistance characteristics. This test is performed by the sampling measurement mode as shown below.
1. applies stress voltage
2. performs measurement and saves measurement data
3. calculates the device failure time

[Device Under Test]
Wiring device, 2 terminals

[Device Parameters]
D: Wiring pattern length
W: Wiring pattern width
Temp: Temperature (deg C)

[Test Parameters]
IntegTime: Integration time
TotalStressTime: Total stress time
StopCondition: Measurement stop condition (% changes of wire resistance)
Port1: SMU connected to Port1, constant voltage output
Port2: SMU connected to Port2, constant voltage output
V1Stress: Port1 stress voltage

[Extended Test Parameters]
V2: Port2 voltage
I1Limit: Port1 current compliance
HoldTime: Hold time
Port1MinRng: Minimum range for Port1 current measurement

[User Function]
Wiring resistance value R=Vport1/Iport1

[Test Output: X-Y Graph]
X axis: Accumulated stress time TimeList
Y1 axis: Port1 current Iport1List
Y2 axis: Wiring resistance value RList
Y3 axis: Offset from initial resistance value DeltaRList

[Test Output: List Display]
Accumulated stresss time TimeList
Port1 current Iport1List
Wiring resistance value RList
Offset from initial resistance value DeltaRList

[Test Output: Parameters]
FailureTime: Time to failure
11 Reliability

11.24 EM Vstress2[2]: Electromigration test, voltage stressed, 2 SMUs (A.03.10)

[Supported Analyzer]

[Description]
Performs the Electromigration (EM) test, and plots the stress time vs resistance characteristics. This test is performed by the sampling measurement mode as shown below.
1. applies stress voltage
2. performs measurement and saves measurement data
3. calculates the device failure time

[Device Under Test]
Wiring device, 2 terminals

[Device Parameters]
D: Wiring pattern length
W: Wiring pattern width
Temp: Temperature (deg C)

[Test Parameters]
Port1: SMU connected to Port1, constant voltage output
Port2: SMU connected to Port2, constant voltage output
TotalStressTime: Total stress time
FailureCondition: Measurement stop condition (%changes of wire resistance)
V1Stress: Port1 stress voltage
I1Limit: Port1 current compliance
IntegTime: Integration time
PointPerDecade: Number of samples in 1 decade
Interval: Sampling interval

[Extended Test Parameters]
V2: Port2 terminal voltage
HoldTime: Hold time
Port1MinRng: Minimum range for the port1 current measurement
R_Max: Y axis maximum value for resistance
StoringRuntimeData: Data save during stress output, Yes or No

[Measurement Parameters]
Port1 current Iport1
Port1 voltage Vport2

[User Function]
Wiring resistance value R=Vport1/Iport1

[X-Y Graph]
X axis: Stress time Time (LOG)
Y1 axis: Port1 current Iport1 (LOG)
Y2 axis: Resistance of wiring device R (LINEAR)

[List Display]
Stress time Time
Port1 current Iport1
Resistance of wiring device R
[Test Output: X-Y Graph]
X axis: Accumulated stress time TimeList (LOG)
Y1 axis: Port1 current Iport1List (LINEAR)
Y2 axis: Resistance of wiring device RList (LINEAR)
Y3 axis: Difference from initial resistance DeltaRList (LINEAR)

[Test Output: List Display]
Accumulated stress time TimeList
Port1 current Iport1List
Resistance of wiring device RList
Difference from initial resistance DeltaRList

[Test Output: Parameters]
Time to failure FailureTime
**11.25 EM Vstress[6]: Electromigration test, voltage stressed, 6 SMUs (A.01.20)**

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Performs the Electromigration (EM) test for a wiring device with extrusion lines, and plots the stress time vs resistance characteristics. This test is performed by the sampling measurement mode as shown below.
1. applies stress voltage
2. performs measurement and saves measurement data
3. calculates the device failure time

[Device Under Test]
Wiring device with extrusion lines, 6 terminals

[Device Parameters]
D: Wiring pattern length
W: Wiring pattern width
Temp: Temperature (deg C)

[Test Parameters]
IntegTime: Integration time
TotalStressTime: Total stress time
StopCondition: Measurement stop condition 1 (%changes of wire resistance)
ExtCondition: Measurement stop condition 2 (current to extrusion line)
Port1: SMU connected to Port1, constant voltage output
Port2: SMU connected to Port2, constant voltage output
Port3: SMU connected to Extrusion Line, constant voltage output
Port4: SMU connected to Extrusion Line, constant voltage output
VM1: SMU for Port1 voltage monitoring, constant voltage output
VM2: SMU for Port2 voltage monitoring, constant voltage output
V1Stress: Port1 stress voltage

[Extended Test Parameters]
V2: Port2 voltage
V3: Port3 voltage
V4: Port4 voltage
IM1: VM1 output current
IM2: VM2 output current
I1Limit: Port1 current compliance
I3Limit: Port3 current compliance
I4Limit: Port4 current compliance
HoldTime: Hold time
DelayTime: Delay time
Port1MinRng: Minimum range for Port1 current measurement

[User Function]
Potential difference between lines DeltaV=VM1-VM2
Wiring resistance value R=DeltaV/Iport1

[Test Output: X-Y Graph]
X axis: Accumulated stress time TimeList
Y1 axis: Wiring resistance value RList
Y2 axis: Port1 current Iport1List
Y3 axis: Port3 current Iport3List
Y4 axis: Port4 current Iport4List
Y5 axis: Offset from initial resistance value DeltaRList

[Test Output: List Display]
Accumulated stress time TimeList
Port1 current Iport1List
Wiring resistance value RList
Port3 current Iport3List
Port4 current Iport4List
Offset from initial resistance value DeltaRList

[Test Output: Parameters]
R_FailureTime: Time to failure (Resistance)
E_FailureTime: Time to failure (Extrusion)
11.26 EM Vstress2[6]: Electromigration test, voltage stressed, 6 SMUs (A.03.10)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Performs the Electromigration (EM) test for a wiring device with extrusion lines, and plots the stress time vs resistance characteristics. This test is performed by the sampling measurement mode as shown below.
1. applies stress voltage
2. performs measurement and saves measurement data
3. calculates the device failure time

[Device Under Test]
Wiring device with extrusion lines, 6 terminals

[Device Parameters]
D: Wiring pattern length
W: Wiring pattern width
Temp: Temperature (deg C)

[Test Parameters]
Port1: SMU connected to Port1, constant voltage output
Port2: SMU connected to Port2, constant voltage output
Port3: SMU connected to Extrusion Line, constant voltage output
Port4: SMU connected to Extrusion Line, constant voltage output
VM1: SMU for Port1 voltage monitoring, constant voltage output
VM2: SMU for Port2 voltage monitoring, constant voltage output
TotalStressTime: Total stress time.
FailureCondition: Measurement stop condition 1 (%changes of wire resistance)
ExtCondition: Measurement stop condition 2 (current to extrusion line)
V1Stress: Port1 stress voltage
I1Limit: Port1 current compliance
I3Limit: Port3 current compliance
I4Limit: Port4 current compliance
IntegTime: Integration time
PointPerDecade: Number of samples in 1 decade
Interval: Sampling interval

[Extended Test Parameters]
V2: Port2 voltage
V3: Port3 voltage
V4: Port4 voltage
IM1: VM1 output current
IM2: VM2 output current
HoldTime: Hold time
Port1MinRng: Minimum range for Port1 current measurement
Port3MinRng: Minimum range for Port3 current measurement
Port4MinRng: Minimum range for Port4 current measurement
R_Max: Y axis maximum value for resistance
StoringRuntimeData: Data save during stress output, Yes or No
[Measurement Parameters]
  Port1 current Iport1
  Port3 current Iport3
  Port4 current Iport4

[User Function]
  Voltage between terminals of wiring device DeltaV=Vm1-Vm2
  Resistance of wiring device R=Vport1/Iport2

[X-Y Graph]
  X axis: Stress time Time (LOG)
  Y1 axis: Resistance of wiring device R (LINEAR)
  Y2 axis: Port1 current Iport1 (LINEAR)
  Y3 axis: Port3 current Iport3 (LINEAR)
  Y4 axis: Port4 current Iport4 (LINEAR)
  Y5 axis: Voltage between terminals of wiring device DeltaV (LINEAR)

[List Display]
  Stress time Time
  Resistance of wiring device R
  Port1 current Iport1
  Port3 current Iport3
  Port4 current Iport4
  Voltage between terminals of wiring device DeltaV

[Test Output: X-Y Graph]
  X axis: Accumulated stress time TimeList (LOG)
  Y1 axis: Resistance of wiring device RList (LINEAR)
  Y2 axis: Port1 current Iport1List (LINEAR)
  Y3 axis: Port3 current Iport3List (LINEAR)
  Y4 axis: Port4 current Iport4List (LINEAR)
  Y5 axis: Difference from initial resistance DeltaRList (LINEAR)

[Test Output: List Display]
  Accumulated stress time TimeList
  Resistance of wiring device RList
  Port1 current Iport1List
  Port3 current Iport3List
  Port4 current Iport4List
  Difference from initial resistance DeltaRList

[Test Output: Parameters]
  Time to failure given by rate of resistance change R_FailureTime
  Time to failure given by monitoring extrusion lines E_FailureTime
11.27 HCI 3devices: Hot Carrier Injection test, 4 terminals, 3 devices (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Performs the hot carrier injection test, and plots the accumulated stress time vs threshold voltage/drain current characteristics. Maximum three devices can be measured by a test execution. This test is performed as follows.
1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

[Device Under Test]
MOSFET, 4 terminals, 3 devices

[Required Accessories]
Keysight B2200A or B2201A switching matrix 1 unit
GPIB cable

Connect B2200A/B2201A to B1500A with a measuring cable and GPIB cable.
Set information on B1500A SMU channel's connection to the B2200A/B2201A input port properly on the Switching Matrix tab screen of the Configuration window.
Set the output channel number of B2200A/B2201A connected to each terminal of a device under test properly in the Tr#Gate/Tr#Drain/Tr#Source/Tr#Subs field (# is an integer from 1 to 3) of Test Parameters area.

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value)
Lg: Gate length
Wg: Gate width
Temp: Temperature (deg C)

[Test Parameters]
IntegTime: Integration time (SHORT, MEDIUM, LONG)
Tr#Gate: SWM Pin Assign settings for Gate terminal of devices
Tr#Drain: SWM Pin Assign settings for Drain terminal of devices
Tr#Source: SWM Pin Assign settings for Source terminal of devices
Tr#Subs: SWM Pin Assign settings for Substrate terminal of devices

where, # is an integer from 1 to 3.

[Test Parameters for Sampling_Stress]
TotalStrsTime: Total stress time
Tr#/StrsGate: SMU connected to Gate terminal of devices, constant voltage output
Tr#/StrsDrain: SMU connected to Drain terminal of devices, constant voltage output
StrsSource: SMU connected to Source terminal of devices, constant voltage output
StrsSubs: SMU connected to Substrate terminal of devices, constant voltage output
Tr#VgStrs: Gate terminal stress voltage for the devices
Tr#VdStrs: Drain terminal stress voltage for the devices
VsubsStrs: Substrate terminal stress voltage for the devices
VsStrs: Source terminal stress voltage for the devices

where, # is an integer from 1 to 3.
[Test Parameters for IvSweep_ConstId]
MeasGate: SMU connected to the basic characteristics acquisition Gate terminal, primary sweep voltage output
MeasDrain: SMU connected to the basic characteristics acquisition Drain terminal, constant voltage output
MeasSource: SMU connected to the basic characteristics acquisition Source terminal, constant voltage output
MeasSubs: SMU connected to the basic characteristics acquisition Substrate terminal, constant voltage output
Id@Vth: Drain current to decide the Vth, per unit area
VgStart1: Sweep start voltage for Gate terminal
VgStop1: Sweep stop voltage for Gate terminal
VgStep1: Sweep step voltage for Gate terminal
Vd1: Drain terminal voltage

[Test Parameters for IvSweep_gmmax]
MeasGate: SMU connected to the basic characteristics acquisition Gate terminal, primary sweep voltage output
MeasDrain: SMU connected to the basic characteristics acquisition Drain terminal, constant voltage output
MeasSource: SMU connected to the basic characteristics acquisition Source terminal, constant voltage output
MeasSubs: SMU connected to the basic characteristics acquisition Substrate terminal, constant voltage output
VgStart2: Sweep start voltage for Gate terminal
VgStop2: Sweep stop voltage for Gate terminal
VgStep2: Sweep step voltage for Gate terminal
Vd2: Drain voltage

[Test Parameters for Sampling_Ids]
MeasGate: SMU connected to the basic characteristics acquisition Gate terminal, primary sweep voltage output
MeasDrain: SMU connected to the basic characteristics acquisition Drain terminal, constant voltage output
MeasSource: SMU connected to the basic characteristics acquisition Source terminal, constant voltage output
MeasSubs: SMU connected to the basic characteristics acquisition Substrate terminal, constant voltage output
Vg3: Gate terminal voltage
Vd3: Drain terminal voltage

[Extended Test Parameters]
[Extended Test Parameters for IvSweep_ConstId]
HoldTime: Hold time
DelayTime: Delay time
Vsubs: Substrate terminal voltage
Vs: Source terminal voltage
IgLimit: Gate current compliance of devices
IdLimit: Drain current compliance of devices
IsubsLimit: Substrate current compliance
DrainMinRng1: Minimum range for drain current measurement on device 1
DrainMinRng2: Minimum range for drain current measurement on device 2
DrainMinRng3: Minimum range for drain current measurement on device 3

[Extended Test Parameters for IvSweep_gmmax]
HoldTime: Hold time
DelayTime: Delay time
Vsubs: Substrate terminal voltage
Vs: Source terminal voltage
IgLimit: Gate current compliance of devices
IdLimit: Drain current compliance of devices
IsubsLimit: Substrate current compliance
gmMax_Min: Minimum gmMax value for graph scale
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gmMax _Max: Maximum gmMax value for graph scale
DrainMinRng1: Minimum range for drain current measurement on device 1
DrainMinRng2: Minimum range for drain current measurement on device 2
DrainMinRng3: Minimum range for drain current measurement on device 3

[Extended Test Parameters for Sampling_Id]
Vsubs: Substrate terminal voltage
Vs: Source terminal voltage
IgLimit: Gate current compliance of devices
IdLimit: Drain current compliance of devices
IsubsLimit: Substrate current compliance
DrainMinRng1: Minimum range for drain current measurement on device 1
DrainMinRng2: Minimum range for drain current measurement on device 2
DrainMinRng3: Minimum range for drain current measurement on device 3

[User Function]
[User Function for Sampling_Stress]
Maximum elapsed time value MaxTime=max(Time)
Stress time StressTime=AccTime+Time

[User Function for IvSweep_ConstId]
Maximum drain current value IdMax=max(abs(Idrain)) (For initial measurement only)

[User Function for IvSweep_gmmax]
Minimum drain current value IdMin=min(abs(Idrain)) (For initial measurement only)
Transconductance gm=dif(Idrain,Vgate)
Maximum transconductance value gmMax=max(gm)

[Analysis Function]
[Analysis Function for IvSweep_ConstId]
Vth@Id=@L1X (X intercept of Line1)

[Analysis Function for IvSweep_gmmax]
Vth@Gm=@L1X (X intercept of Line1)

[Auto Analysis]
[Auto Analysis for IvSweep_ConstId]
Line1: Vertical line for Y1 at Idrain=Id@Vth

[Auto Analysis for IvSweep_gmmax]
Line1: Tangent line for Y1 at gm=gmMax

[Test Output: X-Y Graph]
X axis: Elapsed time TimeList (LOG)
Y1 axis: Drain current for device 1 Dev1_IdsList (LOG)
Y2 axis: Drain current for device 2 Dev2_IdsList (LOG)
Y3 axis: Drain current for device 3 Dev3_IdsList (LOG)
Y4 axis: Maximum transconductance value for device 1 Dev1_gmMaxList (LINEAR)
Y5 axis: Maximum transconductance value for device 2 Dev2_gmMaxList (LINEAR)
Y6 axis: Maximum transconductance value for device 3 Dev3_gmMaxList (LINEAR)

[Test Output: List Display]
TimeList: Elapsed time
Dev1_IdsList: Drain current for device 1
Dev2_IdsList: Drain current for device 2
Dev3_IdslList: Drain current for device 3
Dev1_VthIdList: Vth for device 1, determined by constant current method
Dev2_VthIdList: Vth for device 2, determined by constant current method
Dev3_VthIdList: Vth for device 3, determined by constant current method
Dev1_VthGmList: Vth for device 1, determined by extrapolation method
Dev2_VthGmList: Vth for device 2, determined by extrapolation method
Dev3_VthGmList: Vth for device 3, determined by extrapolation method
Dev1_gmMaxList: Maximum transconductance value for device 1
Dev2_gmMaxList: Maximum transconductance value for device 2
Dev3_gmMaxList: Maximum transconductance value for device 3
11.28 HCI: Hot Carrier Injection test, 4 terminals (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Performs the hot carrier injection test, and plots the accumulated stress time vs threshold voltage/drain current characteristics.
This test is performed as follows.
1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

[Device Under Test]
MOSFET, 4 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value)
Lg: Gate length
Wg: Gate width
Temp: Temperature (deg C)

[Test Parameters]
IntegTime: Integration time (SHORT, MEDIUM, LONG)
TotalStressTime: Total stress time
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Subs: SMU connected to Substrate terminal, constant voltage output
Source: SMU connected to Source terminal, constant voltage output
VgStress: Gate terminal stress voltage
VdStress: Drain terminal stress voltage
VsubsStress: Substrate terminal stress voltage
Vsubs: Substrate terminal voltage

[Test Parameters for IvSweep_ConstId]
Id@Vth: Drain current to decide the Vth, per unit area
VgStart1: Sweep start voltage for Gate terminal
VgStop1: Sweep stop voltage for Gate terminal
VgStep1: Sweep step voltage for Gate terminal
Vd1: Drain terminal voltage, constant value

[Test Parameters for IvSweep_gmmax]
VgStart2: Sweep start voltage for Gate terminal
VgStop2: Sweep stop voltage for Gate terminal
VgStep2: Sweep step voltage for Gate terminal
Vd2: Drain voltage

[Test Parameters for Sampling_Idx]
Vg3: Gate terminal voltage
Vd3: Drain terminal voltage

[Extended Test Parameters]
[Extended Test Parameters for IvSweep_ConstId]
HoldTime: Hold time
DelayTime: Delay time
Vs: Source terminal voltage
IgLimit: Gate current compliance
IdLimit: Drain current compliance
IsubsLimit: Substrate current compliance
DrainMinRng: Minimum range for drain current measurement

[Extended Test Parameters for IvSweep_gmmax]
HoldTime: Hold time
DelayTime: Delay time
Vs: Source terminal voltage
IgLimit: Gate current compliance
IdLimit: Drain current compliance
IsubsLimit: Substrate current compliance
Vth_Min: Minimum Vth value for graph scale
Vth_Max: Maximum Vth value for graph scale
gmMax_Min: Minimum gmMax value for graph scale
gmMax_Max: Maximum gmMax value for graph scale
DrainMinRng: Minimum range for drain current measurement

[Extended Test Parameters for Sampling_Ids]
Vs: Source terminal voltage
IgLimit: Gate current compliance
IdLimit: Drain current compliance
IsubsLimit: Substrate current compliance
DrainMinRng: Minimum range for drain current measurement

[User Function]
[User Function for Sampling_Stress]
Maximum elapsed time value MaxTime=max(Time)
Stress time StressTime=AccTime+Time

[User Function for IvSweep_ConstId]
Maximum drain current value IdMax=max(abs(Idrain))  (For initial measurement only)

[User Function for IvSweep_gmmax]
Maximum drain current value IdMax=max(abs(Idrain))  (For initial measurement only)
Transconductance gm=diff(Idrain,Vgate)
Maximum transconductance value gmMax=max(gm)

[Analysis Function]
[Analysis Function for IvSweep_ConstId]
Vth@Id=@L1X (X intercept of Line1)

[Analysis Function for IvSweep_gmmax]
Vth@Gm=@L1X (X intercept of Line1)

[Auto Analysis]
[Auto Analysis for IvSweep_ConstId]
Line1: Vertical line for Y1 at Idrain=Id@Vth

[Auto Analysis for IvSweep_gmmax]
Line1: Tangent line for Y1 at gm=gmMax
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[Test Output: X-Y Graph]
- X axis: Elapsed time TimeList (LOG)
- Y1 axis: Maximum transconductance value gmMaxList (LINEAR)
- Y2 axis: Vth by constant current method VthIdList (LINEAR)
- Y3 axis: Vth by extrapolation method VthGmList (LINEAR)
- Y4 axis: Drain current IdsList (LOG)

[Test Output: List Display]
- Elapsed time TimeList
- Vth by constant current method VthIdList
- Vth by extrapolation method VthGmList
- Drain current IdsList
- Maximum transconductance value gmMaxList
11.29 HCI2: Hot Carrier Injection test, 4 terminals (A.03.10)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Performs the hot carrier injection test, and plots the accumulated stress time vs threshold voltage/drain current characteristics.
This test is performed as follows.
1. performs initial characterization
2. applies stress voltage
3. performs interim characterization
4. saves measurement data
5. repeats 2 to 4 until TotalStressTime elapses

[Device Under Test]
MOSFET, 4 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value)
Lg: Gate length
Wg: Gate width
Temp: Temperature (deg C)

[Test Parameters]
IntegTime: Integration time (SHORT, MEDIUM, LONG)
TotalStressTime: Total stress time
Gate: SMU connected to Gate terminal, primary sweep voltage output
Drain: SMU connected to Drain terminal, constant voltage output
Subs: SMU connected to Substrate terminal, constant voltage output
Source: SMU connected to Source terminal, constant voltage output
VgStress: Gate terminal stress voltage
VdStress: Drain terminal stress voltage
VsSubsStress: Substrate terminal stress voltage
IdLimit: Drain current compliance
MeasConstId: Measurement by constant current method, Yes or No
MeasGmMax: Measurement by extrapolation method, Yes or No
MeasIds: Drain current measurement, Yes or No
MeasTiming: Timing to measure device parameter

[Test Parameters for IvSweep CONSTId]
Id@Vth: Drain current to decide the Vth, per unit area
VgStart1: Sweep start voltage for Gate terminal
VgStop1: Sweep stop voltage for Gate terminal
VgStep1: Sweep step voltage for Gate terminal
Vd1: Drain terminal voltage, constant value
VthStopRate: Vth_CONSTId change rate to stop testing

[Test Parameters for IvSweep gmax]
VgStart2: Sweep start voltage for Gate terminal
VgStop2: Sweep stop voltage for Gate terminal
VgStep2: Sweep step voltage for Gate terminal
Vd2: Drain voltage
GmStopRate: Vth_GmMax change rate to stop testing
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[Test Parameters for Sampling_Ids]
Vg3: Gate terminal voltage
Vd3: Drain terminal voltage
IdsStopRate: Ids change rate to stop testing

[Extended Test Parameters]
StoringRuntimeData: Data save during stress output, Yes or No

[Extended Test Parameters for IvSweep_ConstId]
HoldTime: Hold time
DelayTime: Delay time
Vs: Source terminal voltage
Vsubs: Substrate terminal voltage
IgLimit: Gate current compliance
IsubsLimit: Substrate current compliance
DrainMinRng: Minimum range for drain current measurement

[Extended Test Parameters for IvSweep_gmmax]
HoldTime: Hold time
DelayTime: Delay time
Vs: Source terminal voltage
Vsubs: Substrate terminal voltage
IgLimit: Gate current compliance
IsubsLimit: Substrate current compliance
Vth_Min: Minimum Vth value for graph scale
Vth_Max: Maximum Vth value for graph scale
gmMax_Min: Minimum gmMax value for graph scale
gmMax_Max: Maximum gmMax value for graph scale
DrainMinRng: Minimum range for drain current measurement

[Extended Test Parameters for Sampling_Ids]
Vs: Source terminal voltage
Vsubs: Substrate terminal voltage
IgLimit: Gate current compliance
IsubsLimit: Substrate current compliance
DrainMinRng: Minimum range for drain current measurement

[Measurement Parameters]
[Measurement Parameters by Sampling_Stress]
Drain current Idrain

[Measurement Parameters by IvSweep_ConstId]
Drain current Idrain

[Measurement Parameters by IvSweep_gmmax]
Drain current Idrain

[Measurement Parameters by IvSweep_Ids]
Drain current Idrain

[User Function]
[User Function for IvSweep_ConstId]
Maximum drain current value IdMax=max(abs(Idrain)) (For initial measurement only)
[User Function for IvSweep_gmmax]
Maximum drain current value IdMax=max(abs(Idrain))  (For initial measurement only)
Transconductance gm=diff(Idrain,Vgate)
Maximum transconductance value gmMax=max(gm)

[Analysis Function]
[Analysis Function for IvSweep_ConstId]
Vth@Id=@L1X (X intercept of Line1)

[Analysis Function for IvSweep_gmmax]
Vth@Gm=@L1X (X intercept of Line1)

[Auto Analysis]
[Auto Analysis for IvSweep_ConstId]
Line1: Vertical line for Y1 at Idrain=Id@Vth

[Auto Analysis for IvSweep_gmmax]
Line1: Tangent line for Y1 at gm=gmMax

[X-Y Graph]
[X-Y Graph for Sampling_Stress]
X axis: Stress time StressTime (LINEAR)
Y1 axis: Drain current Idrain (LOG)

[X-Y Graph for IvSweep_ConstId]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)

[X-Y Graph for IvSweep_gmmax]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Transconductance gm (LINEAR)

[X-Y Graph for Sampling_Id]
X axis: Elapsed time Time (LINEAR)
Y1 axis: Drain current Idrain (LOG)

[List Display]
[List Display for Sampling_Stress]
Stress time StressTime
Elapsed time Time
Gate voltage Vgate
Drain voltage Vdrain
Drain current Idrain

[List Display for IvSweep_ConstId]
Gate voltage Vgate
Drain voltage Vdrain
Drain current Idrain

[List Display for IvSweep_gmmax]
Gate voltage Vgate
Drain voltage Vdrain
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Drain current \( I_{\text{drain}} \)
Transconductance \( g_m \)

[List Display for Sampling_Ids]
Elapsed time \( T_{\text{ime}} \)
Drain current \( I_{\text{drain}} \)

[Test Output: X-Y Graph]
X axis: Elapsed time \( T_{\text{ime}} \) List (LOG)
Y1 axis: Maximum transconductance value \( g_{m\text{ax}} \) List (LINEAR)
Y2 axis: \( V_{\text{th}} \) by constant current method \( V_{\text{thId}} \) List (LINEAR)
Y3 axis: \( V_{\text{th}} \) by extrapolation method \( V_{\text{thGm}} \) List (LINEAR)
Y4 axis: Drain current \( I_{\text{ds}} \) List (LOG)

[Test Output: List Display]
Elapsed time \( T_{\text{ime}} \) List
\( V_{\text{th}} \) by constant current method \( V_{\text{thId}} \) List
\( V_{\text{th}} \) by extrapolation method \( V_{\text{thGm}} \) List
Drain current \( I_{\text{ds}} \) List
Maximum transconductance value \( g_{m\text{ax}} \) List
11.30 J-Ramp: Insulator lifetime evaluation, current stressed (A.01.20)

[Supported Analyzer]

[Description]
Measures the time vs current/voltage characteristics with current stress, and extracts the lifetime of the gate oxide, insulator and so on.

[Device Under Test]
MOS capacitor, oxide layer, insulator and so on

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
TimeMax: Maximum value of X axis
Gate: SMU connected to Gate, primary sweep, current output
IgStart: Sweep start current
IgStop: Sweep stop current
VgLimit: Gate voltage compliance
Subs: SMU connected to Substrate, constant voltage output

[Extended Test Parameters]
Vsubs: Substrate voltage
HoldTime: Hold time
DelayTime: Delay time
SubsMinRng: Minimum range for the substrate current measurement

[User Function]
IgatePerArea=Igate/Lg/Wg
IsubsPerArea=Isubs/Lg/Wg
Qbdi=integ(Igate,Time)/Lg/Wg

[Test Output: X-Y Graph]
X axis: Time stamp TimeList (LINEAR)
Y1 axis: Gate current IgateList (LOG)
Y2 axis: Gate voltage VgateList (LINEAR)

[Test Output: List Display]
Time stamp TimeList
Gate current IgateList
Gate voltage VgateList

[Test Output: Parameters]
Breakdown voltage Vbd
Time to breakdown Tbd
Charge to breakdown Qbd
11.31 TDDB Istress 3devices: TDDB Test, current stressed, 3 devices (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Performs the TDDB (time dependent dielectric breakdown) test, and plots the stress time vs voltage characteristics. This test is performed by the sampling measurement mode. This test also supports 3-device connection.

[Device Under Test]
MOS capacitor, insulator, oxide layer, and so on

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
L: Length of pattern
W: Width of pattern
Temp: Temperature

[Test Parameters]
Port1: SMU connected to Port1 terminal
Port2: SMU connected to Port2 terminal
Port3: SMU connected to Port3 terminal
Port4: SMU connected to Port4 terminal
TotalStressTime: Total stress time.
StopCondition: Terminal voltage to decide the breakdown
I1Stress: Port1 stress current
I2Stress: Port2 stress current
I3Stress: Port3 stress current
NoOfSamples: Number of samples
IntegTime: Integration time

[Extended Test Parameters]
V4: Port4 terminal voltage
V1Limit: Port1/Port2/Port3 voltage compliance
I4Limit: Port4 current compliance
HoldTime: Hold time
Port4MinRng: Minimum range for the port4 current measurement

[User Function]
IPort1PerArea=Iport1/L/W
IPort2PerArea=Iport2/L/W
IPort3PerArea=Iport3/L/W
IPort4PerArea=Iport4/L/W

[Test Output: X-Y Graph]
X axis: Stress time TimeList (LOG)
Y1 axis: Port1 terminal voltage Vport1List (LOG)
Y2 axis: Port2 terminal voltage Vport2List (LOG)
Y3 axis: Port3 terminal voltage Vport3List (LOG)

[Test Output: Parameters]
Device1 breakdown voltage Vbd1
Device2 breakdown voltage Vbd2
Device3 breakdown voltage $V_{bd3}$
Device1 time to breakdown $T_{bd1}$
Device2 time to breakdown $T_{bd2}$
Device3 time to breakdown $T_{bd3}$
Device1 charge to breakdown $Q_{bd1}$
Device2 charge to breakdown $Q_{bd2}$
Device3 charge to breakdown $Q_{bd3}$
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11.32 TDDB Istress2 3devices: TDDB Test, current stressed, 3 devices (A.03.10)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Performs the TDDB (time dependent dielectric breakdown) test, and plots the stress time vs voltage characteristics. This test is performed by the sampling measurement mode. This test also supports 3-device connection.

[Device Under Test]
MOS capacitor, insulator, oxide layer, and so on

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
L: Length of pattern
W: Width of pattern
Temp: Temperature

[Test Parameters]
Port1: SMU connected to Port1 terminal
Port2: SMU connected to Port2 terminal
Port3: SMU connected to Port3 terminal
Port4: SMU connected to Port4 terminal
TotalStressTime: Total stress time.
I1Stress: Port1 stress current
I2Stress: Port2 stress current
I3Stress: Port3 stress current
IntegTime: Integration time
PointPerDecade: Number of samples in 1 decade
Interval: Sampling interval
FailureCondition: Measurement stop condition

[Extended Test Parameters]
V4: Port4 terminal voltage
V1Limit: Port1/Port2/Port3 voltage compliance
I4Limit: Port4 current compliance
HoldTime: Hold time
Port4MinRng: Minimum range for the port4 current measurement
StoringRuntimeData: Data save during stress output, Yes or No

[Measurement Parameters]
Port1 voltage Vport1
Port2 voltage Vport2
Port3 voltage Vport3

[User Function]
I1Port1PerArea=Iport1/L/W
I2Port2PerArea=Iport2/L/W
I3Port3PerArea=Iport3/L/W
I4Port4PerArea=Iport4/L/W

[X-Y Graph]
X axis: Stress time Time (LOG)
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Y1 axis: Port1 terminal voltage Vport1 (LOG)
Y2 axis: Port2 terminal voltage Vport2 (LOG)
Y3 axis: Port3 terminal voltage Vport3 (LOG)

[List Display]
Stress time Time
Port1 terminal voltage Vport1
Port2 terminal voltage Vport2
Port3 terminal voltage Vport3
Port1 current Iport1
Port2 current Iport2
Port3 current Iport3

[Test Output: X-Y Graph]
X axis: Stress time TimeList (LOG)
Y1 axis: Port1 terminal voltage Vport1List (LOG)
Y2 axis: Port2 terminal voltage Vport2List (LOG)
Y3 axis: Port3 terminal voltage Vport3List (LOG)

[Test Output: List Display]
Stress time Time
Port1 terminal voltage Vport1
Port2 terminal voltage Vport2
Port3 terminal voltage Vport3

[Test Output: Parameters]
Device1 breakdown voltage Vbd1
Device2 breakdown voltage Vbd2
Device3 breakdown voltage Vbd3
Device1 time to breakdown Tbd1
Device2 time to breakdown Tbd2
Device3 time to breakdown Tbd3
Device1 charge to breakdown Qbd1
Device2 charge to breakdown Qbd2
Device3 charge to breakdown Qbd3
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11.33 TDDB Istress: TDDB Test, current stressed (A.01.20)

[Supported Analyzer]

[Description]
Performs the TDDB (time dependent dielectric breakdown) test, and plots the stress time vs voltage characteristics. This test is performed by the sampling measurement mode.

[Device Under Test]
MOS capacitor, insulator, oxide layer, and so on

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
L: Port1 terminal length
W: Port1 terminal width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
TotalStressTime: Total stress time. 10 to 10000 seconds.
NoOfSamples: Number of samples
Port1: SMU connected to Port1 terminal
I1Stress: Port1 stress current
Port2: SMU connected to Port2 terminal

[Extended Test Parameters]
V2: Port2 terminal voltage
V1Limit: Port1 voltage compliance
I2Limit: Port2 current compliance
HoldTime: Hold time
Port2MinRng: Minimum range for the port2 current measurement

[User Function]
I1PerArea=Iport1/L/W
I2PerArea=Iport2/L/W

[Test Output: X-Y Graph]
X axis: Stress time TimeList (LOG)
Y1 axis: Port1 terminal voltage Vport1List (LINEAR)

[Test Output: List Display]
Stress time TimeList
Port1 terminal voltage Vport1List

[Test Output: Parameters]
Breakdown voltage Vbd
Time to breakdown Tbd
Charge to breakdown Qbd

[Qbd calculation]
Qbd=I1Stress*Tbd/L/W
11.34  **TDDB Istress2: TDDB Test, current stressed (A.03.10)**

[Supported Analyzer]

[Description]
Performs the TDDB (time dependent dielectric breakdown) test, and plots the stress time vs voltage characteristics. This test is performed by the sampling measurement mode.

[Device Under Test]
MOS capacitor, insulator, oxide layer, and so on

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
L: Port1 terminal length
W: Port1 terminal width
Temp: Temperature

[Test Parameters]
Port1: SMU connected to Port1 terminal
Port2: SMU connected to Port2 terminal
TotalStressTime: Total stress time. 10 to 10000 seconds.
I1Stress: Port1 stress current
V1Limit: Port1 voltage compliance
I2Limit: Port2 current compliance
IntegTime: Integration time
PointPerDecade: Number of samples in 1 decade
Interval: Sampling interval
FailureCondition: Measurement stop condition

[Extended Test Parameters]
V2: Port2 terminal voltage
HoldTime: Hold time
Port2MinRng: Minimum range for the port2 current measurement
StoringRuntimeData: Data save during stress output, Yes or No

[Measurement Parameters]
Port1 voltage Vport1

[User Function]
I1PerArea=Iport1/L/W
I2PerArea=Iport2/L/W

[X-Y Graph]
X axis: Stress time Time (LOG)
Y1 axis: Port1 terminal voltage Vport1 (LINEAR)

[List Display]
Stress time Time
Port1 terminal voltage Vport1

[Test Output: X-Y Graph]
X axis: Stress time TimeList (LOG)
Y1 axis: Port1 terminal voltage Vport1List (LINEAR)
11 Reliability

[Test Output: List Display]
Stress time TimeList
Port1 terminal voltage Vport1List

[Test Output: Parameters]
Breakdown voltage Vbd
Time to breakdown Tbd
Charge to breakdown Qbd

[Qbd calculation]
\[Q_{bd} = I_{Stress} \cdot T_{bd} \cdot L / W\]
11.35 TDDB Vstress 3devices: TDDB Test, voltage stressed, 3 devices (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Performs the TDDB (time dependent dielectric breakdown) test, and plots the stress time vs current characteristics. This test is performed by the sampling measurement mode. This test also supports 3-device connection.

[Device Under Test]
MOS capacitor, insulator, oxide layer, and so on

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
L: Length of pattern
W: Width of pattern
Temp: Temperature

[Test Parameters]
Port1: SMU connected to Port1 terminal
Port2: SMU connected to Port2 terminal
Port3: SMU connected to Port3 terminal
Port4: SMU connected to Port4 terminal
TotalStressTime: Total stress time.
StopCondition: Terminal current to decide the breakdown
V1Stress: Port1 stress voltage
V2Stress: Port2 stress voltage
V3Stress: Port3 stress voltage
NoOfSamples: Number of samples
IntegTime: Integration time

[Extended Test Parameters]
V4: Port4 terminal voltage
I1Limit: Port1/Port2/Port3 current compliance
HoldTime: Hold time
Port1MinRng: Minimum range for the port1 current measurement
Port2MinRng: Minimum range for the port2 current measurement
Port3MinRng: Minimum range for the port3 current measurement
Port4MinRng: Minimum range for the port4 current measurement

[User Function]
IPort1PerArea=Iport1/L/W
IPort2PerArea=Iport2/L/W
IPort3PerArea=Iport3/L/W
IPort4PerArea=Iport4/L/W
Qbd1val=integ(Iport1,Time)/L/W
Qbd2val=integ(Iport2,Time)/L/W
Qbd3val=integ(Iport3,Time)/L/W
11 Reliability

[Test Output: X-Y Graph]
  X axis: Stress time TimeList (LOG)
  Y1 axis: Port1 terminal current Iport1List (LOG)
  Y2 axis: Port2 terminal current Iport2List (LOG)
  Y3 axis: Port3 terminal current Iport3List (LOG)

[Test Output: Parameters]
  Device1 time to breakdown Tbd1
  Device2 time to breakdown Tbd2
  Device3 time to breakdown Tbd3
  Device1 charge to breakdown Qbd1
  Device2 charge to breakdown Qbd2
  Device3 charge to breakdown Qbd3
11.36 TDDB Vstress2 3devices: TDDB Test, voltage stressed, 3 devices (A.03.10)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Performs the TDDB (time dependent dielectric breakdown) test, and plots the stress time vs current characteristics. This test is performed by the sampling measurement mode. This test also supports 3-device connection.

[Device Under Test]
MOS capacitor, insulator, oxide layer, and so on

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
L: Length of pattern
W: Width of pattern
Temp: Temperature

[Test Parameters]
Port1: SMU connected to Port1 terminal
Port2: SMU connected to Port2 terminal
Port3: SMU connected to Port3 terminal
Port4: SMU connected to Port4 terminal
TotalStressTime: Total stress time.
FailureCondition: Measurement stop condition
V1Stress: Port1 stress voltage
V2Stress: Port2 stress voltage
V3Stress: Port3 stress voltage
IntegTime: Integration time
PointPerDecade: Number of samples in 1 decade
Interval: Sampling interval

[Extended Test Parameters]
V4: Port4 terminal voltage
I1Limit: Port1/Port2/Port3 current compliance
HoldTime: Hold time
Port1MinRng: Minimum range for the port1 current measurement
Port2MinRng: Minimum range for the port2 current measurement
Port3MinRng: Minimum range for the port3 current measurement
Port4MinRng: Minimum range for the port4 current measurement
StoringRuntimeData: Data save during stress output, Yes or No

[Measurement Parameters]
Port1 current Iport1
Port2 current Iport2
Port3 current Iport3
Port4 current Iport4

[User Function]
IPort1PerArea=Iport1/L/W
IPort2PerArea=Iport2/L/W
IPort3PerArea=Iport3/L/W
Qbd1val=integ(Iport1,Time)/L/W
11 Reliability

Qbd2val = integ(Iport2, Time) / L/W
Qbd3val = integ(Iport3, Time) / L/W

[X-Y Graph]
X axis: Stress time Time (LOG)
Y1 axis: Port1 current Iport1 (LOG)
Y2 axis: Port2 current Iport2 (LOG)
Y3 axis: Port3 current Iport3 (LOG)
Y4 axis: Port4 current Iport4 (LOG)

[List Display]
Stress time Time
Port1 current Iport1
Port2 current Iport2
Port3 current Iport3
Port4 current Iport4
Port1 voltage Vport1
Port2 voltage Vport2
Port3 voltage Vport3
Port4 voltage Vport4

[Test Output: X-Y Graph]
X axis: Stress time TimeList (LOG)
Y1 axis: Port1 current Iport1List (LOG)
Y2 axis: Port2 current Iport2List (LOG)
Y3 axis: Port3 current Iport3List (LOG)

[Test Output: List Display]
Stress time TimeList
Port1 current Iport1List
Port2 current Iport2List
Port3 current Iport3List
Device1 charge to breakdown Qbd1List
Device2 charge to breakdown Qbd2List
Device3 charge to breakdown Qbd3List

[Test Output: Parameters]
Device1 time to breakdown Tbd1
Device2 time to breakdown Tbd2
Device3 time to breakdown Tbd3
Device1 charge to breakdown Qbd1
Device2 charge to breakdown Qbd2
Device3 charge to breakdown Qbd3
11.37 TDDB Vstress: TDDB Test, voltage stressed (A.01.20)

[Supported Analyzer]

[Description]
Performs the TDDB (time dependent dielectric breakdown) test, and plots the stress time vs current characteristics. This test is performed by the sampling measurement mode.

[Device Under Test]
MOS capacitor, insulator, oxide layer, and so on

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
L: Port1 terminal length
W: Port1 terminal width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
TotalStressTime: Total stress time. 10 to 10000 seconds.
StopCondition: Port1 terminal current to decide the breakdown
NoOfSamples: Number of samples
Port1: SMU connected to Port1 terminal
V1Stress: Port1 stress voltage
Port2: SMU connected to Port2 terminal

[Extended Test Parameters]
V2: Port2 terminal voltage
I1Limit: Current compliance
HoldTime: Hold time
Port1MinRng: Minimum range for the port1 current measurement

[User Function]
IPort1PerArea=Iport1/L/W
IPort2PerArea=Iport2/L/W
Qbdval=integ(Iport1,Time)/L/W

[Test Output: X-Y Graph]
X axis: Stress time TimeList (LOG)
Y1 axis: Port1 terminal current Iport1List (LOG)

[Test Output: List Display]
Stress time TimeList
Port1 terminal current Iport1List
Charge to breakdown QbdList

[Test Output: Parameters]
Time to breakdown Tbd
Charge to breakdown Qbd
11 Reliability

11.38 TDDB Vstress2: TDDB Test, voltage stressed (A.03.10)

[SUPPORTED ANALYZER]

[DESCRIPTION]
Performs the TDDB (time dependent dielectric breakdown) test, and plots the stress time vs current characteristics. This test is performed by the sampling measurement mode.

[DEVICE UNDER TEST]
MOS capacitor, insulator, oxide layer, and so on

[DEVICE PARAMETERS]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
L: Port1 terminal length
W: Port1 terminal width
Temp: Temperature

[TEST PARAMETERS]
Port1: SMU connected to Port1 terminal
Port2: SMU connected to Port2 terminal
TotalStressTime: Total stress time. 10 to 10000 seconds.
FailureCondition: Port1 terminal current to decide the breakdown
V1Stress: Port1 stress voltage
IntegTime: Integration time
PointPerDecade: Number of samples in 1 decade
Interval: Sampling interval

[EXTENDED TEST PARAMETERS]
V2: Port2 terminal voltage
I1Limit: Current compliance
HoldTime: Hold time
Port1MinRng: Minimum range for the port1 current measurement
StoringRuntimeData: Data save during stress output, Yes or No

[MEASUREMENT PARAMETERS]
Port1 current Iport1

[USER FUNCTION]
IPort1PerArea=Iport1/L/W
IPort2PerArea=Iport2/L/W
Qbdval=integ(Iport1,Time)/L/W

[X-Y GRAPH]
X axis: Stress time Time (LOG)
Y1 axis: Port1 current Iport1 (LOG)

[List Display]
Stress time Time
Port1 current Iport1

[Test Output: X-Y Graph]
X axis: Stress time TimeList (LOG)
Y1 axis: Port1 current Iport1List (LOG)

[Test Output: List Display]
Stress time TimeList
Port1 current Iport1List
Charge to breakdown QbdList

[Test Output: Parameters]
Time to breakdown Tbd
Charge to breakdown Qbd
11.39 Timing On-the-fly NBTI (A.03.11)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
This test examines the MOSFET Negative Bias Temperature Instability test. The output is a plot of the drain current versus cumulative stress time. The time sampling characteristics of drain current is plotted between the stress cycles. Test is performed as follows.

1. Measures drain current (measures using Sampling_Ids classic test and the results are stored in IdsList.)
2. The stress is applied based on the Stress_Time_List parameter table. The stress time can be adjusted with roughly 100 ms accuracy by properly adjusting the Stress_T_adj parameter.
3. Measurements of the Id in the step 1 are repeated.
4. Perform measurements by repeating step 2 and step 3 till the cumulative stress time exceeds the TotalStressTime. TotalStressTime can be set from 10 sec to 10,000 sec

[Device Under test]
MOSFET, 4 terminals

[Device Parameters]
Polarity: Nch or Pch
Temp: Temperature

[Test Parameters]
Sampling measurements: Perform Id sampling measurements after applying negative bias stress.
Sampling Time Parameters: Set sampling time parameters for Id characterization.
- SamplingInterval: Set sampling time interval for Id characterizes.
- SamplingNumber: Set sampling number for sampling measurements.
- NegativeHoldTime: Set sampling time under the negative bias stress before starting the id sampling characterization.
- Id sampling characterization is made by the parameters Vg, Vd, Vsubs, and Vs.

Negative Bias Stress: Apply a specified stress for NBTI degradation test.
- TotalStressTime: Specify the maximum negative bias stress time
- Stress condition is defined by the parameters VgStress, VdStress, VsubStress, and VsStress.

[Extended Test Parameters]
- IgLimit : Set Current compliance of Gate SMU.
- IdLimit: Set Current compliance of Drain SMU.
- IsubLimit: Set Current compliance of Bulk SMU.
- NBTI_PlotTime: Sampling time of the data used for NBTI degradation plot.
- RecordSamplingData: On saves the Id sampling data and OFF does not save the data.
- YaxStress: Set Y axis maximum of the graph display under the stress condition.
- YaxIdMin: Set Y axis maximum under the Id sampling measurements.
- YaxStressMin: Set Y axis minimum of the graph display under the stress condition.
- HSADC_AvN : Set averaging of HSADC. Additional sampling is performed with 45 us interval, and averaged data is returned.

[Device_ID_Override]
DEVICE ID display in the Results area is made as “new_device_id @ measurement time” if this parameter is set to Y.
11 Reliability

[Sampling Timing adjustment]
SamplingDelay: Adjust this parameter so as the start timing of the sampling measurement observed in the oscilloscope becomes the same as the sampling start display (is Stress_time_at_ in the Parameter display).
Note: Recommend to use the default 50 ms.
Stress_T_adj: Time (negative) for adjusting the stress time accuracy which depends on the measurement setup or a PC speed used for Desktop EasyEXPERT.
Note: Stress_T_adj parameter is adjusted so as the Stree_time_at_ display in the Sampling_Ids graph becomes closer to the end value of the previous stress time. Default value is tuned for the use on the B1500A EasyEXPERT and the RecordSamplingData=ON condition.

[Test Output: X-Y plot]
X axis: Cumulative stress time or sampling time
Y-axis: Id
11.40 Timing On-the-fly NBTI-Mch (A.05.03.2013.0124_2007.02.28.1)

NBTI: Negative Bias Temperature Instability Test

[Supported Analyzer]
B1500A

[Description]
This test examines the MOSFET Negative Bias Temperature Instability of Multi-drain device. The output is a plot of the drain current versus cumulative stress time. The time sampling characteristics of drain current is plotted between the stress cycles.
Test is performed as follows.

Step1. Measures multiple drain currents (measures using “Sampling_Ids” classic test and the results are stored in “IdxsList”. x=1~4)
Step2. The stress is applied based on the Stress_Time_List parameter table.
   The stress time can be adjusted with roughly a few 100ms accuracy by properly adjusting the "Stress_T_adj" parameter.
Step3. Measurements of the Id in the step 1 is repeated.
Step4. Perform measurements by repeating step2 and step3 till the cumulative stress time exceeds the "TotalStressTime".
   TotalStressTime can be set from 10 sec to 10,000 sec.

[Limitation]
- EasyEXPERT version A.02.10 or later is required to execute this application test definition.
- The minimum sampling interval is 100us + (20us x #of additional Drain SMUs) if used more than one SMU is used for Id measurements.

[Reference]
Multi-Channel Parallel Timing-on-the-fly NBTI Characterization Using Keysight B1500A

[Device Under test]
- MOSFET, 4 terminals or Common gate, common Source and common subs with independent 4 Drain device.
- The drain measurements acn be selected from one of (1) for single Dr SMU ch. or (2) simultaneous 4 ch. drain NBTI measurements. (Specify with "N0_of_Drain_Ch" parameter)

[Device Parameters]
Polarity: Nch or Pch
Temp: Temperature

[Test Parameters]
Sampling measurements: Perform Id sampling measurements after applying negative bias stress.
   Sampling Time Parameters: Set sampling time parameters for Id characterization.
   - SamplingInterval: Set sampling time interval for Id characterizes.
   - SamplingNumber: Set sampling number for sampling measurements.
   - NegativeHoldTime: Set sampling time under the negative bias stress before starting the id sampling characterization.
   - Id sampling characterization is made using the following parameters:
     o Vg, Vd, Vsubs, Vs

Negative Bias Stress: Apply a specified stress for NBTI degradation test.
   - TotalStressTime: Specify the maximum negative bias stress time
   - The following parameters are applied in the stress condition.
     o VgStress, VdStress, VsubStress, VsStress
11 Reliability

[Extended Test Parameters]
- IgLimit : Set Current compliance of Gate SMU.
- IdLimit: Set Current compliance of Drain SMU.
  Note: Is compliance is set by the smaller value from "IdLimit x No_of_Drain"_Ch or "100 mA".
- IsubLimit: Set Current compliance of Bulk SMU.
- NBTI_PlotTime: Sampling time of the data used for NBTI degradation plot.
- RecordSamplingData: On saves the Id sampling data and OFF does not save the data.
- YaxStress: Set Y axis maximum of the graph display under the stress condition.
- YaxIdMin: Set Y axis maximum under the Id sampling measurements.
- YaxStressMin: Set Y axis minimum of the graph display under the stress condition.
- No_of_Drain_Ch : 1 or 4ch for drain SMU can be selectable.

[Device_ID Override]
"DEVICE ID" display in the Results area is made as "New_Device_Id"@"Measured time" if this parameter is set to "Y".

[Sampling Timing adjustment]
- SamplingDelay: Adjust this parameter so as the start timing of the sampling measurement observed in the oscilloscope becomes the same as the sampling start display (is "stress_time_at" in the Parameter display).
  Note: Recommend to use the default 200 ms.
- Stress_T_adj: Time (negative) for adjusting the stress time accuracy which depends on the measurement setup or a PC speed used for Desktop EasyEXPERT.
  Note: Stress_T_adj parameter is adjustes so as the "Stree_time_at_" display in the Sampling_Ids graph becomes closer to the end value of the previos stress time. Default value is tuned for the use on the B1500A EasyEXPERT and the "RecordSamplingData=ON" condition.

[Test Output: X-Y plot]
- X axis: Cumulative stress time or sampling time
- Y-axis: Id
11.41 TZDB: TZDB Test of oxide layer (A.01.20)

[Supported Analyzer]

[Description]
Performs the TZDB (time zero dielectric breakdown) test, and plots the current vs voltage characteristics.

[Device Under Test]
MOS capacitor, oxide layer, and so on

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Gate: SMU connected to Gate, primary sweep, voltage output
VgStart: Sweep start voltage
VgStop: Sweep stop voltage
VgStep: Sweep step voltage
IgLimit: Gate current compliance
Subs: SMU connected to Substrate, constant voltage output

[Extended Test Parameters]
Vsubs: Substrate voltage
HoldTime: Hold time
DelayTime: Delay time
GateMinRng: Minimum range for the gate current measurement
SubsMinRng: Minimum range for the substrate current measurement

[User Function]
IgatePerArea=Igate/L/W
IsubsPerArea=Isubs/L/W

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Gate current Igate (LOG)
Y2 axis: Gate current per unit area IgatePerArea (LOG)
11 Reliability

11.42 V-Ramp: Insulator lifetime evaluation, voltage stressed (A.01.20)

[Supported Analyzer]

[Description]
Measures the time vs current/voltage characteristics with voltage stress, and extracts the lifetime of the gate oxide, insulator and so on.

[Device Under Test]
MOS capacitor, oxide layer, insulator and so on

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
TimeMax: Maximum value of X axis
Gate: SMU connected to Gate, primary sweep, voltage output
VgStart: Sweep start voltage
VgStop: Sweep stop voltage
VgStep: Sweep step voltage
Ibd: Gate current to decide the breakdown
Subs: SMU connected to Substrate, constant voltage output

[Extended Test Parameters]
Vsubs: Substrate voltage
HoldTime: Hold time
DelayTime: Delay time
GateMinRng: Minimum range for the gate current measurement
SubsMinRng: Minimum range for the substrate current measurement

[User Function]
IgatePerArea=Igate/Lg/Wg
IsubsPerArea=Isubs/Lg/Wg
Qbd=\int(Igate,Time)/Lg/Wg

[Test Output: X-Y Graph]
X axis: Time stamp TimeList (LINEAR)
Y1 axis: Gate current IgateList (LOG)
Y2 axis: Gate voltage VgateList (LINEAR)

[Test Output: List Display]
Time stamp TimeList
Gate current IgateList
Gate voltage VgateList
Charge to breakdown QbdList

[Test Output: Parameters]
Breakdown voltage Vbd
Charge to breakdown Qbd
Time to breakdown Tbd
1. Vth gmMax and Id: Extrapolation Vth and Constant Vth (A.04.00)
2. Vth gmMax and Id [2HL]: Extrapolation Vth and Constant current Vth (A.06.10)
12.1 Vth gmMax and Id: Extrapolation Vth and Constant Vth (A.04.00)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures MOSFET Id-Vg characteristics, and extracts the threshold voltage (Vth) by the extrapolation method and the threshold voltage (Vth@Id) by the constant current method.

[Device Under Test]
MOSFET, 4 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
Id@Vth: Drain current to decide Vth by the constant current method
Gate: SMU connected to Gate terminal, primary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Drain: SMU connected to Drain terminal, constant voltage output
Vd: Drain voltage
Subs: SMU connected to Substrate, constant voltage output
Vsubs: Substrate voltage
Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]
Vs: Source voltage
IgLimit: Gate current compliance
IsubsLimit: Substrate current compliance
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
Drain current Idrain

[User Function]
gm=diff(Idrain,Vgate)

[Analysis Function]
gmMax=max(gm)
Von=@L1X (X intercept of Line1)
Vth=Von-Vd/2
Vth@Id=@MX (X coordinate of Marker)

Vth is given by the following formula.
Vth=Vg(gmMax)-Id(gmMax)/gmMax
12 Sample

Vd/2 is necessary to compensate the secondary term of Vd in theory.

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Transconductance gm (LINEAR)
Y3 axis: Drain current Idrain (LOG)

[Parameters Display Area]
Threshold voltage by extrapolation method Vth
Maximum gm value gmMax
Threshold voltage by constant current method Vth@Id

[Auto Analysis] set in Vth_gmMax and Id test definition
Line1: Tangent line for Y1 at gm=gmMax

[Auto Analysis] set after Vth_gmMax and Id test definition
Marker: Data point specified by Idrain=Id@Vth*Polarity
12.2 $V_{th \, \text{gmMax}}$ and $I_d [2HL]$: Extrapolation $V_{th}$ and Constant current $V_{th}$ (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures MOSFET $I_d-V_g$ characteristics, and extracts the threshold voltage ($V_{th}$) by the extrapolation method and the threshold voltage ($V_{th}@I_d$) by the constant current method.

[Device Under Test]
MOSFET, 4 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
$L_g$: Gate length
$W_g$: Gate width
$T_{emp}$: Temperature
$I_{dMax}$: Drain current compliance

[Test Parameters]
$IntegTime$: Integration time
$I_d@V_{th}$: Drain current to decide $V_{th}$ by the constant current method
$G_{ate}$: SMU connected to Gate terminal, primary sweep voltage output
$V_{gStart}$: Sweep start voltage for Gate terminal
$V_{gStop}$: Sweep stop voltage for Gate terminal
$V_{gStep}$: Sweep step voltage for Gate terminal
$D_{rain}$: SMU connected to Drain terminal, constant voltage output
$V_d$: Drain voltage

[Extended Test Parameters]
$I_gLimit$: Gate current compliance
$HoldTime$: Hold time
$DelayTime$: Delay time
$DrainMinRng$: Minimum range for the drain current measurement

[Measurement Parameters]
$D_{rain}$ current $I_{drain}$

[User Function]
gm=$\text{diff}(I_{drain},V_{gate})$

[Analysis Function]
gmMax=$\text{max}(gm)$
$V_{on}=@L1\times (X \text{ intercept of Line1})$
$V_{th}=V_{on}-\frac{V_d}{2}$
$V_{th}@I_d=@MX \ (X \text{ coordinate of Marker})$

$V_{th}$ is given by the following formula.
$V_{th}=V_g(gm_{Max})-I_d(gm_{Max})/gm_{Max}$
$V_d/2$ is necessary to compensate the secondary term of $V_d$ in theory.

[X-Y Plot]
12 Sample

X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Transconductance gm (LINEAR)
Y3 axis: Drain current Idrain (LOG)

[Parameters Display Area]
Threshold voltage by extrapolation method Vth
Maximum gm value gmMax
Threshold voltage by constant current method Vth@Id

[Auto Analysis] set in Vth_gmMax and Id test setup
Line1: Tangent line for Y1 at gm=gmMax

[Auto Analysis] set after Vth_gmMax and Id test setup
Marker: Data point specified by Idrain=Id@Vth*Polarity
13 Solar Cell
13 Solar Cell

1. Solar Cell Cp-AC Level: Solar Cell Cp-Vac characteristics (A.05.03.2013.0124_2013.02.27.1)
2. Solar Cell Cp-Freq Log: Solar Cell Cp-f characteristics (A.05.03.2013.0124_2013.02.27.1)
3. Solar Cell Cp-V: Cp-V characteristics of Solar Cell (A.05.03.2013.0124_2013.02.27.1)
4. Solar Cell DLCP: Solar Cell drive-level capacitance profiling (A.05.03.2013.0124_2013.02.27.1)
5. Solar Cell IV: Solar Cell IV characteristics (A.05.03.2013.0124_2013.02.27.1)
6. Solar Cell IV [1HL]: Solar Cell IV characteristics (A.06.10)
7. Solar Cell IV Fwd: Solar Cell forward bias characteristics (A.05.03.2013.0124_2013.02.27.1)
8. Solar Cell IV Fwd [1HL]: Solar Cell forward bias characteristics (A.06.10)
9. Solar Cell IV Rev: Solar Cell reverse bias characteristics (A.05.03.2013.0124_2013.02.27.1)
10. Solar Cell IV Rev [1HL]: Solar Cell reverse bias characteristics (A.06.10)
11. Solar Cell Nc-W: Nc-W characteristics of Solar Cell (A.05.03.2013.0124_2013.02.27.1)
12. Solar Cell Nyquist Plot: Solar Cell Nyquist Plot (A.05.03.2013.0124_2013.02.27.1)
13.1 Solar Cell Cp-AC Level: Solar Cell Cp-Vac characteristics (A.05.03.2013.0124_2013.02.27.1)

[Supported Analyzer]
B1500A

[Description]
Measures the anode-cathode capacitance (Cp) of the solar cell with sweeping the signal level (Vac), and plots the Cp-Vac characteristics.
DC bias output is fixed at Vdc. Vac is swept for the peak-to-peak voltage Vpp to change from VppStart to VppStop in VppStep steps. The maximum and minimum value of the applied voltage should be kept Vdc, Vdc-Vpp respectively. The CMU performs spot measurement of the parallel capacitance (Cp) and conductance (G) at each signal level.

[Reference]
IV and CV Characterizations of Solar/Photovoltaic Cells Using the B1500A

[Device Under Test]
Solar Cell

[Required Modules and Accessories]
Keysight B1520A MFCMU 1 unit

[Device Parameters]
Temp: Temperature
Area: Area of the solar cell
Es: Relative permittivity of semiconductor

[Test Parameters]
IntegTime: Integration time
VppStart: Peak-to-peak voltage (Vpp) start value
VppStop: Vpp stop value
VppStep: Vpp step value
FREQ: Measurement frequency
Anode: CMU connected between Anode and Cathode (CV spot measurement)
Vdc: Anode-Cathode voltage, constant voltage output

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
CpMin: Minimum value of Cp axis for X-Y graph
CpMax: Maximum value of Cp axis for X-Y graph
GMin: Minimum value of G axis for X-Y graph
GMax: Maximum value of G axis for X-Y graph

[Measurement Parameters]
Parallel capacitance cp
Conductance g

[User Function]
PI=3.141592653589
\[d=g/(2*PI*FREQ*cp)\]
13 Solar Cell

\[ \text{rp} = \frac{1}{g} \]
\[ \text{Vpp} = \text{OscLevel} \times 2 \times \sqrt{2} \]
\[ \text{vc} = \text{Vc} \]

[Analysis Function]

[X-Y Graph]
- X axis: Peak-to-peak voltage Vpp (LINEAR)
- Y1 axis: Anode-Cathode capacitance (parallel capacitance) cp (LINEAR)
- Y2 axis: Conductance g (LINEAR)

[List Display]
- Peak-to-peak voltage Vpp
- Anode-Cathode capacitance (parallel capacitance) cp
- Conductance g

[Parameters Display Area]

[Auto Analysis]

[Test Output: X-Y Graph]
- X axis: Peak-to-peak voltage VPP (LINEAR)
- Y1 axis: Anode-Cathode capacitance (parallel capacitance) Cp (LINEAR)
- Y2 axis: Conductance G (LINEAR)

[Test Output: List Display]
- Peak-to-peak voltage VPP
- Anode-Cathode capacitance (parallel capacitance Cp
- Conductance G
- Dissipation factor D
- Parallel resistance Rp
- Actual DC bias voltage VC

[Test Output: Parameters Display Area]
- Intercept of Cp-Vac characteristics C0
- Slope of Cp-Vac characteristics C1
- Drive-level density Ndl
- Depletion width W
13 Sollar Cell

### 13.2 Solar Cell Cp-Freq Log: Solar Cell Cp-f characteristics
(A.05.03.2013.0124_2013.02.27.1)

[SUPPORTED ANALYZER]
B1500A

[DESCRIPTION]
Measures Solar Cell's characteristics of anode-to-cathode capacitance (Cp, linear) vs frequency (f, log). The measurement frequency is 10 points per decade.

[REFERENCE]
IV and CV Characterizations of Solar/Photovoltaic Cells Using the B1500A

[DEVICE UNDER TEST]
Solar Cell

[REQUIRED MODULES AND ACCESSORIES]
1 unit of Keysight B1520A MFCMU

[DEVICE PARAMETERS]
Temp: Temperature

[TEST PARAMETERS]
IntegTime: Integration time
Anode: CMU connected between Anode and Cathode
FreqStart: Sweep start frequency
NoOfDecade: Number of decades for data collection
OscLevel: Measurement signal level
Vdc: Anode-Cathode voltage, constant voltage output

[EXTENDED TEST PARAMETERS]
Hold_time: Hold time
Delay_time: Delay time
Cp_Min: Minimum value of Cp axis for X-Y graph
Cp_Max: Maximum value of Cp axis for X-Y graph
G_Min: Minimum value of G axis for X-Y graph
G_Max: Maximum value of G axis for X-Y graph

[MEASUREMENT PARAMETERS]
Parallel capacitance Cp
Conductance G

[USER FUNCTION]
Pİ=3.141592653589
D=G/(2*Pİ*Freq*Cp)
Rp=1/G
Cs=(1+D^2)*Cp
X=-1/(2*Pİ*Freq*Cs)
Rs=D*abs(X)
Z=sqrt(Rs^2+X^2)
Theta=atan(X/Rs)
13 Solar Cell

[Analysis Function]

[X-Y Graph]
X axis: Frequency Freq (LOG)
Y1 axis: Anode-Cathode capacitance (parallel capacitance) Cp (LINEAR)
Y2 axis: Conductance G (LINEAR)

[List Display]
Frequency Freq
Bias voltage Vnode
Anode-Cathode capacitance (parallel capacitance) Cp
Conductance G
Parallel resistance Rp
Dissipation factor D
Impedance Z
Phase Theta

[Parameters Display Area]

[Auto Analysis]

[Test Output: X-Y Graph]
X axis: Frequency FreqList (LOG)
Y1 axis: Anode-Cathode capacitance (parallel capacitance) CpList (LINEAR)
Y2 axis: Conductance GList (LINEAR)
Y3 axis: Impedance ZList (LOG)
Y4 axis: Phase ThetaList (LOG)

[Test Output: List Display]
Frequency FreqList
Bias voltage VcList
Anode-Cathode capacitance (parallel capacitance) CpList
Conductance GList
Parallel resistance RpList
Dissipation factor DList
Impedance ZList
Phase ThetaList

[Test Output: Parameters Display Area]
13.3 Solar Cell Cp-V: Cp-V characteristics of Solar Cell  
(A.05.03.2013.0124_2013.02.27.1)

[Supported Analyzer]
B1500A

[Description]
Measures the capacitance (Cp) of the solar cell with sweeping the bias voltage, and plots the Cp-Vdc characteristics.

[Reference]
IV and CV Characterizations of Solar/Photovoltaic Cells Using the B1500A  

[Device Under Test]
Solar Cell

[Required Modules and Accessories]
1 unit of Keysight B1520A MFCMU

[Device Parameters]
Temp: Temperature
Area: Area of the solar cell
Es: Relative permittivity of semiconductor

[Test Parameters]
IntegTime: Integration time
FREQ: Measurement frequency
OscLevel: Measurement signal level
Anode: CMU connected between Anode and Cathode (CV sweep measurement)
VdcStart: DC bias start voltage
VdcStop: DC bias stop voltage
VdcStep: DC bias step voltage

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
CpMin: Minimum value of Cp axis for X-Y graph
CpMax: Maximum value of Cp axis for X-Y graph
GMin: Minimum value of G axis for X-Y graph
GMax: Maximum value of G axis for X-Y graph
NMin: Minimum value of N axis for X-Y graph
NMax: Maximum value of N axis for X-Y graph

[Measurement Parameters]
Parallel capacitance Cp
Conductance G

[User Function]
P1=3.141592653589
E0=8.854188E-14
D=G/(2*PI*FREQ*Cp)
Rp=1/G
13 Solar Cell

Vdc=Vanode
Cp_2=1/(Cp^2)
diff_Cp_2=diff(Cp_2,Vdc)
N=-2/(q*Es*E0*(Area^2)*diff_Cp_2)
W=Es*(E0)*Area/Cp/10^2

[Analysis Function]

[X-Y Graph]
X axis: Anode-Cathode voltage Vdc (LINEAR)
Y1 axis: Anode-Cathode capacitance (parallel capacitance) Cp (LINEAR)
Y2 axis: Inverted value of the squared Cp (LINEAR)
Y3 axis: Conductance G (LINEAR)
Y4 axis: Carrier density N (LOG)
Y5 axis: Depletion width W (LINEAR)

[List Display]
Anode-Cathode voltage Vdc
Anode-Cathode capacitance (parallel capacitance) Cp
Conductance G
Parallel resistance Rp
Dissipation factor D
Carrier density N
Depletion width W

[Parameters Display Area]

[Auto Analysis]
13.4 Solar Cell DLCP: Solar Cell drive-level capacitance profiling
(A.05.03.2013.0124_2013.02.27.1)

[Supported Analyzer]
B1500A

[Description]
Measures the anode-cathode capacitance (Cp)-DC bias output(Vdc) characteristics of the solar cell with
sweeping the signal level (Vac), and plots the drive-level density (Ndl) - the depletion width (W) characteristics.
Vdc is changed from VdcStart to VdcStop in VdcStep steps. Vac is swept for the peak-to-peak voltage Vpp to
change from VppStart to VppStop in VppStep steps. The maximum and minimum value of the applied voltage
should be kept Vdc, Vdc-Vpp respectively. The CMU performs Vdc sweep measurement of the parallel
capacitance (Cp) and conductance (G) at each signal level.

[Reference]
IV and CV Characterizations of Solar/Photovoltaic Cells Using the B1500A

[Device Under Test]
Solar Cell

[Required Modules and Accessories]
1 unit of Keysight B1520A MFCMU

[Device Parameters]
Temp: Temperature
Area: Area of the solar cell
Es: Relative permittivity of semiconductor

[Test Parameters]
IntegTime: Integration time
VppStart: Peak-to-peak voltage (Vpp) start value
VppStop: Vpp stop voltage
VppStep: Vpp step voltage
FREQ: Measurement frequency
Anode: CMU connected between Anode and Cathode (CV spot measurement)
VdcStart: DC bias voltage (Vdc) start voltage
VdcStop: Vdc stop voltage
Vdcstep: Vdc step voltage

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
CpMin: Minimum value of Cp axis for X-Y graph
CpMax: Maximum value of Cp axis for X-Y graph
GMin: Minimum value of G axis for X-Y graph
GMax: Maximum value of G axis for X-Y graph
NdlMin: Minimum value of Ndl axis for X-Y graph
NdlMax: Maximum value of Ndl axis for X-Y graph
WMin: Minimum value of W axis for X-Y graph
WMax: Maximum value of W axis for X-Y graph

[Measurement Parameters]
13 Sollar Cell

Parallel capacitance \( cp \)
Conductance \( g \)

[User Function]
\[ PI=3.141592653589 \]
\[ d=g/(2*PI*FREQ*cp) \]
\[ rp=1/g \]
\[ Vpp=OscLevel*2*sqrt(2) \]

[Analysis Function]

[X-Y Graph]
X axis: DC bias voltage \( Vosc \) (LINEAR)
Y1 axis: Anode-Cathode capacitance (parallel capacitance) \( cp \) (LINEAR)
Y2 axis: Conductance \( g \) (LINEAR)

[List Display]
Peak-to-peak voltage \( Vpp \)
DC bias voltage \( Vosc \)
Anode-Cathode capacitance (parallel capacitance) \( cp \)
Conductance \( g \)

[Parameters Display Area]

[Auto Analysis]

[Test Output: X-Y Graph]
X axis: Depletion width \( W \) (LINEAR)
Y1 axis: Drive-level density \( Ndl \) (LOG)

[Test Output: List Display]
Drive-level density \( Ndl \)
Depletion width \( W \)
Intercept of \( Cp-Vac \) characteristics \( C0 \)
Slope of \( Cp-Vac \) characteristics \( C1 \)
Peak-to-peak voltage \( VPP \)
DC bias voltage setting \( VDC \)
Actual DC bias voltage \( VDCACT \)
Anode-Cathode capacitance (parallel capacitance \( Cp \)
Conductance \( G \)

[Test Output: Parameters Display Area]
13.5 Solar Cell IV: Solar Cell IV characteristics
(A.05.03.2013.0124_2013.02.27.1)

[Supported Analyzer]
B1500A

[Description]
Measures anode voltage vs anode current characteristics of the solar cell.

[Reference]
IV and CV Characterizations of Solar/Photovoltaic Cells Using the B1500A

[Device Under Test]
Solar cell

[Required Modules and Accessories]
1 unit among the followings
Keysight B1510A HPSMU
Keysight B1511A MPSMU
Keysight B1517A HRSMU

[Device Parameters]
Temp: Temperature
Icomp: Current compliance
Area: Area of solar cell

[Test Parameters]
IntegTime: Integration time
Anode: SMU connected to Anode terminal, primary sweep voltage output
VanodeStart: Sweep start voltage for Anode terminal
VanodeStop: Sweep stop voltage for Anode terminal
VanodeStep: Sweep step voltage for Anode terminal
Cathode: SMU or GNDU connected to Cathode terminal, constant voltage output (0V)

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
AnodeMinRng: Minimum range for the anode current measurement

[Measurement Parameters]
Ianode: Anode current of the solar cell

[User Function]
Power=-1*Ianode*Vanode
Isolar=-1*Ianode
Jsolar=-1*Ianode/Area
Vsolar=Vanode

[Analysis Function]
13 Solar Cell

[X-Y Graph]
X axis: Anode voltage of the solar cell V_{solar} (LINEAR)
Y1 axis: Anode current of the solar cell I_{solar} (LINEAR)
Y2 axis: Power of the solar cell Power (LINEAR)
Y3 axis: Anode current density of the solar cell J_{solar} (LINEAR)

[List Display]
- Anode voltage of the solar cell V_{solar}
- Anode current of the solar cell I_{solar}
- Power of the solar cell Power
- Anode current density of the solar cell J_{solar}

[Parameters Display Area]

[Auto Analysis]
13.6 Solar Cell IV [1HL]: Solar Cell IV characteristics (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures anode voltage vs anode current characteristics of the solar cell.

[Reference]
IV Characterizations of Solar Cells Using the B2900A Series of SMUs

[Device Under Test]
Solar cell

[Device Parameters]
Temp: Temperature
Icomp: Current compliance
Area: Area of solar cell

[Test Parameters]
IntegTime: Integration time
Anode: High connected to Anode terminal, primary sweep voltage output
VanodeStart: Sweep start voltage for Anode terminal
VanodeStop: Sweep stop voltage for Anode terminal
VanodeStep: Sweep step voltage for Anode terminal
Cathode: Low connected to Cathode terminal, constant voltage output (0V)

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
AnodeMinRng: Minimum range for the anode current measurement

[Measurement Parameters]
Ianode: Anode current of the solar cell

[User Function]
Power=-1*Ianode*Vanode
Isolar=-1*Ianode
Jsolar=-1*Ianode/Area
Vsolar=Vanode

[Analysis Function]

[X-Y Graph]
X axis: Anode voltage of the solar cell Vsolar (LINEAR)
Y1 axis: Anode current of the solar cell Isolar (LINEAR)
Y2 axis: Power of the solar cell Power (LINEAR)
Y3 axis: Anode current density of the solar cell Jsolar (LINEAR)
13 Sollar Cell

[List Display]
Anode voltage of the solar cell $V_{solar}$
Anode current of the solar cell $I_{solar}$
Power of the solar cell $Power$
Anode current density of the solar cell $J_{solar}$

[Parameters Display Area]

[Auto Analysis]
13.7 Solar Cell IV Fwd: Solar Cell forward bias characteristics
(A.05.03.2013.0124_2013.02.27.1)

[Supported Analyzer]
B1500A

[Description]
Measures the forward bias anode voltage vs anode current characteristics of the solar cell.

[Reference]
IV and CV Characterizations of Solar/Photovoltaic Cells Using the B1500A

[Device Under Test]
Solar Cell

[Required Modules and Accessories]
1 unit among the followings
Keysight B1510A HPSMU
Keysight B1511A MPSMU
Keysight B1517A HRSMU

[Device Parameters]
Temp: Temperature
Icomp: Current compliance
Area: Area of solar cell
E: Input light irradiance

[Test Parameters]
IntegTime: Integration time
Anode: SMU connected to Anode terminal, primary sweep voltage output
VanodeStart: Sweep start voltage for Anode terminal
VanodeStop: Sweep stop voltage for Anode terminal
VanodeStep: Sweep step voltage for Anode terminal
Cathode: SMU or GNDU connected to Cathode terminal, constant voltage output (0V)

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
AnodeMinRng: Minimum range for the anode current measurement

[Measurement Parameters]
Ianode: Anode current of the solar cell

[User Function]
Power=-1*Ianode*Vanode
Isolar=-1*Ianode
Vsolar=Vanode
Jsolar=-1*Ianode/Area
Idiff=diff(Isolar,Vsolar)

[Analysis Function]
Pmax=max(Power)
13 SOLAR CELL

\[ V_{\text{max}} = @MX \]
\[ I_{\text{max}} = @MY \]
\[ I_{\text{sc}} = \text{at}(I_{\text{solar}}, 1, 1) \]
\[ J_{\text{sc}} = \text{at}(J_{\text{solar}}, 1, 1) \]
\[ V_{\text{oc}} = @L2X \]
\[ \text{FF} = \frac{(@MX * @MY)}{\text{at}(I_{\text{solar}}, 1, 1) * @L2X} \]
\[ \text{CE} = \frac{(@MX * @MY)}{(\text{Area} * E) * 100} \]
\[ R_{\text{sh}} = \frac{1}{\text{at}(I_{\text{diff}}, 1, 1)} \]
\[ R_s = \frac{1}{@L2G} \]

FF (Fill Factor) and CE (Conversion Efficiency) are given by the following formulas.

\[ \text{FF} = \frac{P_{\text{max}}}{I_{\text{sc}} * V_{\text{oc}}} \]
\[ \text{CE} = \frac{P_{\text{max}}}{\text{Area} * E} \]

[X-Y Graph]
- X axis: Anode voltage of the solar cell \( V_{\text{solar}} \) (LINEAR)
- Y1 axis: Anode current of the solar cell \( I_{\text{solar}} \) (LINEAR)
- Y2 axis: Power of the solar cell \( \text{Power} \) (LINEAR)
- Y3 axis: Anode current density of the solar cell \( J_{\text{solar}} \) (LINEAR)

[List Display]
- Anode voltage of the solar cell \( V_{\text{solar}} \)
- Anode current of the solar cell \( I_{\text{solar}} \)
- Power of the solar cell \( \text{Power} \)
- Anode current density of the solar cell \( J_{\text{solar}} \)

[Parameters Display Area]
- Maximum power output of the cell \( P_{\text{max}} \)
- Voltage at \( P_{\text{max}} \) \( V_{\text{max}} \)
- Current at \( P_{\text{max}} \) \( I_{\text{max}} \)
- Short-circuit current \( I_{\text{sc}} \)
- Short-circuit current density \( J_{\text{sc}} \)
- Open-circuit voltage \( V_{\text{oc}} \)
- Fill factor \( \text{FF} \)
- Conversion efficiency of the cell \( \text{CE} \)
- Shunt resistance of the cell \( R_{\text{sh}} \)
- Series resistance of the cell \( R_s \)

[Auto Analysis]
- Line1: Tangent line for \( Y1 \) at \( \text{Power} = P_{\text{max}} \)
- Line2: Tangent line for \( Y1 \) at \( I_{\text{solar}} = 0 \)
13.8 Solar Cell IV Fwd [IHL]: Solar Cell forward bias characteristics (A.06.10)

[Supported Analyzer]
   B2901A, B2902A, B2911A, B2912A

[Description]
   Measures the forward bias anode voltage vs anode current characteristics of the solar cell.

[Reference]
   IV Characterizations of Solar Cells Using the B2900A Series of SMUs

[Device Under Test]
   Solar Cell

[Device Parameters]
   Temp: Temperature
   Icomp: Current compliance
   Area: Area of solar cell
   E: Input light irradiance

[Test Parameters]
   IntegTime: Integration time
   Anode: High connected to Anode terminal, primary sweep voltage output
   VanodeStart: Sweep start voltage for Anode terminal
   VanodeStop: Sweep stop voltage for Anode terminal
   VanodeStep: Sweep step voltage for Anode terminal
   Cathode: Low connected to Cathode terminal, constant voltage output (0V)

[Extended Test Parameters]
   HoldTime: Hold time
   DelayTime: Delay time
   AnodeMinRng: Minimum range for the anode current measurement

[Measurement Parameters]
   Ianode: Anode current of the solar cell

[User Function]
   Power=-1*Ianode*Vanode
   Isolar=-1*Ianode
   Vsmart=Vanode
   Jsmart=-1*Ianode/Area
   Idiff=diff(Isolar,Vsmart)

[Analysis Function]
   Pmax=max(Power)
   Vmax=@MX
   Imax=@MY
   Isc=at(Isolar,1,1)
   Jsc=at(Jsmart,1,1)
   Voc=@L2X
   FF=(@MX*@MY)/(at(Isolar,1,1)*@L2X)
   CE=(@MX*@MY)/(Area*E)*100
   Rsh=-1/at(Idiff,1,1)
13 Solar Cell

Rs=-1/@L2G

FF (Fill Factor) and CE (Conversion Efficiency) are given by the following formulas.
FF = Pmax/(Isc*Voc)
CE = Pmax/Area*E

[X-Y Graph]
X axis: Anode voltage of the solar cell Vsolar (LINEAR)
Y1 axis: Anode current of the solar cell Isolar (LINEAR)
Y2 axis: Power of the solar cell Power (LINEAR)
Y3 axis: Anode current density of the solar cell Jsolar (LINEAR)

[List Display]
Anode voltage of the solar cell Vsolar
Anode current of the solar cell Isolar
Power of the solar cell Power
Anode current density of the solar cell Jsolar

[Parameters Display Area]
Maximum power output of the cell Pmax
Voltage at Pmax Vmax
Current at Pmax Imax
Short-circuit current Isc
Short-circuit current density Jsc
Open-circuit voltage Voc
Fill factor FF
Conversion efficiency of the cell CE
Shunt resistance of the cell Rsh
Series resistance of the cell Rs

[Auto Analysis]
Line1: Tangent line for Y1 at Power=Pmax
Line2: Tangent line for Y1 at Isolar=0
13.9 Solar Cell IV Rev: Solar Cell reverse bias characteristics (A.05.03.2013.0124_2013.02.27.1)

[Supported Analyzer]
B1500A

[Description]
Measures the reverse bias anode voltage vs anode current characteristics of the solar cell.

[Reference]
IV and CV Characterizations of Solar/Photovoltaic Cells Using the B1500A

[Device Under Test]
Solar Cell

[Required Modules and Accessories]
1 unit among the followings
Keysight B1510A HPSMU
Keysight B1511A MPSMU
Keysight B1517A HRSMU

[Device Parameters]
Temp: Temperature
Icomp: Current compliance
Area: Area of Solar Cell
V_rsh: Voltage to estimate Rsh from the slope of IV characteristics

[Test Parameters]
IntegTime: Integration time
Anode: SMU connected to Anode terminal, primary sweep voltage output
VanodeStart: Sweep start voltage for Anode terminal
VanodeStop: Sweep stop voltage for Anode terminal
VanodeStep: Sweep step voltage for Anode terminal
Cathode: SMU or GNDU connected to Cathode terminal, constant voltage output (0V)

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
AnodeMinRng: Minimum range for the anode current measurement

[Measurement Parameters]
Ianode: Anode current of the solar cell

[User Function]
Isolar=-1*Ianode
Jsolar=-1*Ianode/Area
Vsolar=Vanode

[Analysis Function]
Rsh=-1/@L1G

[X-Y Graph]
13 Solar Cell

X axis: Anode voltage of the solar cell Vsolar (LINEAR)
Y1 axis: Anode current of the solar cell Isolar (LINEAR)
Y2 axis: Anode current density of the solar cell Jsolar (LINEAR)

[List Display]
- Anode voltage of the solar cell Vsolar
- Anode current of the solar cell Isolar
- Anode current density of the solar cell Jsolar

[Parameters Display Area]
- Shunt Resistance of the cell Rsh

[Auto Analysis]
- Line1: Tangent line for Y1 at Vsolar=V_{rsh}
13.10 Solar Cell IV Rev [1HL]: Solar Cell reverse bias characteristics (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the reverse bias anode voltage vs anode current characteristics of the solar cell.

[Reference]
IV Characterizations of Solar Cells Using the B2900A Series of SMUs

[Device Under Test]
Solar Cell

[Device Parameters]
Temp: Temperature
Icomp: Current compliance
Area: Area of Solar Cell
V_rsh: Voltage to estimate Rsh from the slope of IV characteristics

[Test Parameters]
IntegTime: Integration time
Anode: High connected to Anode terminal, primary sweep voltage output
VanodeStart: Sweep start voltage for Anode terminal
VanodeStop: Sweep stop voltage for Anode terminal
VanodeStep: Sweep step voltage for Anode terminal
Cathode: Low connected to Cathode terminal, constant voltage output (0V)

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
AnodeMinRng: Minimum range for the anode current measurement

[Measurement Parameters]
Ianode: Anode current of the solar cell

[User Function]
Isolar=-1*Ianode
Jsolar=-1*Ianode/Area
Vsolar=Vanode

[Analysis Function]
Rsh=-1/@L1G

[X-Y Graph]
X axis: Anode voltage of the solar cell Vsolar (LINEAR)
13 Solar Cell

Y1 axis: Anode current of the solar cell Isolar (LINEAR)
Y2 axis: Anode current density of the solar cell Jsolar (LINEAR)

[List Display]
Anode voltage of the solar cell V_{solar}
Anode current of the solar cell I_{solar}
Anode current density of the solar cell J_{solar}

[Parameters Display Area]
Shunt Resistance of the cell R_{sh}

[Auto Analysis]
Line1: Tangent line for Y1 at V_{solar}=V_{rsh}
13.11 Solar Cell Nc-W: Nc-W characteristics of Solar Cell
(A.05.03.2013.0124_2013.02.27.1)

[Supported Analyzer]
B1500A

[Description]
Measures the capacitance (Cp) of the solar cell with sweeping the bias voltage, and plots the carrier density (Nc) - the depletion width (W) characteristics.

[Reference]
IV and CV Characterizations of Solar/Photovoltaic Cells Using the B1500A

[Device Under Test]
Solar Cell

[Required Modules and Accessories]
1 unit of Keysight B1520A MFCMU

[Device Parameters]
Temp: Temperature
Area: Area of the solar cell
Es: Relative permittivity of semiconductor

[Test Parameters]
IntegTime: Integration time
FREQ: Measurement frequency
OscLevel: Measurement signal level
Anode: CMU connected between Anode and Cathode (CV sweep measurement)
VdcStart: DC bias start voltage
VdcStop: DC bias stop voltage
VdcStep: DC bias step voltage

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
NMin: Minimum value of N axis for X-Y graph
NMax: Maximum value of N axis for X-Y graph
WMin: Minimum value of W axis for X-Y graph
WMax: Maximum value of W axis for X-Y graph
CpMin: Minimum value of Cp axis for X-Y graph
CpMax: Maximum value of Cp axis for X-Y graph

[Measurement Parameters]
Parallel capacitance Cp
Conductance G

[User Function]
PI=3.141592653589
E0=8.854188E-14
D=G/(2*PI*FREQ*Cp)
Rp=1/G
13 Solar Cell

\[ V_{dc} = V_{anode} \]
\[ C_{p,2} = \frac{1}{(C_p)^2} \]
\[ \text{diff}_C_{p,2} = \text{diff}(C_{p,2}, V_{dc}) \]
\[ N = \frac{-2}{(q*E_s*E_0*(\text{Area}^2)\text{*diff}_C_{p,2})} \]
\[ W = E_s*(E_0)*\text{Area}/C_p/10^2 \]

[Analysis Function]

[X-Y Graph]
- X axis: Depletion width \( W \) (LINEAR)
- Y1 axis: Carrier density \( N \) (LINEAR)
- Y2 axis: Anode-Cathode capacitance (parallel capacitance) \( C_p \) (LINEAR)
- Y3 axis: Inverted value of the squared \( C_p \) (LINEAR)

[List Display]
- Depletion width \( W \)
- Carrier density \( N \)
- Anode-Cathode voltage \( V_{dc} \)
- Anode-Cathode capacitance (parallel capacitance) \( C_p \)
- Conductance \( G \)
- Parallel resistance \( R_p \)
- Dissipation factor \( D \)

[Parameter Display Area]

[Auto Analysis]
13.12 Solar Cell Nyquist Plot: Solar Cell Nyquist Plot (A.05.03.2013.0124_2013.02.27.1)

[Supported Analyzer]
B1500A

[Description]
Measures Solar Cell's characteristics of anode-to-cathode capacitance (Cp, linear) vs frequency (f, log) and makes Nyquist plot. The measurement frequency is 10 points per decade.

[Reference]
IV and CV Characterizations of Solar/Photovoltaic Cells Using the B1500A

[Device Under Test]
Solar Cell

[Required Modules and Accessories]
Keysight B1520A MFCMU 1 unit

[Device Parameters]
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Anode: CMU connected between Anode and Cathode
FreqStart: Sweep start frequency
NoOfDecade: Number of decades for data collection
OscLevel: Measurement signal level
Vdc: Anode-Cathode voltage, constant voltage output

[Extended Test Parameters]
Hold_time: Hold time
Delay_time: Delay time
Z1_Max: Maximum value of Z1 axis for X-Y graph
Z2_Max: Maximum value of Z2 axis for X-Y graph

[Measurement Parameters]
Parallel capacitance Cp
Conductance G

[User Function]
PI=3.141592653589
D=G/(2*PI*FREQ*Cp)
Rp=1/G
Z1=G/(G^2+(2*PI*Freq*Cp)^2)
Z2=(2*PI*Freq*Cp)/(G^2+(2*PI*Freq*Cp)^2)

[Analysis Function]

[X-Y Graph]
X axis: Frequency Freq (LOG)
13 Solar Cell

Y1 axis: Anode-Cathode capacitance (parallel capacitance) Cp (LINEAR)
Y2 axis: Conductance G (LINEAR)

[List Display]
Frequency Freq
Bias voltage Vanode
Anode-Cathode capacitance (parallel capacitance) Cp
Conductance G
Parallel resistance Rp
Dissipation factor D
Real part of the impedance Z1
Imaginary part of the impedance Z2

[Parameters Display Area]

[Auto Analysis]

[Test Output: X-Y Graph]
X axis: Real part of the impedance Z1List (LINEAR)
Y1 axis: Imaginary part of the impedance Z2List (LINEAR)

[Test Output: List Display]
Frequency FreqList
Bias voltage VcList
Anode-Cathode capacitance (parallel capacitance) CpList
Conductance GList
Parallel resistance RpList
Dissipation factor DList
Real part of the impedance Z1List
Imaginary part of the impedance Z2List

[Test Output: Parameters Display Area]
1. SPGU_PLSDIV: SPGU PLSDIV (A.05.03.2013.0124_2013.02.27.1)
2. SPGU PLSDIV Id-Vd: SPGU PLSDIV Id-Vd (A.05.03.2013.0124_2013.02.27.1)
3. SPGU PLSDIV Id-Vg: SPGU PLSDIV Id-Vg (A.05.03.2013.0124_2013.02.27.1)
14.1 SPGU PLSDIV (A.05.03.2013.0124_2013.02.27.1)

[Supported Analyzer]
B1500A

[Description]
Performs the SPGU output setup and the measurement setup.
Click the Single button to perform the SPGU output and measurement.

[Reference]
Easy High Power Pulsed IV Measurement Using the Keysight B1500A's HV-SPGU Module

[Test Parameters]
Period: Pulse period (*Adjust the time using Period_adj)
Period_adj: The time for compensating the period setting (*1)

(*1) SPGU PLDIV is realized by repeating a single pulse, thus the actual period is 'Period' plus overhead to repeat a single pulse. Period_adj is the overhead value for compensating the actual period. You have to monitor the actual waveform by an oscilloscope to tune it. The default value is tuned for B1500A A.05.02 on Windows 7.

[SPGU1 and SPGU2]
SPGU: SPGU channel to use
SPGU1: Primary sweep
SPGU2: Secondary sweep
Delay: Pulse delay time
Width: Pulse width
Transition: Pulse transition (leading, trailing) time
Start: Start voltage
Stop: Stop voltage
Step: Step voltage
Base: Pulse base voltage

[Meas]
MeasCh: Measurement SPGU channel
MeasDelay: Delay till start of measurement
MeasInterval: Measuring interval
NumOfAverage: Measurement repetitions
MeasAdjust: Status of measurement adjustment function
MeasMaxCurrent: Measurement Maximum Current (*2)
OverCurrentStopCondition: Less or Greater_Or_Equal (*2)

(*2) When maximum current force ability of SPGU is exceeded, SPGU output will be disconnected automatically. In order to avoid disconnection, if 'Less' is set to 'OverCurrentStopCondition', over current is judged by a predicted current value before reaching the meas max current.

[SMU1 and SMU2]
SMU: SMU channel
Voltage: SMU output voltage
Icomp: SMU current compliance value

[Extended Test Parameters]
LogLevel: Disable (0) or Enable (>=1)
14 SPGU_PLSDIV

LogFile: Absolute path name of the log file
LoopMax: Maximum loop count of measurement adjustment
LimitAbs: Limit when target voltage = 0 of measurement adjustment
LimitRate: Limit when target voltage != 0 of measurement adjustment
Damper: Damper coefficient of measurement adjustment
VbOption1: Select the SPGU1 base voltage will be Base1 or Peak1. (*3)
VbOption2: Select the SPGU2 base voltage will be Base2 or Peak2. (*3)

(*3) If you select 'Peak' for VbOption, the pulse base voltage is same as Peak, and the output waveform will be kind of pseudo-DC bias.
14.2 SPGU PLSDIV Id-Vd (A.05.03.2013.0124_2013.02.27.1)

[Supported Analyzer]
B1500A

[Description]
Measures the drain current vs drain voltage characteristics of MOSFET with pulsed gate and drain voltage using SPGU.

[Reference]
Easy High Power Pulsed IV Measurement Using the Keysight B1500A’s HV-SPGU Module

[Device Under Test]
MOSFET

[Device Parameters]
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
Period: Pulse period
Period_adj: The time for compensating the period setting (*1)

(*1) SPGU PLDIV is realized by repeating a single pulse, thus the actual period is 'Period' plus overhead to repeat a single pulse. Period_adj is the overhead value for compensating the actual period. You have to monitor the actual waveform by an oscilloscope to tune it. The default value is tuned for B1500A A.05.02 on Windows 7.

Gate: Gate terminal definition
VgStart: Gate start voltage
VgStop: Gate stop voltage
VgStep: Gate step voltage
VgBase: Gate pulse base voltage
GateDelay: Gate pulse delay time
GateWidth: Gate pulse width
GateTransition: Gate pulse transition (leading, trailing) time

Drain: Drain terminal definition
VdStart: Drain start voltage
VdStop: Drain stop voltage
VdStep: Drain step voltage
VdBase: Drain pulse base voltage
IdLimit: Current limitation for drain terminal
DrainDelay: Drain pulse delay time
DrainWidth: Drain pulse width
DrainTransition: Drain pulse transition (leading, trailing) time

MeasDelay: Delay till start of measurement
MeasInterval: Measuring interval
NumOfAverage: Measurement repetitions

[Extended Test Parameters]
LogLevel: Disable (0) or Enable (>=1)
LogFile: Absolute path name of the log file
LoopMax: Maximum loop count of measurement adjustment
LimitAbs: Limit when target voltage = 0 of measurement adjustment
LimitRate: Limit when target voltage != 0 of measurement adjustment
Damper: Damper coefficient of measurement adjustment
VgBaseOption: Select the gate base voltage will be VgBase or VgPeak (*2)
VdBaseOption: Select the drain base voltage will be VdBase or VdPeak (*2)

(*2) If you select 'VxPeak' for VxBaseOption, the pulse base voltage is same as Peak, and the output waveform will be kind of pseudo-DC bias.
**14.3 SPGU PLSDIV Id-Vg (A.05.03.2013.0124_2013.02.27.1)**

[Supported Analyzer]
B1500A

[Description]
Measures the drain current vs gate voltage characteristics of MOSFET with pulsed gate and drain voltage using SPGU.

[Reference]
Easy High Power Pulsed IV Measurement Using the Keysight B1500A's HV-SPGU Module

[Device Under Test]
MOSFET

[Device Parameters]
- Lg: Gate length
- Wg: Gate width
- Temp: Temperature

[Test Parameters]
- Period: Pulse period
- Period_adj: The time for compensating the period setting (*1)

(*1) SPGU PLDIV is realized by repeating a single pulse, thus the actual period is 'Period' plus overhead to repeat a single pulse. Period_adj is the overhead value for compensating the actual period. You have to monitor the actual waveform by an oscilloscope to tune it. The default value is tuned for B1500A A.05.02 on Windows 7.

- Gate: Gate terminal definition
- VgStart: Gate start voltage
- VgStop: Gate stop voltage
- VgStep: Gate step voltage
- VgBase: Gate pulse base voltage
- GateDelay: Gate pulse delay time
- GateWidth: Gate pulse width
- GateTransition: Gate pulse transition (leading, trailing) time

- Drain: Drain terminal definition
- Vd: Drain bias
- IdLimit: Current limitation for drain terminal
- DrainDelay: Drain pulse delay time
- DrainWidth: Drain pulse width
- DrainTransition: Drain pulse transition (leading, trailing) time

- MeasDelay: Delay till start of measurement
- MeasInterval: Measuring interval
- NumOfAverage: Measurement repetitions

[Extended Test Parameters]
- LogLevel: Disable (0) or Enable (>=1)
- LogFile: Absolute path name of the log file
- LoopMax: Maximum loop count of measurement adjustment
LimitAbs: Limit when target voltage = 0 of measurement adjustment
LimitRate: Limit when target voltage != 0 of measurement adjustment
Damper: Damper coefficient of measurement adjustment
VgBaseOption: Select the gate base voltage will be VgBase or VgPeak (*2)
VdBaseOption: Select the drain base voltage will be VdBase or VdPeak (*2)

(*2) If you select 'VxPeak' for VxBaseOption, the pulse base voltage is same as Peak, and the output waveform will be kind of pseudo-DC bias.
15 Structure
15 Structure

1. BVgb ThinOx: MOS capacitor Ig-Vg characteristics (A.01.20)
2. BVgb ThinOx [1HL]: MOS capacitor Ig-Vg characteristics (A.06.10)
3. BVgb: MOS capacitor Gate-Substrate breakdown voltage (A.01.20)
4. BVgb [1HL]: MOS capacitor Gate-Substrate breakdown voltage (A.06.10)
5. Cgb-Freq[2] Log: Cgb-f characteristics, 2 terminals (A.01.20)
6. Cgb-Vg 2Freq: MOS capacitor Cgb-Vg characteristics, 2-frequency method (A.01.11)
7. Cgb-Vg[2]: MOS capacitor Cgb-Vg characteristics (A.01.11)
8. Cj-Freq Log: Cj-f characteristics, junction device (A.01.20)
9. Cj-V: Junction capacitance Cj-V characteristics (A.01.11)
10. Diode BVAndCj-V ASU: Diode junction capacitance and breakdown voltage measurement using ASUs (A.01.20)
11. Diode BVAndCj-V SCUU: Diode junction capacitance and breakdown voltage measurement using SCUU (A.01.20)
12. Ig-Vg Iforce: MOS capacitor Ig-Vg characteristics, current sweep (A.01.20)
13. Ig-Vg Iforce [1HL]: MOS capacitor Ig-Vg characteristics, current sweep (A.06.10)
14. Ig-Vg Vforce: MOS capacitor Ig-Vg characteristics, voltage sweep (A.01.20)
15. Ig-Vg Vforce [1HL]: MOS capacitor Ig-Vg characteristics, voltage sweep (A.06.10)
16. Interconnect CouplingCap: Interconnection capacitance (A.01.11)
17. Interconnect OverlapCap: Layer to layer film capacitance (A.01.11)
18. Junction BV: Junction device breakdown voltage (A.01.20)
19. Junction BV [1HL]: Junction device breakdown voltage (A.06.10)
20. Junction DeParam: Junction device DC parameters (Is,N,Rs) (A.01.20)
21. Junction DeParam [1HL]: Junction device DC parameters (Is,N,Rs) (A.06.10)
22. Junction IV Fwd: Diode forward bias characteristics (A.01.20)
23. Junction IV Rev [1HL]: Diode reverse bias characteristics (A.01.20)
24. Junction IV Rev: Diode reverse bias characteristics (A.06.10)
25. Junction IV Rev [1HL]: Diode reverse bias characteristics (A.06.10)
26. QSCV[2] C-Vg, Ig-Vg (2-terminal) (A.03.00)
27. QSCV C Offset Meas Offset capacitance measurement
28. Rdiff-I Kelvin: Diffusion resistor R-I characteristics, Kelvin connection (A.01.11)
29. Rdiff-I: Diffusion resistor R-I characteristics (A.01.11)
30. Rdiff-I [2HL]: Diffusion resistor R-I characteristics (A.06.10)
31. Rdiff-V Kelvin: Diffusion resistor R-V characteristics, Kelvin connection (A.01.20)
32. Rdiff-V: Diffusion resistor R-V characteristics (A.01.20)
33. Rdiff-V [2HL]: Diffusion resistor R-V characteristics (A.06.10)
34. R-I DVM: Low resistance measurement using 3458A, current force (A.01.20)
35. R-I Kelvin: Resistor R-I characteristics, Kelvin connection (A.01.11)
36. R-I Kelvin [2HL]: Resistor R-I characteristics, Kelvin connection (A.06.10)
37. R-I: Resistor R-I characteristics (A.01.11)
38. R-I [1HL]: Resistor R-I characteristics (A.06.10)
39. R-V DVM: Low resistance measurement using 3458A, voltage force (A.01.20)
40. R-V Kelvin: Resistor R-V characteristics, Kelvin connection (A.01.20)
41. R-V Kelvin [2HL]: Resistor R-V characteristics, Kelvin connection (A.06.10)
42. R-V: Resistor R-V characteristics (A.01.20)
43. R-V [1HL]: Resistor R-V characteristics (A.06.10)
44. VanDerPauw Square: Van Der Pauw pattern sheet resistance (A.01.11)
45. VanDerPauw Square [2HL]: Van Der Pauw pattern sheet resistance (A.06.10)
46. Van Der Pau NonUniform: Application Test Library to measure resistance by Van Der Pau NonUniform Method (A.06.10)
15.1 BVgb ThinOx: MOS capacitor Ig-Vg characteristics (A.01.20)

[Supported Analyzer]

[Description]
Extracts the gate current vs gate voltage (Ig-Vg) characteristics of MOS capacitor which has an ultra thin gate insulator. The primary sweep channel applies the quasi-pulsed voltage to Gate terminal, and measures Gate current at both pulse base and peak. The measurements are repeated ABS(VgStop-VgStart)/VgStep times to extract the Ig-Vg characteristics. The pulse base value is the primary sweep start value and can be set by the VgLow parameter. The pulse peak value is the primary sweep stop value and corresponds to Vg.

[Device Under Test]
MOS capacitor

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Gate: SMU connected to Gate, primary sweep voltage output
VgStart: Pulse peak start value
VgStop: Pulse peak stop value
VgStep: Pulse peak step value
VgLow: Pulse base value, primary sweep start value
IgLimit: Gate current compliance
Subs: SMU connected to Substrate, constant voltage output
Vsubs: Substrate voltage

VgStart, VgStop, VgStep values are used to calculate the primary sweep stop value.

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
GateMinRng: Minimum range for the gate current measurement
SubsMinRng: Minimum range for the substrate current measurement

[Measurement Parameters]
Gate current Igate
Substrate current Isubs

[User Function]
Gate current per Gate unit area IgatePerArea=Igate/Lg/Wg
Substrate current per Gate unit area IsubsPerArea=Isubs/Lg/Wg

[Calculation After Measurement]
Buffer=getVectorData("Vgate")
V_gate=storeAt(Vgate,I,1,at(Buffer,2,1))
Buffer=getVectorData("Igate")
I_gate=storeAt(Igate,I,1,at(Buffer,2,1))
I_gate@LowVg=storeAt(Igate,I,1,at(Buffer,1,1))
15 Structure

Val = at(Buffer,1,1)
Val = Val/Lg/Wg*1E-12
I_gate@LowVgPerArea = storeAt(I_gate@LowVgPerArea,1,1,Val)
Buffer = getVectorData(“IgatePerArea”)
I_gatePerArea = storeAt(I_gatePerArea,1,1,at(Buffer,1,1))
I = I+1

[Test Output: X-Y Graph]
X axis: Gate voltage V_gate (LINEAR)
Y1 axis: Gate current I_gate (LOG)
Y2 axis: Gate current at pulse base voltage I_gate@LowVg (LOG)

[Test Output: List Display]
Gate voltage V_gate
Gate current I_gate
Gate current at pulse base voltage I_gate@LowVg
Gate current per Gate unit area I_gatePerArea
I_gate@LowVg per Gate unit area I_gate@LowVgPerArea
15.2 \textit{BVgb ThinOx [1HL]}: MOS capacitor Ig-Vg characteristics (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Extracts the gate current vs gate voltage (Ig-Vg) characteristics of MOS capacitor which has an ultra thin gate insulator. The primary sweep channel applies the quasi-pulsed voltage to Gate terminal, and measures Gate current at both pulse base and peak. The measurements are repeated \(\text{ABS}(\text{VgStop}-\text{VgStart})/\text{VgStep}\) times to extract the Ig-Vg characteristics. The pulse base value is the primary sweep start value and can be set by the VgLow parameter. The pulse peak value is the primary sweep stop value and corresponds to Vg.

[Device Under Test]
MOS capacitor

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Gate: SMU connected to Gate, primary sweep voltage output
VgStart: Pulse peak start value
VgStop: Pulse peak stop value
VgStep: Pulse peak step value
VgLow: Pulse base value, primary sweep start value
IgLimit: Gate current compliance

VgStart, VgStop, VgStep values are used to calculate the primary sweep stop value.

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
GateMinRng: Minimum range for the gate current measurement

[Measurement Parameters]
Gate current Igate

[User Function]
Gate current per Gate unit area IgatePerArea=Igate/Lg/Wg

[Calculation After Measurement]
Buffer=getVectorData("Vgate")
V_gate=storeAt(Vgate,I,1,at(Buffer,2,1))
Buffer=getVectorData("Igate")
I_gate=storeAt(Igate,I,1,at(Buffer,2,1))
I_gate@LowVg=storeAt(Igate,I,1,at(Buffer,1,1))
Val=at(Buffer,1,1)
Val=Val/Lg/Wg*1E-12
I_gate@LowVgPerArea=storeAt(I_gate@LowVgPerArea,I,1,Val)
Buffer=getVectorData("IgatePerArea")
I_gatePerArea=storeAt(I_gatePerArea,I,1,at(Buffer,1,1))
15 Structure

I=I+1

[Test Output: X-Y Graph]
X axis: Gate voltage V_gate (LINEAR)
Y1 axis: Gate current I_gate (LOG)
Y2 axis: Gate current at pulse base voltage I_gate@LowVg (LOG)

[Test Output: List Display]
Gate voltage V_gate
Gate current I_gate
Gate current at pulse base voltage I_gate@LowVg
Gate current per Gate unit area I_gatePerArea
I_gate@LowVg per Gate unit area I_gate@LowVgPerArea
15.3 BVgb: MOS capacitor Gate-Substrate breakdown voltage (A.01.20)

[Supported Analyzer]

[Description]
Measures the gate current vs gate voltage characteristics and extracts the breakdown voltage between gate and substrate (BVgb) of MOS capacitor.

[Device Under Test]
MOS capacitor

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Ig@BVgb: Gate current to decide the breakdown
Gate: SMU connected to Gate, primary sweep voltage output
VgStart: Sweep start voltage for Gate
VgStop: Sweep stop voltage for Gate
VgStep: Sweep step voltage for Gate
Subs: SMU connected to Substrate, constant voltage output
Vsubs: Substrate voltage

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
GateMinRng: Minimum range for the gate current measurement

[Measurement Parameters]
Gate current Igate
For the all terminals, the SMU current compliance is set to Ig@BVgb*1.1.

[User Function]
Gate current per Gate unit area Igate_Area=Igate/Lg/Wg

[Analysis Function]
BVgb=@L1X (X intercept of Line1)

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Gate current Igate (LOG)
Y2 axis: Gate current per Gate unit area Igate_Area (LOG)

[Parameters Display Area]
Gate-Substrate breakdown voltage BVgb

[Auto Analysis]
Line1: Vertical line through Y1 data at Igate=Ig@BVgb
15.4 BVgb [IHL]: MOS capacitor Gate-Substrate breakdown voltage (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the gate current vs gate voltage characteristics and extracts the breakdown voltage between gate and substrate (BVgb) of MOS capacitor.

[Device Under Test]
MOS capacitor

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Ig@BVgb: Gate current to decide the breakdown
Gate: SMU connected to Gate, primary sweep voltage output
VgStart: Sweep start voltage for Gate
VgStop: Sweep stop voltage for Gate
VgStep: Sweep step voltage for Gate

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
GateMinRng: Minimum range for the gate current measurement

[Measurement Parameters]
Gate current Igate
For the all terminals, the SMU current compliance is set to Ig@BVgb*1.1.

[User Function]
Gate current per Gate unit area Igate_Area=Igate/Lg/Wg

[Analysis Function]
BVgb=@L1X (X intercept of Line1)

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Gate current Igate (LOG)
Y2 axis: Gate current per Gate unit area Igate_Area (LOG)

[Parameters Display Area]
Gate-Substrate breakdown voltage BVgb

[Auto Analysis]
Line1: Vertical line through Y1 data at Igate=Ig@BVgb
15.5 Cgb-Freq[2] Log: Cgb-f characteristics, 2 terminals (A.01.20)

[Supported Analyzer]
B1500A

[Description]
Measures MOS capacitor's characteristics of gate-to-substrate capacitance (Cgb, linear) vs frequency (f, log). The measurement frequency is 10 points per decade.
For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.
Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
MOS capacitor, 2 terminals
Connect CMU High and CMU Low to the substrate and gate respectively.

[Required Modules and Accessories]
Keysight B1520A MFCMU 1 unit

[Device Parameters]
Polarity: Nch (CMU forces the specified value) or Pch (CMU forces the negative specified value)
Lg: Gate length
Wg: Gate width
Temp: Temperature (deg C)

[Test Parameters]
IntegTime: Integration time
FreqStart: Sweep start frequency, LOG sweep
NoOfDecade: Number of decades for data collection
OscLevel: Measurement signal level
Gate: CMU connected to Gate terminal
Vgs: Voltage for Gate terminal, constant voltage

[Extended Test Parameters]
G_Min: Minimum transconductance value for graph
G_Max: Maximum transconductance value for graph
Cp_Min: Minimum capacitance value for graph
Cp_Max: Maximum capacitance value for graph

[Measurement Parameters]
Parallel capacitance Cp
Conductance G

[User Function]
Circular constant PI=3.141592653589
Frequency Frequency=Freq
Dissipation factor D=G/(2*PI*Freq*Cp)
Parallel resistance Rp=1/G
15 Structure

Series capacitance \( Cs=(1+D^2)C_p \)
Reactance \( X=-1/(2\pi Freq*Cs) \)
Series resistance \( Rs=D*abs(X) \)
Impedance \( Z=\sqrt{Rs^2+X^2} \)
Phase \( \Theta=\text{atan}(X/Rs) \)

[X-Y Plot]
X axis: Frequency Freq (LOG)
Y1 axis: Gate capacitance (parallel capacitance) \( C_p \) (LINEAR)
Y2 axis: Conductance \( G \) (LINEAR)

[List Display]
Frequency Freq
Gate capacitance (parallel capacitance) \( C_p \)
Conductance \( G \)
Series capacitance \( C_s \)
Series resistance \( R_s \)
Parallel resistance \( R_p \)
Dissipation factor \( D \)
Reactance \( X \)
Impedance \( Z \)
Phase \( \Theta \)
Substrate voltage \( V_{subs} \)

[Test Output: X-Y Graph]
X axis: Frequency list FreqList (LOG)
Y1 axis: Gate capacitance (parallel capacitance) list \( C_p \) (LINEAR)
Y2 axis: Conductance list \( G \) (LINEAR)

[Test Output: List Display]
Frequency FreqList
Gate capacitance (parallel capacitance) \( C_p \) List
Conductance \( G \) List
Series capacitance \( C_s \) List
Series resistance \( R_s \) List
Parallel resistance \( R_p \) List
Dissipation factor \( D \) List
Reactance \( X \) List
Impedance \( Z \) List
Phase \( \Theta \) List
Substrate voltage \( V_{subs} \) List
15.6 Cgb-Vg 2Freq: MOS capacitor Cgb-Vg characteristics, 2-frequency method (A.01.11)

[Supported Analyzer]
B1500A

[Description]
Measures the Gate-Substrate capacitance (Cgb) by using two-frequency method, and plots the Cgb-Vg characteristics.
DC bias output is performed from -VgbStart to -VgbStop in -VgbStep steps.
The Cgb value is given by the following formula. Then C1 and C2 are capacitance, D1 and C2 are dissipation factor measured at the frequency (f1 and f2).

\[ C_{gb} = \frac{[f1^2*C1*(1+D1^2)-f2^2*C2*(1+D2^2)]}{[f2^2-f1^2]} \]

For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
MOS capacitor
Connect Gate to the CMU Low, and Substrate to the CMU High.

[Device Parameters]
Polarity: Nch (CMU forces the specified value) or Pch (CMU forces the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
FREQ1: Measurement frequency #1
FREQ2: Measurement frequency #2
OscLevel: Measurement signal level
Gate: CMU connected between Gate and channel (CV sweep measurement)
VgbStart: DC bias start voltage
VgbStop: DC bias stop voltage
VgbStep: DC bias step voltage

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Parallel capacitance Cp
Dissipation factor D
15 Structure

[User Function]
Vgb=-Vsubs

[Display Setup: X-Y Graph]
X axis: Gate voltage Vgb (LINEAR)
Y1 axis: Gate capacitance (parallel capacitance) Cp (LINEAR)
Y2 axis: Dissipation factor D (LINEAR)

[Display Setup: List Display]
Measurement frequency Freq
Gate voltage Vgb
Gate capacitance (parallel capacitance) Cp
Dissipation factor D

[Test Output: X-Y Graph]
X axis: Gate voltage VGB (LINEAR)
Y1 axis: Gate capacitance (parallel capacitance) Cgb (LINEAR)
Y2 axis: Gate capacitance (parallel capacitance) Cp_FREQ1 (LINEAR)
Y3 axis: Gate capacitance (parallel capacitance) Cp_FREQ2 (LINEAR)

[Test Output: List Display]
Gate voltage VGB
Gate capacitance (parallel capacitance) Cgb
Gate capacitance (parallel capacitance) Cp_FREQ1
Gate capacitance (parallel capacitance) Cp_FREQ2
Dissipation factor D_FREQ1
Dissipation factor D_FREQ2
15.7 Cgb-Vg[2]: MOS capacitor Cgb-Vg characteristics (A.01.11)

[Supported Analyzer]
B1500A

[Description]
Measures the Gate-Substrate capacitance (Cgb), and plots the Cgb-Vg characteristics. DC bias output is performed from -VgbStart to -VgbStop in -VgbStep steps. For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement. If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
MOS capacitor
Connect Gate to the CMU Low, and Substrate to the CMU High.

[Device Parameters]
Polarity: Nch (CMU forces the specified value) or Pch (CMU forces the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
FREQ: Measurement frequency
OscLevel: Measurement signal level
Gate: CMU connected between Gate and channel (CV sweep measurement)
VgbStart: DC bias start voltage
VgbStop: DC bias stop voltage
VgbStep: DC bias step voltage

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Parallel capacitance Cp
Conductance G

[User Function]
PI=3.141592653589
D=G/(2*PI*FREQ*Cp)
Rp=1/G
Cs=(1+D^2)*Cp
X=-1/(2*PI*FREQ*Cs)
Rs=D*abs(X)
Z=sqrt(Rs^2+X^2)
Theta=atan(X/Rs)
15 Structure

\[ V_{\text{gate}} = -V_{\text{subs}} \]
\[ C_{\text{PerArea}} = \frac{C_p}{L_g/W_g} \]
\[ C_{\text{PerWg}} = \frac{C_p}{W_g} \]

[X-Y Graph]

X axis: Gate voltage \( V_{\text{gate}} \) (LINEAR)
Y1 axis: Gate capacitance (parallel capacitance) \( C_p \) (LINEAR)
Y2 axis: Conductance \( G \) (LINEAR)

[List Display]

Gate voltage \( V_{\text{gate}} \)
Gate capacitance (parallel capacitance) \( C_p \)
Conductance \( G \)
Series capacitance \( C_s \)
Series resistance \( R_s \)
Parallel resistance \( R_p \)
Dissipation factor \( D \)
Reactance \( X \)
Impedance \( Z \)
Phase Theta
Gate-Substrate capacitance per Gate unit area \( C_{\text{PerArea}} \)
Gate-Substrate capacitance per Gate unit width \( C_{\text{PerWg}} \)
15.8 Cj-Freq Log: Cj-f characteristics, junction device (A.01.20)

[Supported Analyzer]
B1500A

[Description]
Measures the junction capacitance (Cj, linear) vs frequency (f, log) characteristics of a junction device. The measurement frequency is 10 points per decade.

[Device Under Test]
Junction device (diode), 2 terminals
Connect CMU High and CMU Low to the anode and cathode respectively.
For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Required Modules and Accessories]
Keysight B1520A MFCMU 1 unit

[Device Parameters]
L: Junction length
W: Junction width
Temp: Temperature (deg C)

[Test Parameters]
IntegTime: Integration time
FreqStart: Sweep start frequency, LOG sweep
NoOfDecade: Number of decades for data collection
OscLevel: Measurement signal level
Anode: CMU connected between Anode and Cathode
Vanode: Voltage applied on Anode

[Extended Test Parameters]
G_Min: Minimum transconductance value for graph
G_Max: Maximum transconductance value for graph
Cp_Min: Minimum capacitance value for graph
Cp_Max: Maximum capacitance value for graph

[Measurement Parameters]
Parallel capacitance Cp
Conductance G

[User Function]
Circular constant PI=3.141592653589
Frequency Frequency=Freq
Dissipation factor D=G/(2*PI*Freq*Cp)
Parallel resistance Rp=1/G
Series capacitance Cs=(1+D^2)*Cp
15 Structure

Reactance \( X = -1/(2\pi\text{Freq}\times Cs) \)
Series resistance \( Rs = D\times |X| \)
Impedance \( Z = \sqrt{Rs^2 + X^2} \)
Phase Theta = \( \text{atan}(X/Rs) \)

[X-Y Plot]
X axis: Frequency Freq (LOG)
Y1 axis: Junction capacitance (parallel capacitance) Cp (LINEAR)
Y2 axis: Conductance G (LINEAR)

[List Display]
Frequency Freq
Anode voltage Vanode
Junction capacitance (parallel capacitance) Cp
Conductance G
Series capacitance Cs
Series resistance Rs
Parallel resistance Rp
Dissipation factor D
Reactance X
Impedance Z
Phase Theta

[Test Output: X-Y Graph]
X axis: Frequency list FreqList (LOG)
Y1 axis: Gate capacitance (parallel capacitance) list CpList (LINEAR)
Y2 axis: Conductance list GList (LINEAR)

[Test Output: List Display]
Frequency FreqList
Anode voltage VaList
Gate capacitance (parallel capacitance) CpList
Conductance GList
Series capacitance CsList
Series resistance RsList
Parallel resistance RpList
Dissipation factor DList
Reactance XList
Impedance ZList
Phase ThetaList
15.9 Cj-V: Junction capacitance Cj-V characteristics (A.01.11)

[Supported Analyzer]
B1500A

[Description]
Measures the junction capacitance (Cj), and plots the Cj-V characteristics.
For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
Junction device, diode

[Device Parameters]
L: Junction length
W: Junction width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
FREQ: Measurement frequency
OscLevel: Measurement signal level
Anode: CMU connected between Anode and Cathode (CV sweep measurement)
VacStart: DC bias start voltage
VacStop: DC bias stop voltage
VacStep: DC bias step voltage

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Parallel capacitance Cp
Conductance G

[User Function]
PI=3.141592653589
D=G/(2*PI*FREQ*Cp)
Rp=1/G
Cs=(1+D^2)*Cp
X=-1/(2*PI*FREQ*Cs)
Rs=D*abs(X)
Z=sqrt(Rs^2+X^2)
Theta=atan(X/Rs)
Vgate=-Vsubs
CpPerArea=Cp/L/W
CpPerWg=Cp/W
15 Structure

[X-Y Graph]
X axis: Anode voltage Vanode (LINEAR)
Y1 axis: Junction capacitance (parallel capacitance) Cp (LINEAR)
Y2 axis: Conductance G (LINEAR)

[List Display]
Anode voltage Vanode
Junction capacitance (parallel capacitance) Cp
Conductance G
Series capacitance Cs
Series resistance Rs
Parallel resistance Rp
Dissipation factor D
Reactance X
Impedance Z
Phase Theta
Junction capacitance per unit area CpPerArea
Junction capacitance per unit width CpPerWg
15.10 Diode BVAndCj-V ASU : Diode junction capacitance and breakdown voltage measurement using ASUs (A.01.20)

[Supported Analyzer]
B1500A

[Description]
Measures the reverse bias junction capacitance and breakdown voltage by using one MFCMU and two sets of the HRSMU/ASU.
For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
Diode

[Required Modules and Accessories]
One MFCMU module and two sets of HRSMU/ASU are required.
ASU#1 connections: Output: anode, SMU: HRSMU, AUX: MFCMU High
ASU#2 connections: Output: cathode, SMU: HRSMU, AUX: MFCMU Low
Connection wire must be connected between the CMU Return terminals of ASUs.
Setting of ASU I/O Path, ASU tab, Configuration window: AUX

[Device Parameters]
L: Diode length
W: Diode width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time

[Test Parameters: for Junction Capacitance Measurements]
AnodeAC: CMU connected to Anode terminal
FREQ: Measurement frequency
OscLevel: Measurement signal level
VBiasStart: DC bias start voltage
VBiasStop: DC bias stop voltage
VBiasStep: DC bias step voltage

[Test Parameters: for Breakdown Voltage Measurements]
AnodeDC: SMU connected to Anode terminal, primary sweep voltage output
VanodeStart: Sweep start voltage for Anode terminal
VanodeStop: Sweep stop voltage for Anode terminal
VanodeStep: Sweep step voltage for Anode terminal
Ianode@BV: Anode current to decide the breakdown
CathodeDC: SMU connected to Cathode terminal, constant voltage output
[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
AnodeMinRng: Minimum range for the anode current measurement

[Junction Capacitance Measurements: Measurement Parameters]
Parallel capacitance Cp
Conductance G

[Junction Capacitance Measurements: X-Y Plot]
X axis: Anode voltage (LINEAR)
Y1 axis: Junction capacitance Cp (LINEAR)
Y2 axis: Conductance G (LINEAR)

[Junction Capacitance Measurements: List Display]
Impedance Z
Phase Theta
Series capacitance Cs
Series resistance Rs
Parallel resistance Rp
Dissipation factor D
Reactance X
Capacitance per junction unit area Cp_S

[Junction Capacitance Measurements: Parameters Display Area]
Zero bias capacitance value Cj0

[Breakdown Voltage Measurements: Measurement Parameters]
Anode current
For the anode terminal, the SMU current compliance is set to Ianode@BD*1.1.

[Breakdown Voltage Measurements: User Function]
Anode current per junction unit area Ianode_S

[Breakdown Voltage Measurements: X-Y Plot]
X axis: Anode voltage (LINEAR)
Y1 axis: Anode current (LOG)

[Breakdown Voltage Measurements: Parameters Display Area]
Junction breakdown voltage BV
Zero bias capacitance value Cj0
15.11 Diode BV\textit{And}Cj-V SCUU: Diode junction capacitance and breakdown voltage measurement using SCUU (A.01.20)

[Supported Analyzer]
B1500A

[Description]
Measures the reverse bias junction capacitance and breakdown voltage by using one MFCMU, two SMUs, and a set of SCUU/HSWI.
For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
Diode

[Required Modules and Accessories]
One MFCMU module, two SMU modules, and a set of SCUU/HSWI are required.
SCUU connections: Output1: anode, Output2: cathode
Connection wire must be connected between the GSWU and the DUT interface High/Low guard lines for the capacitance measurements.

[Device Parameters]
L: Diode length
W: Diode width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time

[Test Parameters: for Junction Capacitance Measurements]
AnodeAC: CMU connected to Anode terminal
FREQ: Measurement frequency
OscLevel: Measurement signal level
VBiasStart: DC bias start voltage
VBiasStop: DC bias stop voltage
VBiasStep: DC bias step voltage

[Test Parameters: for Breakdown Voltage Measurements]
AnodeDC: SMU connected to Anode terminal, primary sweep voltage output
VanodeStart: Sweep start voltage for Anode terminal
VanodeStop: Sweep stop voltage for Anode terminal
VanodeStep: Sweep step voltage for Anode terminal
Ianode@BV: Anode current at breakdown
CathodeDC: SMU connected to Cathode terminal, constant voltage output

[Extended Test Parameters]
15 Structure

HoldTime: Hold time
DelayTime: Delay time
AnodeMinRng: Minimum range for the anode current measurement

[Junction Capacitance Measurements: Measurement Parameters]
Parallel capacitance Cp
Conductance G

[Junction Capacitance Measurements: X-Y Plot]
X axis: Anode voltage (LINEAR)
Y1 axis: Junction capacitance Cp (LINEAR)
Y2 axis: Conductance G (LINEAR)

[Junction Capacitance Measurements: List Display]
Impedance Z
Phase Theta
Series capacitance Cs
Series resistance Rs
Parallel resistance Rp
Dissipation factor D
Reactance X
Capacitance per junction unit area Cp_S

[Junction Capacitance Measurements: Parameters Display Area]
Zero bias capacitance value Cj0

[Breakdown Voltage Measurements: Measurement Parameters]
Anode current
For the anode terminal, the SMU current compliance is set to Ianode@BD*1.1.

[Breakdown Voltage Measurements: User Function]
Anode current per junction unit area Ianode_S

[Breakdown Voltage Measurements: X-Y Plot]
X axis: Anode voltage (LINEAR)
Y1 axis: Anode current (LOG)

[Breakdown Voltage Measurements: Parameters Display Area]
Junction breakdown voltage BV
Zero bias capacitance value Cj0
15.12 Ig-Vg Iforce: MOS capacitor Ig-Vg characteristics, current sweep (A.01.20)

[Supported Analyzer]

[Description]
Measures gate current vs gate voltage (Ig-Vg) characteristics of MOS capacitor gate insulator.

[Device Under Test]
MOS capacitor

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Gate: SMU connected to Gate terminal, primary sweep current output
IgStart: Sweep start current for Gate terminal
IgStop: Sweep stop current for Gate terminal
VgLimit: Gate voltage compliance
Subs: SMU connected to Substrate, constant voltage output
Vsubs: Substrate voltage

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
SubsMinRng: Minimum range for the substrate current measurement

[Measurement Parameters]
Gate voltage Vgate
Substrate current Isubs

[User Function]
IgatePerArea: Gate current per unit gate area IgatePerArea=Igate/Lg/Wg
IsubsPerArea: Substrate current per unit gate area IsubsPerArea=Isubs/Lg/Wg

[X-Y Plot]
X axis: Gate current Igate (LOG)
Y1 axis: Gate voltage Vgate (LINEAR)
15.13  Ig-Vg Iforce [IHL]: MOS capacitor Ig-Vg characteristics, current sweep (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures gate current vs gate voltage (Ig-Vg) characteristics of MOS capacitor gate insulator.

[Device Under Test]
MOS capacitor

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Gate: SMU connected to Gate terminal, primary sweep current output
IgStart: Sweep start current for Gate terminal
IgStop: Sweep stop current for Gate terminal
VgLimit: Gate voltage compliance

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Gate voltage Vgate

[User Function]
IgatePerArea: Gate current per unit gate area IgatePerArea=Igate/Lg/Wg

[X-Y Plot]
X axis: Gate current Igate (LOG)
Y1 axis: Gate voltage Vgate (LINEAR)
15.14 Ig-Vg Vforce: MOS capacitor Ig-Vg characteristics, voltage sweep (A.01.20)

[Supported Analyzer]

[Description]
Measures gate current vs gate voltage (Ig-Vg) characteristics of MOS capacitor gate insulator.

[Device Under Test]
MOS capacitor

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Gate: SMU connected to Gate terminal, primary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
IgLimit: Gate current compliance
Subs: SMU connected to Substrate, constant voltage output
Vsubs: Substrate voltage

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
GateMinRng: Minimum range for the gate current measurement
SubsMinRng: Minimum range for the substrate current measurement

[Measurement Parameters]
Gate current Igate
Substrate current Isubs

[User Function]
IgatePerArea: Gate current per unit gate area \( I_{gatePerArea} = \frac{I_{gate}}{L_g W_g} \)
IsubsPerArea: Substrate current per unit gate area \( I_{subsPerArea} = \frac{I_{subs}}{L_g W_g} \)

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Gate current Igate (LOG)

[List Display]
Gate voltage Vgate
Gate current Igate
Substrate current Isubs
15 Structure

15.15 Ig-Vg Vforce [1HL]: MOS capacitor Ig-Vg characteristics, voltage sweep (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures gate current vs gate voltage (Ig-Vg) characteristics of MOS capacitor gate insulator.

[Device Under Test]
MOS capacitor

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Gate: SMU connected to Gate terminal, primary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
IgLimit: Gate current compliance

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
GateMinRng: Minimum range for the gate current measurement

[Measurement Parameters]
Gate current Igate

[User Function]
IgatePerArea: Gate current per unit gate area IgatePerArea=Igate/Lg/Wg

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Gate current Igate (LOG)

[List Display]
Gate voltage Vgate
Gate current Igate
**15.16 Interconnect CouplingCap: Interconnection capacitance (A.01.11)**

[Supported Analyzer]
B1500A

[Application]
Measures the interconnection capacitance, and plots the C-V characteristics.
For a more accurate measurement, perform correction data measurement at the measurement frequency before
starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced
Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU
Calibration window.
Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M,
3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
Capacitor generated between two interconnections in the same layer

[Device Parameters]
L: Metal length
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
FREQ: Measurement frequency
OscLevel: Measurement signal level
MetalA: CMU connected between MetalA and MetalB (CV sweep measurement)
Vstart: DC bias start voltage
Vstop: DC bias stop voltage
Vstep: DC bias step voltage

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Parallel capacitance Cp
Conductance G

[User Function]
PI=3.141592653589
D=G/(2*PI*FREQ*Cp)
Rp=1/G
Cs=(1+D^2)*Cp
X=-1/(2*PI*FREQ*Cs)
Rs=D*abs(X)
Z=sqrt(Rs^2+X^2)
Theta=atan(X/Rs)
CsPerLength=Cs/L
CpPerLength=Cp/L

[X-Y Graph]
15 Structure

X axis: DC bias VmetalA (LINEAR)
Y1 axis: Interconnection capacitance (parallel capacitance) Cp (LINEAR)
Y2 axis: Dissipation factor D (LINEAR)
Y3 axis: Conductance G (LINEAR)

[List Display]
Measurement frequency Freq
DC bias VmetalA
Interconnection capacitance (parallel capacitance) Cp
Conductance G
Series capacitance Cs
Series resistance Rs
Parallel resistance Rp
Dissipation factor D
Reactance X
Impedance Z
Phase Theta
Cs per unit length CpPerLength
Cp per unit length CpPerLength
15.17 Interconnect OverlapCap: Layer to layer film capacitance (A.01.11)

[Supported Analyzer]
B1500A

[Application]
Measures the capacitance of the film between two interconnection layers, and plots the C-V characteristics. For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
Film capacitor generated between two interconnection layers

[Device Parameters]
L: Metal length
W: Metal width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
FREQ: Measurement frequency
OscLevel: Measurement signal level
MetalA: CMU connected between MetalA and MetalB (CV sweep measurement)
Vstart: DC bias start voltage
Vstop: DC bias stop voltage
Vstep: DC bias step voltage

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Parallel capacitance Cp
Conductance G

[User Function]
Pİ=3.141592653589
D=G/(2*PI*FREQ*Cp)
Rp=1/G
Cs=(1+D^2)*Cp
X=-1/(2*PI*FREQ*Cs)
Rs=D*abs(X)
Z=sqrt(Rs^2+X^2)
Theta=atan(X/Rs)

[X-Y Graph]
X axis: DC bias VmetalA (LINEAR)
15 Structure

Y1 axis: Film capacitance (parallel capacitance) Cp (LINEAR)
Y2 axis: Dissipation factor D (LINEAR)
Y3 axis: Conductance G (LINEAR)

[List Display]
Measurement frequency Freq
DC bias VmetalA
Film capacitance (parallel capacitance) Cp
Conductance G
Series capacitance Cs
Series resistance Rs
Parallel resistance Rp
Dissipation factor D
Reactance X
Impedance Z
Phase Theta
15.18 Junction BV: Junction device breakdown voltage (A.01.20)

[Supported Analyzer]

[Description]
Measures the junction device reverse bias characteristics, and extracts the breakdown voltage.

[Device Under Test]
Junction device, diode

[Device Parameters]
L: Junction length
W: Junction width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Ianode@BV: Anode current to decide the breakdown
Anode: SMU connected to Anode terminal, primary sweep voltage output
VanodeStart: Sweep start voltage for Anode terminal
VanodeStop: Sweep stop voltage for Anode terminal
VanodeStep: Sweep step voltage for Anode terminal
Cathode: SMU connected to Cathode terminal, constant voltage output

[Extended Test Parameters]
Vcathode: Cathode voltage
HoldTime: Hold time
DelayTime: Delay time
AnodeMinRng: Minimum range for the anode current measurement

[Measurement Parameters]
Anode current Ianode
Cathode current Icathode

[User Function]
IanodePerArea=Ianode/L/W
IcathodePerArea=Icathode/L/W

[Analysis Function]
BV=@L1X (X intercept of Line1)

[X-Y Plot]
X axis: Anode voltage Vanode (LINEAR)
Y1 axis: Anode current Ianode (LINEAR)
Y2 axis: Anode current Ianode (LOG)
Y3 axis: Cathode current Icathode (LINEAR)
Y4 axis: Cathode current Icathode (LOG)
15 Structure

[List Display]
- Anode voltage Vanode
- Anode current Ianode
- Anode current per unit area IanodePerArea
- Cathode current Icathode
- Cathode current per unit area IcathodePerArea

[Parameters Display Area]
- Junction breakdown voltage BV

[Auto Analysis]
- Line1: Vertical line through Y1 data at Ianode=Ianode@BV
15.19 Junction BV [1HL]: Junction device breakdown voltage (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the junction device reverse bias characteristics, and extracts the breakdown voltage.

[Device Under Test]
Junction device, diode

[Device Parameters]
L: Junction length
W: Junction width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Ianode@BV: Anode current to decide the breakdown
Anode: SMU connected to Anode terminal, primary sweep voltage output
VanodeStart: Sweep start voltage for Anode terminal
VanodeStop: Sweep stop voltage for Anode terminal
VanodeStep: Sweep step voltage for Anode terminal

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
AnodeMinRng: Minimum range for the anode current measurement

[Measurement Parameters]
Anode current Ianode

[User Function]
IanodePerArea=Ianode/L/W

[Analysis Function]
BV=\@L1X (X intercept of Line1)

[X-Y Plot]
X axis: Anode voltage Vanode (LINEAR)
Y1 axis: Anode current Ianode (LINEAR)
Y2 axis: Anode current Ianode (LOG)

[List Display]
Anode voltage Vanode
Anode current Ianode
Anode current per unit area IanodePerArea

[Parameters Display Area]
Junction breakdown voltage BV

[Auto Analysis]
Line1: Vertical line through Y1 data at Ianode=Ianode@BV
15.20 Junction DcParam: Junction device DC parameters (Is,N,Rs) (A.01.20)


[Description] Measures the forward bias anode voltage vs anode current characteristics, and extracts the slope minimum value (N_Min), the reverse direction saturation current minimum value (IsMin, IsMin2), and the series resistance (Rs).

[Device Under Test] Junction device, diode

[Device Parameters]
L: Junction length
W: Junction width
Temp: Temperature
Imax: Current compliance

[Test Parameters]
IntegTime: Integration time
Anode: SMU connected to Anode terminal, primary sweep voltage output
VanodeStart: Sweep start voltage for Anode terminal
VanodeStop: Sweep stop voltage for Anode terminal
VanodeStep: Sweep step voltage for Anode terminal
Cathode: SMU connected to Cathode terminal, constant voltage output

[Extended Test Parameters]
Vcathode: Cathode voltage
HoldTime: Hold time
DelayTime: Delay time
AnodeMinRng: Minimum range for the anode current measurement

[Measurement Parameters]
Anode current Ianode
Cathode current Icathode

[User Function]
IanodePerArea=Ianode/L/W
IcathodePerArea=Icathode/L/W
Vt=k*(Temp+273.15)/q
N=1/Vt(diff(log(Ianode),Vanode))
N_Min=min(N)
Slope=diff(log(Ianode),Vanode)
Is=lgtn(Ianode,Slope*Vanode)
IsMin=min(Is)
SmplNum=abs((VanodeStop-VanodeStart)/VanodeStep)+1
I_Rs=at(Ianode,SmplNum,1)
deltaV_Rs=VanodeStop-N_Min*Vt*log(I_Rs/IsMin)
Rs=deltaV_Rs/I_Rs

[Analysis Function]
IsMin2=@L1Y (Y intercept of Line1)
[X-Y Plot]
X axis: Anode voltage $V_{anode}$ (LINEAR)
Y1 axis: Anode current $I_{anode}$ (LOG)
Y2 axis: Anode current $I_{anode}$ (LINEAR)
Y3 axis: Slope $N$ (LINEAR)

[Parameters Display Area]
Slope minimum value $N_{min}$
Reverse direction saturation current minimum value $I_{sMin}$
Reverse direction saturation current minimum value $I_{sMin2}$
Series resistance $R_s$

[Auto Analysis]
Line1: Tangent line through Y1 data at $Slope = \max(Slope)$
15.21 Junction DcParam [1HL]: Junction device DC parameters (Is,N,Rs) (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the forward bias anode voltage vs anode current characteristics, and extracts the slope minimum value (N_Min), the reverse direction saturation current minimum value (IsMin, IsMin2), and the series resistance (Rs).

[Device Under Test]
Junction device, diode

[Device Parameters]
L: Junction length
W: Junction width
Temp: Temperature
Imax: Current compliance

[Test Parameters]
IntegTime: Integration time
Anode: SMU connected to Anode terminal, primary sweep voltage output
VanodeStart: Sweep start voltage for Anode terminal
VanodeStop: Sweep stop voltage for Anode terminal
VanodeStep: Sweep step voltage for Anode terminal

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
AnodeMinRng: Minimum range for the anode current measurement

[Measurement Parameters]
Anode current Ianode

[User Function]
IanodePerArea=Ianode/L/W
Vt=k*(Temp+273.15)/q
N=1/Vt*(diff(log(Ianode),Vanode))
N_Min=min(N)
Slope=diff(lgt(Ianode),Vanode)
Is=lgt(Ianode)-Slope*Vanode
IsMin=min(Is)
SmplNum=abs((VanodeStop-VanodeStart)/VanodeStep)+1
I_Rs=at(Ianode,SmplNum,1)
deltaV_Rs=VanodeStop-N_Min*Vt*log(I_Rs/IsMin)
Rs=deltaV_Rs/I_Rs

[Analysis Function]
IsMin2=@L1Y (Y intercept of Line1)

[X-Y Plot]
X axis: Anode voltage Vanode (LINEAR)
Y1 axis: Anode current I_anode (LOG)
Y2 axis: Anode current I_anode (LINEAR)
Y3 axis: Slope N (LINEAR)

[Parameters Display Area]
Slope minimum value N_Min
Reverse direction saturation current minimum value I_sMin
Reverse direction saturation current minimum value I_sMin2
Series resistance Rs

[Auto Analysis]
Line1: Tangent line through Y1 data at Slope=max(Slope)
15 Structure

15.22 Junction IV Fwd: Diode forward bias characteristics (A.01.20)

[Supported Analyzer]

[Description]
Measures the forward bias anode voltage vs anode current characteristics.

[Device Under Test]
Junction device, diode

[Device Parameters]
L: Junction length
W: Junction width
Temp: Temperature
Imax: Current compliance

[Test Parameters]
IntegTime: Integration time
Anode: SMU connected to Anode terminal, primary sweep voltage output
VanodeStart: Sweep start voltage for Anode terminal
VanodeStop: Sweep stop voltage for Anode terminal
VanodeStep: Sweep step voltage for Anode terminal
Cathode: SMU connected to Cathode terminal, constant voltage output

[Extended Test Parameters]
Vcathode: Cathode voltage
HoldTime: Hold time
DelayTime: Delay time
AnodeMinRng: Minimum range for the anode current measurement

[Measurement Parameters]
Anode current Ianode
Cathode current Icathode

[User Function]
IanodePerArea=Ianode/L/W
IcathodePerArea=Icathode/L/W

[X-Y Plot]
X axis: Anode voltage Vanode (LINEAR)
Y1 axis: Anode current Ianode (LINEAR)
Y2 axis: Anode current Ianode (LOG)
15.23 Junction IV Fwd [1HL]: Diode forward bias characteristics (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the forward bias anode voltage vs anode current characteristics.

[Device Under Test]
Junction device, diode

[Device Parameters]
L: Junction length
W: Junction width
Temp: Temperature
Imax: Current compliance

[Test Parameters]
IntegTime: Integration time
Anode: SMU connected to Anode terminal, primary sweep voltage output
VanodeStart: Sweep start voltage for Anode terminal
VanodeStop: Sweep stop voltage for Anode terminal
VanodeStep: Sweep step voltage for Anode terminal

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
AnodeMinRng: Minimum range for the anode current measurement

[Measurement Parameters]
Anode current Ianode

[User Function]
IanodePerArea=Ianode/L/W

[X-Y Plot]
X axis: Anode voltage Vanode (LINEAR)
Y1 axis: Anode current Ianode (LINEAR)
Y2 axis: Anode current Ianode (LOG)
15.24 Junction IV Rev: Diode reverse bias characteristics (A.01.20)

[Supported Analyzer]

[Description]
Measures the reverse bias anode voltage vs anode current characteristics.

[Device Under Test]
Junction device, diode

[Device Parameters]
L: Junction length
W: Junction width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Anode: SMU connected to Anode terminal, primary sweep voltage output
VanodeStart: Sweep start voltage for Anode terminal
VanodeStop: Sweep stop voltage for Anode terminal
VanodeStep: Sweep step voltage for Anode terminal
IanodeLimit: Anode current compliance
Cathode: SMU connected to Cathode terminal, constant voltage output

[Extended Test Parameters]
Vcathode: Cathode voltage
HoldTime: Hold time
DelayTime: Delay time
AnodeMinRng: Minimum range for the anode current measurement

[Measurement Parameters]
Anode current Ianode
Cathode current Icathode

[User Function]
IanodePerArea=Ianode/L/W
IcathodePerArea=Icathode/L/W

[X-Y Plot]
X axis: Anode voltage Vanode (LINEAR)
Y1 axis: Anode current Ianode (LOG)
Y2 axis: Cathode current Icathode (LOG)
15.25  Junction IV Rev [IHL]: Diode reverse bias characteristics (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the reverse bias anode voltage vs anode current characteristics.

[Device Under Test]
Junction device, diode

[Device Parameters]
L: Junction length
W: Junction width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Anode: SMU connected to Anode terminal, primary sweep voltage output
VanodeStart: Sweep start voltage for Anode terminal
VanodeStop: Sweep stop voltage for Anode terminal
VanodeStep: Sweep step voltage for Anode terminal
IanodeLimit: Anode current compliance

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
AnodeMinRng: Minimum range for the anode current measurement

[Measurement Parameters]
Anode current Ianode

[User Function]
IanodePerArea=Ianode/L/W

[X-Y Plot]
X axis: Anode voltage Vanode (LINEAR)
Y1 axis: Anode current Ianode (LOG)
15 Structure

15.26 QSCV[2]: C-Vg, Ig-Vg (2-terminal) (A.03.00)

[Supported Analyzer]
B1500A, B1505A

[Description]
Measures the oxide film capacitance of a MOSFET by using the quasi-static CV method, and plots the C-V characteristics.
To obtain the measurement data after the capacitance offset cancel, perform the QSCV C Offset Meas application test before this test.

[Device Under Test]
MOS capacitance, 2 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force negative specified value)
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep (QSCV) voltage output
Subs: SMU connected to Substrate terminal, constant voltage output
IMeasSMU: SMU to measure current and capacitance, connected to Gate terminal or Substrate terminal
Vstart: Sweep start voltage
Vstop: Sweep stop voltage
Vstep: Sweep step voltage
QSCVM measV: QSCV measurement voltage
I_Comp: Current compliance
LeakCompen: Leakage current compensation on/off
MeasRange: Current measurement range used for the QSCV measurement, fixed range
Integ_C: Integration time for the capacitance measurement
Integ_L: Integration time for the leakage current measurement
HoldTime: Hold time
DelayTime: Delay time
IOffsetCancel: QSCV smart operation enable/disable
IOffsetSink: SMU to perform QSCV smart operation, connected to terminal which connected to IMeasSMU

QSCV smart operation is effective for QSCV measurements with a large leakage current. The SMU set as the IOffsetSink performs the current force operation to minimize the measurement error caused by an offset current.

[Extended Test Parameters]
StepDelay: Step delay time
OutputRange: Ranging type for voltage output
SwpMode: Sweep mode
VCompSinkSMU: Voltage compliance of SMU for QSCV smart operation
Cmin: Minimum capacitance value for graph
Cmax: Maximum capacitance value for graph
IgMin: Minimum leakage current value for graph
IgMax: Maximum leakage current value for graph
[Measurement parameters]
Capacitance C
Leakage current IgLeak

[X-Y Graph]
X axis: Gate Voltage Vg (LINEAR)
Y1 axis: Capacitance C (LINEAR)
Y2 axis: Leakage current Ig (LINEAR)

[List Display]
Gate voltage Vg
Capacitance C
Leakage current Ig
15.27 QSCV C Offset Meas: Offset capacitance measurement (A.03.00)

[Supported Analyzer]
B1500A, B1505A

[Description]
Measures the offset capacitance of the cables and DUT interface by using the QSCV method when measurement terminals are open.

[Device Under Test]
MOS capacitance, 2 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force negative specified value)
Lg: Gate length
Wg: Gate width
Temp: Temperature

[Test Parameters]
IMeasSMU: SMU to measure current and capacitance, connected to Gate terminal or Substrate terminal
MeasRange: Current measurement range used for the QSCV measurement, fixed range
Integ_C: Integration time for the capacitance measurement
Integ_L: Integration time for the leakage current measurement
HoldTime: Hold time
DelayTime: Delay time

[Extended Test Parameters]
StepDelay: Step delay time

[Measurement parameters]
Capacitance C

[List Display]
Capacitance C
15.28 \textit{Rdiff-I kelvin: Diffusion resistor R-I characteristics, Kelvin connection (A.01.11)}

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the resistance vs current characteristics (R-I characteristic).

[Device Under Test]
Diffusion resistor, 3 terminals
Connect the Port1 and VM1 modules to a terminal, the Port2 and VM2 modules to the other terminal.

[Device Parameters]
Polarity: Ntype (SMUs force the specified value) or Ptype (SMUs force the negative specified value).
L: Resistor length
W: Resistor width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Port1: SMU connected to resistor, primary sweep current output
I1Start: Primary sweep start current
I1Stop: Primary sweep stop current
I1Step: Primary sweep step current
VLimit: Port1 voltage compliance
Subs: SMU connected to substrate, secondary sweep voltage output
VsubsStart: Secondary sweep start voltage
VsubsStop: Secondary sweep stop voltage
VsubsStep: Secondary sweep step voltage
Ilimit: Subs current compliance
Port2: SMU connected to resistor, constant voltage output
VM1: SMU connected to resistor, constant current output
VM2: SMU connected to resistor, constant current output

[Extended Test Parameters]
V2: Port2 output voltage
IM1: VM1 output current
IM2: VM2 output current
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Port1 measurement voltage V1
VM1 measurement voltage Vm1
VM2 measurement voltage Vm2

[User Function]
Voltage between terminals \( \Delta V = V_{m1} - V_{m2} \)
Resistance \( R = \Delta V / I_1 \)
Sheet resistance \( R_{\text{sheet}} = R * W / L \)

[X-Y Graph]
15 Structure

X axis: Port1 output current I1 (LINEAR)
Y1 axis: Resistance R (LINEAR)
Y2 axis: Voltage between terminals DeltaV (LINEAR)

[List Display]
Port1 output current I1
Port1 measurement voltage V1
Subs output voltage Vsubs
Voltage between terminals DeltaV
Resistance R
Sheet resistance Rsheet
15.29 Rdiff-I: Diffusion resistor R-I characteristics (A.01.11)

[Supported Analyzer]

[Description]
Measures the resistance vs current characteristics (R-I characteristic).

[Device Under Test]
Diffusion resistor, 3 terminals

[Device Parameters]
Polarity: Ntype (SMUs force the specified value) or Ptype (SMUs force the negative specified value).
L: Resistor length
W: Resistor width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Port1: SMU connected to resistor, primary sweep current output
I1Start: Primary sweep start current
I1Stop: Primary sweep stop current
I1Step: Primary sweep step current
V1Limit: Port1 voltage compliance
Subs: SMU connected to substrate, secondary sweep voltage output
VsubsStart: Secondary sweep start voltage
VsubsStop: Secondary sweep stop voltage
VsubsStep: Secondary sweep step voltage
IsubsLimit: Subs current compliance
Port2: SMU connected to resistor, constant voltage output

[Extended Test Parameters]
V2: Port2 output voltage
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Port1 measurement voltage V1

[User Function]
Resistance R=V1/I1
Sheet resistance Rsheet=R*W/L

[X-Y Graph]
X axis: Port1 output current I1 (LINEAR)
Y1 axis: Port1 measurement voltage V1 (LINEAR)
Y2 axis: Resistance R (LINEAR)

[List Display]
Port1 output current I1
Port1 measurement voltage V1
Resistance R
Sheet resistance Rsheet
15.30 Rdiff-I [2HL]: Diffusion resistor R-I characteristics (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the resistance vs current characteristics (R-I characteristic).

[Device Under Test]
Diffusion resistor, 3 terminals

[Device Parameters]
Polarity: Ntype (SMUs force the specified value) or Ptype (SMUs force the negative specified value).
L: Resistor length
W: Resistor width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Port1: SMU connected to resistor, primary sweep current output
I1Start: Primary sweep start current
I1Stop: Primary sweep stop current
I1Step: Primary sweep step current
V1Limit: Port1 voltage compliance
Subs: SMU connected to substrate, secondary sweep voltage output
VsubsStart: Secondary sweep start voltage
VsubsStop: Secondary sweep stop voltage
VsubsStep: Secondary sweep step voltage
IsubsLimit: Subs current compliance

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Port1 measurement voltage V1

[User Function]
Resistance R=V1/I1
Sheet resistance Rsheet=R*W/L

[X-Y Graph]
X axis: Port1 output current I1 (LINEAR)
Y1 axis: Port1 measurement voltage V1 (LINEAR)
Y2 axis: Resistance R (LINEAR)

[List Display]
Port1 output current I1
Port1 measurement voltage V1
Resistance R
Sheet resistance Rsheet
15.31 Rdiff-V kelvin: Diffusion resistor R-V characteristics, Kelvin connection (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the resistance vs voltage characteristics (R-V characteristic).

[Device Under Test]
Diffusion resistor, 3 terminals
Connect the Port1 and VM1 modules to a terminal, the Port2 and VM2 modules to the other terminal.

[Device Parameters]
Polarity: Ntype (SMUs force the specified value) or Ptype (SMUs force the negative specified value).
L: Resistor length
W: Resistor width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Port1: SMU connected to resistor, primary sweep voltage output
V1Start: Primary sweep start voltage
V1Stop: Primary sweep stop voltage
V1Step: Primary sweep step voltage
I1Limit: Port1 current compliance
Subs: SMU connected to substrate, secondary sweep voltage output
VsubsStart: Secondary sweep start voltage
VsubsStop: Secondary sweep stop voltage
VsubsStep: Secondary sweep step voltage
IsubsLimit: Subs current compliance
Port2: SMU connected to resistor, constant voltage output
VM1: SMU connected to resistor, constant current output
VM2: SMU connected to resistor, constant current output

[Extended Test Parameters]
V2: Port2 output voltage
IM1: VM1 output current
IM2: VM2 output current
HoldTime: Hold time
DelayTime: Delay time
Port1MinRng: Minimum range for the port1 current measurement

[Measurement Parameters]
Port1 measurement current I1
VM1 measurement voltage Vm1
VM2 measurement voltage Vm2

[User Function]
Voltage between terminals DeltaV=Vm1-Vm2
Resistance R=DeltaV/I1
Sheet resistance Rsheet=R*W/L
15 Structure

[X-Y Graph]
X axis: Port1 output voltage V1 (LINEAR)
Y1 axis: Port1 measurement current I1 (LINEAR)
Y2 axis: Resistance R (LINEAR)

[List Display]
Port1 output voltage V1
Voltage between terminals DeltaV
Port1 measurement current I1
Resistance R
Sheet resistance Rsheet
15.32 Rdiff-V: Diffusion resistor R-V characteristics (A.01.20)

[Supported Analyzer]

[Description]
Measures the resistance vs voltage characteristics (R-V characteristic).

[Device Under Test]
Diffusion resistor, 3 terminals

[Device Parameters]
Polarity: Ntype (SMUs force the specified value) or Ptype (SMUs force the negative specified value).
L: Resistor length
W: Resistor width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Port1: SMU connected to resistor, primary sweep voltage output
V1Start: Primary sweep start voltage
V1Stop: Primary sweep stop voltage
V1Step: Primary sweep step voltage
I1Limit: Port1 current compliance
Subs: SMU connected to substrate, secondary sweep voltage output
VsubsStart: Secondary sweep start voltage
VsubsStop: Secondary sweep stop voltage
VsubsStep: Secondary sweep step voltage
IsubsLimit: Subs current compliance
Port2: SMU connected to resistor, constant voltage output

[Extended Test Parameters]
V2: Port2 output voltage
HoldTime: Hold time
DelayTime: Delay time
Port1MinRng: Minimum range for the port1 current measurement

[Measurement Parameters]
Port1 measurement current I1

[User Function]
Resistance R=V1/I1
Sheet resistance Rsheet=R*W/L

[X-Y Graph]
X axis: Port1 output voltage V1 (LINEAR)
Y1 axis: Resistance R (LINEAR)
Y2 axis: Port1 measurement current I1 (LINEAR)

[List Display]
Port1 output voltage V1
Port1 measurement current I1
Resistance R
Sheet resistance Rsheet
15.33  **Rdiff-V [2HL]: Diffusion resistor R-V characteristics (A.06.10)**

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the resistance vs voltage characteristics (R-V characteristic).

[Device Under Test]
Diffusion resistor, 3 terminals

[Device Parameters]
Polarity: Ntype (SMUs force the specified value) or Ptype (SMUs force the negative specified value).
L: Resistor length
W: Resistor width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Port1: SMU connected to resistor, primary sweep voltage output
V1Start: Primary sweep start voltage
V1Stop: Primary sweep stop voltage
V1Step: Primary sweep step voltage
I1Limit: Port1 current compliance
Subs: SMU connected to substrate, secondary sweep voltage output
VsubsStart: Secondary sweep start voltage
VsubsStop: Secondary sweep stop voltage
VsubsStep: Secondary sweep step voltage
IsubsLimit: Subs current compliance

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
Port1MinRng: Minimum range for the port1 current measurement

[Measurement Parameters]
Port1 measurement current I1

[User Function]
Resistance R=V1/I1
Sheet resistance Rsheet=R*W/L

[X-Y Graph]
X axis: Port1 output voltage V1 (LINEAR)
Y1 axis: Resistance R (LINEAR)
Y2 axis: Port1 measurement current I1 (LINEAR)

[List Display]
Port1 output voltage V1
Port1 measurement current I1
Resistance R
Sheet resistance Rsheet
15.34 R-I DVM: Low resistance measurement using 3458A, current force (A.01.20)

[Supported Analyzer]

[Description]
Measures the low resistance of a 2-terminal device. SMU forces current and DVM (3458A) measures voltage between terminals. Resistance is calculated from the output value of a current and measured value of a voltage between terminals. For the purpose of excluding thermoelectric power, this test is designed to measure resistance again by switching the direction of voltage and to get the average value of resistance as a test result.

[Device Under Test]
Resistor element, 2 terminals

[Required Modules and Accessories]
Keysight 3458A digital multimeter 1 unit
GPIB cable

[Required Test Definition]
Measure Diff-V

[Device Parameters]
L: Resistor length
W: Resistor width
Temp: Temperature (deg C)

[Test Parameters]
IntegTime: Integration time
Port1: SMU connected to resistor, current output
I1: Applied current
V1Limit: Port1 voltage compliance
Port2: SMU connected to resistor, constant voltage output
GPIB_Adr: GPIB address of DVM

[Extended Test Parameters]
V2: Port2 output voltage
HoldTime: Hold time
DelayTime: Delay time
PortMinRng: Minimum range for port current measurement

[Measurement Parameters]
[Measurement Parameters for first measurement (Vpos)]
Vport1: Port1 voltage

[Measurement Parameters for second measurement (Vneg)]
Vport2: Port2 voltage

[X-Y Plot]
[X-Y Plot for first measurement (Vpos)]
X axis: Applied current Iport1 (LINEAR)
Y1 axis: Measured voltage Vport1 (LINEAR)
15 Structure

[X-Y Plot for second measurement (Vneg)]
X axis: Applied current Iport2 (LINEAR)
Y1 axis: Measured voltage Vport2 (LINEAR)

[List Display]
[X-Y Plot for first measurement (Vpos)]
Applied current Iport1
Measured voltage Vport1

[X-Y Plot for second measurement (Vneg)]
Applied current Iport2
Measured voltage Vport2

[Test Output: X-Y Graph]
X axis: Applied current IsmuList (LINEAR)
Y1 axis: DVM measurement result voltage VdvmList (LINEAR)
Y2 axis: Measured voltage VsmuList (LINEAR)
Y3 axis: Resistance value (LINEAR)

[Test Output: List Display]
IsmuList: Applied current
VsmuList: Measured voltage
VdvmList: DVM measured voltage
RList: Resistance value

[Test Output: Parameters]
Rav: Average resistance value of 2 measurements
15.35 R-I kelvin: Resistor R-I characteristics, Kelvin connection (A.01.11)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the resistance vs current characteristics (R-I characteristic).

[Device Under Test]
Resistor, 2 terminals
Connect the Port1 and VM1 modules to a terminal, the Port2 and VM2 modules to the other terminal.

[Device Parameters]
L: Resistor length
W: Resistor width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Port1: SMU connected to resistor, primary sweep current output
I1Start: Sweep start current
I1Stop: Sweep stop current
I1Step: Sweep step current
V1Limit: Port1 voltage compliance
Port2: SMU connected to resistor, constant voltage output
VM1: SMU connected to resistor, constant current output
VM2: SMU connected to resistor, constant current output

[Extended Test Parameters]
V2: Port2 output voltage
IM1: VM1 output current
IM2: VM2 output current
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Port1 measurement voltage V1
VM1 measurement voltage Vm1
VM2 measurement voltage Vm2

[User Function]
Voltage between terminals DeltaV=Vm1-Vm2
Resistance R=DeltaV/I1
Sheet resistance Rsheet=R*W/L

[X-Y Graph]
X axis: Port1 output current I1 (LINEAR)
Y1 axis: Resistance R (LINEAR)
Y2 axis: Voltage between terminals DeltaV (LINEAR)

[List Display]
Port1 output current I1
Port1 measurement voltage V1
Resistance R
Voltage between terminals DeltaV
15 Structure

15.36 R-I Kelvin [2HL]: Resistor R-I characteristics, Kelvin connection (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the resistance vs current characteristics (R-I characteristic).

[Device Under Test]
Resistor, 2 terminals
Connect the Port1 and VM1 modules to a terminal, the Port1 and VM1 modules of the Low side to the other terminal.

[Device Parameters]
L: Resistor length
W: Resistor width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Port1: SMU connected to resistor, primary sweep current output
I1Start: Sweep start current
I1Stop: Sweep stop current
I1Step: Sweep step current
V1Limit: Port1 voltage compliance
VM1: SMU connected to resistor, constant current output

[Extended Test Parameters]
IM1: VM1 output current
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Port1 measurement voltage V1
VM1 measurement voltage Vm1

[User Function]
Voltage between terminals DeltaV=Vm1
Resistance R=DeltaV/I1
Sheet resistance Rsheet=R*W/L

[X-Y Graph]
X axis: Port1 output current I1 (LINEAR)
Y1 axis: Resistance R (LINEAR)
Y2 axis: Voltage between terminals DeltaV (LINEAR)

[List Display]
Port1 output current I1
Port1 measurement voltage V1
Resistance R
Voltage between terminals DeltaV
15.37 R-I: Resistor R-I characteristics (A.01.11)

[Supported Analyzer]

[Description]
Measures the resistance vs current characteristics (R-I characteristic).

[Device Under Test]
Resistor, 2 terminals

[Device Parameters]
L: Resistor length
W: Resistor width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Port1: SMU connected to resistor, primary sweep current output
I1Start: Sweep start current
I1Stop: Sweep stop current
I1Step: Sweep step current
V1Limit: Port1 voltage compliance
Port2: SMU connected to resistor, constant voltage output

[Extended Test Parameters]
V2: Port2 output voltage
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Port1 measurement voltage V1

[User Function]
Resistance R=V1/I1
Sheet resistance Rsheet=R*W/L

[X-Y Graph]
X axis: Port1 output current I1 (LINEAR)
Y1 axis: Port1 measurement voltage V1 (LINEAR)
Y2 axis: Resistance R (LINEAR)

[List Display]
Port1 output current I1
Port1 measurement voltage V1
Resistance R
Sheet resistance Rsheet
15 Structure

15.38  **R-I [1HL]: Resistor R-I characteristics (A.06.10)**

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the resistance vs current characteristics (R-I characteristic).

[Device Under Test]
Resistor, 2 terminals

[Device Parameters]
L: Resistor length
W: Resistor width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Port1: SMU connected to resistor, primary sweep current output
I1Start: Sweep start current
I1Stop: Sweep stop current
I1Step: Sweep step current
V1Limit: Port1 voltage compliance

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Port1 measurement voltage V1

[User Function]
Resistance R=V1/I1
Sheet resistance Rsheet=R*W/L

[X-Y Graph]
X axis: Port1 output current I1 (LINEAR)
Y1 axis: Port1 measurement voltage V1 (LINEAR)
Y2 axis: Resistance R (LINEAR)

[List Display]
Port1 output current I1
Port1 measurement voltage V1
Resistance R
Sheet resistance Rsheet
15.39 R-V DVM: Low resistance measurement using 3458A, voltage force (A.01.20)

[Supported Analyzer]

[Description]
Measures the low resistance of a 2-terminal device. SMU forces voltage and measures current, and DVM (3458A) measures voltage between terminals. Resistance is calculated from the measured value of a current and that of a voltage between terminals. For the purpose of excluding thermoelectric power, this test is designed to measure resistance again by switching the direction of voltage and to get the average value of resistance as a test result.

[Device Under Test]
Resistor element, 2 terminals

[Required Modules and Accessories]
Keysight 3458A digital multimeter 1 unit
GPIB cable

[Required Test Definition]
Measure Diff-V

[Device Parameters]
L: Resistor length
W: Resistor width
Temp: Temperature (deg C)

[Test Parameters]
IntegTime: Integration time
Port1: SMU connected to resistor, voltage output
V1: Applied voltage
I1Limit: Port1 current compliance
Port2: SMU connected to resistor, constant voltage output
GPIB-Adr: GPIB address of DVM

[Extended Test Parameters]
V2: Output voltage
HoldTime: Hold time
DelayTime: Delay time
PortMinRng: Minimum range for port current measurement

[Measurement Parameters]
[Measurement Parameters for first measurement (Vpos)]
Iport2: Measured current

[Measurement Parameters for second measurement (Vneg)]
Iport1: Measured current

[X-Y Plot]
[X-Y Plot for first measurement (Vpos)]
X axis: Applied voltage on Port1 Vport1 (LINEAR)
Y1 axis: Measured current Iport2 (LINEAR)
15 Structure

[X-Y Plot for second measurement (Vneg)]
X axis: Applied voltage on Port2 Vport2 (LINEAR)
Y1 axis: Measured current Iport1 (LINEAR)

[List Display]
[X-Y Plot for first measurement (Vpos)]
Applied voltage Vport1
Measured current Iport2

[X-Y Plot for second measurement (Vneg)]
Applied voltage Vport2
Measured current Iport1

[Test Output: X-Y Graph]
X axis: Applied voltage VsmuList (LINEAR)
Y1 axis: DVM measurement result voltage VdvmList (LINEAR)
Y2 axis: Measured current IsmuList (LINEAR)
Y3 axis: Resistance value RList (LINEAR)

[Test Output: List Display]
VdvmList: DVM measured voltage
IsmuList: Measured current
RList: Resistance value

[Test Output: Parameters]
Rav: Average resistance value of 2 measurements
15.40 R-V kelvin: Resistor R-V characteristics, Kelvin connection (A.01.20)

[Supported Analyzer]
B1500A, E5260A, E5270B

[Description]
Measures the resistance vs voltage characteristics (R-V characteristic).

[Device Under Test]
Resistor, 2 terminals
Connect the Port1 and VM1 modules to a terminal, the Port2 and VM2 modules to the other terminal.

[Device Parameters]
L: Resistor length
W: Resistor width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Port1: SMU connected to resistor, primary sweep voltage output
V1Start: Sweep start voltage
V1Stop: Sweep stop voltage
V1Step: Sweep step voltage
I1Limit: Port1 current compliance
Port2: SMU connected to resistor, constant voltage output
VM1: SMU connected to resistor, constant current output
VM2: SMU connected to resistor, constant current output

[Extended Test Parameters]
V2: Port2 output voltage
I1M1: VM1 output current
I1M2: VM2 output current
HoldTime: Hold time
DelayTime: Delay time
Port1MinRng: Minimum range for the port1 current measurement

[Measurement Parameters]
Port1 measurement current I1
VM1 measurement voltage Vm1
VM2 measurement voltage Vm2

[User Function]
Voltage between terminals DeltaV=Vm1-Vm2
Resistance R=DeltaV/I1
Sheet resistance Rsheet=R*W/L

[X-Y Graph]
X axis: Port1 output voltage V1 (LINEAR)
Y1 axis: Resistance R (LINEAR)
Y2 axis: Port1 measurement current I1 (LINEAR)

[List Display]
Port1 output voltage V1
Voltage between terminals DeltaV
Port1 measurement current I1
Resistance R
Sheet resistance Rsheet
**15.41 R-V Kelvin [2HL]: Resistor R-V characteristics, Kelvin connection (A.06.10)**

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the resistance vs voltage characteristics (R-V characteristic).

[Device Under Test]
Resistor, 2 terminals
Connect the Port1 and VM1 modules to a terminal, the Port1 and VM1 modules of the Low side to the other terminal.

[Device Parameters]
L: Resistor length
W: Resistor width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Port1: SMU connected to resistor, primary sweep voltage output
V1Start: Sweep start voltage
V1Stop: Sweep stop voltage
V1Step: Sweep step voltage
I1Limit: Port1 current compliance
VM1: SMU connected to resistor, constant current output

[Extended Test Parameters]
IM1: VM1 output current
HoldTime: Hold time
DelayTime: Delay time
Port1MinRng: Minimum range for the port1 current measurement

[Measurement Parameters]
Port1 measurement current I1
VM1 measurement voltage Vm1

[User Function]
Voltage between terminals DeltaV=Vm1
Resistance R=DeltaV/I1
Sheet resistance Rsheet=R*W/L

[X-Y Graph]
X axis: Port1 output voltage V1 (LINEAR)
Y1 axis: Resistance R (LINEAR)
Y2 axis: Port1 measurement current I1 (LINEAR)

[List Display]
Port1 output voltage V1
Voltage between terminals DeltaV
Port1 measurement current I1
Resistance R
Sheet resistance Rsheet
15.42 R-V: Resistor R-V characteristics (A.01.20)

[Supported Analyzer]

[Description]
Measures the resistance vs voltage characteristics (R-V characteristic).

[Device Under Test]
Resistor, 2 terminals

[Device Parameters]
L: Resistor length
W: Resistor width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Port1: SMU connected to resistor, primary sweep voltage output
V1Start: Sweep start voltage
V1Stop: Sweep stop voltage
V1Step: Sweep step voltage
I1Limit: Port1 current compliance
Port2: SMU connected to resistor, constant voltage output

[Extended Test Parameters]
V2: Port2 output voltage
HoldTime: Hold time
DelayTime: Delay time
Port1MinRng: Minimum range for the port1 current measurement

[Measurement Parameters]
Port1 measurement current I1

[User Function]
Resistance R=V1/I1
Sheet resistance Rsheet=R*W/L

[X-Y Graph]
X axis: Port1 output voltage V1 (LINEAR)
Y1 axis: Resistance R (LINEAR)
Y2 axis: Port1 measurement current I1 (LINEAR)

[List Display]
Port1 output voltage V1
Port1 measurement current I1
Resistance R
Sheet resistance Rsheet
15.43  R-V [1HL]: Resistor R-V characteristics (A.06.10)

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the resistance vs voltage characteristics (R-V characteristic).

[Device Under Test]
Resistor, 2 terminals

[Device Parameters]
L: Resistor length
W: Resistor width
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Port1: SMU connected to resistor, primary sweep voltage output
V1Start: Sweep start voltage
V1Stop: Sweep stop voltage
V1Step: Sweep step voltage
I1Limit: Port1 current compliance

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
Port1MinRng: Minimum range for the port1 current measurement

[Measurement Parameters]
Port1 measurement current I1

[User Function]
Resistance R=V1/I1
Sheet resistance Rsheet=R*W/L

[X-Y Graph]
X axis: Port1 output voltage V1 (LINEAR)
Y1 axis: Resistance R (LINEAR)
Y2 axis: Port1 measurement current I1 (LINEAR)

[List Display]
Port1 output voltage V1
Port1 measurement current I1
Resistance R
Sheet resistance Rsheet
15.44 VanDerPauw Square: Van Der Pauw pattern sheet resistance (A.01.11)

[Supported Analyzer]
   B1500A, E5260A, E5270B

[Description]
   Measures the sheet resistance of the Van Der Pauw pattern, and plots the sheet resistance vs input current characteristics.

[Device Under Test]
   Van Der Pauw pattern, 4 terminals

[Device Parameters]
   Temp: Temperature

[Test Parameters]
   IntegTime: Integration time
   Port1: SMU connected to pattern, primary sweep current output
   I1Start: Sweep start current
   I1Stop: Sweep stop current
   I1Step: Sweep step current
   V1Limit: Port1 voltage compliance
   Port2: SMU connected to pattern, constant voltage output
   VM1: SMU connected to pattern, constant current output
   VM2: SMU connected to pattern, constant current output

[Extended Test Parameters]
   V2: Port2 output voltage
   IM1: VM1 output current
   IM2: VM2 output current
   HoldTime: Hold time
   DelayTime: Delay time

[Measurement Parameters]
   VM1 measurement voltage Vm1
   VM2 measurement voltage Vm2

[User Function]
   Voltage between terminals DeltaV=Vm1-Vm2
   Sheet resistance Rsheet=(3.141592/log(2))*(DeltaV/I1)

[X-Y Graph]
   X axis: Port1 output current I1 (LINEAR)
   Y1 axis: Voltage between terminals DeltaV (LINEAR)
   Y2 axis: Sheet resistance Rsheet (LINEAR)

[List Display]
   Port1 output current I1
   Voltage between terminals DeltaV
   Sheet resistance Rsheet
15.45 *VanDerPauw Square [2HL]: Van Der Pauw pattern sheet resistance (A.06.10)*

[Supported Analyzer]
B2901A, B2902A, B2911A, B2912A

[Description]
Measures the sheet resistance of the Van Der Pauw pattern, and plots the sheet resistance vs input current characteristics.

[Device Under Test]
Van Der Pauw pattern, 4 terminals

[Device Parameters]
Temp: Temperature

[Test Parameters]
IntegTime: Integration time
Port1: SMU connected to pattern, primary sweep current output
I1Start: Sweep start current
I1Stop: Sweep stop current
I1Step: Sweep step current
V1Limit: Port1 voltage compliance
VM1: SMU connected to pattern, constant current output

[Extended Test Parameters]
IM1: VM1 output current
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
VM1 measurement voltage Vm1

[User Function]
Voltage between terminals DeltaV=Vm1
Sheet resistance Rsheet=(3.141592/log(2))*(DeltaV/I1)

[X-Y Graph]
X axis: Port1 output current I1 (LINEAR)
Y1 axis: Voltage between terminals DeltaV (LINEAR)
Y2 axis: Sheet resistance Rsheet (LINEAR)

[List Display]
Port1 output current I1
Voltage between terminals DeltaV
Sheet resistance Rsheet
15.46 Van Der Pau NonUniform: Application Test Library to measure resistance by Van Der Pau NonUniform Method (A.06.10)

[Supported Analyzer]
B1500A

[Description]
Measures the non-uniformed sheet resistance using the Van Der Pau method

[Device Under Test]
4 terminals non-uniformed sheet resistance

[Required Modules and Accessories]
4 SMUs are required from MPSMU, HPSMU or HRSMU

[Device Parameters]
Temp: Temperature

[Test Parameters]
SMU1: SMU connected Terminal 1 to pattern, constant voltage output and sweep
SMU2: SMU connected Terminal 2 to pattern, constant voltage output and sweep
SMU3: SMU connected Terminal 3 to pattern, constant voltage output and sweep
SMU4: SMU connected Terminal 4 to pattern, constant voltage output and sweep
ForceI: Applied current
IntegPLC: PLC value for integration time
Hold: Hold time

[Extended Test Parameters]
VmeasI: Output current of SMU to measure voltage
Vcomp: Compliance value
DispIntResult: Show display result during each measurement results

[Measurement Parameters]
R21_34 : I1,I2,V3,V4
R12_43 : I1,I2,V3,V4
R43_12 : V1,V2,I3,I4
R34_21 : V1,V2,I3,I4
R32_41 : V1,I2,I3,V4
R23_14 : V1,I2,I3,V4
R14_23 : I1,V2,V3,V4
R41_32 : I1,V2,V3,I4

[User Function]
R21_34 = V34 / I21, I21 = I2, V34 = V3 - V4
R12_43 = V43 / I12, I12 = I1, V43 = V4 - V3
R43_12 = V12 / I43, I43 = I4, V12 = V1 - V2
R34_21 = V21 / I34, I34 = I3, V21 = V2 - V1
R32_41 = V41 / I32, I32 = I3, V41 = V4 - V1
R23_14 = V14 / I23, I23 = I2, V14 = V1 - V4
R14_23 = V23 / I14, I14 = I1, V23 = V2 - V3
R41_32 = V32 / I41, I41 = I4, V32 = V3 - V2
Ra = (R2134 + R1243 + R4312 + R3421) / 4
Rb = (R3241 + R2314 + R1423 + R4132) / 4
15 Structure

[X-Y Graph]
---

[List Display]
---

[Parameters Display Area]
- R2134: The vertical direction R measurement
- R1243: The vertical direction R measurement
- R4312: The vertical direction R measurement
- R3421: The vertical direction R measurement
- R1423: The horizontal direction R measurement
- R4132: The horizontal direction R measurement
- R2314: The horizontal direction R measurement
- R3241: The horizontal direction R measurement
- Ra: Average of the vertical direction R measurement
- Rb: Average of the horizontal direction R measurement
- Rs: Calculated sheet resistance by the Newton-Raphson method.

[Auto Analysis]
---

[Note]
- Call Van der pauw NonUniform Child Calc_cs in the Test Contents.
- RsInit = Ra
- Conv = 0.001
- Rs = Van der pauw NonUniform Child Calc_cs (Ra,Rb,RsInit,Conv)
1. TFT Id-Vd: TFT Id-Vd characteristics (A.01.20)
2. TFT Id-Vg: TFT Id-Vg characteristics (A.01.20)
16.1 TFT Id-Vd: TFT Id-Vd characteristics (A.01.20)

[Supported Analyzer]

[Description]
Measures the drain current vs drain voltage characteristic of TFT.

[Device Under Test]
Thin Film Transistor, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
Drain: SMU connected to Drain terminal, primary sweep voltage output
VdStart: Sweep start voltage for Drain terminal
VdStop: Sweep stop voltage for Drain terminal
VdStep: Sweep step voltage for Drain terminal
Gate: SMU connected to Gate terminal, secondary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]
Vs: Source voltage
IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
Drain current Idrain

[User Function]
gds: Output conductance gds=diff(Idrain,Vdrain)
Rds: Output resistance Rds=1/gds

[X-Y Graph]
X axis: Drain voltage Vdrain (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)

[List Display]
Drain voltage Vdrain
Gate voltage Vgate
Drain current Idrain
Output conductance gds
Output resistance Rds
16.2 TFT Id-Vg: TFT Id-Vg characteristics (A.01.20)

[Supported Analyzer]

[Description]
Measures the drain current vs gate voltage characteristics of TFT.

[Device Under Test]
Thin Film Transistor, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Lg: Gate length
Wg: Gate width
Temp: Temperature
IdMax: Drain current compliance

[Test Parameters]
IntegTime: Integration time
Gate: SMU connected to Gate terminal, primary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
IgLimit: Gate current compliance
Drain: SMU connected to Drain terminal, secondary sweep voltage output
VdStart: Sweep start voltage for Drain terminal
VdStop: Sweep stop voltage for Drain terminal
VdStep: Sweep step voltage for Drain terminal
Source: SMU connected to Source terminal, constant voltage output

[Extended Test Parameters]
Vs: Source voltage
HoldTime: Hold time
DelayTime: Delay time
DrainMinRng: Minimum range for the drain current measurement

[Measurement Parameters]
Drain current Idrain

[User Function]
IdrainPerWg: Drain current per unit gate width \( I_{\text{drain}} = \frac{I_{\text{drain}}}{W_g} \)
gm: Transconductance \( g_m = \frac{\text{diff}(I_{\text{drain}}, V_{\text{gate}})}{\text{diff}(I_{\text{drain}}, V_{\text{gate}})} \)
gmPerWg: Transconductance per unit gate width \( g_{m\text{PerWg}} = \frac{\text{diff}(I_{\text{drain}}, W_g, V_{\text{gate}})}{\text{diff}(I_{\text{drain}}, W_g, V_{\text{gate}})} \)

[X-Y Graph]
X axis: Gate voltage \( V_{\text{gate}} \) (LINEAR)
Y1 axis: Drain current \( I_{\text{drain}} \) (LINEAR)
Y2 axis: Drain current \( I_{\text{drain}} \) (LOG)
Y3 axis: Transconductance \( g_m \) (LINEAR)

[List Display]
Gate voltage \( V_{\text{gate}} \)
Drain voltage \( V_{\text{drain}} \)
Drain current \( I_{\text{drain}} \)
Transconductance \( g_m \)
Drain current per unit gate width \( I_{\text{drain}} \text{PerWg} \)
Transconductance per unit gate width \( g_{m\text{PerWg}} \)
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17.1 *ForcePG1: PG Output1 (A.01.20)*

[Description]
Sets the Output1 of the Keysight 81110A Pulse Generator, and triggers it.

[Input Parameters]
- **Address:** GPIB address of the Keysight 81110A Pulse Generator
- **Period1:** Output1 pulse period [s]
- **Delay1:** Output1 delay time [s]
- **Dcyc1:** Output1 duty cycle [%]
- **Level1:** Output1 pulse level [V]
- **Base1:** Output1 base level [V]
- **TrigCount:** Number of output pulses (1 to 65536)
17 Utility

17.2 ForcePG2: PG Output2 (A.01.20)

[Description]
Sets the Output2 of the Keysight 81110A Pulse Generator, and triggers it.

[Input Parameters]
Address: GPIB address of the Keysight 81110A Pulse Generator
Period2: Output2 pulse period [s]
Delay2: Output2 delay time [s]
Duty2: Output2 duty cycle [%]
Level2: Output2 pulse level [V]
Base2: Output2 base level [V]
TrigCount: Number of output pulses (1 to 65536)
### 17.3 ForcePG2P: PG Output1/Output2 (A.01.20)

[Description]
Sets Output1 and Output2 of Keysight 81110A Pulse Generator, and triggers it. Pulse leading/trailing edge transition time can be set.
Execute ResetPG to stop pulse output before the specified pulses are applied.

[Required Modules and Accessories]
- Keysight 81110A Pulse Generator (2-output, PGU1 and PGU2)
- GPIB cable

[Test Parameters]
- Address: GPIB address of Keysight 81110A Pulse Generator
- Period1: Pulse period [s] for port 1
- Delay1: Pulse delay time [s] for port 1
- Width1: Pulse width [s] for port 1
- LeadTime1: Pulse leading edge transition time [s] for port 1
- TrailTime1: Pulse trailing edge transition time [s] for port 1
- Level1: Pulse High level [V] for port 1
- Base1: Pulse Low level [V] for port 1
- ExtImp1: Load impedance [ohm] for port 1
- Period2: Pulse period [s] for port 2
- Delay2: Pulse delay time [s] for port 2
- Width2: Pulse width [s] for port 2
- LeadTime2: Pulse leading edge transition time [s] for port 2
- TrailTime2: Pulse trailing edge transition time [s] for port 2
- Level2: Pulse High level [V] for port 2
- Base2: Pulse Low level [V] for port 2
- ExtImp2: Load impedance [ohm] for port 2
- NoOfPulse12: Number of output pulses
17 Utility

17.4 ForcePG12: PG Output1/Output2 (A.01.20)

[Description]
Sets Output1 and Output2 of Keysight 81110A Pulse Generator, and triggers it. Pulse leading/trailing edge transition time can be set.
Execute ResetPG to stop pulse output before the specified pulses are applied.

[Required Modules and Accessories]
Keysight 81110A Pulse Generator (2-output, PGU1 and PGU2)
GPIB cable

[Test Parameters]
Address: GPIB address of the Keysight 81110A Pulse Generator
Period1: Output1 pulse period [s]
Delay1: Output1 delay time [s]
Dcyc1: Output1 duty cycle [%]
LeadTime1: Output1 pulse leading edge transition time [s]
TrailTime1: Output1 pulse trailing edge transition time [s]
Level1: Output1 pulse high level [V]
Base1: Output1 pulse low level [V]
ExtImp1: Output1 load impedance [ohm]
NoOfPulse12: Number of output pulses (1 to 65536)
Period2: Output2 pulse period [s]
Delay2: Output2 delay time [s]
Dcyc2: Output2 duty cycle [%]
LeadTime2: Output2 pulse leading edge transition time [s]
TrailTime2: Output2 pulse trailing edge transition time [s]
Level2: Output2 pulse high level [V]
Base2: Output2 pulse low level [V]
ExtImp2: Output2 load impedance [ohm]
17.5 ForcePG: PG OutputX (A.01.20)

[Description]
Sets Output1 or Output2 of Keysight 81110A Pulse Generator, and triggers it. Pulse leading/trailing edge transition time can be set.
Execute ResetPG to stop pulse output before the specified pulses are applied.

[Required Modules and Accessories]
Keysight 81110A Pulse Generator (2-output, PGU1 and PGU2)
GPIB cable

[Test Parameters]
Address: GPIB address of Keysight 81110A Pulse Generator
SelectPort: Pulse output port
Period: Pulse period [s]
Delay: Pulse delay time [s]
Width: Pulse width [s]
LeadTime: Pulse leading edge transition time [s]
TrailTime: Pulse trailing edge transition time [s]
Level: Pulse High level [V]
Base: Pulse Low level [V]
ExtImp: Load impedance [ohm]
NoOfPulse: Number of output pulses
17.6 **ForcePGC: PG Output1 Continuous Output (A.01.20)**

[Description]
Sets Output1 of Keysight 81110A Pulse Generator, and triggers continuous pulse output. Pulse leading/trailing edge transition time can be set.
Execute ResetPG to stop pulse output before the specified pulses are applied.

[Required Modules and Accessories]
Keysight 81110A Pulse Generator (2-output, PGU1 and PGU2)
GPIB cable

[Test Parameters]
Address: GPIB address of Keysight 81110A Pulse Generator
Period1: Pulse period [s]
Delay1: Pulse delay time [s]
Dcyc1: Duty cycle [%]
LeadTime1: Pulse leading edge transition time [s]
TrailTime1: Pulse trailing edge transition time [s]
Level1: Pulse High level [V]
Base1: Pulse Low level [V]
ExtImp1: Load impedance [ohm]
17.7 Measure Diff-V: Voltage measurement by 3458A (A.01.20)

[Description]
Performs voltage measurement between two terminals by using Keysight 3458A Digital Multimeter. Measurement data is stored to DVM_Val variable.

[Required Modules and Accessories]
Keysight 3458A Digital Multimeter
GPIB cable

[Input Parameters]
Adrs: GPIB address of Keysight 3458A Digital Multimeter

[Test Output: Analysis Parameters]
DVM_Val: Voltage measurement data [V]
**17 Utility**

### 17.8 QSCV C Offset Meas: Offset capacitance measurement (A.03.00)

[Supported Analyzer]
- B1500A, B1505A

[Description]
Measures the offset capacitance of the cables and DUT interface by using the QSCV method when measurement terminals are open.

[Device Under Test]
MOS capacitance, 2 terminals

[Device Parameters]
- Polarity: Nch (SMUs force the specified value) or Pch (SMUs force negative specified value)
- Lg: Gate length
- Wg: Gate width
- Temp: Temperature

[Test Parameters]
- IMeasSMU: SMU to measure current and capacitance, connected to Gate terminal or Substrate terminal
- MeasRange: Current measurement range used for the QSCV measurement, fixed range
- Integ_C: Integration time for the capacitance measurement
- Integ_L: Integration time for the leakage current measurement
- HoldTime: Hold time
- DelayTime: Delay time

[Extended Test Parameters]
- StepDelay: Step delay time

[Measurement parameters]
- Capacitance C

[List Display]
- Capacitance C
17.9 ResetPG: PG reset (A.01.20)

[Description]
Resets Keysight 81110A Pulse Generator.

[Required Modules and Accessories]
Keysight 81110A Pulse Generator (2-output, PGU1 and PGU2)
GPIB cable

[Input Parameter]
GPIB address of Keysight 81110A Pulse Generator
17 Utility

17.10 Subsite move: Probing next subsite (A.02.00)

[Description]
Moves wafer prober chuck to the next subsite, reads device ID from the prober, and sets it to the Device ID of the test record.

[Supported Probers]
While this application test supports Cascade Microtech, SUSS MicroTec and Vector Semiconductor wafer prober drivers as standard basis, you may specify a command path name into the CustomProber entry field to operate with a non-standard wafer prober driver.

[Test Parameters]
ProberType: Type of wafer prober
CustomProber: Command path name for non-standard wafer probers

If CustomProber is not blank, ProberType field is ignored.
17.11 CVSweep4284_a: C-V measurement by 4284A/E4980A (A.03.10)

[Description]
Performs the capacitance vs DC bias voltage measurement by using Keysight 4284A/E4980A LCR meter.

[Device Under Test]
Capacitor, 2 terminals
Connect the LCR meter high terminal to the DUT low terminal and the LCR meter low terminal to the DUT high terminal.

[Required Modules and Accessories]
Keysight 4284A Precision LCR Meter or Keysight E4980A Precision LCR Meter
GPIB cable

[Test Parameters]
Address: GPIB address of LCR meter
Osc_Level: Measurement signal level
Frequency: Measurement frequency
Integ_Time: Integration time
Vstart: C-V measurement start voltage
Vstop: C-V measurement stop voltage
Sweep_Pts: Number of sweep points
Cmax: Maximum value of graph axis for plotting capacitance

[Extended Test Parameters]
Delay_Time: Delay time
Hold_Time: Hold time
Real_Time_Display: Run time automatic update of graph display

[Measurement Parameters]
Capacitance Cdata
Dissipation factor Dispersion

[X-Y Graph]
X axis: Bias voltage Vsweep (LINEAR)
Y1-axis: Parallel capacitance Cdata (LINEAR)
Y2-axis: Dissipation factor Dispersion (LINEAR)

[List Display]
Bias voltage Vsweep
Parallel capacitance Cdata
Dissipation factor Dispersion
17.12 CV Curve Parameter Calculator: Calculates CMOS transistor parameters from capacitance versus voltage sweeps. (A.01.02)

[Description]
Device parameters (Nsub, Cfb, Vfb, etc.) for an NMOS or PMOS transistor are calculated from the inputted CV curve using standard equations.

[Device Measured]
No measurement performed; this application test does analysis only. This application test is designed to be used inside of another application test. Within the umbrella application test you can make the CV measurement using either a classic test C-V Sweep or another application test. In fact, you do not need to use the B1500A MFCMU to make the CV measurement; you can also generate the CV curve with the SMUs using the QSCV function or with an external C-meter (such as a 4284A, E4980A or 4294A) that is being controlled by an application test.

[Device Parameters]
Area: Area of the transistor gate (cm^2)
TempC: Ambient temperature (degrees Celsius)
Pm: Work function of the gate material (Volts)
Device: Device type (NMOS=-1, PMOS=1)

[Test Parameters]
Vsweep: Vector containing a minimum of 3 and a maximum of 1001 points representing the voltage applied to the transistor gate
Cmeas: Vector containing a minimum of 3 and a maximum of 1001 points representing the measured gate-to-substrate capacitance

[Extended Test Parameters]
Autoscale: Variable to control auto scaling of the display (0=Off, 1=On)

[Measurement Parameters]
None

[User Function]
None

[X-Y Plot]
X axis: Applied gate voltage (LINEAR)
Y1 axis: Measured gate-to-substrate capacitance (LINEAR)

[List Display]
Vsweep: Applied gate voltage (Volts)
Cmeas: Measured gate-to-substrate capacitance (Farads)

[Parameter Display]
Cox (Farads)
Cmin (Farads)
tox (Angstroms)
ni (1/cm^3)
Nsub (1/cm^3)
Pfermi (Volts)
Cfb (Farads)
Vfb (Volts)
Qsslq (1/cm^3)
Qb (Coulomb/cm^2)
Vth (Volts)

Note #1: Qsslq is "Qss over q". This is the only compact way to represent this variable within EasyEXPERT.

Note #2: Sample QSCV and HFCV measurement data for a device is included with this application test. Clicking on the input box for "Cmeas" will make softkey entries for these two data sets appear. The other default parameters for this application test are correct for this data.
17 Utility

17.13 TSet_T2420: Allows you to remotely control a Thermonics T-2420 precision temperature forcing system. (A.06.00)

[Description]
This application test does no measurement. It only sets the Thermonics to a specified temperature. You can save multiple instances of this application test with different temperature settings into a “My Favorites” setup. Using Quick Test Mode you can then call this application test to set a temperature, run multiple tests at that temperature, and then set the next temperature and repeat this process.

[Device Measured]
No measurement performed; this application test only sets a temperature.

[Device Parameters]
None

[Test Parameters]
Temp: Desired device measurement temperature.
Tlimit: Acceptable temperature range around the desired temperature within which the measurement can start.
Address: GPIB address of the Thermonics test temperature system.
Ambient_Temp: Temperature value to use as the ambient temperature.
Ambient_Limit: Acceptable temperature range around the ambient temperature. Any temperatures above or below the Ambient_Temp by the Ambient_Limit value are considered to be “ambient.”

[Extended Test Parameters]
Channel: Thermocouple channel on the N1265A to be used for temperature measurement.

[Measurement Parameters]
None

[User Function]
None

[X-Y Plot]
None

[List Display]
None

[Parameter Display]
None
1. Fast BTI(AC stress Id-Sampling): Bias Temperature Instability Test, using WGFMU (A.03.20)
2. Fast BTI(DC stress Id-Sampling): Bias Temperature Instability Test, using WGFMU (A.03.20)
3. Fast BTI(AC stress Id-Vg): Bias Temperature Instability Test, using WGFMU (A.03.20)
4. Fast BTI(DC stress Id-Vg): Bias Temperature Instability Test, using WGFMU (A.03.20)
5. TRANSIV DC IdVd: Id-Vd characteristics, using RSU (A.03.20)
6. TRANSIV DC IdVg: Id-Vg characteristics, using RSU (A.03.20)
7. WGFMU Pattern Editor: WGFMU Pattern Editor (A.03.20)
18.1 Fast BTI(AC stress Id-Sampling): Bias Temperature Instability Test, using WGFMU (A.03.20)

[Supported Analyzer]
B1500A

[Description]
Performs the bias temperature instability test with the AC stress, and plots the accumulated stress time vs drain current characteristics. This test is performed by repeating the following steps for the accumulated stress time defined in Accumulated_Stress_Time.
1. AC stress output
2. Drain current measurement

[Device Under Test]
MOSFET, 3 or 4 terminals
Drain and gate must be connected to WGFMU channel through RSU.
Source and substrate must be connected to WGFMU ground which is the outer conductor of the RSU Output terminals used for Drain and Gate.

[Required Modules and Accessories]
Keysight B1530A WGFMU 1 unit
Keysight B1531A RSU 2 set

[Device Parameters]
Polarity: Nch (forces specified value) or Pch (forces negative specified value)
Temp: Temperature (deg C)
L: Gate length
W: Gate width

[Test Parameters]
GateCh: WGFMU channel connected to Gate terminal
DrainCh: WGFMU channel connected to Drain terminal
IdMeasRange: Drain current measurement range (for Id measurement)
IdStressRange: Drain current measurement range (for AC stress)
RangeChangeHold: Wait time at the transition from stress to measurement

RangeChangeHold must be set to minimize the impact of the range change.

[Stress Setup]
VgStress: AC stress peak voltage for Gate terminal
VgStressBase: AC stress base voltage for Gate terminal
VdStress: AC stress peak voltage for Drain terminal
VdStressBase: AC stress base voltage for Drain terminal
StressFreq: Set frequency of stress.
StressEdge: Set rise and fall time of stress pulses.
StressDuty: Set duty ratio of stress pulses.
Accumulated_Stress_Time: Accumulated stress time

Accumulated stress time can be defined by using the Define vector data dialog box. Enter the accumulated stress time values in the first column from up to down. To open the Define vector data dialog box, click the left button in the Accumulated_Stress_Time field. Clicking the * button on the dialog box increases the entry fields.

[Meas Setup]
18 WGFMU

VgMeas: Gate voltage for Id measurement
VdMeas: Drain voltage for Id measurement
MeasDelay: Delay time until the measurement is started after the transition to the measurement voltage is started
MeasInterval: Sampling interval (for Id measurement)
MeasPoints: Number of the Id measurement points
IntegTime: Integration time for one measurement point
TransEdge: Voltage change time between the stress voltage and the measurement voltage, for both Gate and Drain terminals
SeqDelay: Device delay time
Lin_Log: Linear (linear sampling), Log10 (10 points/decade log sampling), or Log25 (25 points/decade log sampling)
PointToPlot: Data index to specify the Id measurement data used for result data plot

Device delay time must be set to avoid that the high voltage is applied to the drain and gate terminals simultaneously at the transition between stress and measurement. The value depends on the device under test, TransEdge value, and such.

PointToPlot must be 1 to MeasPoints. PointToPlot=1 specifies the first measurement data.

[Device_ID_Setup]
Device_ID_Override: Y (sets the New_Device_ID value to the Device ID) or N (does not set)
New_Device_ID: Device ID

[Pattern_Validate_Setup]
PatternValidateFile: Absolute path name of the file for checking WGFMU output waveform.

[Extended Test Parameters]
VgForceRange: Gate voltage output range
VdForceRange: Drain voltage output range

[Test Output: X-Y Graph]
Id-AccumulatedStressTime: Drain current vs Accumulated stress time characteristics
18.2 Fast BTI(DC stress Id-Sampling): Bias Temperature Instability Test, using WGFMU (A.03.20)

[Supported Analyzer]
B1500A

[Description]
Performs the bias temperature instability test with the DC stress, and plots the accumulated stress time vs drain current characteristics. This test is performed by repeating the following steps for the accumulated stress time defined in Accumulated_Stress_Time.
1. DC stress output
2. Drain current measurement

[Device Under Test]
MOSFET, 3 or 4 terminals
Drain and gate must be connected to WGFMU channel through RSU.
Source and substrate must be connected to WGFMU ground which is the outer conductor of the RSU Output terminals used for Drain and Gate.

[Required Modules and Accessories]
Keysight B1530A WGFMU 1 unit
Keysight B1531A RSU 2 set

[Device Parameters]
Polarity: Nch (forces specified value) or Pch (forces negative specified value)
Temp: Temperature (deg C)
L: Gate length
W: Gate width

[Test Parameters]
GateCh: WGFMU channel connected to Gate terminal
DrainCh: WGFMU channel connected to Drain terminal
IdMeasRange: Drain current measurement range (for Id measurement)
IdStressRange: Drain current measurement range (for DC stress)
RangeChangeHold: Wait time at the transition from stress to measurement

RangeChangeHold must be set to minimize the impact of the range change.

[Stress Setup]
VgStress: Stress voltage for Gate terminal
VdStress: Stress voltage for Drain terminal
Accumulated_Stress_Time: Accumulated stress time

Accumulated stress time can be defined by using the Define vector data dialog box. Enter the accumulated stress time values in the first column from up to down. To open the Define vector data dialog box, click the left button in the Accumulated_Stress_Time field. Clicking the * button on the dialog box increases the entry fields.

[Meas Setup]
VgMeas: Gate voltage for Id measurement
VdMeas: Drain voltage for Id measurement
MeasDelay: Delay time until the measurement is started after the transition to the measurement voltage is started
MeasInterval: Sampling interval (for Id measurement)
MeasPoints: Number of the Id measurement points
IntegTime: Integration time for one measurement point
TransEdge: Voltage change time between the stress voltage and the measurement voltage, for both Gate and Drain terminals
SeqDelay: Device delay time
Lin_Log: Linear (linear sampling), Log10 (10 points/decade log sampling), or Log25 (25 points/decade log sampling)
PointToPlot: Data index to specify the Id measurement data used for result data plot

Device delay time must be set to avoid that the high voltage is applied to the drain and gate terminals simultaneously at the transition between stress and measurement. The value depends on the device under test, TransEdge value, and such.

PointToPlot must be 1 to MeasPoints. PointToPlot=1 specifies the first measurement data.

[Device_ID_Setup]
Device_ID_Override: Y (sets the New_Device_ID value to the Device ID) or N (does not set)
New_Device_ID: Device ID

[Extended Test Parameters]
VgForceRange: Gate voltage output range
VdForceRange: Drain voltage output range

[Test Output: X-Y Graph]
Id-AccumlatedStressTime: Drain current vs Accumulated stress time characteristics
### 18.3 Fast BTI (AC stress Id-Vg): Bias Temperature Instability Test, using WGFMU (A.03.20)

[Supported Analyzer]
B1500A

[Description]
Performs the bias temperature instability test with the AC stress, and plots the accumulated stress time vs threshold voltage characteristics. This test is performed by repeating the following steps for the accumulated stress time defined in Accumulated_Stress_Time.
1. AC stress output
2. Id-Vg measurement

[Device Under Test]
MOSFET, 3 or 4 terminals
Drain and gate must be connected to WGFMU channel through RSU.
Source and substrate must be connected to WGFMU ground which is the outer conductor of the RSU Output terminals used for Drain and Gate.

[Required Modules and Accessories]
Keysight B1530A WGFMU 1 unit
Keysight B1531A RSU 2 set

[Device Parameters]
Polarity: Nch (forces specified value) or Pch (forces negative specified value)
Temp: Temperature (deg C)
L: Gate length
W: Gate width
Id_at_Vth: Drain current to decide the Vth

[Test Parameters]
GateCh: WGFMU channel connected to Gate terminal
DrainCh: WGFMU channel connected to Drain terminal
IdMeasRange: Drain current measurement range (for Id-Vg measurement)
IdStressRange: Drain current measurement range (for AC stress)
RangeChangeHold: Wait time at the transition from stress to measurement

RangeChangeHold must be set to minimize the impact of the range change.

[Stress Setup]
VgStress: AC stress peak voltage for Gate terminal
VgStressBase: AC stress base voltage for Gate terminal
VdStress: AC stress peak voltage for Drain terminal
VdStressBase: AC stress base voltage for Drain terminal
StressFreq: Set frequency of stress.
StressEdge: Set rise and fall time of stress pulses.
StressDuty: Set duty ratio of stress pulses.
Accumulated_Stress_Time: Accumulated stress time

Accumulated stress time can be defined by using the Define vector data dialog box. Enter the accumulated stress time values in the first column from up to down. To open the Define vector data dialog box, click the left button in the Accumulated_Stress_Time field. Clicking the * button on the dialog box increases the entry fields.

[Meas Setup]
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
**StepNum**: Number of measurement points (number of sweep steps) per 1 sweep

**StepRise**: Step voltage change time (not available for the ramp sweep)

**Sweep**: Step (step sweep) or Ramp (ramp sweep)

**Slope**: Single (VgStart to VgStop) or Dual (VgStart to VgStop to VgStart)

**VdMeas**: Drain voltage for the Id-Vg measurement

**SeqDelay**: Device delay time

**TransEdge**: Voltage change time between the stress voltage and the measurement voltage, for both Gate and Drain terminals

**IntegTime**: Integration time for one measurement point

**StepDelay**: Step delay time

**Hold**: Hold time

Device delay time must be set to avoid that the high voltage is applied to the drain and gate terminals simultaneously at the transition between stress and measurement. The value depends on the device under test, TransEdge value, and such.

Step delay time is defined as the time from the step output start to the step measurement start.

Hold time is defined as the time from the measurement voltage output start to the sweep operation start. For the Dual slope, the hold time is taken at the sweep start of both forward sweep and reverse sweep.

[**Device_ID_Setup**]

**Device_ID_Override**: Y (sets the New_Device_ID value to the Device ID) or N (does not set)

**New_Device_ID**: Device ID

[**PatternValidate_Setup**]

**PatternValidateFile**: Absolute path name of the file for checking WGFMU output waveform.

[**Extended Test Parameters**]

**VgForceRange**: Gate voltage output range

**VdForceRange**: Drain voltage output range

**StepMargin**: Time from the step measurement end to the next step output start (not available for the ramp sweep)

[**Test Output: X-Y Graph**]

**Id-t**: Drain current vs Time characteristics

**Id-Vg**: Drain current vs Gate voltage characteristics

**Vth-AccumulatedStressTime**: Threshold voltage vs Accumulated stress time characteristics
18.4 Fast BTI (DC stress Id-Vg): Bias Temperature Instability Test, using WGFMU (A.03.20)

[Supported Analyzer]
B1500A

[Description]
Performs the bias temperature instability test with the DC stress, and plots the accumulated stress time vs threshold voltage characteristics. This test is performed by repeating the following steps for the accumulated stress time defined in Accumulated_Stress_Time.
1. DC stress output
2. Id-Vg measurement

[Device Under Test]
MOSFET, 3 or 4 terminals
Drain and gate must be connected to WGFMU channel through RSU.
Source and substrate must be connected to WGFMU ground which is the outer conductor of the RSU Output terminals used for Drain and Gate.

[Required Modules and Accessories]
Keysight B1530A WGFMU 1 unit
Keysight B1531A RSU 2 set

[Device Parameters]
Polarity: Nch (forces specified value) or Pch (forces negative specified value)
Temp: Temperature (deg C)
L: Gate length
W: Gate width
Id_at_Vth: Drain current to decide the Vth

[Test Parameters]
GateCh: WGFMU channel connected to Gate terminal
DrainCh: WGFMU channel connected to Drain terminal
IdMeasRange: Drain current measurement range (for Id-Vg measurement)
IdStressRange: Drain current measurement range (for DC stress)
RangeChangeHold: Wait time at the transition from stress to measurement

RangeChangeHold must be set to minimize the impact of the range change.

[Stress Setup]
VgStress: Stress voltage for Gate terminal
VdStress: Stress voltage for Drain terminal
Accumulated_Stress_Time: Accumulated stress time

Accumulated stress time can be defined by using the Define vector data dialog box. Enter the accumulated stress time values in the first column from up to down. To open the Define vector data dialog box, click the left button in the Accumulated_Stress_Time field. Clicking the * button on the dialog box increases the entry fields.

[Meas Setup]
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
StepNum: Number of measurement points (number of sweep steps) per 1 sweep
StepRise: Step voltage change time (not available for the ramp sweep)
Sweep: Step (step sweep) or Ramp (ramp sweep)
Slope: Single (VgStart to VgStop) or Dual (VgStart to VgStop to VgStart)
VdMeas: Drain voltage for the Id-Vg measurement
SeqDelay: Device delay time
TransEdge: Voltage change time between the stress voltage and the measurement voltage, for both Gate and Drain terminals
IntegTime: Integration time for one measurement point
StepDelay: Step delay time
Hold: Hold time

Device delay time must be set to avoid that the high voltage is applied to the drain and gate terminals simultaneously at the transition between stress and measurement. The value depends on the device under test, TransEdge value, and such.

Step delay time is defined as the time from the step output start to the step measurement start.

Hold time is defined as the time from the measurement voltage output start to the sweep operation start. For the Dual slope, the hold time is taken at the sweep start of both forward sweep and reverse sweep.

[Device_ID_Setup]
Device_ID_OVERRIDE: Y (sets the New_Device_ID value to the Device ID) or N (does not set)
New_Device_ID: Device ID

[Extended Test Parameters]
VgForceRange: Gate voltage output range
VdForceRange: Drain voltage output range
StepMargin: Time from the step measurement end to the next step output start (not available for the ramp sweep)

[Test Output: X-Y Graph]
Id-t: Drain current vs Time characteristics
Id-Vg: Drain current vs Gate voltage characteristics
Vth-AccumulatedStressTime: Threshold voltage vs Accumulated stress time characteristics
18.5 TRANSIV DC IdVd: Id-Vd characteristics, using RSU (A.03.20)

[Supported Analyzer]
B1500A

[Description]
Measures the drain current vs drain voltage characteristics of MOSFET.

[Device Under Test]
MOSFET, 3 or 4 terminals
Drain and gate must be connected to SMU through RSU.
Source and substrate must be connected to WGFMU ground which is the outer conductor of the RSU Output terminals used for Drain and Gate.

[Required Modules and Accessories]
Keysight B1530A WGFMU 1 unit
Keysight B1531A RSU 2 set

[Device Parameters]
Polarity: Nch (SMU forces specified value) or Pch (SMU forces negative specified value)
L: Gate length
W: Gate width
Temp: Temperature (deg C)
IdLimit: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, secondary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Drain: SMU connected to Drain terminal, primary sweep voltage output
VdStart: Sweep start voltage for Drain terminal
VdStop: Sweep stop voltage for Drain terminal
VdStep: Sweep step voltage for Drain terminal

[Extended Test Parameters]
IgLimit: Gate current compliance
IntegTime: Integration time
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Drain current Id

[User Function]
IdPerW: Drain current per unit gate width IdPerW=Id/W

[X-Y Plot]
X axis: Gate voltage Vd (LINEAR)
Y1 axis: Drain current Id (LINEAR)

[List Display]
Gate voltage Vg
Drain voltage Vd
Drain current Id
Drain current per unit gate width IdPerW
18.6 TRANSIV DC IdVg: Id-Vg characteristics, using RSU (A.03.20)

[Supported Analyzer]
B1500A

[Description]
Measures the drain current vs gate voltage characteristics of MOSFET.

[Device Under Test]
MOSFET, 3 or 4 terminals
Drain and gate must be connected to SMU through RSU.
Source and substrate must be connected to WGFMU ground which is the outer conductor of the RSU Output terminals used for Drain and Gate.

[Required Modules and Accessories]
Keysight B1530A WGFMU 1 unit
Keysight B1531A RSU 2 set

[Device Parameters]
Polarity: Nch (SMU forces specified value) or Pch (SMU forces negative specified value)
L: Gate length
W: Gate width
Temp: Temperature (deg C)
IdLimit: Drain current compliance

[Test Parameters]
Gate: SMU connected to Gate terminal, primary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Drain: SMU connected to Drain terminal, secondary sweep voltage output
VdStart: Sweep start voltage for Drain terminal
VdStop: Sweep stop voltage for Drain terminal
VdStep: Sweep step voltage for Drain terminal

[Extended Test Parameters]
IgLimit: Gate current compliance
IntegTime: Integration time
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Drain current Id

[User Function]
IdPerW: Drain current per unit gate width IdPerW=Id/W

[X-Y Plot]
X axis: Gate voltage Vg (LINEAR)
Y1 axis: Drain current Id (LINEAR)

[List Display]
Gate voltage Vg
Drain voltage Vd
Drain current Id
Drain current per unit gate width IdPerW
18.7 WGFMU Pattern Editor (A.03.20)

[Supported Analyzer]
B1500A

[Description]
Performs the WGFMU channel output setup and the measurement setup.
Set the ExecutionMode to Run Vector and click the Single button to perform the WGFMU channel output and measurement.

[Test Parameters]
ExecutionMode: Execution mode
  Run Vector: Performs the waveform output and measurement
  Pattern Validation: Displays the waveform and measurement setup, for debugging

[WGFMU1 and WGFMU2]
Enable: Enable (uses the channel) or Disable (does not use)
Channel: WGFMU channel to use
OperationMode: Operation mode
  PG Vmeas (PG mode, voltage measurement)
  Fast IV Imeas (Fast IV mode, current measurement)
  Fast IV Vmeas (Fast IV mode, voltage measurement)
VForceRange: Voltage output range
  Auto, 3V, 5V, -10V to 0V, or 0V to 10V
InitMeasRange: Measurement range
  For current measurement: 1uA, 10uA, 100uA, 1mA, or 10mA
  For voltage measurement: 5V or 10V

[Pattern]
RepeatCount: Repeat count of waveform data and measurement event data
WaveformCh1: Channel1 waveform data
WaveformCh2: Channel2 waveform data
MeasurementEvent: Measurement event data

Waveform data and measurement event data can be defined by using the Define vector data dialog box. To open the Define vector data dialog box, click the left button of each field. Clicking the * button on the dialog box increases the row.

Waveform data:
  Column 1: Time (absolute value)
  Column 2: Voltage output value

Measurement event data:
  Column 1: Sampling measurement start time (absolute value)
  Column 2: Number of measurement points per one sampling
  Column 3: Sampling interval
  Column 4: Averaging time per one point measurement
  Column 5: Ch1 range event
  Column 6: Ch2 range event

For the column 5 and 6, 0 is set normally. For the current measurement, setting a number from 1 to 5 enables the range event. This changes the current measurement range to the specified range when the sampling measurement is started.
  1: 1uA, 2: 10uA, 3: 100uA, 4: 1mA, 5: 10mA

To set the range event only without the measurement event, enter 0 to the column 2 and set the column 5 and 6.
To obtain the stable result for the current measurement with range changing, set the sampling measurement start time to the value which exceeds 100 micro seconds after the range is changed.

[Output_to_File_for_PatternValidation] Not effective for Run Vector mode
Output_Enable: Enable or Disable
   Enable (saves the waveform and measurement setup data to the file specified by Output_Filename)
   Disable (does not save)
Output_Filename: Absolute path name of the file to save the waveform and measurement setup data

[DataDisplay_for_RunVector] Not effective for Pattern Validation mode
DataDisplay_PatternValidation: PatternValidation data display mode
   Disable (does not display PatternValidation data during measurement)
   Enable_Waveform (displays Waveform during measurement)
   Enable_Waveform_MeasTiming (displays Waveform and MeasTiming during measurement)
DataDisplay_Mode: Data Display window display mode
   x(time)_y(meas): Time for X axis and measurement data for Y axis
   x(meas1)_y(meas2): Ch1 measurement data for X axis and Ch2 measurement data for Y axis

[Extended Test Parameters]
LogToFile: Enable or Disable
   Enable (logs error and warning)
   Disable (does not log)
LogFile: Absolute path name of the log file
WarningLevel: Warning level
   Off: No warning is reported
   Severe: Severe warning is reported
   Normal: Normal warning is reported
   Information: Information warning is reported
IForceRange1: Current measurement range when the sampling measurement is started
   1uA, 10uA, 100uA, 1mA, or 10mA
   This value is effective until the range is changed by the range event.
Result_Update_Interval_s: Interval of updating the measurement result. 2 to 100 seconds.
1. WGFMU DCIV: WGFMU DCIV (A.05.03.2013.0124_2013.03.26.1)
2. WGFMU Id-Vd (DC): WGFMU Id-Vd (DC) (A.05.03.2013.0124_2013.03.26.1)
3. WGFMU Id-Vd pulse: WGFMU Id-Vd pulse (A.05.03.2013.0124_2013.03.26.1)
4. WGFMU Id-Vg (DC): WGFMU Id-Vg (DC) (A.05.03.2013.0124_2013.03.26.1)
5. WGFMU Id-Vg pulse: WGFMU Id-Vg pulse (A.05.03.2013.0124_2013.03.26.1)
6. WGFMU PLSDIV: WGFMU PLSDIV (A.05.03.2013.0124_2013.03.26.1)
19.1 WGFMU DCIV (A.05.03.2013.0124_2013.03.26.1)

[Supported Analyzer]
B1500A

[Description]
Ch1 and Ch2 measures current or voltage with Ch1 sweeping dc output, and Ch2 constant output

[Test Parameters]

[Ch1 and Ch2]
ChX: WGFMU channel to use
ChXOperationMode: Operation mode
  PG Vmeas (PG mode, voltage measurement)
  Fast IV Imeas (Fast IV mode, current measurement)
  Fast IV Vmeas (Fast IV mode, voltage measurement)
ChXVForceRange: Voltage output range
  Auto, 3V, 5V, -10V to 0V, or 0V to 10V
ChXMeasRange: Measurement range
  For current measurement: 1uA, 10uA, 100uA, 1mA, or 10mA
  For voltage measurement: 5V or 10V
Ch1VStart: Ch1 start voltage
Ch1VStop: Sweep stop voltage
Ch1VStep: Sweep step voltage
Ch2VConst: Constant voltage
RiseTime: Rise time of each step
Hold: Hold time
MeasDelay: Measurement delay time
AveragingTime: Measurement averaging time

For detailed timing information, please scroll down to the bottom of Test Parameters window.

[Extended Test Parameters]
DataDisplay_PatternValidation : PatternValidation data display mode (Not effective for Pattern Validation mode)
  Disable (does not display PatternValidation data during measurement)
  Enable_Waveform_MeasTiming (displays Waveform and MeasTiming during measurement)

ExecutionMode: Execution mode
  Run Vector: Performs the waveform output and measurement
  Pattern Validation: Displays the waveform and measurement setup, for debugging
19.2 WGF MU Id-Vd (DC) (A.05.03.2013.0124_2013.03.26.1)

[Supported Analyzer]
B1500A

[Description]
Measures the drain current vs drain voltage characteristics of MOSFET using WGF MU

[Device Under Test]
MOSFET

[Device Parameters]
Lg: Gate Length
Wg: Gate Width
Temp: Temperature

[Test Parameters]
Period: Pulse period

Drain: WGF MU connected to Drain, primary sweep voltage output
VdStart: Sweep start voltage for Drain
VdStop: Sweep stop voltage for Drain
VdStep: Sweep step voltage for Drain

Gate: WGF MU connected to Gate, secondary sweep voltage output
VgStart: Sweep start voltage for Gate
VgStop: Sweep stop voltage for Gate
VgStep: Sweep step voltage for Gate

MeasRange: Measurement range for drain current
RiseTime: Rise time of each step
Hold: Hold time
MeasDelay: Measurement delay time
AveragingTime: Measurement averaging time

[Extended Test Parameters]
DataDisplay_PatternValidation : PatternValidation data display mode (Not effective for Pattern Validation mode)
  Disable (does not display PatternValidation data during measurement)
  Enable_Waveform_MeasTiming (displays Waveform and MeasTiming during measurement)

ExecutionMode: Execution mode
  Run Vector: Performs the waveform output and measurement
  Pattern Validation: Displays the waveform and measurement

[Measurement Parameters]
Id: Drain current

[X-Y Plot]
X axis: Vd, Drain voltage (LINEAR)
Y1 axis: Id, Drain current (LINEAR)

[List Display]
Vd, Drain voltage
Id, Drain current
Vg, gate voltage
19.3 WGFMU Id-Vd pulse (A.05.03.2013.0124_2013.03.26.1)

[Supported Analyzer]
B1500A

[Description]
Measures the drain current vs drain voltage characteristics of MOSFET using WGFMU pulse

[Device Under Test]
MOSFET

[Device Parameters]
Lg: Gate Length
Wg: Gate Width
Temp: Temperature

[Test Parameters]
Period: Pulse period

Drain: WGFMU connected to Drain, primary sweep voltage output
VdStart: Sweep start voltage of pulse top for Drain
VdStop: Sweep stop voltage of pulse top for Drain
VdStep: Sweep step voltage of pulse top for Drain
VdPulseBase: Pulse base voltage for Drain
VdPulseDelay: Pulse delay for Drain
VdPulseRiseTime: Pulse rise time for Drain
VdPulseWidth: Pulse width for Drain
VdPulseFallTime: Pulse fall time for Drain

Gate: WGFMU connected to Gate, secondary sweep voltage output
VgStart: Sweep start voltage of pulse top for Gate
VgStop: Sweep stop voltage of pulse top for Gate
VgStep: Sweep step voltage of pulse top for Gate
VgPulseBase: Pulse base voltage for Gate
VgPulseDelay: Pulse delay for Gate
VgPulseRiseTime: Pulse rise time for Gate
VgPulseWidth: Pulse width for Gate
VgPulseFallTime: Pulse fall time for Gate

MeasRange: Measurement range for drain current
Hold: Hold Time
MeasDelay: Measurement delay time
AveragingTime: Measurement averaging time

[Extended Test Parameters]
DataDisplay_PatternValidation : PatternValidation data display mode (Not effective for Pattern Validation mode)
  Disable (does not display PatternValidation data during measurement)
  Enable_Waveform_MeasTiming (displays Waveform and MeasTiming during measurement)

ExecutionMode: Execution mode
  Run Vector: Performs the waveform output and measurement
  Pattern Validation: Displays the waveform and measurement
19 WGFUM_IV

[Measurement Parameters]
Id: Drain current

[X-Y Plot]
X axis: Vd, Drain voltage (LINEAR)
Y1 axis: Id, Drain current (LINEAR)

[List Display]
Vd, Drain voltage
Id, Drain current
Vg, gate voltage
19.4 WGFMU Id-Vg (DC) (A.05.03.2013.0124_2013.03.26.1)

[Supported Analyzer]
B1500A

[Description]
Measures the drain current vs gate voltage characteristics of MOSFET using WGFMU

[Device Under Test]
MOSFET

[Device Parameters]
Lg: Gate Length
Wg: Gate Width
Temp: Temperature

[Test Parameters]
Period: Pulse period

Drain: WGFMU connected to Drain, secondary sweep voltage output
VdStart: Sweep start voltage for Drain
VdStop: Sweep stop voltage for Drain
VdStep: Sweep step voltage for Drain

Gate: WGFMU connected to Gate, primary sweep voltage output
VgStart: Sweep start voltage for Gate
VgStop: Sweep stop voltage for Gate
VgStep: Sweep step voltage for Gate

MeasRange: Measurement range for drain current
RiseTime: Rise time of each step
Hold: Hold time
MeasDelay: Measurement delay time
AveragingTime: Measurement averaging time

[Extended Test Parameters]
DataDisplay_PatternValidation: PatternValidation data display mode (Not effective for Pattern Validation mode)
    Disable (does not display PatternValidation data during measurement)
    Enable_Waveform_MeasTiming (displays Waveform and MeasTiming during measurement)

ExecutionMode: Execution mode
    Run Vector: Performs the waveform output and measurement
    Pattern Validation: Displays the waveform and measurement

[Measurement Parameters]
Id: Drain current

[X-Y Plot]
X axis: Vg, Gate voltage (LINEAR)
Y1 axis: Id, Drain current (LINEAR)

[List Display]
Vg, gate voltage
Id, Drain current
Vd, Drain voltage
19.5 WGF MU Id-Vg pulse (A.05.03.2013.0124_2013.03.26.1)

[Supported Analyzer]
B1500A

[Description]
Measures the drain current vs gate voltage characteristics of MOSFET using WGF MU pulse

[Device Under Test]
MOSFET

[Device Parameters]
Lg: Gate Length
Wg: Gate Width
Temp: Temperature

[Test Parameters]
Period: Pulse period

Drain: WGF MU connected to Drain, secondary sweep voltage output
VdStart: Sweep start voltage of pulse top for Drain
VdStop: Sweep stop voltage of pulse top for Drain
VdStep: Sweep step voltage of pulse top for Drain
VdPulseBase: Pulse base voltage for Drain
VdPulseDelay: Pulse delay for Drain
VdPulseRiseTime: Pulse rise time for Drain
VdPulseWidth: Pulse width for Drain
VdPulseFallTime: Pulse fall time for Drain

Gate: WGF MU connected to Gate, primary sweep voltage output
VgStart: Sweep start voltage of pulse top for Gate
VgStop: Sweep stop voltage of pulse top for Gate
VgStep: Sweep step voltage of pulse top for Gate
VgPulseBase: Pulse base voltage for Gate
VgPulseDelay: Pulse delay for Gate
VgPulseRiseTime: Pulse rise time for Gate
VgPulseWidth: Pulse width for Gate
VgPulseFallTime: Pulse fall time for Gate

MeasRange: Measurement range for drain current
Hold: Hold Time
MeasDelay: Measurement delay time
AveragingTime: Measurement averaging time

[Extended Test Parameters]
DataDisplay_PatternValidation : PatternValidation data display mode (Not effective for Pattern Validation mode)
  Disable (does not display PatternValidation data during measurement)
  Enable_Waveform_MeasTiming (displays Waveform and MeasTiming during measurement)

ExecutionMode: Execution mode
  Run Vector: Performs the waveform output and measurement
  Pattern Validation: Displays the waveform and measurement
[Measurement Parameters]
Id: Drain current

[X-Y Plot]
X axis: Vg, Gate voltage (LINEAR)
Y1 axis: Id, Drain current (LINEAR)

[List Display]
Vg, gate voltage
Id, Drain current
Vd, Drain voltage
19 WGFMU_IV

19.6 WGFMU PLSDIV (A.05.03.2013.0124_2013.03.26.1)

[Supported Analyzer]
B1500A

[Description]
Ch1 and Ch2 measures current or voltage with Ch1 sweeping pulsed output, and Ch2 constant output

[Test Parameters]
PulsePeriod: Pulse period

[Ch1 and Ch2]
ChX: WGFMU channel to use
ChXOperationMode: Operation mode
  - PG Vmeas (PG mode, voltage measurement)
  - Fast IV Imeas (Fast IV mode, current measurement)
  - Fast IV Vmeas (Fast IV mode, voltage measurement)
Ch XVForceRange: Voltage output range
  - Auto, 3V, 5V, -10V to 0V, or 0V to 10V
ChXMeasRange: Measurement range
  - For current measurement: 1uA, 10uA, 100uA, 1mA, or 10mA
  - For voltage measurement: 5V or 10V
Ch1VStart: Ch1 start voltage
ChX PulseBase: Pulse base voltage
ChX PulseDelay: Pulse Delay
ChX Pulse Rise Time: Pulse Rise Time
ChX Pulse Width: Pulse width
ChX Pulse Fall Time: Pulse Fall Time
Ch1VStart: Sweep start voltage of pulse top
Ch1VStop: Sweep stop voltage of pulse top
Ch1VStep: Sweep step voltage of pulse top
Ch2VConst: Constant voltage of pulse top
Hold: Hold time
MeasDelay: Measurement delay time
AveragingTime: Measurement averaging time

For detailed timing information, please scroll down to the bottom of Test Parameters window.

[Extended Test Parameters]
DataDisplay_PatternValidation: PatternValidation data display mode (Not effective for Pattern Validation mode)
  - Disable (does not display PatternValidation data during measurement)
  - Enable_Waveform_MeasTiming (displays Waveform and MeasTiming during measurement)

ExecutionMode: Execution mode
  - Run Vector: Performs the waveform output and measurement
  - Pattern Validation: Displays the waveform and measurement setup, for debugging
20 GaN Diode
20 GaN Diode

1. Diode Current Collapse IV-t Sampling:
   GaN Diode Current Collapse characteristics (using N1267A) (A.05.02)

2. Diode Current Collapse Signal Monitor:
   GaN Diode Current Collapse characteristics (using N1267A) (A.05.03)
20.1 Diode Current Collapse IV-t Sampling: GaN Diode Current Collapse characteristics (using N1267A) (A.05.02)

[Supported Analyzer]
B1505A

[Description]
Measures Current Collapse of GaN Diode.
On state current, voltage and resistance after off state are sampled using N1267A.

[Device Under Test]
GaN Diode, 3 terminals

[Device Parameters]
Temp: Temperature
RAxisMin: Y axis (R) minimum value
RAxisMax: Y axis (R) maximum value
VAxisMin: Y axis (V) minimum value
VAxisMax: Y axis (V) maximum value
IAxisMin: Y axis (I) minimum value
IAxisMax: Y axis (I) maximum value

[Test Parameters]
Memo: Memorandum
GNDU: GNDU connected to N1267A GNDU input
HVSMU: HVSMU connected to N1267A HVSMU input
HCSMU: HCSMU connected to N1267A HCSMU input
SwitchControl: MCSMU connected to N1267A Switch Control
Substrate: SMU/GNDU connected to Substrate
VOff: Cathode voltage applied while off state
VOn: Cathode voltage applied while on state (Voltage drops inside of N1267A according to on state current)
IOnLimit: Current compliance for on state
OffStressTime: Duration of VOff application
SamplingInterval: Sampling interval
NumberOfSamples: Number of samples

[Extended Test Parameters]
SamplingMode: Options for linear or log sampling
SamplingStartTime: Time offset from turning DUT on to starting sampling
MaxPlottingTime: Max time of graph X axis for plotting
MeasurementTime: Actural measurement time for a sample (effective in case of 2ms or above
SamplingInterval)
IOffLimit: Current compliance for off state  (AUTO: 8mA for VOff up to 1500V, 4mA for VOff above 3kV)
VerboseDataStore: Option for saving data of the embedded classic test setup

[Measurement Parameters]
Time: On state time
V_HCSMU: Voltage measured by HCSMU
I_HCSMU: Current measured by HCSMU
V_HVSMU: Voltage measured by HVSMU
I_HVSMU: Current measured by HVSMU
V_SwitchControl: Voltage measured by Switch Control MCSMU
I_SwitchControl: Current measured by Switch Control MCSMU
20 GaN Diode

[User Function]
V: Voltage (= V_HVSMU)
I: Current (= I_HCSMU + I_HVSMU)
R: Resistance (= V / I)
Ta: Temperature (= Temp)

[X-Y Plot]
X axis: Time
Y1 axis: R
Y2 axis: V
Y3 axis: I

[List Display]
Time
R
V
I
V_HCSMU
I_HCSMU
V_HVSMU
I_HVSMU
V_SwitchControl
I_SwitchControl

[Parameter Display Area]
Ta
20.2 Diode Current Collapse Signal Monitor: GaN Diode Current Collapse characteristics (using N1267A) (A.05.03)

[Supported Analyzer]
B1505A

[Description]
Measures Current Collapse of GaN Diode.
On state current, voltage and resistance after off state are measured by pulse and signal monitor using N1267A.

[Device Under Test]
GaN Diode, 3 terminals

[Device Parameters]
Temp: Temperature
RAxisMin: Y axis (R) minimum value
RAxisMax: Y axis (R) maximum value
VAxisMin: Y axis (V) minimum value
VAxisMax: Y axis (V) maximum value
IAxisMin: Y axis (I) minimum value
IAxisMax: Y axis (I) maximum value

[Test Parameters]
Memo: Memorandum
GNDU: GNDU connected to N1267A GNDU input
HVSMU: HVSMU connected to N1267A HVSMU input
HCSMU: HCSMU connected to N1267A HCSMU input
SwitchControl: MCSMU connected to N1267A Switch Control
Substrate: SMU/GNDU connected to Substrate
VOff: Cathode voltage applied while off state
VOn: Cathode voltage applied while on state (Voltage drops inside N1267A according to on state current)
IOnLimit: Current compliance for on state
OffStressTime: Duration of VOff application
OnTime: Duration of VOn application

[Extended Test Parameters]
MonitorStartTime: Time offset from turning DUT on to starting signal monitor
MonitorDuration: Duration of signal monitor
IOffLimit: Current compliance for off state (AUTO: 8mA for VOff up to 1500V, 4mA for VOff above 3kV)
VOnHoldTime: Hold time of VOn output by HCSMU before turning DUT on
TimeAxisScale: Option for scale of X axis (Time)
VerboseDataStore: Option for saving data of the embedded classic test setup

[Measurement Parameters]
Time: On state time
V_HCSMU: Voltage measured by HCSMU
I_HCSMU: Current measured by HCSMU
V: Voltage measured by HVSMU
I_HVSMU: Current measured by HVSMU
Vsw: Voltage measured by Switch Control MCSMU
I_SwitchControl: Current measured by Switch Control MCSMU

[User Function]
20 GaN Diode

I: Drain current (= I_HCSMU + I_HVSMU)
R: Drain-Source resistance (= V / I)
Ta: Temperature (= Temp)

[X-Y Plot]
X axis: Time
Y1 axis: R
Y2 axis: V
Y3 axis: I
Y4 axis: Vsw

[Table Display]
Time
R
V
I
Vsw
V_HCSMU
I_HCSMU
I_HVSMU
I_SwitchControl

[Parameter Display Area]
Ta
21 GaN FET
1. FET Current Collapse IV-t Sampling (I Force):
   GaN FET Current Collapse characteristics (using N1267A) (A.05.02)
2. FET Current Collapse IV-t Sampling:
   GaN FET Current Collapse characteristics (using N1267A) (A.05.02)
3. FET Current Collapse Signal Monitor (I Force):
   GaN FET Current Collapse characteristics (using N1267A) (A.05.03)
4. FET Current Collapse Signal Monitor:
   GaN FET Current Collapse characteristics (using N1267A) (A.05.03)
5. Id-Vds Current Collapse:
   GaN FET Current Collapse characteristics (using N1267A) (A.05.02)
21.1 FET Current Collapse IV-t Sampling (I Force): GaN FET Current Collapse characteristics (using N1267A) (A.05.02)

[Supported Analyzer]
B1505A

[Description]
Measures Current Collapse of GaN FET.
On state current, voltage and resistance after off state are sampled using N1267A.

[Device Under Test]
GaN FET, 4 terminals

[Device Parameters]
Temp: Temperature
RdsAxisMin: Y axis (Rds) minimum value
RdsAxisMax: Y axis (Rds) maximum value
VdsAxisMin: Y axis (Vds) minimum value
VdsAxisMax: Y axis (Vds) maximum value
IdAxisMin: Y axis (Id) minimum value
IdAxisMax: Y axis (Id) maximum value

[Test Parameters]
Memo: Memorandum
GNDU: GNDU connected to N1267A GNDU input
HVSMU: HVSMU connected to N1267A HVSMU input
HCSMU: HCSMU connected to N1267A HCSMU input
SwitchControl: MCSMU connected to N1267A Switch Control
Gate: MCSMU/HCSMU connected to Gate terminal
Substrate: SMU/GNDU connected to Substrate
VgOff: Gate off voltage
VgOn: Gate on voltage
VdOff: Drain voltage applied while off state
VdOnLimit: Drain voltage compliance for on state (Voltage drops inside of N1267A according to on state current)
IdOn: Drain current applied while on state
OffStressTime: Duration of VdOff application
SamplingInterval: Sampling interval
NumberOfSamples: Number of samples

[Extended Test Parameters]
SamplingMode: Options for linear or log sampling
SamplingStartTime: Time offset from turning DUT on to starting sampling
MaxPlottingTime: Max time of graph X axis for plotting
MeasurementTime: Actual measurement time for a sample (effective in case of 2ms or above
SamplingInterval)
IgLimit: Gate current compliance
IdOffLimit: Drain current compliance for off state (AUTO: 8mA for VdOff up to 1500V, 4mA for VdOff above 3kV)
DischargingSwitchControl: Option for discharging by N1267A internal switch (for the case of on state current less than IdOffLimit)
VerboseDataStore: Option for saving data of the embedded classic test setup
21 GaN FET

[Measurement Parameters]
Time: On state time
V_HCSMU: Voltage measured by HCSMU
I_HCSMU: Current measured by HCSMU
V_HVSMU: Voltage measured by HVSMU
I_HVSMU: Current measured by HVSMU
V_SwitchControl: Voltage measured by Switch Control MCSMU
I_SwitchControl: Current measured by Switch Control MCSMU
V_Gate: Gate voltage
I_Gate: Gate current

[User Function]
Vds: Drain-Source voltage (= V_HVSMU)
Id: Drain current (= I_HCSMU + I_HVSMU)
Rds: Drain-Source resistance (= Vds / Id)
Vgs: Gate-Source voltage (= V_Gate)
Ig: Gate current (= I_Gate)
Ta: Temperature (= Temp)

[X-Y Plot]
X axis: Time
Y1 axis: Rds
Y2 axis: Vds
Y3 axis: Id

[List Display]
Time
Rds
Vds
Id
Vgs
Ig
V_HCSMU
I_HCSMU
V_HVSMU
I_HVSMU
V_SwitchControl
I_SwitchControl

[Parameter Display Area]
Ta
21.2 FET Current Collapse IV-t Sampling: GaN FET Current Collapse characteristics (using N1267A) (A.05.02)

[Supported Analyzer]
B1505A

[Description]
Measures Current Collapse of GaN FET.
On state current, voltage and resistance after off state are sampled using N1267A.

[Device Under Test]
GaN FET, 4 terminals

[Device Parameters]
Temp: Temperature
RdsAxisMin: Y axis (Rds) minimum value
RdsAxisMax: Y axis (Rds) maximum value
VdsAxisMin: Y axis (Vds) minimum value
VdsAxisMax: Y axis (Vds) maximum value
IdAxisMin: Y axis (Id) minimum value
IdAxisMax: Y axis (Id) maximum value

[Test Parameters]
Memo: Memorandum
GNDU: GNDU connected to N1267A GNDU input
HVSMU: HVSMU connected to N1267A HVSMU input
HCSMU: HCSMU connected to N1267A HCSMU input
SwitchControl: MCSMU connected to N1267A Switch Control
Gate: MCSMU/HCSMU connected to Gate terminal
Substrate: SMU/GNDU connected to Substrate
VgOff: Gate off voltage
VgOn: Gate on voltage
VdOff: Drain voltage applied while off state
VdOn: Drain voltage applied while on state (Voltage drops inside of N1267A according to on state current)
IdOnLimit: Drain current compliance for on state
OffStressTime: Duration of VdOff application
SamplingInterval: Sampling interval
NumberOfSamples: Number of samples

[Extended Test Parameters]
SamplingMode: Options for linear or log sampling
SamplingStartTime: Time offset from turning DUT on to starting sampling
MaxPlottingTime: Max time of graph X axis for plotting
MeasurementTime: Actual measurement time for a sample (effective in case of 2ms or above SamplingInterval)
IgLimit: Gate current compliance
IdOffLimit: Drain current compliance for off state (AUTO: 8mA for VdOff up to 1500V, 4mA for VdOff above 3kV)
DischargingSwitchControl: Option for discharging by N1267A internal switch (for the case of on state current less than IdOffLimit)
VerboseDataStore: Option for saving data of the embedded classic test setup

[Measurement Parameters]
21 GaN FET

Time: On state time
V_HCSMU: Voltage measured by HCSMU
I_HCSMU: Current measured by HCSMU
V_HVSMU: Voltage measured by HVSMU
I_HVSMU: Current measured by HVSMU
V_SwitchControl: Voltage measured by Switch Control MCSMU
I_SwitchControl: Current measured by Switch Control MCSMU
V_Gate: Gate voltage
I_Gate: Gate current

[User Function]
Vds: Drain-Source voltage (= V_HVSMU)
Id: Drain current (= I_HCSMU + I_HVSMU)
Rds: Drain-Source resistance (= Vds / Id)
Vgs: Gate-Source voltage (= V_Gate)
Ig: Gate current (= I_Gate)
Ta: Temperature (= Temp)

[X-Y Plot]
X axis: Time
Y1 axis: Rds
Y2 axis: Vds
Y3 axis: Id

[List Display]
Time
Rds
Vds
Id
Vgs
Ig
V_HCSMU
I_HCSMU
V_HVSMU
I_HVSMU
V_SwitchControl
I_SwitchControl

[Parameter Display Area]
Ta
21.3 FET Current Collapse Signal Monitor (I Force): GaN FET Current Collapse characteristics (using N1267A) (A.05.03)

[Supported Analyzer]
B1505A

[Description]
Measures Current Collapse of GaN FET.
On state current, voltage and resistance after off state are measured by pulse and signal monitor using N1267A.

[Device Under Test]
GaN FET, 4 terminals

[Device Parameters]
Temp: Temperature
RdsAxisMin: Y axis (Rds) minimum value
RdsAxisMax: Y axis (Rds) maximum value
VdsAxisMin: Y axis (Vds) minimum value
VdsAxisMax: Y axis (Vds) maximum value
IdAxisMin: Y axis (Id) minimum value
IdAxisMax: Y axis (Id) maximum value

[Test Parameters]
Memo: Memorandum
GNDU: GNDU connected to N1267A GNDU input
HVSMU: HVSMU connected to N1267A HVSMU input
HCSMU: HCSMU connected to N1267A HCSMU input
SwitchControl: MCSMU connected to N1267A Switch Control
Gate: MCSMU/HCSMU connected to Gate terminal
Substrate: SMU/GNDU connected to Substrate
VgOff: Gate off voltage
VgOn: Gate on voltage
VdOff: Drain voltage applied while off state
VdOnLimit: Drain voltage compliance for on state (Voltage drops inside of N1267A according to on state current)
IdOn: Drain current applied while on state
OffStressTime: Duration of VdOff application
OnTime: Duration of VdOn application

[Extended Test Parameters]
MonitorStartTime: Time offset from turning DUT on to starting signal monitor
MonitorDuration: Duration of signal monitor
IgLimit: Gate current compliance
IdOffLimit: Drain current compliance for off state (AUTO: 8mA for VdOff up to 1500V, 4mA for VdOff above 3kV)
DischargingSwitchControl: Option for discharging by N1267A internal switch (for the case of on state current less than IdOffLimit)
DischargingWaitTime: Wait time for outputting gate on voltage after starting discharging by N1267A internal switch (effective in case of DischargingSwitchControl On)
VOnHoldTime: Hold time of VOn output by HCSMU before turning DUT on
TimeAxisScale: Option for scale of X axis (Time)
VerboseDataStore: Option for saving data of the embedded classic test setup
21 GaN FET

[Measurement Parameters]
Time: On state time
V_HCSMU: Voltage measured by HCSMU
I_HCSMU: Current measured by HCSMU
Vds: Voltage measured by HVSMU
I_HVSMU: Current measured by HVSMU
V_SwitchControl: Voltage measured by Switch Control MCSMU
I_SwitchControl: Current measured by Switch Control MCSMU
Vgs: Gate voltage
Ig: Gate current

[User Function]
Id: Drain current (= I_HCSMU + I_HVSMU)
Rds: Drain-Source resistance (= Vds / Id)
Ta: Temperature (= Temp)

[X-Y Plot]
X axis: Time
Y1 axis: Rds
Y2 axis: Vds
Y3 axis: Id
Y4 axis: Vgs

[List Display]
Time
Rds
Vds
Id
Vgs
Ig
V_HCSMU
I_HCSMU
I_HVSMU
V_SwitchControl
I_SwitchControl

[Parameter Display Area]
Ta
21.4 FET Current Collapse Signal Monitor: GaN FET Current Collapse characteristics (using N1267A) (A.05.03)

[Supported Analyzer]
B1505A

[Description]
Measures Current Collapse of GaN FET.
On state current, voltage and resistance after off state are measured by pulse and signal monitor using N1267A.

[Device Under Test]
GaN FET, 4 terminals

[Device Parameters]
Temp: Temperature
RdsAxisMin: Y axis (Rds) minimum value
RdsAxisMax: Y axis (Rds) maximum value
VdsAxisMin: Y axis (Vds) minimum value
VdsAxisMax: Y axis (Vds) maximum value
IdAxisMin: Y axis (Id) minimum value
IdAxisMax: Y axis (Id) maximum value

[Test Parameters]
Memo: Memorandum
GNDU: GNDU connected to N1267A GNDU input
HVSMU: HVSMU connected to N1267A HVSMU input
HCSMU: HCSMU connected to N1267A HCSMU input
SwitchControl: MCSMU connected to N1267A Switch Control
Gate: MCSMU/HCSMU connected to Gate terminal
Substrate: SMU/GNDU connected to Substrate
VgOff: Gate off voltage
VgOn: Gate on voltage
VdOff: Drain voltage applied while off state
VdOn: Drain voltage applied while on state (Voltage drops inside of N1267A according to on state current)
IdOnLimit: Drain current compliance for on state
OffStressTime: Duration of VdOff application
OnTime: Duration of VdOn application

[Extended Test Parameters]
MonitorStartTime: Time offset from turning DUT on to starting signal monitor
MonitorDuration: Duration of signal monitor
IgLimit: Gate current compliance
IdOffLimit: Drain current compliance for off state (AUTO: 8mA for VdOff up to 1500V, 4mA for VdOff above 3kV)
DischargingSwitchControl: Option for discharging by N1267A internal switch (for the case of on state current less than IdOffLimit)
DischargingWaitTime: Wait time for outputting gate on voltage after starting discharging by N1267A internal switch (effective in case of DischargingSwitchControl On)
VOnHoldTime: Hold time of VOn output by HCSMU before turning DUT on
TimeAxisScale: Option for scale of X axis (Time)
VerboseDataStore: Option for saving data of the embedded classic test setup

[Measurement Parameters]
21 GaN FET

Time: On state time
V_HCSMU: Voltage measured by HCSMU
I_HCSMU: Current measured by HCSMU
Vds: Voltage measured by HVSMU
I_HVSMU: Current measured by HVSMU
V_SwitchControl: Voltage measured by Switch Control MCSMU
I_SwitchControl: Current measured by Switch Control MCSMU
Vgs: Gate voltage
Ig: Gate current

[User Function]
Id: Drain current (= I_HCSMU + I_HVSMU)
Rds: Drain-Source resistance (= Vds / Id)
Ta: Temperature (= Temp)

[X-Y Plot]
X axis: Time
Y1 axis: Rds
Y2 axis: Vds
Y3 axis: Id
Y4 axis: Vgs

[List Display]
Time
Rds
Vds
Id
Vgs
Ig
V_HCSMU
I_HCSMU
I_HVSMU
V_SwitchControl
I_SwitchControl

[Parameter Display Area]
Ta
21.5 Id-Vds Current Collapse: GaN FET Current Collapse characteristics (using N1267A) (A.05.02)

[Supported Analyzer]
B1505A

[Description]
Measures Current Collapse of GaN FET.
Id-Vds in on state is measured after applying off stress using N1267A.

[Device Under Test]
GaN FET, 4 terminals

[Device Parameters]
Temp: Temperature
XAxisVdsMin: X axis (Vds) minimum value
XAxisVdsMax: X axis (Vds) maximum value
YAxisIdMin: Y axis (Id) minimum value
YAxisIdMax: Y axis (Id) maximum value

[Test Parameters]
Memo: Memorandum
GNDU: GNDU connected to N1267A GNDU input
HVSMU: HVSMU connected to N1267A HVSMU input
HCSMU: HCSMU connected to N1267A HCSMU input
SwitchControl: MCSMU connected to N1267A Switch Control
Gate: MCSMU/HCSMU connected to Gate terminal
Substrate: SMU/GNDU connected to Substrate
VgOff: Gate off voltage
VgOn: Gate on voltage
VdOff: Drain voltage applied while off state
VdStart: Start value of drain voltage sweep for on state (Voltage drops inside of N1267A according to on state current)
VdStop: Stop value of drain voltage sweep for on state (Voltage drops inside of N1267A according to on state current)
IdOnLimit: Drain current compliance for on state
OffStressTime: Duration of VdOff application
StepTime: Step time of drain voltage sweep
NOS: Number of steps of drain voltage sweep

[Extended Test Parameters]
IgLimit: Gate current compliance
IdOffLimit: Drain current compliance for off state (AUTO: 8mA for VdOff up to 1500V, 4mA for VdOff above 3kV)
MeasurementTime: Actural measurement time for each step of drain voltage sweep
DischargingSwitchControl: Option for discharging by N1267A internal switch (for the case of on state current less than IdOffLimit)
IdOffMonitor: Option for measurement of drain current in off state
VerboseDataStore: Option for saving data of the embedded classic test setup

[Measurement Parameters]
V_HCSMU: Voltage measured by HCSMU
I_HCSMU: Current measured by HCSMU
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V_HVSMU: Voltage measured by HVSMU
I_HVSMU: Current measured by HVSMU
V_SwitchControl: Voltage measured by Switch Control MCSMU
I_SwitchControl: Current measured by Switch Control MCSMU
V_Gate: Gate voltage
I_Gate: Gate current

[User Function]
Vds: Drain-Source voltage (= V_HVSMU)
Id: Drain current (= I_HCSMU + I_HVSMU)
Vgs: Gate-Source voltage (= V_Gate)
Ig: Gate current (= I_Gate)
Ta: Temperature (= Temp)

[X-Y Plot]
X axis: Vds
Y1 axis: Id

[List Display]
Vds
Id
Vgs
Ig
V_HCSMU
I_HCSMU
V_HVSMU
I_HVSMU
V_SwitchControl
I_SwitchControl

[Parameter Display Area]
Ta
<p>| | |</p>
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<thead>
<tr>
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<th></th>
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<tbody>
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<td>1.</td>
<td>Cce:</td>
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<tr>
<td>2.</td>
<td>Cge:</td>
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<tr>
<td>3.</td>
<td>Cge:</td>
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<td>4.</td>
<td>Cge-Vge:</td>
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<td>5.</td>
<td>Ic(off)-Vce:</td>
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<tr>
<td>6.</td>
<td>Ic-Vce:</td>
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<tr>
<td>7.</td>
<td>Ic-Vge:</td>
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<td>8.</td>
<td>TDDB Constant V:</td>
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<td>9.</td>
<td>Vce(sat):</td>
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<td>10.</td>
<td>Vth Vge(off):</td>
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<td>11.</td>
<td>Ic-Vge for Expanders:</td>
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<td>12.</td>
<td>Vce-Vge:</td>
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<td>Cce (N1272A):</td>
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<td>14.</td>
<td>Cge (N1272A):</td>
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<tr>
<td>15.</td>
<td>Cge (N1272A):</td>
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<tr>
<td>16.</td>
<td>Cies (N1272A):</td>
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<tr>
<td>17.</td>
<td>Coes (N1272A):</td>
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<td>18.</td>
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<td>21.</td>
<td>Cies-Vge (N1272A):</td>
</tr>
</tbody>
</table>
22.1 Cce: IGBT Cce-Vc characteristics (A.04.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Collector-Emitter capacitance (Cce), and plots Cce-Vc characteristics.
For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
IGBT, 3 terminals
Connect Collector, Emitter, and Gate to the High Voltage Bias-T High, Low, and AC Guard respectively.
Or, connect Collector, Emitter, and Gate to the Test Fixture MFCMU High, MFCMU Low, and AUX circuit common respectively.

[Required Modules and Accessories]
Keysight B1520A MFCMU 1 unit
Keysight N1260A High Voltage Bias-T or Keysight N1259A Test Fixture with the option N1259A-020

[Device Parameters]
Polarity: Nch (SMU forces the specified value) or Pch (SMU forces the negative specified value).
Temp: Temperature
YAxisCceMin: Y axis (Cce) minimum value
YAxisCceMax: Y axis (Cce) maximum value

[Test Parameters]
Memo: Memorandum
IntegTime: Integration time
Frequency: Measurement frequency
OscLevel: Measurement signal level
Scale: Scale of DC bias sweep, LINEAR, LOG10, LOG25, or LOG50
Collector: CMU used for the capacitance measurement
VcBias: SMU used for the DC bias sweep source
VcStart: DC bias sweep start voltage
VcStop: DC bias sweep stop voltage
VcLinearStep: DC bias sweep step voltage, effective if Scale=LINEAR
IcLimit: Collector current compliance

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
IcMinRange: Minimum range for the collector current measurement

[Measurement Parameters]
Collector-Emitter capacitance Cds
Collector-Emitter current Ids
[User Function]
Ta: Temperature Ta=Temp

[X-Y Plot]
For Scale=LINEAR:
X axis: Collector voltage Vcollector (LINEAR)
Y1 axis: Collector-Emitter capacitance Cce (LOG)

For Scale=LOG10, LOG25, or LOG50:
X axis: Collector voltage Vcollector (LOG)
Y1 axis: Collector-Emitter capacitance Cce (LOG)

[List Display]
Collector voltage Vdrain
Collector-Emitter capacitance Cce
Collector-Emitter current Ice

[Parameters Display Area]
Temperature Ta=Temp
22.2 Cgc: IGBT Cgc-Vc characteristics (A.04.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Collector-Gate capacitance (Cgc), and plots Cgc-Vc characteristics.
For a more accurate measurement, perform correction data measurement at the measurement frequency before
starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options...
button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration
window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M,
4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
IGBT, 3 terminals
Connect Collector, Gate, and Emitter to the High Voltage Bias-T High, Low, and AC Guard respectively.
Or, connect Collector, Gate, and Emitter to the Test Fixture MFCMU High, MFCMU Low, and AUX circuit
common respectively.

[Required Modules and Accessories]
Keysight B1520A MFCMU 1 unit
Keysight N1260A High Voltage Bias-T or Keysight N1259A Test Fixture with the option N1259A-020

[Device Parameters]
Polarity: Nch (SMU forces the specified value) or Pch (SMU forces the negative specified value).
Temp: Temperature
YAxisCgcMin: Y axis (Cgc) minimum value
YAxisCgcMax: Y axis (Cgc) maximum value

[Test Parameters]
Memo: Memorandum
IntegTime: Integration time
Frequency: Measurement frequency
OscLevel: Measurement signal level
Scale: Scale of DC bias sweep, LINEAR, LOG10, LOG25, or LOG50
Collector: CMU used for the capacitance measurement
VcBias: SMU used for the DC bias sweep source
VcStart: DC bias sweep start voltage
VcStop: DC bias sweep stop voltage
VcLinearStep: DC bias sweep step voltage, effective if Scale=LINEAR
IcLimit: Collector current compliance

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
IcMinRange: Minimum range for the collector current measurement

[Measurement Parameters]
Gate-Collector capacitance Cgc
Collector current Icollector

[User Function]
Ta: Temperature Ta=Temp

[X-Y Plot]
For Scale=LINEAR:
X axis: Collector voltage Vcollector (LINEAR)
Y1 axis: Gate-Collector capacitance C_{gc} (LOG)

For Scale=LOG10, LOG25, or LOG50:
X axis: Collector voltage Vcollector (LOG)
Y1 axis: Gate-Collector capacitance C_{gc} (LOG)

[List Display]
Collector voltage V_{collector}
Gate-Collector capacitance C_{gc}
Collector current I_{collector}

[Parameters Display Area]
Temperature Ta=Temp
22.3 Cge: IGBT Cge-Vc characteristics (A.05.50)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Gate-Emitter capacitance (Cge), and plots Cge-Vc characteristics. For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
IGBT, 3 terminals

[Required Modules and Accessories]
Keysight B1520A MFCMU 1 unit
Keysight N1260A High Voltage Bias-T or Keysight N1259A Test Fixture with the option N1259A-020

[Device Parameters]
Polarity: Nch (SMU forces the specified value) or Pch (SMU forces the negative specified value).
Temp: Temperature
YAxisCgeMin: Y axis (Cge) minimum value
YAxisCgeMax: Y axis (Cge) maximum value

[Test Parameters]
Memo: Memorandum
IntegTime: Integration time
Frequency: Measurement frequency
OscLevel: Measurement signal level
Scale: Scale of DC bias sweep, LINEAR, LOG10, LOG25, or LOG50
Gate: CMU used for the capacitance measurement
VcBias: SMU used for the DC bias sweep source
VcStart: DC bias sweep start voltage
VcStop: DC bias sweep stop voltage
VcLinearStep: DC bias sweep step voltage, effective if Scale=LINEAR
IcLimit: Collector current compliance

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
IcMinRange: Minimum range for the collector current measurement

[Measurement Parameters]
Gate-Emitter capacitance Cge
Collector-Emitter current Ids

[User Function]
Ta: Temperature Ta=Temp

[X-Y Plot]
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For Scale=LINEAR:
X axis: Collector voltage Vcollector (LINEAR)
Y1 axis: Gate-Emitter capacitance Cge (LOG)

For Scale=LOG10, LOG25, or LOG50:
X axis: Collector voltage Vcollector (LOG)
Y1 axis: Gate-Emitter capacitance Cge (LOG)

[List Display]
Collector voltage Vcollector
Gate-Emitter capacitance Cge
Collector-Emitter current Ice

[Parameters Display Area]
Temperature Ta=Temp
22.4 Cge-Vge: IGBT Cge-Vg characteristics (A.05.50)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Gate-Emitter capacitance (Cge), and plots Cge-Vg characteristics.
For a more accurate measurement, perform correction data measurement at the measurement frequency before
starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced
Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU
Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M,
3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
IGBT, 3 terminals

[Device Parameters]
Polarity: Nch (SMU forces the specified value) or Pch (SMU forces the negative specified value).
Temp: Temperature
YAxisCgeMin: Y axis (Cge) minimum value
YAxisCgeMax: Y axis (Cge) maximum value

[Test Parameters]
Memo: Memorandum
IntegTime: Integration time
Frequency: Measurement frequency
OscLevel: Measurement signal level
Gate: CMU used for the capacitance measurement
VgStart: DC bias sweep start voltage
VgStop: DC bias sweep stop voltage
VgStep: DC bias sweep step voltage
Vg@Cge0: Gate voltage for Cge0

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Gate-Emitter capacitance Cge
Gate-Emitter conductance Gge

[User Function]
Ta: Temperature Ta=Temp

[Analysis Function]
Cge0=@MY (Y coordinate of Marker)

[Auto Analysis]
Marker: Vgate=Vg@Cge0
22 IGBT

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Gate-Emitter capacitance Cge (LINEAR)

[List Display]
Gate voltage Vgate
Gate-Emitter capacitance Cge
Gate-Emitter conductance Gge

[Parameter Display Area]
Gate-Emitter capacitance for zero bias Cge0
Temperature Ta=Temp


22.5 \( I_{c(\text{off})}-V_{ce} \): IGBT \( I_{c(\text{off})}-V_{ce} \) characteristics (A.04.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures and plots Collector current vs Collector-Emitter voltage in cutoff region and extracts Collector-Emitter cutoff current and breakdown voltage.

[Device Under Test]
IGBT, 3 terminals

[Device Parameters]
Polarity: Nch (SMU forces the specified value) or Pch (SMU forces the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
IntegTime: Integration time
Collector: SMU connected to Collector terminal, primary sweep voltage output
\( Vc@Ices \): Collector voltage to decide Collector-Emitter cutoff current \( Ices \)
\( Ic@BVces \): Collector current to decide Collector-Emitter breakdown voltage \( BVces \)
\( VcStart \): Sweep start voltage for Collector terminal
\( VcStop \): Sweep stop voltage for Collector terminal
\( VcStep \): Sweep step voltage for Collector terminal
Gate: SMU connected to Gate terminal, constant voltage output
\( Vg \): Gate voltage
Emitter: GNDU connected to Emitter terminal
\( IcLimit \): Collector current compliance

[Extended Test Parameters]
\( IgLimit \): Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
\( IcZero \): \( Y \) axis (\( I_{collector} \)) minimum value
\( IcMinRange \): Minimum range for the collector current measurement
\( IgMinRange \): Minimum range for the gate current measurement

[Measurement Parameters]
Collector current \( I_{collector} \)
Gate current \( I_{gate} \)

[User Function]
\( Ta \): Temperature \( Ta=Temp \)

[Analysis Function]
\( BVces=@MX \) (\( X \) coordinate of Marker)
\( Ices=@LIY \) (\( Y \) intercept of Line1)

[Auto Analysis]
Marker: \( I_{collector}=Ic@BVces \)
Line1: \( V_{collector}=Vc@Ices \)

[X-Y Plot]
X axis: Collector voltage Vcollector (LINEAR)
Y1 axis: Collector current Icollector (LINEAR)
Y2 axis: Collector current Icollector (LOG)

[List Display]
Collector voltage Vcollector
Collector current Icollector
Gate voltage Vgate
Gate current Igate

[Parameter Display Area]
Collector-Emitter breakdown voltage BVces
Collector-Emitter cutoff current Ices
Temperature Ta=Temp
22.6 Ic-Vce: IGBT Ic-Vce characteristics, SMU Pulse (A.05.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Ic-Vce characteristics. SMU pulse is used for the Collector-Emitter voltage output.

[Device Under Test]
IGBT, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
Collector: SMU connected to Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcLinearStep: Sweep step voltage for Collector terminal, effective if Scale=LINEAR
PulsePeriodMode: Pluse period mode, AUTO or MANUAL
ManualPulsePeriod: Pulse period, effective if PulsePeriodMode=MANUAL
PulseWidth: Pulse width
Gate: SMU connection to Gate terminal, secondary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Emitter: GNDU connected to Emitter terminal
Scale: Scale of sweep, LINEAR, LOG10, LOG25, or LOG50
IcLimit: Collector current compliance
PcLimit: Collector power compliance

[Extended Test Parameters]
PulseBase: Pulse base voltage
PulseAvgCnt: Pulse averaging count
IgLimit: Gate current compliance
VcLimit: Collector voltage compliance (applicable to UHCU/HVMCU/UHVU)
HoldTime: Hold time
IcZero: Y axis (Ic) minimum value
MeasurementTime: Actual measurement time for a pulse period

[Measurement Parameters]
Collector current Icollector
Gate current Igate

[User Function]
Ta: Temperature Ta=Temp

[X-Y Plot]
For Scale=LINEAR:
X axis: Collector voltage Vcollector (LINEAR)
Y axis: Collector current Icollector (LINEAR)
For Scale=LOG10, LOG25, or LOG50:
X axis: Collector voltage Vcollector (LOG)
Y axis: Collector current Icollector (LOG)

[List Display]
Collector voltage Vcollector
Collector current Icollector
Gate voltage Vgate
Gate current Igate

[Parameter Display Area]
Temperature Ta=Temp
22.7 Ic-Vge: IGBT Ic-Vge characteristics, SMU Pulse (A.04.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Ic-Vge characteristics. SMU pulse is used for the Collector-Emitter voltage output.

[Device Under Test]
IGBT, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature
YAxisgfeMin: Y axis (gfe) minimum value
YAxisgfeMax: Y axis (gfe) maximum value

[Test Parameters]
Memo: Memorandum
Gate: SMU connected to Gate terminal, primary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
PulsePeriodMode: Pulse period mode, AUTO or MANUAL
ManualPulsePeriod: Pulse period, effective if PulsePeriodMode=MANUAL
PulseWidth: Pulse width
Collector: SMU connected to Collector terminal, secondary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcPoint: Number of collector voltage sweep steps
Emitter: GNDU connected to Emitter terminal
IcLimit: Collector current compliance

[Extended Test Parameters]
PulseBase: Pulse base voltage
PulseAvgCnt: Pulse averaging count
IgLimit: Gate current compliance
HoldTime: Hold time
MeasurementTime: Actual measurement time for a pulse period

[Measurement Parameters]
Collector current Icollector
Gate current Igate

[User Function]
gfe: Forward transconductance gfe=diff(Icollector,Vgate)
Ta: Temperature Ta=Temp

[Analysis Function]
gfeMax=max(gfe)
Vth=@L1X (X intercept of Line1)

[Auto Analysis]
Line1: Tangent for Y2 data at the point of gfe=gfeMax
22 IGBT

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Forward transconductance gfe (LINEAR)
Y2 axis: Collector current Icollector (LINEAR)

[List Display]
Collector voltage Vcollector
Collector current Icollector
Gate voltage Vgate
Gate current Igate
Forward transconductance gfe

[Parameter Display]
Temperature Ta
Maximum value of forward transconductance gfeMax
Threshold voltage Vth
22.8 TDDB Constant V: Constant voltage TDDB (A.04.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Performs TDDB (Time Dependent Dielectric Breakdown) test and plots stress time vs leak current characteristics using I/V-t Sampling measurement.

[Device Under Test]
MOS capacitor etc., 2 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
IntegTime: Integration time
TotalStressTime: Total stress time, 10 s to 10000 s
FailureCondition: Stress current to decide the breakdown
PointPerDecade: Number of samples for one decade
Interval: Sampling interval
Port1: SMU connected to Port1 terminal
VStress: Stress voltage
Port2: SMU connected to Port2 terminal

[Extended Test Parameters]
ILimit: Current compliance
HoldTime: Hold time
MinRange: Minimum current measurement range
StoringRuntimeData: Data save during stress output, Yes or No
IStressZero: Minimum value of IStress for Y axis

[Measurement Parameters]
Stress current IStress

[User Function]
Ta: Temperature Ta=Temp
Qbdval: Charge per unit time Qbdval=integ(IStress,Time)
DN: Number of data DN=dim1Size(Index)

[X-Y Plot]
X axis: Stress time Time (LOG)
Y axis: Stress current IStress (LOG)

[List Display]
Stress time Time
Stress current IStress
Stress voltage ConstantV

[Parameter Display]
Temperature Ta
[Test Output: X-Y Graph]
X axis: Stress time TimeList (LOG)
Y axis: Stress current IStressList (LOG)

[Test Output: List Display]
Stress time TimeList
Stress current IStressList
Charge for device failure QbdList

[Parameter Display Area]
Device failure time Timebd
Device failure charge Qbd
Temperature Ta=Temp
22.9 $V_{ce(sat)}$: **IGBT $V_{ce(sat)}$ characteristics, SMU Pulse (A.04.00)**

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Collector-Emitter saturation voltage characteristics. SMU pulse is used for the Collector-Emitter current output.

[Device Under Test]
IGBT, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
Collector: SMU connected to Collector terminal, primary sweep current output
IcStart: Sweep start current for Collector terminal
IcStop: Sweep stop current for Collector terminal
IcLinearStep: Sweep step current for Collector terminal, effective if Scale=LINEAR
PulsePeriodMode: Pulse period mode, AUTO or MANUAL
ManualPulsePeriod: Pulse period, effective if PulsePeriodMode=MANUAL
PulseWidth: Pulse width
Gate: SMU connected to Gate terminal, secondary sweep voltage output
Vg: Gate voltage
Emitter: GNDU connected to Emitter terminal
VcLimit: Collector voltage compliance
Scale: Scale of sweep, LINEAR, LOG10, LOG25, or LOG50

[Extended Test Parameters]
PulseBase: Pulse base current
PulseAvgCnt: Pulse averaging count
IgLimit: Gate current compliance
HoldTime: Hold time
VcZero: Y axis ($V_{collector}$) minimum value
MeasurementTime: Actual measurement time for a pulse period

[Measurement Parameters]
Collector current $I_{collector}$
Collector voltage $V_{collector}$

[User Function]
Ta: Temperature $T_a$=Temp

[X-Y Plot]
For Scale=LINEAR:
X axis: Collector current $I_{collector}$ (LINEAR)
Y axis: Collector voltage $V_{collector}$ (LINEAR)

For Scale=LOG10, LOG25, or LOG50:
X axis: Collector current $I_{collector}$ (LOG)
Y axis: Collector voltage $V_{collector}$ (LOG)
[List Display]
Collector current $I_{collector}$
Collector voltage $V_{collector}$
Gate voltage $V_{gate}$
Gate current $I_{Gate}$

[Parameter Display Area]
Temperature $T_a=\text{Temp}$
22.10 \textit{Vth Vge\textcopyright{}}: IGBT \textit{Vth or Vge\textcopyright{}} measurement (A.04.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures \textit{Ic-Vge} characteristics and extracts threshold voltage or cutoff voltage.

[Device Under Test]
IGBT, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
Gate: SMU connected to Gate terminal, primary sweep voltage output
\textit{VgStart}: Sweep start voltage for Gate terminal
\textit{VgStop}: Sweep stop voltage for Gate terminal
\textit{VgStep}: Sweep step voltage for Gate terminal
Collector: SMU connected to Collector terminal
\textit{Vc}: Collector voltage
Emitter: GNDU connected to Emitter terminal
\textit{Ic@Vth\_Vge\textcopyright{}}: Collector current to decide \textit{Vth} or \textit{Vge\textcopyright{}}
\textit{MeasMode}: Measurement parameter, \textit{Vth} or \textit{Vge\textcopyright{}}
\textit{IntegTime}: Integration time
\textit{IcLimit}: Collector current compliance

[Extended Test Parameters]
\textit{IgLimit}: Gate current compliance
\textit{HoldTime}: Hold time
\textit{DelayTime}: Delay time
\textit{IcZero}: \textit{Y} axis (\textit{Icollector}) minimum value
\textit{IcMinRange}: Minimum range for the collector current measurement
\textit{IgMinRange}: Minimum range for the gate current measurement

[Measurement Parameters]
Collector current \textit{Icollector}
Gate current \textit{Igate}

[User Function]
\textit{Ta}: Temperature \textit{Ta}=\textit{Temp}

[Analysis Function]
In case of \textit{Vth} measurement,
\textit{Vth}=\textit{@MX} (X coordinate of Marker)

In case of \textit{Vge\textcopyright{}} measurement,
\textit{Vge\textcopyright{}}=\textit{@MX} (X coordinate of Marker)

[Auto Analysis]
Marker: \textit{Icollector}=\textit{Ic@Vth\_Vge\textcopyright{}}
22 IGBT

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Collector current Icollector (LINEAR)
Y2 axis: Collector current Icollector (LOG)

[List Display]
Collector voltage Vcollector
Collector current Icollector
Gate voltage Vgate
Gate current Igate

[Parameter Display Area]
Temperature Ta=Temp
For MeasMode=Vth:
Threshold voltage Vth
For MeasMode=Vgeoff:
Cutoff voltage Vgeoff
22.11 Ic-Vge for Expanders (A.05.01.2012.07.31)

[Supported Analyzer]
B1505A, B1506A

[Description]
Ic-Vge measurement by using UHCU, HVMCU and UHVU while the voltage drop at the output resistance of expanders is compensated to make Vce constant.

[Device Under Test]
IGBT, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Y1AxisIcMin: Y1 axis (Ic) minimum value
Y1AxisIcMax: Y1 axis (Ic) maximum value
Y2AxisGfsMin: Y2 axis (Gfs) minimum value
Y2AxisGfsMax: Y2 axis (Gfs) maximum value

[Test Parameters]
Memo: Memorandum
Gate: SMU connected to gate terminal, primary sweep voltage output
VgeStart: Sweep start voltage for gate pulse bias
VgeStop: Sweep stop voltage for gate pulse bias
VgeStep: Sweep step voltage for gate pulse bias
IgLimit: Upper limit of gate current
Vgewidth: Gate pulse width
VgeDelay: Gate pulse delay time

Collector: SMU connected to Collector terminal, Constant voltage output
Vce: Collector voltage
IcLimit: Upper limit of collector current
VceBase: Collector pulse base line voltage
VceWidth: Collector pulse width
VceDelay: Collector pulse delay time

Emitter: GNDU connected to Эmitter terminal

PulsePeriodMode: Pluse period mode, AUTO or MANUAL
ManualPulsePeriod: Pulse period, effective if PulsePeriodMode=MANUAL
MeasurementTime: Actural measurement time for a pulse period
PulseAvgCnt: Pulse averaging count

[Extended Test Parameters]
VceLimit: Upper limit of drain voltage during a search
VSrcchOffset: Offset voltage to start searching
VSrcchRange: Minimum search range of collector voltage
VSrcchPoint: Search step count
VSrcchLimit: Limit of output voltage during a search
Debug: Turn on/off debug mode
LoopMax: Maximum loop count for repetitive search
Step Mode: Sweep stop mode. SKIP AT ANY ABNORMAL, STOP AT ANY ABNORMAL or CONTINUE AT ANY

[Measurement Parameters]
Collector Current: IC
Gate Voltage: VGE
Collector Voltage: VCE

[User Function]
Gfs: Forward transconductance gfs

[Analysis Function]

[Auto Analysis]

[X-Y Plot]
X axis: Gate voltage VGE (LINEAR)
Y1 axis: Collector current IC (LINEAR)
Y2 axis: Forward transconductance Gfs (LINEAR)

[List Display]
Gate voltage: VGE
Collector current: IC
Forward transconductance: Gfs
Collector voltage: VCE
SearchStat: Status of search termination. 1: Search target is found. -1: Output voltage over its limit. -2: Measured voltage over its limit. -3: Measured current over its limit. -4: Oscillation or other abnormal status is detected. -5: Search loop count over its limit.

[Parameter Display Area]
22.12 Vce-Vge: IGBT Vce-Vge characteristics, SMU Pulse (A.05.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Vce-Vge characteristics. SMU pulse is used for the Collector current output.

[Device Under Test]
IGBT, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
Gate: SMU connected to Gate terminal, primary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
PulsePeriodMode: Pulse period mode, AUTO or MANUAL
ManualPulsePeriod: Pulse period, effective if PulsePeriodMode=MANUAL
PulseWidth: Pulse width
Collector: SMU connected to Collector terminal, secondary sweep current output
IcStart: Sweep start current for Collector terminal
IcStep: Sweep current step for Collector terminal
IcPoint: Number of collector current sweep steps
Emitter: GNDU connected to Emitter terminal
VcLimit: Collector voltage compliance
PcLimit: Collector power compliance

[Extended Test Parameters]
PulseBase: Pulse base current
PulseAvgCnt: Pulse averaging count
IgLimit: Gate current compliance
VcStop: Sweep stop Collector voltage (applicable to UHCU/HVMCU/UHVU)
HoldTime: Hold time
MeasurementTime: Actual measurement time for a pulse period
VceScale: Graph scale option for Vce
VceZero: Log scale minimum value for Vce

[Measurement Parameters]
Collector voltage Vce
Gate current Ig

[User Function]
Ta: Temperature Ta=Temp

[X-Y Plot]
X axis: Gate voltage Vge (LINEAR)
Y1 axis: Collector voltage Vce (LINEAR/LOG)

[List Display]
22 IGBT

Collector current Ic
Collector voltage Vce
Gate voltage Vge
Gate current Ig

[Parameter Display]
Temperature T_a
22.13 Cce (N1272A): Collector to emitter capacitance measurement (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Device Parameters]
CceMinYAxis: Minimum end point of Y axis for Cce (F)
CceMaxYAxis: Maximum end point of Y axis for Cce (F)

[Test Parameters]
Frequency: Measurement signal frequency (Hz)
VGE: Gate bias voltage (V)
VCEStart: VCE sweep start voltage (V)
VCEStop: VCE sweep stop voltage (V)
SweepOutput: Sweep output
LinearNOS: Number Of Step for LINEAR SweepOutput

[Extended Test Parameters]
Hold: Hold time for sweep start output (s)
Delay: Delay time before measurement in sweep step (s)
ACGuard: AC guard output (1: Common, 2: Floating)
OscLevel: Measurement signal level (V)
NPLC: Measurement time in Power Line Cycle
PhaseCompensation: Phase compensation mode (0: Auto, 2: Adaptive)
SweepDirection: Sweep direction
DischargingDelay: Time for discharging after DUT breakdown check (s)
InCaseOfBreakdown: Action taken in case of DUT breakdown detection (0: Skip, 1: Error)

[X-Y Plot]
X: Collector-Emitter voltage VCE (V)
Y1: Collector-Emitter capacitance Cce (F)

[List Display]
VCE: Collector-Emitter voltage (V)
Cce: Collector-Emitter capacitance (F)
G: Collector-Emitter conductance (S)
IC: Collector current (A)
VGE: Gate-Emitter voltage (V)
IG: Gate current (A)

[Parameters Display Area]
Frequency: Measurement signal frequency (Hz)
22.14 Cgc (N1272A): Gate to collector capacitance measurement (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Device Parameters]
CgcMinYAxis: Minimum end point of Y axis for Cgc (F)
CgcMaxYAxis: Maximum end point of Y axis for Cgc (F)

[Test Parameters]
Frequency: Measurement signal frequency (Hz)
VGE: Gate bias voltage (V)
VCEStart: VCE sweep start voltage (V)
VCEStop: VCE sweep stop voltage (V)
SweepOutput: Sweep output
LinearNOS: Number Of Step for LINEAR SweepOutput

[Extended Test Parameters]
Hold: Hold time for sweep start output (s)
Delay: Delay time before measurement in sweep step (s)
ACGuard: AC guard output (1: Common, 2: Floating)
OscLevel: Measurement signal level (V)
NPLC: Measurement time in Power Line Cycle
PhaseCompensation: Phase compensation mode (0: Auto, 2: Adaptive)
SweepDirection: Sweep direction
DischargingDelay: Time for discharging after DUT breakdown check (s)
InCaseOfBreakdown: Action taken in case of DUT breakdown detection (0: Skip, 1: Error)

[X-Y Plot]
X: Collector-Emitter voltage VCE (V)
Y1: Gate-Collector capacitance Cgc (F)

[List Display]
VCE: Collector-Emitter voltage (V)
Cgc: Gate-Collector capacitance (F)
G: Gate-Collector conductance (S)
IC: Collector current (A)
VGE: Gate-Emitter voltage (V)
IG: Gate current (A)

[Parameters Display Area]
Frequency: Measurement signal frequency (Hz)
22.15 Cge (N1272A): Gate to emitter capacitance measurement (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Device Parameters]
CgeMinYAxis: Minimum end point of Y axis for Cge (F)
CgeMaxYAxis: Maximum end point of Y axis for Cge (F)

[Test Parameters]
Frequency: Measurement signal frequency (Hz)
VGE: Gate bias voltage (V)
VCEStart: VCE sweep start voltage (V)
VCEStop: VCE sweep stop voltage (V)
SweepOutput: Sweep output
LinearNOS: Number Of Step for LINEAR SweepOutput

[Extended Test Parameters]
Hold: Hold time for sweep start output (s)
Delay: Delay time before measurement in sweep step (s)
ACGuard: AC guard output (1: Common, 2: Floating)
OscLevel: Measurement signal level (V)
NPLC: Measurement time in Power Line Cycle
PhaseCompensation: Phase compensation mode (0: Auto, 2: Adaptive)
SweepDirection: Sweep direction
DischargingDelay: Time for discharging after DUT breakdown check (s)
InCaseOfBreakdown: Action taken in case of DUT breakdown detection (0: Skip, 1: Error)

[X-Y Plot]
X: Collector-Emitter voltage VCE (V)
Y1: Gate-Emitter capacitance Cge (F)

[List Display]
VCE: Collector-Emitter voltage (V)
Cge: Gate-Emitter capacitance (F)
G: Gate-Emitter conductance (S)
IC: Collector current (A)
VGE: Gate-Emitter voltage (V)
IG: Gate current (A)

[Parameters Display Area]
Frequency: Measurement signal frequency (Hz)
### 22.16 Cies (N1272A): Input capacitance measurement (A.06.00)

- **[Supported Analyzer]**
  - B1505A, B1506A

- **[Device Parameters]**
  - CiesMinYAxis: Minimum end point of Y axis for Cies (F)
  - CiesMaxYAxis: Maximum end point of Y axis for Cies (F)

- **[Test Parameters]**
  - Frequency: Measurement signal frequency (Hz)
  - VGE: Gate bias voltage (V)
  - VCEStart: VCE sweep start voltage (V)
  - VCEStop: VCE sweep stop voltage (V)
  - SweepOutput: Sweep output
  - LinearNOS: Number Of Step for LINEAR SweepOutput

- **[Extended Test Parameters]**
  - Hold: Hold time for sweep start output (s)
  - Delay: Delay time before measurement in sweep step (s)
  - ACGuard: AC guard output (1: Common, 2: Floating)
  - OscLevel: Measurement signal level (V)
  - NPLC: Measurement time in Power Line Cycle
  - PhaseCompensation: Phase compensation mode (0: Auto, 2: Adaptive)
  - SweepDirection: Sweep direction
  - DischargingDelay: Time for discharging after DUT breakdown check (s)
  - InCaseOfBreakdown: Action taken in case of DUT breakdown detection (0: Skip, 1: Error)

- **[X-Y Plot]**
  - X: Collector-Emitter voltage VCE (V)
  - Y1: Input capacitance Cies (F)

- **[List Display]**
  - VCE: Collector-Emitter voltage (V)
  - Cies: Input capacitance (F)
  - G: Input conductance (S)
  - IC: Collector current (A)
  - VGE: Gate-Emitter voltage (V)
  - IG: Gate current (A)

- **[Parameters Display Area]**
  - Frequency: Measurement signal frequency (Hz)
22.17 Coes (N1272A): Output capacitance measurement (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Device Parameters]
CoesMinYAxis: Minimum end point of Y axis for Coes (F)
CoesMaxYAxis: Maximum end point of Y axis for Coes (F)

[Test Parameters]
Frequency: Measurement signal frequency (Hz)
VGE: Gate bias voltage (V)
VCEStart: VCE sweep start voltage (V)
VCEStop: VCE sweep stop voltage (V)
SweepOutput: Sweep output
LinearNOS: Number Of Step for LINEAR SweepOutput

[Extended Test Parameters]
Hold: Hold time for sweep start output (s)
Delay: Delay time before measurement in sweep step (s)
ACGuard: AC guard output (1: Common, 2: Floating)
OscLevel: Measurement signal level (V)
NPLC: Measurement time in Power Line Cycle
PhaseCompensation: Phase compensation mode (0: Auto, 2: Adaptive)
SweepDirection: Sweep direction
DischargingDelay: Time for discharging after DUT breakdown check (s)
InCaseOfBreakdown: Action taken in case of DUT breakdown detection (0: Skip, 1: Error)

[X-Y Plot]
X: Collector-Emitter voltage VCE (V)
Y1: Output capacitance Coes (F)

[List Display]
VCE: Collector-Emitter voltage (V)
Coes: Output capacitance (F)
G: Output conductance (S)
IC: Collector current (A)
VGE: Gate-Emitter voltage (V)
IG: Gate current (A)

[Parameters Display Area]
Frequency: Measurement signal frequency (Hz)
22.18 ICES (N1272A): Collector leakage current measurement (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Device Parameters]
ICESMinYAxis: Minimum end point of Y axis for ICES (A)
ICESMaxYAxis: Maximum end point of Y axis for ICES (A)
ICESYAxisScale: Scale of Y axis for ICES (0: Log, 1: Linear)

[Test Parameters]
IGLimit: Gate leak current limit (A)
VGE: Gate bias voltage (V)
ICLimit: Collector leak current limit (A)
VCEStart: VCE sweep start voltage (V)
VCEStop: VCE sweep stop voltage (V)
SweepOutput: Sweep output
LinearNOS: Number Of Step for LINEAR SweepOutput

[Extended Test Parameters]
IGMinRange: Minimum range for IG measurement
ICMinRange: Minimum range for IC measurement
NPLC: Measurement time in Power Line Cycle
Hold: Hold time for sweep start output (s)
Delay: Delay time before measurement in sweep step (s)
DCGuard: DC guard output (1: Common, 2: HVSMU)
InCaseOfAbnormalStatus: Action taken in case of abnormal measurement status

[X-Y Plot]
X: Collector-Emitter voltage VCE (V)
Y1: Collector current IC (A)

[List Display]
VCE: Collector-Emitter voltage (V)
IC: Collector current (A)
VGE: Gate-Emitter voltage (V)
IG: Gate current (A)
22.19 Cres (N1272A): Reverse transfer capacitance measurement (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Device Parameters]
CresMinYAxis: Minimum end point of Y axis for Cres (F)
CresMaxYAxis: Maximum end point of Y axis for Cres (F)

[Test Parameters]
Frequency: Measurement signal frequency (Hz)
VGE: Gate bias voltage (V)
VCEStart: VCE sweep start voltage (V)
VCEStop: VCE sweep stop voltage (V)
SweepOutput: Sweep output
LinearNOS: Number Of Step for LINEAR SweepOutput

[Extended Test Parameters]
Hold: Hold time for sweep start output (s)
Delay: Delay time before measurement in sweep step (s)
ACGuard: AC guard output (1: Common, 2: Floating)
OscLevel: Measurement signal level (V)
NPLC: Measurement time in Power Line Cycle
PhaseCompensation: Phase compensation mode (0: Auto, 2: Adaptive)
SweepDirection: Sweep direction
DischargingDelay: Time for discharging after DUT breakdown check (s)
InCaseOfBreakdown: Action taken in case of DUT breakdown detection (0: Skip, 1: Error)

[X-Y Plot]
X: Collector-Emitter voltage VCE (V)
Y1: Reverse transfer capacitance Cres (F)

[List Display]
VCE: Collector-Emitter voltage (V)
Cres: Reverse transfer capacitance (F)
G: Reverse transfer conductance (S)
IC: Collector current (A)
VGE: Gate-Emitter voltage (V)
IG: Gate current (A)

[Parameters Display Area]
Frequency: Measurement signal frequency (Hz)
### 22.20 IGES (N1272A): Gate leakage current measurement (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Device Parameters]
- IGESMinYAxis: Minimum end point of Y axis for IGES (A)
- IGESMaxYAxis: Maximum end point of Y axis for IGES (A)
- IGESYAxisScale: Scale of Y axis for IGES (0: Log, 1: Linear)

[Test Parameters]
- IGLimit: Gate leak current limit
- VGEStart: VGE sweep start voltage (V)
- VGEStop: VGE sweep stop voltage (V)
- SweepOutput: Sweep output
- LinearNOS: Number Of Step for LINEAR SweepOutput
- ICLimit: Collector leak current limit
- VCE: Collector bias voltage (V)

[Extended Test Parameters]
- IGMinRange: Minimum range for IG measurement
- ICMinRange: Minimum range for IC measurement
- NPLC: Measurement time in Power Line Cycle
- Hold: Hold time for sweep start output (s)
- Delay: Delay time before measurement in sweep step (s)
- DCGuard: DC guard output (1: Common, 2: HVSMU)
- InCaseOfAbnormalStatus: Action taken in case of abnormal measurement status

[X-Y Plot]
- X: Gate-Emitter voltage VGE (V)
- Y1: Gate current IG (A)

[List Display]
- VGE: Gate-Emitter voltage (V)
- IG: Gate current (A)
- VCE: Collector-Emitter voltage (V)
- IC: Collector current (A)
22.21 Cies-Vge (N1272A) (A.06.10)

[Supported Analyzer]
B1505A, B1506A

[Description]
Cies-Vge measurement

[Device Parameters]
CiesMinYAxis: Minimum end point of Y axis for Cies (F)
CiesMaxYAxis: Maximum end point of Y axis for Cies (F)

[Test Parameters]
Frequency: Measurement signal frequency (Hz)
VGEStart: VGE sweep start voltage (V)
VGESTop: VGE sweep stop voltage (V)
SweepOutput: Sweep output
LinearNOS: Number Of Step for LINEAR SweepOutput
VCE: Collector-Emitter voltage (V)

[Extended Test Parameters]
Model: 2-element model option
Hold: Hold time for sweep start output (s)
Delay: Delay time before measurement in sweep step (s)
ACGuard: AC guard output (1: Common, 2: Floating)
OscLevel: Measurement signal level (V)
NPLC: Measurement time in Power Line Cycle
PhaseCompensation: Phase compensation mode (0: Auto, 2: Adaptive)
SweepDirection: Sweep direction
DischargingDelay: Time for discharging after DUT breakdown check (s)
InCaseOfBreakdown: Action taken in case of DUT breakdown detection (0: Skip, 1: Error)

[X-Y Plot]
X: Gate-Emitter voltage VGE (V)
Y1: Input capacitance Cies (F)

[List Display]
VGE: Gate-Emitter voltage (V)
Cies: Input capacitance (F)
Gies: Input conductance (S) (in case of Cp-G model)
Rg: Gate resistance (ohm) (in case of Cs-Rs model)
VCE: Collector-Emitter voltage (V)
IC: Collector current (A)

[Parameters Display Area]
Frequency: Measurement signal frequency (Hz)
23 Interconnection
23 Interconnection

1. Residual R: R-I characteristics of interconnection residual resistance, SMU Pulse (A.04.00)
23.1 Residual R: R-I characteristics of interconnection residual resistance, SMU Pulse (A.04.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures the residual resistance vs current characteristics of Interconnection. SMU pulse is used for current output.

[Device Under Test]
Interconnection, 2 terminals

[Device Parameters]
YAxisResidualRMin: Y axis (ResidualR) minimum value
YAxisResidualRMax: Y axis (ResidualR) maximum value

[Test Parameters]
Memo: Memorandum
Port1: SMU connected to Port1 terminal, primary sweep current output
IStart: Sweep start current for Port1 terminal
IStop: Sweep stop current for Port1 terminal
ILinearStep: Sweep step current for Port1 terminal, effective if Scale=LINEAR
VLimit: Voltage compliance
PulsePeriodMode: Pulse period mode, AUTO or MANUAL
ManualPulsePeriod: Pulse period, effective if PulsePeriodMode=MANUAL
PulseWidth: Pulse width
Port2: GNDU connected to Port2 terminal
Scale: Scale of sweep, LINEAR, LOG10, LOG25, or LOG50

[Extended Test Parameters]
PulseBase: Pulse base current
PulseAvgCnt: Pulse averaging count
HoldTime: Hold time
MeasurementTime: Actual measurement time for a pulse period

[Measurement Parameters]
Measure voltage Vm

[User Function]
ResidualR: Residual resistance ResidualR=Vm/If
Ta: Temperature Ta=Temp

[X-Y Plot]
For Scale=LINEAR:
X axis: Force current If (LINEAR)
Y axis: Residual resistance ResidualR (LINEAR)

For Scale=LOG10, LOG25, or LOG50:
X axis: Force current If (LOG)
Y axis: Residual resistance ResidualR (LOG)

[List Display]
23 Interconnection

Force current If
Measure voltage Vm
Residual resistance ResidualR

[Parameter Display Area]
Temperature Ta=Temp
24 MISCAP

1. BV: MISCAP Gate-Body breakdown voltage measurement (A.04.00)
2. C(MISCAP): MISCAP C-V characteristics (A.04.00)
3. Ileak-V: MISCAP I-V characteristics (A.04.00)
4. TDDB Constant V: Constant voltage TDDB (A.04.00)
24.1 BV: MISCAP Gate-Body breakdown voltage measurement (A.04.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures MISCAP Gate current vs voltage characteristics and extracts the Gate-Body breakdown voltage.

[Device Under Test]
MISCAP, 2 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
IntegTime: Integration time
Gate: SMU connected to Gate terminal, primary sweep current output
IgStart: Sweep start current for Gate terminal
IgStop: Sweep stop current for Gate terminal
IgStep: Sweep step current for Gate terminal
Body: GNDU connected to Body terminal
Ileak@BV: Gate current to decide breakdown voltage BV
VgLimit: Gate voltage compliance

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
VgMinRange: Minimum range for gate voltage measurement

[Measurement Parameters]
Gate voltage Vgate

[User Function]
Ta: Temperature Ta=Temp

[Analysis Function]
BV=@MX (X coordinate of Marker)

[Auto Analysis]
Marker: Igate=Ileak@BV

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y axis: Gate current Igate (LINEAR)

[List Display]
Gate current Igate
Gate voltage Vgate

[Parameter Display Area]
Gate-Body breakdown voltage BV
Temperature Ta=Temp
24.2 C(MISCAP): MISCAP C-V characteristics (A.04.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures MISCAP Gate-Body capacitance, and plots the C-V characteristics. For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement. If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
MISCAP, 2 terminals
Connect Gate and Body to CMU Low and CMU High respectively.

[Device Parameters]
Polarity: Nch (CMU forces the specified value) or Pch (CMU forces the negative specified value).
Temp: Temperature
YAxisCMin: Y1 axis (C) minimum value
YAxisCMax: Y1 axis (C) maximum value
YAxisGMin: Y2 axis (G) minimum value
YAxisGMax: Y2 axis (G) maximum value

[Test Parameters]
Memo: Memorandum
IntegTime: Integration time
Frequency: Measurement frequency
OscLevel: Measurement signal level
Gate: CMU used for C-V measurement
VgStart: DC bias sweep start voltage
VgStop: DC bias sweep stop voltage
VgStep: DC bias sweep step voltage

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Gate-Body capacitance C
Gate-Body conductance G

[User Function]
Ta: Temperature Ta=Temp

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Gate-Body capacitance C (LINEAR)
Y2 axis: Gate-Body conductance G (LINEAR)
[List Display]
Gate voltage Vgate
Gate-Body capacitance C
Gate-Body conductance G

[Parameter Display Area]
Temperature Ta=Temp
24 MISCAP

24.3 Ileak-V: MISCAP I-V characteristics (A.04.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures MISCAP I-V characteristics and extracts Gate-Body breakdown voltage.

[Device Under Test]
MISCAP, 2 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
IntegTime: Integration time
Gate: SMU connected to Gate terminal, primary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Body: GNDU connected to Body terminal
Ileak@BV: Gate current to decide breakdown voltage BV
IgLimit: Gate current compliance

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
IgZero: Y axis (Ig) minimum value
IgMinRange: Minimum range for gate current measurement

[Measurement Parameters]
Gate current Igate

[User Function]
Ta: Temperature Ta=Temp

[Analysis Function]
BV=@MX (X coordinate of Marker)

[Auto Analysis]
Marker: Igate=Ileak@BV

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Gate current Igate (LINEAR)
Y2 axis: Gate current Igate (LOG)

[List Display]
Gate voltage Vgate
Gate current Igate

[Parameter Display Area]
Gate-Body breakdown voltage BV
Temperature Ta=Temp
24.4 TDDB Constant V: Constant voltage TDDB (A.04.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Performs TDDB (Time Dependent Dielectric Breakdown) test and plots stress time vs leak current characteristics using I/V-t Sampling measurement.

[Device Under Test]
MOS capacitor etc., 2 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
IntegTime: Integration time
TotalStressTime: Total stress time, 10 s to 10000 s
FailureCondition: Stress current to decide the breakdown
PointPerDecade: Number of samples for one decade
Interval: Sampling interval
Port1: SMU connected to Port1 terminal
VStress: Stress voltage
Port2: SMU connected to Port2 terminal

[Extended Test Parameters]
ILimit: Current compliance
HoldTime: Hold time
MinRange: Minimum current measurement range
StoringRuntimeData: Data save during stress output, Yes or No
IStressZero: Minimum value of IStress for Y axis

[Measurement Parameters]
Stress current IStress

[User Function]
Ta: Temperature Ta=Temp
Qbdval: Charge per unit time Qbdval=integ(IStress,Time)
DN: Number of data DN=dim1Size(Index)

[X-Y Plot]
X axis: Stress time Time (LOG)
Y axis: Stress current IStress (LOG)

[List Display]
Stress time Time
Stress current IStress
Stress voltage ConstantV

[Parameter Display]
Temperature Ta
MISCAP

[Test Output: X-Y Graph]
X axis: Stress time TimeList (LOG)
Y axis: Stress current IStressList (LOG)

[Test Output: List Display]
Stress time TimeList
Stress current IStressList
Charge for device failure QbdList

[Parameter Display Area]
Device failure time Timebd
Device failure charge Qbd
Temperature Ta=Temp
PowerBJT
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1. Ic-VCEO:  Ic-VCEO characteristics (A.05.00)
2. Ic-VCEO(PowerBJT):  Ic-VCEO characteristics, SMU Pulse (A.05.00)
3. Ic-VCEO:  Ic-VCEO characteristics (A.04.10)
4. Ic-VCEES:  Ic-VCEES characteristics (A.04.10)
5. Ic-VCEO:  Ic-VCEO characteristics (A.04.10)
6. VCEO(sat)-Ic:  VCEO(sat)-Ic characteristics (A.05.00)
7. G-Plot for Expanders:  G-Plot for Expanders (A.05.03)
8. Ic-Ib for Expanders:  Ic-Ib for Expanders (A.05.03)
25.1 Ic-Vcbo: Ic-Vcbo characteristics (A.05.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Collector current vs Collector-Base voltage characteristics and extracts Collector-Base breakdown voltage. (Open Emitter)

[Device Under Test]
Power BJT, 3 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
IntegTime: Integration time
Collector: SMU connected to Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcStep: Sweep step voltage for Collector terminal
Base: GNDU connected to Base terminal
Ic@BVcbo: Collector current to decide Collector-Base breakdown voltage BVcbo
IcLimit: Collector current compliance

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
IcZero: Y axis (Icollector) minimum value
IcMinRange: Minimum range for collector current measurement

[Measurement Parameters]
Collector current Icollector

[User Function]
Ta: Temperature Ta=Temp

[Analysis Function]
BVcbo=@MX (X coordinate of Marker)

[Auto Analysis]
Marker: Icollector=Ic@BVcbo
[X-Y Plot]
X axis: Collector voltage Vcollector (LINEAR)
Y1 axis: Collector current Icollector (LINEAR)
Y2 axis: Collector current Icollector (LOG)
[List Display]
Collector voltage Vcollector
Collector current Icollector
[Parameter Display Area]
Collector-Base breakdown voltage BVcbo
Temperature Ta=Temp
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25.2 Ic-Vce(PowerBJT): Ic-Vce characteristics, SMU Pulse (A.05.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Ic-Vce characteristics. SMU pulse is used for the Collector-Emitter voltage output.

[Device Under Test]
Power BJT, 3 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
Collector: SMU connected to Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcLinearStep: Sweep step voltage for Collector terminal
PulsePeriodMode: Pulse period mode, AUTO or MANUAL
ManualPulsePeriod: Pulse period, effective if PulsePeriodMode=MANUAL
VcPulseWidth: Pulse width of Collector voltage
IbPulseWidth: Pulse width of Base current
Base: SMU connection to Base terminal, secondary sweep current output
IbStart: Sweep start current for Base terminal
IbStop: Sweep stop current for Base terminal
VgStep: Sweep step current for Base terminal
Emitter: GNDU connected to Emitter terminal
IcLimit: Collector current compliance
PcLimit: Collector power compliance

[Extended Test Parameters]
VcPulseBase: Pulse base voltage for Collector terminal
IbPulseBase: Pulse base current for Base terminal
PulseAvgCnt: Pulse averaging count
VbLimit: Base voltage compliance
VcLimit: Collector voltage compliance (applicable for UHCU/HVMCU/UHVU)
HoldTime: Hold time
VcPulseDelayTime: Delay time of Collector voltage pulse
IbPulseDelayTime: Delay time of Base current pulse
MeasurementTime: Actual measurement time for a pulse period

[Measurement Parameters]
Collector voltage Vcollector
Collector current Icollector
Base voltage Vbase
Base current Ibase

[User Function]
Ta: Temperature Ta=Temp

[X-Y Plot]
X axis: Collector voltage V_{collector} (LINEAR)
Y axis: Collector current I_{collector} (LINEAR)

[List Display]
Collector voltage V_{collector}
Collector current I_{collector}
Base voltage V_{base}
Base current I_{base}

[Parameter Display Area]
Temperature T_a=Temp
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25.3 Ic-Vceo: Ic-Vceo characteristics (A.04.10)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Collector current vs Collector-Emitter voltage and extracts Collector-Emitter breakdown voltage. (Open Base)

[Device Under Test]
Power BJT, 3 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
IntegTime: Integration time
Collector: SMU connected to Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcStep: Sweep step voltage for Collector terminal
Emitter: GNDU connected to Emitter terminal
Ic@BVceo: Collector current to decide Collector-Emitter breakdown voltage BVceo
IcLimit: Collector current compliance

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
IcZero: Y axis (Icollector) minimum value
IcMinRange: Minimum range for collector current measurement

[Measurement Parameters]
Collector current Icollector

[User Function]
Ta: Temperature Ta=Temp

[Analysis Function]
BVceo=@MX (X coordinate of Marker)

[Auto Analysis]
Marker: Icollector=Ic@BVceo

[X-Y Plot]
X axis: Collector voltage Vcollector (LINEAR)
Y1 axis: Collector current Icollector (LINEAR)
Y2 axis: Collector current Icollector (LOG)

[List Display]
Collector voltage Vcollector
Collector current Icollector

[Parameter Display Area]
Collector-Emitter breakdown voltage BVceo
Temperature Ta=Temp
25.4 Ic-Vces: Ic-Vces characteristics (A.04.10)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Collector current vs Collector-Emitter voltage and extracts Collector-Emitter breakdown voltage. (Common Base)

[Device Under Test]
Power BJT, 3 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
IntegTime: Integration time
Collector: SMU connected to Collector terminal, primary sweep voltage output
VcStart: Sweep start voltage for Collector terminal
VcStop: Sweep stop voltage for Collector terminal
VcStep: Sweep step voltage for Collector terminal
Emitter: GNDU connected to Emitter terminal
Base: SMU connected to Base terminal, voltage output
Vb: Base voltage
Ic@BVces: Collector current to decide Collector-Emitter breakdown voltage BVces
IcLimit: Collector current compliance

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
IcZero: Y axis (Icollector) minimum value
IcMinRange: Minimum range for collector current measurement
IbMinRange: Minimum range for base current measurement

[Measurement Parameters]
Collector current Icollector
Base current Ibase

[User Function]
Ta: Temperature Ta=Temp

[Analysis Function]
BVces=@MX (X coordinate of Marker)

[Auto Analysis]
Marker: Icollector=Ic@BVces

[X-Y Plot]
X axis: Collector voltage Vcollector (LINEAR)
Y1 axis: Collector current Icollector (LINEAR)
Y2 axis: Collector current Icollector (LOG)
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[List Display]
Collector voltage Vc
Collector current Ic
Base voltage Vb
Base current Ib

[Parameter Display Area]
Collector-Emitter breakdown voltage BVce
Temperature Ta=Temp
25.5 *Ie-Vebo: Ie-Vebo characteristics (A.04.10)*

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Emitter current vs Emitter-Base voltage and extracts Emitter-Base breakdown voltage. (Open Collector)

[Device Under Test]
Power BJT, 3 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
IntegTime: Integration time
Emitter: SMU connected to Emitter terminal, primary sweep voltage output
VeStart: Sweep start voltage for Emitter terminal
VeStop: Sweep stop voltage for Emitter terminal
VeStep: Sweep step voltage for Emitter terminal
Base: GNDU connected to Base terminal
Ie@BVebo: Emitter current to decide Emitter-Base breakdown voltage BVebo
IeLimit: Emitter current compliance

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
IeZero: Y axis (Icollector) minimum value
IeMinRange: Minimum range for emitter current measurement

[Measurement Parameters]
Emitter current Iemitter

[User Function]
Ta: Temperature Ta=Temp

[Analysis Function]
BVebo=@MX (X coordinate of Marker)

[Auto Analysis]
Marker: Iemitter=Ie@BVebo

[X-Y Plot]
X axis: Emitter voltage Vemitter (LINEAR)
Y1 axis: Emitter current Iemitter (LINEAR)
Y2 axis: Emitter current Iemitter (LOG)

[List Display]
Emitter voltage Vemitter
Emitter current Iemitter

[Parameter Display Area]
Emitter-Base breakdown voltage BVebo
Temperature Ta=Temp
25.6 \textit{Vce(sat)}-\textit{Ic: Vce(sat)}-\textit{Ic characteristics (A.05.00)}

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Vce(sat)-Ic and Vbe(sat)-Ic characteristics. SMU pulse is used for Collector current output and Base current output.

[Device Under Test]
Power BJT, 3 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value). Temp: Temperature

[Test Parameters]
Memo: Memorandum
Scale: Scale of sweep, LINEAR, LOG10, LOG25, or LOG50
Collector: SMU connected to Collector terminal, primary sweep current output
Ic/IbRatio: Ratio between Collector current and Base current (Ibase=Icollector/Ic/IbRatio)
IcStart: Sweep start current for Collector terminal
IcStop: Sweep stop current for Collector terminal
IcLinearStep: Sweep step current for Collector terminal, effective if Scale=LINEAR
PulsePeriodMode: Pulse period mode, AUTO or MANUAL
ManualPulsePeriod: Pulse period, effective if PulsePeriodMode=MANUAL
IcPulseWidth: Pulse width of Collector current
IbPulseWidth: Pulse width of Base current
Base: SMU connection to Base terminal, synchronous sweep current output
Emitter: GNDU connected to Emitter terminal
VcLimit: Collector voltage compliance

[Extended Test Parameters]
IcPulseBase: Pulse base current for Collector terminal
IbPulseBase: Pulse base current for Base terminal
PulseAvgCnt: Pulse averaging count
HoldTime: Hold time
IcPulseDelayTime: Delay time of Collector current pulse
IbPulseDelayTime: Delay time of Base current pulse
VbLimit: Base voltage compliance
VcStop: Sweep stop Collector voltage (applicable to UHCU/HVMCU/UVHU)
VcZero: Y1 axis (Vcollector) minimum value
VbZero: Y2 axis (Vbase) minimum value
MeasurementTime: Actual measurement time for a pulse period

[Measurement Parameters]
Collector voltage Vcollector
Collector current Icollector
Base voltage Vbase
Base current Ib base

[User Function]
Ta: Temperature Ta=Temp
[X-Y Plot]
For Scale=LINEAR:
X axis: Collector current Icollector (LINEAR)
Y1 axis: Collector voltage Vcollector (LINEAR)
Y2 axis: Base voltage Vbase (LINEAR)

For Scale=LOG10, LOG25, or LOG50:
X axis: Collector current Icollector (LOG)
Y1 axis: Collector voltage Vcollector (LOG)
Y2 axis: Base voltage Vbase (LOG)

[List Display]
Collector voltage Vcollector
Collector current Icollector
Base voltage Vbase
Base current Ibase

[Parameter Display Area]
Temperature Ta=Temp
25.7 G-Plot for Expanders (A.05.03)

[Supported Analyzer]
B1505A, B1506A

[Description]
Gummel-Plot measurement by using UHCU, HVMCU and UHVU while the voltage drop at the output resistance of expanders is compensated to make Vce constant.

[Device Under Test]
Power BJT, 3 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Y1AxisIcMin: Y1 axis (Ic) minimum value
Y1AxisIcMax: Y1 axis (Ic) maximum value
Y2AxishFEMin: Y2 axis (hFE) minimum value
Y2AxishFEMax: Y2 axis (hFE) maximum value

[Test Parameters]
Memo: Memorandum
Base: SMU connected to Base terminal, primary sweep voltage output
VbeStart: Sweep start voltage for base pulse bias
VbeStop: Sweep stop voltage for base pulse bias
VbeStep: Sweep step voltage for gate pulse bias
IbLimit: Upper limit of gate current
VbeBase: Base pulse baseline voltage
Vbewidth: Base pulse width
VbeDElay: Base pulse delay time

Collector: SMU connected to drain terminal, constant voltage output
Vce: Collector voltage
IcLimit: Upper limit of drain current
VceBase: Collector pulse base line voltage
VceWidth: Collector pulse width
VceDelay: Collector pulse delay time

Emitter: GNDU connected to emitter terminal
PulsePeriodMode: Pluse period mode, AUTO or MANUAL
ManualPulsePeriod: Pulse period, effective if PulsePeriodMode=MANUAL
MeasurementTime: Actual measurement time for a pulse period
PulseAvgCnt: Pulse averaging count

[Extended Test Parameters]
VceLimit: Upper limit of collector voltage during a search
VSrchOffset: Offset voltage to start searching
VSrchRange: Minimum search range of collector voltage
VSrchPoint: Search step count
VSrchLimit: Limit of output voltage during a search
Debug: Turn on/off debug mode
LoopMax: Maximum loop count for repetitive search
Stop Mode: Sweep stop mode. SKIP AT ANY ABNORMAL, STOP AT ANY ABNORMAL or CONTINUE AT ANY

[Measurement Parameters]
Collector Current: IC
Base Voltage: VBE
Collector Voltage: VCE

[User Function]
hFE: DC current gain

[Auto Analysis]

[X-Y Plot]
X axis: Base voltage VBE (LINEAR)
Y1 axis: Collector current IC (LINEAR)
Y2 axis: DC current gain hFE (LINEAR)

[List Display]
Base voltage: VBE
Collector current: IC
DC current gain: hFE
Base current: IB
Collector voltage: VCE
SearchStat: Status of search termination. 1: Search target is found. -1: Output voltage over its limit. -2: Measured voltage over its limit. -3: Measured current over its limit. -4: Oscillation or other abnormal status is detected. -5: Search loop count over its limit.

[Parameter Display Area]
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25.8 Ic-Ib for Expanders (A.05.03)

[Supported Analyzer]
B1505A, B1506A

[Description]
Gummel-Plot measurement by using UHCU, HVMCU and UHVU while the voltage drop at the output resistance of expanders is compensated to make Vce constant.

[Device Under Test]
Power BJT, 3 terminals

[Device Parameters]
Polarity: NPN (SMUs force the specified value) or PNP (SMUs force the negative specified value).
Y1AxisIcMin: Y1 axis (Ic) minimum value
Y1AxisIcMax: Y1 axis (Ic) maximum value
Y2AxishFEMin: Y2 axis (hFE) minimum value
Y2AxishFEMax: Y2 axis (hFE) maximum value

[Test Parameters]
Memo: Memorandum
Base: SMU connected to Base terminal, primary sweep voltage output
IbStart: Sweep start current for base pulse bias
IbStop: Sweep stop current for base pulse bias
IbStep: Sweep step current for gate pulse bias
VbeLimit: Upper limit of gate voltage
IbBase: Base pulse baseline current
Ibwidth: Base pulse width
IbDelay: Base pulse delay time

Collector: SMU connected to drain terminal, constant voltage output
Vce: Collector voltage
IcLimit: Upper limit of drain current
VceBase: Collector pulse base line voltage
VceWidth: Collector pulse width
VceDelay: Collector pulse delay time

Emitter: GNDU connected to emitter terminal

PulsePeriodMode: Pluse period mode, AUTO or MANUAL
ManualPulsePeriod: Pulse period, effective if PulsePeriodMode=MANUAL
MeasurementTime: Actural measurement time for a pulse period
PulseAvgCnt: Pulse averaging count

[Extended Test Parameters]
VceLimit: Upper limit of collector voltage during a search
VSrchOffset: Offset voltage to start searching
VSrchRange: Minimum search range of collector voltage
VSrchPoint: Search step count
VSrchLimit: Limit of output voltage during a search
Debug: Turn on/off debug mode
LoopMax: Maximum loop count for repetitive search
Stop Mode: Sweep stop mode. SKIP AT ANY ABNORMAL, STOP AT ANY ABNORMAL or CONTINUE AT ANY

[Measurement Parameters]
Collector Current: IC
Base Voltage: VBE
Collector Voltage: VCE

[User Function]
hFE: DC current gain

[Auto Analysis]

[X-Y Plot]
X axis: Base current IB (LINEAR)
Y1 axis: Collector current IC (LINEAR)
Y2 axis: DC current gain hFE (LINEAR)

[List Display]
Base voltage: VBE
Collector current: IC
DC current gain: hFE
Base current: IB
Collector voltage: VCE
SearchStat: Status of search termination. 1: Search target is found. -1: Output voltage over its limit. -2: Measured voltage over its limit. -3: Measured current over its limit. -4: Oscillation or other abnormal status is detected. -5: Search loop count over its limit.

[Parameter Display Area]
1. Cj-Vr: Junction capacitance Cj-Vr characteristics (A.05.50)
2. If-Vf: Diode forward bias characteristics, SMU voltage pulse (A.05.00)
3. Ir-Vr: Diode reverse bias characteristics (A.05.00)
4. Vf: Diode forward bias characteristics, SMU current pulse (A.05.00)
5. CT (N1272A) Total Capacitance measurement (A.06.00)
6. IR (N1272A) Reverse current/leak current measurement (A.06.00)
26.1 Cj-Vr: Junction capacitance Cj-Vr characteristics (A.05.50)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures the junction capacitance by applying the reverse bias, and plots the Cj-Vr characteristics. For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
Junction device, diode, 2 terminals
Connect Cathode and Anode to the High Voltage Bias-T High and Low respectively.
Or, connect Cathode and Anode to the Test Fixture MFCMU High and MFCMU Low respectively.

[Required Modules and Accessories]
Keysight B1520A MFCMU 1 unit
Keysight N1260A High Voltage Bias-T or Keysight N1259A Test Fixture with the option N1259A-020

[Device Parameters]
Temp: Temperature
YAxisCjMin: Y1/Y2 axis (Cj) minimum value
YAxisCjMax: Y1/Y2 axis (Cj) maximum value

[Test Parameters]
Memo: Memorandum
IntegTime: Integration time
Frequency: Measurement frequency
OscLevel: Measurement signal level
Cathode: CMU used for the capacitance measurement
VrStart: Reverse bias sweep start voltage
VrStop: Reverse bias sweep stop voltage
VrLinearStep: Reverse bias sweep step voltage, effective if Scale=LINEAR
IrLimit: Reverse current compliance
Scale: Scale of the reverse bias sweep, LINEAR, LOG10, LOG25, or LOG50
VrBias: SMU used for the reverse DC bias sweep source

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
IrZero: Y3 axis (Ir) minimum value
IrMinRange: Minimum range for the reverse current measurement

[Measurement Parameters]
Junction capacitance Cj
Reverse current Ir
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[User Function]
Ta: Temperature Ta=Temp

[X-Y Plot]
For Scale=LINEAR:
X axis: Reverse bias Vr (LINEAR)
Y1 axis: Junction capacitance Cj (LINEAR)
Y2 axis: Junction capacitance Cj (LOG)
Y3 axis: Reverse current Ir (LOG)

For Scale=LOG10, LOG25, or LOG50:
X axis: Reverse bias Vr (LOG)
Y1 axis: Junction capacitance Cj (LINEAR)
Y2 axis: Junction capacitance Cj (LOG)
Y3 axis: Reverse current Ir (LOG)

[List Display]
Reverse bias Vr
Junction Capacitance Cj
Reverse current Ir

[Parameter Display Area]
Temperature Ta=Temp
26.2 If-Vf: Diode forward bias characteristics, SMU voltage pulse (A.05.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures the forward bias voltage vs current characteristics. SMU voltage pulse is used for the forward bias output.

[Device Under Test]
Junction device, diode, 2 terminals

[Device Parameters]
Temp: Temperature

[Test Parameters]
Memo: Memorandum
Anode: SMU connected to Anode terminal, primary sweep voltage output
VfStart: Sweep start voltage for Anode terminal
VfStop: Sweep stop voltage for Anode terminal
VfLinearStep: Sweep step voltage for Anode terminal, effective if Scale=LINEAR
Cathode: GNDU connected to Cathode terminal
PulsePeriodMode: Pluse period mode, AUTO or MANUAL
ManualPulsePeriod: Pulse period, effective if PulsePeriodMode=MANUAL
PulseWidth: Pulse width
IfLimit: Current compliance
Scale: Scale of sweep, LINEAR, LOG10, LOG25, or LOG50

[Extended Test Parameters]
PulseBase: Pulse base voltage
PulseAvgCnt: Pulse averaging count
HoldTime: Hold time
IfZero: Y axis (If) minimum value
MeasurementTime: Actual measurement time for a pulse period

[Measurement Parameters]
Forward current If

[User Function]
Ta: Temperature Ta=Temp

[X-Y Plot]
For Scale=LINEAR:
  X axis: Forward voltage Vf (LINEAR)
  Y1 axis: Forward current If (LINEAR)
  Y2 axis: Forward current If (LOG)
For Scale=LOG10, LOG25, or LOG50:
  X axis: Forward voltage Vf (LOG)
  Y1 axis: Forward current If (LINEAR)
  Y2 axis: Forward current If (LOG)
[List Display]
  Forward voltage Vf
  Forward current If
[Parameter Display Area]
  Temperature Ta=Temp
26.3 \textit{Ir-Vr: Diode reverse bias characteristics (A.05.00)}

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures the reverse bias voltage vs current characteristics.

[Device Under Test]
Junction device, diode, 2 terminals

[Device Parameters]
Temp: Temperature

[Test Parameters]
Memo: Memorandum
IntegTime: Integration time
Anode: GNDU connected to Anode terminal
VrStart: Sweep start voltage for Cathode terminal
VrStop: Sweep stop voltage for Cathode terminal
VrStep: Sweep step voltage for Cathode terminal
Cathode: SMU connected to Cathode terminal, primary sweep voltage output
IrLimit: Current compliance
VrSpec@Ir: Voltage to decide reverse current (Ir@VrSpec)

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
IrZero: Y axis (Ir) minimum value
IrMinRange: Minimum range for Ir measurement

[Measurement Parameters]
Reverse current Ir

[User Function]
Ta: Temperature Ta=Temp

[Analysis Function]
Ir@VrSpec=@MY (Y coordinate of Marker)

[Auto Analysis]
Marker: Vr=VrSpec@Ir

[X-Y Plot]
X axis: Reverse voltage Vr (LINEAR)
Y axis: Reverse current Ir (LINEAR)

[List Display]
Reverse voltage Vr
Reverse current Ir

[Parameter Display Area]
Reverse current Ir@VrSpec
Temperature Ta=Temp
26.4 Vf: Diode forward bias characteristics, SMU current pulse (A.05.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures the forward bias voltage vs current characteristics. SMU current pulse is used for the forward bias output.

[Device Under Test]
Diode

[Device Parameters]
Temp: Temperature

[Test Parameters]
Memo: Memorandum
Anode: SMU connected to Anode terminal, primary sweep current output
IfStart: Sweep start current for Anode terminal
IfStep: Sweep step current for Anode terminal
IfStop: Sweep stop current for Anode terminal
Cathode: GNDU connected to Cathode terminal
PulsePeriodMode: Pulse period mode, AUTO or MANUAL
ManualPulsePeriod: Pulse period, effective if PulsePeriodMode=MANUAL
PulseWidth: Pulse width
IfSpec@Vf: Current to decide forward voltage (Vf@IfSpec)
VfLimit: Voltage compliance

[Extended Test Parameters]
PulseBase: Pulse base current
PulseAvgCnt: Pulse averaging count
HoldTime: Hold time
MeasurementTime: Actual measurement time for a pulse period

[Measurement Parameters]
Forward voltage Vf

[User Function]
Ta: Temperature Ta=Temp

[Analysis Function]
Vf@IfSpec=@MX (X coordinate of Marker)

[Auto Analysis]
Marker: If=IfSpec@Vf

[X-Y Plot]
X axis: Forward voltage Vf (LINEAR)
Y axis: Forward current If (LINEAR)

[List Display]
Forward Current If
Forward Voltage Vf
26 PowerDiode

[Parameter Display Area]
Forward voltage Vf@IfSpec
Temperature Ta=Temp
26.5 CT (N1272A): Total Capacitance measurement (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures the total capacitance of diode.

[Device Under Test]
Diode

[Device Parameters]
CTMinYAxis: Minimum end point of Y axis for CT (F)
CTMaxYAxis: Maximum end point of Y axis for CT (F)

[Test Parameters]
Frequency: Measurement signal frequency (Hz)
VStart: V sweep start voltage (V)
VStop: V sweep stop voltage (V)
SweepOutput: Sweep output
LinearNOS: Number Of Step for LINEAR SweepOutput

[Extended Test Parameters]
Hold: Hold time for sweep start output (s)
Delay: Delay time before measurement in sweep step (s)
ACGuard: AC guard output (1: Common, 2: Floating)
OscLevel: Measurement signal level (V)
NPLC: Measurement time in Power Line Cycle
PhaseCompensation: Phase compensation mode (0: Auto, 2: Adaptive)
SweepDirection: Sweep direction
DischargingDelay: Time for discharging after DUT breakdown check (s)
InCaseOfBreakdown: Action taken in case of DUT breakdown detection (0: Skip, 1: Error)

[X-Y Plot]
X: Cathode-Anode voltage V (V)
Y1: Total Capacitance CT (F)

[List Display]
V: Cathode-Anode voltage (V)
CT Total Capacitance (F)
G: Conductance (S)
I: Reverse current (A)

[Parameters Display Area]
Frequency: Measurement signal frequency (Hz)
26.6 IR (N1272A): Reverse current/leak current measurement (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures the reverse current/leak current of diode.

[Device Under Test]
Diode

[Device Parameters]
IRMinYAxis: Minimum end point of Y axis for IR (A)
IRMaxYAxis: Maximum end point of Y axis for IR (A)
IRYAxisScale: Scale of Y axis for IR (0: Log, 1: Linear)

[Test Parameters]
IRLimit: Reverse current limit (A)
VRStart: VR sweep start voltage (V)
VRStop: VR sweep stop voltage (V)
SweepOutput: Sweep output
LinearNOS: Number Of Step for LINEAR SweepOutput

[Extended Test Parameters]
IRMinRange: Minimum range for IR measurement
NPLC: Measurement time in Power Line Cycle
Hold: Hold time for sweep start output (s)
Delay: Delay time before measurement in sweep step (s)
DCGuard: DC guard output (1: Common, 2: HVSMU)
InCaseOfAbnormalStatus: Action taken in case of abnormal measurement status

[X-Y Plot]
X: Reverse voltage VR (V)
Y1: Reverse current IR (A)

[List Display]
VR: Reverse voltage (V)
IR: Reverse current (A)
PowerMOSFET, PMIC, SiC
1. Cds: Power MOSFET Cds-Vd characteristics (A.05.50)
2. Cgd: Power MOSFET Cgd-Vd characteristics (A.05.50)
3. Cgs: Power MOSFET Cgs-Vd characteristics (A.05.50)
4. Cgs-Vgs: Power MOSFET Cgs-Vg characteristics (A.05.50)
5. Id(off)-Vds: Id(off)-Vds characteristics (A.05.00)
6. Id-Vds: Id-Vds characteristics, SMU Pulse (A.05.00)
7. Id-Vgs: Id-Vgs characteristics, SMU Pulse (A.05.00)
8. Rds-Id: Rds-Id characteristics, SMU Pulse (A.05.00)
9. TDDB Constant V: Constant voltage TDDB (A.04.10)
10. Vth Vgs(off): Vth or Vgs(off) measurement (A.05.00)
11. Id-Vgs for Expanders: Id-Vgs for Expanders (A.05.01)
12. Vds-Vgs: Vds-Vgs characteristics, Rds-Vgs characteristics, SMU Pulse (A.05.00)
13. Ciss (N1272A): Input capacitance measurement (A.06.00)
14. Coss (N1272A): Output capacitance measurement (A.06.00)
15. Crss (N1272A): Reverse transfer capacitance measurement (A.06.00)
16. Cds (N1272A): Drain to source capacitance measurement (A.06.00)
17. Cgd (N1272A): Gate to drain capacitance measurement (A.06.00)
18. Cgs (N1272A): Gate to source capacitance measurement (A.06.00)
19. Rg (N1272A) for PowerMOSFET: Gate resistance measurement (A.06.00)
20. IDSS (N1272A): Drain leakage current measurement (A.06.00)
21. IGSS (N1272A): Gate leakage current measurement (A.06.00)
22. Ciss-Vgs (N1272A): Ciss-Vgs measurement (A.06.10)
27.1 Cds: Power MOSFET Cds-Vd characteristics (A.05.50)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Drain-Source capacitance (Cds), and plots Cds-Vd characteristics.
For a more accurate measurement, perform correction data measurement at the measurement frequency before starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
Power MOSFET, 3 terminals
Connect Drain, Source, and Gate to the High Voltage Bias-T High, Low, and AC Guard respectively.
Or, connect Drain, Source, and Gate to the Test Fixture MFCMU High, MFCMU Low, and AUX circuit common respectively.

[Required Modules and Accessories]
Keysight B1520A MFCMU 1 unit
Keysight N1260A High Voltage Bias-T or Keysight N1259A Test Fixture with the option N1259A-020

[Device Parameters]
Polarity: Nch (SMU forces the specified value) or Pch (SMU forces the negative specified value).
Temp: Temperature
YAxisCdsMin: Y axis (Cds) minimum value
YAxisCdsMax: Y axis (Cds) maximum value

[Test Parameters]
Memo: Memorandum
IntegTime: Integration time
Frequency: Measurement frequency
OscLevel: Measurement signal level
Scale: Scale of DC bias sweep, LINEAR, LOG10, LOG25, or LOG50
Drain: CMU used for the capacitance measurement
VdBias: SMU used for the DC bias sweep source
VdStart: DC bias sweep start voltage
VdStop: DC bias sweep stop voltage
VdLinearStep: DC bias sweep step voltage, effective if Scale=LINEAR
IdLimit: Drain current compliance

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
IdMinRange: Minimum range for the drain current measurement

[Measurement Parameters]
Drain-Source capacitance Cds
Drain-Source current Ids
27 PowerMOSFET, PMIC, SiC

[User Function]
Ta: Temperature Ta=Temp

[X-Y Plot]
For Scale=LINEAR:
X axis: Drain voltage Vdrain (LINEAR)
Y1 axis: Drain-Source capacitance Cds (LOG)

For Scale=LOG10, LOG25, or LOG50:
X axis: Drain voltage Vdrain (LOG)
Y1 axis: Drain-Source capacitance Cds (LOG)

[List Display]
Drain voltage Vdrain
Drain-Source capacitance Cds
Drain-Source current Ids

[Parameters Display Area]
Temperature Ta=Temp
27.2 Cgd: Power MOSFET Cgd-Vd characteristics (A.05.50)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Gate-Drain capacitance (Cgd), and plots Cgd-Vd characteristics.
For a more accurate measurement, perform correction data measurement at the measurement frequency before
starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced
Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU
Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M,
3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
Power MOSFET, 3 terminals
Connect Drain, Gate, and Source to the High Voltage Bias-T High, Low, and AC Guard respectively.
Or, connect Drain, Gate, and Source to the Test Fixture MFCMU High, MFCMU Low, and AUX circuit
common respectively.

[Required Modules and Accessories]
Keysight B1520A MFCMU 1 unit
Keysight N1260A High Voltage Bias-T or Keysight N1259A Test Fixture with the option N1259A-020

[Device Parameters]
Polarity: Nch (SMU forces the specified value) or Pch (SMU forces the negative specified value).
Temp: Temperature
YAxisCgdMin: Y axis (Cgd) minimum value
YAxisCgdMax: Y axis (Cgd) maximum value

[Test Parameters]
Memo: Memorandum
IntegTime: Integration time
Frequency: Measurement frequency
OscLevel: Measurement signal level
Scale: Scale of DC bias sweep, LINEAR, LOG10, LOG25, or LOG50
Drain: CMU used for the capacitance measurement
VdBias: SMU used for the DC bias sweep source
VdStart: DC bias sweep start voltage
VdStop: DC bias sweep stop voltage
VdLinearStep: DC bias sweep step voltage, effective if Scale=LINEAR
IdLimit: Drain current compliance

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
IdMinRange: Minimum range for the drain current measurement

[Measurement Parameters]
Gate-Drain capacitance Cgd
Drain current Idrain

Keysight EasyEXPERT Application Library Reference 27-5
[User Function]
Ta: Temperature Ta=Temp

[X-Y Plot]
For Scale=LINEAR:
X axis: Drain voltage Vdrain (LINEAR)
Y1 axis: Gate-Drain capacitance Cgd (LOG)

For Scale=LOG10, LOG25, or LOG50:
X axis: Drain voltage Vdrain (LOG)
Y1 axis: Gate-Drain capacitance Cgd (LOG)

[List Display]
Drain voltage Vdrain
Gate-Drain capacitance Cgd
Drain current Idrain

[Parameters Display Area]
Temperature Ta=Temp
27.3 Cgs: Power MOSFET Cgs-Vd characteristics (A.05.50)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Gate-Source capacitance (Cgs), and plots Cgs-Vd characteristics.
For a more accurate measurement, perform correction data measurement at the measurement frequency before
starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced
Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU
Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M,
3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
Power MOSFET, 3 terminals

[Required Modules and Accessories]
Keysight B1520A MFCMU 1 unit
Keysight N1260A High Voltage Bias-T or Keysight N1259A Test Fixture with the option N1259A-020

[Device Parameters]
Polarity: Nch (SMU forces the specified value) or Pch (SMU forces the negative specified value).
Temp: Temperature
YAxisCgsMin: Y axis (Cgs) minimum value
YAxisCgsMax: Y axis (Cgs) maximum value

[Test Parameters]
Memo: Memorandum
IntegTime: Integration time
Frequency: Measurement frequency
OscLevel: Measurement signal level
Scale: Scale of DC bias sweep, LINEAR, LOG10, LOG25, or LOG50
Gate: CMU used for the capacitance measurement
VdBias: SMU used for the DC bias sweep source
VdStart: DC bias sweep start voltage
VdStop: DC bias sweep stop voltage
VdLinearStep: DC bias sweep step voltage, effective if Scale=LINEAR
IdLimit: Drain current compliance

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
IdMinRange: Minimum range for the drain current measurement

[Measurement Parameters]
Gate-Source capacitance Cgs
Drain-Source currentIds

[User Function]
Ta: Temperature Ta=Temp

Keysight EasyEXPERT Application Library Reference 27-7
[X-Y Plot]
For Scale=LINEAR:
X axis: Drain voltage $V_{\text{drain}}$ (LINEAR)
Y1 axis: Gate-Source capacitance $C_{\text{gs}}$ (LOG)

For Scale=LOG10, LOG25, or LOG50:
X axis: Drain voltage $V_{\text{drain}}$ (LOG)
Y1 axis: Gate-Source capacitance $C_{\text{gs}}$ (LOG)

[List Display]
Drain voltage $V_{\text{drain}}$
Gate-Source capacitance $C_{\text{gs}}$
Drain-Source current $I_{\text{ds}}$

[Parameters Display Area]
Temperature $T_a=\text{Temp}$
27.4 Cgs-Vgs: Power MOSFET Cgs-Vg characteristics (A.05.50)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Gate-Source capacitance (Cgs), and plots Cgs-Vg characteristics.
For a more accurate measurement, perform correction data measurement at the measurement frequency before
starting the capacitance measurement.
If the measurement frequency is not included in the list of default frequencies below, click the Advanced
Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU
Calibration window.

Default frequencies:
1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M,
3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

[Device Under Test]
Power MOSFET, 3 terminals

[Device Parameters]
Polarity: Nch (CMU forces the specified value) or Pch (CMU forces the negative specified value).
Temp: Temperature
YAxisCgsMin: Y axis (Cgs) minimum value
YAxisCgsMax: Y axis (Cgs) maximum value

[Test Parameters]
Memo: Memorandum
IntegTime: Integration time
Frequency: Measurement frequency
OscLevel: Measurement signal level
Gate: CMU used for the capacitance measurement
VgStart: DC bias sweep start voltage
VgStop: DC bias sweep stop voltage
VgStep: DC bias sweep step voltage
Vg@Cgs0: Gate voltage for Cgs0

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time

[Measurement Parameters]
Gate-Source capacitance Cgs
Gate-Source conductance Ggs

[User Function]
Ta: Temperature Ta=Temp

[Analysis Function]
Cgs0=@MY (Y coordinate of Marker)

[Auto Analysis]
Marker: Vgate=Vg@Cgs0
27 PowerMOSFET, PMIC, SiC

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Gate-Source capacitance Cgs (LINEAR)

[List Display]
Gate voltage Vgate
Gate-Source capacitance Cgs
Gate-Source conductance Ggs

[Parameter Display Area]
Gate-Source capacitance at zero bias Cgs0
Temperature Ta=Temp
27.5 \( \text{Id}(\text{off})-\text{Vds}: \text{Id}(\text{off})-\text{Vds} \) characteristics (A.05.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures and plots Drain current vs Drain voltage characteristics in the cutoff region, and extracts the breakdown voltage and the cutoff current.

[Device Under Test]
Power MOSFET, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
IntegTime: Integration time
Drain: SMU connected to Drain terminal, primary sweep voltage output
\( \text{Vd}@\text{Idss} \): Drain voltage to decide the cutoff current \( \text{Ids} \)
\( \text{Id}@\text{BVdss} \): Drain current to decide the breakdown voltage \( \text{BVdss} \)
\( \text{VdStart} \): Sweep start voltage for Drain terminal
\( \text{VdStop} \): Sweep stop voltage for Drain terminal
\( \text{VdStep} \): Sweep step voltage for Drain terminal
Gate: SMU connected to Gate terminal, constant voltage output
\( \text{Vg} \): Gate voltage
Source: GNDU connected to Source terminal
\( \text{IdLimit} \): Drain current compliance

[Extended Test Parameters]
\( \text{IgLimit} \): Gate current compliance
\( \text{HoldTime} \): Hold time
\( \text{DelayTime} \): Delay time
\( \text{IdZero} \): Y axis (Idrain) minimum value
\( \text{IdMinRange} \): Minimum range for the drain current measurement
\( \text{IgMinRange} \): Minimum range for the gate current measurement

[Measurement Parameters]
Drain current \( \text{Idrain} \)
Gate current \( \text{Igate} \)

[User Function]
\( \text{Ta} \): Temperature \( \text{Ta} = \text{Temp} \)

[Analysis Function]
\( \text{BVdss}@\text{MX} \) (X coordinate of Marker)
\( \text{Idss}@\text{L1Y} \) (Y intercept of Line1)

[Auto Analysis]
Marker: \( \text{Idrain} = \text{Id}@\text{BVdss} \)
Line1: \( \text{Vdrain} = \text{Vd}@\text{Idss} \)

[X-Y Plot]
27 PowerMOSFET, PMIC, SiC

X axis: Drain voltage Vdrain (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)

[List Display]
Drain voltage Vdrain
Drain current Idrain
Gate voltage Vgate
Gate current Igate

[Parameter Display Area]
Drain-Source breakdown voltage BVdss
Drain-Source cutoff current Idss
Temperature Ta=Temp
27.6 *Id-Vds: Id-Vds characteristics, SMU Pulse (A.05.00)*

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Drain current vs Drain voltage characteristics. SMU pulse is used for the Drain-Source voltage output.

[Device Under Test]
Power MOSFET, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
Drain: SMU connected to Drain terminal, primary sweep voltage output
VdStart: Sweep start voltage for Drain terminal
VdStop: Sweep stop voltage for Drain terminal
VdLinearStep: Sweep step voltage for Drain terminal, effective if Scale=LINEAR
PulsePeriodMode: Pulse period mode, AUTO or MANUAL
ManualPulsePeriod: Pulse period, effective if PulsePeriodMode=MANUAL
PulseWidth: Pulse width
Gate: SMU connection to Gate terminal, secondary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Source: GNDU connected to Source terminal
Scale: Scale of sweep, LINEAR, LOG10, LOG25, or LOG50
IdLimit: Drain current compliance
PdLimit: Drain power compliance

[Extended Test Parameters]
PulseBase: Pulse base voltage
PulseAvgCnt: Pulse averaging count
IgLimit: Gate current compliance
VdLimit: Drain voltage compliance (applicable to UHCU/HVMCU/UHVU)
HoldTime: Hold time
IdZero: Y axis (Id) minimum value
MeasurementTime: Actual measurement time for a pulse period

[Measurement Parameters]
Drain current Idrain
Gate current Igate

[User Function]
Ta: Temperature Ta=Temp

[X-Y Plot]
For Scale=LINEAR:
X axis: Drain voltage Vdrain (LINEAR)
Y axis: Drain current Idrain (LINEAR)
27 PowerMOSFET, PMIC, SiC

For Scale=LOG10, LOG25, or LOG50:
X axis: Drain voltage Vdrain (LOG)
Y axis: Drain current Idrain (LOG)

[List Display]
Drain voltage Vdrain
Drain current Idrain
Gate voltage Vgate
Gate current Igate

[Parameter Display Area]
Temperature Ta=Temp
27.7 *Id-Vgs: Id-Vgs characteristics, SMU Pulse (A.05.00)*

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Drain current vs Gate voltage characteristics. SMU pulse is used for the Drain-Source voltage output.

[Device Under Test]
Power MOSFET, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature
YAxisgfsMin: Y axis (gfs) minimum value
YAxisgfsMax: Y axis (gfs) maximum value

[Test Parameters]
Memo: Memorandum
Gate: SMU connected to Gate terminal, primary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
PulsePeriodMode: Pluse period mode, AUTO or MANUAL
ManualPulsePeriod: Pulse period, effective if PulsePeriodMode=MANUAL
PulseWidth: Pulse width
Drain: SMU connected to Drain terminal, secondary sweep voltage output
VdStart: Sweep start voltage for Drain terminal
VdStop: Sweep stop voltage for Drain terminal
VdPoint: Number of drain voltage sweep steps
Source: GNDU connected to Source terminal
IdLimit: Drain current compliance

[Extended Test Parameters]
PulseBase: Pulse base voltage
PulseAvgCnt: Pulse averaging count
IgLimit: Gate current compliance
HoldTime: Hold time
MeasurementTime: Actural measurement time for a pulse period

[Measurement Parameters]
Drain current Idrain
Gate current Igate

[User Function]
gfs: Forward transconductance gfs=diff(Idrain,Vgate)
Ta: Temperature Ta=Temp

[Analysis Function]
gfsMax=max(gfs)
Vth=@L1X (X intercept of Line1)

[Auto Analysis]
Line1: Tangent for Y2 data at the point of gfs=gfsMax
27 PowerMOSFET, PMIC, SiC

[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Forward transconductance gfs (LINEAR)
Y2 axis: Drain current Idrain (LINEAR)

[List Display]
Drain voltage Vdrain
Drain current Idrain
Gate voltage Vgate
Gate current Igate
Forward transconductance gfs

[Parameter Display Area]
Temperature Ta=Temp
Maximum value of forward transconductance gfsMax
Threshold voltage Vth
27.8 Rds-Id: Rds-Id characteristics, SMU Pulse (A.05.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Drain-Source resistance vs Drain current characteristics. SMU pulse is used for the Drain current output.

[Device Under Test]
Power MOSFET, 3 terminals

[Device Parameters]
Temp: Temperature
YAxisRdsMin: Y axis (Rds) minimum value
YAxisRdsMax: Y axis (Rds) maximum value

[Test Parameters]
Memo: Memorandum
Drain: SMU connected to Drain terminal, primary sweep current output
IdStart: Sweep start current for Drain terminal
IdStop: Sweep stop current for Drain terminal
IdLinearStep: Linear sweep step current for Drain terminal, effective if Scale=LINEAR
PulsePeriodMode: Pluse period mode, AUTO or MANUAL
ManualPulsePeriod: Pulse period, effective if PulsePeriodMode=MANUAL
PulseWidth: Pulse width
Gate: SMU connection to Gate terminal, secondary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Source: GNDU connected to Source terminal
Scale: Scale of sweep, LINEAR, LOG10, LOG25, or LOG50
VdLimit: Drain voltage compliance

[Extended Test Parameters]
PulseBase: Pulse base current
PulseAvgCnt: Pulse averaging count
IgLimit: Gate current compliance
VdStop: Sweep stop Drain voltage (applicable to UHCU/HVMCU/UHVU)
HoldTime: Hold time
MeasurementTime: Actural measurement time for a pulse period

[Measurement Parameters]
Drain voltage Vdrain
Gate current Igate
Drain-Source resistance Rds

[User Function]
Ta: Temperature Ta=Temp
Rds: Drain-Source resistance Rds=Vdrain/Idrain

[X-Y Plot]
For Scale=LINEAR:
X axis: Drain current Idrain (LINEAR)
Y axis: Drain-Source resistance $R_{ds}$ (LINEAR)

For Scale=LOG10, LOG25, or LOG50:
X axis: Drain current $I_{drain}$ (LOG)
Y axis: Drain-Source resistance $R_{ds}$ (LOG)

[List Display]
Drain voltage $V_{drain}$
Drain current $I_{drain}$
Gate voltage $V_{gate}$
Gate current $I_{Gate}$
Drain-Source resistance $R_{ds}$

[Parameter Display Area]
Temperature $Ta=\text{Temp}$
27.9 TDDB Constant V: Constant voltage TDDB (A.04.10)

[Supported Analyzer]
B1505A, B1506A

[Description]
Performs TDDB (Time Dependent Dielectric Breakdown) test and plots stress time vs leak current characteristics using I/V-t Sampling measurement.

[Device Under Test]
MOS capacitor etc., 2 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
IntegTime: Integration time
TotalStressTime: Total stress time, 10 s to 10000 s
FailureCondition: Stress current to decide the breakdown
PointPerDecade: Number of samples for one decade
Interval: Sampling interval
Port1: SMU connected to Port1 terminal
VStress: Stress voltage
Port2: SMU connected to Port2 terminal

[Extended Test Parameters]
ILimit: Current compliance
HoldTime: Hold time
MinRange: Minimum current measurement range
StoringRuntimeData: Data save during stress output, Yes or No
IStressZero: Minimum value of IStress for Y axis

[Measurement Parameters]
Stress current IStress

[User Function]
Ta: Temperature Ta=Temp
Qbdval: Charge per unit time Qbdval=integ(IStress,Time)
DN: Number of data DN=dim1Size(Index)

[X-Y Plot]
X axis: Stress time Time (LOG)
Y axis: Stress current IStress (LOG)

[List Display]
Stress time Time
Stress current IStress
Stress voltage ConstantV

[Parameter Display]
Temperature Ta
[Test Output: X-Y Graph]
X axis: Stress time TimeList (LOG)
Y axis: Stress current IStressList (LOG)

[Test Output: List Display]
Stress time TimeList
Stress current IStressList
Charge for device failure QbdList

[Parameter Display Area]
Device failure time Timebd
Device failure charge Qbd
Temperature Ta=Temp
27.10 $V_{th} \, V_{gs(off)}$: $V_{th}$ or $V_{gs(off)}$ measurement (A.05.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Drain current vs Gate-Source voltage characteristics and extracts the threshold voltage or the cutoff voltage.

[Device Under Test]
Power MOSFET, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
Gate: SMU connected to Gate terminal, primary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
Drain: SMU connected to Drain terminal
Vd: Drain voltage
Source: GNDU connected to Source terminal
Id@Vth_Vgsoff: Drain current to decide $V_{th}$ or $V_{gs(off)}$
MeasMode: Measurement parameter, $V_{th}$ or $V_{gs(off)}$
IntegTime: Integration time
IdLimit: Drain current compliance

[Extended Test Parameters]
IgLimit: Gate current compliance
HoldTime: Hold time
DelayTime: Delay time
IdZero: Y axis (Idrain) minimum value
IdMinRange: Minimum range for the drain current measurement
IgMinRange: Minimum range for the gate current measurement

[Measurement Parameters]
Drain current Idrain
Gate current Igate

[User Function]
Ta: Temperature $Ta=Temp$

[Analysis Function]
For MeasMode=$V_{th}$:
$V_{th}=@MX$ (X coordinate of Marker)

For MeasMode=$V_{gs(off)}$:
$V_{gs(off)}=@MX$ (X coordinate of Marker)

[Auto Analysis]
Marker: Idrain=Id@Vth_Vgsoff
[X-Y Plot]
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Drain current Idrain (LINEAR)
Y2 axis: Drain current Idrain (LOG)

[List Display]
Drain voltage Vdrain
Drain current Idrain
Gate voltage Vgate
Gate current Igate

[Parameter Display Area]
Temperature Ta=Temp
For MeasMode=Vth:
Threshold voltage Vth
For MeasMode=Vgsoff:
Cutoff voltage Vgsoff
27.11 Id-Vgs for Expanders (A.05.01)

[Supported Analyzer]
B1505A, B1506A

[Description]
Id-Vgs measurement by using UHCU, HVMCU and UHVU while the voltage drop at the output resistance of expanders is compensated to make Vds constant.

[Device Under Test]
Power MOSFET, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Y1AxisIdMin: Y1 axis (Id) minimum value
Y1AxisIdMax: Y1 axis (Id) maximum value
Y2AxisGfsMin: Y2 axis (Gfs) minimum value
Y2AxisGfsMax: Y2 axis (Gfs) maximum value

[Test Parameters]
Memo: Memorandum
Gate: SMU connected to gate terminal, primary sweep voltage output
VgsStart: Sweep start voltage for gate pulse bias
VgsStop: Sweep stop voltage for gate pulse bias
VgsStep: Sweep step voltage for gate pulse bias
IgLimit: Upper limit of gate current
VgsBase: Gate pulse baseline voltage
VgsWidth: Gate pulse width
VgsDelay: Gate pulse delay time

Drain: SMU connected to drain terminal, constant voltage output
Vds: Drain voltage
IdLimit: Upper limit of drain current
VdsBase: Drain pulse base line voltage
VdsWidth: Drain pulse width
VdsDelay: Drain pulse delay time

Source: GNDU connected to source terminal

PulsePeriodMode: Pluse period mode, AUTO or MANUAL
ManualPulsePeriod: Pulse period, effective if PulsePeriodMode=MANUAL
MeasurementTime: Actual measurement time for a pulse period
PulseAvgCnt: Pulse averaging count

[Extended Test Parameters]
VdsLimit: Upper limit of drain voltage during a search
VSrchOffset: Offset voltage to start searching
VSrchRange: Minimum search range of collector voltage
VSrchPoint: Search step count
VSrchLimit: Limit of output voltage during a search
Debug: Turn on/off debug mode
LoopMax: Maximum loop count for repetitive search
27 PowerMOSFET, PMIC, SiC

Stop Mode: Sweep stop mode. SKIP AT ANY ABNORMAL, STOP AT ANY ABNORMAL or CONTINUE AT ANY

[Measurement Parameters]
Drain Current: ID
Gate Voltage: VGS
Drain Voltage: VDS

[User Function]
Gfs: Forward transconductance gfs

[Analysis Function]

[Auto Analysis]

[X-Y Plot]
X axis: Gate voltage VGS (LINEAR)
Y1 axis: Drain current ID (LINEAR)
Y2 axis: Forward transconductance Gfs (LINEAR)

[List Display]
Gate voltage: VGS
Drain current: ID
Forward transconductance: Gfs
Drain voltage: VDS
SearchStat: Status of search termination. 1: Search target is found. -1: Outout voltage over its limit. -2: Measured voltage over its limit. -3: Measured current over its limit. -4: Oscillation or other abnormal status is detected. -5: Search loop count over its limit.

[Parameter Display Area]
27.12 **Vds-Vgs: Vds-Vgs characteristics, Rds-Vgs characteristics, SMU Pulse (A.05.00)**

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Vds-Vgs characteristics. SMU pulse is used for the Drain current output.

[Device Under Test]
Power MOSFET, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value). Temp: Temperature

[Test Parameters]
Memo: Memorandum
Gate: SMU connected to Gate terminal, primary sweep voltage output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
PulsePeriodMode: Pulse period mode, AUTO or MANUAL
ManualPulsePeriod: Pulse period, effective if PulsePeriodMode=MANUAL
PulseWidth: Pulse width
Drain: SMU connected to Drain terminal, secondary sweep current output
IdStart: Sweep start current for Drain terminal
IdStep: Sweep current step for Drain terminal
IdPoint: Number of Drain current sweep steps
Source: GNDU connected to Source terminal
VdLimit: Drain voltage compliance
PdLimit: Drain power compliance

[Extended Test Parameters]
PulseBase: Pulse base current
PulseAvgCnt: Pulse averaging count
IgLimit: Gate current compliance
VdStop: Sweep stop Drain voltage (applicable to UHCU/HVMCU/UHVU)
HoldTime: Hold time
MeasurementTime: Actual measurement time for a pulse period
VdsScale: Graph scale option for Vds
VdsZero: Log scale minimum value for Vds
RdsScale: Graph scale option for Rds
RdsZero: Log scale minimum value for Rds
RdsMax: Scale maximum value for Rds

[Measurement Parameters]
Drain voltage Vds
Gate current Ig
Drain-Source resistance Rds

[User Function]
Ta: Temperature Ta=Temp
Rds: Drain-Source resistance $R_{ds} = V_{ds}/I_d$

[X-Y Plot]
X axis: Gate voltage $V_{gs}$ (LINEAR)
Y1 axis: Drain voltage $V_{ds}$ (LINEAR/LOG)
Y2 axis: Drain-Source resistance $R_{ds}$ (LINEAR/LOG)

[List Display]
Drain current $I_d$
Drain voltage $V_{ds}$
Drain-Source resistance $R_{ds}$
Gate voltage $V_{gs}$
Gate current $I_g$

[Parameter Display]
Temperature $T_a$
27.13 Ciss (N1272A): Input capacitance measurement (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures the input capacitance of power MOSFET.

[Device Under Test]
Power MOSFET, 3 terminals

[Device Parameters]
CissMinYAxis: Minimum end point of Y axis for Ciss (F)
CissMaxYAxis: Maximum end point of Y axis for Ciss (F)

[Test Parameters]
Frequency: Measurement signal frequency (Hz)
VGS: Gate bias voltage (V)
VDSStart: VDS sweep start voltage (V)
VDSStop: VDS sweep stop voltage (V)
SweepOutput: Sweep output
LinearNOS: Number Of Step for LINEAR SweepOutput

[Extended Test Parameters]
Hold: Hold time for sweep start output (s)
Delay: Delay time before measurement in sweep step (s)
ACGuard: AC guard output (1: Common, 2: Floating)
OscLevel: Measurement signal level (V)
NPLC: Measurement time in Power Line Cycle
PhaseCompensation: Phase compensation mode (0: Auto, 2: Adaptive)
SweepDirection: Sweep direction
DischargingDelay: Time for discharging after DUT breakdown check (s)
InCaseOfBreakdown: Action taken in case of DUT breakdown detection (0: Skip, 1: Error)

[X-Y Plot]
X: Drain-Source voltage VDS (V)
Y1: Input capacitance Ciss (F)

[List Display]
VDS: Drain-Source voltage (V)
Ciss: Input capacitance (F)
G: Input conductance (S)
ID: Drain current (A)
VGS: Gate-Source voltage (V)
IG: Gate current (A)

[Parameters Display Area]
Frequency: Measurement signal frequency (Hz)
27 PowerMOSFET, PMIC, SiC

27.14 Coss (N1272A): Output capacitance measurement (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures the output capacitance of power MOSFET.

[Device Under Test]
Power MOSFET, 3 terminals

[Device Parameters]
CossMinYAxis: Minimum end point of Y axis for Coss (F)
CossMaxYAxis: Maximum end point of Y axis for Coss (F)

[Test Parameters]
Frequency: Measurement signal frequency (Hz)
VGS: Gate bias voltage (V)
VDSStart: VDS sweep start voltage (V)
VDSStop: VDS sweep stop voltage (V)
SweepOutput: Sweep output
LinearNOS: Number Of Step for LINEAR SweepOutput

[Extended Test Parameters]
Hold: Hold time for sweep start output (s)
Delay: Delay time before measurement in sweep step (s)
ACGuard: AC guard output (1: Common, 2: Floating)
OscLevel: Measurement signal level (V)
NPLC: Measurement time in Power Line Cycle
PhaseCompensation: Phase compensation mode (0: Auto, 2: Adaptive)
SweepDirection: Sweep direction
DischargingDelay: Time for discharging after DUT breakdown check (s)
InCaseOfBreakdown: Action taken in case of DUT breakdown detection (0: Skip, 1: Error)

[X-Y Plot]
X: Drain-Source voltage VDS (V)
Y1: Output capacitance Coss (F)

[List Display]
VDS: Drain-Source voltage (V)
Coss: Output capacitance (F)
G: Output conductance (S)
ID: Drain current (A)
VGS: Gate-Source voltage (V)
IG: Gate current (A)

[Parameters Display Area]
Frequency: Measurement signal frequency (Hz)
27.15 Crss (N1272A): Reverse transfer capacitance measurement (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures the reverse transfer capacitance of power MOSFET.

[Device Under Test]
Power MOSFET, 3 terminals

[Device Parameters]
CrssMinYAxis: Minimum end point of Y axis for Crss (F)
CrssMaxYAxis: Maximum end point of Y axis for Crss (F)

[Test Parameters]
Frequency: Measurement signal frequency (Hz)
VGS: Gate bias voltage (V)
VDSStart: VDS sweep start voltage (V)
VDSStop: VDS sweep stop voltage (V)
SweepOutput: Sweep output
LinearNOS: Number Of Step for LINEAR SweepOutput

[Extended Test Parameters]
Hold: Hold time for sweep start output (s)
Delay: Delay time before measurement in sweep step (s)
ACGuard: AC guard output (1: Common, 2: Floating)
OscLevel: Measurement signal level (V)
NPLC: Measurement time in Power Line Cycle
PhaseCompensation: Phase compensation mode (0: Auto, 2: Adaptive)
SweepDirection: Sweep direction
DischargingDelay: Time for discharging after DUT breakdown check (s)
InCaseOfBreakdown: Action taken in case of DUT breakdown detection (0: Skip, 1: Error)

[X-Y Plot]
X: Drain-Source voltage VDS (V)
Y1: Reverse transfer capacitance Crss (F)

[List Display]
VDS: Drain-Source voltage (V)
Crss: Reverse transfer capacitance (F)
G: Reverse transfer conductance (S)
ID: Drain current (A)
VGS: Gate-Source voltage (V)
IG: Gate current (A)

[Parameters Display Area]
Frequency: Measurement signal frequency (Hz)
27.16 Cds (N1272A): Drain to source capacitance measurement (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures the drain to source capacitance of power MOSFET.

[Device Under Test]
Power MOSFET, 3 terminals

[Device Parameters]
CdsMinYAxis: Minimum end point of Y axis for Cds (F)
CdsMaxYAxis: Maximum end point of Y axis for Cds (F)

[Test Parameters]
Frequency: Measurement signal frequency (Hz)
VGS: Gate bias voltage (V)
VDSStart: VDS sweep start voltage (V)
VDSStop: VDS sweep stop voltage (V)
SweepOutput: Sweep output
LinearNOS: Number Of Step for LINEAR SweepOutput

[Extended Test Parameters]
Hold: Hold time for sweep start output (s)
Delay: Delay time before measurement in sweep step (s)
ACGuard: AC guard output (1: Common, 2: Floating)
OscLevel: Measurement signal level (V)
NPLC: Measurement time in Power Line Cycle
PhaseCompensation: Phase compensation mode (0: Auto, 2: Adaptive)
SweepDirection: Sweep direction
DischargingDelay: Time for discharging after DUT breakdown check (s)
InCaseOfBreakdown: Action taken in case of DUT breakdown detection (0: Skip, 1: Error)

[X-Y Plot]
X: Drain-Source voltage VDS (V)
Y1: Drain-Source capacitance Cds (F)

[List Display]
VDS: Drain-Source voltage (V)
Cds: Drain-Source capacitance (F)
G: Drain-Source conductance (S)
ID: Drain current (A)
VGS: Gate-Source voltage (V)
IG: Gate current (A)

[Parameters Display Area]
Frequency: Measurement signal frequency (Hz)
27.17 Cgd (N1272A): Gate to drain capacitance measurement (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures the gate to drain capacitance of power MOSFET.

[Device Under Test]
Power MOSFET, 3 terminals

[Device Parameters]
CgdMinYAxis: Minimum end point of Y axis for Cgd (F)
CgdMaxYAxis: Maximum end point of Y axis for Cgd (F)

[Test Parameters]
Frequency: Measurement signal frequency (Hz)
VGS: Gate bias voltage (V)
VDSStart: VDS sweep start voltage (V)
VDSStop: VDS sweep stop voltage (V)
SweepOutput: Sweep output
LinearNOS: Number Of Step for LINEAR SweepOutput

[Extended Test Parameters]
Hold: Hold time for sweep start output (s)
Delay: Delay time before measurement in sweep step (s)
ACGuard: AC guard output (1: Common, 2: Floating)
OscLevel: Measurement signal level (V)
NPLC: Measurement time in Power Line Cycle
PhaseCompensation: Phase compensation mode (0: Auto, 2: Adaptive)
SweepDirection: Sweep direction
DischargingDelay: Time for discharging after DUT breakdown check (s)
InCaseOfBreakdown: Action taken in case of DUT breakdown detection (0: Skip, 1: Error)

[X-Y Plot]
X: Drain-Source voltage VDS (V)
Y1: Gate-Drain capacitance Cgd (F)

[List Display]
VDS: Drain-Source voltage (V)
Cgd: Gate-Drain capacitance (F)
G: Gate-Drain conductance (S)
ID: Drain current (A)
VGS: Gate-Source voltage (V)
IG: Gate current (A)

[Parameters Display Area]
Frequency: Measurement signal frequency (Hz)
27.18 Cgs (N1272A): Gate to source capacitance measurement (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures the gate to source capacitance of power MOSFET.

[Device Under Test]
Power MOSFET, 3 terminals

[Device Parameters]
CgsMinYAxis: Minimum end point of Y axis for Cgs (F)
CgsMaxYAxis: Maximum end point of Y axis for Cgs (F)

[Test Parameters]
Frequency: Measurement signal frequency (Hz)
VGS: Gate bias voltage (V)
VDSStart: VDS sweep start voltage (V)
VDSStop: VDS sweep stop voltage (V)
SweepOutput: Sweep output
LinearNOS: Number Of Step for LINEAR SweepOutput

[Extended Test Parameters]
Hold: Hold time for sweep start output (s)
Delay: Delay time before measurement in sweep step (s)
ACGuard: AC guard output (1: Common, 2: Floating)
OscLevel: Measurement signal level (V)
NPLC: Measurement time in Power Line Cycle
PhaseCompensation: Phase compensation mode (0: Auto, 2: Adaptive)
SweepDirection: Sweep direction
DischargingDelay: Time for discharging after DUT breakdown check (s)
InCaseOfBreakdown: Action taken in case of DUT breakdown detection (0: Skip, 1: Error)

[X-Y Plot]
X: Drain-Source voltage VDS (V)
Y1: Gate-Source capacitance Cgs (F)

[List Display]
VDS: Drain-Source voltage (V)
Cgs: Gate-Source capacitance (F)
G: Gate-Source conductance (S)
ID: Drain current (A)
VGS: Gate-Source voltage (V)
IG: Gate current (A)

[Parameters Display Area]
Frequency: Measurement signal frequency (Hz)
27.19 Rg (N1272A) for PowerMOSFET: Gate resistance measurement (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures the gate resistance of power MOSFET.

[Device Under Test]
Power MOSFET, 3 terminals

[Device Parameters]
RgMinYAxis: Minimum end point of Y axis for Rg (ohm)
RgMaxYAxis: Maximum end point of Y axis for Rg (ohm)

[Test Parameters]
Frequency: Measurement signal frequency (Hz)
VGSStart: VGS sweep start voltage (V)
VGSSStop: VGS sweep stop voltage (V)
SweepOutput: Sweep output
LinearNOS: Number Of Step for LINEAR SweepOutput

[Extended Test Parameters]
Hold: Hold time for sweep start output (s)
Delay: Delay time before measurement in sweep step (s)
ACGuard: AC guard output (1: Common, 2: Floating)
OscLevel: Measurement signal level (V)
NPLC: Measurement time in Power Line Cycle
PhaseCompensation: Phase compensation mode (0: Auto, 2: Adaptive)
SweepDirection: Sweep direction
DischargingDelay: Time for discharging after DUT breakdown check (s)
InCaseOfBreakdown: Action taken in case of DUT breakdown detection (0: Skip, 1: Error)

[X-Y Plot]
X: Gate-Source voltage VGS (V)
Y1: Gate resistance Rg (ohm)

[List Display]
VGS: Gate-Source voltage (V)
Rg: Gate resistance (ohm)
C: Gate capacitance (F)
VDS: Drain-Source voltage (V)
ID: Drain current (A)

[Parameters Display Area]
Frequency: Measurement signal frequency (Hz)
27 PowerMOSFET, PMIC, SiC

27.20 IDSS (N1272A): Drain leakage current measurement (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures the drain leakage current of power MOSFET.

[Device Under Test]
Power MOSFET, 3 terminals

[Device Parameters]
IDSSMinYAxis: Minimum end point of Y axis for IDSS (A)
IDSSMaxYAxis: Maximum end point of Y axis for IDSS (A)
IDSSYAxisScale: Scale of Y axis for IDSS (0: Log, 1: Linear)

[Test Parameters]
IGLimit: Gate leak current limit (A)
VGS: Gate bias voltage (V)
IDLimit: Drainleak current limit (A)
VDSSStart: VDS sweep start voltage (V)
VDSSStop: VDS sweep stop voltage (V)
SweepOutput: Sweep output
LinearNOS: Number Of Step for LINEAR SweepOutput

[Extended Test Parameters]
IGMinRange: Minimum range for IG measurement
IDMinRange: Minimum range for ID measurement
NPLC: Measurement time in Power Line Cycle
Hold: Hold time for sweep start output (s)
Delay: Delay time before measurement in sweep step (s)
DCGuard: DC guard output (1: Common, 2: HVSMU)
InCaseOfAbnormalStatus: Action taken in case of abnormal measurement status

[X-Y Plot]
X: Drain-Source voltage VDS (V)
Y1: Drain current ID (A)

[List Display]
VDS: Drain-Source voltage (V)
ID: Drain current (A)
VGS: Gate-Source voltage (V)
IG: Gate current (A)
27.21 IGSS (N1272A): Gate leakage current measurement (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures the gate leakage current of power MOSFET.

[Device Under Test]
Power MOSFET, 3 terminals

[Device Parameters]
IGSSMinYAxis: Minimum end point of Y axis for IGSS (A)
IGSSMaxYAxis: Maximum end point of Y axis for IGSS (A)
IGSSYAxisScale: Scale of Y axis for IGSS (0: Log, 1: Linear)

[Test Parameters]
IGLimit: Gate leak current limit
VGSStart: VGS sweep start voltage (V)
VGSSStop: VGS sweep stop voltage (V)
SweepOutput: Sweep output
LinearNOS: Number Of Step for LINEAR SweepOutput
IDLimit: Drain leak current limit
VDS: Drain bias voltage (V)

[Extended Test Parameters]
IGMinRange: Minimum range for IG measurement
IDMinRange: Minimum range for ID measurement
NPLC: Measurement time in Power Line Cycle
Hold: Hold time for sweep start output (s)
Delay: Delay time before measurement in sweep step (s)
DCGuard: DC guard output (1: Common, 2: HVSMU)
InCaseOfAbnormalStatus: Action taken in case of abnormal measurement status

[X-Y Plot]
X: Gate-Source voltage VGS (V)
Y1: Gate current IG (A)

[List Display]
VGS: Gate-Source voltage (V)
IG: Gate current (A)
VDS: Drain-Source voltage (V)
ID: Drain current (A)
27.22  **Ciss-Vgs (N1272A): Ciss-Vgs measurement (A.06.10)**

[Supported Analyzer]
B1505A, B1506A

[Description]
Ciss-Vgs measurement

[Device Parameters]
CissMinYAxis: Minimum end point of Y axis for Ciss (F)
CissMaxYAxis: Maximum end point of Y axis for Ciss (F)

[Test Parameters]
Frequency: Measurement signal frequency (Hz)
VGSStart: VGS sweep start voltage (V)
VGSStop: VGS sweep stop voltage (V)
SweepOutput: Sweep output
LinearNOS: Number Of Step for LINEAR SweepOutput

[Extended Test Parameters]
Model: 2-element model option
Hold: Hold time for sweep start output (s)
Delay: Delay time before measurement in sweep step (s)
ACGuard: AC guard output (1: Common, 2: Floating)
OscLevel: Measurement signal level (V)
NPLC: Measurement time in Power Line Cycle
PhaseCompensation: Phase compensation mode (0: Auto, 2: Adaptive)
SweepDirection: Sweep direction
DischargingDelay: Time for discharging after DUT breakdown check (s)
InCaseOfBreakdown: Action taken in case of DUT breakdown detection (0: Skip, 1: Error)

[X-Y Plot]
X: Gate-Source voltage VGS (V)
Y1: Input capacitance Ciss (F)

[List Display]
VGS: Gate-Source voltage (V)
Ciss: Input capacitance (F)
Giss: Input conductance (S) (in case of Cp-G model)
Rg: Gate resistance (ohm) (in case of Cs-Rs model)
VDS: Drain-Source voltage (V)
ID: Drain current (A)

[Parameters Display Area]
Frequency: Measurement signal frequency (Hz)
GateCharge, PowerMOSFET
1. \( Q_g (\text{High Id} + \text{High Vds} + \text{JESD24-2}) \): High current and high voltage gate charge measurement and characterization (A.06.00)

2. \( Q_g (\text{R Load High Id} + \text{High Vds} + \text{JESD24-2}) \): High current (with resistive load) and high voltage gate charge measurement and characterization (A.06.00)

3. \( Q_g (\text{High Id} + \text{JESD24-2}) \): High current gate charge measurement and characterization (A.06.00)

4. \( Q_g (\text{R Load High Id} + \text{JESD24-2}) \): High current (with resistive load) gate charge measurement and characterization (A.06.00)

5. \( Q_g (\text{High Vds} + \text{JESD24-2}) \): High voltage gate charge measurement and characterization (A.06.00)

6. \( Q_g (\text{JESD24-2 High Id} + \text{JESD24-2 High Vds}) \): Gate charge characterization (A.06.00)

7. \( Q_g (\text{High Id} + \text{High Vds}) \): High current and high voltage gate charge measurement (A.06.00)

8. \( Q_g (\text{R Load High Id} + \text{High Vds}) \): High current (with resistive load) and high voltage gate charge measurement (A.06.00)

9. \( Q_g (\text{High Id}) \): High current gate charge measurement (A.06.00)

10. \( Q_g (\text{R Load High Id}) \): High current (with resistive load) gate charge measurement (A.06.00)

11. \( Q_g (\text{High Vds}) \): High voltage gate charge measurement (A.06.00)
28.1 Qg (High Id + High Vds + JESD24-2): High current and high voltage gate charge measurement and characterization (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Performs the high current and the high voltage gate charge measurements and the characterization by specifying the on voltage, on current, and range of the gate voltages.

[Device Under Test]
Power MOSFET

[Device Parameters]
QgMaxXAxis: Maximum end point of Y axis for Qg (C)
VgsTh: Gate threshold voltage (V)

[Test Parameters]
VdsOff: Off-state Drain to Source voltage (V)
IdOn: On-state Drain current (A)
VgsOff: Off-state Gate to Source voltage (V)
VgsOn: On-state Gate to Source voltage (V)
IgHC: Gate current for the high current Qg measurement (A)
IgHV: Gate current for the high voltage Qg measurement (A)
LoadVgsOff: Off-state Gate to Source voltage of the constant current load (V)
LoadVgsOn: On-state Gate to Source voltage of the constant current load (V)
LoadIg: Gate current of the constant current load (A)
LoadVgs: Gate to Source voltage of the constant current load (V) (-30: Auto)
RgExtHC: Gate resistance selection for the high current Qg measurement (ohm)
RgExtHV: Gate resistance selection for the high voltage Qg measurement (ohm)
RgDUT: Gate series resistance (ohm)
VgsStartOffsetHC: Offset voltage of Gate to Source start voltage for the high current Qg measurement (V)
VgsStopOffsetHC: Offset voltage of Gate to Source stop voltage for the high current Qg measurement (V)
DelayVdsHC: Delay time to change Drain to Source voltage of the high current Qg measurement (s)
DelayVgsHC: Delay time to change Gate to Source voltage of the high current Qg measurement (s)
OnPeriodHC: On period for the high current Qg measurement (s)
VgsStartOffsetHV: Offset voltage of Gate to Source start voltage for the high voltage Qg measurement (V)
VgsStopOffsetHV: Offset voltage of Gate to Source stop voltage for the high voltage Qg measurement (V)
DelayVgsHV: Delay time to change Gate to Source voltage of the high voltage Qg measurement (s)
OnPeriodHV: On period for the high voltage Qg measurement (s)

[X-Y Plot]
X: Gate charge Qg (C)
Y1: Gate to Source voltage derived from JESD24-2 line fitting VgsJESD24_2 (V)
Y2: Gate to Source voltage of the high current Qg measurement VgsHC (V)
Y3: Gate to Source voltage of the high voltage Qg measurement VgsHV (V)

[List Display]
Qg: Gate charge (C)
VgsJESD24_2: Gate to Source voltage derived from JESD24-2 line fitting (V)
VgsHC: Gate to Source voltage of the high current Qg measurement (V)
VgsHV: Gate to Source voltage of the high voltage Qg measurement (V)
VdsHC: Drain to Source voltage of the high current Qg measurement (V)
VdsHV: Drain to Source voltage of the high voltage Qg measurement (V)

[Parameters Display Area]

VOff: Off-state Drain to Source voltage (V)
ION: On-state Drain current (A)
VgsPl: Gate plateau voltage (V)
Qgs: Gate-Source charge (C)
Qgd: Gate-Drain charge (C)
QgTh: Gate-Source threshold charge (C)
QgOn: Total Gate charge (C)
S1: Slope1 (V/nC)
S2: Slope2 (V/nC)
C1: Qgs/(VgsPl-VgsOff) (F)
C2: (QgOn-Qgs-Qgd)/(VgsOn-VgsPl) (F)
OpenCHC: Open compensation capacitance of the high current Qg measurement (F)
ShortRHC: Short compensation resistance of the high current Qg measurement (ohm)
OpenCHV: Open compensation capacitance of the high voltage Qg measurement (F)
ShortRHV: Short compensation resistance of the high voltage Qg measurement (ohm)
28.2 Qg (R Load High Id + High Vds + JESD24-2): High current (with resistive load) and high voltage gate charge measurement and characterization (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Performs the high current (with resistive load) and the high voltage gate charge measurements and characterization by specifying the on voltage, on current, and the range of the gate voltages.

[Device Under Test]
Power MOSFET

[Device Parameters]
QgMaxXAxis: Maximum end point of Y axis for Qg (C)
VgsTh: Gate threshold voltage (V)

[Test Parameters]
LoadV: Load voltage (V) (0: Auto). In case of Auto, load voltage will be adjusted for IdOn.
VdsOff: Off-state Drain to Source voltage (V)
IdOn: On-state Drain current (A)
VgsOff: Off-state Gate to Source voltage (V)
VgsOn: On-state Gate to Source voltage (V)
IgHC: Gate current for the high current Qg measurement (A)
IgHV: Gate current for the high voltage Qg measurement (A)
RgExtHC: Gate resistance selection for the high current Qg measurement (ohm)
RgExtHV: Gate resistance selection for the high voltage Qg measurement (ohm)
RgDUT: Gate series resistance (ohm)
VgsStartOffsetHC: Offset voltage of Gate to Source start voltage for the high current Qg measurement (V)
VgsStopOffsetHC: Offset voltage of Gate to Source stop voltage for the high current Qg measurement (V)
DelayVgsHC: Delay time to change Gate to Source voltage of the high current Qg measurement (s)
OnPeriodHC: On period for the high current Qg measurement (s)
VgsStartOffsetHV: Offset voltage of Gate to Source start voltage for the high voltage Qg measurement (V)
VgsStopOffsetHV: Offset voltage of Gate to Source stop voltage for the high voltage Qg measurement (V)
DelayVgsHV: Delay time to change Gate to Source voltage of the high voltage Qg measurement (s)
OnPeriodHV: On period for the high voltage Qg measurement (s)

[X-Y Plot]
X: Gate charge Qg (C)
Y1: Gate to Source voltage derived from JESD24-2 line fitting VgsJESD24_2 (V)
Y2: Gate to Source voltage of the high current Qg measurement VgsHC (V)
Y3: Gate to Source voltage of the high voltage Qg measurement VgsHV (V)

[List Display]
Qg: Gate charge (C)
VgsJESD24_2: Gate to Source voltage derived from JESD24-2 line fitting (V)
VgsHC: Gate to Source voltage of the high current Qg measurement (V)
VgsHV: Gate to Source voltage of the high voltage Qg measurement (V)
VdsHC: Drain to Source voltage of the high current Qg measurement (V)
VdsHV: Drain to Source voltage of the high voltage Qg measurement (V)
[Parameters Display Area]
- VOff: Off-state Drain to Source voltage (V)
- IOn: On-state Drain current (A)
- VgsPl: Gate plateau voltage (V)
- Qgs: Gate-Source charge (C)
- Qgd: Gate-Drain charge (C)
- QgTh: Gate-Source threshold charge (C)
- QgOn: Total Gate charge (C)
- S1: Slope1 (V/nC)
- S2: Slope2 (V/nC)
- C1: Qgs/(VgsPl-VgsOff) (F)
- C2: (QgOn-Qgs-Qgd)/(VgsOn-VgsPl) (F)
- OpenCHC: Open compensation capacitance of the high current Qg measurement (F)
- ShortRHC: Short compensation resistance of the high current Qg measurement (ohm)
- OpenCHV: Open compensation capacitance of the high voltage Qg measurement (F)
- ShortRHV: Short compensation resistance of the high voltage Qg measurement (ohm)
28.3 $Q_g$ (High Id + JESD24-2): High current gate charge measurement and characterization (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Performs the high current gate charge measurement and characterization by specifying the on voltage, on current, and the range of gate voltages.

[Device Under Test]
Power MOSFET

[Device Parameters]
QgMaxXAxis: Maximum end point of Y axis for $Q_g$ (C)
VgsTh: Gate threshold voltage (V)

[Test Parameters]
VdsOff: Off-state Drain to Source voltage (V)
IdOn: On-state Drain current (A)
VgsOff: Off-state Gate to Source voltage (V)
VgsOn: On-state Gate to Source voltage (V)
Ig: Gate current (A)
LoadVgsOff: Off-state Gate to Source voltage of the constant current load (V)
LoadVgsOn: On-state Gate to Source voltage of the constant current load (V)
LoadIg: Gate current of the constant current load (A)
LoadVgs: Gate to Source voltage of the constant current load (V) (-30: Auto)
RgExt: Gate resistance selection (ohm)
RgDUT: Gate series resistance (ohm)
VgsStartOffset: Offset voltage of Gate to Source start voltage (V)
VgsStopOffset: Offset voltage of Gate to Source stop voltage (V)
DelayVds: Delay time to change Drain to Source voltage (s)
DelayVgs: Delay time to change Gate to Source voltage (s)
OnPeriod: On period (s)

[X-Y Plot]
X: Gate charge $Q_g$ (C)
Y1: Gate to Source voltage derived from JESD24-2 line fitting $V_{gsJESD24_2}$ (V)
Y2: Gate to Source voltage $V_{gs}$ (V)

[List Display]
Qg: Gate charge (C)
VgsJESD24_2: Gate to Source voltage derived from JESD24-2 line fitting (V)
Vgs: Gate to Source voltage (V)
Vds: Drain to Source voltage (V)

[Parameters Display Area]
VOff: Off-state Drain to Source voltage (V)
IOn: On-state Drain current (A)
VgsPl: Gate plateau voltage (V)
Qgs: Gate-Source charge (C)
Qgd: Gate-Drain charge (C)
QgTh: Gate-Source threshold charge (C)
28 GateCharge, PowerMOSFET

QgOn: Total Gate charge (C)
S1: Slope1 (V/nC)
S2: Slope2 (V/nC)
C1: Qgs/(VgsPl-VgsOff) (F)
C2: (QgOn-Qgs-Qgd)/(VgsOn-VgsPl) (F)
OpenC: Open compensation capacitance (F)
ShortR: Short compensation resistance (ohm)
28.4 \( Q_g (R \text{ Load High Id + JESD24-2}): \) High current (with resistive load) gate charge measurement and characterization (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Performs the high current (with resistive load) gate charge measurement and characterization by specifying the on voltage, on current, and the range of gate voltages.

[Device Under Test]
Power MOSFET

[Device Parameters]
QgMaxXAxis: Maximum end point of Y axis for Qg (C)
VgsTh: Gate threshold voltage (V)

[Test Parameters]
LoadV: Load voltage (V) (0: Auto). In case of Auto, load voltage will be adjusted for IdOn.
VdsOff: Off-state Drain to Source voltage (V)
IdOn: On-state Drain current (A)
VgsOff: Off-state Gate to Source voltage (V)
VgsOn: On-state Gate to Source voltage (V)
Ig: Gate current (A)
RgExt: Gate resistance selection (ohm)
RgDUT: Gate series resistance (ohm)
VgsStartOffset: Offset voltage of Gate to Source start voltage (V)
VgsStopOffset: Offset voltage of Gate to Source stop voltage (V)
DelayVgs: Delay time to change Gate to Source voltage (s)
OnPeriod: On period (s)

[X-Y Plot]
X: Gate charge Qg (C)
Y1: Gate to Source voltage derived from JESD24-2 line fitting VgsJESD24_2 (V)
Y2: Gate to Source voltage Vgs (V)

[List Display]
Qg: Gate charge (C)
VgsJESD24_2: Gate to Source voltage derived from JESD24-2 line fitting (V)
Vgs: Gate to Source voltage (V)
Vds: Drain to Source voltage (V)

[Parameters Display Area]
VOff: Off-state Drain to Source voltage (V)
ION: On-state Drain current (A)
VgsPl: Gate plateau voltage (V)
Qgs: Gate-Source charge (C)
Qgd: Gate-Drain charge (C)
QgTh: Gate-Source threshold charge (C)
QgOn: Total Gate charge (C)
S1: Slope1 (V/nC)
S2: Slope2 (V/nC)
C1: Qgs/(VgsPl-VgsOff) (F)
C2: (QgOn-Qgs-Qgd)/(VgsOn-VgsPl) (F)
OpenC: Open compensation capacitance (F)
ShortR: Short compensation resistance (ohm)
28 GateCharge, PowerMOSFET

28.5 \textbf{Qg (High Vds + JESD24-2): High voltage gate charge measurement and characterization (A.06.00)}

[Supported Analyzer]
B1505A, B1506A

[Description]
Performs the high voltage gate charge measurement and characterization by specifying the on voltage, on current, and the range of gate voltages.

[Device Under Test]
Power MOSFET

[Device Parameters]
\textbf{QgMaxXAxis}: Maximum end point of Y axis for Qg (C)
\textbf{VgsTh}: Gate threshold voltage (V)

[Test Parameters]
\textbf{VdsOff}: Off-state Drain to Source voltage (V)
\textbf{VgsOff}: Off-state Gate to Source voltage (V)
\textbf{VgsOn}: On-state Gate to Source voltage (V)
\textbf{Ig}: Gate current (A)
\textbf{RgExt}: Gate resistance selection (ohm)
\textbf{RgDUT}: Gate series resistance (ohm)
\textbf{VgsStartOffset}: Offset voltage of Gate to Source start voltage (V)
\textbf{VgsStopOffset}: Offset voltage of Gate to Source stop voltage (V)
\textbf{DelayVgs}: Delay time to change Gate to Source voltage (s)
\textbf{OnPeriod}: On period (s)

[X-Y Plot]
\textbf{X}: Gate charge Qg (C)
\textbf{Y1}: Gate to Source voltage derived from JESD24-2 line fitting VgsJESD24_2 (V)
\textbf{Y2}: Gate to Source voltage Vgs (V)

[List Display]
\textbf{Qg}: Gate charge (C)
\textbf{VgsJESD24_2}: Gate to Source voltage derived from JESD24-2 line fitting (V)
\textbf{Vgs}: Gate to Source voltage (V)
\textbf{Vds}: Drain to Source voltage (V)

[Parameters Display Area]
\textbf{VOff}: Off-state Drain to Source voltage (V)
\textbf{VgsPl}: Gate plateau voltage (V)
\textbf{Qgs}: Gate-Source charge (C)
\textbf{Qgd}: Gate-Drain charge (C)
\textbf{QgTh}: Gate-Source threshold charge (C)
\textbf{QgOn}: Total Gate charge (C)
\textbf{S1}: Slope1 (V/nC)
\textbf{S2}: Slope2 (V/nC)
\textbf{C1}: Qgs/(VgsPl-VgsOff) (F)
\textbf{C2}: (QgOn-Qgs-Qgd)/(VgsOn-VgsPl) (F)
\textbf{OpenC}: Open compensation capacitance (F)
\textbf{ShortR}: Short compensation resistance (ohm)
28.6  \( Q_g (JESD24-2 \text{ High Id} + JESD24-2 \text{ High Vds}): \text{ Gate charge characterization (A.06.00)} \)

[Supported Analyzer]
   B1505A, B1506A

[Description]
   Performs the high current and high voltage gate charge characterization.

[Device Under Test]
   Power MOSFET

[Device Parameters]
   \( Q_g \text{MaxXAxis}: \text{Maximum end point of Y axis for } Q_g \text{ (C)} \)
   \( V_{gsTh}: \text{Gate threshold voltage (V)} \)

[X-Y Plot]
   \( X: \text{Gate charge } Q_g \text{ (C)} \)
   \( Y_1: \text{Gate to Source voltage derived from JESD24-2 line fitting } V_{gsJESD24_2} \text{ (V)} \)

[List Display]
   \( Q_g: \text{Gate charge (C)} \)
   \( V_{gsJESD24_2}: \text{Gate to Source voltage derived from JESD24-2 line fitting (V)} \)

[Parameters Display Area]
   \( V_{Off}: \text{Off-state Drain to Source voltage (V)} \)
   \( I_{On}: \text{On-state Drain current (A)} \)
   \( V_{gsPl}: \text{Gate plateau voltage (V)} \)
   \( Q_{gs}: \text{Gate-Source charge (C)} \)
   \( Q_{gd}: \text{Gate-Drain charge (C)} \)
   \( Q_{gTh}: \text{Gate-Source threshold charge (C)} \)
   \( Q_{gOn}: \text{Total Gate charge (C)} \)
   \( S1: \text{Slope1 (V/nC)} \)
   \( S2: \text{Slope2 (V/nC)} \)
   \( C1: Q_{gs}/(V_{gsPl}-V_{gsOff}) \text{ (F)} \)
   \( C2: (Q_{gOn}-Q_{gs}-Q_{gd})/(V_{gsOn}-V_{gsPl}) \text{ (F)} \)
28.7  **Qg (High Id + High Vds): High current and high voltage gate charge measurement (A.06.00)**

[Supported Analyzer]
B1505A, B1506A

[Description]
Performs the high current and high voltage gate charge measurement.

[Device Under Test]
Power MOSFET

[Device Parameters]
QgMaxXAxis: Maximum end point of Y axis for Qg (C)

[Test Parameters]
VdsOff: Off-state Drain to Source voltage (V)
IdOn: On-state Drain current (A)
VgsOff: Off-state Gate to Source voltage (V)
VgsOn: On-state Gate to Source voltage (V)
IgHC: Gate current for the high current Qg measurement (A)
IgHV: Gate current for the high voltage Qg measurement (A)
LoadVgsOff: Off-state Gate to Source voltage of the constant current load (V)
LoadVgsOn: On-state Gate to Source voltage of the constant current load (V)
LoadIg: Gate current of the constant current load (A)
LoadVgs: Gate to Source voltage of the constant current load (V) (-30: Auto)
RgExtHC: Gate resistance selection for the high current Qg measurement (ohm)
RgExtHV: Gate resistance selection for the high voltage Qg measurement (ohm)
RgDUT: Gate series resistance (ohm)
VgsStartOffsetHC: Offset voltage of Gate to Source start voltage for the high current Qg measurement (V)
VgsStopOffsetHC: Offset voltage of Gate to Source stop voltage for the high current Qg measurement (V)
DelayVdsHC: Delay time to change Drain to Source voltage of the high current Qg measurement (s)
DelayVgsHC: Delay time to change Gate to Source voltage of the high current Qg measurement (s)
OnPeriodHC: On period for the high current Qg measurement (s)
VgsStartOffsetHV: Offset voltage of Gate to Source start voltage for the high voltage Qg measurement (V)
VgsStopOffsetHV: Offset voltage of Gate to Source stop voltage for the high voltage Qg measurement (V)
DelayVgsHV: Delay time to change Gate to Source voltage of the high voltage Qg measurement (s)
OnPeriodHV: On period for the high voltage Qg measurement (s)

[X-Y Plot]
X: Gate charge Qg (C)
Y1: Gate to Source voltage of the high current Qg measurement VgsHC (V)
Y2: Gate to Source voltage of the high voltage Qg measurement VgsHV (V)

[List Display]
Qg: Gate charge (C)
VgsHC: Gate to Source voltage of the high current Qg measurement (V)
VgsHV: Gate to Source voltage of the high voltage Qg measurement (V)
VdsHC: Drain to Source voltage of the high current Qg measurement (V)
VdsHV: Drain to Source voltage of the high voltage Qg measurement (V)

[Parameters Display Area]
VOff: Off-state Drain to Source voltage (V)
IOn: On-state Drain current (A)
QgOnHC: Total gate charge of the high current Qg measurement (C)
QgOnHV: Total gate charge of the high voltage Qg measurement (C)
OpenCHC: Open compensation capacitance of the high current Qg measurement (F)
ShortRHC: Short compensation resistance of the high current Qg measurement (ohm)
OpenCHV: Open compensation capacitance of the high voltage Qg measurement (F)
ShortRHV: Short compensation resistance of the high voltage Qg measurement (ohm)
28.8  \( Q_g (R \text{ Load High Id + High Vds}): \text{High current (with resistive load) and high voltage gate charge measurement (A.06.00)} \)

[Supported Analyzer]
B1505A, B1506A

[Description]
Performs the high current (with resistive load) and high voltage gate charge measurement.

[Device Under Test]
Power MOSFET

[Device Parameters]
- \( Q_{gMaxXAxis} \): Maximum end point of Y axis for \( Q_g \) (C)

[Test Parameters]
- \( \text{LoadV} \): Load voltage (V) (0: Auto). In case of Auto, load voltage will be adjusted for \( \text{IdOn} \).
- \( \text{VdsOff} \): Off-state Drain to Source voltage (V)
- \( \text{IdOn} \): On-state Drain current (A)
- \( \text{VgsOff} \): Off-state Gate to Source voltage (V)
- \( \text{VgsOn} \): On-state Gate to Source voltage (V)
- \( \text{IgHC} \): Gate current for the high current \( Q_g \) measurement (A)
- \( \text{IgHV} \): Gate current for the high voltage \( Q_g \) measurement (A)
- \( \text{RgExtHC} \): Gate resistance selection for the high current \( Q_g \) measurement (ohm)
- \( \text{RgExtHV} \): Gate resistance selection for the high voltage \( Q_g \) measurement (ohm)
- \( \text{RgDUT} \): Gate series resistance (ohm)
- \( \text{VgsStartOffsetHC} \): Offset voltage of Gate to Source start voltage for the high current \( Q_g \) measurement (V)
- \( \text{VgsStopOffsetHC} \): Offset voltage of Gate to Source stop voltage for the high current \( Q_g \) measurement (V)
- \( \text{DelayVgsHC} \): Delay time to change Gate to Source voltage of the high current \( Q_g \) measurement (s)
- \( \text{OnPeriodHC} \): On period for the high current \( Q_g \) measurement (s)
- \( \text{VgsStartOffsetHV} \): Offset voltage of Gate to Source start voltage for the high voltage \( Q_g \) measurement (V)
- \( \text{VgsStopOffsetHV} \): Offset voltage of Gate to Source stop voltage for the high voltage \( Q_g \) measurement (V)
- \( \text{DelayVgsHV} \): Delay time to change Gate to Source voltage of the high voltage \( Q_g \) measurement (s)
- \( \text{OnPeriodHV} \): On period for the high voltage \( Q_g \) measurement (s)

[X-Y Plot]
- \( X \): Gate charge \( Q_g \) (C)
- \( Y_1 \): Gate to Source voltage of the high current \( Q_g \) measurement \( \text{VgsHC} \) (V)
- \( Y_2 \): Gate to Source voltage of the high voltage \( Q_g \) measurement \( \text{VgsHV} \) (V)

[List Display]
- \( Q_g \): Gate charge (C)
- \( \text{VgsHC} \): Gate to Source voltage of the high current \( Q_g \) measurement (V)
- \( \text{VgsHV} \): Gate to Source voltage of the high voltage \( Q_g \) measurement (V)
- \( \text{VdsHC} \): Drain to Source voltage of the high current \( Q_g \) measurement (V)
- \( \text{VdsHV} \): Drain to Source voltage of the high voltage \( Q_g \) measurement (V)

[Parameters Display Area]
- \( \text{VOff} \): Off-state Drain to Source voltage (V)
- \( \text{ION} \): On-state Drain current (A)
- \( \text{QgOnHC} \): Total gate charge of the high current \( Q_g \) measurement (C)
- \( \text{QgOnHV} \): Total gate charge of the high voltage \( Q_g \) measurement (C)
- \( \text{OpenCHC} \): Open compensation capacitance of the high current \( Q_g \) measurement (F)
- \( \text{ShortRHC} \): Short compensation resistance of the high current \( Q_g \) measurement (ohm)
- \( \text{OpenCHV} \): Open compensation capacitance of the high voltage \( Q_g \) measurement (F)
- \( \text{ShortRHV} \): Short compensation resistance of the high voltage \( Q_g \) measurement (ohm)
28.9  \textit{Qg (High Id): High current gate charge measurement (A.06.00)}

[Supported Analyzer]
B1505A, B1506A

[Description]
Performs the high current gate charge measurement.

[Device Under Test]
Power MOSFET

[Device Parameters]
\textit{QgMaxXAxis}: Maximum end point of Y axis for Qg (C)

[Test Parameters]
\textit{VdsOff}: Off-state Drain to Source voltage (V)
\textit{IdOn}: On-state Drain current (A)
\textit{VgsOff}: Off-state Gate to Source voltage (V)
\textit{VgsOn}: On-state Gate to Source voltage (V)
\textit{Ig}: Gate current (A)
\textit{LoadVgsOff}: Off-state Gate to Source voltage of the constant current load (V)
\textit{LoadVgsOn}: On-state Gate to Source voltage of the constant current load (V)
\textit{LoadIg}: Gate current of the constant current load (A)
\textit{LoadVgs}: Gate to Source voltage of the constant current load (V) (-30: Auto)
\textit{RgExt}: Gate resistance selection (ohm)
\textit{RgDUT}: Gate series resistance (ohm)
\textit{VgsStartOffset}: Offset voltage of Gate to Source start voltage (V)
\textit{VgsStopOffset}: Offset voltage of Gate to Source stop voltage (V)
\textit{DelayVds}: Delay time to change Drain to Source voltage (s)
\textit{DelayVgs}: Delay time to change Gate to Source voltage (s)
\textit{OnPeriod}: On period (s)

[X-Y Plot]
\textit{X}: Gate charge Qg (C)
\textit{Y1}: Gate to Source voltage Vgs (V)

[List Display]
\textit{Qg}: Gate charge (C)
\textit{Vgs}: Gate to Source voltage (V)
\textit{Vds}: Drain to Source voltage (V)

[Parameters Display Area]
\textit{VOff}: Off-state Drain to Source voltage (V)
\textit{ION}: On-state Drain current (A)
\textit{QgOn}: Total Gate charge (C)
\textit{OpenC}: Open compensation capacitance (F)
\textit{ShortR}: Short compensation resistance (ohm)
28.10 Qg (R Load High Id): High current (with resistive load) gate charge measurement (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Performs the high current (with resistive load) gate charge measurement.

[Device Under Test]
Power MOSFET

[Device Parameters]
QgMaxXAxis: Maximum end point of Y axis for Qg (C)

[Test Parameters]
LoadV: Load voltage (V) (0: Auto). In case of Auto, load voltage will be adjusted for IdOn.
VdsOff: Off-state Drain to Source voltage (V)
IdOn: On-state Drain current (A)
VgsOff: Off-state Gate to Source voltage (V)
VgsOn: On-state Gate to Source voltage (V)
Ig: Gate current (A)
RgExt: Gate resistance selection (ohm)
RgDUT: Gate series resistance (ohm)
VgsStartOffset: Offset voltage of Gate to Source start voltage (V)
VgsStopOffset: Offset voltage of Gate to Source stop voltage (V)
DelayVgs: Delay time to change Gate to Source voltage (s)
OnPeriod: On period (s)

[X-Y Plot]
X: Gate charge Qg (C)
Y1: Gate to Source voltage Vgs (V)

[List Display]
Qg: Gate charge (C)
Vgs: Gate to Source voltage (V)
Vds: Drain to Source voltage (V)

[Parameters Display Area]
VOff: Off-state Drain to Source voltage (V)
IOn: On-state Drain current (A)
QgOn: Total Gate charge (C)
OpenC: Open compensation capacitance (F)
ShortR: Short compensation resistance (ohm)
28.11 Qg (High Vds): High voltage gate charge measurement (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Performs the high voltage gate charge measurement.

[Device Under Test]
Power MOSFET

[Device Parameters]
QgMaxXAxis: Maximum end point of Y axis for Qg (C)

[Test Parameters]
VdsOff: Off-state Drain to Source voltage (V)
VgsOff: Off-state Gate to Source voltage (V)
VgsOn: On-state Gate to Source voltage (V)
Ig: Gate current (A)
RgExt: Gate resistance selection (ohm)
RgDUT: Gate series resistance (ohm)
VgsStartOffset: Offset voltage of Gate to Source start voltage (V)
VgsStopOffset: Offset voltage of Gate to Source stop voltage (V)
DelayVgs: Delay time to change Gate to Source voltage (s)
OnPeriod: On period (s)

[X-Y Plot]
X: Gate charge Qg (C)
Y1: Gate to Source voltage Vgs (V)

[List Display]
Qg: Gate charge (C)
Vgs: Gate to Source voltage (V)
Vds: Drain to Source voltage (V)

[Parameters Display Area]
VOff: Off-state Drain to Source voltage (V)
QgOn: Total Gate charge (C)
OpenC: Open compensation capacitance (F)
ShortR: Short compensation resistance (ohm)
28 GateCharge, PowerMOSFET
GateCharge, IGBT
1. Qg (High Ic + High Vce + JESD24-2): High current and high voltage gate charge measurement and characterization (A.06.00)
2. Qg (R Load High Ic + High Vce + JESD24-2): High current (with resistive load) and high voltage gate charge measurement and characterization (A.06.00)
3. Qg (High Ic + JESD24-2): High current gate charge measurement and characterization (A.06.00)
4. Qg (R Load High Ic + JESD24-2): High current (with resistive load) gate charge measurement and characterization (A.06.00)
5. Qg (High Vce + JESD24-2): High voltage gate charge measurement and characterization (A.06.00)
6. Qg (JESD24-2 High Ic + JESD24-2 High Vce): Gate charge characterization (A.06.00)
7. Qg (High Ic + High Vce): High current and high voltage gate charge measurement (A.06.00)
8. Qg (R Load High Ic + High Vce): High current (with resistive load) and high voltage gate charge measurement (A.06.00)
9. Qg (High Ic): High current gate charge measurement (A.06.00)
10. Qg (R Load High Ic): High current (with resistive load) gate charge measurement (A.06.00)
11. Qg (High Vce): High voltage gate charge measurement (A.06.00)
29.1 \( Qg \) (High \( Ic \) + High \( Vce \) + JESD24-2): High current and high voltage gate charge measurement and characterization (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Performs the high current and the high voltage gate charge measurements and the characterization by specifying the on voltage, on current, and range of the gate voltages.

[Device Under Test]
IGBT

[Device Parameters]
QgMaxXAxis: Maximum end point of Y axis for Qg (C)
VgeTh: Gate threshold voltage (V)

[Test Parameters]
VceOff: Off-state Collector to Emitter voltage (V)
IcOn: On-state Collector current (A)
VgeOff: Off-state Gate to Emitter voltage (V)
VgeOn: On-state Gate to Emitter voltage (V)
IgHC: Gate current for the high current Qg measurement (A)
IgHV: Gate current for the high voltage Qg measurement (A)
LoadVgeOff: Off-state Gate to Emitter voltage of the constant current load (V)
LoadVgeOn: On-state Gate to Emitter voltage of the constant current load (V)
LoadIg: Gate current of the constant current load (A)
LoadVge: Gate to Emitter voltage of the constant current load (V) (-30: Auto)
RgExtHC: Gate resistance selection for the high current Qg measurement (ohm)
RgExtHV: Gate resistance selection for the high voltage Qg measurement (ohm)
RgDUT: Gate series resistance (ohm)
VgeStartOffsetHC: Offset voltage of Gate to Emitter start voltage for the high current Qg measurement (V)
VgeStopOffsetHC: Offset voltage of Gate to Emitter stop voltage for the high current Qg measurement (V)
DelayVceHC: Delay time to change Collector to Emitter voltage of the high current Qg measurement (s)
DelayVgeHC: Delay time to change Gate to Emitter voltage of the high current Qg measurement (s)
OnPeriodHC: On period for the high current Qg measurement (s)
VgeStartOffsetHV: Offset voltage of Gate to Emitter start voltage for the high voltage Qg measurement (V)
VgeStopOffsetHV: Offset voltage of Gate to Emitter stop voltage for the high voltage Qg measurement (V)
DelayVgeHV: Delay time to change Gate to Emitter voltage of the high voltage Qg measurement (s)
OnPeriodHV: On period for the high voltage Qg measurement (s)

[X-Y Plot]
X: Gate charge Qg (C)
Y1: Gate to Emitter voltage derived from JESD24-2 line fitting \( VgeJESD24_2 \) (V)
Y2: Gate to Emitter voltage of the high current Qg measurement \( VgeHC \) (V)
Y3: Gate to Emitter voltage of the high voltage Qg measurement \( VgeHV \) (V)

[List Display]
Qg: Gate charge (C)
VgeJESD24_2: Gate to Emitter voltage derived from JESD24-2 line fitting (V)
VgeHC: Gate to Emitter voltage of the high current Qg measurement (V)
VgeHV: Gate to Emitter voltage of the high voltage Qg measurement (V)
VceHC: Collector to Emitter voltage of the high current Qg measurement (V)
GateCharge, IGBT

VceHV: Collector to Emitter voltage of the high voltage Qg measurement (V)

[Parameters Display Area]
VOff: Off-state Collector to Emitter voltage (V)
ION: On-state Collector current (A)
VgePl: Gate plateau voltage (V)
Qge: Gate-Emitter charge (C)
Qgc: Gate-Collector charge (C)
QgTh: Gate-Emitter threshold charge (C)
QgOn: Total Gate charge (C)
S1: Slope1 (V/nC)
S2: Slope2 (V/nC)
C1: Qge/(VgePl-VgeOff) (F)
C2: (QgOn-Qge-Qgc)/(VgeOn-VgePl) (F)
OpenCHC: Open compensation capacitance of the high current Qg measurement (F)
ShortRHC: Short compensation resistance of the high current Qg measurement (ohm)
OpenCHV: Open compensation capacitance of the high voltage Qg measurement (F)
ShortRHV: Short compensation resistance of the high voltage Qg measurement (ohm)
29.2 \( Q_g \) (\( R \) Load High \( I_c \) + High \( V_{ce} \) + JESD24-2): High current (with resistive load) and high voltage gate charge measurement and characterization (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Performs the high current (with resistive load) and high voltage gate charge measurement and characterization by specifying the on voltage, on current, and the range of gate voltages.

[Device Under Test]
IGBT

[Device Parameters]
- \( Q_{gMaxXAxis} \): Maximum end point of Y axis for \( Q_g \) (C)
- \( V_{geTh} \): Gate threshold voltage (V)

[Test Parameters]
- \( V_{load} \): Load voltage (V) (0: Auto). In case of Auto, load voltage will be adjusted for \( I_{cOn} \).
- \( V_{ceOff} \): Off-state Collector to Emitter voltage (V)
- \( I_{cOn} \): On-state Collector current (A)
- \( V_{geOff} \): Off-state Gate to Emitter voltage (V)
- \( V_{geOn} \): On-state Gate to Emitter voltage (V)
- \( I_{gHC} \): Gate current for the high current \( Q_g \) measurement (A)
- \( I_{gHV} \): Gate current for the high voltage \( Q_g \) measurement (A)
- \( R_{gExtHC} \): Gate resistance selection for the high current \( Q_g \) measurement (ohm)
- \( R_{gExtHV} \): Gate resistance selection for the high voltage \( Q_g \) measurement (ohm)
- \( R_{gDUT} \): Gate series resistance (ohm)
- \( V_{geStartOffsetHC} \): Offset voltage of Gate to Emitter start voltage for the high current \( Q_g \) measurement (V)
- \( V_{geStopOffsetHC} \): Offset voltage of Gate to Emitter stop voltage for the high current \( Q_g \) measurement (V)
- \( V_{ceHC} \): Collector to Emitter voltage of the high current \( Q_g \) measurement (V)
- \( V_{ceHV} \): Collector to Emitter voltage of the high voltage \( Q_g \) measurement (V)
- \( V_{geStartOffsetHV} \): Offset voltage of Gate to Emitter start voltage for the high voltage \( Q_g \) measurement (V)
- \( V_{geStopOffsetHV} \): Offset voltage of Gate to Emitter stop voltage for the high voltage \( Q_g \) measurement (V)
- \( V_{geHV} \): Gate to Emitter voltage of the high voltage \( Q_g \) measurement (V)
- \( V_{ceHV} \): Collector to Emitter voltage of the high voltage \( Q_g \) measurement (V)
- \( V_{ceOn} \): On-state Collector current (A)
- \( V_{geOn} \): On-state Gate to Emitter voltage (V)
- \( V_{geOff} \): Off-state Gate to Emitter voltage (V)
- \( I_{gOn} \): On-state Gate current (A)
- \( I_{gOff} \): Off-state Gate current (A)
- \( V_{geTh} \): Gate threshold voltage (V)
- \( R_{gDUT} \): Gate series resistance (ohm)

[X-Y Plot]
- \( X \): Gate charge \( Q_g \) (C)
- \( Y_1 \): Gate to Emitter voltage derived from JESD24-2 line fitting \( V_{geJESD24_2} \) (V)
- \( Y_2 \): Gate to Emitter voltage of the high current \( Q_g \) measurement \( V_{geHC} \) (V)
- \( Y_3 \): Gate to Emitter voltage of the high voltage \( Q_g \) measurement \( V_{geHV} \) (V)

[List Display]
- \( Q_g \): Gate charge (C)
- \( V_{geJESD24_2} \): Gate to Emitter voltage derived from JESD24-2 line fitting (V)
- \( V_{geHC} \): Gate to Emitter voltage of the high current \( Q_g \) measurement (V)
- \( V_{geHV} \): Gate to Emitter voltage of the high voltage \( Q_g \) measurement (V)
- \( V_{ceHC} \): Collector to Emitter voltage of the high current \( Q_g \) measurement (V)
- \( V_{ceHV} \): Collector to Emitter voltage of the high voltage \( Q_g \) measurement (V)
29 GateCharge, IGBT

[Parameters Display Area]
VOff: Off-state Collector to Emitter voltage (V)
ION: On-state Collector current (A)
VgePl: Gate plateau voltage (V)
Qge: Gate-Emitter charge (C)
Qgc: Gate-Collector charge (C)
QgTh: Gate-Emitter threshold charge (C)
QgOn: Total Gate charge (C)
S1: Slope1 (V/nC)
S2: Slope2 (V/nC)
C1: Qge/(VgePl-VgeOff) (F)
C2: (QgOn-Qge-Qgc)/(VgeOn-VgePl) (F)
OpenCHC: Open compensation capacitance of the high current Qg measurement (F)
ShortRHC: Short compensation resistance of the high current Qg measurement (ohm)
OpenCHV: Open compensation capacitance of the high voltage Qg measurement (F)
ShortRHV: Short compensation resistance of the high voltage Qg measurement (ohm)
29.3 $Q_g$ (High Ic + JESD24-2): High current gate charge measurement and characterization (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Performs the high current gate charge measurement and characterization by specifying the on voltage, on current, and the range of gate voltages.

[Device Under Test]
IGBT

[Device Parameters]
$Q_g$MaxXAxis: Maximum end point of Y axis for $Q_g$ (C)
$V_{ge}$Th: Gate threshold voltage (V)

[Test Parameters]
$V_{ce}$Off: Off-state Collector to Emitter voltage (V)
$I_{c}$On: On-state Collector current (A)
$V_{ge}$Off: Off-state Gate to Emitter voltage (V)
$V_{ge}$On: On-state Gate to Emitter voltage (V)
$I_g$: Gate current (A)
Load$V_{ge}$Off: Off-state Gate to Emitter voltage of the constant current load (V)
Load$V_{ge}$On: On-state Gate to Emitter voltage of the constant current load (V)
Load$I_g$: Gate current of the constant current load (A)
Load$V_{ge}$: Gate to Emitter voltage of the constant current load (V) (-30: Auto)
$R_g$Ext: Gate resistance selection (ohm)
$R_g$DUT: Gate series resistance (ohm)
$V_{ge}$StartOffset: Offset voltage of Gate to Emitter start voltage (V)
$V_{ge}$StopOffset: Offset voltage of Gate to Emitter stop voltage (V)
Delay$V_{ce}$: Delay time to change Collector to Emitter voltage (s)
Delay$V_{ge}$: Delay time to change Gate to Emitter voltage (s)
OnPeriod: On period (s)

[X-Y Plot]
X: Gate charge $Q_g$ (C)
Y1: Gate to Emitter voltage derived from JESD24-2 line fitting $V_{ge}$JESD24_2 (V)
Y2: Gate to Emitter voltage $V_{ge}$ (V)

[List Display]
$Q_g$: Gate charge (C)
$V_{ge}$JESD24_2: Gate to Emitter voltage derived from JESD24-2 line fitting (V)
$V_{ge}$: Gate to Emitter voltage (V)
$V_{ce}$: Collector to Emitter voltage (V)

[Parameters Display Area]
$V_{Off}$: Off-state Collector to Emitter voltage (V)
$I_{On}$: On-state Collector current (A)
$V_{ge}$Pl: Gate plateau voltage (V)
$Q_{ge}$: Gate-Emitter charge (C)
$Q_{gc}$: Gate-Collector charge (C)
$Q_{gTh}$: Gate-Emitter threshold charge (C)
GateCharge, IGBT

QgOn: Total Gate charge (C)
S1: Slope1 (V/nC)
S2: Slope2 (V/nC)
C1: Qge/(VgePl-VgeOff) (F)
C2: (QgOn-Qge-Qgc)/(VgeOff-VgePl) (F)
OpenC: Open compensation capacitance (F)
ShortR: Short compensation resistance (ohm)
29.4 \textit{Qg (R Load High \textit{Ic} + JESD24-2): High current (with resistive load) gate charge measurement and characterization (A.06.00)}

[Supported Analyzer]
B1505A, B1506A

[Description]
Performs the high current (with resistive load) gate charge measurement and characterization by specifying the on voltage, on current, and the range of gate voltages.

[Device Under Test]
IGBT

[Device Parameters]
\text{QgMaxXAxis: Maximum end point of Y axis for Qg (C)}
\text{VgeTh: Gate threshold voltage (V)}

[Test Parameters]
\text{LoadV: Load voltage (V) (0: Auto). In case of Auto, load voltage will be adjusted for IcOn.}
\text{VceOff: Off-state Collector to Emitter voltage (V)}
\text{IcOn: On-state Collector current (A)}
\text{VgeOff: Off-state Gate to Emitter voltage (V)}
\text{VgeOn: On-state Gate to Emitter voltage (V)}
\text{Ig: Gate current (A)}
\text{RgExt: Gate resistance selection (ohm)}
\text{RgDUT: Gate series resistance (ohm)}
\text{VgeStartOffset: Offset voltage of Gate to Emitter start voltage (V)}
\text{VgeStopOffset: Offset voltage of Gate to Emitter stop voltage (V)}
\text{DelayVge: Delay time to change Gate to Emitter voltage (s)}
\text{OnPeriod: On period (s)}

[X-Y Plot]
\text{X: Gate charge Qg (C)}
\text{Y1: Gate to Emitter voltage derived from JESD24-2 line fitting VgeJESD24_2 (V)}
\text{Y2: Gate to Emitter voltage Vge (V)}

[List Display]
\text{Qg: Gate charge (C)}
\text{VgeJESD24_2: Gate to Emitter voltage derived from JESD24-2 line fitting (V)}
\text{Vge: Gate to Emitter voltage (V)}
\text{Vce: Collector to Emitter voltage (V)}

[Parameters Display Area]
\text{VOff: Off-state Collector to Emitter voltage (V)}
\text{IOn: On-state Collector current (A)}
\text{VgePl: Gate plateau voltage (V)}
\text{Qge: Gate-Emitter charge (C)}
\text{Qgc: Gate-Collector charge (C)}
\text{QgTh: Gate-Emitter threshold charge (C)}
\text{QgOn: Total Gate charge (C)}
\text{S1: Slope1 (V/nC)}
\text{S2: Slope2 (V/nC)}
\text{C1: Qge/(VgePl-VgeOff) (F)}
29 GateCharge, IGBT

C2: (QgOn-Qge-Qgc)/(VgeOn-VgePl) (F)
OpenC: Open compensation capacitance (F)
ShortR: Short compensation resistance (ohm)
29.5 Qg (High Vce + JESD24-2): High voltage gate charge measurement and characterization (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Performs the high voltage gate charge measurement and characterization by specifying the on voltage, on current, and the range of gate voltages.

[Device Under Test]
IGBT

[Device Parameters]
QgMaxXAxis: Maximum end point of Y axis for Qg (C)
VgeTh: Gate threshold voltage (V)

[Test Parameters]
VceOff: Off-state Collector to Emitter voltage (V)
VgeOff: Off-state Gate to Emitter voltage (V)
VgeOn: On-state Gate to Emitter voltage (V)
Ig: Gate current (A)
RgExt: Gate resistance selection (ohm)
RgDUT: Gate series resistance (ohm)
VgeStartOffset: Offset voltage of Gate to Emitter start voltage (V)
VgeStopOffset: Offset voltage of Gate to Emitter stop voltage (V)
DelayVge: Delay time to change Gate to Emitter voltage (s)
OnPeriod: On period (s)

[X-Y Plot]
X: Gate charge Qg (C)
Y1: Gate to Emitter voltage derived from JESD24-2 line fitting VgeJESD24_2 (V)
Y2: Gate to Emitter voltage Vge (V)

[List Display]
Qg: Gate charge (C)
VgeJESD24_2: Gate to Emitter voltage derived from JESD24-2 line fitting (V)
Vge: Gate to Emitter voltage (V)
Vce: Collector to Emitter voltage (V)

[Parameters Display Area]
VOff: Off-state Collector to Emitter voltage (V)
VgePl: Gate plateau voltage (V)
Qge: Gate-Emitter charge (C)
Qgc: Gate-Collector charge (C)
QgTh: Gate-Emitter threshold charge (C)
QgOn: Total Gate charge (C)
S1: Slope1 (V/nC)
S2: Slope2 (V/nC)
C1: Qge/(VgePl-VgeOff) (F)
C2: (QgOn-Qge-Qgc)/(VgeOn-VgePl) (F)
OpenC: Open compensation capacitance (F)
ShortR: Short compensation resistance (ohm)
29.6 $Q_g$ (JESD24-2 High $I_c$ + JESD24-2 High $V_{ce}$): Gate charge characterization (A.06.00)

[Supported Analyzer]
- B1505A, B1506A

[Description]
Performs the high current and high voltage gate charge characterization.

[Device Under Test]
IGBT

[Device Parameters]
- $Q_g_{MaxXAxis}$: Maximum end point of Y axis for $Q_g$ (C)
- $V_{geTh}$: Gate threshold voltage (V)

[X-Y Plot]
- X: Gate charge $Q_g$ (C)
- Y1: Gate to Emitter voltage derived from JESD24-2 line fitting $V_{geJESD24_2}$ (V)

[List Display]
- $Q_g$: Gate charge (C)
- $V_{geJESD24_2}$: Gate to Emitter voltage derived from JESD24-2 line fitting (V)

[Parameters Display Area]
- $V_{Off}$: Off-state Collector to Emitter voltage (V)
- $I_{On}$: On-state Collector current (A)
- $V_{gePl}$: Gate plateau voltage (V)
- $Q_{ge}$: Gate-Emitter charge (C)
- $Q_{gc}$: Gate-Collector charge (C)
- $Q_{gTh}$: Gate-Emitter threshold charge (C)
- $Q_{gOn}$: Total Gate charge (C)
- $S_1$: Slope1 (V/nC)
- $S_2$: Slope2 (V/nC)
- $C_1$: $Q_{ge}/(V_{gePl}-V_{geOff})$ (F)
- $C_2$: $(Q_{gOn}-Q_{ge}-Q_{gc})/(V_{geOn}-V_{gePl})$ (F)
29.7 $Q_g$ (High $I_c$ + High $V_{ce}$): High current and high voltage gate charge measurement (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Performs the high current and high voltage gate charge measurement.

[Device Under Test]
IGBT

[Device Parameters]
$Q_{g\text{MaxXAxis}}$: Maximum end point of Y axis for $Q_g$ (C)

[Test Parameters]
$V_{ce\text{Off}}$: Off-state Collector to Emitter voltage (V)
$I_{c\text{On}}$: On-state Collector current (A)
$V_{ge\text{Off}}$: Off-state Gate to Emitter voltage (V)
$V_{ge\text{On}}$: On-state Gate to Emitter voltage (V)
$I_{g\text{HC}}$: Gate current for the high current $Q_g$ measurement (A)
$I_{g\text{HV}}$: Gate current for the high voltage $Q_g$ measurement (A)
$LoadV_{ge\text{Off}}$: Off-state Gate to Emitter voltage of the constant current load (V)
$LoadV_{ge\text{On}}$: On-state Gate to Emitter voltage of the constant current load (V)
$LoadI_g$: Gate current of the constant current load (A)
$LoadV_{ge}$: Gate to Emitter voltage of the constant current load (V) (-30: Auto)
$R_{g\text{ExtHC}}$: Gate resistance selection for the high current $Q_g$ measurement (ohm)
$R_{g\text{ExtHV}}$: Gate resistance selection for the high voltage $Q_g$ measurement (ohm)
$R_{g\text{DUT}}$: Gate series resistance (ohm)
$V_{ge\text{StartOffsetHC}}$: Offset voltage of Gate to Emitter start voltage for the high current $Q_g$ measurement (V)
$V_{ge\text{StopOffsetHC}}$: Offset voltage of Gate to Emitter stop voltage for the high current $Q_g$ measurement (V)
$DelayV_{ge\text{HC}}$: Delay time to change Collector to Emitter voltage of the high current $Q_g$ measurement (s)
$DelayV_{ge\text{HC}}$: Delay time to change Gate to Emitter voltage of the high current $Q_g$ measurement (s)
$OnPeriodHC$: On period for the high current $Q_g$ measurement (s)
$V_{ge\text{StartOffsetHV}}$: Offset voltage of Gate to Emitter start voltage for the high voltage $Q_g$ measurement (V)
$V_{ge\text{StopOffsetHV}}$: Offset voltage of Gate to Emitter stop voltage for the high voltage $Q_g$ measurement (V)
$DelayV_{ge\text{HV}}$: Delay time to change Gate to Emitter voltage of the high voltage $Q_g$ measurement (s)
$OnPeriodHV$: On period for the high voltage $Q_g$ measurement (s)

[X-Y Plot]
X: Gate charge $Q_g$ (C)
Y1: Gate to Emitter voltage of the high current $Q_g$ measurement $V_{ge\text{HC}}$ (V)
Y2: Gate to Emitter voltage of the high voltage $Q_g$ measurement $V_{ge\text{HV}}$ (V)

[List Display]
$Q_g$: Gate charge (C)
$V_{ge\text{HC}}$: Gate to Emitter voltage of the high current $Q_g$ measurement (V)
$V_{ge\text{HV}}$: Gate to Emitter voltage of the high voltage $Q_g$ measurement (V)
$V_{ce\text{HC}}$: Collector to Emitter voltage of the high current $Q_g$ measurement (V)
$V_{ce\text{HV}}$: Collector to Emitter voltage of the high voltage $Q_g$ measurement (V)

[Parameters Display Area]
$V_{c\text{Off}}$: Off-state Collector to Emitter voltage (V)
29 GateCharge, IGBT

ION: On-state Collector current (A)
QgOnHC: Total gate charge of the high current Qg measurement (C)
QgOnHV: Total gate charge of the high voltage Qg measurement (C)
OpenCHC: Open compensation capacitance of the high current Qg measurement (F)
ShortRHC: Short compensation resistance of the high current Qg measurement (ohm)
OpenCHV: Open compensation capacitance of the high voltage Qg measurement (F)
ShortRHV: Short compensation resistance of the high voltage Qg measurement (ohm)
29.8 $Q_g (R \text{ Load High } I_c + \text{ High } V_{ce})$: High current (with resistive load) and high voltage gate charge measurement (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Performs the high current (with resistive load) and high voltage gate charge measurement.

[Device Under Test]
IGBT

[Device Parameters]
$Q_{g\text{Max}X\text{Axis}}$: Maximum end point of Y axis for $Q_g$ (C)

[Test Parameters]
LoadV: Load voltage (V) (0: Auto). In case of Auto, load voltage will be adjusted for $I_{c\text{On}}$.
$V_{c\text{Off}}$: Off-state Collector to Emitter voltage (V)
$I_{c\text{On}}$: On-state Collector current (A)
$V_{ge\text{Off}}$: Off-state Gate to Emitter voltage (V)
$V_{ge\text{On}}$: On-state Gate to Emitter voltage (V)
$I_{g\text{HC}}$: Gate current for the high current $Q_g$ measurement (A)
$I_{g\text{HV}}$: Gate current for the high voltage $Q_g$ measurement (A)
$R_{g\text{ExtHC}}$: Gate resistance selection for the high current $Q_g$ measurement (ohm)
$R_{g\text{ExtHV}}$: Gate resistance selection for the high voltage $Q_g$ measurement (ohm)
$R_{g\text{DUT}}$: Gate series resistance (ohm)
$V_{ge\text{StartOffsetHC}}$: Offset voltage of Gate to Emitter start voltage for the high current $Q_g$ measurement (V)
$V_{ge\text{StopOffsetHC}}$: Offset voltage of Gate to Emitter stop voltage for the high current $Q_g$ measurement (V)
$\text{Delay}_{V_{ge\text{HC}}}$: Delay time to change Gate to Emitter voltage of the high current $Q_g$ measurement (s)
$\text{OnPeriod}_{HC}$: On period for the high current $Q_g$ measurement (s)
$V_{ge\text{StartOffsetHV}}$: Offset voltage of Gate to Emitter start voltage for the high voltage $Q_g$ measurement (V)
$V_{ge\text{StopOffsetHV}}$: Offset voltage of Gate to Emitter stop voltage for the high voltage $Q_g$ measurement (V)
$\text{Delay}_{V_{ge\text{HV}}}$: Delay time to change Gate to Emitter voltage of the high voltage $Q_g$ measurement (s)
$\text{OnPeriod}_{HV}$: On period for the high voltage $Q_g$ measurement (s)

[X-Y Plot]
X: Gate charge $Q_g$ (C)
Y1: Gate to Emitter voltage of the high current $Q_g$ measurement $V_{ge\text{HC}}$ (V)
Y2: Gate to Emitter voltage of the high voltage $Q_g$ measurement $V_{ge\text{HV}}$ (V)

[List Display]
$Q_g$: Gate charge (C)
$V_{ge\text{HC}}$: Gate to Emitter voltage of the high current $Q_g$ measurement (V)
$V_{ge\text{HV}}$: Gate to Emitter voltage of the high voltage $Q_g$ measurement (V)
$V_{c\text{eHC}}$: Collector to Emitter voltage of the high current $Q_g$ measurement (V)
$V_{c\text{eHV}}$: Collector to Emitter voltage of the high voltage $Q_g$ measurement (V)

[Parameters Display Area]
$V_{c\text{Off}}$: Off-state Collector to Emitter voltage (V)
$I_{c\text{On}}$: On-state Collector current (A)
$Q_{g\text{OnHC}}$: Total gate charge of the high current $Q_g$ measurement (C)
$Q_{g\text{OnHV}}$: Total gate charge of the high voltage $Q_g$ measurement (C)
$\text{OpenCHC}$: Open compensation capacitance of the high current $Q_g$ measurement (F)
29 GateCharge, IGBT

ShortRHC: Short compensation resistance of the high current Qg measurement (ohm)
OpenCHV: Open compensation capacitance of the high voltage Qg measurement (F)
ShortRHV: Short compensation resistance of the high voltage Qg measurement (ohm)
29.9 Qg (High Ic): High current gate charge measurement (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Performs the high current gate charge measurement.

[Device Under Test]
IGBT

[Device Parameters]
QgMaxXAxis: Maximum end point of Y axis for Qg (C)

[Test Parameters]
VceOff: Off-state Collector to Emitter voltage (V)
IcOn: On-state Collector current (A)
VgeOff: Off-state Gate to Emitter voltage (V)
VgeOn: On-state Gate to Emitter voltage (V)
Ig: Gate current (A)
LoadVgeOff: Off-state Gate to Emitter voltage of the constant current load (V)
LoadVgeOn: On-state Gate to Emitter voltage of the constant current load (V)
LoadIg: Gate current of the constant current load (A)
LoadVge: Gate to Emitter voltage of the constant current load (V) (-30: Auto)
RgExt: Gate resistance selection (ohm)
RgDUT: Gate series resistance (ohm)
VgeStartOffset: Offset voltage of Gate to Emitter start voltage (V)
VgeStopOffset: Offset voltage of Gate to Emitter stop voltage (V)
DelayVce: Delay time to change Collector to Emitter voltage (s)
DelayVge: Delay time to change Gate to Emitter voltage (s)
OnPeriod: On period (s)

[X-Y Plot]
X: Gate charge Qg (C)
Y1: Gate to Emitter voltage Vge (V)

[List Display]
Qg: Gate charge (C)
Vge: Gate to Emitter voltage (V)
Vce: Collector to Emitter voltage (V)

[Parameters Display Area]
VOff: Off-state Collector to Emitter voltage (V)
ION: On-state Collector current (A)
QgOn: Total Gate charge (C)
OpenC: Open compensation capacitance (F)
ShortR: Short compensation resistance (ohm)
29 GateCharge, IGBT

29.10 Qg (R Load High Ic): High current (with resistive load) gate charge measurement (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Performs the high current (with resistive load) gate charge measurement.

[Device Under Test]
IGBT

[Device Parameters]
QgMaxXAxis: Maximum end point of Y axis for Qg (C)

[Test Parameters]
LoadV: Load voltage (V) (0: Auto). In case of Auto, load voltage will be adjusted for IcOn.
VceOff: Off-state Collector to Emitter voltage (V)
IcOn: On-state Collector current (A)
VgeOff: Off-state Gate to Emitter voltage (V)
VgeOn: On-state Gate to Emitter voltage (V)
Ig: Gate current (A)
RgExt: Gate resistance selection (ohm)
RgDUT: Gate series resistance (ohm)
VgeStartOffset: Offset voltage of Gate to Emitter start voltage (V)
VgeStopOffset: Offset voltage of Gate to Emitter stop voltage (V)
DelayVge: Delay time to change Gate to Emitter voltage (s)
OnPeriod: On period (s)

[X-Y Plot]
X: Gate charge Qg (C)
Y1: Gate to Emitter voltage Vge (V)

[List Display]
Qg: Gate charge (C)
Vge: Gate to Emitter voltage (V)
Vce: Collector to Emitter voltage (V)

[Parameters Display Area]
VOff: Off-state Collector to Emitter voltage (V)
ION: On-state Collector current (A)
QgOn: Total Gate charge (C)
OpenC: Open compensation capacitance (F)
ShortR: Short compensation resistance (ohm)
29.11 Qg (High Vce): High voltage gate charge measurement (A.06.00)

[Supported Analyzer]
  B1505A, B1506A

[Description]
Performs the high voltage gate charge measurement.

[Device Under Test]
IGBT

[Device Parameters]
QgMaxXAxis: Maximum end point of Y axis for Qg (C)

[Test Parameters]
  VceOff: Off-state Collector to Emitter voltage (V)
  VgeOff: Off-state Gate to Emitter voltage (V)
  VgeOn: On-state Gate to Emitter voltage (V)
  Ig: Gate current (A)
  RgExt: Gate resistance selection (ohm)
  RgDUT: Gate series resistance (ohm)
  VgeStartOffset: Offset voltage of Gate to Emitter start voltage (V)
  VgeStopOffset: Offset voltage of Gate to Emitter stop voltage (V)
  DelayVge: Delay time to change Gate to Emitter voltage (s)
  OnPeriod: On period (s)

[X-Y Plot]
  X: Gate charge Qg (C)
  Y1: Gate to Emitter voltage Vge (V)

[List Display]
  Qg: Gate charge (C)
  Vge: Gate to Emitter voltage (V)
  Vce: Collector to Emitter voltage (V)

[Parameters Display Area]
  VOff: Off-state Collector to Emitter voltage (V)
  QgOn: Total Gate charge (C)
  OpenC: Open compensation capacitance (F)
  ShortR: Short compensation resistance (ohm)
GateCharge, IGBT
1. IV Path (N1272A): Build N1272A path for IV measurement (A.06.00)
2. N1272ACheckBreakdown For checking DUT breakdown prior to capacitance measurement (A.06.00)
30.1 IV Path (N1272A): Build N1272A path for IV measurement (A.06.00)

[Supported Analyzer]
   B1505A, B1506A

[Description]
   Builds N1272A path for IV measurement.

[Test Parameters]
   DCGuard: DC guard output (1: Common, 2: HVSMU)
30.2 N1272A CheckBreakdown: For checking DUT breakdown prior to capacitance measurement (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Checks if the DUT breakdown is caused or not under the specified conditions before executing the capacitance measurement.

[Test Parameters]
Hold: Hold time for applying biases (s)
Delay: Delay time after applying biases (s)
Gate: MPSMU for gate bias
VGS: Gate bias voltage (V)
Drain: HVSMU for drain bias
VDS: Drain bias voltage (V)
InCaseOfBreakdown: Action taken in case of DUT breakdown detection (0: Tacit, 1: Error)

[Output Parameters]
Failed: Breakdown detection result (1: breakdown detected, 0: others)
31 MultiHVSMU
1. Switch HVSMU Output Mode: Switches Multi-HVSMU operation mode using HVSMUOP command (A.06.00)
31.1 Switch HVSMU Output Mode: Switches Multi-HVSMU operation mode using HVSMUOP command. (A.06.00)

[Supported Analyzer]
B1505A

[Description]
Switches the output operation mode of the Multi-HVSMU by using HVSMUOP command.
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32.1 ThermoStream WaitReady: Wait for the ready bit of the ThermoStream (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Waits until the ready bit of the ThermoStream is set.

[Test Parameters]
GPIBAddress: GPIB address of the ThermoStream (0 - 31)
32 Thermal

32.2 *ThermoStream FlowOff: Stop of the ThermoStream air flow (A.06.00)*

[Supported Analyzer]
B1505A, B1506A

[Description]
Turn the ThermoStream air flow off.

[Test Parameters]
GPIBAddress: GPIB address of the ThermoStream (0 - 31)
32.3 *ThermoStream Initialize: ThermoStream Initialize: Initialization of the ThermoStream (A.06.00)*

[Supported Analyzer]
B1505A, B1506A

[Description]
Initialize the ThermoStream.

[Test Parameters]
GPIBAddress: GPIB address of the ThermoStream (0 - 31)
32.4 ThermoStream DefineParameters: ThermoStream DefineParameters: A setting the ThermoStream parameters (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Set the ThermoStream parameters.

[Test Parameters]
GPIBAddress: GPIB address of the ThermoStream (0 - 31)
DUT_sensor: DUT sensor type to use (0: OFF, 1: T, 2: K)
DUT_self_tuning_control: DUT self tuning control (0: OFF, 1: ON)
DUT_thermal_constant: DUT thermal constant (20 - 500)
Air_to_DUT_max: Maximum allowable temperature difference between Air and DUT in deg C (10 - 300)
Air_temperature_max: Maximum air temperature (deg C)
Air_temperature_min: Minimum air temperature (deg C)
32.5 ThermoStream Control Temperature: A setting the ThermoStream target temperature (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Set the set point temperature and ramp rate to the ThermoStream and turn on the air flow.

[Test Parameters]
GPIBAddress: GPIB address of the ThermoStream (0 - 31)
Thermometer: Thermometer to use (0: Air, 1: DUT)
SetPoint: Target temperature (deg C)
RampRate: Temperature ramp rate (deg C/min)
32.6 *ThermoStream WaitTemperature: A waiting for a target temperature with the ThermoStream thermometer (A.06.00)*

[Supported Analyzer]
B1505A, B1506A

[Description]
Wait until the reading of the ThermoStream thermometer reaches the target temperature. In addition, record the last temperature reading with the test result of the succeeding tests.

[Test Parameters]
- GPIBAddress: GPIB address of the ThermoStream (0 - 31)
- Thermometer: Thermometer to use (0: Air, 1: DUT)
- HoldTime: Wait time before starting reading of the temperature (s)
- Center: Center of the expected temperature range (deg C)
- Radius: Radius of the expected temperature range (deg C)
- SoakTime: Soak time after the temperature into the expected temperature range (s)
- ReadingSpan: Thermometer reading time span (s)
- Timeout: Timeout of the temperature waiting (s) (-1: Never)

[Parameters Display Area]
Temperature: The last thermometer reading (deg C)
32.7 N1265A WaitTemperature: A waiting for a target temperature with the N1265 thermometer (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Wait until the reading of the N1265A thermometer reaches the target temperature.

[Test Parameters]
Thermometer: Thermometer to use (1: Ch1, 2: Ch2, 0: Ch1 - Ch2)
HoldTime: Wait time before starting reading of the temperature (s)
Center: Center of the expected temperature range (deg C)
Radius: Radius of the expected temperature range (deg C)
SoakTime: Soak time after the temperature into the expected temperature range (s)
ReadingSpan: Thermometer reading time span (s)
Timeout: Timeout of the temperature waiting (s) (-1: Never)

[Parameters Display Area]
TemperatureCh1: The last thermometer reading of Ch1 (deg C)
TemperatureCh2: The last thermometer reading of Ch2 (deg C)
TemperatureCh1_Ch2: The last thermometer reading of (Ch1 - Ch2) (deg C)
32 Thermal

32.8 ThermoStream ReadTemperature: Reading and recording of the ThermoStream temperature (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Read the thermometer of the ThermoStream and record it with the test result of the succeeding tests.

[Test Parameters]
GPIBAddress: GPIB address of the ThermoStream (0 - 31)
Thermometer: Thermometer to use (0: Air, 1: DUT)
HoldTime: Wait time before starting reading of the temperature (s)

[Parameters Display Area]
Temperature: Thermometer reading (deg C)
32.9 ThermalPlate ControlTemperature: A setting the ThermalPlate target temperature (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Set the set point temperature and ramp rate to the ThermalPlate.

[Test Parameters]
GPIBAddress: GPIB address of the ThermalPlate (0 - 31)
SetPoint: Target temperature (deg C)
RampRate: Temperature ramp rate (deg C/min)
32.10 *ThermalPlate DefineParameters: A setting the ThermalPlate parameters. (A.06.00)*

[Supported Analyzer]
B1505A, B1506A

[Description]
Set the ThermalPlate parameters.

[Test Parameters]
GPIBAddress: GPIB address of the ThermalPlate (0 - 31)
Frequency: Line frequency (3: 50Hz, 4: 60Hz)
Upper_temperature_limit: Upper temperature limit value (deg C)
32.11 ThermalPlate Initialize: Initialization of the ThermalPlate (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Initialize the ThermalPlate.

[Test Parameters]
GPIBAddress: GPIB address of the ThermalPlate (0 - 31)
32.12 ThermalPlate ReadTemperature: Reading and recording of the ThermalPlate temperature (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Read the thermometer of the ThermalPlate and record it with the test result of the succeeding tests.

[Test Parameters]
GPIBAddress: GPIB address of the ThermalPlate (0 - 31)
HoldTime: Wait time before starting reading of the temperature (s)

[Parameters Display Area]
Temperature: Thermometer reading (deg C)
32.13 ThermalPlate WaitTemperature: A waiting for a target temperature with the ThermalPlate thermometer (A.06.00)

[Supported Analyzer]
B1505A, B1506A

[Description]
Wait until the reading of the ThermalPlate thermometer reaches the target temperature. In addition, record the last temperature reading with the test result of the succeeding tests.

[Test Parameters]
GPIBAddress: GPIB address of the ThermalPlate (0 - 31)
HoldTime: Wait time before starting reading of the temperature (s)
Center: Center of the expected temperature range (deg C)
Radius: Radius of the expected temperature range (deg C)
SoakTime: Soak time after the temperature into the expected temperature range (s)
ReadingSpan: Thermometer reading time span (s)
Timeout: Timeout of the temperature waiting (s) (-1: Never)

[Parameters Display Area]
Temperature: The last thermometer reading (deg C)
32 Thermal
1. IV Path (N1274A): Build N1274A path for IV measurement (A.06.00)
33.1 IV Path (N1274A): Build N1274A path for IV measurement (A.06.00)

[Supported Analyzer]
B1505A

[Description]
Builds N1274A path for IV measurement.
1. FERAM Hysteresis       FERAM Hysteresis characteristics (A.06.20)
2. FERAM PUND            FERAM PUND characteristics (A.06.20)
3. FERAM Endurance       FERAM Endurance test (A.06.20)
4. ReRAM IV-Butterfly    ReRAM IV characteristics - Butterfly curve (A.06.20)
5. ReRAM FORM            ReRAM FORM characteristics (A.06.20)
6. ReRAM Set ResetV-Loop ReRAM Set and ResetV-Loop characteristics (A.06.20)
7. ReRAM Reset SetV-Loop ReRAM Reset and SetV-Loop characteristics (A.06.20)
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9. ReRAM Endurance       ReRAM Endurance test (A.06.20)
10. PCRAM Reset-Set      PCRAM Reset-Set characteristics (A.06.20)
11. PCRAM ResetV-Loop    PCRAM ResetV-Loop characteristics (A.06.20)
12. PCRAM SetV-Loop      PCRAM SetV-Loop characteristics (A.06.20)
13. PCRAM Endurance      PCRAM Endurance test (A.06.20)
34.1 FERAM Hysteresis: FERAM Hysteresis characteristics (A.06.20)

[Supported Analyzer]
B1500A

[Description]
Performs hysteresis characteristics measurements of the Ferro-electric material. Triangular wave is applied, and measures the displacement current through the Ferro-electric material. The hysteresis charge is displayed, and the hysteresis parameters are extracted.

[Device Under Test]
Capacitor structure with Ferro-electric material as capacitor dielectric.

[Required Modules and Accessories]
Keysight B1530A WGFMU 1 unit
Keysight B1531A RSU 2 set

[Device Parameters]
Area: Area of capacitor electrode
Gap: Electrode Gap
Temp: Temperature

[Test Parameters]
Waveform Parameters (Vs):
  - Vp: Peak voltage for both + & - triangular pulse
  - Frequency: Frequency of the Triangular waveform.
  - Dt: Delay time. Only set in the beginning of the test wave.
  - Note: Delaytime is not set between the repeat triangular wave.

Measurement (Im) & Display Parameters:
  - Meas_Points: Total measurement points. Multiples of 4 are required.
  - IrangeIm: Current range of the Im RSU
  - Display_Mode: Output data choice of the output display.
    - Charge: Display charge vs. voltage x-y graph
    - ChargeAndCurrent: Display charge(Y1) and current(Y2) vs. voltage x-y graph
    - ChargeAndCapacitor: Display charge(Y1) and capacitor(Y2) vs. voltage x-y graph

Measurement resources:
  - Vs: RSU channel of the Vs -Voltage source RSU.
  - Im: RSU channel of the Im - Current measurement RSU.

[Extended Test Parameters]
  - Dt_AtVp: Put a delay time at the top of the Vp before the start of the next slope.
    - If "0 ns", the next measurement point is the 2nd points of the next slope.
  - Freq_WarningP: Frequency range warning limit percentage:
    - Example: 10 = 10% error does show warning message.
  - Repeat: Repeats the Triangular waveform. Maximum 10.
  - IV_CurvePosition: Specified number is used when plotting the IV curve when the triangular waveform is repeated.
  - IrangeVs: Output current range of the Vs.

DataDisplay_PatternValidation: this parameter is effective in “Run Vector” execution setting.
  - Enable (Waveform or Waveform_MeasTiming): shows “PatternValidation Data Display”.
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- Disable: Does not show “PatternValidation Data Display”.

ExecutionMode: Choice of “Execution Mode”
- Run Vector: Measurement is made with the WGFMU/RSU
- Pattern Validation: Used to check the vector data created to run WGFMU/RSU.
  Can be executed without running the B1500A.

[X-Y Plot: Measurement Parameters]
Charge vs. voltage x-y graph:
  Extracted parameters:
  - Frequency_kHz: Frequency used for the measurements.
  - Prp, Prn, Ecp, Ecn
Charge and current vs. voltage x-y graph:
  Extracted parameters:
  - Frequency_kHz: Frequency used for the measurements.
  - Prp, Prn, Ecp, Ecn
Charge and capacitor vs. voltage x-y graph:
  Extracted parameters:
  - Frequency_kHz: Frequency used for the measurements.
34.2 FERAM PUND: FERAM PUND characteristics (A.06.20)

[Supported Analyzer]
B1500A

[Description]
PUND waves are applied to the ferro-electric material, and the applied voltage and current or charge are displayed with the extracted PUND parameters.

[Device Under Test]
Capacitor structure with Ferro-electric material as capacitor dielectric.

[Required Modules and Accessories]
Keysight B1530A WGMFU 1 unit
Keysight B1531A RSU 2 set

[Device Parameters]
Area: Area of capacitor electrode
Gap: Electrode Gap
Temp: Temperature

[Test Parameters]
Waveform Parameters (Vs):
  - Vp: Peak voltage for both + & - triangular pulse
  - Trf: Rise time (Tr) and Fall time (Tf)
  - TopWidth: Pulse top width
  - DelayTime: Delay time. Only set in the beginning of the test wave.
  - Note: "DelayTime" is not set between the repeat triangular wave.

Measurement Parameters (Im):
  - IrangelIm: Current range of the Im RSU

Measurement resources:
  - Vs: RSU channel of the Vs - Voltage source RSU.
  - Im: RSU channel of the Im - Current measurement RSU.

[Extended Test Parameters]
Sampling_interval: Minimum sampling interval used for obtaining the proper test parameters for RSU.
  - "Trf/Sampling interval >10" are required.

Display_Mode: Output data selection of the output display.
  - Charge: Display charge vs. time x-y graph
  - ChargeAndCurrent: Display charge(Y1) and current(Y2) vs. time x-y graph

IrangelVs: Output current range of the Vs RSU.

DataDisplay_PatternValidation: this parameter is effective in “Run Vector” execution setting.
  - Enable (Waveform or Waveform_MeasTiming): shows “PatternValidation Data Display”.
  - Disable: Does not show “PatternValidation Data Display”.

ExecutionMode: Choice of “Execution Mode”
  - Run Vector: Measurement is made with the WGMFU/RSU
  - Pattern Validation: Used to check the vector data created to run WGMFU/RSU.
    Can be executed without running the B1500A.
[X-Y Plot: Measurement Parameters]
Charge vs. Time x-y graph:
   Extracted parameters:
      - ChargeP, ChargeU, ChargeN, ChargeD, ChargePa, ChargeUa, ChargeNa, ChargeDa,
Charge and current vs. Time x-y graph:
   Extracted parameters:
      - ChargeP, ChargeU, ChargeN, ChargeD, ChargePa, ChargeUa, ChargeNa, ChargeDa,
34.3 FERAM Endurance: FERAM Endurance test (A.06.20)

[Supported Analyzer]
B1500A

[Description]
A stress/measure cycle test is performed by applying a user specified PUND stress waveforms and Max_loops stress cycle. Following test options are available for fatigue measurement numbers per decade of stress cycle, and the test exit criteria conditions before reaching to the specified Max_loops stress cycle.

[Device Under Test]
Capacitor structure with Ferro-electric material as capacitor dielectric.

[Required Modules and Accessories]
Keysight B1530A WGFMU 1 unit
Keysight B1531A RSU 2 set

[Device Parameters]
Area: Area of capacitor electrode
Gap: Electrode Gap
Temp: Temperature

[Test Parameters]
Waveform Parameters (Vs):
Vp: Peak voltage for both + & - triangular pulse
Trf: Rise time (Tr) and Fall time (Tf)
TopWidth: Pulse top width
DelayTime: Delay time. Only set in the beginning of the test wave.
Note: "DelayTime" is not set between the repeat triangular wave.

Measurement Parameters (Im):
Fatigue_C_dec: Specify the number of fatigue measurements in one decade of endurance stress cycle.
Sampling_Interval: Sampling interval in the fatigue PUND test to measure the PUND charge.
- "Trf/Sampling interval >10" are required.
IrangelIm: Current range of the Im RSU

Measurement resources:
Vs: RSU channel of the Vs -Voltage source RSU.
Im: RSU channel of the Im - Current measurement RSU.

[Extended Test Parameters]
Start_Fatigue_C: X-axis start number of the Fatigue count in the endurance test result display.
Rec_CharData: "NO" is recommended. "YES" saves all the intermediate characterization graph in the "Results area".
Rec_StrsData: "NO" is recommended. "YES" saves all the intermediate stress indication data in the "Results area".

DataDisplay_PatternValidation: this parameter is effective in “Run Vector” execution setting.
- Enable (Waveform or Waveform_MeasTiming): shows “PatternValidation Data Display”.
- Disable: Does not show “PatternValidation Data Display”.

ExecutionMode: Choice of “Execution Mode”
- Run Vector: Measurement is made with the WGFMU/RSU
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- Pattern Validation: Used to check the vector data created to run WGFMU/RSU.
  Can be executed without running the B1500A.

Irangel_Vs: Output current range of the Vs RSU.

[X-Y Plot: Measurement Parameters]
Display Data: PUND - Fatigue counts Setup graph: Displays the intermediate endurance test progress of the
following parameters:
- Displays Charge_P (Y1), Charge_U (Y2), Charge_N (Y3), Charge_D (Y4), vs. Fatigue_Count (X)

Display Data: PUND - Iterations Setup: Final output graph
- Displays Charge_P (Y1), Charge_U (Y2), Charge_N (Y3), Charge_D (Y4), vs. Iterations (X)
34.4 ReRAM IV-Butterfly: ReRAM IV characteristics - Butterfly curve (A.06.20)

[Supported Analyzer]
B1500A

[Description]
Performs double IV sweep starting from 0 V to SetV and ResetV. Y-axis choices of absolute-Log scale and linear are available. A control option for using external current limit device is available.

[Device Under Test]
ReRAM materials with the ReRAM memory structure.
Optionally, a ReRAM structure with a current limit FET (internal or outside the structure) is supported to apply a DC bias.

[Required Modules and Accessories]
SMU 2 modules (3 modules for current limit control option)
GNDU
Keysight B1530A WGF MU 1 unit
Keysight B1531A RSU 2 set
N1254A-100 GNDU to Kelvin Adapter
Triax TEE adapter (F-M-F) 1qty, Keysight P/N: 12500-1551
Triax (F) - BNC (M) adapter 2 qty, Keysight P/N: N1254-105
BNC (F-F) adapter 1 qty, Keysight P/N: 1250-0080

[Device Parameters]
Temp: Temperature

[Test Parameters]
V Source (Vs):
SetV: Maximum voltage to sweep in the SET direction.
ResetV: Maximum voltage to sweep in the RESET direction.
StepV: Step voltage of the sweep.
I_compliance: Current compliance of SMU_Vs.

Measurement & Display:
IntegTime: Integration time of SMU_Vs in the current measurement.
DelayTime: Delay time between the step measurements.
HoldTime: Hold time at the timing of the start, SetV, 0V to ResetV, and ResetV.
Display_Opt: Y axis scale selection from "Log (absolute)" and "Linear":
- LOG_Absolute: Plots absolute Im (Log Y axis) vs. Vm graph
- LINEAR: Plots Im vs. Vm graph

Measurement resources:
SMU_Vs: SMU channel of the SMU_Vs
SMU_Vm: SMU channel of the SMU_Vm.
- SMU_Vm is used to measure the output voltage of the SMU_Vs even when SMU_Vs is in a current limit status.
- 1 Mohm internal output resistor is used.
Optional Connection for current limit control for ReRAM device:

- **Enable_SMU_Vg**: "Disable" does not use SMU_Vg. "Enable" must specify both the SMU channel ("SMU_Vg") connected to the current limit transistor, and the gate voltage "Vg".
- **SMU_Vg**: SMU channel assignment of the gate connection (optional)
- **Vg**: Gate voltage of the current limit transistor (FET).

Specify the Vg to limit the ReRAM current in ON status. This current must be set larger than SMU_Vs's compliance "I_compliance".

**[Extended Test Parameters]**

- **Vs_MinRange**: Minimum current range setting of the limited auto-range of SMU_Vs.

**[X-Y Plot: Measurement Parameters]**

- Display Im versus Vm graph.
  - One selected from the two options is displayed:
    - **LOG_Absolute**: Plots absolute Im (Log Y axis) vs. Vm graph (Butterfly curve)
    - **LINEAR**: Plots Im vs. Vm graph
34.5 ReRAM FORM: ReRAM FORM characteristics (A.06.20)

[Supported Analyzer]
B1500A

[Description]
Performs Forming process characterization and the resistance measurement just after the Forming process. In the FORM process, a linear ramp slope pulse is applied, and the current through the ReRAM resistor device is measured. By detecting the sudden increase timing of Forming current, the FORM voltage is detected. A control option for using external current limit device is available.

[Device Under Test]
ReRAM materials with the ReRAM memory structure.
Optionally, a ReRAM structure with a current limit FET (internal or outside the structure) is supported to apply a DC bias.

[Required Modules and Accessories]
Keysight B1530A WGFMU 1 unit
Keysight B1531A RSU 2 set
SMU 1 unit (optional)

[Device Parameters]
Temp: Temperature

[Test Parameters]
Waveform output - Form:
- Vmax: Max voltage of the FORM pulse of the RSU_Vs.
  Set higher voltage than the FORM voltage of the ReRAM device.
- FORM_Tr: Rise time of the FORM pulse. At least, "FORM_Tr/ FORM_SamplingInterval >= 5" must be satisfied to detect the FORM voltage of the device.
- FORM_Tf: Fall time of the FORM pulse.
- TopWidth: Top width of the FORM Pulse.

Waveform output - R Measure:
- Rm_V: R measurement voltage after the FORM pulse.

Measurement:
- FORM_SamplingInterval: Sampling interval to measure the current in the FORM pulse. To detect the FORM voltage, sampling interval must be at least 5 times shorter than FORM_Tr.
- FORM_Im_range: Current range of RSU_Im (Im RSU). FORM current is measured by RSU_Im.
- FORM_detect_I: Current threshold which is set smaller than the FORM current in the specified measurement condition, and used to detect FORM voltage better in the output graph.
- Rm_Im_range: Current range of RSU_Im used measuring the R after the FORM pulse.
- Rm_AveragingTime: Averaging time when measuring the R after the FORM pulse.
- Rm_DelayTime: Delay time from the start of the Rm pulse to the start of the R measurement. Delay time must be larger than "RmP_RiseTime" and its transient periods.
- Rm_adjust: Subtracts Rm_adjust from the Rm value for adjusting the R of the current limit transistor.

Measurement resources:
- RSU_Vs: RSU channel of the Vs - Voltage source RSU.
- RSU_Im: RSU channel of the Im - Current measurement RSU.
Optional Connection for current limit control for ReRAM device:
   Enable_SMU_Vg: "Disable" does not use SMU_Vg. "Enable" must specify both the SMU channel
       ("SMU_Vg") connected to the current limit transistor, and the gate voltage "Vg".
   SMU_Vg: SMU channel assignment of the gate connection (optional)
   Vg: Gate voltage of the current limit transistor (FET).
       Specify the Vg to limit the ReRAM current in ON status.

[Extended Test Parameters]
   DelayTime: Delay time.
   RSU_Vs_Range: Current range of RSU_Vs (Vs RSU)
   RmP_RiseTime: Rise/Fall time of R measure pulse

   DataDisplay_PatternValidation: this parameter is effective in “Run Vector” execution setting.
   - Enable (Waveform or Waveform_MeasTiming): shows “PatternValidation Data Display”.
   - Disable: Does not show “PatternValidation Data Display”.

   ExecutionMode: Choice of “Execution Mode”
   - Run Vector: Measurement is made with the WGFMU/RSU
   - Pattern Validation: Used to check the vector data created to run WGFMU/RSU.
       Can be executed without running the B1500A.

[X-Y Plot: Measurement Parameters]
   Display ReRAM FORM graph: Displays Form_V(Y1), Form_I(Y2) versus FPRM_TIME sampling data graph.

   Following parameters are extracted:
   - FormR: Measured R value after the FORM pulse.
   - FORM_Im: Current measured just after the FORM detection.
   - FORM_Vm: Source voltage just before the FORM detection.
34.6 ReRAM Set ResetV-Loop: ReRAM Set and ResetV-Loop characteristics (A.06.20)

[Supported Analyzer]
B1500A

[Description]
Performs repeat R measurements by increasing the RESET voltage after the initial SET measurements. The RESET voltage can be easily found by the test. A control option for using external current limit device is available.

[Device Under Test]
ReRAM materials with the ReRAM memory structure. Optionally, a ReRAM structure with a current limit FET (internal or outside the structure) is supported to apply a DC bias.

[Required Modules and Accessories]
Keysight B1530A WGFMU 1 unit
Keysight B1531A RSU 2 set
SMU 1 unit (optional)

[Device Parameters]
Temp: Temperature

[Test Parameters]
Waveform output - RESET/SET:
SET_V: SET voltage
SET_Tr: Rise time of the SET pulse
RESET_startV: Start voltage of RESET V loop
RESET_stopV: Stop voltage of RESET V loop
N_of_steps: Number of steps in the voltage loop
RESET_Tr: Rise time of the RESET pulse
TopWidth: Top width of the SET and RESET pulse.

Waveform output - R Measure:
Rm_V: R measurement voltage after the SET & RESET pulse.

Measurement - RESET / SET:
SamplingInterval: Sampling interval to measure the current in the SET pulse. To detect the SET voltage, sampling interval must be at least 5 times shorter than SET_Tr.
RESET_Im_range: Current range of RSU_Im (Im RSU), used in the RESET pulse stage to measure the RESET current.
SET_Im_range: Current range of RSU_Im (Im RSU), used in the SET pulse stage to measure the SET current.
RESET_detect_R: Threshold RESET R value to detect the RESET voltage in the step loop. Detection is made when the measured R exceeds the threshold R.

Measurement - R Measure:
SET_Rm_ImRange: Current range of RSU_Im used to measure R after the SET pulse.
RESET_Rm_ImRange: Current range of RSU_Im used to measure R after the RESET pulse.
Rm_AveragingT: Averaging time to measure SET_R & RESET_R.
Rm_DelayTime: Delay time between the start of the Rm pulse and the start of the R measurement. Delay time must be larger than "Rm_TrTT" and its transient periods.
Rm_adjust: Subtracts Rm_adjust from the Rm value for adjusting the R of the current limit transistor.

Measurement resources:
- RSU_Vs: RSU channel of the Vs Voltage source RSU.
- RSU_Im: RSU channel of the Im Current measurement RSU.

Optional Connection for current limit control for ReRAM device:
- Enable_SMU_Vg: "Disable" does not use SMU_Vg. "Enable" must specify both the SMU channel ("SMU_Vg") connected to the current limit transistor, and the gate voltage "Vg".
- SMU_Vg: SMU channel assignment of the gate connection (optional)
- Vg: Gate voltage of the current limit transistor (FET). Specify the Vg to limit the ReRAM current in ON status.

[Extended Test Parameters]
- DataDisplay_PatternValidation: this parameter is effective in “Run Vector” execution setting.
  - Enable (Waveform or Waveform_MeasTiming): shows “PatternValidation Data Display”.
  - Disable: Does not show “PatternValidation Data Display”.

ExecutionMode: Choice of “Execution Mode”
- Run Vector: Measurement is made with the WGFMU/RSU
  Can be executed without running the B1500A.
- Pattern Validation: Used to check the vector data created to run WGFMU/RSU

DelayTime: Delay time.
- SET_Tf: Fall time of the SET pulse.
- RESET_Tf: Fall time of the RESET pulse.
- Rm_TrTf: Rise/Fall time of R measure pulse
- Vs_range: Current range of RSU_Vs (Vs RSU)

[X-Y Plot: Measurement Parameters]
- Set-Reset V incremental graph: Displays RESET_R versus RESET_Pulse_V graph.
  - Y axis: RESET_R
  - X axis: Absolute RESET_Pulse_V

Extracted parameter:
- Reset_Vm: The RESET voltage at the" RESET_R" value get higher than "RESET_detect_R", the voltage is recorded as "Reset_Vm", and marker is shown on that voltage.
  If there is no detection, 9999 is returned and displayed.
34.7 ReRAM Reset SetV-Loop: ReRAM Reset and SetV-Loop characteristics (A.06.20)

[Supported Analyzer]
B1500A

[Description]
Performs repeat R measurements by increasing the SET voltage after the initial SET measurements. The SET voltage can be easily found by the test.

[Device Under Test]
ReRAM materials with the ReRAM memory structure. Optionally, a ReRAM structure with a current limit FET (internal or outside the structure) is supported to apply a DC bias.

[Required Modules and Accessories]
Keysight B1530A WGF MU 1 unit
Keysight B1531A RSU 2 set
SMU 1 unit (optional)

[Device Parameters]
Temp: Temperature

[Test Parameters]
Waveform output - RESET/SET:
- RESET_V: RESET voltage
- RESET_Tr: Rise time of the RESET pulse.
- SET_startV: Start voltage of SET V loop
- SET_stopV: Stop voltage of SET V loop
- N_of_steps: Number of steps in the voltage loop.
- SET_Tr: Rise time of the SET pulse.
- TopWidth: Top width of the SET and RESET pulse.

Waveform output - R Measure:
- Rm_V: R measurement voltage after the SET & RESET pulse.

Measurement - RESET / SET:
- SamplingInterval: Sampling interval to measure the current in the SET pulse. To detect the SET voltage, sampling interval must be at least 5 times shorter than SET_Tr.
- RESET_Im_range: Current range of RSU_Im (Im RSU), used in the RESET pulse stage to measure the RESET current.
- SET_Im_range: Current range of RSU_Im (Im RSU), used in the SET pulse stage to measure the SET current.
- SET_detect_R: Threshold SET R value to detect the SET voltage in the step loop. Detection is made when the measured R decreases the threshold R.

Measurement - R Measure:
- SET_Rm_ImRange: Current range of RSU_Im used to measure R after the SET pulse.
- RESET_Rm_ImRange: Current range of RSU_Im used to measure R after the RESET pulse.
- Rm_AveragingT: Averaging time to measure SET_R & RESET_R.
- Rm_DelayTime: Delay time between the start of the Rm pulse and the start of the R measurement. Delay time must be larger than "Rm_TrTf" and its transient periods.
- Rm_adjust: Subtracts Rm_adjust from the Rm value for adjusting the R of the current limit transistor.
Measurement resources:
  RSU_Vs: RSU channel of the Vs - Voltage source RSU.
  RSU_Im: RSU channel of the Im - Current measurement RSU.

Optional Connection for current limit control for ReRAM device:
  Enable_SMU_Vg: "Disable" does not use SMU_Vg. "Enable" must specify both the SMU channel
                  ("SMU_Vg") connected to the current limit transistor, and the gate voltage "Vg".
  SMU_Vg: SMU channel assignment of the gate connection (optional)
  Vg: Gate voltage of the current limit transistor (FET).
      Specify the Vg to limit the ReRAM current in ON status.

[Extended Test Parameters]
  DataDisplay_PatternValidation: this parameter is effective in “Run Vector” execution setting.
    - Enable (Waveform or Waveform_MeasTiming): shows “PatternValidation Data Display”.
    - Disable: Does not show “PatternValidation Data Display”.

  ExecutionMode: Choice of “Execution Mode”
    - Run Vector: Measurement is made with the WGFMU/RSU
    - Pattern Validation: Used to check the vector data created to run WGFMU/RSU.
      Can be executed without running the B1500A.

  DelayTime: Delay time.
  SET_Tf: Fall time of the SET pulse.
  RESET_Tf: Fall time of the RESET pulse.
  Rm_TrTf: Rise/Fall time of R measure pulse
  Vs_range: Current range of RSU_Vs (Vs RSU)

[X-Y Plot: Measurement Parameters]
  Reset-Set V incremental graph: Displays SET_R versus SET_Pulse_V graph.
    - Y axis: SET_R
    - X axis: SET_Pulse_V

  Extracted parameter:
    - SET_Vm: The SET voltage at the" SET_R" value get lower than "SET_detect_R" value, the voltage is
               recorded as "SET_Vm, and marker is shown on that voltage.
               If there is no detection, 9999 is returned and displayed.
34.8 ReRAM Reset-Set: ReRAM Reset-Set characteristics (A.06.20)

[Supported Analyzer]
B1500A

[Description]
Performs SET characterization followed by the RESET measurements. SET characterization is almost the same as the FORM application test.
A control option for using external current limit device is available.

[Device Under Test]
ReRAM materials with the ReRAM memory structure.
Optionally, a ReRAM structure with a current limit FET (internal or outside the structure) is supported to apply a DC bias.

[Required Modules and Accessories]
Keysight B1530A WGFMU 1 unit
Keysight B1531A RSU 2 set
SMU 1 unit (optional)

[Device Parameters]
Temp: Temperature

[Test Parameters]
Waveform output - RESET/SET:
  RESET_V: RESET voltage
  RESET_Tr: Rise time of the RESET pulse.
  SET_Vmax: Max voltage of the SET pulse of the RSU_Vs. Set higher voltage than the SET voltage of the ReRAM device.
  SET_Tr: Rise time of the SET pulse.
  TopWidth: Top width of the SET and RESET pulse.

Waveform output - R Measure:
  Rm_V: R measurement voltage after the SET & RESET pulse.

Measurement - RESET / SET:
  SamplingInterval: Sampling interval to measure the current in the SET pulse. To detect the SET voltage, sampling interval must be at least 5 times shorter than SET_Tr.
  RESET_Im_range: Current range of RSU_Im (Im RSU), used in the RESET pulse stage to measure the RESET current.
  RESET_detect_I: Current threshold to detect the RESET V. When the current difference between two sampling points in the RESET_Tr slope exceeds "RESET_detect_I", the voltage of the slope is recorded as RESET V.
  SET_Im_range: Current range of RSU_Im (Im RSU), used in the SET pulse stage to measure the SET current.
  SET_detect_I: Current threshold to detect the SET V. When the current difference between two sampling points in the SET_Tr slope exceeds "SET_detect_I", the voltage of the slope is recorded as SET V.

Measurement - R Measure:
  SET_Rm_ImRange: Current range of RSU_Im used to measure R after the SET pulse.
  RESET_Rm_ImRange: Current range of RSU_Im used to measure R after the RESET pulse.
  Rm_AveragingT: Averaging time to measure SET_R & RESET_R.
Rm_DelayTime: Delay time between the start of the Rm pulse and the start of the R measurement. Delay time must be larger than "Rm_TrTf" and its transient periods.
Rm_adjust: Subtracts Rm_adjust from the Rm value for adjusting the R of the current limit transistor.

Measurement resources:
RSU_Vs: RSU channel of the Vs -Voltage source RSU.
RSU_Im: RSU channel of the Im - Current measurement RSU.

Optional Connection for current limit control for ReRAM device:
Enable_SMU_Vg: "Disable" does not use SMU_Vg. "Enable" must specify both the SMU channel ("SMU_Vg") connected to the current limit transistor, and the gate voltage "Vg".
SMU_Vg: SMU channel assignment of the gate connection (optional)
Vg: Gate voltage of the current limit transistor (FET).
   Specify the Vg to limit the ReRAM current in ON status.

[Extended Test Parameters]
DataDisplay_PatternValidation: Enable (Waveform or Waveform_MeasTiming) or Disable to show PatternValidation Data Display, this parameter is effective for Run Vector.
ExecutionMode: Execution Mode.
DelayTime: Delay time.
SET_Tf: Fall time of the SET pulse.
RESET_Tf: Fall time of the RESET pulse.
Rm_TrTf: Rise/Fall time of R measure pulse
Vs_range: Current range of RSU_Vs (Vs RSU)

[X-Y Plot: Measurement Parameters]
Two graphs, one for RESET characterization, and the other for SET characterization are displayed.
- RESET graph:
  X axis: Plots the RESET_Time sampling time
  Y1 axis: Reset_V, Output from the RSU_Vs
  Y2 axis: Reset_I, Measurement current of RSU_Im
  Extracted parameter:
  Reset_R: measured RESET R
  Reset_Im: Peak current which is measured one sampling point before when the RESET is detected.
     If RESET is not detected, 9999 is returned.
  Reset_Vm: Peak voltage which is measured one sampling point before when the RESET is detected.
     If RESET is not detected, 9999 is returned.

- SET graph:
  X axis: Plots the SET_Time sampling time
  Y1 axis: Set_V, Output from the RSU_Vs
  Y2 axis: Set_I, Measurement current of RSU_Im
  Extracted parameter:
  Set_R: measured SET R
  SET_Im: Peak current when the SET is detected. If SET is not detected, 9999 is returned.
  SET_Vm: Peak voltage which is measured one sampling point before when the SET is detected. If SET is not detected, 9999 is returned.
34.9 ReRAM Endurance: ReRAM Endurance test (A.06.20)

[Supported Analyzer]
B1500A

[Description]
A stress/measure cycle test is performed by applying only a RESET & SET repeat stress pulses and the following RESET-SET characterization within the Max_loops stress cycle. Following test options are available for fatigue measurement numbers per decade of stress cycle, and the test exit criteria conditions before reaching to the specified Max_loops stress cycle. A control option for using external current limit device is available.

[Device Under Test]
ReRAM materials with the ReRAM memory structure. Optionally, a ReRAM structure with a current limit FET (internal or outside the structure) is supported to apply a DC bias.

[Required Modules and Accessories]
Keysight B1530A WGFMU 1 unit
Keysight B1531A RSU 2 set
SMU 1 unit (optional)

[Device Parameters]
Temp: Temperature

[Test Parameters]
Waveform output - RESET/SET
  RESET_V: RESET voltage
  RESET_Tr: Rise time of the RESET pulse used for parameter measurements.
  SET_V: SET voltage.
  SET_Tr: Rise time of the SET pulse used for parameter measurements.
  TopWidth: Top width of the SET and RESET pulse.
  RESET_Tr_Cycle: Rise time of the RESET pulse used for Stress cycle.
  SET_Tr_Cycle: Rise time of the SET pulse used for Stress cycle.

Waveform output - R Measure:
  Rm_V: R measurement voltage after the FORM pulse.

Measurement - Endurance:
  Max_loops: Maximum loops of the endurance test. The RESET_SET waves are repeated, and ReRAM characterizations are made in the specified log interval.
  Fatigue_C_dec: Number of fatigue measurements in one decade of endurance stress cycle.

Measurement - RESET / SET:
  RESET_Im_range: Current range of RSU_Im (Im RSU), used in the RESET pulse stage to measure the RESET current.
  SET_Im_range: Current range of RSU_Im (Im RSU), used in the SET pulse stage to measure the SET current.
  SamplingInterval: Sampling interval to measure the current in the SET pulse. To detect the SET voltage, sampling interval must be at least 5 times shorter than SET_Tr.
  Rm_AveragingT: Averaging time to measure SET_R & RESET_R.
  Rm_DelayTime: Delay time between the start of the Rm pulse and the start of the R measurement. Delay time must be larger than "Rm_TrTf" and its transient periods.
  RESET_Rm_ImRange: Current range of RSU_Im used to measure R after the RESET pulse.
SET_Rm_ImRange: Current range of RSU_Im used to measure R after the SET pulse.
Rm_adjust: Subtracts Rm_adjust from the Rm value for adjusting the R of the current limit transistor.

Measurement resources:
  RSU_Vs: RSU channel of the Vs -Voltage source RSU.
  RSU_Im: RSU channel of the Im - Current measurement RSU.

Optional Connection for current limit control for ReRAM device:
  Enable_SMU_Vg: "Disable" does not use SMU_Vg. "Enable" must specify both the SMU channel
        ("SMU_Vg") connected to the current limit transistor, and the gate voltage "Vg".
  SMU_Vg: SMU channel assignment of the gate connection (optional)
  Vg: Gate voltage of the current limit transistor (FET).
    Specify the Vg to limit the ReRAM current in ON status.

[Extended Test Parameters]
  Start_Fatigue_C: X-axis start number of the Fatigue count in the endurance test result display.
  Do_PreTest: "YES" executes pre-RESET-SET test before starting the endurance stress cycle.
  Rec_CharData: "NO" is recommended. "YES" saves all the intermediate characterization graph
    in the "Results area".
  Rec_StrsData: "NO" is recommended. "YES" saves all the intermediate stress indication data
    in the "Results area".
  Stop_by_ResetR: Flag if to terminate the endurance test. "NO" does not terminate.
    - "Over" terminates when the RESET R exceeds the "Stop_ResetR".
    - "Down" does when the R decreases the "Stop_ResetR".
  Stop_ResetR: R value to determine the "Stop_by_ResetR" condition.
  Stop_by_SetR: Flag if to terminate the endurance test. "NO" does not terminate.
    - "Over" terminates when the SET R exceeds the "Stop_SetR".
    - "Down" does when the R decreases the "Stop_SetR".
  Stop_SetR: R value to determine the "Stop_by_SetR" condition.
  DataDisplay_PatternValidation: Enable (Waveform or Waveform_MeasTiming) or Disable to show
    PatternValidation Data Display, this parameter is effective for Run Vector.

ExecutionMode: Execution Mode.
DelayTime: Delay time.
SET_Tf: Fall time of the SET pulse.
RESET_Tf: Fall time of the RESET pulse.
Rm_TrTf: Rise/Fall time of R measure pulse
Vs_Im_range: Current range of RSU_Vs (Vs RSU)

[X-Y Plot: Measurement Parameters]
Plots Endurance test graph: SET R (Y1) and RESET R (Y2) vs. Fatigue count (X axis)

Parameter output:
  Displays the following parameters:
    - Init_ResetR: Initial RESET R
    - Init_SETR: Initial SET R
34.10 PCRAM Reset-Set: PCRAM Reset-Set characteristics (A.06.20)

[Supported Analyzer]
B1500A

[Description]
Performs RESET & SET characterization. First, a fast RESET pulse is applied using the SPGU and measures the RESET resistance using RSU. Next, SET pulse is applied and SET resistance is measured by RSU.

[Device Under Test]
PCRAM materials with the PCRAM memory structure.

[Required Modules and Accessories]
Keysight B1530A WGFMU 1 unit
Keysight B1531A RSU 2 set
Keysight B1525A SPGU 1 unit
SPGU cable to RSU adapter:
- Triax (M) - BNC (F) adapter 1 qty, Keysight P/N: N1254A-106
50 ohm Triax terminator: Configure with the following adapters
- GNDU to Kelvin adapter 1 qty, Keysight P/N: N1254A-100
- 50 ohm BNC terminator, Keysight P/N: 1250-0207

[Device Parameters]
Temp: Temperature

[Test Parameters]
Waveform output - RESET/SET:
- RESET_V: RESET voltage
- RESET_Tr: Rise time of the RESET pulse.
- RESET_Tf: Fall time of the RESET pulse.
- RESET_TopWidth: Top width of the RESET pulse.
- SET_V: SET voltage
- SET_Tr: Rise time of the SET pulse.
- SET_Tf: Fall time of the SET pulse.
- SET_TopWidth: Top width of the SET pulse.

Waveform output - R Measure:
- Rm_V: R measurement voltage after the SET & RESET pulse.

Measurement - SET:
- SET_Im_range: Current range of RSU_Im (Im RSU), used in the SET pulse stage to measure the SET current.
- AveragingTime: Averaging time to measure SET current.
  Averaging time must be shorter than "SET_TopWidth".
- SET_Im_DelayTime: Delay time between start of SET pulse and the start of SET_Im measurements.
  (SET_Im_DelayTime - SET_Tr + AveragingTime <= SET_TopWidth) must be met.

Measurement - R Measure:
- RESET_Rm_ImRange: Current range of RSU_Im used to measure R after the RESET pulse.
- SET_Rm_ImRange: Current range of RSU_Im used to measure R after the SET pulse.
- Rm_DelayTime: Delay time between the start of the Rm pulse and the start of the R measurement.
  Delay time must be larger than "Rm_TrTf" and its transient periods.
- Rm_AveragingTime: Averaging time to measure SET_R & RESET_R.
Measurement resources:
- SPGU: SPGU channel that is used as RESET Voltage source.
- Vs: RSU channel of the Vs -Voltage source RSU.
- Im: RSU channel of the Im - Current measurement RSU.

[Extended Test Parameters]
- Rm_TrTf: Rise/Fall time of R measure pulse
- DelayTime: Delay time.
- Rec_SubData: "NO" is recommended.
  "YES" saves the intermediate SPGU stress display graph in the "Results area".
- Vs_Irange: Current range of RSU_Vs (Vs RSU)
- DataDisplay_PatternValidation: Enable (Waveform or Waveform_MeasTiming) or Disable to show
  PatternValidation Data Display, this parameter is effective for Run Vector.
- ExecutionMode: Execution Mode.

[X-Y Plot: Measurement Parameters]
There is no graph available.

Parameters section:
- RESET_V: RESET pulse V applied to the DUT.
- RESET_Rm: RESET R measured after the RESET pulse.
- SET_V: SET pulse V applied to the DUT.
- SET_Im: SET current measured at the top of the SET pulse.
- SET_Rm: SET R measured after the SET pulse.
34.11 PCRAM ResetV-Loop: PCRAM ResetV-Loop characteristics (A.06.20)

[Supported Analyzer]
B1500A

[Description]
A step increasing RESET pulses are repeatedly applied to the PCRAM material and the RESET R are measured after the initial SET pulse measurement. The RESET voltage can be easily found by the test.

[Device Under Test]
PCRAM materials with the PCRAM memory structure.

[Required Modules and Accessories]
Keysight B1530A WGFMU 1 unit
Keysight B1531A RSU 2 set
Keysight B1525A SPGU 1 unit
SPGU cable to RSU adapter:
- Triax (M) - BNC (F) adapter 1 qty, Keysight P/N: N1254A-106
50 ohm Triax terminator: Configure with the following adapters
- GNDU to Kelvin adapter 1 qty, Keysight P/N: N1254A-100
- 50 ohm BNC terminator, Keysight P/N: 1250-0207

[Device Parameters]
Temp: Temperature

[Test Parameters]
Waveform output - RESET/SET:
- SET_V: SET voltage
- SET_Tr: Rise time of the SET pulse.
- SET_Tf: Fall time of the SET pulse.
- SET_TopWidth: Top width of the SET pulse.
- RESET_StartV: Start voltage of RESET V loop.
- RESET_StopV: Stop voltage of RESET V loop.
- N_of_Steps: Number of steps in the voltage loop.
  Example: 1 = 1 measurement, 6 = Initial V + 5 steps measurements
- RESET_Tr: Rise time of the RESET pulse.
- RESET_Tf: Fall time of the RESET pulse.
- RESET_TopWidth: Top width of the RESET pulse.

Waveform output - R Measure:
- Rm_V: R measurement voltage after the SET & RESET pulse.

Measurement - SET:
- SET_Im_range: Current range of RSU_Im (Im RSU), used in the SET pulse stage to measure the SET current.
- SET_Im_DelayTime: Delay time between start of SET pulse and the start of SET_Im measurements.
  (SET_Im_DelayTime - SET_Tr + AveragingTime <= SET_TopWidth) must be met.
- SET_Im_AveragingT: Averaging time to measure SET current.
  Averaging time must be shorter than "SET_TopWidth".

Measurement - R Measure:
- SET_Rm_ImRange: Current range of RSU_Im used to measure R after the SET pulse.
- RESET_Rm_ImRange: Current range of RSU_Im used to measure R after the RESET pulse.
- Rm_AveragingTime: Averaging time to measure SET_R & RESET_R.
Rm_DelayTime: Delay time between the start of the Rm pulse and the start of the R measurement. Delay time must be larger than "Rm_TrTf" and its transient periods.

ResetLoop_Detect_R: Detect RESET V at which the RESET R exceeds this value in the V loop. "0" ohm disables this function.

Measurement resources:
- PGU: SPGU channel that is used as RESET Voltage source.
- Vs: RSU channel of the Vs -Voltage source RSU.
- Im: RSU channel of the Im - Current measurement RSU.

[Extended Test Parameters]
- Rm_TrTf: Rise/Fall time of R measure pulse
- DelayTime: Delay time.
- Vs_Irange: Current range of RSU_Vs (Vs RSU)
- DataDisplay_PatternValidation: Enable (Waveform or Waveform_MeasTiming) or Disable to show PatternValidation Data Display, this parameter is effective for Run Vector.
- ExecutionMode: Execution Mode.
- Rec_LoopData: "NO" disables the store of the PGU's output progress time data in the "Results" area. (database)
- Display_Control: "YES" disables the display of the intermediate measurement process.

[X-Y Plot: Measurement Parameters]
- Plots the RESET R versus RESET pulse V graph.
  - Y axis: RESET Rm, RESET R measured in each RESET V steps.
  - X axis: RESET_V, RESET Pulse V

Extracted parameter:
- ResetV_dtct: The RESET voltage detected at the "RESET_Rm" value get higher than "ResetLoop_Detect_R".
  The voltage is recorded as "ResetV_dtct", and marker is shown on that voltage.
  If there is no detection, 9999 is returned and displayed.
- SET_I: SET current measured at initial SET operation.
- SET_R: SET resistance measured at initial SET operation.
- ResetR_Low: Lowest RESET R value in the RESET V loop.
- ResetR_High: Highest RESET R value in the RESET V loop.
34.12 PCRAM SetV-Loop: PCRAM SetV-Loop characteristics (A.06.20)

[Supported Analyzer]
B1500A

[Description]
A step increasing SET pulses are repeatedly applied to the PCRAM material and both the SET current and SET R are measured after the initial RESET pulse measurement. The SET voltage can be easily found by the test.

[Device Under Test]
PCRAM materials with the PCRAM memory structure.

[Required Modules and Accessories]
Keysight B1530A WGFMU 1 unit
Keysight B1531A RSU 2 set
Keysight B1525A SPGU 1 unit
SPGU cable to RSU adapter:
- Triax (M) - BNC (F) adapter 1 qty, Keysight P/N: N1254A-106
50 ohm Triax terminator: Configure with the following adapters
- GNDU to Kelvin adapter 1 qty, Keysight P/N: N1254A-100
- 50 ohm BNC terminator, Keysight P/N: 1250-0207

[Device Parameters]
Temp: Temperature

[Test Parameters]
Waveform output - RESET/SET:
- RESET_V: RESET pulse voltage.
- RESET_Tr: Rise time of the RESET pulse.
- RESET_Tf: Fall time of the RESET pulse.
- RESET_TopWidth: Top width of the RESET pulse.
- SET_StartV: Start voltage of SET V loop.
- SET_StopV: Stop voltage of SET V loop.
- N_of_Steps: Number of steps in the voltage step loop.
  Example: 1 = 1 measurement, 6 = Initial V + 5 steps measurements
- SET_Tr: Rise time of the SET pulse.
- SET_Tf: Fall time of the SET pulse.
- SET_TopWidth: Top width of the SET pulse.

Waveform output - R Measure:
- Rm_V: R measurement voltage after the SET & RESET pulse.

Measurement - SET:
- SET_Im_range: Current range of RSU_Im (Im RSU), used in the SET pulse stage to measure the SET current.
- SET_Im_AveragingT: Averaging time to measure SET current.
  Averaging time must be shorter than "SET_TopWidth".
- SET_Im_DelayTime: Delay time between start of SET pulse and the start of SET_Im measurements.
  (SET_Im_DelayTime - SET_Tr + AveragingTime <= SET_TopWidth) must be met.

Measurement - R Measure:
- RESET_Rm_ImRange: Current range of RSU_Im used to measure R after the RESET pulse.
- SET_Rm_ImRange: Current range of RSU_Im used to measure R after the SET pulse.
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Rm_AveragingTime: Averaging time to measure SET_R & RESET_R.
Rm_DelayTime: Delay time between the start of the Rm pulse and the start of the R measurement.
    Delay time must be larger than "Rm_TrTf" and its transient periods.
SET_loop_DetectR: Detect SET V at which the SET R exceeds this value in the V loop. "0" ohm disables
    this function.

Measurement resources:
    SPGU: SPGU channel that is used as RESET Voltage source.
    Vs: RSU channel of the Vs -Voltage source RSU.
    Im: RSU channel of the Im - Current measurement RSU.

[Extended Test Parameters]
Rm_TrTf: Rise/Fall time of R measure pulse
DelayTime: Delay time.
Rec_SubData: "NO" disables the store of the SET loop pulse data in the "Results" area. (database)
Vs_Irange: Current range of RSU_Vs (Vs RSU)
DataDisplay_PatternValidation: Enable (Waveform or Waveform_MeasTiming) or Disable to show
    PatternValidation Data Display, this parameter is effective for Run Vector.
ExecutionMode: Execution Mode.

[X-Y Plot: Measurement Parameters]
Plots the Set_R (Y1) and Set_I (Y2) versus SET_Pulse_V (X axis) graph.
    Y1 axis: Set_R, SET R measured at each SET V step.
    Y2 axis: Set_I, SET current measured at each SET V step.
    X axis: SET_Pulse_V, SET Pulse Voltage.

Extracted parameter:
- SetV_dtct: The SET voltage detected at the "Set_R" value get lower than "SET_loop_DetectR ".
    The voltage is recorded as "SetV_dtct", and a marker is shown on that voltage.
    If there is no detection, -999 is returned and displayed.
- ResetV: Reset voltage used for RESET.
- Reset_R: RESET resistance measured at initial RESET operation.
34.13 PCRAM Endurance: PCRAM Endurance test (A.06.20)

[Supported Analyzer]
B1500A

[Description]
A stress/measure cycle test is performed by applying only a RESET & SET repeat stress pulses of the SPGU. Then RESET-SET characterization set by the fatigue measurement timing is made within the Max_loops stress cycle. Following test options are available for fatigue measurement numbers per decade of stress cycle, and the test exit criteria conditions before reaching to the specified Max_loops stress cycle.

[Device Under Test]
PCRAM materials with the PCRAM memory structure.

[Required Modules and Accessories]
Keysight B1530A WGF MU 1 unit
Keysight B1531A RSU 2 set
Keysight B1525A SPGU 1 unit
SPGU cable to RSU adapter:
- Triax (M) - BNC (F) adapter 1 qty, Keysight P/N: N1254A-106
- 50 ohm Triax terminator: Configure with the following adapters
- GNDU to Kelvin adapter 1 qty, Keysight P/N: N1254A-100
- 50 ohm BNC terminator, Keysight P/N: 1250-0207

[Device Parameters]
Temp: Temperature

[Test Parameters]
Waveform output - RESET/SET
  RESET_V: RESET voltage.
  RESET_Tr: Rise time of the RESET pulse.
  RESET_Tf: Fall time of the RESET pulse.
  RESET_TopWidth: Top width of the RESET pulse.
  DelayTime: Delay time.
  SET_V: SET voltage
  SET_Tr: Rise time of the SET pulse.
  SET_Tf: Fall time of the SET pulse.
  SET_TopWidth: Top width of the SET pulse of PGU (Stress cycle).
  SET_Im_TopWidth: Top width of the SET pulse of RSU (Characterization phase).

Waveform output - R Measure:
  Rm_V: R measurement voltage after the FORM pulse.

Measurement - Endurance:
  Max_loops: Maximum loops of the endurance test. The RESET_SET waves are repeated, and PCRAM characterizations are made in the specified log interval.
  Fatigue_C_dec: Number of fatigue measurements in one decade of endurance stress cycle.

Measurement - R Measure:
  RESET_Rm_ImRange: Current range of RSU_Im used to measure R after the SET pulse.
  SET_Rm_ImRange: Current range of RSU_Im used to measure R after the RESET pulse.
  Rm_AveragingTime: Averaging time to measure SET_R & RESET_R.
  Rm_DelayTime: Delay time between the start of the Rm pulse and the start of the R measurement. Delay time must be larger than "RmP_TrTf" and its transient periods.
Measurement - SET:
   SET_Im_range: Current range of RSU_Im (Im RSU), used in the SET pulse stage to measure the SET current.

Measurement resources:
   PGU: SPGU channel that is used as RESET Voltage source.
   Vs: RSU channel of the Vs -Voltage source RSU.
   Im: RSU channel of the Im - Current measurement RSU.

[Extended Test Parameters]
SET_Im_AveragingTime: Averaging time to measure SET current. Averaging time must be shorter than "SET_TopWidth".

SetIm_DelayTime: Delaytime between start of SET pulse and the start of SET_Im measurements. :
   \[(SET_Im_DelayTime - SET_Tr + AveragingTime <= SET_TopWidth)\] must be met.

Stop_by_ResetR: Flag if to terminate the endurance test.
   - "NO" does not terminate.
   - "Over" terminates when the RESET R exceeds the "Stop_ResetR".
   - "Down" does when the R decreases the "Stop_ResetR".

ResetR_to_Stop: R value to determine the "Stop_by_ResetR" condition.
Stop_by_SetR: Flag if to terminate the endurance test.
   - "NO" does not terminate.
   - "Over" terminates when the SET R exceeds the "Stop_SetR".
   - "Down" does when the R decreases the "Stop_SetR".

SetR_to_Stop: value to determine the "Stop_by_SetR" condition.

Start_Fatigue_C: axis start number of the Fatigue count in the endurance test result display.

Do_PreTest: "YES" executes pre-RESET-SET test before starting the endurance stress cycle.

Rec_CharData: "NO" is recommended. "YES" saves all the intermediate characterization graph in the "Results area".

Rec_StrsData: "NO" is recommended. "YES" saves all the intermediate stress indication data in the "Results area".

Rm_TrTf: Rise/Fall time of R measure pulse

Vs_Irange: Current range of RSU_Vs (Vs RSU)

DataDisplay_PatternValidation: Enable (Waveform or Waveform_MeasTiming) or Disable to show PatternValidation Data Display, this parameter is effective for Run Vector.

ExecutionMode: Execution Mode.

[X-Y Plot: Measurement Parameters]
Plots Endurance test graph: SET R (Y1) and RESET R (Y2) vs. Fatigue count (X axis)
   X-axis: Fatigue_Count - Fatigue count in log scale
   Y1 axis: Endu_SetR - SET R plot vs. Fatigue_Count.
   Y2 axis: Endu_ResetR - RESET R plot vs. Fatigue_Count.

Parameter output:
   Displays the following parameters:
   - Init_ResetR: Initial RESET R
   - Init_SETR: Initial SET R
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35.1 Ia-Vak (PULSE): Thyristor Ia-Vak characteristics. HCSMU, UHCU, HVMCU Pulse (A.05.50)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Ia-Vak characteristics. UHCU/HVMCU pulse is used for the Anode-Cathode voltage output. Gate pulse current is swept as the secondary sweep. The voltage drop caused by the optional series resistor inserted to the anode and the gate path is compensated in the result display output.

[Device Under Test]
Thyristor, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
YScale: Y axis Scale, LINEAR or LOG
Anode: SMU connected to Anode terminal, primary sweep voltage output
VaStart: Sweep start voltage for Anode terminal
VaStop: Sweep stop voltage for Anode terminal
VaStep: Sweep step voltage for Anode terminal
IaLimit: Anode current compliance
PaLimit: Anode power compliance
MeasurementTime: Measurement time
PulsePeriodMode: Pulse period mode, AUTO or MANUAL
ManualPulsePeriod: Pulse period, effective if PulsePeriodMode=MANUAL or AUTO
AnodePulseWidth: Anode pulse width
Gate: SMU connection to Gate terminal, secondary sweep current output
IgStart: Sweep start current for Gate terminal
IgStop: Sweep stop current for Gate terminal
IgStep: Sweep step current for Gate terminal
VgLimit: Gate voltage compliance
Cathode: GNDU connected to Cathode terminal
Ra: Optional series resistor inserted to the anode SMU
Rg: Optional series resistor inserted to the gate SMU

[Extended Test Parameters]
GatePWratio: Gate pulse width=GatePWratio * AnodePulseWidth
PulseBase: Pulse base voltage
HoldTime: Hold time
IaZero: Y axis (Ia) minimum value (Effective for YScale=LOG)
IaZeroLin: Y axis (Ia) minimum value (Effective for YScale=LINEAR)
VaLimit: Anode voltage compliance (applicable to UHCU/HVMCU/UHVU)
GatePulseDelay:Gate pulse delay time
AnodePulseDelay: Anode pulse delay time

[Measurement Parameters]
Anode current Ianode
Gate current Igate
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[User Function]
Ta: Temperature Ta=Temp
VRa=Ianode*Ra
Vanode=Va-VRa
VRg=Igate*Rg
Vgate=VG-VRg

[X-Y Plot]
For YScale=LINEAR:
X axis: Anode voltage Vanode (LINEAR)
Y axis: Anode current Ianode (LINEAR)

For Scale=LOG:
X axis: Anode voltage Vanode (LINEAR)
Y axis: Anode current Ianode (LOG)

[List Display]
Anode voltage Vanode
Anode current Ianode
Gate voltage Vgate
Gate current Igate
Anode SMU output voltage: Va
Gate SMU output voltage: Vg

[Parameter Display Area]
Temperature Ta=Temp
35.2 Ia-Vak: Thyristor Ia-Vak characteristics, SMU DC (A.05.50)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Ia-Vak characteristics. SMU DC is used for the Anode and gate SMUs. Gate current is swept as the secondary sweep. The voltage drops caused by the optional series resistor inserted to the anode and the gate path are compensated in the result display output.

[Device Under Test]
Thyristor, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
YScale: Y axis Scale, LINEAR or LOG
Anode: SMU connected to Anode terminal, primary sweep voltage output
VaStart: Sweep start voltage for Anode terminal
VaStop: Sweep stop voltage for Anode terminal
VaStep: Sweep step voltage for Anode terminal
IaLimit: Anode current compliance
PaLimit: Anode power compliance
MeasurementTime: Measurement time
Gate: SMU connection to Gate terminal, secondary sweep current output
IgStart: Sweep start current for Gate terminal
IgStop: Sweep stop current for Gate terminal
IgStep: Sweep step current for Gate terminal
VgLimit: Gate voltage compliance
Cathode: GNDU connected to Cathode terminal
Ra: Optional series resistor inserted to the anode SMU
Rg: Optional series resistor inserted to the gate SMU

[Extended Test Parameters]
HoldTime: Hold time
IaZero: Y axis (Ianode) minimum value (Effective for YScale=LOG)

[Measurement Parameters]
Anode current Ianode
Gate current Igate

[User Function]
Ta: Temperature Ta=Temp
VRa=Ianode*Ra
Vanode=Va-VRa
VRg=Igate*Rg
Vgate=VG-VRg

[X-Y Plot]
For YScale=LINEAR:
X axis: Anode voltage Vanode (LINEAR)
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Y axis: Anode current I_anode (LINEAR)

For Scale=LOG:
X axis: Anode voltage V_anode (LINEAR)
Y axis: Anode current I_anode (LOG)

[List Display]
- Anode voltage V_anode
- Anode current I_anode
- Gate voltage V_gate
- Gate current I_gate
- Anode SMU output voltage: V_a
- Gate SMU output voltage: V_g

[Parameter Display Area]
- Temperature T_a=Temp
35.3 35.3 IGT,VGT_Ia-Ig: Thyristor IGT,VGT_Ia-Ig characteristics, SMU DC (A.05.50)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Ia-Ig characteristics using SMU DC for detecting the DC gate current and voltage required to trigger (turn on) the anode - Cathode path. The anode current to detect the turn-on condition is set by Ia@GT parameter. Gate current is swept as the primary sweep while the anode is biased in constant voltage. The voltage drop caused by the optional series resistor inserted to the anode path is compensated in the result display output.

[Device Under Test]
Thyristor, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
Anode: SMU connected to Anode terminal, constant voltage output
Va: Fixed constant voltage for Anode terminal
IaLimit: Anode current compliance
Ra: Optional series resistor inserted to the anode SMU
MeasurementTime: measurement time
Ia@GT: Anode current to detect the gate turn-on condition
Gate: SMU connection to Gate terminal, primary sweep current output
IgStart: Sweep start current for Gate terminal
IgStop: Sweep stop current for Gate terminal
IgStep: Sweep step current for Gate terminal
VgLimit: Gate voltage compliance
Cathode: GNDU connected to Cathode terminal

[Extended Test Parameters]
HoldTime: Hold time

[Measurement Parameters]
Anode current Ianode
Anode voltage Vanode
Gate current Igate
Gate voltage Vgate

[User Function]
Ta: Temperature Ta=Temp
VRa=Ianode*Ra
Vanode=V_a-VRa

[Analysis Function]
IGT@L1=@L1X (Detect Igate of Line 1)
VGT@L2=@L2Y (Detect Vgate of Line 2)
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[Auto Analysis]
  Line: Draw two lines at Ianode=Ia@GT. Line1 (Vertical X axis) and Line2 (Horizontal Y2 axis)
  Marker: Marker is on at Ianode=Ia@GT

[X-Y Plot]
  X axis: Gate current Igate (LINEAR)
  Y1 axis: Anode current Ianode (LINEAR)
  Y2 axis: Gate voltage Vgate (LINEAR)
  Y3 axis: Anode voltage Vanode (LINEAR)

[List Display]
  Gate current Igate
  Gate voltage Vgate
  Anode current Ianode
  Anode voltage Vanode
  Anode SMU output voltage: V_a

[Parameter Display Area]
  Temperature Ta=Temp
  Gate trigger current IGT@L1
  Gate trigger voltage VGT@L2
35.4 IH_Ia-Vak: Thyristor Ia-Vak characteristics, SMU DC (A.05.50)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures holding current IH characteristics using Va-Vak sweep measurements after the anode - cathode path is turned on. SMU is used for the Anode-Cathode voltage output. The voltage drop caused by the optional series resistor inserted to the anode path is compensated in the result display output.

[Device Under Test]
Thyristor, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
Anode: SMU connected to Anode terminal. Constant voltage source output when triggering the Thyristor, and voltage source sweep output when measuring IH.
VaTrigger: Anode voltage when used to turn on the Thyristor.
Following parameters are for IH measurement:
  VaHoldStart: Sweep start voltage for Anode terminal
  VaHoldStop: Sweep stop voltage for Anode terminal
  VaHoldStep: Sweep step voltage for Anode terminal
IaLimit: Anode current compliance
Ra: Optional series resistor inserted to the anode SMU
InitOnTime: Initial ON state period in the triggering of the Thyristor, before starting the IH measurement.
MeasurementTime: Anode voltage measurement time to detect the hold status.
Gate: SMU connection to Gate terminal, constant voltage output
IgLimit: Gate current compliance
VgTrigger: Gate voltage when used to turn on the Thyristor in the triggering stage
VgHold: Gate voltage when used to measure IH
Cathode: GNDU connected to Cathode terminal

[Extended Test Parameters]
IHratio: The ratio over IaLimit to start searching the holding current
RecordRawData: Switch if to save the raw sweep data

[Measurement Parameters]
Anode current Ianode
Gate current Igate

[User Function]
Ta: Temperature Ta=Temp
VRa=Ianode*Ra
Vanode=Va-VRa

[Analysis Function]
IH=@L1Y
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[Auto Analysis Setup]
Line 1: I_anode=I_aLimit*I_Hratio
Marker: I_anode=I_aLimit*I_Hratio

[X-Y Plot]
X axis: Anode voltage Vanode
Y axis: Anode current I_anode

[List Display]
Anode voltage Vanode
Anode current I_anode
Gate voltage V_gate
Gate current I_gate
Anode SMU output voltage: V_a

[Parameter Display Area]
Temperature T_a=Temp
IH Holding current
35.5 *IH_Va-Iak: Thyristor Va-Iak IH characteristics, SMU DC (A.05.50)*

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures holding current IH characteristics using Va-Iak sweep measurements after the anode - cathode path is turned on. SMU is used for the Anode-Cathode voltage output (turn on stage) and current (IH stage) output.

[Device Under Test]
Thyristor, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
Anode: SMU connected to Anode terminal. Voltage source output when triggering the thyristor, and current source sweep output when measuring IH.
VaTrigger: Anode voltage when used to turn on the Thyristor.
Following parameters are for IH measurement:
- IaHoldStart: Sweep start current for Anode terminal
- IaHoldStop: Sweep stop current for Anode terminal
- IaHoldStep: Sweep step current for Anode terminal
- VaLimit: Anode voltage compliance
InitOnTime: Initial ON state period in the triggering of the thyristor, before starting the IH measurement.
MeasurementTime: Anode voltage measurement time to detect the hold status.
Gate: SMU connection to Gate terminal, constant voltage output
IgLimit: Gate current compliance
VgTrigger: Gate voltage when used to turn on the Thyristor in the triggering stage
VgHold: Gate voltage when used to measure IH
Cathode: GNDU connected to Cathode terminal

[Extended Test Parameters]
V_IHthreshold: Anode voltage to start searching the holding current IH
RecordRawData: Switch if to save the raw sweep data

[Measurement Parameters]
Anode current Ianode
Gate current Igate

[User Function]
Ta: Temperature Ta=Temp

[Analysis Function]
IH=@L1Y

[Auto Analysis Setup]
Line 1: Vanode=V_IHthreshold
Marker: Vanode=V_IHthreshold

[X-Y Plot]
X axis: Anode voltage Vanode
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Y axis: Anode current $I_{anode}$

[List Display]
Anode voltage $V_{anode}$
Anode current $I_{anode}$
Gate voltage $V_{gate}$
Gate current $I_{gate}$

[Parameter Display Area]
Temperature $T_a$=Temp
IH Holding current
35.6 IL_Va-Ia: Thyristor IL latching characteristics extraction using Ia-Vak measurements, SMU DC/Pulse (A.05.50)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures IL latching characteristics using Ia-Vak repeated (looped) measurements by increasing the Ia. SMU DC is used for the Anode-Cathode current output. Gate pulse is used to trigger the anode. The voltage drop caused by the optional series resistor inserted to the anode path is compensated in the result display output.

[Device Under Test]
Thyristor, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
Anode: SMU connected to Anode terminal, sweeps current output
IaStart: Sweep start current for Anode terminal
IaStop: Sweep stop current for Anode terminal
IaStep: Sweep step current for Anode terminal
VaLimit: Anode voltage compliance
Ra: Optional series resistor inserted to the anode SMU
Va@Threshold: Anode voltage to trigger the IL current. Specify higher voltage than the maximum on-state anode voltage.
MeasurementTime: Actual measurement time for a pulse period
Gate: SMU connection to Gate terminal, constant voltage output
Note: Actual operation is current source mode with IgLimit as the current force value in the triggering stage while it operates as voltage source mode when measuring IL.
VgTrigger: Voltage used in the trigger stage for Gate terminal
IgLimit: Gate current compliance
VgLathing: Voltage used in the lathing current test stage for Gate terminal
Cathode: GNDU connected to Cathode terminal
PulsePeriodMode: Pulse period mode, AUTO or MANUAL
ManualPulsePeriod: Pulse period, effective if PulsePeriodMode=MANUAL
GatePulseWidth: Gate Trigger Pulse width. Must be set more than 20 us longer than the MeasurementTime.

[Extended Test Parameters]
VgPulseBase: Pulse base voltage for gate to turn on the Thyristor
RecordRawData: Switch used if to save the raw sweep data. At "ON" status, the raw Va-Vg measurement data for detecting the latching status is recorded and the Device ID field is over-ridden by the anode current used in the measurement.

[Measurement Parameters]
Anode current Ianode
Gate current Igate

[User Function]
Ta: Temperature Ta=Temp
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\[ \text{VRa} = \text{Ianode} \times \text{Ra} \]
\[ \text{Vanode} = \text{Va} - \text{VRa} \]

[AutoAnalysis]
Marker: Vanode = VaLimit \times 0.9
Line 1: Vanode = VaLimit \times 0.9

[X-Y Plot]
X axis: Anode current Ianode
Y axis: Anode voltage Vanode

[List Display]
Anode current Ianode
Anode voltage Vanode

[Parameter Display Area]
Lathing current IL
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35.7 Off_Ia-Vak (PULSE): Thyristor Off-state Ia-Vak characteristics, HVMCU Pulse (A.05.50)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Ia-Vak characteristics of Off-state. HVMCU pulse is used for the Anode-Cathode voltage output. Detects off-state current at the specified VDRM.

[Device Under Test]
Thyristor, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
MeasurementTime: Actual measurement time for a pulse period
Anode: SMU connected to Anode terminal, primary sweep voltage output
VaStart: Sweep start voltage for Anode terminal
VaStop: Sweep stop voltage for Anode terminal
VaStep: Sweep step voltage for Anode terminal
IaLimit: Anode current compliance
PaLimit: Anode power compliance
VDRM@IDRM: VDRM voltage to measure IDRM current
PulsePeriodMode: Pulse period mode, AUTO or MANUAL
ManualPulsePeriod: Pulse period, effective if PulsePeriodMode=MANUAL
PulseWidth: Pulse width
Gate: SMU connection to Gate terminal, constant voltage output
Vg: Bias voltage for Gate terminal
IgLimit: Gate current compliance
Cathode: GNDU connected to Cathode terminal

[Extended Test Parameters]
PulseBase: Pulse base voltage
HoldTime: Hold time
IaZero: Y axis (Ianode) minimum value (Effective for YScale=LOG)
GatePulseDelay: Gate pulse delay time
GatePWratio: Gate pulse width=GatePWratio * AnodePulseWidth

[Measurement Parameters]
Anode current Ianode
Gate current Igate

[User Function]
Ta: Temperature Ta=Temp

[Analysis Function]
IDRM=@L1Y (Detect Ia of Line1)

[Auto Analysis]
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Line: Draw two lines at Vanode=VDRM@IDRM. Line1 (Horizontal) and Line2 (Vertical)
Marker: Marker is on at Vanode=VDRM@IDRM

[X-Y Plot]
X axis: Anode voltage Vanode (LINEAR)
Y1 axis: Anode current Ianode (LINEAR)
Y2 axis: Anode current Ianode (LOG)

[List Display]
Anode voltage Vanode
Anode current Ianode
Gate voltage Vgate
Gate current Igate

[Parameter Display Area]
Temperature Ta=Temp
Off0state Current: IDRM
35.8 Off_Ia-Vak: Thyristor Off-state Ia-Vak characteristics, HVSMU DC (A.05.50)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Ia-Vak characteristics of Off-state. SMU is used for the Anode-Cathode voltage output. Detects off-state current at the specified VDRM.
The voltage drop caused by the optional series resistor inserted to the anode gate path is compensated in the result display output.

[Device Under Test]
Thyristor, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
MeasurementTime: Measurement time
Anode: SMU connected to Anode terminal, primary sweep voltage output
VaStart: Sweep start voltage for Anode terminal
VaStop: Sweep stop voltage for Anode terminal
VaStep: Sweep step voltage for Anode terminal
IaLimit: Anode current compliance
VDRM@IDRM: VDRM voltage to measure IDRM current
Ra: Optional series resistor inserted to the anode SMU
Gate: SMU connection to Gate terminal, constant voltage output
Vg: Bias voltage for Gate terminal
IgLimit: Gate current compliance
Cathode: GNDU connected to Cathode terminal

[Extended Test Parameters]
HoldTime: Hold time
DelayTime: Delay time
IaZero: Y axis (Ianode) minimum value (Effective for YScale=LOG)

[Measurement Parameters]
Anode current Ianode
Gate current Igate

[User Function]
Ta: Temperature Ta=Temp
VRa=Ianode*Ra
Vanode=Va-VRa

[Analysis Function]
IDRM=@L1Y (Detect Ia of Line1)

[Auto Analysis]
Line: Draw two lines at Vanode=VDRM@IDRM. Line1 (Horizontal) and Line2 (Vertical)
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Marker: Marker is on at Vanode=VDRM@IDRM

[X-Y Plot]
X axis: Anode voltage Vanode (LINEAR)
Y1 axis: Anode current Ianode (LINEAR)
Y2 axis: Anode current Ianode (LOG)

[List Display]
Anode voltage Vanode
Anode current Ianode
Gate voltage Vgate
Gate current Igate
Anode SMU output voltage Va

[Parameter Display Area]
Temperature Ta=Temp
Off0state Current: IDRM
35.9 R_Ia-Vak (PULSE): Thyristor Reverse Ia-Vak characteristics, HVMCU Pulse (A.05.50)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures reverse Ia-Vak characteristics. HVMCU pulse is used for the Anode-Cathode voltage output. Detects IPRM current at the specified VPRM.

[Device Under Test]
Thyristor, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
MeasurementTime: Measurement time for a pulse period
Anode: SMU connected to Anode terminal, primary sweep voltage output
VaStart: Sweep start voltage for Anode terminal
VaStop: Sweep stop voltage for Anode terminal
VaStep: Sweep step voltage for Anode terminal
IaLimit: Anode current compliance
PaLimit: Anode power compliance
VPRM@IPRM: VDRM voltage to measure IDRM current
PulsePeriodMode: Pulse period mode, AUTO or MANUAL
ManualPulsePeriod: Pulse period, effective if PulsePeriodMode=MANUAL
PulseWidth: Pulse width
Gate: SMU connection to Gate terminal, constant voltage output
Vg: Bias voltage for Gate terminal
IgLimit: Gate current compliance
Cathode: GNDU connected to Cathode terminal

[Extended Test Parameters]
PulseBase: Pulse base voltage
HoldTime: Hold time
IaZero: Y axis (Ianode) minimum value (Effective for YScale=LOG)
IaZeroL: Y axis (Ianode) minimum value (Effective for YScale=LINEAR)

[Measurement Parameters]
Anode current Ianode
Gate current Igate

[User Function]
Ta: Temperature Ta=Temp

[Analysis Function]
IPRM=@L1Y (Detect Ia of Line1)

[Auto Analysis]
Line: Draw two lines at Vanode=VPRM@IPRM. Line1 (Horizontal) and Line2 (Vertical)
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Marker: Marker is on at Vanode=VPRM@IPRM

[X-Y Plot]
X axis: Anode voltage Vanode (LINEAR)
Y1 axis: Anode current Ianode (LINEAR)
Y2 axis: Anode current Ianode (LOG)

[List Display]
Anode voltage Vanode
Anode current Ianode
Gate voltage Vgate
Gate current Igate

[Parameter Display Area]
Temperature Ta=Temp
Reverse Current: IPRM
35.10 R_Ia-Vak: Thyristor Reverse Ia-Vak characteristics, HVSMU DC
(A.05.50)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures reverse Ia-Vak characteristics. SMU is used for the Anode-Cathode voltage output. Detects IPRM current at the specified VPRM.

[Device Under Test]
Thyristor, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
MeasurementTime: Measurement time
Anode: SMU connected to Anode terminal, primary sweep voltage output
VaStart: Sweep start voltage for Anode terminal
VaStop: Sweep stop voltage for Anode terminal
VaStep: Sweep step voltage for Anode terminal
IaLimit: Anode current compliance
VPRM@IPRM: VPRM voltage to measure IPRM current
Ra: Optional series resistor inserted to the anode SMU
Gate: SMU connection to Gate terminal, constant voltage output
Vg: Bias voltage for Gate terminal
IgLimit: Gate current compliance
Cathode: GNDU connected to Cathode terminal

[Extended Test Parameters]
DelayTime: Delay Time
HoldTime: Hold time
IaZero: Y axis (Ianode) minimum value (Effective for YScale=LOG)

[Measurement Parameters]
Anode current Ianode
Gate current Igate

[User Function]
Ta: Temperature Ta=Temp
VRa=Ianode*Ra
Vanode=Va-VRa

[Analysis Function]
IDRM=@L1Y (Detect Ia of Line1)

[Auto Analysis]
Line: Draw two lines at Vanode=VPRM@IPRM. Line1 (Horizontal) and Line2 (Vertical)
Marker: Marker is on at Vanode=VPRM@IPRM
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[X-Y Plot]
X axis: Anode voltage Vanode (LINEAR)
Y1 axis: Anode current Ianode (LINEAR)
Y2 axis: Anode current Ianode (LOG)

[List Display]
Anode voltage Vanode
Anode current Ianode
Gate voltage Vgate
Gate current Igate
Anode SMU output voltage Va

[Parameter Display Area]
Temperature Ta=Temp
Off0state Current: IPRM
35.11 VGD, IGD_Ia-Vgk (PULSE): Thyristor VGD, IGD_Ia-Vak characteristics, HVSMU and HVMCU Pulse (A.05.50)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Ia-Vgk characteristics while a high voltage is applied to the anode terminal. Gate current is swept until the anode current exceeds the specified current. The voltage drop caused by the optional series resistor inserted to the anode and the gate path is compensated in the result display output.

[Device Under Test]
Thyristor, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
YScale: Y axis Scale, LINEAR or LOG
Anode: SMU connected to Anode terminal, primary sweep voltage output
Va: Fixed bias voltage for Anode terminal
IaLimit: Anode current compliance
MeasurementTime: measurement time
Ia@Threshold: Anode current of starting conduction of the anode and the cathode.
Following pulse parameter is effective for only HVMCU.
  PulsePeriodMode: Pulse period mode, AUTO or MANUAL
  ManualPulsePeriod: Pulse period, effective if PulsePeriodMode=MANUAL
  PulseWidth: Pulse width
Gate: SMU connection to Gate terminal, secondary sweep current output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
IgLimit: Gate current compliance
Cathode: GNDU connected to Cathode terminal
Ra: Optional series resistor inserted to the anode SMU
Rg: Optional series resistor inserted to the gate SMU

[Extended Test Parameters]
HoldTime: Hold time
PulseBase: Pulse base voltage
PulseAvgCnt: Pulse averaging count
IaZero: Y axis (Ianode) minimum value (Effective for YScale=LOG)
VgDelay: The gate delay time for HVMCU gate pulse. The gate delay helps for not to turn on the thyristor when HVMCU pulse is throughing in the pulse rise up.

[Measurement Parameters]
Anode current Ianode
Anode voltage Vanode
Gate current Igate
Gate voltage Vgate
[User Function]
Ta: Temperature Ta=Temp
VRa=Ianode*Ra
Vanode=Va-VRa
VRg=Igate*Rg
Vgate=VG-VRg

[Analysis Function]
IGD@L1=@L1Y (Detects Igate of Line 1)
VGD@L2=@L2X (Detects Vgate of Line 2)

[Auto Analysis]
Line: Draw two lines at Ianode=IaThreshold. Line1 (Horizontal) and Line2 (Vertical)
Marker: Marker is on at Vanode=IaThreshold

[X-Y Plot]
For YScale=LINEAR:
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Anode current Ianode (LINEAR)
Y2 axis: Gate current Igate (LINEAR)
Y3 axis: Anode voltage Vanode (LINEAR)

For YScale=LOG:
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Anode current Ianode (LOG)
Y2 axis: Gate current Igate (LINEAR)
Y3 axis: Anode voltage Vanode (LINEAR)

[List Display]
Anode voltage Vanode
Anode current Ianode
Gate voltage Vgate
Gate current Igate
Anode SMU output voltage: Va
Gate SMU output voltage: Vg

[Parameter Display Area]
Temperature Ta=Temp
IGD@L1: Gate current not to trigger
VGD@L2: Gate voltage not to trigger
35.12 VGD,IGD_Ia-Vak: Thyristor VGD,IGD_Ia-Vak characteristics, HVSMU DC (A.05.50)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Ia-Vgk characteristics while a high voltage is applied to the anode terminal. Gate current is swept until the anode current exceeds the specified current. The voltage drop caused by the optional series resistor inserted to the anode and the gate path is compensated in the result display output.

[Device Under Test]
Thyristor, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
YScale: Y axis Scale, LINEAR or LOG
Anode: SMU connected to Anode terminal, primary sweep voltage output
Va: Fixed bias voltage for Anode terminal
IaLimit: Anode current compliance
MeasurementTime: measurement time
Ia@Threshold: Anode current of starting conduction of the anode and the cathode.
Gate: SMU connection to Gate terminal, secondary sweep current output
VgStart: Sweep start voltage for Gate terminal
VgStop: Sweep stop voltage for Gate terminal
VgStep: Sweep step voltage for Gate terminal
IgLimit: Gate current compliance
Cathode: GNDU connected to Cathode terminal
Ra: Optional series resistor inserted to the anode SMU
Rg: Optional series resistor inserted to the gate SMU

[Extended Test Parameters]
HoldTime: Hold time
IaZero: Y axis (Ianode) minimum value (Effective for YScale=LOG)

[Measurement Parameters]
Anode current Ianode
Anode voltage Vanode
Gate current Igate
Gate voltage Vgate

[User Function]
Ta: Temperature Ta=Temp
VRa=Ianode*Ra
Vanode=Va-VRa
VRg=Igate*Rg
Vgate=VG-VRg
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[Analysis Function]
IGD@L1=@L1Y (Dectes Igate of Line 1)
VGD@L2=@L2X (Dectes Vgate of Line 2)

[Auto Analysis]
Line: Draw two lines at Ianode=IaThreshold. Line1 (Horizontal) and Line2 (Vertical)
Marker: Marker is on at Vanode=IaThreshold

[X-Y Plot]
For YScale=LINEAR:
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Anode current Ianode (LINEAR)
Y2 axis: Gate current Igate (LINEAR)
Y3 axis: Anode voltage Vanode (LINEAR)

For YScale=LOG:
X axis: Gate voltage Vgate (LINEAR)
Y1 axis: Anode current Ianode (LOG)
Y2 axis: Gate current Igate (LINEAR)
Y3 axis: Anode voltage Vanode (LINEAR)

[List Display]
Anode voltage Vanode
Anode current Ianode
Gate voltage Vgate
Gate current Igate
Anode SMU output voltage: Va
Gate SMU output voltage: Vg

[Parameter Display Area]
Temperature Ta=Temp
IGD@L1: Gate current not to trigger
VGD@L2: Gate voltage not to trigger
35.13 VTM_Ia-Vak: Thyristor VTM_Ia-Vak characteristics, SMU Pulse (A.05.50)

[Supported Analyzer]
B1505A, B1506A

[Description]
Measures Ia-Vak characteristics using SMU pulse for the Anode-Cathode voltage output at the specified Gate current. This application test extracts the VTM on-state voltage at the specified ITM on-state current.

[Device Under Test]
Thyristor, 3 terminals

[Device Parameters]
Polarity: Nch (SMUs force the specified value) or Pch (SMUs force the negative specified value).
Temp: Temperature

[Test Parameters]
Memo: Memorandum
YScale: Y axis Scale, LINEAR or LOG
Anode: SMU connected to Anode terminal, primary sweep voltage output
VaStart: Sweep start voltage for Anode terminal
VaStop: Sweep stop voltage for Anode terminal
VaStep: Sweep step voltage for Anode terminal
IaLimit: Anode current compliance
PaLimit: Anode power compliance
ITM@VTM: ITM current to measure VTM voltage
PulsePeriodMode: Pulse period mode, AUTO or MANUAL
ManualPulsePeriod: Pulse period, effective if PulsePeriodMode=MANUAL
AnodePulseWidth: Anode Pulse width
Gate: SMU connection to Gate terminal, secondary sweep current output
Ig: Constant bias current for Gate terminal
VgLimit: Gate voltage compliance
Cathode: GNDU connected to Cathode terminal
Ra: Optional series resistor inserted to the anode SMU
Rg: Optional series resistor inserted to the gate SMU

[Extended Test Parameters]
XaxisMax: Maximum X axis scale in the graph display (Anode voltage)
IaZero: Y axis (Ianode) minimum value (Effective for YScale=LOG)
PulseBase: Pulse base voltage
HoldTime: Hold time
Vcompliance: Anode voltage compliance (Effective for UHCU)
GatePWratio: Gate pulse width=GatePWratio * AnodePulseWidth

[Measurement Parameters]
Anode voltage Vanode
Anode current Ianode

[User Function]
Ta: Temperature Ta=Temp
VRa=Ianode*Ra
Vanode=Va-VRa
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VRg=Igate*Rg
Vgate=VG-VRg

[Analysis Function]
VTM=@L2X (Detect Vanode of Line1)

[Auto Analysis]
Line: Draw two lines at lanode=ITM@VTM. Line1 (Horizontal) and Line2 (Vertical)
Marker: Marker is on at Vanode=VDRM@IDRM

[X-Y Plot]
X axis: Anode voltage Vanode
Y axis: Anode current Ianode

[List Display]
Anode voltage Vanode
Anode current Ianode
Gate voltage Vgate
Gate current Igate
Anode SMU output voltage: Va
Gate SMU output voltage: Vg

[Parameter Display Area]
Temperature Ta=Temp
On voltage = VTM