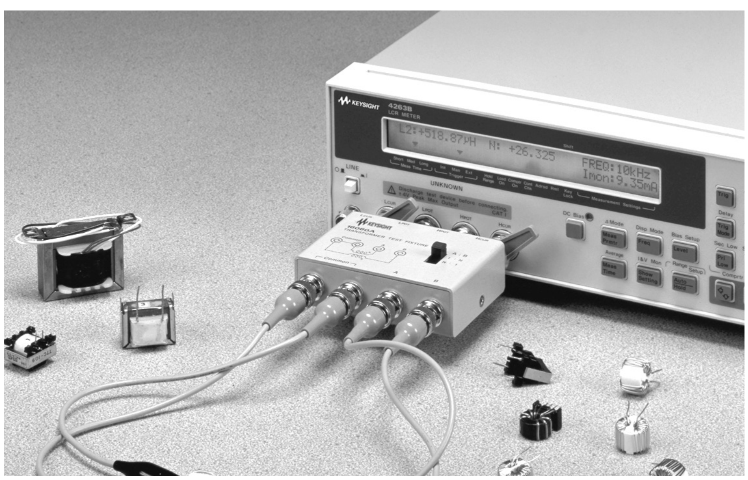
Keysight Technologies

Effective Multi-tap Transformer Measurement using a Scanner and the 4263B LCR Meter

Application Note



KEYSIGHT TECHNOLOGIES

Introduction

With the progress of recent electronics equipment and digital networks, production amounts are increasing of the transformers which contribute to equipment miniaturization, low power dissipation and higher quality. Therefore, improvement of select estimate efficiency is required at the production line or incoming inspection. Noticed recently, improvement of estimation efficiency is required for pulse transformers which are used in LAN or ISDN digital networks, and for multi.-tap transformers with three or more pole taps, such as switching power transformers. This application note shows an effective multi-tap transformer measurement using a scanner and the 4263B LCR meter.

The 4263B Transformer Measurement Capability

The 4263B LCR meter is a low price instrument which measures the fundamental parameters of LCR components with speeds as fast as 25ms, at frequencies of 100, 120, 1k, 10k and 100kHz, In addition, with option 001, the 4263B measures turns ratio (N), mutual inductance (M) and dc resistance (DCR) which are required for transformer measurement. Figure 1 shows a 4263B simple block diagram for L, M, and DCR measurement.

For example, in the inductance-turns ratio (L-N) measurement, an ac voltage is applied at the Hcur terminal. Self-inductance value (L1) is calculated from the measured values of V1 and I1. Turns ratio (N) is automatically obtained from the ratio of measured values V1 and V2 (discriminating the polarity simultaneously).

In the dc resistance (of L-DCR) measurement, the applied voltage at the Hcur terminal is dc. Dc resistance value (DCR1) is calculated from the measured values V1 and I1.

There are, however, the following limitations when using the measurement connection.

– Only primary self-inductance and dc resistance of the transformer can be measured. For the secondary values, the transformer connections must be changed.

– Turns ratio must be 0.9 or more (In the case of less than 0.9, the measurement is not performed due to saturation of internal circuitry).

The Keysight Technologies, Inc. 16060A transformer test fixture can be used to overcome these limitations. By changing the external switch of this fixture, connections to the transformer are changed and thus both primary and secondary parameters and turns ratio can easily be measured. Figure 2 shows the simple block diagram of the 16060A.

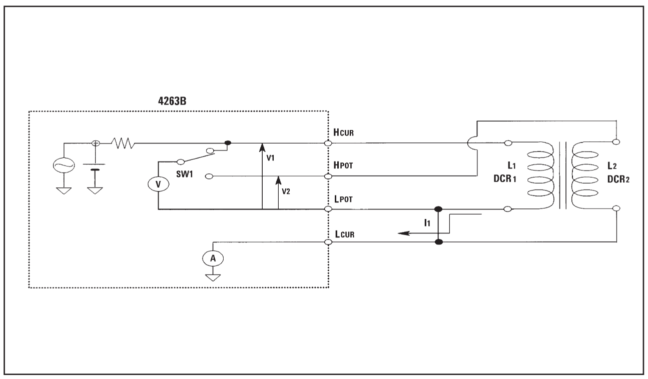


Figure 1. The 4263B block diagram for L, M, and DCR measurement

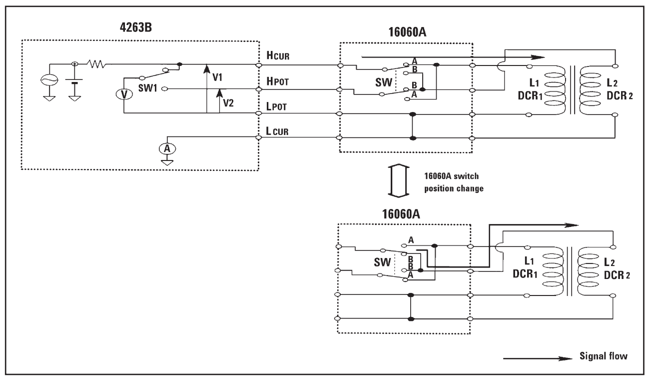


Figure 2. Keysight 16060A block diagram

Multi-Tap Transformer Measurement Using a Scanner

Multi-tap transformers having two or more poles can be measured with the 4263B and a scanner.

(A) System configuration

Figure 3 shows the system configuration for measuring a multi-tap transformer that has 4 taps.

The 3488A switch/control unit with a 4 x 4 matrix switch module (Opt. 013) is used. Option 013 offers highly flexible switching, and any combination of 4 input channels may be connected to any combination of 4 output channels. Thus option 013 is suitable for testing the multi-tap transformer. Figure 4 shows the hardware configuration of the 4 x 4 matrix switch module.

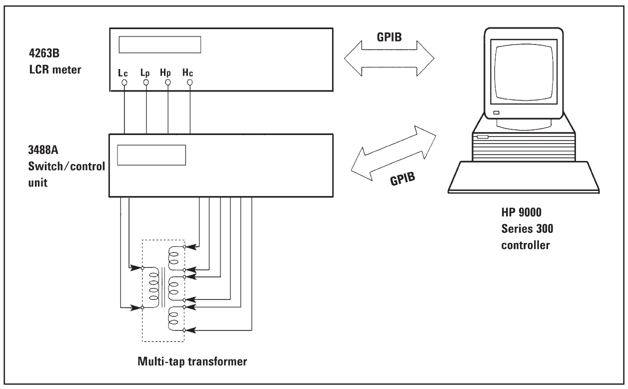


Figure 3. System configuration for multi-tap transformer

(B) System construction recommendations

When constructing the system, the following points must be considered to assure the measurements are as precise as can be. (See figure 5)

1.Make measurement cables as short as possible. The parasitic inductance and resistance of measurement cables make a large contribution to measurement error. For recommendable length, conductive wire inductance value must be 1/10 or less than the measured inductance value (similarly conductive wire resistance).

2. Configure into a shielded 2 terminal configuration, to prevent the influence of external noise or stray capacitance.

3. Connect the low terminals close to the transformer. In the 4263B transformer measurement, the primary and secondary inductors' low terminals of the transformer must be connected together. Whenusing a scanner, these connections should be close to the transformer under test. If connecting at a far point from the transformer (for example, input point of scanner module), low side wire resistance would contribute to increase measurement error.

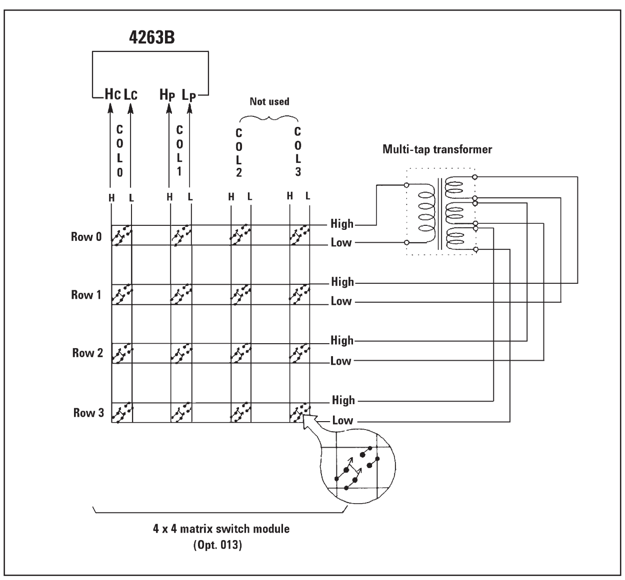


Figure 4. Option 013 4 x 4 matrix module

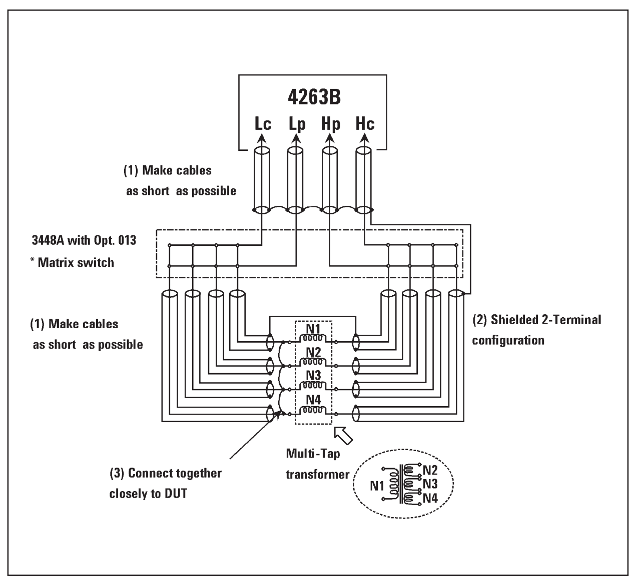


Figure 5. System construction

(C) Measurement procedure

All measurements of the multi-tap transformer, self-inductance, dc resistance, and turns ratio, can be measured with only one connection by using the sample program shown at the end of this note (for HP 9000 Series 300 Controller). Figure 6 show the flow chart of the sample program.

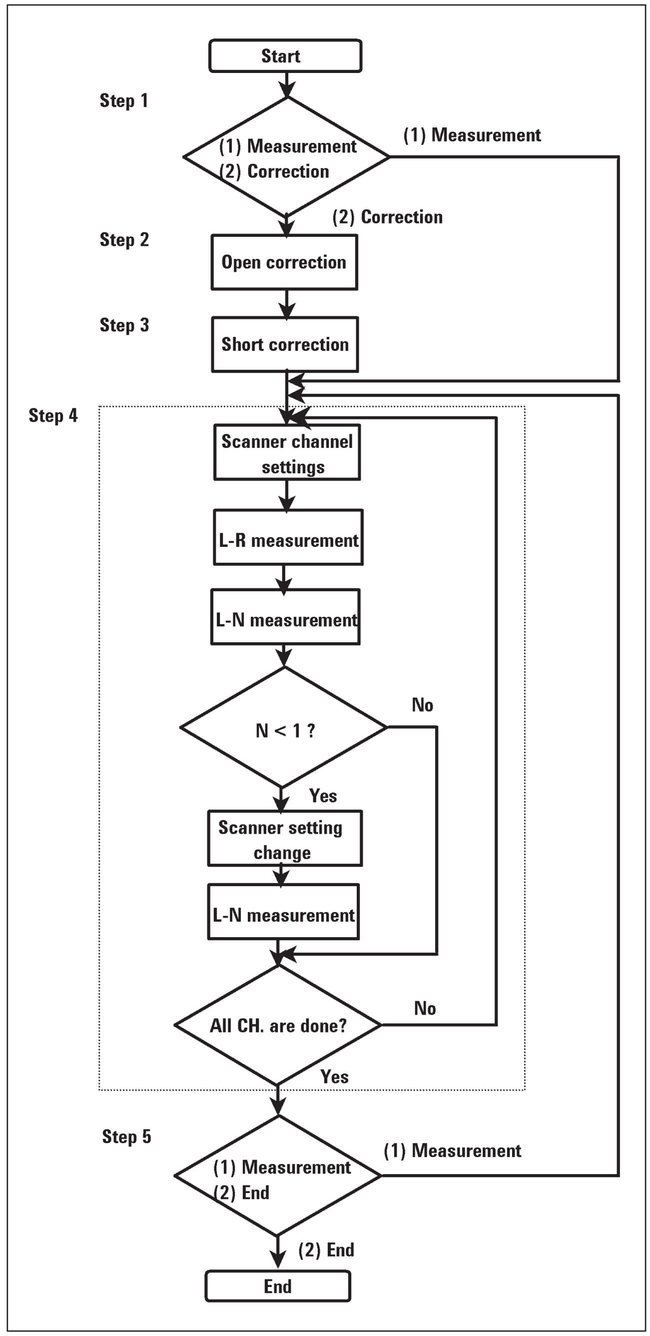


Figure 6. Flow chart of sample program

This program executes the open and short corrections and displays each measured value of each tap of the transformer. If turns ratio measurement cannot be made due to the condition that turns ratio must be 0.9 or greater, the scanner will be automatically changed and the measurements re-done. This program can be modified to match other systems or conditions.

The following steps outline the program procedure:

Step 1. Run the program. The following message is displayed on the controller's display.

```
Selection (1) Measurement (2) Correction ?
Type number and press RETURN key
```

At this point, select the measurement directly , or first the measurement of correction data. To execute the measurement, type 1 and press RETURN key on the controller (Go to step 4). To measure the correction data, type 2 and press RETURN key on the controller.

Step 2. If the measurement of correction data in step 1 was selected, the following message is displayed on the controller's display. The open correction data of each channel of the scanner (CH.0-CH.3) is now measured.

```
CH.0 Open measurement
Open test terminals of CH.0
Start open meas. (2) Skip CH.0 open meas?

Type number and press RETURN key
```

To measure the open correction data, set all channels to the open condition as shown in figure 7. Then, type 1 and press RETURN key on the controller. Open correction data of channel number 0 (CH.0) is acquired. Continue to acquire data for channels 1 - 3.

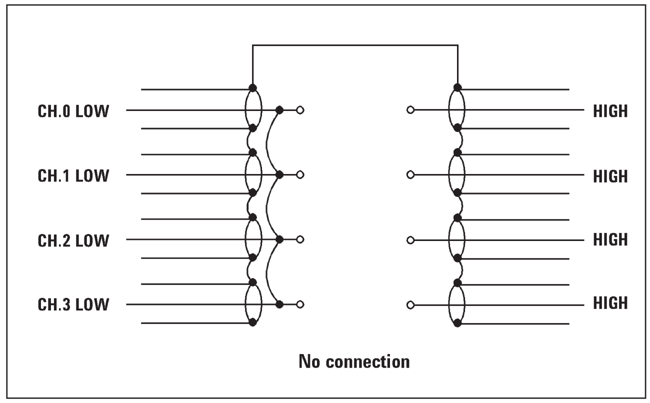


Figure 7. OPEN Condition

Step 3. After the open correction measurements are completed, the following messages is displayed on the controller's display. The short correction data of each channel of the scanner (CH.0 - CH.3) is now measured.

```
CH.0 Short measurement
Short test terminals of CH.0
Start short meas. (2) Skip CH.0 short meas.?

Type number and press RETURN key
```

To measure the short correction data, set all channels to short condition as shown in figure 8. Then, type 1 and press the RETURN key on the controller. Short correction data of channel number 0 (CH.0) is acquired. Continue to acquire data for channels 1 - 3.

Step 4. After the open/short correction data is acquired, the following message (same as in step 1) is displayed on the controller's display.

```
Selection (1) Measurement (2) Correction?
Type number and press RETURN key
```

To execute the measurement, connect the multi-tap transformer under test to the scanner as shown in figure 9. Type 1 and press the RETURN key on the controller.

Self-inductance, dc resistance and turns ratio are measured by scanning each tap of the multi-tap transformer.

```
N1: L[H]: 6.00928E-6 DCR [OHM]: .0134568726173 N: 1
N2: L[H]: 2.392557E-5 DCR [OHM]: .0171348134407 N: 2.1304
N3: L[H]: 9.603832E-5 DCR [OHM]: .0230939715609 N: 4.0630
N4: L[H]: .00038334126 DCR [OHM]: .0250939715609 N: 8.0188

Do you want to continue to measure (1) yes (2) no
```

Step 5. If you want to repeat the measurement, type 1 and press RETURN key on the controller. Or to end the program, type 2 and press RETURN key on the controller.

(D) Additional measurement error

The system configuration shown in figure 3, slightly increases measurement errors, in comparison with measured values using the 16060A transformer test fixture. These errors (supplemental characteristics) are the following using frequency: 1 kHz, signal level: 1 Vrms, measurement time: Medium.

Self-inductance: refer to figure 10
Dc resistance: refer to figure 11
Turns ratio: 0.02 % or less

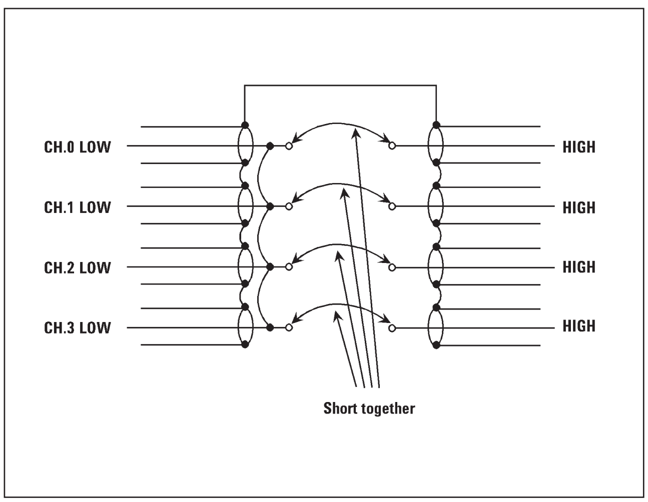


Figure 8. SHORT Condition

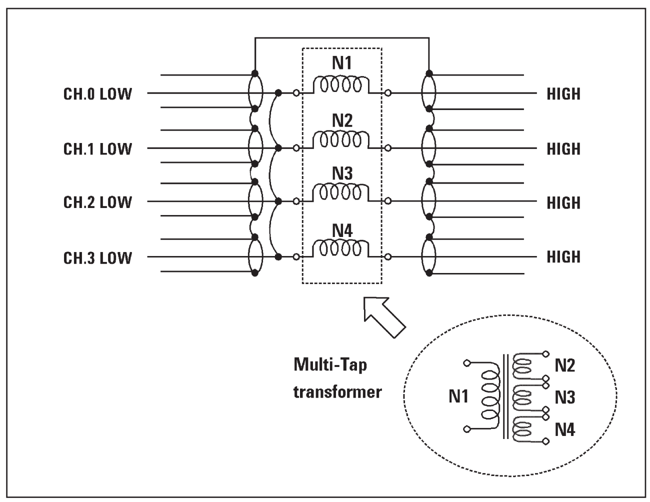


Figure 9. Connection of multi-tap transformer

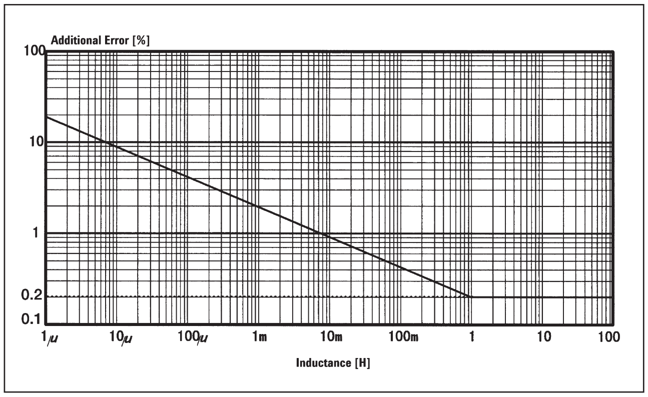


Figure 10 . Self-Inductance additional error

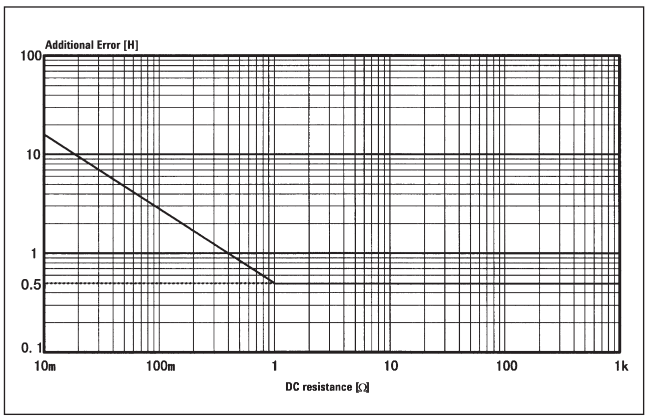


Figure 11. Dc resistance additional error

Conclusion

By combining the 4263B (with Option 001) with a scanner, the required parameters of a multi-tap transformer can be measured with only one connection. Using this method improves efficiency at the production line or incoming inspection.

Appendix. Sample Program

```
10     !********************************************
20     !*  4263B with Option 001                   *
30     !*  Transformer Measurement using scanner   *
40     !********************************************
50     !
60     OPTION BASE 0
70     DIM Ch_hc(3),Ch_hp(3)
80     DIM Meas_r(3),Meas_l(3),Dummy(3),N(3),True_r(3),True_l(3)
90     DIM Open_r(3),Open_l(3),Open_g(3),Open_b(3),Short_r(3),Short_l(3)
100                                             !
110    4263B=717                                ! 4263B GPIB Address = 717
120    3488a=709                                ! 3488A GPIB Address = 709
130    Nch=3                                    ! (#-1) of Transformer tap
140    F=1.0E+3                                 ! Test Frequency
150    V=1                                      ! Test Signal Level
160    T=.065                                   ! Measurement Speed
170    N(0)=1                                   ! N1=1 as reference
180                                             !
190 Main_menu:                                  ! << MAIN MEMU >>
200                                             !
210    PRINT CHR$(12)                           ! Clear screen
220    Work=0                                   !
230    PRINT "SELECT FUNCTION (1) MEASUREMENT (2) CORRECTION ?" !
240    INPUT "TYPE NUMBER AND PRESS RETURN KEY",Work !
250    IF Work=1 THEN Measurement               !
260    IF Work=2 THEN Correction                !
270                                             !
280 Correction:                                 ! << CORRECTION >>
290                                             !
300 Open_correction:                            ! << OPEN correction >>
310                                             !
320    OUTPUT 4263B;":SYSTEM:PRESET"            ! Reset the 4263B
330    OUTPUT 4263B;":SOURCE:FREQ ";F           !  Frequency: F
340    OUTPUT 4263B;":SOURCE:VOLTAGE ";V        !  Signal level: V
350    OUTPUT 4263B;":SENS:FIMP:APER 0.5"       !  Meas. speed: LONG
360                                             !
370    FOR Ch=0 TO Nch                          !
380                                             !
390      Ch$=VAL$(Ch)                           !
400      PRINT CHR$(12)                         !
410      PRINT "CH."&Ch$&" OPEN MEASUREMENT"    !
420      IF Ch=0 THEN PRINT "OPEN TEST TERMINALS OF CH.0 AND CH.1"!
430      IF Ch<>0 THEN PRINT "OPEN TEST TERMINALS OF CH.0 AND CH."&Ch$!
440      PRINT " (1) START OPEN MEAS.    (2) SKIP CH."&Ch$&" OPEN MEAS.?"
450      Work=0                                 !
460      INPUT "TYPE NUMBER AND PRESS RETURN KEY",Work !
470      IF Work<>1 AND Work<>2 THEN 460        !
480      IF Work=1 THEN Open_meas               !
490      IF Work=2 THEN Open_skip_ch            !
500                                             !
510 Open_meas:                                  !
520                                             !
530      Ch_hc(Ch)=200+Ch*10                    ! Channel Setting of Hcur/Lcur
540      IF Ch=0 THEN Ch_hp(Ch)=211             ! Channel Setting of Hpot/Lcur
550      IF Ch<>0 THEN Ch_hp(Ch)=201            !
560                                             !
570      OUTPUT 3488a;"RESET"                   ! Reset the 3488A
580      OUTPUT 3488a;"CLOSE";Ch_hc(Ch),Ch_hp(Ch) ! Close the channels
590      OUTPUT 4263B;":SENS:FUNC:CONC ON"      !  Meas.mode: L2-R2
600      OUTPUT 4263B;":SENS:FUNC 'IMP','RES'"  !
610      OUTPUT 4263B;":CALC1:FORM LS"          !
620      OUTPUT 4263B;":CALC2:FORM REAL"        !
630      OUTPUT 4263B;"TRIG:SOUR BUS"           !  Trigger mode: BUS
640      OUTPUT 4263B;"*TRG"                    ! OPEN correction data
650      ENTER 4263B;S,Open_l(Ch),Open_r(Ch)    !
660      IF S<>0 THEN 640
670      OUTPUT 3488a;"OPEN";Ch_hc(Ch),Ch_hp(Ch)   ! Open the channels
680      Open_g(Ch)=1/Open_r(Ch)                !
690      Open_b(Ch)=1/Open_l(Ch)                !
700                                             !
710 Open_skip_ch:                               !
720                                             !
730    NEXT Ch                                  !
740                                             !
750 Short_correct:                              ! << SHORT Correction >>
760                                             !
770    OUTPUT 4263B;":SYSTEM:PRESET"            ! Reset the 4263B
780    OUTPUT 4263B;":SOURCE:FREQ ";F           !  Frequency: F
790    OUTPUT 4263B;":SOURCE:VOLTAGE ";V        !  Signal level: V
800    OUTPUT 4263B;":SENS:FIMP:APER 0.5"       !  Meas. speed: LONG
810                                             !
820    FOR Ch=0 TO Nch                          !
830                                             !
840      PRINT CHR$(12)                         ! Clear screen
850      Ch$=VAL$(Ch)                           !
860      PRINT "CH."&Ch$&" SHORT MEASUREMENT" !
870      IF Ch=0 THEN PRINT "SHORT TEST TERMINALS OF CH.0 AND CH.1"!
880      IF Ch<>0 THEN PRINT "SHORT TEST TERMINALS OF CH.0 AND CH."&Ch$ !
890      PRINT "(1) START SHORT MEAS.   (2) SKIP CH."&Ch$&" SHORT MEAS.?" !
900      Work=0                                 !
910      INPUT "TYPE NUMBER AND PRESS RETURN KEY",Work !
920      IF Work<>1 AND Work<>2 THEN 910        !
930      IF Work=1 THEN Short_meas              !
940      IF Work=2 THEN Short_skip_ch           !
950                                             !
```

```
960 Short_meas:                                   !
970                                               !
980     Ch_hc(Ch)=200+Ch*10                       ! Channel Setting for Hcur/Lcur
990     IF Ch=0 THEN Ch_hp(Ch)=211                ! Channel Setting for Hpot/Lpot
1000    IF Ch<>0 THEN Ch_hp(Ch)=201               !
1010                                              !
1020    OUTPUT 3488a;"RESET"                      ! Reset the 3488A
1030    OUTPUT 3488a;"CLOSE";Ch_hc(Ch),Ch_hp(Ch)  ! Close the channels
1040    OUTPUT 4263B;":SENS:FUNC:CONC ON"         !  Meas.mode: L2-R2
1050    OUTPUT 4263B;":SENS:FUNC 'IMP','RES'"     !
1060    OUTPUT 4263B;":CALC1:FORM LS"             !
1070    OUTPUT 4263B;":CALC2:FORM REAL"           !
1080    OUTPUT 4263B;"TRIG:SOUR BUS"              !  Trigger mode: BUS
1090    OUTPUT 4263B:"*TRG"                       ! SHORT correction data
1100    ENTER 4263B;S,Short_l(Ch),Short_r(Ch)     !
1110    IF S<>0 THEN 1090                         !
1120    OUTPUT 3488a;"OPEN";Ch_hc(Ch),Ch_hp (Ch)! Open the channels
1130                                              !
1140 Short_skip_ch:                               !
1150                                              !
1160  NEXT Ch                                     !
1170                                              !
1180  GOTO Main_menu                              ! Return to Main Menu
1190                                              !
1200 Measurement:                                 ! << MEASUREMENT >>
1210                                              !
1220  PRINT CHR$(12)                              ! Clear screen
1230  OUTPUT 4263B;":SYSTEM:PRESET"               ! Reset the 4263B
1240  OUTPUT 4263B;":SOURCE:FREQ ";F              !  Frequency: F
1250  OUTPUT 4263B;":SOURCE:VOLTAGE ";V           !  Teset signal level: V
1260  OUTPUT 4263B;":SENS:FIMP:APER ";T           !  Measurement Speed: T
1270  OUTPUT 4263B;":TRIG:SOUR BUS"               !  Trigger mode: BUS
1280  OUTPUT 3488a;"RESET"                        ! Reset the 3488A
1290                                              !
1300  FOR Ch=0 TO Nch                             !
1310                                              !
1320    OUTPUT 4263B;":SENS:FUNC:CONC ON"         !  Meas.mode: L2-R2
1330    OUTPUT 4263B;":SENS:FUNC 'IMP','RES'"     !
1340    OUTPUT 4263B;":CALC1:FORM LS"             !
1350    OUTPUT 4263B;":CALC2:FORM REAL"           !
1360    Ch_hc(Ch)=200+Ch*10                       ! Channel Setting for Hcur/Lcur
1370    IF Ch=0 THEN Ch_hp(Ch)=211                ! Channel Setting for Hpot/Lpot
1380    IF Ch<>0 THEN Ch_hp(Ch)=201               !
1390    OUTPUT 3488a;"CLOSE";Ch_hc(Ch),Ch_hp (Ch) ! Close the channels
1400    OUTPUT 4263B:"*TRG"                       ! L2-R2 measurement
1410    ENTER 4263B;S,Meas_l(Ch),Meas_r(Ch)       !
1420    True_l(Ch)=(Meas_l(Ch)-Short_l(Ch))/((1-(Meas_l(Ch)-Short_l(Ch))*Open_b(Ch)))
1430    True_r(Ch)=(Meas_r(Ch)-Short_r(Ch))/((1-(Meas_r(Ch)-Short_r(Ch))*Open_g(Ch)))
1440                                              !
1450    IF Ch=0 THEN Skip_meas                    !
1460                                              !
1470    OUTPUT 4263B;":SENS:FUNC 'IMP','VOLT:AC'" ! Meas.mode: L-N
1480    OUTPUT 4263B;"*TRG"                       ! N measurement
1490    ENTER 717;S,Dummy(Ch),N(Ch)               !
1500                                              !
1510    IF S=1 THEN                               ! Hcur-Hpot CHANGE for OVLD
1520      OUTPUT 3488a;"OPEN";Ch_hc(Ch),Ch_hp(Ch) ! Open channels
1530      Ch_hc(Ch)=201+Ch*10                     ! Hcur channel CHANGE
1540      Ch_hp(Ch)=200                           ! Hpot channel CHANGE
1550      OUTPUT 3488a;"CLOSE";Ch_hc(Ch),Ch_hp (Ch) ! Close the changed ch.
1560      OUTPUT 4263B;"*TRG"                     ! N measurement
1570      ENTER 4263B;S,Dummy(Ch),N(Ch)           !
1580      N(Ch)=N(0)/N(Ch)                        !  N1:Nx=1:0.XX
1590    END IF                                    !
1600                                              !
1610 Skip_meas:                                   !
1620                                              !
1630    PRINT "N";Ch+1;":","L [H]:";True l(Ch),"DCR [OHM]:";True_r(Ch),"N:";N(Ch)
1640    OUTPUT 3488a;"OPEN";Ch_hc(Ch),Ch_hp (Ch)! Open channels
1650                                              !
1660  NEXT Ch                                     !
1670                                              !
1680  Work=0
1690  INPUT "DO YOU WANT TO CONTINUE TO MEASURE?   (1) YES  (2) NO",Work
1700  IF Work=1 THEN Measurement                  !
1710  IF Work=2 THEN 1740                         !
1720  IF Work<>1 AND Work<>2 THEN 1690            !
1730                                              !
1740  END
```

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