

Keysight Technologies

DC Power Supplies for Base Station Testing

Application Note



Using DC power supplies in base station subassembly, module, and final test systems to:

- Reduce test system development time
- Design in reconfigurability
- Maximize test throughput
- Maximize production yield
- Minimize cost of test
- Increase confidence in base station product quality

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1. Introduction

1.1 Reduce test system development time

This application note provides information on how to maximize the utility of the DC power supplies that are in your base station test systems. Sometimes it seems that DC power supplies are just volts and amps. But in reality, the way you choose and use DC power supplies can affect your time to market, time to volume, and time to profit.

There never seems to be sufficient time to complete all the tasks involved in developing a new test platform in a fast-moving business like base station manufacturing. Production must begin and in order to meet end-customer demands and market windows the engineer must quickly create systems that can reliably test the products. Keysight Technologies, Inc. can help you quickly design the power supply portion of your system, leaving more time for you to concentrate on the critical issues of leading-edge base station technology.

Reduce software development time

Learning to program all of the different electronic instruments in a test system takes time, which delays the beginning of actual system development. All of the Keysight DC power supplies mentioned in this application note have industry standard SCPI (Standard Commands for Programmable Instruments) commands. Each command functions the same for any SCPI instrument with similar functions. For example, setting output voltage is the same for any power supply output, and measuring the voltage is the same as it would be with a digital multimeter (DMM). You learn each command only once, making both programming and software documentation quicker and easier.

Drivers speed software development by allowing the system designer to use National Instruments LabView or Keysight Vee. These drivers can also be used to speed the development process in Visual C++ or Visual BASIC environments. Drivers are available for all of the DC power supplies mentioned in this application note.

Reduce hardware development time

There are many efficiencies that the test engineer can gain by utilizing the advanced built-in output measurement and status monitoring capabilities in Keysight system DC power supplies. Monitoring the current drawn at the bias inputs of a subassembly or module during test helps to find marginally performing components and to raise confidence in the subassembly's long-term performance.

A typical base station subassembly requires multiple bias inputs. One DMM might monitor all DC inputs, using a multi-plexing (MUX) switch between them. Measuring current normally involves a complicated set-up with precision resistors in series with each bias input. The wiring must be done with care to avoid noise pickup. This can all be avoided by using the internal current measuring feature that is standard with all Keysight system DC power supplies. Wiring and system complexity are immediately reduced, and the quality of current measurement can actually improve. Hardware and software design efforts are simplified with this approach.

There are many additional monitoring features built into the Keysight DC power supplies that are discussed throughout this application note. In all cases, equivalent external implementation of these features would add complexity to the system design.

1.2 Maximize overall throughput by minimizing unexpected delays

Resolve system design and implementation problems quickly

During the design phase of the test system, questions may arise concerning the use of DC power supplies or other Keysight test equipment. Trained specialists are available worldwide to help you to quickly resolve your system design problems. When you're ready to build test systems, you will need the equipment without delay. Let your Keysight sales representative know that you have a tight schedule, so that Keysight can work with you to make sure that your production line is up and operating when its needed.

Test system downtime is unacceptable in the high volume base station manufacturing facility. The benefits of increased system throughput can instantly be nullified by a failure of one of the test systems. One test system down could delay or actually stop a complete production process, causing reduced product shipments and revenues and end-customer dissatisfaction.

Choosing the most reliable test instruments is the beginning of building a reliable test system. Compared to the cost of downtime, the initial investment can easily be justified. Instruments that produce or dissipate large amounts of power are especially susceptible to reliability issues. Electronic components have limits to the current, voltage, and heat they can handle before beginning to degrade. A DC power supply that will perform trouble-free in the manufacturing environment must be designed for continuous operation at full-rated power. It takes years of experience in the design of power electronics to understand how to design power circuits which will reliably operate under all conditions. Keysight has a long record of providing power products that excel in reliability.

Less complex systems have a lower probability of developing problems. Also, the simpler a system is, the quicker it is to troubleshoot a problem. By using the advanced measurement capabilities of Keysight system DC power supplies, as was described above, you can eliminate many complexities including the number of instruments and wiring connections.

Worldwide support

Keysight has a worldwide support network available to assist you. We will make every effort to respond to your needs, and help you get your test system functioning quickly with minimum disruption to your manufacturing process. No matter where your manufacturing is done, whether it's now or in the future, Keysight will be there with local support for you.

1.3 Planning for the future

The Keysight family of system DC power supplies was designed to provide the flexibility you need for future system enhancements. But sometimes you need more than flexibility. As you work towards optimizing your processes and implementing new base station technologies, allow the application engineers at Keysight to assist you in your effort to choose and get the most from your DC power supplies.

2. Choosing Keysight DC power supplies for base station testing applications

2.1 Phases of base station manufacturing

Listed below are the three major test phases occurring in the assembly of a base station ready to ship to the remote customer site. At each phase, different DC power supplies are required. These phases may not occur at the same site.

Final test

After the hardware is fully integrated and the customizing software/ firmware is downloaded the final testing is done. The testing at this stage verifies only that all of the components communicate properly with each other and work together as intended. It is assumed that all of the components have been verified as fully functional before this test phase begins.

Module test

The base station described above is composed of a variety of modules, including digital input/output (I/O) and control and power amplifiers. These modules all require full functional testing.

Subassembly test

Some of the modules contain multiple printed circuit (PC) board subassemblies that warrant separate testing before being integrated into the modules.

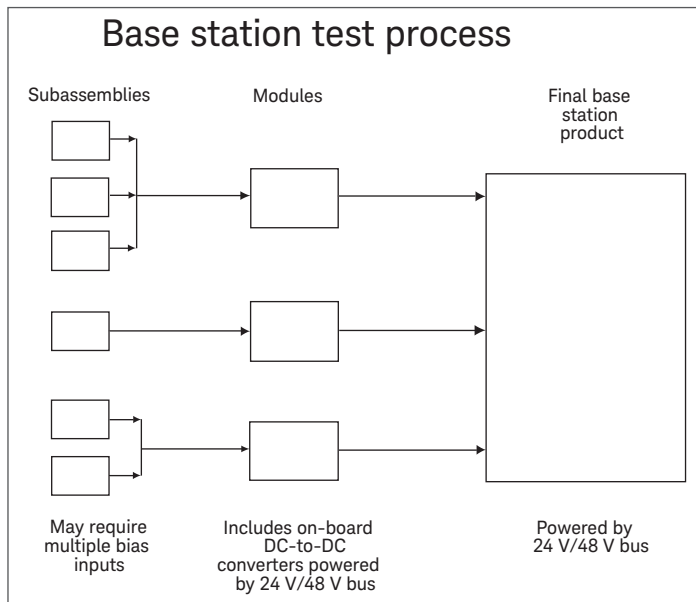


Figure 1. Base station test process

2.2 Get the most from your investment with flexible Keysight DC power supplies at each test phase

Keysight offers an extensive selection of DC power supplies to meet the DC power requirements for testing base station subassemblies, modules and the fully integrated base station. All have the exceptional reliability that Keysight power products are known for, which is key for keeping your production facility running smoothly. Also, protection features within all of these power supplies provide for controlled limiting and/or shutdown

of the DC power if a problem in the module under test occurs. These Keysight products, together with the worldwide network that supports them, will give you the trouble-free DC power you need.

Following is a summary of the Keysight DC power supplies that are optimal for base station testing. They provide the flexibility that is needed for system platforms designed to test a wide range of base station products.

2.3 Keysight DC power supplies for digital I/O, interface, control, and transceiver module and subassembly test



Figure 2. Keysight 66000A series modular power system

66000A series modular power system (MPS)

Many base station modules and subassemblies require multiple DC bias inputs, at a variety of voltage levels. The 66000A mainframe, when configured with up to eight DC power supply modules, provides a compact, easily reconfigurable solution for biasing modules and subassemblies for test. Keysight's MPS mainframe design allows all of those biases to be supplied from one instrument. Polarity reversal relays are also available to easily configure \pm biases (i.e. ± 12 volts). The test program can address all of the power supplies in an MPS mainframe simultaneously, increasing test throughput and simplifying software.

Reconfiguring the system for the next subassembly or module to be tested is easy with flexible power supply architecture. With eight slots available, and the polarity reversal relays, a wide variety of combinations can be designed into your test system platform. With this flexibility, few changes will be needed to keep up with the ever-changing demands on your test systems.

The MPS also provides a convenient source for biasing test fixture circuitry in all phases of the manufacturing process.

66000A series 150 watt DC power modules

Model	66101A	66102A	66103A	66104A	66105A	66106A
Voltage	0-8 V	0-20 V	0-35 V	0-60 V	0-120 V	0-200 V
Current	0-16 A	0-7.5 A	0-4.5 A	0-2.5 A	0-1.25 A	0-0.75 A

Option 760: Output disconnect and polarity reversal relays

2.4 DC power supplies for power amplifier module test

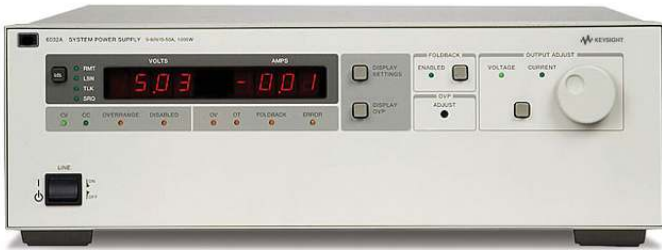


Figure 3. Keysight 6030A series 1000 watt autoranging system power supply

6032A 1000 watt autoranging DC power supply

Most power amplifier test systems must be able to test modules for both 24 VDC base stations and for 48 VDC base stations. One Keysight 6032A autoranging DC power supply can be used to provide power for either type of power amplifier module, because it can source 1000 watts at any voltage between 20 VDC and 60 VDC. This saves both direct cost and in rack space. Extensive protection features will shut the DC power down if an error occurs, allowing the power amplifier module to be recovered for repair before it is damaged, maximizing yield.

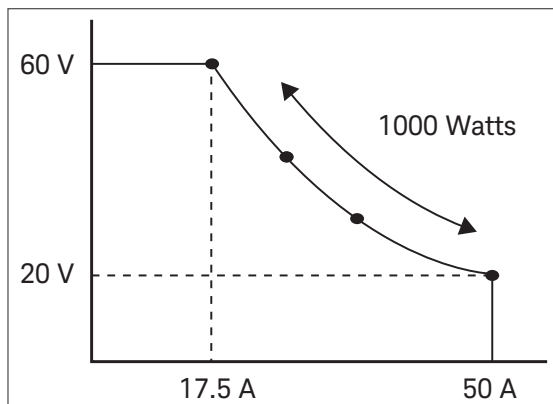


Figure 4. Output characteristic of Keysight 6032A autoranging DC power supply



Figure 5. Keysight 6650A series 500 watt system power supply

6653A 35 V 500 watt DC power supply

6654A 60 V 500 watt DC power supply

These DC power supplies are examples of a series of low-noise power supplies for power amplifier module testing. They also have advanced readback and protection features.

For multiple carrier power amplifier (MCPA) testing, see the higher power units listed below.

Many other autoranging and single range models are also available.

2.5 Keysight DC power supplies for base station final test



Figure 6. Keysight 6680A series 5000 watt system power supply

DC power supply reliability becomes more important, and more difficult to provide, at higher current levels. Keysight provides proven high quality at all power levels, making these the right choice for higher power DC power supplies.

The following power supply models can be connected in parallel or in series for increased current and power output. This is important to help configure a flexible test system that can test either 24 volt or 48 volt base stations.

Model	6673A	6674A	6683A	6684A	6691A	6692A
Max. volts	35 V	60 V	32 V	40 V	30 V	60 V
Max. amps	60 A	35 A	160 A	128 A	220 A	110 A

Please refer to the Keysight Power Products Catalog 5968-2199E for more models and additional specifications.

These Keysight DC power supply models are also very well suited for MCPA assemblies. Their extensive protection features are especially important for testing higher power MCPAs.

3. Verify product under real-life conditions by varying bias input voltage

A base station in the field must operate properly under a wide variety of input power conditions, to fully meet the expectations of your customers. A complete test of the system, therefore, would have to include verification of operation across the full range of possible input voltage variation. This testing is usually done as early as possible in the manufacturing process, on the module or even at the subassembly level. With this testing, full operational confidence has been achieved before the final base station integration and customization phase. This applies to all categories of modules, including the digital control and interface modules, and the power amplifier modules.

The base station modules are designed to be powered by the main base station DC bus, which is nominally either 24 volts or 48 volts. However, on the subassembly level, other voltage levels exist. DC-to-DC converters are incorporated into each module, to convert the main bus voltage to whatever the circuit components require. When the module is broken down into its composite subassemblies, these DC-to-DC converters might not be included in a particular subassembly. Therefore, the test system for these subassemblies must provide whatever assortment of bias inputs each subassembly requires.

In the case of those subassemblies that will be powered in the final product by well-regulated DC-to-DC converters, the test limits can be easily defined by the specifications of the DC-to-DC converter. The DC-to-DC converters, however, need to be able to operate over the full rated range of the main 24 or 48 volt DC bus by which it will be powered.

In the case of those modules and DC-to-DC converters that do operate off of the main 24 or 48 volt DC bus, the possible range of input voltage fluctuations must be fully characterized. Then the test limits can be appropriately defined.

There is no definitive industry standard for DC bus voltage range. However, typically the nominal level of a 24 volt bus is 27 volts, with a normal expected operating range of 24 volts to 28 volts. Typically, the nominal level of a 48 volt DC bus is 54 volts, with a normal expected operating range of 48 volts to 56 volts.

Some general categories of DC bias margin testing that might be included during the manufacturing process are the following.

Low line

Low line is the minimum DC bias level that the module or subassembly is specified to operate at. A test plan might include repetitions of sections of the functional tests at various DC input levels to have full confidence. Another approach is to determine what input levels are most likely to cause problems, based on the circuit designs, and create a test plan to focus on only the worst case conditions. For example, some manufacturers perform the majority of their module testing at the lowest specified DC input level, rather than nominal line. In this way the test cycle might be shortened without a reduction in confidence. For many modules and subassemblies, low line operation is the most likely condition under which to find marginal components, and the most likely to identify functional errors.

For 24 volt systems, 21 volts is typically considered the worst case low line condition. For 48 volt systems, 42 volts is typically considered the worst case low line condition.

Voltage less than the minimum specified for operation

These tests are performed to determine what the module or subassembly response would be if backup power should fail. Sometimes it is specified that the module attempts to continue operating with degraded performance, and sometimes other actions are ex-

pected. Depending upon how the modules are specified to operate under extremely low line conditions, this type of testing may need to be performed to verify that the expected actions (if there are any) occur.

High Line

There are two reasons to test at higher than nominal line. First, correct operation needs to be verified, and second, the higher input voltage might accelerate the failure of weak components.

For 24 volt systems, 30 volts is typically considered the worst case high line condition. For 48 volt systems, 60 volts is typically considered the worst case high line condition.

Note that the system DC parameters must be defined before the test strategy is created.

3.1 Full product testing at the subassembly level, without sacrificing system throughput

When doing bias margin testing on a subassembly which requires a number of different bias voltage levels (i.e. 3.3 V, 5 V, +/-12 V), you would of course vary all bias inputs. However, sending programming commands to all of those power supplies takes valuable test time. It would be desirable to be able to program all of these power supplies with only one command.

When using the Keysight 66000 series MPS, throughput can be maximized during bias margin testing by using the list function. By pre-loading multiple sets of bias levels to the power supplies in a list, command processing time at each test stage is eliminated. During the testing, the computer can use a single command to simultaneously signal all power modules to step through each test condition.

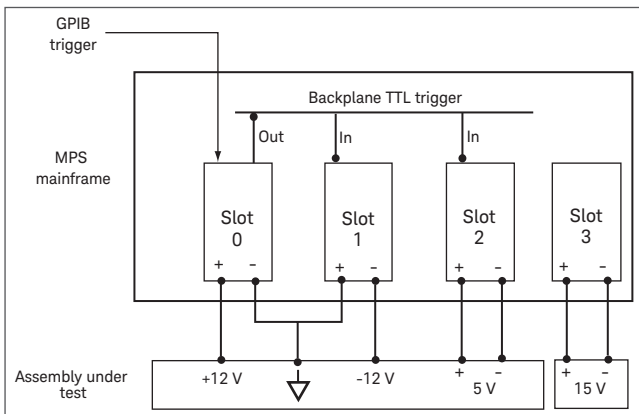


Figure 7. Subassembly under test having three DC bias inputs

In the above example the subassembly under test has three DC bias inputs. A 66000A MPS with the appropriate three power supply modules is used. Margin testing is required for these three bias inputs. A fourth MPS power supply module is used for fixture power. This fourth power supply module will remain unaffected by the margin test routine.

Four DC voltage levels for each of the three bias inputs have been chosen, and are downloaded to the three power supply modules during system set-up. During actual testing, the following would occur.

For power supply module 1

- Trigger the module from a computer trigger command over the GPIB

- Use a trigger-paced list. Each GPIB trigger command will cause the execution of another step in the list
- Generate the output voltage from the list
- Have the module generate a backplane TTL trigger at the start of each point (step) in the list
 - This can be done by triggering on the STS (step started) status condition
 - This backplane TTL trigger will be used to synchronize to the other modules

For power supply modules 2 and 3

- Trigger the module from the backplane TTL trigger bus (from step 4 above)
- Generate the output voltage from a list
- Use a trigger-paced list
 - Each backplane TTL trigger causes the execution of one step in the list

For power supply module 4

This power supply is used for test fixture power, so it is kept at a constant voltage level. Note that the list function need not be enabled on all power supply modules. It is very common in base station module test systems to use an MPS to provide both power supplies for the device under test (DUT), and power supplies for general system needs.

Benefits of using lists and triggers for this application

- By using lists, all three power supply modules change their output voltage simultaneously, without the delays due to individual command processing
- By using triggers, all three power supplies change with one simple command from the computer, greatly reducing command processing time
- The computer loop to do the required functional test at each bias voltage level is simplified because each power supply does not have to be explicitly reprogrammed

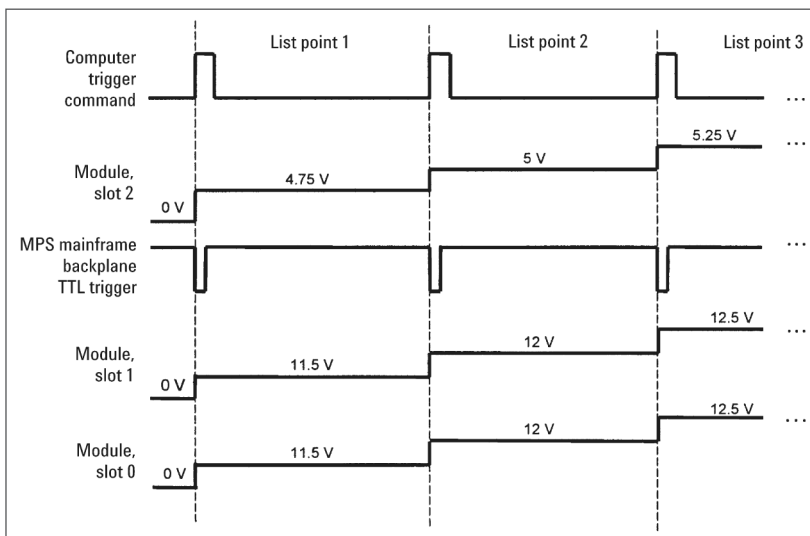


Figure 8. Timing diagram for using lists in the 66000A MPS to vary DC bias inputs

3.2 Sequencing of bias input turn on

Subassemblies sometimes require their bias inputs to turn on in a particular order, so that one specific circuit is active before power is applied to another. The delay function in the MPS list mode can easily be used to accomplish this.

4. Maximizing production yield

It is inevitable that some modules and subassemblies will fail during testing. They will then be repaired and the test cycle begun again. If the failure is caused by a shorted component, however, an excessive amount of current might immediately start to flow through circuits not designed for such an overload. Additional components will fail. The damage might quickly grow to the point of causing irreparable damage to major components and printed circuit boards. This would then increase the possibility of the total loss of that assembly. To keep from incurring these extra expenses, wasted time, and loss of subassemblies or modules, the DC power to the subassembly must be immediately shut down. There are a number of tools available in Keysight DC power supplies that the test engineer can use to minimize this type of loss.

4.1 Current limiting techniques

There are many different ways to implement current limiting. When choosing DC power supplies for test systems, it is important to select those that have the features corresponding to the level of protection that is needed for the subassemblies, modules, or full base stations being tested.

Fixed current limit

A power supply with this type of current limit will not provide more current than the defined limit value. This does provide some protection, but might not protect delicate components. For example, a power supply specified to provide 10 amps maximum might have a fixed current limit of 10.4 amps. This means that if you put a short across the output, 10.4 amps would flow. In this example, a subassembly is being tested that would normally draw 6.0 amps. If the subassembly shorts, the current will limit at 10.4 amps, until the power supply is turned off or disconnected. The 10.4 amps flowing for a period of time into the 6.0 amp assembly might cause additional component damage. If a variable current limit power supply is used, but the appropriate current limit is not set, the same situation would result.

Variable current limit

A power supply with a variable current limit is especially appropriate for test systems that may be used to test a variety of assemblies. For the above example, you might choose to test the 6.0 amp assembly with a 6.5 amp programmed current limit. Now, if the assembly shorts, 6.5 amps rather than 10.4 amps would flow into it until it was turned off or disconnected. There is less current flowing than in the fixed limit case, but it is still continuing to flow after the damage has occurred, possibly causing additional damage.

Variable current limit with automatic shutdown

A power supply with automatic shutdown will not only limit the current to the level that the user sets, but it will immediately program the current to zero amps should that current limit value be reached. In the above example, if the assembly under test were to short, the current would rise to 6.5 amps, then go to zero amps. In this way the damage is limited, and the assembly can be repaired. This feature may be called overcurrent protection, or it may be called current foldback. This procedure could also be accomplished by monitoring the current output of the power supply, and then using the computer to program the power supply to zero. While this would produce the same end result, it would allow the current to flow for a longer period of time, and would also increase total test time because of the extra computer interaction required.

Variable current limit with delayed shutdown

To avoid nuisance shutdown, a common practice is to set the current limit just above the maximum current desired. However, many subassemblies will draw more current upon

initial turn on than at any time during normal operation because their capacitors need to charge. This phenomenon is called inrush current. Because of this, you would need to set a fairly high current limit so that it did not trip on initial assembly turn on. Some power supplies can delay their shutdown features for a set number of milliseconds. This allows a lower current limit to be in affect for the majority of the test time. All of the Keysight DC power supplies mentioned in this application note have this feature.

Active downprogrammer

Most DC power supplies have capacitors at their output to minimize noise. This means that even after a power supply is programmed to zero volts and zero amps, the capacitors on the output would continue to supply current into the load until they are fully discharged. All Keysight base station system power supplies have active downprogramming circuits to help drain the energy from the output capacitors. Active downprogramming also increases system throughput, by reducing the time it takes for the power supply to reduce its voltage.

Discreet fault indicator/remote inhibit (DFI/RI)

Many base station subassemblies require more than one bias input. If a failure causes one of the bias supplies to go into current limit mode, it is advisable to program all of the bias supplies to zero. The quickest and, therefore, safest way to accomplish this is without computer intervention. Some system power supplies are equipped with a TTL I/O connection that allows all of the power supplies in a system to be connected in a daisy chain. This I/O connection is then used for any one power supply to inform all of the other connected power supplies that a predetermined condition has occurred, and then all power supplies program their output down to zero. All of the Keysight DC power supplies recommended in this application note for base station testing have the DFI/RI capability included. An event external to the power supplies could also be configured to trip this protection feature via a TTL signal.

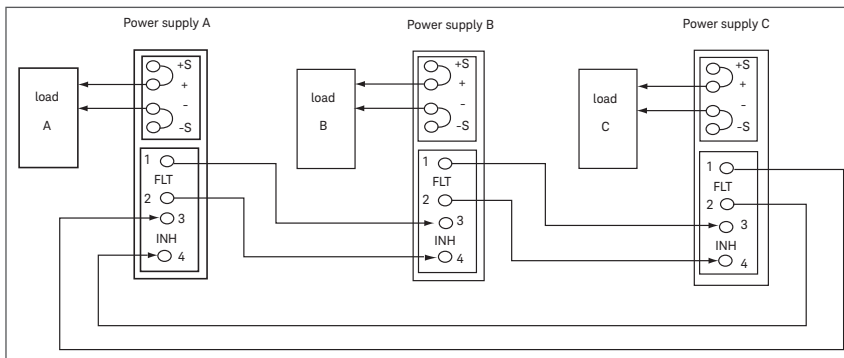


Figure 9. Daisy-chain of three power supplies for emergency shutdown

4.2 Maximizing current protection without sacrificing system throughput

To achieve the maximum level of current protection, it is advisable to characterize the normal input current profile of a subassembly or module under test, and as a result be able to choose the most appropriate current protection settings. The current limit can be reprogrammed to a new level at various stages in the testing, however, this takes valuable test time.

When using the 66000 series MPS, throughput can be maximized by using list mode. By downloading a list of the current limit levels to the MPS power supply modules during system setup, command processing time for these commands at test time is eliminated. The changes of the current limit level could be paced either by programming a dwell time

for each list step, or by sending a GPIB trigger command to begin each list step. By pacing list execution with dwell times, no additional computer intervention is required during testing. By pacing the current limit changes with GPIB trigger commands, then only one simple command would be required to change the current limit level on all of the power supplies in the 66000A mainframe. A detailed example was given in the last section of how lists and triggers can assist you in reducing system throughput. This example only involved an output voltage list. Using an output current list would also save test time, and would be accomplished in a similar way.

When to use current limit protection

As subassemblies are combined into modules and modules combined into the final base station, confidence in the correct operation of the electronics increases with each step. As the base station components step through the manufacturing process, they are less likely to have a failure causing excessive current to flow. However, the potential expense associated with such a failure grows larger as the product is closer to completion. For this reason, it is advisable to take current limiting into account in all stages of the manufacturing process.

Other protection considerations

Even the most reliable DC power supply could weaken and fail. Also, cooling fans in test racks could fail, causing an overheating condition. Keysight system power supplies can be configured to program down to zero upon an over temperature condition and a number of other internal error conditions. This state could then be configured to program down the remainder of the Keysight DC power supplies in the system via the DFI/RI I/O connections. This adds another level of protection for your assemblies under test and therefore another contribution towards yield maximization.

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