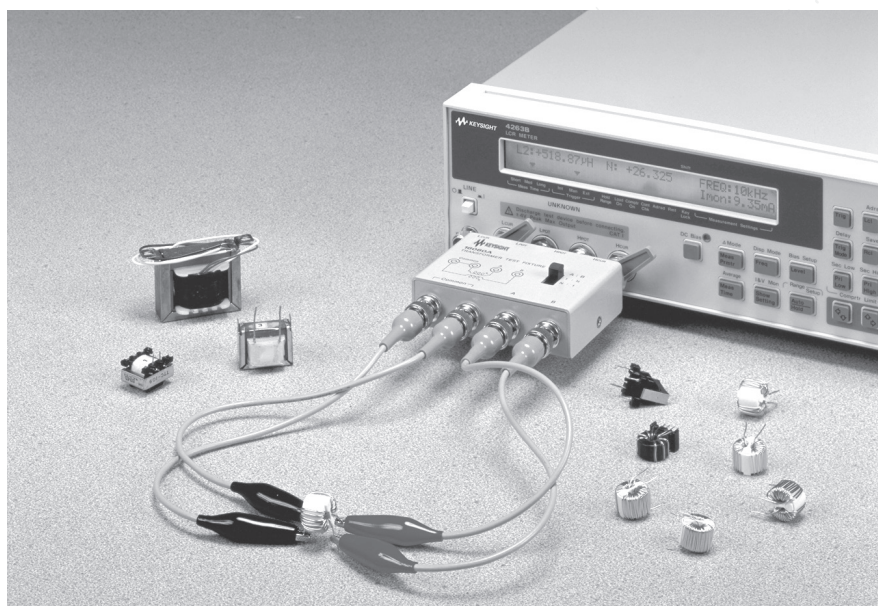


# Effective Multi-tap Transformer Measurement using a Scanner and the 4263B LCR Meter



# 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.

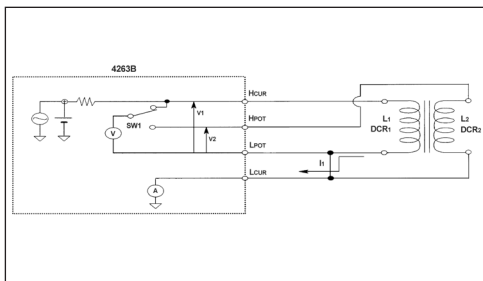


Figure 1. The 4263B block diagram for L, M, and DCR measurement

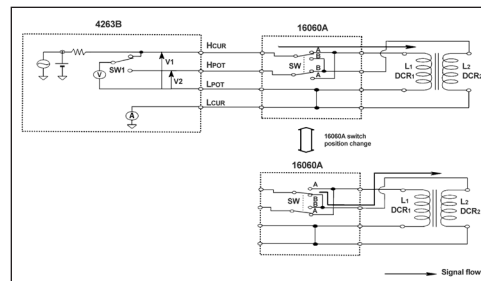


Figure 2. Keysight 16060A block diagram

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

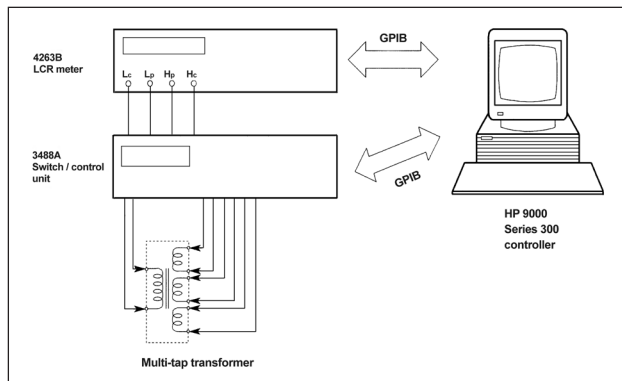


Figure 3. System configuration for multi-tap transformer

### (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. When using 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.

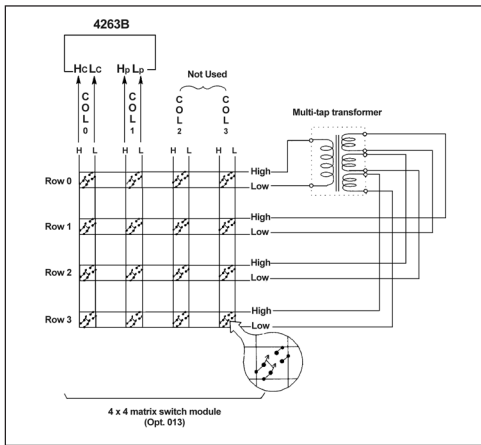


Figure 4. Option 013 4 x 4 matrix module

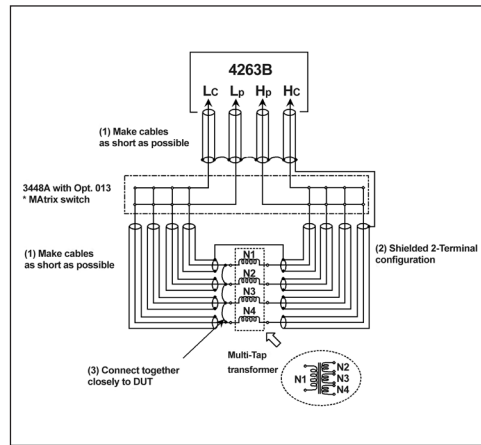
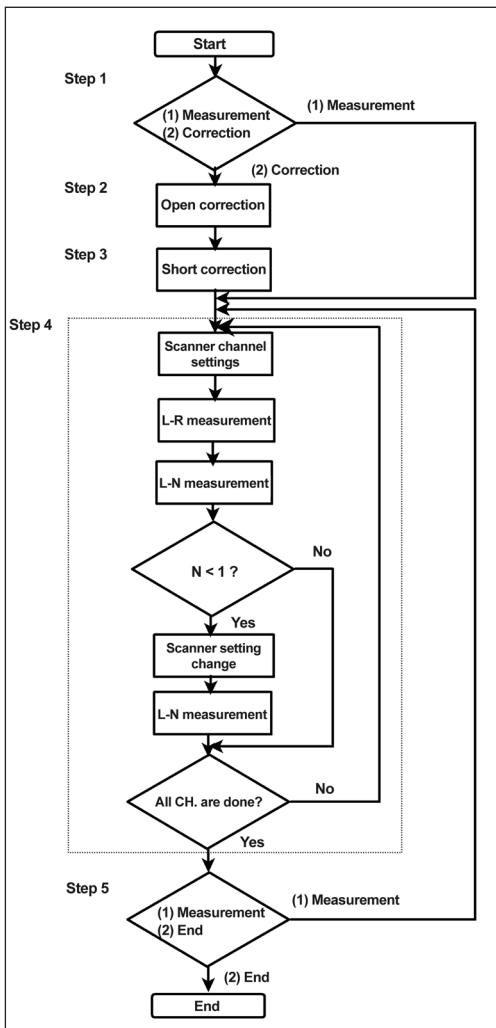


Figure 5. System construction

### (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.



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.

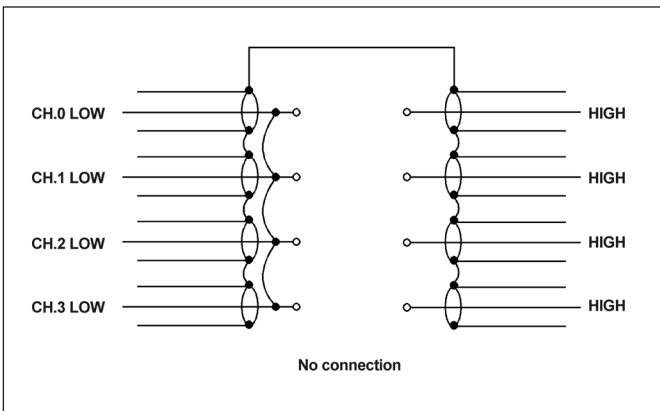


Figure 7. OPEN Condition

**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.

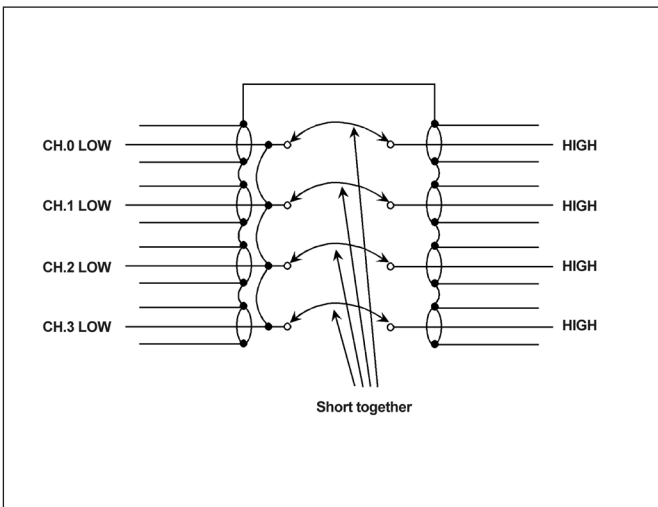


Figure 8. SHORT Condition

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

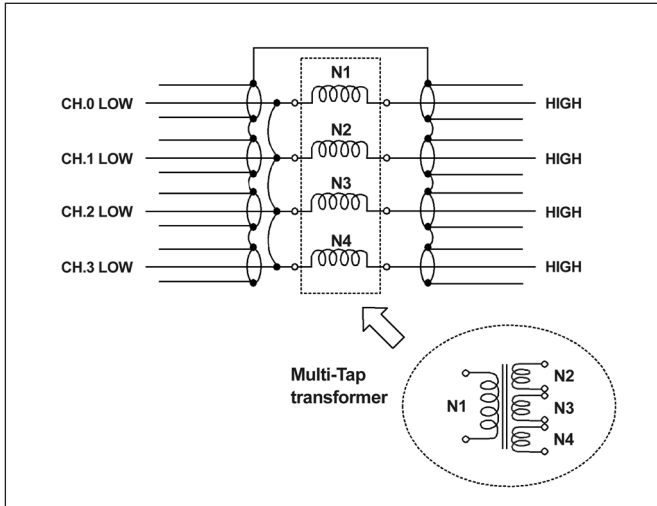


Figure 9. Connection of multi-tap transformer

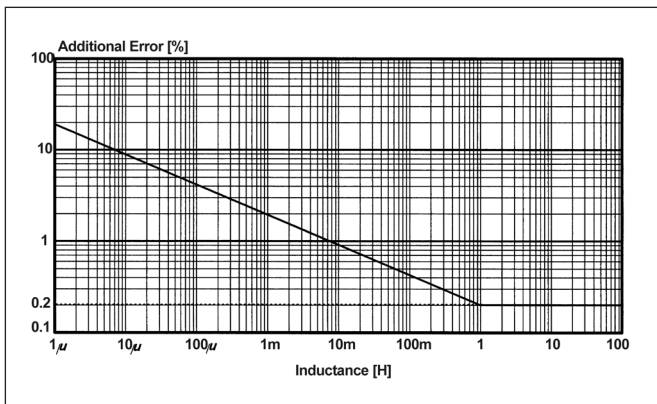


Figure 10 . Self-Inductance additional error

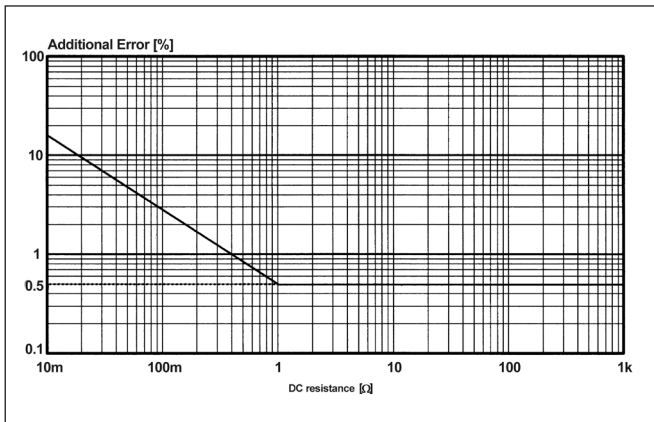


Figure 11. Dc resistance additional error

## 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=0.05 ! Measurement Speed
170 N(0)=1 ! N=1 as reference
180
190 Main_menu: ! << MAIN MENU >>
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$&" OPEN MEAS.?" !
450 Work=0
460 INPUT "TYPE NUMBER AND PRESS RETURN KEY",Work !
470 IF Work<=1 AND Work<=2 THEN 460 !
480 IF Work=1 THEN Open_meas !
490 IF Work=2 THEN Open_skip_ch !
500
510 Open_meas:
520 Ch_hc(Ch)=200+Ch*10 ! Channel Setting of Hcur/Lcur
530 IF Ch=0 THEN Ch_hp(Ch)=211 ! Channel Setting of Hpot/Lcur
540 IF Ch<=0 THEN Ch_hp(Ch)=201 !
550
560 OUTPUT 3488A;"RESET" ! Reset the 3488A
570 OUTPUT 3488A;"CLOSE":Ch_hc(Ch),Ch_hp(Ch) ! Close the channels
580 OUTPUT 4263B;"SENS:FUNC:CONC ON" ! Meas.mode: L2-R2
590 OUTPUT 4263B;"SENS:FUNC "IMP",RES" !
600 OUTPUT 4263B;"CALC1:FORM LS" !
610 OUTPUT 4263B;"CALC2:FORM REAL" !
620 OUTPUT 4263B;"TRIG:SOUR BUS" ! Trigger mode: BUS
630 OUTPUT 4263B;"TRC" ! OPEN correction data
640 ENTER 4263B;"S_Open_l(Ch),Open_r(Ch)" !
650
660 IF S<>0 THEN 640
670 OUTPUT 3488A;"OPEN":Ch_hc(Ch),Ch_hp(Ch) ! Open the channels
680 Open_g(Ch)=1/Open_r(Ch) !
690 Open_b(Ch)=1/Open_l(Ch) !
700
710 Open_skip_ch:
720
730 NEXT Ch
740
750 Short_correct: ! << SHORT Correction >>
760 !
770 OUTPUT 4263B;"SYSTEM:PRESET" ! Reset the 4263B
780 OUTPUT 4263B;"SOURCE:FREQ "f" ! Frequency: F
790 OUTPUT 4263B;"SOURCE:VOLTAGE "v" ! Signal level: V
800 OUTPUT 4263B;"SENS:FIMP:APER 0.5" ! Meas. speed: LONG
810
820 FOR Ch=0 TO Nch
830
840 PRINT CHR$(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 W 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;:"TRIG" | SHORT correction data
1100 ENTER 4263b;S,Short_r(Ch),Short_r(Ch)
1110 IF S<0 THEN TuYu
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:
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 | Reset 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 W Ch_hp(Ch)=201
1390 OUTPUT 3488a;"CLOSE";Ch_hc(Ch),Ch_hp(Ch) | Close the channels
1400 OUTPUT 4263b;:"TRIG" | L2-R2 measurement
1410 ENTER 4263b;S,Meas_r(Ch),Meas_r(Ch)
1420 True_r(Ch)=(Meas_r(Ch)-Short_r(Ch))/(1-(Meas_r(Ch)-Short_r(Ch))*open_b(Ch))
1430 True_g(Ch)=(Meas_g(Ch)-Short_g(Ch))/(1-(Meas_g(Ch)-Short_g(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;:"TRIG" | N measurement
1490 ENTER 717;S,Dummy(Ch),N(Ch)
1500
1510 IF S=1 THEN
1520 OUTPUT 3488a;"OPEN";Ch_hc(Ch),Ch_hp(Ch) | Hcur-Hpot CHANGE for OVLd
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;:"TRIG" | N measurement
1570 ENTER 4263b;S,Dummy(Ch),N(Ch)
1580 N(Ch)=N(O)/N(Lch) | N1:Nx=1:0.XX
1590 END IF
1600
1610 Skip_meas:
1620
1630 PRINT "M:Ch+1;M:" ;M ;"L [N]:" ;True_r(Ch), "OCR [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

```

This document was formerly known as Application Note 1224-5

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