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HP E1411A/B 5 1/2 Digit Multimeter Service Manual

Edition 2

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Notes

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HP E1411A/E1411B 5 1/2-Digit Multimeter Service Manual



Edition 2
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Documentation History

All Editions and Updates of this manual and their creation date are listed below. The first Edition of the manual is Edition 1. The Edition number increments by 1 whenever the manual is revised. Updates, which are issued between Editions, contain replacement pages to correct or add additional information to the current Edition of the manual. Whenever a new Edition is created, it will contain all of the Update information for the previous Edition. Each new Edition or Update also includes a revised copy of this documentation history page.

Edition 1 (Part Number E1411-90000). . . . . October 1995

Edition 2 (Part Number E1411-90011). . . . . August 1996

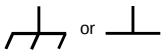
Safety Symbols



Instruction manual symbol affixed to product. Indicates that the user must refer to the manual for specific WARNING or CAUTION information to avoid personal injury or damage to the product.



Indicates the field wiring terminal that must be connected to earth ground before operating the equipment—protects against electrical shock in case of fault.



Frame or chassis ground terminal—typically connects to the equipment's metal frame.



Alternating current (AC).



Direct current (DC).



Indicates hazardous voltages.

WARNING Calls attention to a procedure, practice, or condition that could cause bodily injury or death.

CAUTION Calls attention to a procedure, practice, or condition that could possibly cause damage to equipment or permanent loss of data.

WARNINGS

The following general safety precautions must be observed during all phases of operation, service, and repair of this product. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the product. Hewlett-Packard Company assumes no liability for the customer's failure to comply with these requirements.

Ground the equipment: For Safety Class 1 equipment (equipment having a protective earth terminal), an uninterruptible safety earth ground must be provided from the mains power source to the product input wiring terminals or supplied power cable.

DO NOT operate the product in an explosive atmosphere or in the presence of flammable gases or fumes.

For continued protection against fire, replace the line fuse(s) only with fuse(s) of the same voltage and current rating and type. DO NOT use repaired fuses or short-circuited fuse holders.

Keep away from live circuits: Operating personnel must not remove equipment covers or shields. Procedures involving the removal of covers or shields are for use by service-trained personnel only. Under certain conditions, dangerous voltages may exist even with the equipment switched off. To avoid dangerous electrical shock, DO NOT perform procedures involving cover or shield removal unless you are qualified to do so.

DO NOT operate damaged equipment: Whenever it is possible that the safety protection features built into this product have been impaired, either through physical damage, excessive moisture, or any other reason, REMOVE POWER and do not use the product until safe operation can be verified by service-trained personnel. If necessary, return the product to a Hewlett-Packard Sales and Service Office for service and repair to ensure that safety features are maintained.

DO NOT service or adjust alone: Do not attempt internal service or adjustment unless another person, capable of rendering first aid and resuscitation, is present.

DO NOT substitute parts or modify equipment: Because of the danger of introducing additional hazards, do not install substitute parts or perform any unauthorized modification to the product. Return the product to a Hewlett-Packard Sales and Service Office for service and repair to ensure that safety features are maintained.

Declaration of Conformity

according to ISO/IEC Guide 22 and EN 45014

Manufacturer's Name: Hewlett-Packard Company
Loveland Manufacturing Center

Manufacturer's Address: 815 14th Street S.W.
Loveland, Colorado 80537

declares, that the product:

Product Name: 5 1/2-Digit Multimeter

Model Number: HP E1411A/HP E1411B

Product Options: All

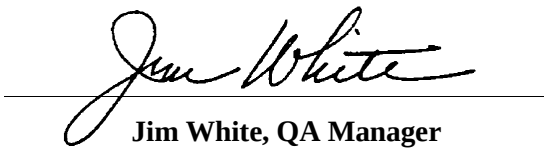
conforms to the following Product Specifications:

Safety: IEC 1010-1 (1990) Incl. Amend 1 (1992)/EN61010-1(1993)
CSA C22.2#1010.1 (1992)
UL 3111

EMC: CISPR 11:1990/EN55011 (1991): Group 1, Class A
EN50082-1:1992
IEC 801-2:1991 : 4kV CD, 8kV AD
IEC 801-3:1984 : 3 V/m
IEC 801-4:1988 : 1kV Power Line, 0.5kV signal lines
ENV50141:1993/prEN50082-1 (1995): 3 Vrms
ENV50142:1994/prEN50082-1 (1995): 1 kV CM, 0.5kV DM
IEC1000-4-8:1993/prEN50082-1 (1995): 3 A/m
EN61000-4-11:1994/prEN50082-1 (1995): 30%,10ms 60%,100ms

Supplementary Information: The product herewith complies with the requirements of the Low Voltage Directive 73/23/EEC and the EMC Directive 89/336/EEC (inclusive 93/68/EEC) and carries the "CE" mark accordingly.

Tested in a typical HP C-Size VXI mainframe configuration.



December 30, 1995 **Jim White, QA Manager**

European contact: Your local Hewlett-Packard Sales and Service Office or Hewlett-Packard GmbH, Department HQ-TRE, Herrenberger Straße 130, D-71034 Böblingen, Germany (FAX +49-7031-14-3143).

Notes

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Edition 2

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• Instructions are easy to understand.	O	O	O	O	O
• The documentation is clearly written.	O	O	O	O	O
• Examples are clear and useful.	O	O	O	O	O
• Illustrations are clear and helpful.	O	O	O	O	O
• The documentation meets my overall expectations.	O	O	O	O	O

Please write any comments or suggestions below--be specific.

Chapter 1
General Information

Introduction

This manual contains information required to test, adjust, troubleshoot, and repair the HP E1411A and HP E1411B C-Size VXI 5 1/2-Digit Multimeters (HP E1411 multimeter). See the *HP E1326A/E1411A User's Manual* or the *HP E1326B/E1411B User's Manual* for additional information on the HP E1411 multimeter. Figure 1-1 shows the HP E1411A and E1411B multimeters.

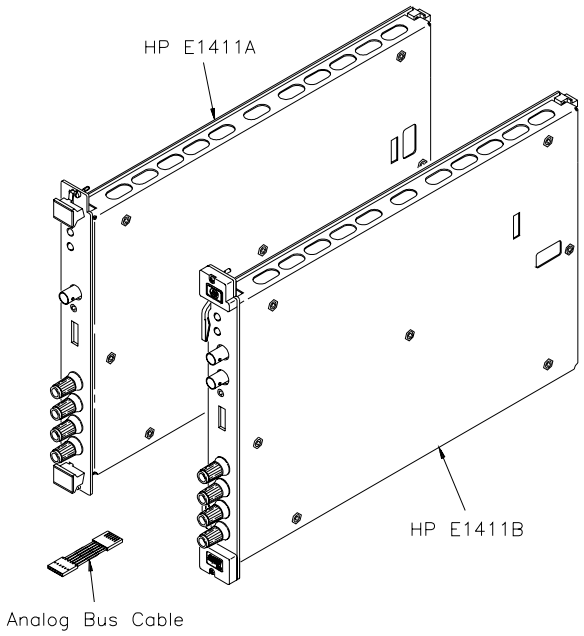


Figure 1-1. HP E1411A/B Multimeters

Safety Considerations

This product is a Safety Class I instrument that is provided with a protective earth terminal when installed in the mainframe. The mainframe, multimeter, and all related documentation should be reviewed for familiarization with safety markings and instructions before operation or service.

Refer to the WARNINGS page (page 4) in this manual for a summary of safety information. Safety information for testing, adjusting, and service follows and is also found throughout this manual.

Warnings and Cautions

This section contains WARNINGS which must be followed for your protection and CAUTIONS which must be followed to avoid damage to the equipment when performing instrument maintenance or repair.

WARNING

SERVICE-TRAINED PERSONNEL ONLY. The information in this manual is for service-trained personnel who are familiar with electronic circuitry and are aware of the hazards involved. To avoid personal injury or damage to the instrument, do not perform procedures in this manual or do any servicing unless you are qualified to do so.

CHECK MAINFRAME POWER SETTINGS. Before applying power, verify that the mainframe setting matches the line voltage and the correct fuse is installed. An uninterruptible safety earth ground must be provided from the main power source to the supplied power cord set.

GROUNDING REQUIREMENTS. Interruption of the protective (grounding) conductor (inside or outside the mainframe) or disconnecting the protective earth terminal will cause a potential shock hazard that could result in personal injury. (Grounding one conductor of a two-conductor outlet is not sufficient protection.)

IMPAIRED PROTECTION. Whenever it is likely that instrument protection has been impaired, the mainframe must be made inoperative and be secured against any unintended operation.

REMOVE POWER IF POSSIBLE. Some procedures in this manual may be performed with power supplied to the mainframe while protective covers are removed. Energy available at many points may, if contacted, result in personal injury. (If maintenance can be performed without power applied, the power should be removed.)

USING AUTOTRANSFORMERS. If the mainframe is to be energized via an autotransformer (for voltage reduction) make sure the common terminal is connected to neutral (that is, the grounded side of the main's supply).

CAPACITOR VOLTAGES. Capacitors inside the mainframe may remain charged even when the mainframe has been disconnected from its source of supply.

WARNING

USE PROPER FUSES. For continued protection against fire hazard, replace the line fuse(s) only with fuses of the same current rating and type (such as normal blow, time delay, etc.). Do not use repaired fuses or short-circuited fuseholders.

CAUTION

Static electricity is a major cause of component failure. To prevent damage to the electrical components in the multimeter, observe anti-static techniques whenever working on the multimeter.

Multimeter Description

The HP E1411 multimeter is an "instrument" in the slots of a VXIbus mainframe. As such, it is assigned an error queue, input and output buffers, status registers, and is allocated a portion of mainframe memory for reading storage.

NOTE

Instruments are based on the logical addresses of the plug-in modules. See the HP 75000 Series C Installation and Getting Started Guide to set the addresses to create an instrument.

The instrument may consist of a multimeter only (stand-alone operation), or can include relay or FET multiplexers (scanning multimeter operation). The instrument is operated from a computer using Standard Commands for Programmable Instruments (SCPI) language.

In stand-alone operation, input signals are connected to the multimeter's external (faceplate) terminals. In scanning multimeter operation, input signals are connected to the multiplexer channels. The multimeter is linked to relay multiplexers via an analog bus cable. The multimeter is linked to FET multiplexers via an analog bus cable and a digital bus cable.

Multimeter Specifications

Multimeter specifications are listed in *Appendix A* of the *HP E1326A/E1411A User's Manual* or the *E1326B/E1411B User's Manual*. These specifications are the performance standards or limits against which the instrument may be tested.

Multimeter Serial Numbers

Multimeters covered by this manual are identified by a serial number prefix listed on the title page. Hewlett-Packard uses a two part serial number in the form 0000A00000, where 0000 is the serial prefix, A is the country of origin (A=USA) and 00000 is the serial suffix. The serial number prefix identifies a series of identical instruments. The serial number suffix is assigned sequentially to each instrument.

If the serial number prefix of your instrument is greater than the one listed on the title page, a Manual Update (as required) will explain how to adapt this manual to your instrument. If the serial number prefix of your instrument is lower than the one listed on the title page, information contained in *Chapter 7- Manual Changes* will explain how to adapt this manual to your instrument.

Multimeter Options

There are no electrical or mechanical options available for the HP E1411 multimeters. However, for the HP E1411B, you can order Option 1BN that provides a MIL-STD-45662A Calibration Certificate. Contact your nearest Hewlett-Packard Sales and Support Office for information on Option 1BN.

Recommended Test Equipment

Table 1-1 lists the test equipment recommended for testing, adjusting and servicing the multimeter. Essential requirements for each piece of test equipment are described in the Requirements column.

Table 1-1. Recommended Test Equipment

Instrument	Requirements	Recommended Model	Use*
Controller, HP-IB	HP-IB compatibility as defined by IEEE Standard 488-1987 and the identical ANSI Standard MC1.1: SH1, AH1, T2, TE0, L2, LE0, SR0, RL0, PP0, DC0, DT0, and C1, 2, 3, 4, 5	HP 9000 Series 300 or IBM Compatible PC with HP BASIC	A,F, P,T
Mainframe	Compatible with multimeter	HP E1400B/T or E1421A/B	A,F, P,T
AC Standard	Voltage Range 0.1 V to 300 V	Datron 4708 with Option 20	A,P
DC Standard	Voltage Range 0.07 V to 300 V	Datron 4708 with Option 10	A,P
Resistance Standard	Values 1 kΩ to 1 MΩ	Datron 4708 with Option 30	A,P
Digital Multimeter	General Purpose Voltage and Resistance	HP 3458A	T

*A = Adjustments, F = Functional Verification, P = Performance Verification Tests, T = Troubleshooting

Chapter 2
Installation

Introduction

This chapter provides information to install the HP E1411 multimeter, including initial inspection, preparation for use, environment, storage and shipment.

Initial Inspection

Inspect the shipping container for damage. If the shipping container or cushioning material is damaged, keep the container until the shipment contents have been checked and the instrument has been checked mechanically and electrically. See Figure 1-1 in *Chapter 1 - General Information* for shipment contents. See *Chapter 4 - Verification Tests* for procedures to check electrical performance.

WARNING

To avoid possible hazardous electrical shock, do not perform electrical tests if there are signs of shipping damage to any portion of the outer enclosure (covers, panels, etc.).

If the contents are incomplete, if there is mechanical damage or defect, or if the instrument does not pass the electrical performance tests, notify your nearest Hewlett-Packard Sales and Support Office. If the shipping container is damaged or the cushioning material shows signs of stress, notify the carrier as well as Hewlett-Packard, and keep the shipping materials for the carrier's inspection.

Preparation for Use

See Chapter 2 of the *HP E1326A/E1411A User's Manual* or the *E1326B/E1411B User's Manual* to prepare an HP E1411 multimeter for use. See the appropriate mainframe user's manual(s) to prepare your mainframe. If your mainframe is not manufactured by Hewlett-Packard, consult the manufacturer for a list of available manual(s).

Recommended operating environment for the HP E1411 multimeters is 0^{o}C to $+55^{o}$C with relative humidity <65% ($0\ ^{o}$C to $+40^{o}$C). The instrument should be stored in a clean, dry environment. For storage and shipment, the temperature range is -40^{o}C to $+75^{o}$C with relative humidity <65% (0^{o}C to $+40^{o}$C).

Shipping the Multimeter

If you need to return an HP E1411 multimeter to Hewlett-Packard, first remove any adapters or connectors before packaging the instrument for shipment. When you return the instrument to Hewlett-Packard, attach a tag to the instrument identifying the owner and indicating service or repair required. In any correspondence, refer to the instrument by model number and full serial number.

When shipping the instrument, we recommend using containers and materials identical to those used in factory packaging, which are available through Hewlett-Packard Sales and Support Offices. Mark the shipping container "FRAGILE" to assure careful handling.

If you use other (commercially available) shipping materials, wrap the instrument in heavy paper or plastic. Use a strong shipping container. A double-wall carton of 2.4 MPa (350 psi) test material is adequate.

Use enough shock-absorbing material (75 to 100 mm layer; 3 to 4 inches) around all sides of the instrument to provide firm cushion and prevent movement in the container. Protect the front panel with cardboard. Seal the shipping container securely and mark the container "FRAGILE" to assure careful handling.

Chapter 3
Operating Instructions

Introduction

This chapter lists operating information for the HP E1411 multimeter, including:

- Multimeter operation
- Operator's check (self-test)

Multimeter Operation

See the *HP E1326A/E1411A User's Manual* or the *E1326B/E1411B User's Manual* for multimeter operation, including:

- Getting started
- Configuring the multimeter
- Using the multimeter
- Understanding the multimeter

- Multimeter command reference
- Multimeter specifications
- Multimeter error messages
- Register-based programming

Operator's Check

The Operator's Check for the HP E1411 multimeter consists of sending the self-test (*TST?) command and checking the return. The operator's check can be used to verify the multimeter is connected properly and is responding to the self-test command.

As required, see the mainframe user's manual for information on address selection. See the *HP E1326A/E1411A User's Manual* or the *E1326B/E1411B User's Manual* for information on multimeter SCPI commands.

Self-Test Procedure

1. Verify the multimeter is properly installed in the mainframe and the mainframe has passed its power-on sequence test.

2. Execute the multimeter functional test using the *TST? command (see example following).

3. A "0" returned means no self-test failure, while "1", "2", "3", or "4" returned means a failure was detected. See *Chapter 8 - Service* for troubleshooting information (see NOTE following).

NOTE

Test failures can be caused by improper cabling, improper selection of the interface select code, primary, and/or secondary address setting. Verify proper connection and address selection before troubleshooting.

Example: Multimeter Self-Test

An example follows which uses an HP 9000 Series 300 computer with HP BASIC and a multimeter address of 70903.

```
10  OUTPUT 70903;"*TST?"        Send the self-test command
20  ENTER 70903;A               Enter self-test result
30  PRINT A
40  END
```

Chapter 4
Verification Tests

Introduction

The three levels of test procedures described in this chapter are used to verify that the HP E1411 multimeter:

- is functional (Functional Verification)
- meets selected testable specifications (Operation Verification)
- meets all testable specifications (Performance Verification)

WARNING

Do not perform any of the following verification tests unless you are a qualified, service-trained person and have read the WARNINGS and CAUTIONS in *Chapter 1 - General Information*.

Test Conditions / Procedures

For valid tests, all test equipment and the multimeter must have a one hour warmup, the line voltage must be 115/230 Vac ± 10%, and multimeter Auto Zero must be set to ON. See Table 1-1, *Recommended Test Equipment,* for test equipment requirements.

For best test accuracy, the ambient temperature of the test area should be between 18^{o}C and 28^{o}C and stable to within $\pm 1^{o}$C. You should perform the Performance Verification tests at least once a year. For heavy use or severe operating environments, perform the tests more often.

The verification tests assume the person performing the tests understands how to operate the mainframe, multimeter and specified test equipment. The test procedures do not specify equipment settings for test equipment, except in general terms. It is assumed a qualified, service-trained person will select and connect the cables, adapters, and probes required for the test.

Performance Test Record

Table 4-1, *Performance Test Record for the HP E1411 Multimeter,* at the end of this chapter, provides space to enter the results of each Performance Verification test and to compare the results with the upper and lower limits for the test. You can make a copy of this form, if desired.

The value in the "Measurement Uncertainty" column of Table 4-1 is derived from the specifications for the source used for the test, and represents the expected accuracy of the source. The value in the "Test Accuracy Ratio (TAR)" column of Table 4-1 is the ratio of multimeter accuracy to measurement uncertainty.

Verification Test Examples

Each Performance Verification Test includes an example program to perform the test. Each example uses address 70903 for the multimeter, and an HP 9000 Series 200/300 computer running HP BASIC and Standard Commands for Programmable Instruments (SCPI) commands. You may need to change the multimeter address and/or command syntax to perform the examples for your setup.

As required, see the mainframe or command module user's manual for information on address selection and cabling guidelines. See the *HP E1326A/E1411A User's Manual* or the *E1326B/E1411B User's Manual* for information on multimeter SCPI commands.

Functional Verification Test

The functional verification test for the HP E1411 multimeter consists of the multimeter self-test. You can perform this test to verify the multimeter is functional and is communicating with the mainframe, external computer and/or external terminal.

Self-Test Procedure

This test verifies the multimeter is communicating with the mainframe, external controller, and/or external terminal by performing a multimeter self-test. Do the following steps to perform the self-test:

1. Verify the multimeter is correctly installed in the mainframe.

2. Connect a power cable to the mainframe and set mainframe power ON. Verify proper mainframe power-up sequence. (See the mainframe user's manual for additional information.) If correct, proceed with step 3. If incorrect, troubleshoot the problem before proceeding.

3. Execute the multimeter functional verification test using the *TST? command. See the following example which uses an HP 9000 Series 300 computer with HP BASIC and a multimeter address of 70903.

4. A "0" returned means no failure, while "1", "2", "3", or "4" returned means a failure was detected. See *Chapter 8 - Service* for trouble-shooting information.

NOTE

Test failures can be caused by improper selection of the interface select code, primary address setting, and/or secondary address setting. Verify proper address selection before troubleshooting.

Example: Self-Test

```
10 OUTPUT 70903;"*TST?"      !Send the self-test command
20 ENTER 70903;A             !Enter the test result
30 PRINT A                   !Display the result
40 END
```

Operation Verification Tests

There are no separate operation verification tests for the HP E1411 multimeter. Use the Performance Verification tests for post-repair checkout.

Performance Verification Tests

Performance verification tests are used to check the multimeter's electrical performance against the specifications in *Appendix A - Specifications* of the *HP E1326A/E1411A User's Manual* or the *E1326B/E1411B User's Manual* as the performance standards. These tests are suitable for incoming inspection and troubleshooting. The performance verification tests for the HP E1411 multimeter are:

- Test 4-1: DC Voltage Test (Zero Volt Input)
- Test 4-2: DC Voltage Test (DCV Input)
- Test 4-3: AC Voltage Test
- Test 4-4: Resistance Test (4-Wire Ohms)

Test 4-1: DC Voltage Test (Zero Volt Input)

This test verifies DC Voltage accuracy on all five ranges using a zero volt input.

Equipment Setup

1. Connect the equipment as shown in Figure 4-1.

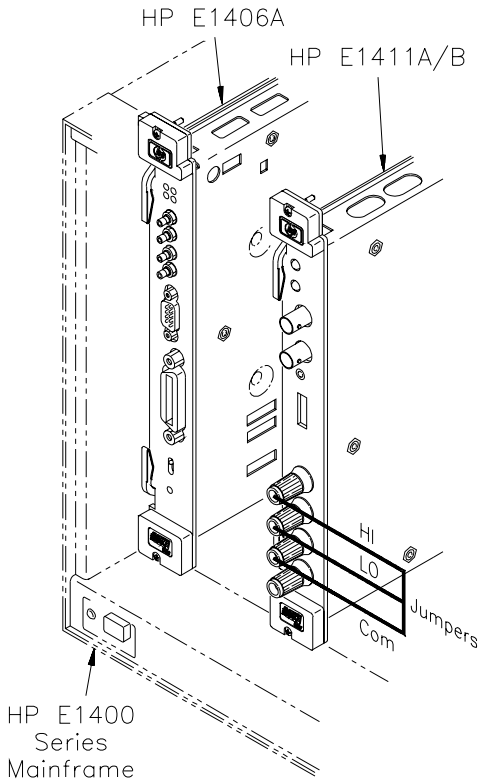


Figure 4-1. DC Voltage (Zero Volt Input) Setup

2. Set the HP E1411 multimeter as follows:

- Reset Multimeter .....*RST
- Auto Zero .....ON
- Power Line Cycles (PLC) 1
- Line Freq Reference (CAL:LFR) ..... 50Hz or 60Hz

NOTE

**RST sets Auto Zero to ON and Power Line Cycles to 1.*

Test Procedure

and

1. Set the HP E1411 range to 0.113 V (0.125 V with 10% over- range) measure the input voltage with MEAS:VOLT:DC? 0.1

Record,

2. Observe the input, record the results on the Performance Test and verify the results are within specified limits (at the range selected for 1 PLC).

3. Repeat steps 1 and 2 for the following ranges:

E1411 Range	10% Overrange	Input
0.91 V	1 V	0 V
7.27 V	8 V	0 V
58.10 V	64 V	0 V
300.00 V	None	0 V

4. Remove power and disconnect test equipment.

Example: Zero Volt DCV Test

This example performs a DCV test for zero volts input and a power line reference frequency of 60 Hz. Change line 20 to OUTPUT 70903;"CAL:LFR 50" for 50 Hz operation.

```
1   !Zero Volts Performance Verification
10  OUTPUT 70903;"*RST"                    !Resets and sets autozero ON and PLC to 1
20  OUTPUT 70903;"CAL:LFR 60"              !Sets line reference to 60 Hz
30  OUTPUT 70903;"MEAS:VOLT:DC? .1"        !Measure 0.113 V range
40  ENTER 70903;A
50  PRINT A
60  OUTPUT 70903;"MEAS:VOLT:DC? .9"        !Measure 0.91 V range
70  ENTER 70903;B
80  PRINT B
90  OUTPUT 70903;"MEAS:VOLT:DC? 7"         !Measure 7.27 V range
100 ENTER 70903;C
110 PRINT C
120 OUTPUT 70903;"MEAS:VOLT:DC? 58"        !Measure 58.1 V range
130 ENTER 70903;D
140 PRINT D
150 OUTPUT 70903;"MEAS:VOLT:DC? 300"       !Measure 300 V range
160 ENTER 70903;E
170 PRINT E
180 END
```

Test 4-2: DC Voltage Test (DCV Input)

This test verifies DC Voltage accuracy on all five ranges with DC voltage inputs.

Equipment Setup

1. Connect the equipment as shown in Figure 4-2.

WARNING

The DC Standard (Datron 4708, Option 10) can produce dangerous voltages which are present on the terminals. Do not touch the front (or rear) panel terminals unless you are sure no dangerous voltage is present.

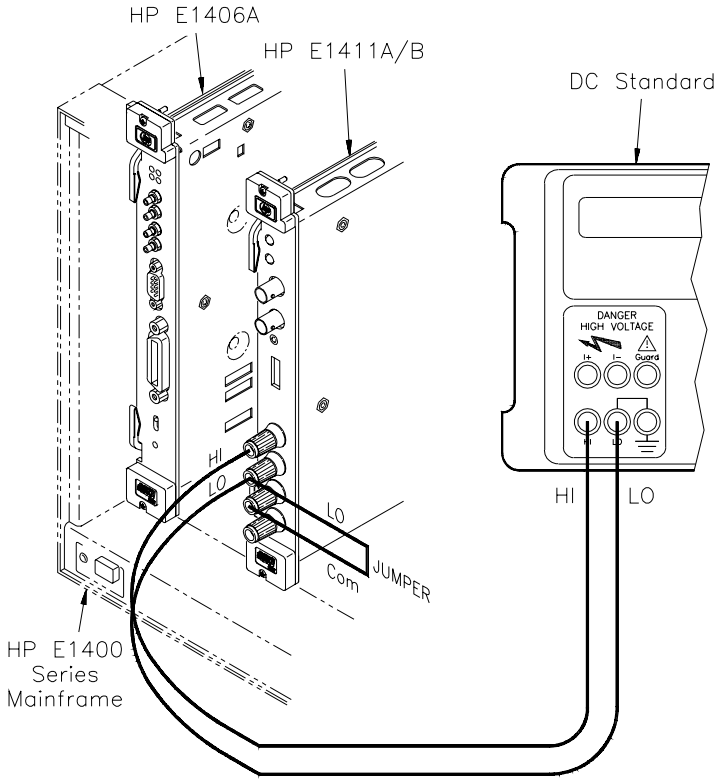


Figure 4-2. DC Voltage (DCV Input) Setup

2. Set the HP E1411 multimeter as follows:

- Reset Multimeter .....*RST
- Auto Zero .....ON
- Power Line Cycles (PLC) 1
- Line Freq Reference (CAL:LFR) ..... 50Hz or 60Hz

NOTE

**RST sets Auto Zero to ON and Power Line Cycles to 1.*

Test Procedure

1. Set the DC Standard Output to 0.1 DCV.

2. Set the HP E1411 range to 0.113 V (0.125 V with 10% overrange) with CONF:VOLT:DC .1

3. Measure the input with READ? and verify the results are within specified limits (at the range selected for 1 PLC). Record results on Performance Test Record.

4. Repeat steps 1 through 3 for the following DC Standard voltage settings and HP E1411 ranges:

E1411 Range	10% overrange	DC Std Output
0.91 V	1 V	0.9 V
7.27 V	8 V	7.0 V
58.10 V	64 V	58.0 V
300.00 V	None	300.0 V

5. Remove power and disconnect test equipment.

Example: DC Voltage Test (DCV Input)

This example performs a DCV test for DC volts input and a power line reference frequency of 60 Hz. Change line 80 to OUTPUT 70903;"CAL:LFR 50" for 50 Hz operation.

NOTE

When connected to the HP E1411 multimeter, some DC Standards may exhibit voltage variations at the start of a measurement. The WAIT 1 statement (line 150) provides a one second wait before measurement to allow settling of the DC Standard output.

```
1     !DC Voltage Performance Verification
10    OPTION BASE 1
20    DIM Range(5), Volts(5), Read_meas(5)
30    DATA 0.113, 0.91, 7.27, 58.1, 300.0
40    READ Range(*)
50    DATA 0.1, 0.9, 7.0, 58.0, 300.0
60    READ Volts(*)
70    OUTPUT 70903;"*RST"              !Set autozero on and PLC 1
80    OUTPUT 70903;"CAL:LFR 60"        !Set 60 Hz line frequency
```

```
90    FOR I=1 TO 5
100       PRINT "Set DC Standard to ";Volts(I);"VDC"
110       PRINT "Press Continue when ready"
120       PAUSE
130       CLEAR SCREEN
140       OUTPUT 70903;"CONF:VOLT:DC";Range(I)  !Set DCV, range
150       WAIT 1                                !Wait for settling
160       OUTPUT 70903;"READ?"
170       ENTER 70903;Read_meas(I)              !Enter DC voltage
180 NEXT I
190 FOR I=1 TO 5
200      PRINT "Voltage on";Range(I);"V range =";Read_meas(I);"VDC"
210 NEXT I
220 END
```

Test 4-3: AC Voltage Test

This test verifies AC voltage accuracy on the 87.5 mV and 300 V ranges using sine wave inputs at ≥50% of full scale. The input frequency varies from 20 Hz to 10 kHz. The DC component must be <10% of the AC component.

NOTE

The DC Voltage Performance test must be performed prior to the AC Voltage test to check the A/D accuracy on all ranges. If the DC Voltage test has not been performed, the AC voltage must be checked on all ranges.

Equipment Setup

1. Connect the equipment as shown in Figure 4-3.

WARNING

The AC Standard (Datron 4708, Option 20) can produce dangerous voltages which are present on the terminals. Do not touch the front (or rear) panel terminals unless you are sure no dangerous voltage is present.

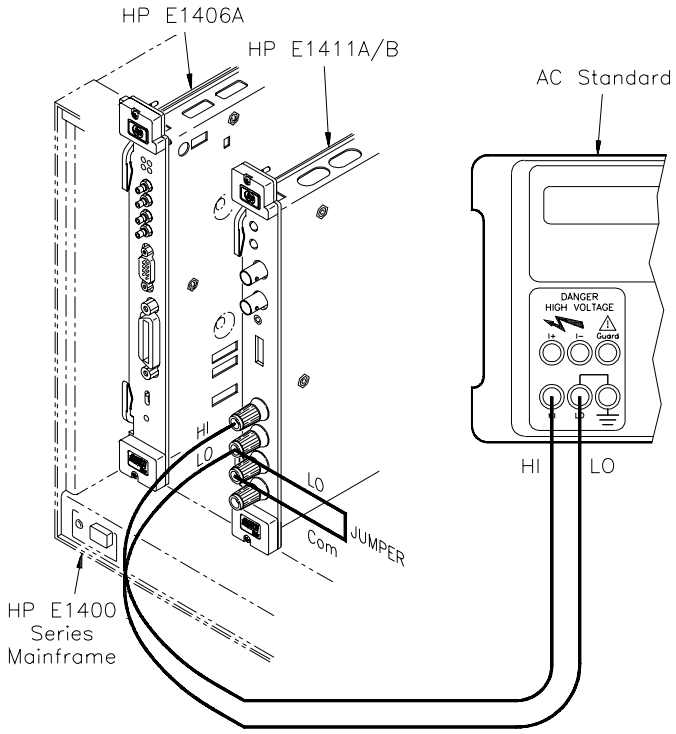


Figure 4-3. AC Voltage Setup

2. Set the HP E1411 multimeter as follows:

- Reset Multimeter .....*RST
- Auto Zero .....ON
- Power Line Cycles (PLC) 1
- Line Freq Reference (CAL:LFR) ..... 50Hz or 60Hz

NOTE

**RST sets Auto Zero to ON and Power Line Cycles to 1.*

Test Procedure

1. Set the AC Standard Output to 0.07 Vac at 20 Hz sine wave.

2. Set the HP E1411 range to 79.5 mV (87.5 mV with 10% overrange) using CONF:VOLT:AC .07.

3. Measure the AC input voltage with READ? and verify the results are within specified limits (at the range selected for 1 PLC). Record the results on the Performance Test Record.

4. Repeat steps 1 through 3 using the following AC Standard voltage and frequency settings, and HP E1411 ranges:

E1411 Range	10% overrange	AC Standard Output	
		Voltage (Vac)	Frequency (Hz)
79.5 mV	87.5 mV	0.07 V	60 Hz
79.5 mV	87.5 mV	0.07 V	5 kHz
79.5 mV	87.5 mV	0.07 V	10 kHz
300.0 V	None	300.00 V	5 kHz

5. Remove power and disconnect test equipment.

Example: AC Voltage Test

This example performs an ACV test for a power line reference frequency of 60 Hz. Change line 80 to OUTPUT 70903;"CAL:LFR 50" for 50 Hz operation.

NOTE

When connected to the HP E1411 multimeter, some AC Standards may exhibit voltage variations at the start of a measurement. The WAIT 1 statement (line 160) allows settling for the AC Standard output.

```
1   ! AC Voltage Performance Verification
10  OPTION BASE 1
20  DIM Read_meas(5),Source_volts(5),Source_freq(5)
30  DATA 0.07, 0.07, 0.07, 0.07, 300.0
40  READ Source_volts(*)
50  DATA 20, 60, 5000, 10000, 5000
60  READ Source_freq(*)
70  OUTPUT 70903;"*RST"                    !Set autozero ON, PLC 1
80  OUTPUT 70903;"CAL:LFR 60"              !Set 60 Hz line ref frequency
90   FOR I=1 TO 5
100   PRINT "1. Set AC Standard output to";Source_volts(I);"Vac"
110   PRINT "2. Set AC Standard frequency to";Source_freq(I);"Hz"
120   PRINT "3. Press Continue when ready"
130   PAUSE
140   CLEAR SCREEN
150   OUTPUT 70903;"CONF:VOLT:AC";Source_volts(I)
160   WAIT 1                                 !One second settling time
170   OUTPUT 70903;"READ?"
180   ENTER 70903;Read_meas(I)
190  NEXT I
200  FOR I=1 TO 5
210   PRINT "Voltage for";Source_volts(I);"Vac range @";Source_freq(I);
"Hz=";Read_meas(I);"Vac"
220  NEXT I
```

```
230 END
```

Test 4-4: Resistance Test (4-Wire Ohms)

This test verifies the 4-wire resistance accuracy of the 2kΩ, 100kΩ, and 1MΩ ranges.

NOTE

The DC Voltage performance test must be performed prior to the Resistance Test to check the A/D accuracy on all ranges. If the DC Voltage test has not been performed, resistance must be checked on all ranges at 0 and at 50% of full scale.

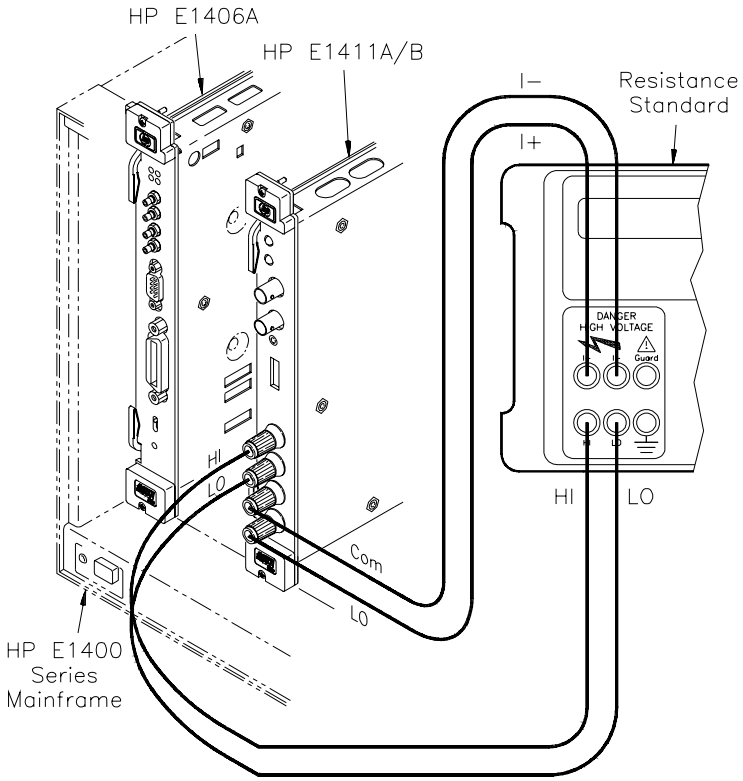


Figure 4-4. Resistance Test Setup

Equipment Setup

1. Connect the equipment as shown in Figure 4-4
2. Set the HP E1411 multimeter as follows:
   - Reset Multimeter .....*RST
   - Auto Zero .....ON
   - Power Line Cycles (PLC) 1

- Line Freq Reference (CAL:LFR) ....50 Hz or 60 Hz

NOTE

**RST sets Auto Zero to ON and Power Line Cycles to 1.*

Test Procedure

1. Set the Resistance Standard to 1 kΩ setting

2. Set the HP E1411 range to 1861Ω (2048Ω with 10% overrange) with CONF:FRES 1861

3. Measure the input resistance with READ? and verify the results are within specified limits (at the range selected for 1 PLC). Record the results on the Performance Test Record.

NOTE

For best measurement accuracy, you may want to measure the ACTUAL Resistance Standard value. You can do this by recording the front panel display of the resistance value, or measuring the resistance with an HP 3458A multimeter or equivalent.

For example, suppose the ACTUAL resistance value for the 1 kΩ setting is 1001.3Ω. Then, the Lower Limit for this value = 1001.03 Ω and the Upper Limit = 1001.57Ω. These limits would replace the existing limits of 999.730Ω and 1000.270Ω shown in Table 4-1. If the measured value falls within the revised limits, the test passes.

---

4. Repeat steps 1 through 3 using the following Resistance Standard settings:

E1411 Range	10% overrange	Resistance Std Setting
119,156 Ω	131,052 Ω	100 kΩ
1,048,576 Ω	N/A	1 MΩ

5. Remove power and disconnect test equipment.

Example: 4-Wire Ohms Test

This example performs a 4-wire ohms resistance test for a power line reference frequency of 60 Hz. Change line 80 to OUTPUT 70903;"CAL:LFR 50" for 50 Hz operation.

The program also calculates the Upper Limit and Lower Limit values for ACTUAL Resistance Standard resistance value (lines 170-190). If the actual Resistance Standard value is different than 1kΩ, 100kΩ, or 1MΩ, replace the Lower Limit and Upper Limit values shown in Table 4-1, *Performance Test Record for the HP E1411 Multimeter*, with the values computed by the program.

```
1    !4-Wire Ohms Performance Verification
10   OPTION BASE 1
20   DIM Range(3),Source(3),Read_meas(3),Limit(3),Ohms(3)
30   DATA 1861, 119156, 1048576
40   READ Range(*)
50   DATA 1000, 100000, 1000000
60   READ Source(*)
70   OUTPUT 70903;"*RST"                    !Set autozero on and PLC 1
80   OUTPUT 70903;"CAL:LFR 60"              !Set 60 Hz line ref frequency
90   FOR I=1 TO 3
100     PRINT "1. Set Resistance Standard to";Source(I);"Ohms"
110     PRINT "2. Measure ACTUAL Resistance Standard value (in Ohms)"
120     PRINT "Enter ACTUAL Resistance Standard value (in
Ohms)",Ohms(I)
130     CLEAR SCREEN
140     OUTPUT 70903;"CONF;FRES";Range(I)!Set 4-wire ohms, range
150     OUTPUT 70903;"READ?"
160     ENTER 70903;Read_meas(I)
170     IF I=1 THEN Limit(I)=.00025*Ohms(I)+2.0E-2   !2 kOhm limits
180     IF I=2 THEN Limit(I)=.00025*Ohms(I)+1        !131 kOhm limits
190     IF I=3 THEN Limit(I)=.00025*Ohms(I)+10       !1 MOhm limits
200  NEXT I
210  PRINT "Measured     Source          Low Limit    High Limit"
220  PRINT "Resistance   Resistance      (Ohms)       (Ohms)"
230  PRINT
240  Format:IMAGE 7D.3D,6X,7D.3D,6X,7D.3D,6X,7D.3D
250 FOR I=1 TO 3
260     PRINT USING Format;Read_meas(I),Ohms(I),Ohms(I)-Limit(I),
Ohms(I)+Limit(I)
270 NEXT I
280 END
```

Performance Test Record

Table 4-1, *Performance Test Record for the HP E1411 Multimeter*, is a form you can copy and use to record performance verification test results for the multimeter. Page 3 of Table 4-1 shows multimeter accuracy, measurement uncertainty and test accuracy ratio (TAR) values. See *Appendix A - Calculating Multimeter Accuracy* for example calculations of Table 4-1 entries.

NOTE

The accuracy, measurement uncertainty, and TAR values shown in Table 4-1 are valid ONLY for the specific test conditions, test equipment, and assumptions described. If you use different test equipment and/or change the test conditions, you will need to compute the specific values for your test setup.

Multimeter Accuracy

Accuracy is defined for DC Voltage, AC Voltage, and 4-Wire Resistance measurements using the 90-day specifications in *Appendix A - Specifications* in the *HP E1326A/E1411A User's Manual* or the *E1326B/E1411B User's Manual.* In Table 4-1, the "High Limit" and "Low Limit" columns represent the multimeter accuracy for the specified test conditions.

Measurement Uncertainty

For the performance verification tests in this manual, measurement uncertainties are calculated assuming a Datron 4708 source for inputs to the multimeter. Measurement uncertainties in Table 4-1 are calculated for the 90-day accuracy specifications in the *Datron 4708 User's Handbook*.

Test Accuracy Ratio (TAR)

In Table 4-1, the "Test Accuracy Ratio (TAR)" is calculated from (high limit - expected measurement)/measurement uncertainty. "N/A" means measurement uncertainty and TAR do not apply to the measurement. If the TAR value is <10:1, the TAR value is listed. If the TAR value is >10:1, the entry is >10:1.

Table 4-1. Performance Test Record for the HP E1411 Multimeter (Page 1 of 3)

Test Facility:

Name _____

Address _____

City/State _____

Phone _____

Report No. _____

Date _____

Customer _____

Tested by _____

Model _____

Serial No. _____

Options _____

Firmware Rev. _____

Ambient temperature _____ °C

Relative humidity _____ %

Line frequency _____ Hz (nominal)

Special Notes:

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Table 4-1. Performance Test Record for the HP E1411 Multimeter (Page 2 of 3)

Model _____ Report No. _____ Date _____

Test Equipment Used: Description	Model No.	Trace No.	Cal Due Date
1. DATRON 4708			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
11.			
12.			
13.			

Table 4-1. Performance Test Record for the HP E1411 Multimeter (Page 3 of 3)

Model _____ Report No. _____ Date_____

90 day Specifications

Test No.	Test Input	DMM Range	Low Limit	Measured Reading	High Limit	Meas Uncert*	Test Acc Ratio (TAR)**
DC Voltage (Zero Volts Input) (Values in V)							
4-1	0.0	0.113	-.000005	_____	+.000005	N/A	N/A
	0.0	0.910	-.000015	_____	+.000015	N/A	N/A
	0.0	7.270	-.000050	_____	+.000050	N/A	N/A
	0.0	58.100	-.001000	_____	+.001000	N/A	N/A
	0.0	300.000	-.005000	_____	+.005000	N/A	N/A
DC Voltage (DCV Input) (Values in VDC)							
4-2	0.1	0.113	.099972	_____	.100028	.0000012	>10:1
	0.9	0.910	.899868	_____	.900132	.0000044	>10:1
	7.0	7.270	6.999250	_____	7.000750	.0000210	>10:1
	58.0	58.100	57.990300	_____	58.009799	.0002820	>10:1
	300.0	300.000	299.950000	_____	300.050000	.0017750	>10:1
AC Voltage (20 Hz, 60 Hz, 10 kHz, 5 kHz) (Values in VAC)							
4-3	0.07	0.0875	.067480	_____	.072523	.000020	>10:1
	0.07	0.0875	.069327	_____	.070673	.000016	>10:1
	0.07	0.0875	.069327	_____	.070673	.000016	>10:1
	0.07	0.0875	.067578	_____	.072423	.000016	>10:1
	300.00	300.00	296.125000	_____	303.875000	.047000	>10:1
4-Wire Resistance (Values in Ohms)							
4-4	1000	2000	999.730	_____	1000.270	0.008	>10:1
	100000	131000	99974.000	_____	100026.000	0.900	>10:1
	1000000	1000000	999740.000	_____	1000260.000	22.000	>10:1

* Measurement Uncertainty of Datron 4708 source for 90 days since calibration and 23^{o}C ±1^{o}C.
** TAR = multimeter accuracy/measurement uncertainty, rounded to nearest integer for <10:1 and >10:1 otherwise.

Notes

Chapter 5
Adjustments

Introduction

This chapter contains procedures to adjust the HP E1411 multimeter for peak performance. For best performance, the instrument should be adjusted after repair. All adjustments are performed electrically, so manual adjustment of the multimeter is not necessary.

WARNING

Do not perform any of the following adjustments unless you are a qualified, service-trained person, and have read the WARNINGS and CAUTIONS in *Chapter 1 - General Information.*

NOTE

ALL adjustment procedures MUST be performed in the order shown in this manual (DC Voltage, then AC Voltage, and then Resistance).

Adjustment Conditions / Procedures

For valid adjustments, the HP E1411 multimeter and test equipment used must have at least a 60 minute warm-up, and the line voltage must be 115/230 Vac ±10%. For best accuracy, the temperature of the area where adjustments are made should be between 18^{o}C and 28^{o}C and stable to within $\pm 1^{o}$C. See Table 1-1, *Recommended Test Equipment*, for test equipment requirements.

The adjustment procedures assume the person performing the adjustments understands how to operate the mainframe, multimeter and specified test equipment. The adjustment procedures do not specify test equipment settings, except in general terms. It is assumed a qualified, service-trained person will select and connect the cables and jumpers required for the adjustments.

DC Voltage Adjustments

This procedure adjusts HP E1411 multimeter DC voltage measurement accuracy.

Equipment Setup

1. Connect the equipment as shown in Figure 5-1.

WARNING

The DC Standard (Datron 4708, Option 10) can produce dangerous voltages which are present on the terminals. Do not touch the front (or rear) panel terminals unless you are sure no dangerous voltage is present.

2. Set the HP E1411 as follows:

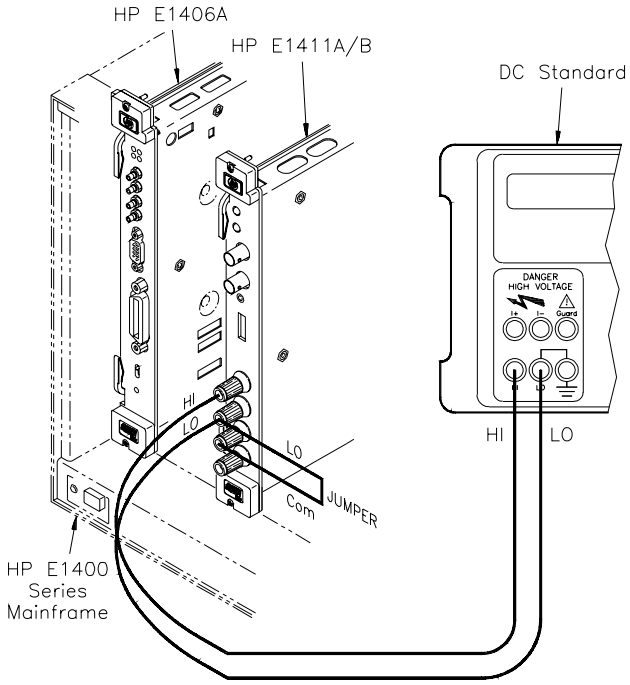


Figure 5-1. DC Voltage Adjustment Setup

- Reset Multimeter .....*RST
- Auto Zero .....ON
- Power Line Cycles (PLC) 1
- Line Freq Reference (CAL:LFR) ..... 50 Hz or 60 Hz

NOTE

**RST sets Auto Zero to ON and Power Line Cycles to 1.*

Adjustment Procedure

1. Set the DC Standard output to 7.7 V

2. Set the HP E1411 range to 8 V, and adjust the multimeter at 7.7 V using:

```
FUNC:VOLT:DC
VOLT:DC:RANG 8
CAL:VAL 7.7
TRIG:DEL .05
CAL?
```

3. Verify that the returned calibration error code is 0 (no error). If not 0, see Table 5-1 for a list of calibration errors and codes. The calibration error can be returned to an external computer using an ENTER type statement.

4. Repeat steps 1 through 3 using the following HP E1411 voltage ranges and DC Standard settings:

HP E1411 range	DC Standard Output
8 V	-7.7 V
0.125 V	+0.121 V
0.125 V	- 0.121 V
1 V	+0.97 V
1 V	- 0.97 V
64 V	+62 V
64 V	-62 V
300 V	+300 V
300 V	-300 V

5. Remove power and disconnect test equipment.

Example: DC Voltage Adjustments

This example performs DC voltage adjustments for a power line reference frequency of 60 Hz. Change line 80 to OUTPUT 70903;"CAL:LFR 50" for 50 Hz operation.

If no calibration error occurs (Cal_code = 0 in line 210), the program displays an "adjustment complete" message. If a calibration error occurs, the program displays the calibration error and prompts you to repeat the adjustment (see Table 5-1 for a list of calibration errors).

When connected to the HP E1411 multimeter, some DC Standards may exhibit voltage variations at the start of a measurement. TRIG:DEL .05 (line 190) adds a 0.8 sec wait before calibration begins to allow settling time for the DC Standard output. TRIG:DEL .05 is used since the input is sampled 16 times before the calibration is performed. Thus, total delay added = 0.05 seconds x 16 = 0.8 seconds.

```
1     ! DC Voltage Adjustments
10    OPTION BASE 1
20    DIM Range(10),Volts(10)
30    DATA 8.0, 8.0, 0.125, 0.125, 1.0, 1.0, 64.0, 64.0, 300.0, 300.0
40    READ Range(*)
50    DATA 7.7, -7.7, .121, -.121, .97, -.97, 62.0, -62.0, 300.0, -300.0
60    READ Volts(*)
70    OUTPUT 70903;"*RST"                    !Set autozero on and PLC 1
80    OUTPUT 70903;"CAL:LFR 60"              !Set 60 Hz line ref frequency
90    FOR I=1 TO 10
100 Re_try: !
110     CLEAR SCREEN
120     PRINT "Set DC Standard to";Volts(I);"VDC"
130     PRINT "Press Continue when ready"
140     PAUSE
150     CLEAR SCREEN
160     OUTPUT 70903;"FUNC:VOLT:DC"    !Set DCV function
170     OUTPUT 70903;"VOLT:RANG ";Range(I) !Set E1411 range
180     OUTPUT 70903;"CAL:VAL";Volts(I)   !Set CAL:VAL value
190     OUTPUT 70903;"TRIG:DEL .05"       !Wait for settling
200     OUTPUT 70903;"CAL?"               !Perform calibration
210     ENTER 70903 USING "K";Cal_code    !Return cal error code
220     IF Cal_code <>0 THEN
230       PRINT "Calibration Error";Cal_code;"for ";Volts(I);"VDC input."
240       PRINT "Check source value/connections, then"
250       PRINT "press Continue to retry this adjustment"
260       PAUSE
270       GOTO Re_try
280     ELSE
290       PRINT "Adjustment complete for";Volts(I);"VDC input"
300     END IF
310     PRINT "Press Continue for the next adjustment"
320     PAUSE
330     CLEAR SCREEN
340   NEXT I
350   END
```

AC Voltage Adjustments

This procedure adjusts the HP E1411 AC voltage measurement accuracy.

NOTE

The DC Voltage adjustment MUST be performed before the AC Voltage adjustment.

Equipment Setup

1. Connect the equipment as shown in Figure 5-2

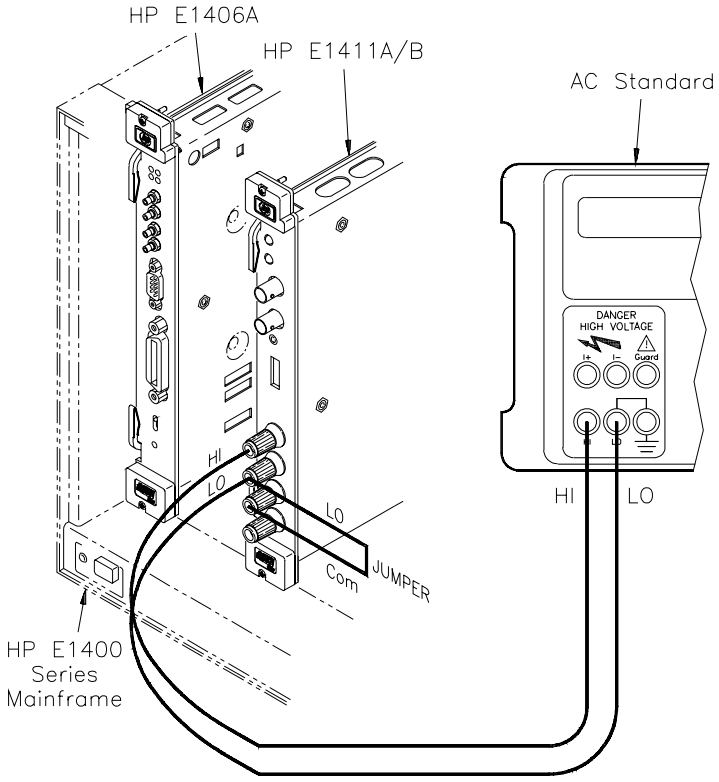


Figure 5-2. AC Voltage Adjustment Setup

2. Set the HP E1411 as follows:

- Reset Multimeter .....*RST
- Auto Zero ..... ON
- Power Line Cycles (PLC) 1
- Line Freq Reference (CAL:LFR) ..... 50 Hz or 60 Hz

NOTE

**RST sets Auto Zero to ON and Power Line Cycles to 1.*

Adjustment Procedure

1. Set the AC Standard output to 5.6 Vac at 1 kHz

2. Set the HP E1411 range to 5.6 V, and adjust the multimeter at 5.6 V using:

```
FUNC:VOLT:AC
VOLT:AC:RANG 5.6
CAL:VAL 5.6
TRIG:DEL .05
CAL?
```

3. Verify that the returned calibration error code is 0 (no error). If not 0, see Table 5-1 for a list of calibration errors and codes.

4. Remove power and disconnect test equipment

Example: AC Voltage Adjustments

This example performs an AC voltage adjustment for a power line reference frequency of 60 Hz. Change line 20 to OUTPUT 70903;"CAL:LFR 50" for 50 Hz operation.

If no calibration error occurs (Cal_code = 0 in line 130), the program displays an "adjustment complete" message. If a calibration error occurs, the program displays the calibration error (see Table 5-1 for a list of calibration errors).

When connected to the HP E1411 multimeter, some AC Standards may exhibit voltage variations at the start of a measurement. TRIG:DEL .05 (line 110) adds a 0.8 sec wait before calibration begins to allow settling time for the AC Standard output. TRIG:DEL .05 is used since the input is sampled 16 times before the calibration is performed. Thus, total delay added = 0.05 seconds x 16 = 0.8 seconds.

```
1     ! AC Voltage Adjustments
10   OUTPUT 70903;"*RST"                    !Set autozero on and PLC 1
20   OUTPUT 70903;"CAL:LFR 60"              !Set 60 Hz line ref frequency
30 Re_try: !
40   PRINT "Set AC Standard to 5.6 Vac at 1.0 kHz"
50   PRINT "Press Continue when ready"
60   PAUSE
70   CLEAR SCREEN
80   OUTPUT 70903;"FUNC:VOLT:AC"            !Set ACV function
90   OUTPUT 70903;"VOLT:RANG 5.6"           !Set 5.6 Vac range
100  OUTPUT 70903;"CAL:VAL 5.6"             !Set 5.6 Vac cal value
110  OUTPUT 70903;"TRIG:DEL .05"            !Wait for settling
120  OUTPUT 70903;"CAL?"                    !Perform calibration
130  ENTER 70903 USING "K";Cal_code
140 IF Cal_code <> 0 THEN
150    PRINT "Calibration Error";Cal_code;"on 5.6 Vac range"
160    PRINT "Check source value/connections, then"
170    PRINT "press Continue to retry this adjustment"
180    PAUSE
190    CLEAR SCREEN
200    GOTO Re_try
210 ELSE
220    PRINT "AC Voltage adjustment complete"
230  END IF
240  END
```

Resistance Adjustments

This procedure adjusts the HP E1411 multimeter 4-wire resistance measurement accuracy.

NOTE

The DC Voltage adjustment and the AC Voltage adjustment MUST be performed before the Resistance adjustment.

Equipment Setup

1. Connect the equipment as shown in Figure 5-3

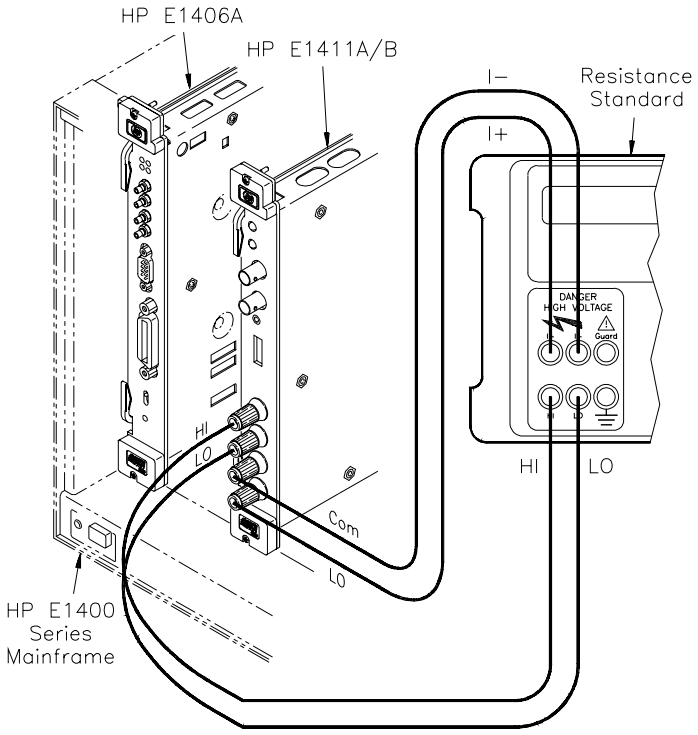


Figure 5-3. Resistance Adjustments Setup

2. Set the HP E1411 as follows:

- Reset Multimeter ..... *RST
- Auto Zero ..... ON
- Power Line Cycles (PLC) 1
- Line Freq Reference (CAL:LFR) ..... 50 Hz or 60 Hz

NOTE

**RST sets Auto Zero to ON and Power Line Cycles to 1.*

Adjustment Procedure

1. Set the Resistance Standard to 1 kΩ.

2. Set the HP E1411 range to 2 kΩ, and adjust the multimeter at 1 kΩ using:

```
FUNC:FRES
FRES:RANG 2000
CAL:VAL 1000
CAL?
```

NOTE

For best adjustment accuracy, you may want to measure the ACTUAL resistance value of the Resistance Standard and use the value in the CAL:VAL command. You can read the actual resistance value from the Datron front panel or you can measure the value with an HP 3458A multimeter or equivalent.

3. Verify that the returned calibration error code is 0 (no error). If not 0, see Table 5-1 for a list of calibration errors and codes. The calibration error can be returned to the external computer using an ENTER type statement.

4. Repeat steps 1 through 3 using the following HP E1411 (and FRES:RANG) ranges, and Resistance Standard (and CAL:VAL) values:

HP E1411 Range	Resistance Standard
16000 Ω	10000 Ω*
1000000 Ω	1000000 Ω*

* Or, use actual measured source resistance value

5. Remove power and disconnect test equipment.

Example: 4-Wire Resistance Adjustments

This example performs a 4-wire ohms resistance adjustment for a power line reference frequency of 60 Hz. Change line 80 to OUTPUT 70903;"CAL:LFR 50" for 50 Hz operation. If a calibration error occurs, the program displays the calibration error and prompts you to repeat the adjustment (see Table 5-1 for a list of calibration errors).

```
1    ! 4-Wire Resistance Adjustments
10   OPTION BASE 1
20   DIM Range(3),Source(3)
30   DATA  2000, 16000, 1048576
40   READ Range(*)
50   DATA 1000, 10000, 1000000
60   READ Source(*)
70   OUTPUT 70903;"*RST"                    !Set autozero on and PLC 1
80   OUTPUT 70903;"CAL:LFR 60"              !Set 60 Hz line ref frequency
90    FOR I=1 TO 3
100 Re_try: !
110    PRINT "1. Set Resistance Standard to";Source(I);"Ohms"
120    PRINT "2. Measure ACTUAL Resistance Standard value (in Ohms)"
130    PRINT "Enter ACTUAL Resistance Standard value (in
Ohms)",Ohms_actual
140    CLEAR SCREEN
150    OUTPUT 70903;"FUNC:FRES"               !Set 4-wire ohms
160    OUTPUT 70903;"FRES:RANG ";Range(I)!Set resistance range
170    OUTPUT 70903;"CAL:VAL";Ohms_actual(I)!Set cal value
180    OUTPUT 70903;"CAL?"                    !Perform calibration
190    ENTER 70903;Cal_code
200    IF Cal_code <> 0  THEN
210     PRINT "Calibration Error";Cal_code;"with";Source(I);"Ohms input."
220     PRINT "Check source value/connections, then"
230     PRINT "Press Continue to repeat this adjustment"
240     PAUSE
250     CLEAR SCREEN
260     GOTO Re_try
270   ELSE
280     PRINT "Adjustment complete with";Source(I);"Ohms source"
290     PRINT "Press Continue for the next adjustment"
300     PAUSE
310     CLEAR SCREEN
320   END IF
330  NEXT I
340  PRINT "Resistance adjustments completed"
350  END
```

Calibration Errors

Table 5-1 summarizes calibration error numbers, titles and descriptions for the HP E1411 multimeter. Note that an error is returned if the adjustment (calibration) standard used is outside the calibration range of the multimeter (between ±[0.5 full scale and full scale]).

Table 5-1. HP E1411 Multimeter Calibration Errors

Error	Title	Description	Code*
0	No Error	No error has occurred since last time the error code was read.	
4	Reading Overrun	The FIFO memory was still full at the time the new reading was ready, or a new command was received while in the middle of outputting a reading. TRIGGER ARM is disabled and the multimeter waits for a new command.	U
6	Calibration Error	An error occurred when computing a calibration constant, probably due to an improper input or a defective Unit Under Test (UUT). Calibration cycle aborted.	U/H
7	Checksum Error	The non-volatile RAM contains a checksum error. The data is assumed to be corrupted.	H
8	Invalid CAL Request	Calibration requested for an invalid combination of multimeter range and function.	U
9	Bad CAL Target	The target value for the calibration was outside the range of ±(0.5 full scale to full scale).	U
11	No Inguard Response	No response from inguard (expected data and got nothing). Timed out instead.	H
13	Linearity CAL Error	An error has occurred during a linearity calibration sequence. Probably a hardware failure of the A/D inguard section.	H
14	Pacer Overrun Error	The pacer is in use and the pacer rate is faster than the maximum A/D conversion rate based on integration time, autorange setting, autozero setting, and interrupts enabled.	U
15	Input Overload	A potentially damaging overload has been applied to the multimeter terminals and the multimeter has disconnected from the input. A new SET RANGE command is necessary to restore normal operation. A damaging overload is defined as: 1. Applying >±40 volts HI to LO or HI to COMMON while in manual range with RANGE ≤ 8 volts. 2. Applying >±40 volts between LO and COMMON under any circumstances.	U

* U = improper operation, H = hardware failure

Notes

Chapter 6
Replaceable Parts

Introduction

This chapter contains information to order replaceable parts for the HP E1411A and E1411B multimeters.

Exchange Assemblies

Tables 6-1 and 6-2 list assemblies that may be replaced on an exchange basis (EXCHANGE ASSEMBLIES). Exchange, factory-repaired, and tested assemblies are available only on a trade-in basis. Defective assemblies must be returned for credit. Assemblies required for spare parts stock must be ordered by the new assembly part number. Contact your nearest Hewlett-Packard Sales and Support Office for details.

Ordering Information

To order a part listed in Table 6-1 or 6-2, specify the Hewlett-Packard part number and the quantity required. Send the order to your nearest Hewlett-Packard Sales and Support Office.

Replaceable Parts List

Table 6-1, *HP E1411A Replaceable Parts*, lists replaceable parts for the HP E11411A multimeter. See Figure 6-1 (page 6-3) for locations of parts listed in Table 6-1. Table 6-2, *HP E1411B Replaceable Parts*, lists replaceable parts for the HP E11411B multimeter. See Figure 6-2 (page 6-5) for locations of parts listed in Table 6-2.

Table 6-1. HP E1411A Replaceable Parts

Reference* Designator	HP Part Number	Qty	Description	Mfr** Code	Mfr Part Number
			EXCHANGE ASSEMBLIES		
	E1411-66201	1	E1411A Multimeter Module (New)	28480	E1411-66201
	E1411-69201	1	E1411A Multimeter Module (Exchange)	28480	E1411-69201
A1	E1411-66501	1	**MULTIMETER PCA [a]**	28480	E1411-66501
A1F1	2110-0712	2	Fuse - Sub Miniature - 4A	75915	R251004T1
A1F2	2110-0712		Fuse - Sub Miniature - 4A	75915	R251004T1
A1J2	1250-1846	1	Connector - Right Angle BNC	24931	28JR342-1
A1J102	1251-3712	1	Connector - Post 2 x 6	18873	68668-004
A1J103	1252-3416	1	Connector - 4 Pin Right Angle	27264	705-53-0108
A1JM1	1251-4927	2	Connector - Header 16 Pin	18873	67997-616
A1JM3	1251-4927		Connector - Header 16 Pin	18873	67997-616
A1K104	0490-1556	2	Relay - Reed	71707	3500-0050
A1K105	0490-1556		Relay - Reed	71707	3500-0050
A1K106	0490-1555	1	Relay - Reed	71707	3500-0051
A1P1	1252-1596	1	Connector - Right Angle - 96 Pin	06776	DIN96CPCSRITR
A1P2	1251-7892	1	Connector - Right Angle - 64 Pin	18873	75882-364
A1P3	1258-0247	1	4-Position Jumper	18873	69146-204
A1SP1	3101-3066	1	Switch - Rocker 8 Position 5 V 0.1 A	81073	76YY22968S
A1XU23	1200-0817	2	Socket - 40 Pin Integrated Circuit	00779	2-640379-1
A1XU104	1200-0817		Socket - 40 Pin Integrated Circuit	00779	2-640379-1
A1XU124	1200-0853	1	Socket - 16 Pin Integrated Circuit	00779	2-640358-1
			CABLE ASSEMBLIES		
CBL1	E1326-61601	1	Cable Assembly - 6 Conductor	28480	E1326-61601
CBL2	E1326-61605	1	Cable Assembly - 4 Conductor	28480	E1326-61605
			MECHANICAL PARTS		
MP1	E1400-84105	2	Handle Kit-Bottom	28480	E1400-84105
MP2	E1400-84106		Handle Kit-Top	28480	E1400-84106
MP3	1510-0091	4	Binding Post - Red	28480	1510-0091
MP4	1510-0091		Binding Post - Red	28480	1510-0091
MP5	1510-0091		Binding Post - Red	28480	1510-0091
MP6	1510-0091		Binding Post - Red	28480	1510-0091
MP7	8160-0686	1	Clip-RFI Strip	30817	00786-185
MP8	1400-0249	1	Cable Tie - 0.062-0.625 IN DIA	59730	TY-23M-8
PNL1	E1411-00201	1	Panel - Faceplate	28480	E1411-00201
SHD1	E1411-00602	1	Shield - Bottom	28480	E1411-00602
SHD2	E1411-00601	1	Shield - Top	28480	E1411-00601
			COMMON HARDWARE		
SCW1, SCW2	0515-0368	2	Screw Pan-Head M2.5 X 12 Torx T8	00000	Order by Description
SCW3-SCW8,	0515-1135	7	Screw Pan-Head M3 X 25 Torx T8	00000	Order by Description
SCW15	0515-1375	3	Screw Flat-Head M2.5 X 6 Torx T8	00000	Order by Description
SCW 9-SCW11	0515-1968	2	Screw Pan-Head M2.5 X 11 Pozidriv	00000	Order by Description
SCW12-SCW13	2950-0001	4	Nut-Hex-DBL Chamfer 3/8 - 32 THD	00000	Order by Description
HDW1-HDW4	3050-0593	4	Washer-Spring NO. 3/8	00000	Order by Description
HDW5-HDW8					

* See Table 6-3 for Reference Designator definitions
** See Table 6-4 for Code List of Manufacturers
[a] Repair limited to replacement of parts listed - see Introduction for ordering information

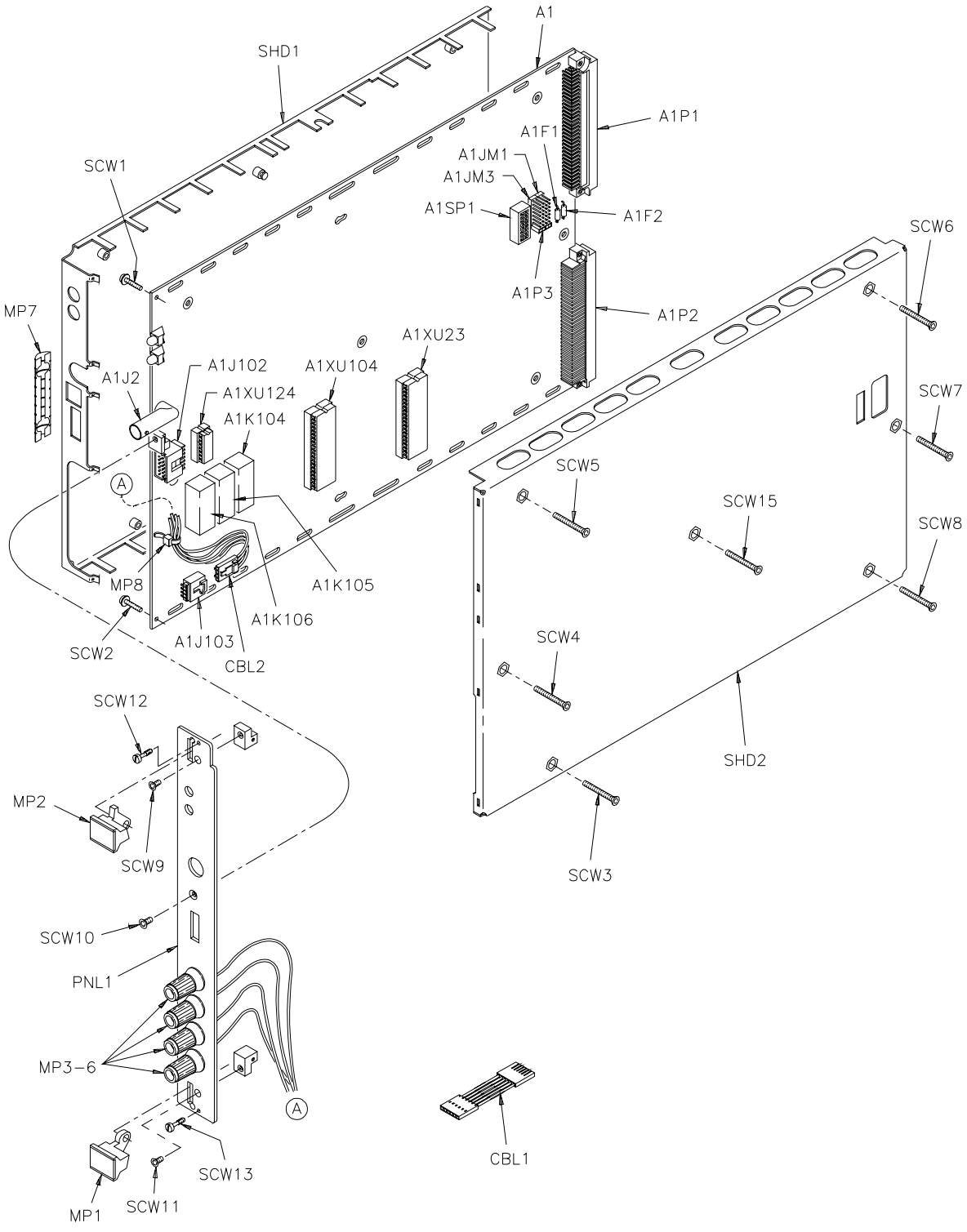


Figure 6-1. HP E1411A Replaceable Parts

Table 6-2. HP E1411B Replaceable Parts

Reference* Designator	HP Part Number	Qty	Description	Mfr** Code	Mfr Part Number
			EXCHANGE ASSEMBLIES		
	E1411-66511***	1	E1411B Multimeter Module (New)	28480	E1411-66511
	E1411-69511***	1	E1411B Multimeter Module (Exchange)	28480	E1411-69511
A1	E1411-66511	1	**MULTIMETER PCA [a]**	28480	E1411-66511
A1F1	2110-0712	2	Fuse - Sub Miniature - 4A	75915	R251004T1
A1F2	2110-0712		Fuse - Sub Miniature - 4A	75915	R251004T1
A1J2	1250-1846	1	Connector - Right Angle BNC	24931	28JR342-1
A1J102	1251-3712	1	Connector - Post 2 x 6	18873	68668-004
A1J103	1252-3416	1	Connector - 4 Pin Right Angle	27264	705-53-0108
A1J301	1250-1846		Connector - Right Angle BNC	24931	28JR342-1
A1JM1	1251-4927	2	Connector - Header 16 Pin	18873	67997-616
A1JM3	1251-4927		Connector - Header 16 Pin	18873	67997-616
A1K104	0490-1556	2	Relay - Reed	71707	3500-0050
A1K105	0490-1556		Relay - Reed	71707	3500-0050
A1K106	0490-1555	1	Relay - Reed	71707	3500-0051
A1P1	1252-1596	1	Connector - Right Angle - 96 Pin	06776	DIN96CPCSRITR
A1P2	1251-7892	1	Connector - Right Angle - 64 Pin	18873	75882-364
A1P3	1258-0247	1	4-Position Jumper	18873	69146-204
A1SP1	3101-3066	1	Switch - Rocker 8 Position 5 V 0.1 A	81073	76YY22968S
A1XU23	1200-0817	2	Socket - 40 Pin Integrated Circuit	00779	2-640379-1
A1XU104	1200-0817		Socket - 40 Pin Integrated Circuit	00779	2-640379-1
A1XU124	1200-0853	1	Socket - 16 Pin Integrated Circuit	00779	2-640358-1
			CABLE ASSEMBLIES		
CBL1	E1326-61601	1	Cable Assembly - 6 Conductor	28480	E1326-61601
CBL2	E1326-61605	1	Cable Assembly - 4 Conductor	28480	E1326-61605
			MECHANICAL PARTS		
MP1	E1400-45102†	1	Handle Bottom Metal Injection	28480	E1400-45102
MP2	E1400-45101†	1	Handle Top Metal Injection	28480	E1400-45101
MP3	1510-0091	4	Binding Post - Red	28480	1510-0091
MP4	1510-0091		Binding Post - Red	28480	1510-0091
MP5	1510-0091		Binding Post - Red	28480	1510-0091
MP6	1510-0091		Binding Post - Red	28480	1510-0091
MP7	8160-0686	1	Clip-RFI Strip	30817	00786-185
MP8	1400-0249	1	Cable Tie - 0.062-0.625 IN DIA	59730	TY-23M-8
PNL1	E1411-00202†	1	Panel - Faceplate	28480	E1411-00202
SHD1	E1411-00612	1	Shield - Bottom	28480	E1411-00602
SHD2	E1411-00611	1	Shield - Top	28480	E1411-00601
			COMMON HARDWARE		
SCW1-SCW2	E1400-00610†	2	Shoulder Screw Assembly	28480	E1400-00610
SCW3-SCW8,	0515-1135	7	Screw Pan-Head M3 X 25 Torx T8	00000	Order by Description
SCW15	0515-1375	1	Screw Flat-Head M2.5 X 6 Torx T8	00000	Order by Description
SCW11	2950-0001	4	Nut-Hex-DBL Chamfer 3/8 - 32 THD	00000	Order by Description
HDW1-HDW4	3050-0593	4	Washer-Spring NO. 3/8	00000	Order by Description
HDW5-HDW8					

* See Table 6-3 for Reference Designator definitions
** See Table 6-4 for Code List of Manufacturers
*** PC Board Replacement only
[a] Repair limited to replacement of parts listed - see Introduction for ordering information
† These parts are not compatible with older versions of the E1411B that have plastic handles. To replace one of these parts on an older E1411B, you must order all four of the parts marked with a † *and* a new top shield.

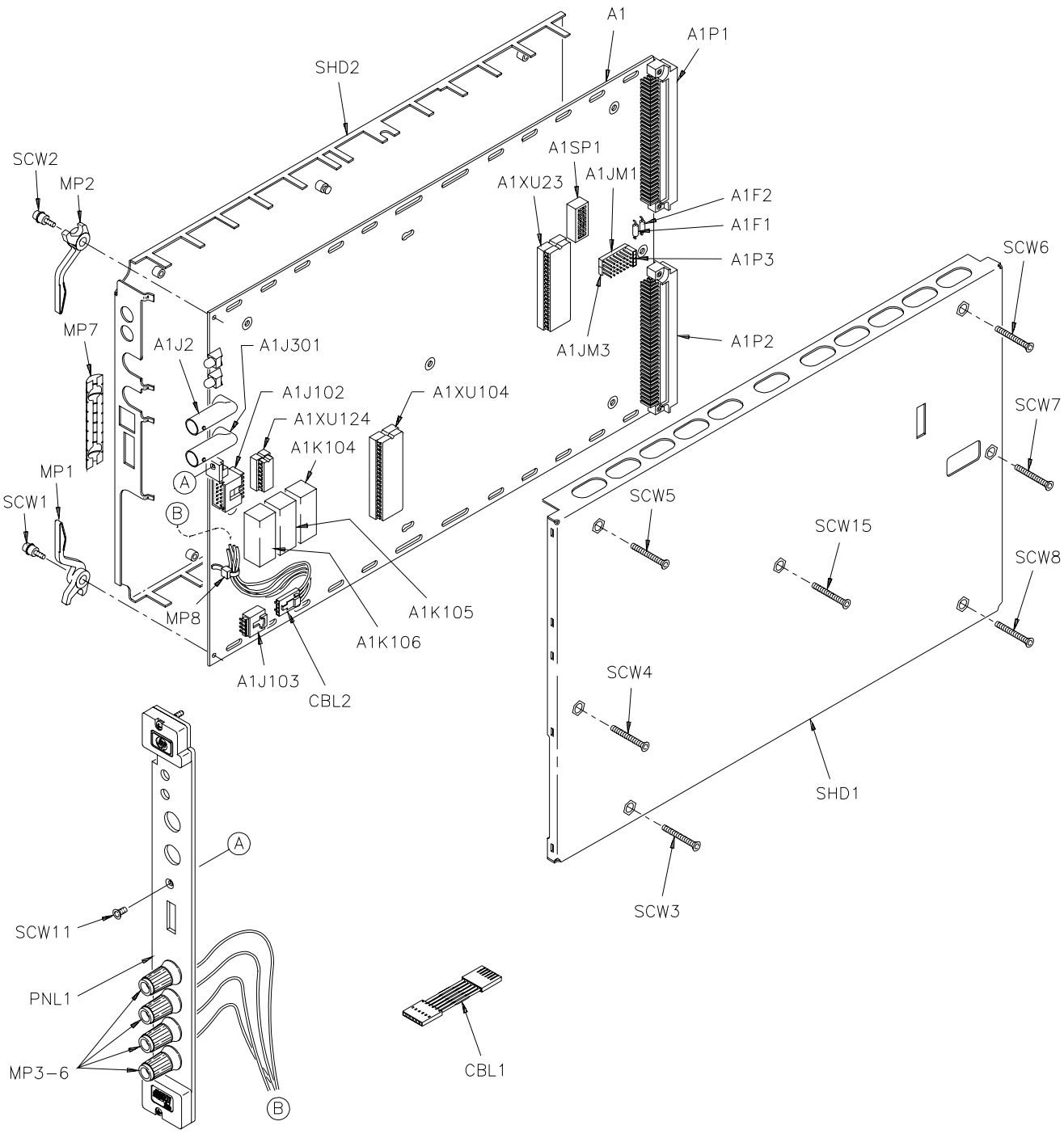


Figure 6-2. HP E1411B Replaceable Parts

Table 6-3. HP E1411 Reference Designators

HP E1411 Reference Designators	
A ..... assembly	MP ..... misc. mechanical part
CBL ..... cable	P ..... electrical connector (plug)
F ..... fuse	PNL ..... panel
J ..... electrical connector (jack)	SHD ..... shield
JM ..... electrical connector (header)	SP ..... switch
K .....relay	XU ..... socket, integrated circuit

Table 6-4. HP E1411 Code List of Manufacturers

Mfr Code	Manufacturer Name	Address
00000	Any satisfactory supplier	
00779	AMP INC	Harrisburg, PA 17111
06776	Robinson Nugent Inc	New Albany, IN 47150
18873	Dupont E I DE Nemours & Co	Wilmington, DE 19801
24931	Specialty Connector Co	Franklin, IN 46131
27264	Molex Inc	Lisle, IL 60532
28480	Hewlett Packard Company	Palo Alto, CA 94304
30817	Instrument Specialties Co Inc	Del Water Gap, PA 07424
59730	Thomas & Betts Corp	Raritan, NJ 08869
71707	Coto Wabash	Providence, RI 02907
75915	Littelfuse Inc	Des Plaines, IL 60016
81073	Grayhill Inc	La Grange, IL 60525

Chapter 7
Manual Changes

Introduction

This chapter contains information to adapt this manual to instruments for which the content does not directly apply. Since this manual applies directly to instruments with serial numbers listed on the title page, change information is not required. See *Multimeter Serial Numbers* in *Chapter 1 - General Information* for HP E1411 multimeter serial number information.

Chapter 8
Service

Introduction

This chapter contains information to service the HP E1411 multimeter including troubleshooting guidelines and repair/maintenance guidelines.

WARNING

Do not perform any of the service procedures shown unless you are a qualified, service-trained person, and have read the WARNINGS and CAUTIONS in *Chapter 1 - General Information*.

Equipment Required

Equipment required for multimeter troubleshooting and repair is listed in Table 1-1, *Recommended Test Equipment*. Any equipment that satisfies the Requirements in the table may be substituted. To avoid damage to the screw head slots, use Pozidriv or Torx drivers as specified in the instructions. Pozidriv and Torx drivers used are listed in Table 8-1.

Table 8-1. Pozidriv/Torx Drivers

Description	HP Part Number
No. 1 Pozidriv No. 2 Pozidriv	8710-0899 8710-0900
Size T-8 Torx Size T-10 Torx Size T-15 Torx	8710-1673 8710-1284 8710-1816

Service Aids

There are no test points or manual adjustment locations for the HP E1411 multimeter. Service aids on printed circuit boards include pin numbers, some reference designations, and assembly part numbers. See *Chapter 6 - Replaceable Parts* for descriptions and location of HP E1411 replaceable parts.

Service notes, manual updates, and service literature for the HP E1411 multimeter may be available through Hewlett-Packard. For information, contact your nearest Hewlett-Packard Sales and Support Office.

Troubleshooting Techniques

There are two main steps to troubleshoot an HP E1411 multimeter problem: (1) identify the problem, and (2) test assemblies to isolate the cause to a user-replaceable component.

Identifying the Problem

Multimeter problems can be divided into four general categories:

- Self-test errors
- Operator errors
- Catastrophic failures
- Performance out of specification

Self-Test Errors

An error number (1, 2, 3, or 4) is returned when the multimeter self-test fails. If a self-test error occurs, recycle power and repeat the self-test. If the error repeats, see "Testing Assemblies" to troubleshoot the multimeter. Table 8-2 shows some typical causes of self-test errors.

Table 8-2. Self-Test Errors

Error	Description	Typical Causes
1	Multimeter does not respond to self-test	. Bad connections/settings . Incorrect operation . Hardware failure (exchange)
2	Invalid communication between A1 and A2 processors	. Bad A1/A2 communication . Hardware failure (exchange)
3	Data line between multimeter and mainframe failed	. Bad connections/settings . Incorrect operation . Hardware failure (exchange)
4	Invalid communication between multimeter and mainframe	. Bad connections/settings . Incorrect operation . Hardware failure (exchange)

Operator Errors

Apparent failures may result from operator errors. See *Appendix B - Error Messages* in the *HP E1326A/E1411A User's Manual* or the *E1326B/E1411B User's Manual* for information on operator errors.

Catastrophic Failure

If a catastrophic failure occurs, see "Testing Assemblies" to troubleshoot the multimeter.

Performance Out of Specification

If the multimeter performance is out of specification limits, use the adjustment procedures in *Chapter 5 - Adjustments* to correct the problem. If the condition repeats, see "Testing Assemblies" to troubleshoot the multimeter.

Testing Assemblies

You can use the tests and checks in Table 8-3 to isolate the problem to a user-replaceable part on the multimeter frame or PCA. See Figure 6-1 (HP E1411A) or Figure 6-2 (HP E1411B) in *Chapter 6 - Replaceable Parts* for locations of user-replaceable parts.

NOTE

If the problem cannot be traced to a user-replaceable part listed in Table 6-1 or Table 6-2, return the multimeter to Hewlett-Packard for exchange. See Chapter 6 - Replaceable Parts for procedures.

Table 8-3. HP E1411 Tests/Checks

Test/Check	Reference Designator	Check:
Heat Damage	- - - - - - - - - -	Discolored PC boards Damaged insulation Evidence of arcing
Switch/Jumper Settings	JM1, JM3, P3 SP1	IRQ Level setting LADDR setting
Frame	CBL1, CBL2 MP3, MP4, MP5, MP6	Cable contact damage Panel binding posts
A1 Printed Circuit Assembly	F1, F2 J2, J102, J103, J301 K104, K105, K106 P1,P2 XU23, XU104, XU124	Fuse continuity Mating connector contacts Relay opening/closure Connector contacts IC contact/connections

Checking Heat Damage

Inspect the multimeter for signs of abnormal internally generated heat such as discolored printed circuit boards or components, damaged insulation, or evidence of arcing. If there is damage, do not operate the multimeter until you correct the problem.

Checking Switches/Jumpers

Verify the logical address setting is set correctly (factory set at 24). Verify the interrupt priority jumpers are set correctly (factory set at level 1). See the *HP E1326A/E1411A User's Manual* or the *E1326B/E1411B User's Manual* for information.

Testing Multimeter Frame

To test the multimeter frame, see Table 8-3 for guidelines to check binding posts MP3, MP4, MP5, and MP6, and cables CBL1 and CBL2. If you need to remove and/or replace the binding posts, see "Removing Binding Posts" in this chapter.

Testing Printed Circuit Assembly

To test the PCA, remove mainframe power and remove the multimeter from the mainframe. Next, remove the Top Shield (see "Removing Top Shield" for instructions). Then, see Table 8-3 for guidelines to isolate the problem to a user-replaceable part.

Repair Guidelines

This section gives guidelines to repair the HP E1411 multimeter, including:

- ESD precautions
- Removing top shield
- Removing front panel/bottom shield
- Removing binding posts
- Soldering printed circuit boards
- Post-repair safety checks

ESD Precautions

Electrostatic discharge (ESD) may damage MOS, CMOS and other static-sensitive devices in the HP E1411 multimeter. This damage can range from slight parameter degradation to catastrophic failure. When handling multimeter assemblies, follow these guidelines to avoid damaging multimeter components:

- Always use a static-free work station with a pad of conductive rubber or similar material when handling multimeter components.
- After you remove an assembly from the multimeter, place the assembly on a conductive surface to guard against ESD damage. Do not stack assemblies.

- Do not use pliers to remove a MOS or CMOS device from a high-grip socket. Instead, use a small screwdriver to pry the device up from one end. Slowly lift the device up, one pair of pins at a time.
- After you remove a MOS or CMOS device from an assembly, place the device onto a pad of conductive foam or other suitable holding material.
- If a device requires soldering, be sure the assembly is placed on a pad of conductive material. Also, be sure you, the pad, and the soldering iron tip are grounded to the assembly. Apply as little heat as possible when soldering.

Removing Top Shield

Use the following steps to remove the top shield from the printed circuit assembly (PCA). See Figure 8-1 for component locations.

1. Remove seven Torx T8 screws
2. Lift top shield from the back until front slots can be disengaged from tabs.
3. Remove the top shield.
4. Reverse steps 1 through 3 to replace top shield.

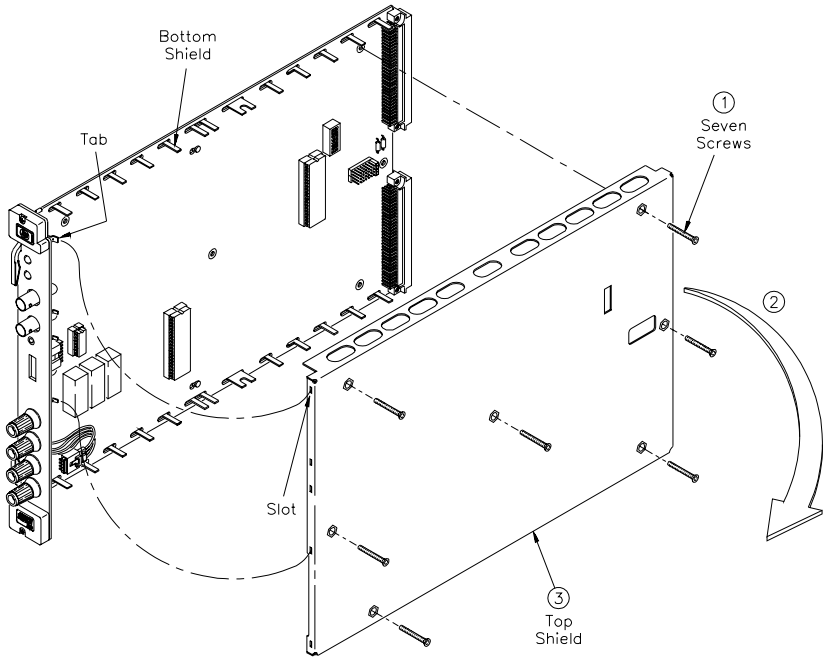


Figure 8-1. Removing Top Shield

NOTE

When reinstalling the top shield, verify that the slots are aligned with the tabs, then set the top shield into place.

Removing Front Panel

Use the following steps to remove the front panel and bottom shield from the printed circuit assembly (PCA). See Figure 8-2 for component locations.

1. Remove Torx T8 screw from front panel
2. Remove two Torx T8 screws from PCA
3. Remove cable assembly from clip
4. Slide PCA off bottom shield
5. Reverse steps 1 through 4 to replace front panel and bottom shield

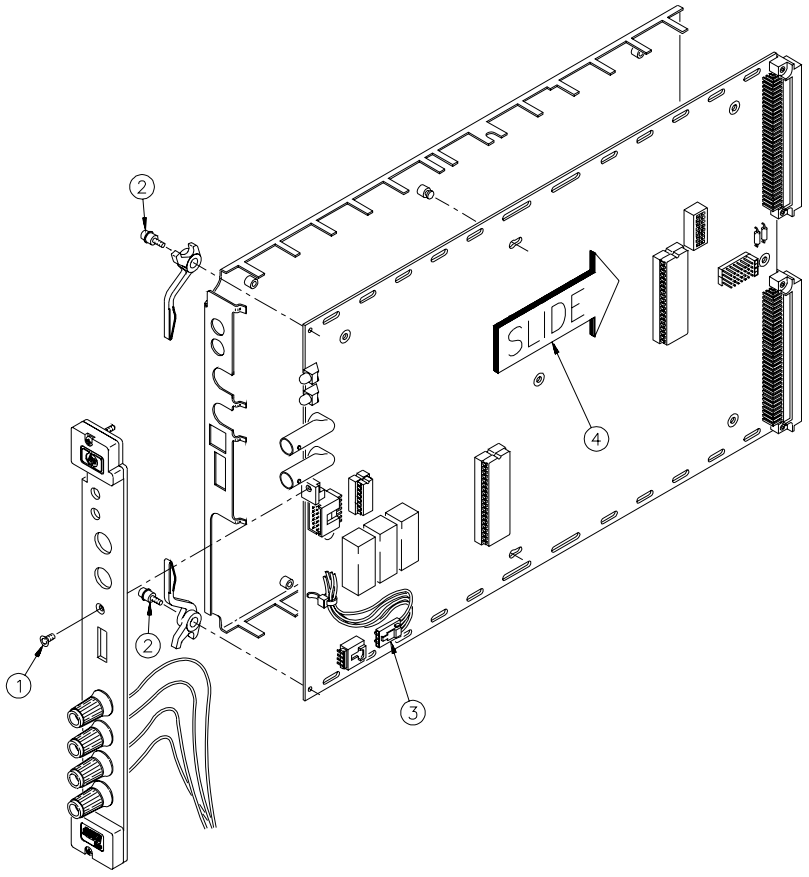


Figure 8-2. Removing Front Panel

Removing Binding Posts

Use the following steps to remove the HP E1411 front panel binding posts (MP3, MP4, MP5, and MP6) (see Figure 8-3).

1. Unsolder wire
2. Remove the 3/8-32 nut and spring washer
3. Remove the binding post
4. Reverse the order to reinstall the binding posts

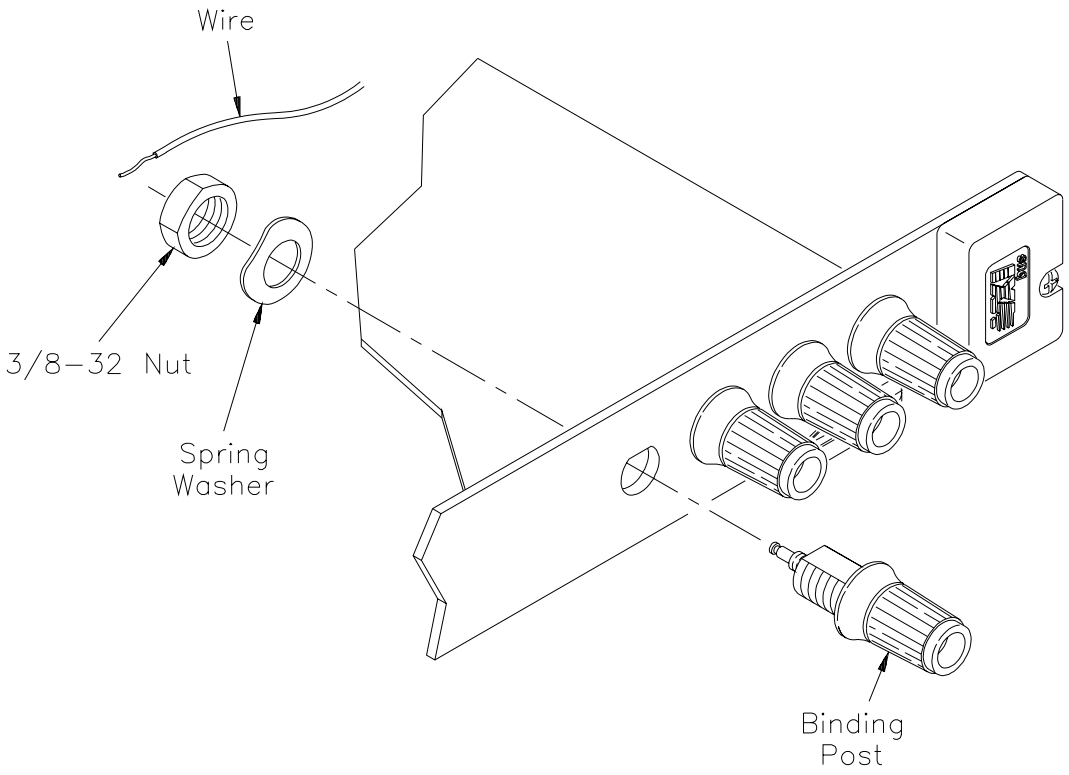


Figure 8-3. Removing Binding Posts

Soldering Printed Circuit Boards

The etched circuit boards in the multimeter have plated-through holes that allow a solder path to both sides of the insulating material. Soldering can be done from either side of the board with equally good results. When soldering to any circuit board, keep in mind the following guidelines:

CAUTION

Do not use a sharp metal object such as an awl or twist drill, since sharp objects may damage the plated-through conductor.

- Avoid unnecessary component unsoldering and soldering. Excessive replacement can result in damage to the circuit board and/or adjacent components.
- Do not use a high power soldering iron on etched circuit boards as excessive heat may lift a conductor or damage the board.
- Use a suction device or wooden toothpick to remove solder from component mounting holes. When using a suction device, be sure the equipment is properly grounded to prevent electrostatic discharge from damaging CMOS devices.

Post-Repair Safety Checks

After making repairs to the HP E1411 multimeter, inspect the multimeter for any signs of abnormal internally generated heat, such as discolored printed circuit boards or components, damaged insulation, or evidence of arcing. Determine and correct the cause of the condition. Then run the self-test (*TST? command) to verify that the multimeter is functional.

Appendix A
Calculating Multimeter Accuracy

Introduction

This appendix shows how multimeter accuracy, measurement uncertainty, and test accuracy ratio (TAR) values are defined and calculated for the performance verification tests for the HP E1411 multimeter.

See Table 4-1, "*Performance Test Record for the HP E1411 Multimeter*" for 90-day specification values of multimeter accuracy, measurement uncertainty, and test accuracy ratios (TARs).

NOTE

Multimeter accuracy, measurement uncertainty, and test accuracy ratios in Table 4-1 are valid ONLY for the specified test conditions and assumptions described in this manual. For the test conditions described, all TARs exceed the 4:1 requirement of MIL-STD-45662A.

Multimeter Accuracy Definition

Multimeter accuracy is the expected accuracy of the measurement due ONLY to the multimeter. The "Low Limit" entry in Table 4-1 is the lower (-) value of multimeter accuracy, while the "High Limit" entry is the upper (+) value of multimeter accuracy.

Measurement Uncertainty Definition

Measurement Uncertainty is the expected accuracy of the source used to input signals to the multimeter. Since the Datron 4708 Autocal Multifunction Standard is the source used for measurements in this manual, the measurement uncertainty of the source is that of the Datron 4708.

This value is shown in the "Measurement Uncertainty" column of Table 4-1. See the *Datron 4708 User's Handbook* for additional information on calculating measurement uncertainty for the Datron 4708 source.

NOTE

Measurement Uncertainty does not apply to the DC Voltage (Zero Volts Input) test, since no input is applied.

Test Accuracy Ratio (TAR) Definition

Test Accuracy Ratio (TAR) is the ratio of multimeter accuracy to measurement uncertainty. For the HP E1411 multimeter performance tests, test accuracy ratio = (High Limit value - Test Input value)/Measurement Uncertainty value. This value is shown in the "Test Accuracy Ratio (TAR)" column of Table 4-1.

NOTE

Test accuracy ratio does not apply to the DC Voltage (Zero Volts Input) test, since no measurement uncertainty value applies.

Multimeter Accuracy Calculations

For the HP E1411 multimeter performance verification tests, multimeter accuracy is defined for DC Voltage, AC Voltage, and 4-Wire Resistance measurements using the 90-day specifications in *Appendix A - Specifications* of the *HP E1326A/E1411A User's Manual* or the *E1326B/E1411B User's Manual*. The **assumed** test conditions are:

- 90 days since calibration
- Temperature within $\pm 5^{o}$C of calibration temperature
- Module calibration temperature 18^{o}C to 28^{o}C
- One hour warmup
- 4-wire ohms resistance measurements
- Aperture = 16.7 msec (60 Hz) or 20 msec (50 Hz)
- Autozero ON

DC Voltage Accuracy Equations

From *Appendix A - Specifications* of the *HP E1326A/E1411A User's Manual* or the *E1326B/E1411B User's Manual*, DC voltage 90-day accuracy = ±(% of reading + volts). The accuracy equations for the ranges and apertures used in the performance verification tests are:

Range	Accuracy [±(% of reading + Volts)]
125 mV	0.023 + 5.0 µV
1 V	0.013 + 15.0 µV
8 V	0.010 + 50.0 µV
64 V	0.015 + 1.0 mV
300 V	0.015 + 5.0 mV

Example: Calculate DC Voltage Accuracy

For a 7.0 DCV input to the multimeter, using the 8 V range and 16.7/20 msec aperture, multimeter accuracy (90-days) = ±(.010% reading + 50.0 µV) = ±(.0001 x 7.0 + 50 x 10^{-6}) = ±0.00075 Volts. Thus, for a 7.0 DCV input the High Limit in Table 4-1 = 7.00075 Volts and the Low Limit = 6.99925 Volts.

AC Voltage Accuracy Equations

From *Appendix A- Specifications* of the *HP E1326A /E1411A or E1326B /E1411B User's Manual*, AC voltage 90-day accuracy = ±(% of reading + volts). The accuracy equations for the ranges, frequencies and apertures used in the performance verification tests are:

Range	Frequency	Accuracy [±(% of reading + Volts)]
87.5 mV	20 Hz	2.175 + 1 mV
87.5 mV	60 Hz	0.675 + 200 µV
87.5 mV	5 kHz	0.675 + 200 µV
87.5 mV	10 kHz	3.175 + 200 µV
300 V	5 kHz	1.125 + 500 mV

Example: Calculate AC Voltage Accuracy

For a 0.07 ACV input to the multimeter, using the 87.5 mV range, 60 Hz frequency, and 16.7/20 msec aperture, multimeter accuracy (90-days) = ±(0.675% reading + 200 µV) = ±(.00675 x 0.07 + 200 x 10^{-6}) = ±0.000673 Volts. Thus, for a 0.07 ACV input the High Limit in Table 4-1 = 0.070673 Volts and the Low Limit = 0.069327 Volts.

4-Wire Ohms Accuracy Equations

From *Appendix A- Specifications* of the *HP E1326A /E1411A or E1326B /E1411B User's Manual*, 4-Wire resistance 90-day accuracy = ±(% of reading + Ohms). The accuracy equations for the ranges and apertures used in the performance verification tests are:

Range	Accuracy [±(% of reading + Ohms)]
2 kΩ	0.025 + 20 mΩ
131 kΩ	0.025 + 1 Ω
1 MΩ	0.025 + 10 Ω

Example: Calculate 4-Wire Resistance Accuracy

For a 1 kΩ input to the multimeter, using the 2 kΩ range and 16.7/20 msec aperture, multimeter accuracy (90-days) = ±(.025% reading + 20 mΩ) = ±(.00025 x 1000 + 20 x 10^{-3}) = ±0.270 Ω. Thus, for a 1 kΩ input the High Limit in Table 4-1 = 1000.27 Ω and the Low Limit = 999.73 Ω.

Measurement Uncertainty Calculations

Measurement uncertainties for the Datron 4708 source are calculated using the 90-day accuracy specifications in the *Datron 4708 User's Handbook:*

Measurement Uncertainty = Datron Accuracy + Calibration Uncertainty, where Datron Accuracy (ppm) = Accuracy Relative to Calibration Standards = ±(ppm OUTPUT + ppm FS)

and FS = 2 x range for all ranges except 1000V
FS = 1100 for the 1000V range

The **assumed** test conditions are:

- Temperature of 23°C±1°C
- 90 days since calibration
- 4-wire sense function for ohms measurements

Calculate DCV Measurement Uncertainty

From *Section 6 - Specifications* of the *Datron 4708 User's Handbook*, DC Voltage (Option 10) Accuracy (90 days since calibration and 23°C ±1° C) follows, where Datron Accuracy = ±(ppm OUTPUT + ppm FS).

Datron OUTPUT (DCV)	Datron Range (Volts)	Datron Accuracy (ppm)	Calibration Uncertainty (ppm)
0.1	1.0000000V	2 + 0.4	2
0.9	1.0000000V	2 + 0.4	2
7.0	10.000000V	1 + 0.15	1.5
58.0	100.00000V	2 + 0.25	2
300.0	1000.0000V	3 + 0.25	2

Example: Calculate DC Voltage Measurement Uncertainty

Since Measurement Uncertainty = Datron Accuracy + Calibration Uncertainty, for a 7.0 DCV OUTPUT and the Datron 4708 range set to 10.000000 V, Measurement Uncertainty (μV)=±[(1.0 x 7.0) + (2 x 0.15 x 10)] + (1.5 x 7.0)] = ±20.5 μV = ±0.000021 V.

Or, with a 300 DCV OUTPUT and the 1000.0000V range, Measurement Uncertainty (μV) = ±[(3.0 x 300) + (0.25 x 1100) + (2.0 x 300)] = ± 1775 μV = ±0.001775 V.

Calculate ACV Measurement Uncertainty

From *Section 6 - Specifications* of the *Datron 4708 User's Handbook* , AC Voltage (Option 20) Accuracy (90 days since calibration and 23°C ±1° C) where Datron Accuracy = ±(ppm OUTPUT + ppm FS).

Datron Output (ACV)	Datron Range	Datron Freq	Datron Accuracy (ppm)	Calibration Uncertainty (ppm)
0.07	100 mV	20 Hz	110 + 20 + 5 µV	30 + 1 µV
0.07	100 mV	60 Hz	60 + 20 + 5 µV	30 + 1 µV
0.07	100 mV	5 kHz	50 + 20 + 5 µV	30 + 1 µV
0.07	100 mV	10 kHz	50 + 20 + 5 µV	30 + 1 µV
300.0	1000 V	5 kHz	90 + 10	30

Example: Calculate AC Voltage Measurement Uncertainty

Since Measurement Uncertainty = Datron Accuracy + Calibration Uncertainty, for a 0.07 ACV OUTPUT to the multimeter and the Datron 4708 range set to 100 mV at 60 Hz, Measurement Uncertainty (µV)=±[(60.0 x 0.07) + (2 x 20 x .1) + 5 + (30 x .07 +1)] = ±16.3 µV = ±0.000016 V.

Or, for a 300 ACV OUTPUT to the multimeter and the Datron 4708 range set to 1000 V at 5 kHz, Measurement Uncertainty (µV) = ±[(90.0 x 300.0) + (10 x 1100) + (30 x 300)] = ± 47000 µV = ±0.047 V.

Calculate Resistance Measurement Uncertainty

From *Section 6 - Specifications* of the *Datron 4708 User's Handbook*, 4-Wire Resistance (Option 30) Accuracy (90 days since calibration and 23°C ±1° C) follows, where Datron Accuracy =±(ppm OUTPUT + ppm FS).

Datron Output	Datron Range (Ohms)	Datron Accuracy (ppm)	Calibration Uncertainty (ppm)
1 k Ω	1.0000000k	3	5
100 k Ω	100.00000k	3	6
1 M Ω	1.0000000M	10	12

Example: Calculate 4-Wire Ohms Measurement Uncertainty

For the 100 kΩ range, measurement uncertainty = $[(3 \times 10^{-6} \times 10^{5}) + (6 \times 10^{-6 \times} 10^{5})]$ Ω = (0.3 + 0.6) Ω = 0.900 Ω.

Test Accuracy Ratio (TAR) Calculations

For the HP E1411 multimeter, Test Accuracy Ratio (TAR) = [High Limit - Input Value]/Measurement Uncertainty where the source input value is in DCV, ACV, or Ohms.

Example: Calculate DCV Test Accuracy Ratio

For a 7.0 DCV measurement if the High Limit value = 7.000750 DCV and the Measurement Uncertainty = .0000115 DCV, Test Accuracy Ratio (TAR) = (7.000750 V - 7.0000000 V)/.0000115 V = 65:1 (rounded to the nearest integer value). Since this value is >10:1, the entry in Table 4-1 is ">10:1".

Appendix B
Verification Tests - C Programs

Functional Verification Test

This program is designed to do the Functional Verification Test found in *Chapter 4 - Verification Tests.*

Example:Self Test

This example performs a multimeter self-test to ensure that the multimeter is communicating with the mainframe, external controller, and/or external terminal.

```
#include <stdio.h>
#include <sicl.h>

#define ADDR "hpib7,9,03"              /* Address of device */

void main ()
{
   INST id;                             /* Define id as an instrument */
   char a[256] = {0};                  /* Result variable */

   id = iopen (ADDR);                   /* Open instrument session */

   ipromptf(id, "*TST?\n", "%t", a);    /* Self test command */

   printf("\n %s", a);                   /* Print result */

   getchar();                            /* Pause */

   iclose (id);                          /* Close instrument session */
}
```

Performance Verification Tests

These programs are designed to do the Performance Verification Tests found in *Chapter 4 - Verification Tests*.

Example: Zero Volt DCV Test

This example performs a DCV test for zero volts input and a power line reference frequency of 60 Hz.

```
/*  Zero Volt DCV Test     E1411A/B  */

#include <stdio.h>
#include <sicl.h>

#define ADDR "hpib7,9,03"            /* Address of HP E1326B */

void main (void)
{
   INST id;                                  /* Define id as an instrument */
   char volt[256] = {0};                     /* Result variable */

   #if defined(__BORLANDC__) && !defined(__WIN32__)
     _InitEasyWin();
   #endif

   ionerror(I_ERROR_EXIT);

   id = iopen (ADDR);                        /* Open instrument session */

   iprintf (id, "*RST\n");                   /* Resets and set autozero
                                                ON and PLC to 1 */
   iprintf (id, "CAL:LFR 60\n");             /* Sets line reference to 60 Hz */

   ipromptf (id, "MEAS:VOLT:DC? .1\n", "%t", volt);
                                             /* Measure 0.113 V range */
   printf ("Voltage for 0.113 V range = %s\n", volt);

   ipromptf (id, "MEAS:VOLT:DC? .9\n", "%t", volt);
                                             /* Measure 0.91 V range */
   printf ("Voltage for 0.91 V range = %s\n", volt);

   ipromptf (id, "MEAS:VOLT:DC? 7\n", "%t", volt);
                                             /* Measure 7.27 V range */
   printf ("Voltage for 7.27 V range = %s\n", volt);

   ipromptf (id, "MEAS:VOLT:DC? 58\n", "%t", volt);
                                              /* Measure 58.1 V range */
   printf ("Voltage for 58.1 V range = %s\n", volt);

   ipromptf (id, "MEAS:VOLT:DC? 300\n", "%t", volt);
                                              /* Measure 300 V range */
   printf ("Voltage for 300 V range = %s\n", volt);

   iclose (id);                               /* Close instrument session */
}
```

Example: DC Voltage Test

This test performs a DC Voltage test for positive input DC volts and a power line reference frequency of 60 Hz.

```
/*  DC Voltage Test (DCV Input)     E1411A/B  */

#include <stdio.h>
#include <sicl.h>

#define ADDR "hpib7,9,03"        /* Address of HP E1326B */

void main ()
{
   INST id;                              /* Define id as an instrument */
   float range[5] = {0.113, 0.910, 7.270, 58.10, 300.0};
   float volts[5] = {0.1, 0.9, 7.0, 58.0, 300.0};
   char measurement[5][256], complete[256];  /* Result variable */
   int i;

   #if defined(__BORLANDC__) && !defined(__WIN32__)
      _InitEasyWin();
   #endif

   ionerror(I_ERROR_EXIT);      /* Exit on error */

   id = iopen (ADDR);                 /* Open instrument session */

   iprintf (id, "*RST\n");            /* Resets and set autozero
                                         ON and PLC to 1 */
   iprintf (id, "CAL:LFR 60\n");      /* Sets line reference to 60 Hz */

   for(i = 0; i < 5; i++)             /* Take voltage measurements */
   {
      printf("\n Set DC Standard to %.1f VDC", volts[i]);
      printf("\n press ENTER when ready\n");
      getchar ();
      iprintf(id, "CONF:VOLT:DC %f\n", range[i]);  /* Voltage range */
      ipromptf(id, "*OPC?\n", "%s", complete);      /* Wait for settling */
      ipromptf(id, "READ?\n", "%t", measurement[i]);  /* Read voltage */
   }

   for (i=0; i < 5; i++)              /* Print voltage measurements */
     printf("\n Voltage on %4f V range = %s ", range[i], measurement[i]);

   iclose (id);                       /* Close instrument session */
}
```

Example: AC Voltage Test

This example performs an AC voltage test for a power line reference frequency of 60 Hz.

```
/*  AC Voltage Test          E1411A/B  */

#include <stdio.h>
#include <sicl.h>

#define ADDR "hpib7,9,03"              /* Address of HP E1326B */

void main ()
{
   INST id;                            /* Define id as an instrument */
   float source_volts[5] = {0.07, 0.07, 0.07, 0.07, 300.0};
   float source_freq[5] = {20, 60, 5000, 10000, 5000};
   char measurement[5][256], complete[256];  /* Result variable */
   int i;

   #if defined(__BORLANDC__) && !defined(__WIN32__)
     _InitEasyWin();
   #endif

   ionerror(I_ERROR_EXIT);     /* Exit on error */

   id = iopen (ADDR);              /* Open instrument session */

   iprintf (id, "*RST\n");             /* Resets and set autozero
                                          ON and PLC to 1 */
   iprintf (id, "CAL:LFR 60\n");   /* Sets line reference to 60 Hz */

   for(i = 0; i < 5; i++)              /* Take voltage measurements */
   {
     printf("\n 1. Set AC Standard output to %.2f VAC",
              source_volts[i]);
     printf("\n 2. Set AC Standard frequency to %.1f
               Hz",source_freq[i]);
     printf("\n 3. Press ENTER when ready\n");
     getchar ();
     iprintf(id, "CONF:VOLT:AC %f\n", source_volts[i]);
                                         /* Set voltage range */
     ipromptf(id, "*OPC?\n", "%s", complete);
     ipromptf(id, "READ?\n", "%t", measurement[i]);
                                         /* Read voltage */
   }

   for (i=0; i < 5; i++)               /* Print voltage measurements */
   printf("\n Voltage for %4f V range at %.1f Hz = %s ", source_volts[i],
            source_freq[i], measurement[i]);

   iclose (id);                        /* Close instrument session */
}
```

Example: Resistance Test

This example performs a 4-wire ohms resistance test. The program also calculates the Upper and Lower Limit values for the ACTUAL resistance values. Use these values in Table 4-1 if they differ from the given values.

```
/*  Resistance Test (4-wire Ohms)     E1411A/B  */

#include <sdtio.h>
#include <sicl.h>

#define ADDR "hpib7,9,03"        /* Address of HP E1326B */

void main ()
{
   INST id;                              /* Define id as an instrument */
   float range[3] = {1861, 119156, 1048576};
   float source[3] = {1000, 100000, 1000000};
   char measurement[3][256], complete[256];
   float limit[3], actual[3];
   int i;

   #if defined(__BORLANDC__) && !defined(__WIN32__)
     _InitEasyWin();
   #endif

   ionerror(I_ERROR_EXIT);       /* Exit on error */

   id = iopen (ADDR);                 /* Open instrument session */

   iprintf (id, "*RST\n");            /* Resets and set autozero
                                         ON and PLC to 1 */
   iprintf (id, "CAL:LFR 60\n");      /* Sets line reference to 60 Hz */

   for(i = 0; i < 3; i++)             /* Take measurements */
   {
      printf("\n 1. Set Resistance Standard to %.1f Ohms", source[i]);
      printf("\n 2. Measure ACTUAL resistance standard value (in
              Ohms)");
      printf("\n 3. Enter ACTUAL resistance standard (in Ohms): ");
      scanf("%f", &actual[i]);

      iprintf(id, "CONF:FRES %f\n", range[i]);
                                         /* Set resistance range */
      ipromptf(id, "*OPC?\n", "%s", complete);     /* Wait for settling */
      ipromptf(id, "READ?\n", "%t", measurement[i]);
                                         /* Read resistance */

      if (i == 0)
         limit[i] = .00025*actual[i] + 0.02;      /* 2kOhm limits */
      if (i == 1)
         limit[i] = .00025*actual[i] + 1.0;       /* 131 kOhm limits */
      if (i == 2)
         limit[i] = .00025*actual[i] + 10;        /* 1 MOhm limits */
   }

   printf("\nMeasured     Source     Low Limit     High Limit");
   printf("\nResistance     Resistance     (Ohms)     (Ohms)\n");

   for (i=0; i < 3; i++)              /* Print measurements and limits */
      printf("\n%s     %10.2f          %10.2f         %10.2f",
             measurement[i],actual[i],  actual[i]-limit[i], actual[i]+limit[i]);

   iclose (id);                       /* Close instrument session */
}
```

Adjustments

These programs are designed to do the adjustments found in *Chapter 5 - Adjustments*.

DC Voltage Adjustments

This example performs DC Voltage adjustments for a power line reference frequency of 60 Hz. If no calibration error occurs, the program displays an "adjustment complete" message. If a calibration error occurs, the program displays the calibration error and prompts you to repeat the adjustment (see Table 5-1 for a list of calibration errors).

```
/*  DC Voltage Adjustments     E1411A/B  */

#include <stdio.h>
#include <sicl.h>

#define ADDR "hpib7,9,03"           /* Address of device */

void main ()
{
   INST id;                                 /* Define id as an instrument */
   float range[10] = {8.0, 8.0, 0.125, 0.125, 1.0, 1.0, 64.0, 64.0,
                      300.0, 300.0};
   float volts[10] = {7.7, -7.7, .121, -.121, .97, -.97, 62.0, -62.0,
                      300.0, -300.0};
   char cal_code[5][256];
   int i;
#if defined(__BORLANDC__) && !defined(__WIN32__)
  _InitEasyWin();
#endif
   ionerror(I_ERROR_EXIT);          /* Exit on error */
   id = iopen (ADDR);                /* Open instrument session */
   iprintf (id, "*RST\n");           /* Resets and set autozero
                                        ON and PLC to 1 */
   iprintf (id, "CAL:LFR 60\n");     /* Sets line reference to 60 Hz */
   for(i = 0; i  10; i++)            /* Take voltage measurements */
   {
    retry:
      printf("\n Set DC Standard to %.1f VDC", volts[i]);
      printf("\n press ENTER when ready\n");
      getchar ();
      iprintf(id, "FUNC:VOLT:DC\n");            /* Set DCV function */
      iprintf(id, "VOLT:RANG %f\n", range[i]);  /* Set E1326B range */
      iprintf(id, "CAL:VAL %f\n", volts[i]);     /* Set CAL:VAL value */
      iprintf(id, "TRIG:DEL .05\n");            /* Wait for settling */
      ipromptf(id, "CAL?\n", "%t", cal_code[i]);  /* Read voltage */

      if (cal_code != 0)
      {
         printf ("\nCalibration Error %s for %f Vdc input", cal_code,
                  volts[i]);
         printf ("\nCheck source value/connections, then");
         printf ("\npress ENTER to retry this adjustment");
         getchar ();
         goto retry;
      }
      else
         printf ("\nAdjustment complete for %f Vdc input", volts[i]);
   }
   iclose (id);                             /* Close instrument session */
}
```

AC Voltage Adjustments

This example performs an AC Voltage adjustment for a power line reference frequency of 60 Hz and an input of 5.6 Vac at 1 kHz. If no calibration error occurs, the program displays an "adjustment complete" message. If a calibration error occurs, the program displays the calibration error and prompts you to repeat the adjustment (see Table 5-1 for a list of calibration errors).

```
/*  AC Voltage Adjustments     E1411A/B  */

#include <sdtio.h>
#include <sicl.h>

#define ADDR "hpib7,9,03"          /* Address of device */

void main ()
{
   INST id;                        /* Define id as an instrument */
   char cal_code[256];

#if defined(__BORLANDC__) && !defined(__WIN32__)
   _InitEasyWin();
#endif

   ionerror(I_ERROR_EXIT);         /* Exit on error */

   id = iopen (ADDR);              /* Open instrument session */

   iprintf (id, "*RST\n");         /* Resets and set autozero
                                      ON and PLC to 1 */
   printf (id, "CAL:LFR 60\n");    /* Sets line reference to 60 Hz */

   retry:
   printf("\n Set AC Standard to 5.6 Vac at 1.0 kHz");
   printf("\n press ENTER when ready\n");
   getchar ();   iprintf(id, "FUNC:VOLT:AC\n");   /* Set DCV function */
   iprintf(id, "VOLT:RANG 5.6\n");                /* Set E1326B range */
   iprintf(id, "CAL:VAL 5.6\n");                   /* Set CAL:VAL value */
   iprintf(id, "TRIG:DEL .05\n");                 /* Wait for settling */
   ipromptf(id, "CAL?\n", "%t", cal_code[i]);    /* Read voltage */

   if (cal_code != 0)
   {
      printf ("\nCalibration Error %s on 5.6 Vac range", cal_code);
      printf ("\nCheck source value/connections, then");
      printf ("\npress ENTER to retry this adjustment");
      getchar ();
      goto retry;
   }
   else
      printf ("\nAdjustment complete for %f Vdc input", volts[i]);

   iclose (id);                    /* Close instrument session */
}
```

Resistance Adjustments

This example performs a 4-wire ohms resistance adjustment for a power line reference frequency of 60 Hz. If a calibration error occurs, the program displays the calibration error and prompts you to repeat the adjustment (see Table 5-1 for a list of calibration errors).

```
/*  4-wire Resistance Adjustments     E1411A/B  */

#include <stdio.h>
#include <sicl.h>

#define ADDR "hpib7,9,03"           /* Address of device */

void main ()
{
   INST id;                                 /* Define id as an instrument */
   float range[3] = {2000, 16000, 1048576};
   float source[3] = {1000, 10000, 1000000};
   char cal_code[5][256];
   float actual[3];
   int i;

#if defined(__BORLANDC__) && !defined(__WIN32__)
   _InitEasyWin();
#endif

   ionerror(I_ERROR_EXIT);          /* Exit on error */

   id = iopen (ADDR);                    /* Open instrument session */

   iprintf (id, "*RST\n");                  /* Resets and set autozero
                                               ON and PLC to 1 */
   iprintf (id, "CAL:LFR 60\n");        /* Sets line reference to 60 Hz */

   for(i = 0; i  3; i++)                  /* Take voltage measurements */
   {
     retry:
      printf("\n Set Resistance Standard to %.1f Ohms", source[i]);
      printf("\n Measure ACTUAL Resistance Standard value (in
                Ohms):");
      scanf ("%f", &actual[i]);

      iprintf(id, "FUNC:FRES\n");                    /* Set DCV function */
      iprintf(id, "FRES:RANG %f\n", range[i]);   /* Set E1326B range */
      iprintf(id, "CAL:VAL %f\n", actual[i]);        /* Set CAL:VAL value */
      ipromptf(id, "CAL?\n", "%t", cal_code[i]);  /* Read voltage */

      if (cal_code != 0)
      {
         printf ("\nCalibration Error %s for %f Ohms", cal_code,
                  source[i]);
         printf ("\nCheck source value/connections, then");
         printf ("\npress ENTER to retry this adjustment");
         getchar ();
         goto retry;
      }
      else
          printf ("\nAdjustment complete with %f Ohms source\n",
                    source[i]);

   }

   iclose (id);                             /* Close instrument session */
}
```

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