HP E1445A
Arbitrary Function Generator

Service Manual

Serial Numbers

This manual applies directly to instruments with serial numbers prefixed with 3144A.
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Edition 2 (Part Number E1445-90011). . . . . . . . . . . . . . . . . . . . . . . . . . . . . . September 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.

Alternating current (AC).

Direct current (DC).

Indicates hazardous voltages.

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

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

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

WARNING

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 I 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: Arbitrary Function Generator
   Model Number: HP E1445A
   Product Options: All

conforms to the following Product Specifications:

       CSA C22.2 #1010.1 (1992)
       UL 3111

EMC: CISPR 11:1990/EN55011 (1991): Group 1, Class A
     IEC 801-2:1991/EN50082-1 (1992): 4kV CD, 8kV AD
     IEC 801-3:1984/EN50082-1 (1992): 3 V/m
       0.5kV Signal Lines


Tested in a typical HP C-Size VXI mainframe.

July 29, 1996

Jim White, Quality 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).
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Reader Comment Sheet

HP E1445A Arbitrary Function Generator Service Manual
Edition 2 (part number E1445-90011)

You can help us improve our manuals by sharing your comments and suggestions. In appreciation of your time, we will enter you in a quarterly drawing for a Hewlett-Packard Palmtop Personal Computer (U.S. government employees are not eligible for the drawing).

__________________________________________________________________________
Your Name

__________________________________________________________________________
Company Name

__________________________________________________________________________
Job Title

__________________________________________________________________________
Address

__________________________________________________________________________
City, State/Province

__________________________________________________________________________
Country

__________________________________________________________________________
Zip/Postal Code

__________________________________________________________________________
Telephone Number with Area Code

________________________________________________________
Please list the system controller, operating system, programming language, and plug-in modules you are using.

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Please pencil-in one circle for each statement below:

- The documentation is well organized.  Disagree ↔ Agree
- Instructions are easy to understand.
- The documentation is clearly written.
- Examples are clear and useful.
- Illustrations are clear and helpful.
- The documentation meets my overall expectations.


Please write any comments or suggestions below—be specific.

__________________________________________________________________________
__________________________________________________________________________
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Chapter 1
General Information

Introduction

This manual contains information required to test, troubleshoot, and repair the HP E1445A C-Size VXI Arbitrary Function Generator (AFG). See the HP E1445A User’s Manual for additional information. Figure 1-1 shows the HP E1445A. This chapter includes the following sections:

- Introduction
- Safety Considerations
- Inspection/Shipping
- Environment
- AFG Description
- Recommended Test Equipment

Figure 1-1. HP E1445A Arbitrary Function Generator
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, AFG, 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 preventive maintenance, testing, 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.

---

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 that 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.)
WARNING

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.

USE PROPER FUSES. For continued protection against fire hazard, replace the line fuses 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 AFG, observe anti-static techniques whenever working on the AFG.
This section describes initial (incoming) inspection and shipping guidelines for the AFG.

Initial Inspection

Use the steps in Figure 1-2 as guidelines to perform initial inspection of the AFG.

WARNING

To avoid possible hazardous electrical shock, do not perform electrical tests if there are signs of shipping damage to the shipping container or to the instrument.

---

**Figure 1-2. Initial (Incoming) Inspection Guidelines**
Shipping Guidelines

Follow the steps in Figure 1-3 to return the AFG to a Hewlett-Packard Sales and Support Office or Service Center.

1. Prepare the module
   - Remove user wiring from terminal block
   - Attach tag to module that identifies:
     - Owner
     - Model Number/Serial Number
     - Service Required
   - Place tagged device in approved anti-static bag

2. Package the module
   - Place packaged module in shipping carton*
   - Place 75 to 100 mm (3 to 4 inches) of shock-absorbing material around the module
   - Seal the shipping container securely
   - Mark the shipping container FRAGILE

3. Ship the module to Hewlett-Packard
   - Place address label on shipping carton
   - Send carton to Hewlett-Packard

* We recommend that you use the same shipping materials as those used in factory packaging (available from Hewlett-Packard). For other (commercially-available) shipping materials, use a double-wall carton with minimum 2.4 MPa (350 psi) test.

Figure 1-3. Packaging/Shipping Guidelines
Environment

The recommended operating environment for the HP E1445A AFG is:

<table>
<thead>
<tr>
<th>Environment</th>
<th>Temperature</th>
<th>Humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating</td>
<td>0°C to +55°C</td>
<td>&lt;65% relative (0°C to +40°C)</td>
</tr>
<tr>
<td>Storage and</td>
<td>-40°C to +75°C</td>
<td>&lt;65% relative (0°C to +40°C)</td>
</tr>
<tr>
<td>Shipment</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

AFG Description

The HP E1445A Arbitrary Function Generator is a VXIbus C-size, message-based instrument. The AFG can operate in a C-size VXIbus mainframe using an HP E1405/E1406 Command Module and Standard Commands for Programmable Instruments (SCPI).

The AFG has 13 bits of resolution (including sign). It uses a sequencer architecture, with 256K points of Segment storage and 32K points of Sequence storage. The AFG has two internal timebases, 40 MHz and (approximately) 42.9 MHz.

AFG Specifications

AFG specifications are listed in Appendix A of the HP E1445A User's Manual. These specifications are the performance standards or limits against which the instrument may be tested.

AFG Options

Arbitrary Waveform Generation Software for HP 9000 Series 300 computers can be ordered as Option 005.

AFG Serial Numbers

Figure 1-4 shows Hewlett-Packard's serial number structure. AFG's covered by this manual are identified by a serial number prefix listed on the title page.

Hewlett-Packard Serial Numbers

<table>
<thead>
<tr>
<th>Serial Number Prefix</th>
<th>A</th>
<th>YYYY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identifies a series of identical instruments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Country of Origin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A = United States</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Serial Number Suffix</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assigned sequentially to each instrument</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 1-4. Hewlett-Packard Serial Numbers
**Recommended Test Equipment**

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

**Table 1-1. Recommended Test Equipment**

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Requirements</th>
<th>Recommended Model</th>
<th>Use*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controller, HP-IB</td>
<td>HP-IB compatibility as defined by IEEE</td>
<td>HP 9000 Series 300 or</td>
<td>F,O,P,</td>
</tr>
<tr>
<td></td>
<td>Standard 488-1988 and the identical</td>
<td>IBM Compatible PC with HP BASIC</td>
<td>A,T</td>
</tr>
<tr>
<td></td>
<td>ANSI Standard MC1.1: SH1, AH1, T2,</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TE0, L2, LEO, SR0, RL0, PP0, DC0, DTR0, and</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C1, 2, 3, 4, 5.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mainframe</td>
<td>Compatible with AFG</td>
<td>HP E1401B/T or E1421B</td>
<td>F,O,P,</td>
</tr>
<tr>
<td>Command Module</td>
<td>10 MHz CKN Out</td>
<td>HP E1405B or HP E1406A</td>
<td>A,T</td>
</tr>
<tr>
<td></td>
<td>TTL compatible Trig Out</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digital Multimeter</td>
<td>DCV, ACV, 4-wire ohms w/offset comp</td>
<td>HP 3458A</td>
<td>O,P,A</td>
</tr>
<tr>
<td>Power Meter</td>
<td>Frequency Range: 400 kHz - 10.8 MHz</td>
<td>HP 8902A</td>
<td>O,P,A</td>
</tr>
<tr>
<td>Power Sensor</td>
<td>Frequency Range: 400 kHz - 10.8 MHz</td>
<td>HP 11722A</td>
<td>O,P,A</td>
</tr>
<tr>
<td>Counter</td>
<td>Frequency Range: 100 Hz - 45 MHz</td>
<td>HP 5334A/B</td>
<td>O,P</td>
</tr>
<tr>
<td>Spectrum Analyzer</td>
<td>Frequency Range: 100 kHz - 150 MHz</td>
<td>HP 8566B</td>
<td>O,P,A</td>
</tr>
<tr>
<td>Oscilloscope</td>
<td>General Purpose Bandwidth: 20 MHz</td>
<td>HP 54111D</td>
<td>F</td>
</tr>
<tr>
<td>50 Ω feed-thru termination</td>
<td>50 ±0.10 Ω</td>
<td>HP 11048C</td>
<td>O,P,A</td>
</tr>
</tbody>
</table>

* F = Functional Verification, O = Operation Verification Tests, P = Performance Verification Tests, A = Adjustments, T = Troubleshooting
Chapter 2
Verification Tests

Introduction

The three levels of test procedures described in this chapter are used to verify that the HP E1445A:

- is fully 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 technician and have read the WARNINGS and CAUTIONS in Chapter 1.

Test Conditions/Procedures

See Table 1-1 for test equipment requirements. You should complete the Performance Verification tests at least once a year. For heavy use or severe operating environments, perform the tests more often.

Before performing these tests, allow the AFG to warm up for at least one hour. The temperature should be within ±5°C of Tcal (the temperature of the most recent calibration), and between 18°C and 28°C.

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

Performance Test Record

The results of each Performance Verification test may be recorded in Table 2-11, HP E1445A Performance Test Record. This form can be copied.

Verification Test Examples

Each verification test procedure includes an example program that performs the test. All example programs assume the following configuration:

- Controller is an HP 9000 Series 200/300 computer
- Programming language is HP BASIC
- AFG address is 70910
Command Coupling

Many of the AFG SCPI commands are value-coupled. In order to prevent "Settings Conflict" errors, coupled commands must be sent contiguously by placing them in the same program line, or by suppressing the end-of-line terminator. (For more information on command coupling and syntax, see Chapter 1 of the HP E1445A User's Manual). In HP BASIC, the end-of-line terminator can be suppressed by linking the commands with a semi-colon (;) and a colon (:), as illustrated below:

ROSC:SOUR INT1;
:TRIG:SOUR INT1

In the Example programs, these commands would appear as follows:

OUTPUT 70910,"ROSC:SOUR:INT1;";
OUTPUT 70910,"::TRIG:SOUR:INT1"

Functional Verification

The purpose of these tests is to verify that the AFG is functioning properly and that all front panel inputs and outputs are working. No attempt is made to verify that the AFG is meeting specifications. Functional Verification for the AFG includes the following tests:

- Self-Test
- Ref In/Marker Out Test
- Start Arm In Test
- Gate In Test
- Output Relay Test

NOTE

For a quick functional check of the AFG, perform only the Self-Test.

An example program that performs all of the Functional Verification tests is included at the end of this section. An HP E1405/E1406 Command Module is required for this program.

NOTE

Some of the tests use the "TRIG OUT" port of the Command Module. This port uses negative logic, i.e., the high voltage is a logical 0 and the low voltage is a logical 1.
Functional Verification: Self-Test

Description

The AFG self-test performs the following internal checks:

- internal interrupt lines
- waveform select RAM
- segment sequence RAM
- waveform segment RAM
- DDS/NCO operation
- sine wave generation
- arbitrary waveform generation
- marker generation
- waveform cycle and arm counters
- sweep timer
- frequency-shift keying
- stop trigger
- DC analog parameters (amplitude, offset, attenuators, filters, calibration DACs)

Test Procedure

1. Remove any connections to the AFG front panel.

2. Reset the AFG:

   "RST;*CLS

   Reset AFG and clear status registers"

3. Execute the AFG self-test:

   "TST?"

   Self-test command

4. Read the result. A "0" indicates that the test passed. A "1" indicates a failure. Read the error queue using the SYST:ERR? command until the error message is "No error".
Functional Verification: Ref In/Marker Out Test

Description

The purpose of this test is to check the Ref/Sample In and Marker Out ports. An external reference is connected to the Ref/Sample In port and sent to the Marker Out port.

Test Procedure

1. Reset the AFG:

*RST,*CLS  \(\text{Reset AFG and clear status registers}\)

2. Set up equipment as shown in Figure 2-1:

![Figure 2-1. Ref/Sample In Test Setup](image)

3. Set up the AFG to output the external reference to the "Marker Out" port:

ROSC:SOUR EXT
MARK:FEED "ROSC"
INIT:IMM  \(\text{External ref oscillator}
\text{Marker source is ROSC}
\text{Initiate}\)

4. Verify that the scope shows a 10 MHz squarewave.
Functional Verification: Start Arm In Test

Description

The purpose of this test is to check the Start Arm In port. The "TRIG OUT" port of the Command Module is used to send a Start Arm signal to the AFG.

Test Procedure

1. Reset the AFG:

   *RST, *CLS

   Reset AFG and clear status registers

2. Set up equipment as shown in Figure 2-2:

3. Send the following commands to the Command Module to output 0 V to the "Trig Out" port:

   *RST
   OUTP:EXT:STAT ON
   OUTP:EXT:SOUR INT
   OUTP:EXT:LEV 1

Figure 2-2. Start Arm In Test Setup
4. Set up the AFG to output a 1 MHz sine wave, with an external Start Arm source:

   FREQ 1E6;  
   VOLT 4VPP  
   ARM:LAY2:SOUR EXT  
   INIT:IMM

   Set freq to 1 MHz
   Set AFG amplitude
   External Start Arm source
   Initiate

5. Verify that no signal appears on the scope. Send the following command to the Command Module to provide a Start Arm signal to the AFG:

   OUTP:EXT:LEV 0

6. Verify that a 1 MHz sine wave appears on the scope.
Functional Verification: Gate In Test

Description

The purpose of this test is to check the gating function. The "TRIG OUT" port of the Command Module is used to gate the output.

Test Procedure

1. Reset the AFG:
   
   *RST;*CLS
   
   Reset AFG and clear status registers

2. Set up the equipment as shown in Figure 2-3.

3. Send the following commands to the Command Module to enable the "Trig Out" port:

   *RST
   OUTP:EXT:STAT ON
   OUTP:EXT:SOUR INT
Functional Verification: Gate In Test (cont'd)

Test Procedure (cont'd)

4. Set up the AFG to output a 1 MHz sinewave with an external gate source:

   TRIG:GATE:SOUR EXT;  
   :TRIG:GATE:STAT ON;  
   :FREQ 1E6;  
   :VOLT 4VPP  
   INIT:IMM  

   External gate source
   Enable gate
   Set freq to 1 MHz
   Set AFG amplitude
   Initiate

5. Send the following command to the Command Module to set the level at the "Trig Out" port to 5 V. Verify that the scope shows a 1 MHz sinewave.

   OUTP:EXT:LEV 0

6. Send the following command to the Command Module to set the level at the "Trig Out" port to 0 V. Verify that the scope shows a DC signal.

   OUTP:EXT:LEV 1
Functional Verification: Output Relay Test

Description

The purpose of this test is to check the output relay.

Test Procedure

1. Reset the AFG:

   *RST;*CLS

   Reset AFG and clear status registers

2. Set up equipment as shown in Figure 2-4:

![Diagram of test setup](image)

   Figure 2-4. Output Relay Test Setup

3. Set up the AFG to output a 1 MHz sinewave:

   FREQ 1E6;
   :VOLT 4VPP
   INIT:IMM

   Set freq to 1 MHz
   Set AFG amplitude
   Initiate

4. Verify that a 1 MHz sinewave appears on the scope.

5. Disable the Output relay:

   OUTP OFF

6. Verify that no signal appears on the scope.
Functional Verification

Example Program

This program performs the Functional Verification Tests for the AFG. An HP E1405/E1406 Command Module is required for this test.

```
10! RE-STORE "FUNC_TEST"
20   COM @Afg.@Cmd_mod,INTEGER Done
30
40 !-------- Set up I/O paths --------
50   ASSIGN @Afg TO 70910
60   ASSIGN @Cmd_mod TO 70900
70
80 !-------- Initialize AFG & Command Module --------
90   Reset_afg
100!
110 !Set up Command Module 'TRIG OUT' port
120   OUTPUT @Cmd_mod;"RST"
130   OUTPUT @Cmd_mod;"OUTP:EXT:STAT ON"
140   OUTPUT @Cmd_mod;"OUTP:EXT:SOUR INT"
150!
160 !-------- Perform tests --------
170   CLEAR SCREEN
180   PRINT "HP E1445A FUNCTIONAL VERIFICATION TESTS"
190   PRINT
200!
210 !Oscilloscope settings
220   PRINT "Set scope to: 2 V/div, .02 usec/div"
230   PRINT
240   Wait_for_cont
250!
250   CALL Self_test
270   CALL Ref_in
280!
290 !Oscilloscope settings
300   CLEAR SCREEN
310   PRINT "Set scope to: 2 V/div, .2 usec/div"
320   PRINT
330   Wait_for_cont
340!
350   CALL Start_arm
360   CALL Gate_in
370   CALL Output_relay
380!
390   Quit: !
400   Reset_afg
410   CLEAR SCREEN
420   DISP "Functional Tests completed."
430   END
```

(Continued on next page)
Functional Verification

Example Program (cont’d)

450 !-------- Subprograms --------
460 SUB Reset_afg
470 COM @Afg.@Cmd_mod,INTEGER Done
480 OUTPUT @Afg;"**RST;"CLS"
490 WAIT 1
500 SUBEND
510 !
520 SUB Self_test
530 COM @Afg.@Cmd_mod,INTEGER Done
540 DIM Message$[255]
550 !
560 Reset_afg
570 !
580 CLEAR SCREEN
590 PRINT "SELF-TEST"
600 PRINT
610 !
620 !Test connections
630 PRINT "Remove any connections from the E1445A front panel."
640 PRINT "Press 'Continue' to initiate Self-Test."
650 PRINT
660 Wait_for_cont
670 !
680 !Perform test
690 OUTPUT @Afg;"**TST?"
700 ENTER @Afg;Result
710 !
720 IF Result=0 THEN
730 PRINT "Self-test passed."
740 ELSE
750 PRINT "Self-test failed."
760 PRINT "The following error(s) occurred:"
770 REPEAT
780 OUTPUT @Afg;"SYST:ERR?"
790 ENTER @Afg;Message$
800 PRINT " &Message$
810 UNTIL POS(Message$,"No error")
820 END IF
830 Wait_for_cont
840 SUBEND
850 !
860 SUB Ref_in
870 COM @Afg.@Cmd_mod,INTEGER Done
880 !

(Continued on next page)
Functional Verification

Example Program (cont'd)

890   Reset_afg
900   !
910   CLEAR SCREEN
920   PRINT "REF IN/MARKER OUT TEST"
930   PRINT
940   !
950   !Test connections
960   PRINT "Connect Scope to 'Marker Out' on the E1445A."
970   PRINT "Connect Command Module 'Clk Out' to 'Ref/Sample In' on the E1445A."
980   PRINT
990   Wait_for_cont
1000  !
1010   !Perform test
1020   OUTPUT @Af{g};"ROSC:SOUR EXT" !External ref osc source
1030   OUTPUT @Af{g};"MARK:FEED ""ROSC""
1040   OUTPUT @Af{g};"INIT:IMM" !Initiate
1050  !
1060   PRINT "Verify that the scope shows a 10 MHz squarewave."
1070   Wait_for_cont
1080   SUBEND
1090  !
1100  SUB Start_arm
1110   COM @Af{g};@Cmd_mod;INTEGER Done
1120  !
1130   Reset_afg
1140  !
1150   CLEAR SCREEN
1160   PRINT "START ARM TEST"
1170   PRINT
1180  !
1190   !Test connections
1200   PRINT "Connect Scope to the E1445A Output."
1210   PRINT "Connect Command Module 'Trig Out' to 'Start Arm In' on the E1445A."
1220   PRINT
1230   Wait_for_cont
1240  !
1250   !Set Command Module's 'TRIG OUT' to 0V (E1445 uses neg logic)
1260   OUTPUT @Cmd_mod;"OUTP:EXT:LEV 1"
1270  !
1280   !Perform test
1290   OUTPUT @Af{g};"FREQ 1E6;" !Set freq to 1 MHz
1300   OUTPUT @Af{g};"VOLT 4VPP"
1310   OUTPUT @Af{g};"ARM:LAY2:SOUR EXT" !Start Arm source is EXT
1320   OUTPUT @Af{g};"INIT:IMM" !Initiate
1330  !

(Continued on next page)
Functional Verification

Example Program (cont'd)

```
1340 PRINT "Verify that no signal appears on the scope."
1350 PRINT "Press 'Continue' to send a START ARM."
1360 PRINT
1370 Wait_for_cont
1380 !
1390 !Set 'TRIG OUT' to 5V
1400 OUTPUT @Cmd_mod;"OUTP:EXT:LEV 0"
1410 !
1420 PRINT "Verify that the scope shows a 1 MHz sinewave."
1430 Wait_for_cont
1440 SUBEND
1450 !
1460 SUB Gate_in
1470 COM @Afg,@Cmd_mod;INTEGER Done
1480 !
1490 Reset_afg
1500 !
1510 CLEAR SCREEN
1520 PRINT "GATE IN TEST"
1530 PRINT
1540 !
1550 !Test connections
1560 PRINT "Connect Scope to the E1445A Output."
1570 PRINT "Connect Command Module 'Trig Out' to 'Stop Trig/FSK/Gate In' on the E1445A."
1580 PRINT
1590 Wait_for_cont
1600 !
1610 !Perform test
1620 OUTPUT @Afg;"TRIG:GATE:SOUR EXT;"; !Gate source is EXT
1630 OUTPUT @Afg;"TRIG:GATE:STAT ON;"; !Enable gate
1640 OUTPUT @Afg;"FREQ 1E6;"; !Set freq to 1 MHz
1650 OUTPUT @Afg;"VOLT 4VPP" !Set amplitude
1660 OUTPUT @Afg;"INIT:IMM" !Initiate
1670 !
1680 PRINT "Verify that the signal displayed on the scope toggles between"
1690 PRINT "a 1 MHz sinewave and a DC signal at 1 second intervals."
1700 !
1710 ON KBD ALL CALL Key_press
1720 DISP "Press any key to continue"
1730 !
1740 Done=0
1750 !Send pulses to 'TRIG OUT' BNC until a key is pressed

(Continued on next page)
Functional Verification

Example Program (cont'd)

1790  REPEAT
1770  OUTPUT @Cmd_mod;"OUTP:EXT:LEV 1"
1780  WAIT 1
1790  OUTPUT @Cmd_mod;"OUTP:EXT:LEV 0"
1800  WAIT 1
1810  UNTIL Done
1820  OFF KBD
1830  SUBEND
1840  !
1850  SUB Output Relay
1860  COM @Afg, @Cmd_mod, INTEGER Done
1870  !
1880  Reset_afg
1890  !
1900  CLEAR SCREEN
1910  PRINT "OUTPUT RELAY TEST"
1920  PRINT
1930  !
1940  "Test connections"
1950  PRINT "Connect Scope to the E1445A Output."
1960  PRINT
1970  Wait_for_cont
1980  !
1990  "Perform test"
2000  OUTPUT @Afg;"FREQ 1E6;",
2010  OUTPUT @Afg;"VOLT 4VPP"
2020  OUTPUT @Afg;"INIT;IMM"
2030  !
2040  PRINT "Verify that the scope shows a 1 MHz sinewave."
2050  PRINT "Press 'Continue' to disable the E1445A output."
2060  PRINT
2070  Wait_for_cont
2080  !
2090  OUTPUT @Afg;"OUTP OFF"
2100  PRINT "Verify that no signal appears on the scope."
2110  Wait_for_cont
2120  SUBEND
2130  !

(Continued on next page)
Functional Verification

Example Program (cont'd)

```
2140  SUB Key_press
2150  COM @Afg.@Cmd_mod,INTEGER Done
2160  Done=1
2170  DISP
2180  SUBEND
2190  !
2200  SUB Wait_for_cont
2210  DISP "Press 'Continue' when ready"
2220  PAUSE
2230  DISP
2240  SUBEND
```
Operation Verification

Operation Verification is a subset of the Performance Verification tests that follow. For the AFG, Operation Verification consists of the following tests:

- DC Accuracy
- AC Accuracy
- Total Harmonic Distortion

Performance Verification

The procedures in this section are used to test the AFG’s electrical performance using the specifications in Appendix A of the *HP E1445A User’s Manual* as the performance standards. These tests are suitable for incoming inspection, troubleshooting, and preventive maintenance. The results of the Performance Verification tests should be recorded in the Performance Test Record (Table 2-11).

Performance Verification includes the following tests:

<table>
<thead>
<tr>
<th>Test #</th>
<th>Test Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-1</td>
<td>DC Zeros</td>
</tr>
<tr>
<td>2-2</td>
<td>DC Accuracy</td>
</tr>
<tr>
<td>2-3</td>
<td>DC Offset</td>
</tr>
<tr>
<td>2-4</td>
<td>AC Accuracy</td>
</tr>
<tr>
<td>2-5</td>
<td>AC Flatness - 250 kHz filter</td>
</tr>
<tr>
<td>2-6</td>
<td>AC Flatness - 10 MHz filter</td>
</tr>
<tr>
<td>2-7</td>
<td>Frequency Accuracy</td>
</tr>
<tr>
<td>2-8</td>
<td>Duty Cycle</td>
</tr>
<tr>
<td>2-9</td>
<td>Total Harmonic Distortion</td>
</tr>
<tr>
<td>2-10</td>
<td>Spurious/Non-harmonic Distortion</td>
</tr>
</tbody>
</table>
Test 2-1: DC Zeros

Description

The purpose of this test is to verify that the AFG meets its specifications for DCV accuracy for an output of zero volts. An arbitrary waveform consisting of zeros is used. The amplitude is varied in order to test each attenuator.

Equipment Setup

- Connect equipment as shown in Figure 2-5
- Set DMM to: DCV, 100 mV range

![Equipment Setup Diagram]

Figure 2-5. Equipment Setup for Test 2-1 thru Test 2-4

Test Procedure

1. Reset the AFG:

   "RST;"*CLS

   Reset AFG and clear status registers

2. Delete all sequences and segments from memory:

   LIST:SSEQ:DEL:ALL
   LIST:SEG:DEL:ALL

   Delete all sequences
   Delete all segments
Test 2-1: DC Zeros (cont'd)

Test Procedure (cont'd)

3. Create a user-defined waveform made up of zeros:

```
LIST:SEGMENT:SEL ZEROS
LIST:SEGMENT:DEF 8
LIST:SEGMENT:VOLT 0,0,0,0,0,0,0,0
LIST:SSEQ:SEL:DC_ZEROS
LIST:SSEQ:DEF 1
LIST:SSEQ:SEQ ZEROS
```

4. Set up the AFG to output the waveform defined above:

```
ROSC:SOUR CLK10;
:VOLT MAX;
:OUTP:LOAD INF;
:FUNC USER
FUNC:USER DC_ZEROS
INIT:IMM
```

**Perform steps 5 - 7 for each amplitude listed in Table 2-1:**

5. Set the AFG output filter as specified in Table 2-1. Use the appropriate command(s) below:

```
OUTP:FILT OFF
or
OUTP:FILT:FREQ 250KHZ
OUTP:FILT ON
or
OUTP:FILT:FREQ 10MHZ
OUTP:FILT ON
```

6. Set the AFG output amplitude:

```
VOLT <amplitude>
```

where `<amplitude>` is the value specified in Table 2-1.

7. Trigger the DMM and record the reading in Table 2-11.
Test 2-1: DC Zeros (cont’d)

Test Procedure
(cont’d)

Table 2-1. DC Zeros Test Points

<table>
<thead>
<tr>
<th>Attenuation (dB)</th>
<th>Amplitude (volts)</th>
<th>Filter</th>
<th>Test Limits (volts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10.23750</td>
<td>None</td>
<td>0 ± 0.0220</td>
</tr>
<tr>
<td>.99</td>
<td>9.13469</td>
<td>None</td>
<td>0 ± 0.0220</td>
</tr>
<tr>
<td>1</td>
<td>9.12416</td>
<td>None</td>
<td>0 ± 0.0220</td>
</tr>
<tr>
<td>2</td>
<td>8.13192</td>
<td>None</td>
<td>0 ± 0.0220</td>
</tr>
<tr>
<td>4</td>
<td>6.45941</td>
<td>None</td>
<td>0 ± 0.0220</td>
</tr>
<tr>
<td>8</td>
<td>4.07560</td>
<td>None</td>
<td>0 ± 0.0220</td>
</tr>
<tr>
<td>13</td>
<td>2.29187</td>
<td>None</td>
<td>0 ± 0.0220</td>
</tr>
<tr>
<td>14</td>
<td>2.04263</td>
<td>None</td>
<td>0 ± 0.0044</td>
</tr>
<tr>
<td>30</td>
<td>0.32372</td>
<td>None</td>
<td>0 ± 0.0044</td>
</tr>
<tr>
<td>0</td>
<td>10.23750</td>
<td>250 kHz</td>
<td>0 ± 0.0220</td>
</tr>
<tr>
<td>.99</td>
<td>9.13469</td>
<td>250 kHz</td>
<td>0 ± 0.0220</td>
</tr>
<tr>
<td>1</td>
<td>9.12416</td>
<td>250 kHz</td>
<td>0 ± 0.0220</td>
</tr>
<tr>
<td>2</td>
<td>8.13192</td>
<td>250 kHz</td>
<td>0 ± 0.0220</td>
</tr>
<tr>
<td>4</td>
<td>6.45941</td>
<td>250 kHz</td>
<td>0 ± 0.0220</td>
</tr>
<tr>
<td>8</td>
<td>4.07560</td>
<td>250 kHz</td>
<td>0 ± 0.0220</td>
</tr>
<tr>
<td>13</td>
<td>2.29187</td>
<td>250 kHz</td>
<td>0 ± 0.0220</td>
</tr>
<tr>
<td>14</td>
<td>2.04263</td>
<td>250 kHz</td>
<td>0 ± 0.0044</td>
</tr>
<tr>
<td>30</td>
<td>0.32372</td>
<td>250 kHz</td>
<td>0 ± 0.0044</td>
</tr>
<tr>
<td>0</td>
<td>10.23750</td>
<td>10 MHz</td>
<td>0 ± 0.0220</td>
</tr>
<tr>
<td>.99</td>
<td>9.13469</td>
<td>10 MHz</td>
<td>0 ± 0.0220</td>
</tr>
<tr>
<td>1</td>
<td>9.12416</td>
<td>10 MHz</td>
<td>0 ± 0.0220</td>
</tr>
<tr>
<td>2</td>
<td>8.13192</td>
<td>10 MHz</td>
<td>0 ± 0.0220</td>
</tr>
<tr>
<td>4</td>
<td>6.45941</td>
<td>10 MHz</td>
<td>0 ± 0.0220</td>
</tr>
<tr>
<td>8</td>
<td>4.07560</td>
<td>10 MHz</td>
<td>0 ± 0.0220</td>
</tr>
<tr>
<td>13</td>
<td>2.29187</td>
<td>10 MHz</td>
<td>0 ± 0.0220</td>
</tr>
<tr>
<td>14</td>
<td>2.04263</td>
<td>10 MHz</td>
<td>0 ± 0.0044</td>
</tr>
<tr>
<td>30</td>
<td>0.32372</td>
<td>10 MHz</td>
<td>0 ± 0.0044</td>
</tr>
</tbody>
</table>
Example Program

This program performs the DC Zeros test. An arbitrary waveform, consisting of zeros, is used with various amplitudes to test a variety of attenuator and filter combinations.

```
101 RE-STORE "DC_ZEROS"
20  COM @Afg
30  DIM Attn(1:9),Vout(1:9)
40  !
50 !------ Set up I/O path and reset AFG -------
60  ASSIGN @Afg TO 70910
70  OUTPUT @Afg,"**RST;**CLS"  !Reset AFG
80  !
90 !------ Initialize variables -------
100  DATA 0.99,1,2,4,8,13,14,30
110  READ Attn(*)
120  !Read in attenuations
130  DATA 10.2375,9.13469,9.12418,8.813192,6.45941,4.0756
140  DATA 2.29187,2.04263,0.32372
150  READ Vout(*)
160  !
170 !------ Set up DMM ------
180  PRINT "Set up DMM;"
190  PRINT "Function -- DCV"
210  PRINT "Range -- 100 mV"
220  PRINT "Connect DMM HI and LO to AFG Output."
240  DISP "Press 'Continue' when ready"
250  PAUSE
260  CLEAR SCREEN
270  !
280 !------ Set up AFG -------
290  OUTPUT @Afg,"**RST"
300  OUTPUT @Afg,"LIST:SSEQ:DEL:ALL"  !Delete all sequences
310  OUTPUT @Afg,"LIST:SEGM:DEL:ALL"  !Delete all segments
320  WAIT .5
330  OUTPUT @Afg,"ROSC:SOUR CLK10;";  !10MHz clock
340  OUTPUT @Afg,"VOLT MAX;"
350  OUTPUT @Afg,"OUTP:LOAD INF;";  !Infinite load
360  OUTPUT @Afg,"FUNC USER"  !User waveform
370  !
380  CALL Def_seq_zeros  !Define waveform
390  OUTPUT @Afg,"FUNC:USER DC_ZEROS"
400  OUTPUT @Afg,"INIT:IMM"
410  !
420 !------ Perform test -------
430  PRINT "ATTEN","FILTER","AMPLITUDE"

(Continued on next page)
```
Test 2-1: DC Zeros (cont’d)

Example Program (cont’d)

```
440 PRINT
460 FOR Filter=0 TO 2
470   SELECT Filter
480   CASE 0 !No filter
490     OUTPUT @Afg:"OUTP: FILT OFF"
500     Filter$="NONE"
510   CASE 1 !250KHZ filter
520     OUTPUT @Afg:"OUTP: FILT:FREQ 250KHZ"
530     OUTPUT @Afg:"OUTP: FILT ON"
540     Filter$="250 kHz"
550   CASE 2 !10MHZ filter
560     OUTPUT @Afg:"OUTP: FILT:FREQ 10MHZ"
570     OUTPUT @Afg:"OUTP: FILT ON"
580     Filter$="10 MHz"
590   END SELECT
600 !
610 FOR l=1 TO 9 !Loop through atten's
620     OUTPUT @Afg: ":VOLT ":VAL$(Vout(l)) !Set AFG amplitude
630     PRINT Attn(l),Filter$;Vout(l)
640 !
650 DISP "Record DMM reading, then press 'Continue'"
660 PAUSE
670 DISP
680 NEXT l !Next attenuation
690 PRINT
700 NEXT Filter !Next filter
710 !
720 OUTPUT @Afg: "RST;*CLS" !Reset AFG
730 END
740 !
750 SUB Def_seq_zeros
760   COM @Afg
770   OUTPUT @Afg:"LIST:SEG:MSEL ZEROS" !Segment name
780   OUTPUT @Afg:"LIST:SEG:DEF 8" !Segment length
790   OUTPUT @Afg:"LIST:SEG:MSEL VOLT 0,0,0,0,0,0,0,0,0,0,0" !Voltage points
800 !
810 OUTPUT @Afg:"LIST:SEQ:MSEL DC_ZEROS" !Sequence name
820 OUTPUT @Afg:"LIST:SEQ:DEF 1" # of segments
830 OUTPUT @Afg:"LIST:SEQ:SEQ ZEROS" !Segment list
840 SUBEND
```
Test 2-2: DC Accuracy

Description

The purpose of this test is to verify that the AFG meets its specifications for DC accuracy.

Equipment Setup

- Connect equipment as shown in Figure 2-5
- Set DMM to DCV, autorange

Test Procedure

1. Reset the AFG:

   *RST;*CLS

   Reset AFG and clear status registers

2. Set up the AFG to output a DC signal:

   FUNC DC;
   :OUTP:LOAD INF;
   :VOLT MAX

   Select DC waveform
   Infinite load
   Set amplitude

Perform steps 3 - 5 for each amplitude listed in Table 2-2:

3. Set up the AFG output filter as specified in Table 2-2. Use the appropriate command(s) below:

   OUTP:FLT OFF
   or
   OUTP:FLT:FREQ 250KHZ
   OUTP:FLT ON
   or
   OUTP:FLT:FREQ 10MHZ
   OUTP:FLT ON

   Disable filter
   Select 250 kHz filter
   Enable filter
   Select 10 MHz filter
   Enable filter

4. Set the AFG output amplitude:

   VOLT <amplitude>

   Set amplitude

   where <amplitude> is the value specified in Table 2-2.

5. Trigger the DMM and record the reading.
Test 2-2: DC Accuracy (cont’d)

Test Procedure (cont’d)

Table 2-2. DC Accuracy Test Points

<table>
<thead>
<tr>
<th>Amplitude (volts)</th>
<th>Filter</th>
<th>Test Limits (volts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.2375</td>
<td>None</td>
<td>10.2375 ± 0.0512</td>
</tr>
<tr>
<td>5.0</td>
<td>None</td>
<td>5.0 ± 0.0355</td>
</tr>
<tr>
<td>0.0</td>
<td>None</td>
<td>0.0 ± 0.0205</td>
</tr>
<tr>
<td>-5.0</td>
<td>None</td>
<td>-5.0 ± 0.0355</td>
</tr>
<tr>
<td>-10.24</td>
<td>None</td>
<td>-10.24 ± 0.0512</td>
</tr>
<tr>
<td>10.2375</td>
<td>250 kHz</td>
<td>10.2375 ± 0.0512</td>
</tr>
<tr>
<td>-10.24</td>
<td>250 kHz</td>
<td>-10.24 ± 0.0512</td>
</tr>
<tr>
<td>10.2375</td>
<td>10 MHz</td>
<td>10.2375 ± 0.0512</td>
</tr>
<tr>
<td>-10.24</td>
<td>10 MHz</td>
<td>10.24 ± 0.0512</td>
</tr>
</tbody>
</table>

Example Program

This program performs the DC Accuracy test.

```
10! RE-STORE "DC_LEVELS"
20 DIM Vout(1:9),Filter(1:9)
30 !
40 ----- Set up I/O path and reset AFG -----!
50 ASSIGN @AfG TO 70910
60 OUTPUT @AfG,""RST,"CLS" "Reset AFG"
70 !
80 ----- Initialize variables -----!
90 DATA 10.2375,5.0,0,-5.0,-10.24,10.2375,-10.24,10.2375,-10.24
100 READ Vout(*)
110 !
120 DATA 0,0,0,0,0,1,1,2,2
130 READ Filter(*)
140 !
150 ----- Set up DMM -----!
160 CLEAR SCREEN
170 PRINT "Set up DMM;"
180 PRINT
190 PRINT " Function – DCV"
200 PRINT " Range – AUTO"
210 PRINT
220 PRINT "Connect DMM HI and LO to AFG Output;" 
230 DISP "Press 'Continue' when ready"
240 PAUSE
250 CLEAR SCREEN

(Continued on next page)
```
Test 2-2: DC Accuracy (cont'd)

Example Program (cont'd)

```
270  !-------- Set up AFG --------!
280  OUTPUT @Afg;"**RST"          !Reset AFG
290  WAIT .5
300  OUTPUT @Afg;"FUNC DC;";       !DC function
310  OUTPUT @Afg;"OUTP:LOAD INF;"; !Infinite load
320  OUTPUT @Afg;"VOLT MAX"        !MAX output
330  !
340  !-------- Perform test --------!
350  PRINT "FILTER","AMPLITUDE"
360  PRINT
370  !
380  FOR I=1 TO 9
390     SELECT Filter(I)
400     CASE 0
410         OUTPUT @Afg;"OUTP:FILT OFF" !No filter
420         Filter$="NONE"
430     CASE 1
440         OUTPUT @Afg;"OUTP:FILT:FREQ 250KHZ" !250kHz filter
450         OUTPUT @Afg;"OUTP:FILT ON"
460         Filter$="250 kHz"
470     CASE 2
480         OUTPUT @Afg;"OUTP:FILT:FREQ 10MHZ" !10MHz filter
490         OUTPUT @Afg;"OUTP:FILT ON"
500         Filter$="10 MHz"
510     END SELECT
520  !
530  OUTPUT @Afg;"VOLT "&VAL$(Vout(I)) !Set amplitude
540  PRINT Filter$,Vout(I)
550  !
560  DISP "Record DMM reading, then press 'Continue'"
570  PAUSE
580  DISP
590  NEXT I
600  !
610  OUTPUT @Afg;"**RST;*CLS"        !Reset AFG
620  END
```
Test 2-3: DC Offset

Description

The purpose of this test is to verify that the AFG meets its specifications for DC offset accuracy.

Equipment Setup

- Connect equipment as shown in Figure 2-5
- Set DMM to DCV, autorange

Test Procedure

1. Reset the AFG:

   "RST;";"CLS

   \textit{Reset AFG and clear status registers}

2. Delete all sequences and segments from memory:

   \texttt{LIST:SSEQ:DEL:ALL}

   \texttt{LIST:SEGM:DEL:ALL}

   \textit{Delete all sequences}

   \textit{Delete all segments}

3. Create a user-defined waveform made up of zeros:

   \texttt{LIST:SEGM:SEL ZEROS}

   \texttt{LIST:SEGM:DEF 8}

   \texttt{LIST:SEGM:VOLT 0,0,0,0,0,0,0,0}

   \texttt{LIST:SSEQ:SEL DC_ZEROS}

   \texttt{LIST:SSEQ:DEF 1}

   \texttt{LIST:SSEQ:SEQ ZEROS}

   \textit{Select segment name}

   \textit{# of segment points}

   \textit{Segment list}

   \textit{Select sequence name}

   \textit{# of segments}

   \textit{Sequence list}

4. Set up the AFG to output the waveform defined above:

   \texttt{ROSC:SOUR CLK10;}

   \texttt{:OUTP:LOAD INF;}

   \texttt{:VOLT MAX;}

   \texttt{:FUNC USER}

   \texttt{FUNC:USER DC_ZEROS}

   \texttt{INIT:IMM}

   \textit{Select 10 MHz clock}

   \textit{Infinite load}

   \textit{Set amplitude}

   \textit{Select user waveform}

   \textit{Select sequence}

   \textit{Initiate waveform}
Test Procedure (cont'd)

Perform steps 5 - 7 for each offset listed in Table 2-3:

5. If necessary, change the AFG output amplitude:

\[
\text{VOLT:OFFS 0; Set offset to 0}
\]

\[
:\text{VOLT <amplitude>; Set amplitude}
\]

where \(<\text{amplitude}>\) is the value specified in Table 2-3.

6. Set AFG offset voltage:

\[
\text{VOLT:OFFS <offset>; Set offset}
\]

where \(<\text{offset}>\) is the value specified in Table 2-3.

7. Trigger the DMM and record the reading.

### Table 2-3. DC Offset Test Points

<table>
<thead>
<tr>
<th>Offset (volts)</th>
<th>Amplitude (volts)</th>
<th>Test Limits (volts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.755</td>
<td>2.29189</td>
<td>9.755 ± 0.1196</td>
</tr>
<tr>
<td>4.000</td>
<td>2.29189</td>
<td>4.0 ± 0.0620</td>
</tr>
<tr>
<td>-4.000</td>
<td>2.29189</td>
<td>-4.0 ± 0.0620</td>
</tr>
<tr>
<td>-9.755</td>
<td>2.29189</td>
<td>-9.755 ± 0.1196</td>
</tr>
<tr>
<td>2.000</td>
<td>0.40756</td>
<td>2.0 ± 0.0244</td>
</tr>
<tr>
<td>-2.000</td>
<td>0.40756</td>
<td>-2.0 ± 0.0244</td>
</tr>
</tbody>
</table>
Test 2-3: DC Offset (cont'd)

Example Program

This program performs the DC Offset Test.

```
10! RE-STORE "DC_OFFSET"
20 COM @Afg
30 DIM offset(1:6)
40 !
50 !------ Set up I/O path and reset AFG ------
60 ASSIGN @Afg TO 70910 ! AFG I/O path
70 OUTPUT @Afg," RST,"CLS" ! Reset AFG
80 !
90 !------ Initialize variables ------
100 DATA 8.755,4.0,-4.0,-9.755,2.0,-2.0 ! Read in offsets
110 READ Offset(*)
120 !
130 Vout_old=0 ! Initialize
140 !
150 !------ Set up DMM ------
160 CLEAR SCREEN
170 PRINT "Set up DMM:",
180 PRINT
190 PRINT " Function -- DCV"
200 PRINT " Range -- AUTO"
210 PRINT
220 PRINT "Connect DMM Hi and LO to AFG Output."
230 DISP "Press 'Continue' when ready"
240 PAUSE
250 CLEAR SCREEN
260 !
270 !------ Set up AFG ------
280 OUTPUT @Afg," RST" ! Reset AFG
290 OUTPUT @Afg,"LIST:SSEQ:DEL:ALL" ! Delete all sequences
300 OUTPUT @Afg,"LIST:SEG:DEL:ALL" ! Delete all segments
310 WAIT .5
320 OUTPUT @Afg,"ROSC:SOUR CLK10;" ! 10MHz clock
330 OUTPUT @Afg,"OUTP:LOAD INF;" ! Infinite load
340 OUTPUT @Afg,"VOLT MAX;" ! MAX output
350 OUTPUT @Afg,"FUNC USER" ! User waveform
360 !
370 CALL Def_seq_zeros ! Define sequence of zeros
380 OUTPUT @Afg,"FUNC:USER DC_ZEROS" ! Select sequence
390 !
400 !------ Perform test ------
410 PRINT "AMPLITUDE"," OFFSET"
420 PRINT
430 !
```

(Continued on next page)
Example Program (cont’d)

```plaintext
440 FOR i=1 TO 6
450 IF i<=4 THEN
460 Vout=2.2819
470 ELSE
480 Vout=.40756
490 END IF
500 !
510 IF Vout>Vout_old THEN
520 !Set offset to zero before changing amplitude
530 OUTPUT @Afg;"VOLT:OFFS 0;"
540 OUTPUT @Afg;"VOLT &VAL$(Vout)&";
550 END IF
560 !
570 OUTPUT @Afg;"VOLT:OFFS &VAL$(Offset(i));Set offset
580 PRINT Vout,Offset(i)
590 !
600 DISP "Record DMM reading, then press 'Continue'"
610 PAUSE
620 DISP
630 Vout_old=Vout
640 NEXT i !Next attenuation
650 !
660 OUTPUT @Afg;"RST;CLS"
670 !Reset AFG
680 !
690 SUB Def_seq_zeros
700 COM @Afg
710 OUTPUT @Afg;"LIST:SEGMENT:SEL ZEROS"
720 OUTPUT @Afg;"LIST:SEGMENT:DEF 8"
730 OUTPUT @Afg;"LIST:SEGMENT:VOLT 0,0,0,0,0,0,0,0"
740 !
750 OUTPUT @Afg;"LIST:SEQ:SEL DC ZEROS" !Sequence name
760 OUTPUT @Afg;"LIST:SEQ:DEF 1" !# of segments
770 OUTPUT @Afg;"LIST:SEQ:SEQ ZEROS" !Segment list
780 SUBEND
```
Test 2-4: AC Accuracy

Description

The purpose of this test is to verify that the AFG meets its specifications for AC accuracy at 1 kHz.

Equipment Setup

- Connect equipment as shown in Figure 2-5
- Set DMM to ACV, autorange

Test Procedure

1. Reset the AFG:

  *RST;*CLS

  *Reset AFG and clear status registers*

2. Set up the AFG to output a 1 kHz sinewave:

  FREQ 1E3;
  :VOLT MAX;
  :OUTP:LOAD INF
  CAL:STAT:AC OFF
  INIT:IMM

  *Set freq to 1 kHz
  Set to max amplitude
  Infinite load
  AC corrections off
  Initiate waveform*

*Perform steps 3 - 5 for each amplitude and filter listed in Table 2-4:*

3. Set up AFG output filter as specified in Table 2-4. Use the appropriate command(s) below:

  OUTP:FILT OFF
  or
  OUTP:FILT:FREQ 250KHZ
  OUTP:FILT ON
  or
  OUTP:FILT:FREQ 10MHZ
  OUTP:FILT ON

  *Disable filter
  Select 250 kHz filter
  Enable filter
  Select 10 MHz filter
  Enable filter*
Test 2-4: AC Accuracy (cont'd)

Test Procedure (cont'd)

4. Set the AFG output amplitude:

\[ \text{VOLT } <\text{amplitude}> \text{VRMS} \quad \text{Set amplitude} \]

where \(<\text{amplitude}>\) is the value specified in Table 2-4.

5. Trigger the DMM and record the reading.

Table 2-4. AC Accuracy Test Points

<table>
<thead>
<tr>
<th>Amplitude (volts rms)</th>
<th>Filter</th>
<th>Test Limits ±(dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.2390</td>
<td>None</td>
<td>0.10</td>
</tr>
<tr>
<td>6.4500</td>
<td>None</td>
<td>0.15</td>
</tr>
<tr>
<td>5.7500</td>
<td>None</td>
<td>0.15</td>
</tr>
<tr>
<td>4.5660</td>
<td>None</td>
<td>0.15</td>
</tr>
<tr>
<td>2.8818</td>
<td>None</td>
<td>0.15</td>
</tr>
<tr>
<td>1.4444</td>
<td>None</td>
<td>0.15</td>
</tr>
<tr>
<td>0.2290</td>
<td>None</td>
<td>0.15</td>
</tr>
<tr>
<td>7.2390</td>
<td>250 kHz</td>
<td>0.10</td>
</tr>
<tr>
<td>7.2390</td>
<td>10 MHz</td>
<td>0.10</td>
</tr>
</tbody>
</table>
Test 2-4: AC Accuracy (cont’d)

Example Program

This program performs the AC Accuracy Test.

```plaintext
10! RE-STORE "AC_LEVELS"
20 DIM Vout(1:9),Filter(1:9)
30 !
40 !------- Set up I/O path and reset AFG -------
50 ASSIGN @Afg TO 70910
60 OUTPUT @Afg,"RST;"CLS"* !Reset AFG
70 !
80 !------- Initialize variables -------
90 DATA 7.239,6.45,5.75,4.565,2.8818,1.4444,.229,7.239,7.239
100 READ Vout(*)
110 !
120 DATA 0,0,0,0,0,0,0,1,2
130 READ Filter(*)
140 !
150 !------- Set up DMM -------
160 CLEAR SCREEN
170 PRINT "Set up DMM:" 
180 PRINT
190 PRINT " Function -- ACV"
200 PRINT " Range -- AUTO"
210 PRINT
220 PRINT "Connect DMM HI and LO to AFG Output."
230 DISP "Press 'Continue' when ready"
240 PAUSE
250 CLEAR SCREEN
260 !
270 !------- Set up AFG -------
280 OUTPUT @Afg;"RST"* !Reset AFG
290 WAIT .5
300 OUTPUT @Afg;"FREQ 1E3;"* !Set freq to 1 kHz
310 OUTPUT @Afg;"VOLT MAX;"* !MAX amplitude
320 OUTPUT @Afg;"OUTP:LOAD INF"* !Infinite load
340 OUTPUT @Afg;"CAL:STAT:AC OFF"* !AC corrections off
350 OUTPUT @Afg;"INIT:IMM"* !Initiate
360 WAIT .5
370 !
380 !------- Perform test -------
390 PRINT "FILTER","AMPLITUDE"
400 PRINT
410 !
```

(Continued on next page)
Test 2-4: AC Accuracy (cont’d)

Example Program (cont’d)

```
420 FOR I = 1 TO 9
430 SELECT Filter(I)
440 CASE 0
450 OUTPUT @Afg:"OUTP: FILT OFF" ! No filter
460 Filter$ = "NONE"
470 CASE 1
480 OUTPUT @Afg:"OUTP: FILT: FREQ 250KHZ" ! 250 kHz filter
490 OUTPUT @Afg:"OUTP: FILT ON"
500 Filter$ = "250 kHz"
510 CASE 2
520 OUTPUT @Afg:"OUTP: FILT: FREQ 10MHZ" ! 10 MHz filter
530 OUTPUT @Afg:"OUTP: FILT ON"
540 Filter$ = "10 MHz"
550 END SELECT
560 OUTPUT @Afg: ":VOLT ":VAL$(Vout(I)) ":VRMS" ! Set amplitude
570 PRINT Filter$, Vout(I)
580 WAIT .5
590 
600 DISP "Record DMM reading, then press 'Continue'"
610 PAUSE
620 DISP
630 NEXT I
640 
650 OUTPUT @Afg:"RST; "CLS" ! Reset AFG
660 END
```
Test 2-5: AC Flatness - 250 kHz Filter

Description

The purpose of this test is to verify that the AFG meets its specifications for AC flatness with the 250 kHz filter enabled.

Equipment Setup

- Connect equipment as shown in Figure 2-6
- Set DMM to ACV, autorange

![Equipment Setup Diagram]

Figure 2-6. Equipment Setup for Test 2-5 and Test 2-6

Test Procedure

1. Reset the AFG:

   *RST;*CLS

   Reset AFG and clear status registers

2. Set up the AFG to output a 24 dBm sinewave with the 250 kHz filter enabled:

   VOLT 24DBM;
   :OUTP:LOAD 50
   OUTP:FILTER:FREQ 250KHZ
   OUTP:FILTER ON
   INIT:IMM

   Set amplitude
   50 ohm load
   250 kHz filter
   Enable filter
   Initiate waveform
Test 2-5: AC Flatness - 250 kHz Filter (cont'd)

Test Procedure (cont'd)

3. Set the AFG output to the reference frequency (1 kHz):

   FREQ 1000

   *Set frequency*

4. Measure the amplitude with the DMM and convert the reading to dBm. Note the result for use in step 6:

   Reference Level (dBm) = 20 × log|Reading (volts)| + 13.0103

   *Perform steps 5 - 6 for each frequency listed in Table 2-5:*

5. Set the AFG output:

   FREQ <frequency>

   *Set frequency*

   where <frequency> is the value specified in Table 2-5.

6. Measure the amplitude with the DMM and convert the reading to dBm. Calculate and record the error relative to the reference level calculated in step 4:

   Reading (dBm) = 20 × log|Reading (volts)| + 13.0103

   Error (dB) = Reading (dBm) - Reference Level (dBm)
Test 2-5: AC Flatness - 250 kHz Filter (cont’d)

Test Procedure (cont’d)

Table 2-5. AC Flatness Test Points - 250 kHz Filter

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Test Limits* ±(dB error)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10E3</td>
<td>0.05 dB</td>
</tr>
<tr>
<td>20E3</td>
<td>0.05 dB</td>
</tr>
<tr>
<td>30E3</td>
<td>0.05 dB</td>
</tr>
<tr>
<td>40E3</td>
<td>0.05 dB</td>
</tr>
<tr>
<td>50E3</td>
<td>0.05 dB</td>
</tr>
<tr>
<td>60E3</td>
<td>0.05 dB</td>
</tr>
<tr>
<td>70E3</td>
<td>0.05 dB</td>
</tr>
<tr>
<td>80E3</td>
<td>0.05 dB</td>
</tr>
<tr>
<td>90E3</td>
<td>0.05 dB</td>
</tr>
<tr>
<td>100E3</td>
<td>0.05 dB</td>
</tr>
<tr>
<td>110E3</td>
<td>0.10 dB</td>
</tr>
<tr>
<td>120E3</td>
<td>0.10 dB</td>
</tr>
<tr>
<td>130E3</td>
<td>0.10 dB</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Test Limits* ±(dB error)</th>
</tr>
</thead>
<tbody>
<tr>
<td>140E3</td>
<td>0.10 dB</td>
</tr>
<tr>
<td>150E3</td>
<td>0.10 dB</td>
</tr>
<tr>
<td>160E3</td>
<td>0.10 dB</td>
</tr>
<tr>
<td>170E3</td>
<td>0.10 dB</td>
</tr>
<tr>
<td>180E3</td>
<td>0.10 dB</td>
</tr>
<tr>
<td>190E3</td>
<td>0.10 dB</td>
</tr>
<tr>
<td>200E3</td>
<td>0.10 dB</td>
</tr>
<tr>
<td>210E3</td>
<td>0.10 dB</td>
</tr>
<tr>
<td>220E3</td>
<td>0.10 dB</td>
</tr>
<tr>
<td>230E3</td>
<td>0.10 dB</td>
</tr>
<tr>
<td>240E3</td>
<td>0.10 dB</td>
</tr>
<tr>
<td>250E3</td>
<td>0.10 dB</td>
</tr>
</tbody>
</table>

* Error relative to 1 kHz

Example Program

See the AC Flatness Adjustment procedure (Chapter 3) for an example program that performs the AC Flatness Test (change line 180 to: MODE$="M" ).
Test 2-6: AC Flatness - 10 MHz Filter

Description

The purpose of this test is to verify that the AFG meets its specifications for AC flatness with the 10 MHz filter enabled.

Equipment Setup

- Connect equipment as shown in Figure 2-6
- Set DMM to ACV, autorange

Test Procedure

1. Reset the AFG:

   *RST,*CLS  \hspace{1cm} \text{Reset AFG and clear status registers}

2. Set up the AFG to output a 24 dBm sinewave with the 10 MHz filter enabled:

   VOLT 24DBM;
   :OUTP:LOAD 50
   OUTP:FILT:FREQ 10MHZ
   OUTP:FILT ON
   INIT:IMM  \hspace{1cm} \text{Set amplitude 50 ohm load 10 MHz filter Initiate waveform}

3. Set AFG output to the reference frequency (1 kHz):

   FREQ 1000  \hspace{1cm} \text{Set frequency}

4. Measure the amplitude with the DMM, convert the reading to dBm, and note the reading for future reference:

   Reference Level (dBm) = 20 \times \log \left| \frac{\text{Reading (volts)}}{13.0103} \right|

5. Set the AFG to the crossover frequency (lowest frequency that the Power Meter can measure):

   FREQ 1E5  \hspace{1cm} \text{Set frequency}

6. Measure the amplitude with the DMM and note the reading for future reference.
Test Procedure (cont'd)

7. Set up the Power Meter:

- Units - Watts
- Power Range - auto
- Reference Oscillator - ON

---

**NOTE**

*Follow the Power Meter manufacturer's instructions for performing an autocalibration and correcting for the power sensor.*

---

8. Connect the equipment as shown in Figure 2-7:

![Equipment Setup](image)

Figure 2-7. Equipment Setup for Test 2-6

9. Set the Power Meter expected frequency to the crossover frequency (100 kHz). Measure the AFG output power and convert the reading to volts:

\[
\text{Reading (volts)} = \left( \sqrt{\text{Reading (watts)}} \times 50 \right)
\]
Test Procedure (cont'd)

10. Calculate the correction factor that will be used to reference the Power Meter to the DMM:

\[
\text{Correction Factor} = \frac{\text{DMM reading at 100 kHz (step 6)}}{\text{Power Meter reading at 100 kHz (step 9)}}
\]

Repeat 11 - 14 for each frequency in Table 2-6:

11. Set the AFG output to the frequency specified in Table 2-6. If the frequency is less than 10.8 MHz, use the following command:

\[
\text{FREQ <frequency>}
\]

where <frequency> is the value specified in Table 2-6. If the frequency is 10.8 MHz, use the following register commands to set the output frequency:

\[
\begin{align*}
\text{DIAG:POKE #HE000A1,8,0} \\
\text{DIAG:POKE #HE000A3,8,126} \\
\text{DIAG:POKE #HE000A5,8,95} \\
\text{DIAG:POKE #HE000A7,8,64} \\
\text{DIAG:POKE #HE0008D,8,0}
\end{align*}
\]

12. Set the Power Meter expected frequency to the AFG output frequency.

13. Measure the amplitude with the Power Meter, convert the reading to volts, and multiply by the correction factor.

\[
\text{Reading (volts)} = \left( \sqrt{\text{Reading (watts)}} \right) \times 50
\]

\[
\text{Corrected Reading (volts)} = \text{Reading (volts)} \times \text{C.F. (step 10)}
\]

14. Convert the reading to dBm. Calculate and record the error relative to the reference level calculated in step 4:

\[
\begin{align*}
\text{Reading (dBm)} & = 20 \times \log \left| \text{Corrected Reading (volts)} \right| + 13.0103 \\
\text{Error (dB)} & = \text{Reading (dBm)} - \text{Reference Level (dBm)}
\end{align*}
\]
Test 2-6: AC Flatness - 10 MHz Filter (cont'd)

Test Procedure (cont'd)

Table 2-6. AC Flatness Test Points - 10 MHz Filter

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Test Limits* ±(dB error)</th>
</tr>
</thead>
<tbody>
<tr>
<td>400E3</td>
<td>0.2 dB</td>
</tr>
<tr>
<td>800E3</td>
<td>0.2 dB</td>
</tr>
<tr>
<td>1.2E6</td>
<td>0.2 dB</td>
</tr>
<tr>
<td>1.6E6</td>
<td>0.2 dB</td>
</tr>
<tr>
<td>2.0E6</td>
<td>0.2 dB</td>
</tr>
<tr>
<td>2.4E6</td>
<td>0.2 dB</td>
</tr>
<tr>
<td>2.8E6</td>
<td>0.2 dB</td>
</tr>
<tr>
<td>3.2E6</td>
<td>0.2 dB</td>
</tr>
<tr>
<td>3.6E6</td>
<td>0.2 dB</td>
</tr>
<tr>
<td>4.0E6</td>
<td>0.2 dB</td>
</tr>
<tr>
<td>4.4E6</td>
<td>0.2 dB</td>
</tr>
<tr>
<td>4.8E6</td>
<td>0.2 dB</td>
</tr>
<tr>
<td>5.2E6</td>
<td>0.2 dB</td>
</tr>
<tr>
<td>5.6E6</td>
<td>0.2 dB</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Test Limits* ±(dB error)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.0E6</td>
<td>0.2 dB</td>
</tr>
<tr>
<td>6.4E6</td>
<td>0.2 dB</td>
</tr>
<tr>
<td>6.8E6</td>
<td>0.2 dB</td>
</tr>
<tr>
<td>7.2E6</td>
<td>0.2 dB</td>
</tr>
<tr>
<td>7.6E6</td>
<td>0.2 dB</td>
</tr>
<tr>
<td>8.0E6</td>
<td>0.2 dB</td>
</tr>
<tr>
<td>8.4E6</td>
<td>0.2 dB</td>
</tr>
<tr>
<td>8.8E6</td>
<td>0.2 dB</td>
</tr>
<tr>
<td>9.2E6</td>
<td>0.2 dB</td>
</tr>
<tr>
<td>9.6E6</td>
<td>0.2 dB</td>
</tr>
<tr>
<td>10.0E6</td>
<td>0.2 dB</td>
</tr>
<tr>
<td>10.4E6</td>
<td>0.2 dB</td>
</tr>
<tr>
<td>10.8E6</td>
<td>0.2 dB</td>
</tr>
</tbody>
</table>

* Error relative to 1 kHz

Example Program

See the AC Flatness Adjustment procedure (Chapter 3) for an example program that performs the AC Flatness Test (change line 180 to: ModeS="M").
Test 2-7: Frequency Accuracy

Description

The purpose of this test is to verify that the AFG meets its specifications for frequency accuracy.

Equipment Setup

- Connect equipment as shown in Figure 2-8
- Set Counter to: Frequency, 50Ω input impedance

![Equipment Setup Diagram]

Figure 2-8. Equipment Setup for Test 2-7

Test Procedure

1. Reset the AFG:

   *RST;*CLS

   *Reset AFG and clear status registers

   Perform steps 2-6 for each entry listed in Table 2-7:

2. Abort the waveform if it has been previously initiated:

   ABORT
Test 2-7: Frequency Accuracy (cont'd)

Test Procedure (cont'd)

3. Set reference oscillator to INT1 or INT2, as specified in Table 2-7:
   
   ROSE:SOUR INT1
   or
   ROSE:SOUR INT2

   Set ref osc to INT1
   Set ref osc to INT2

4. Set marker source to "ROSC" or "TRIG", as specified in Table 2-7:
   
   MARK:FEED "ROSC"
   or
   MARK:FEED "TRIG"

   Set marker source to "ROSC"
   Set marker source to "TRIG"

5. If the marker source is "TRIG", use the following commands to output a squarewave (otherwise, skip this step):
   
   FUNC SQU;
   :FREQ2 <frequency>;
   :TRIG:SOUR INT2
   INIT:IMM

   Select squarewave
   Set AFG frequency
   Set trig source
   Initiate

   where <frequency> is the value given in the "Squarewave Frequency" column of Table 2-7.

---

NOTE

If the marker source is "TRIG", the marker output frequency will be four times the frequency of the squarewave, since it takes four points to produce a squarewave. See Table 2-7 for the expected frequencies.

---

6. Measure frequency with the Counter and record the reading in Table 2-11.
Test 2-7: Frequency Accuracy (cont’d)

Test Procedure (cont’d)

Table 2-7. Frequency Accuracy Test Points

<table>
<thead>
<tr>
<th>Ref Oscillator Source</th>
<th>Marker Source</th>
<th>Squarewave Frequency (Hz)</th>
<th>Test Limits (Hz)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>INT1</td>
<td>&quot;ROSC&quot;</td>
<td>——</td>
<td>42.94967 E6 ± 0.005%</td>
</tr>
<tr>
<td>INT2</td>
<td>&quot;ROSC&quot;</td>
<td>——</td>
<td>40 E6 ± 0.005%</td>
</tr>
<tr>
<td>INT2</td>
<td>&quot;TRIG&quot;</td>
<td>5.0 E6</td>
<td>20 E6 ± 0.005%</td>
</tr>
<tr>
<td>INT2</td>
<td>&quot;TRIG&quot;</td>
<td>3.333 E3</td>
<td>13.3333 E6 ± 0.005%</td>
</tr>
<tr>
<td>INT2</td>
<td>&quot;TRIG&quot;</td>
<td>76.294</td>
<td>305.176 ± 0.005%</td>
</tr>
</tbody>
</table>

*Add aging rate of ±20 ppm/year

Example Program

This program performs the Frequency Accuracy Test.

```
10! RE-STORE "OSC_FREQ"
20  DIM Freq(1:5)
30  !
40  !——— Set up I/O path and reset AFG ———
50  ASSIGN @Afg TO 70910
60  OUTPUT @Afg:""RST:""CLS"
!Reset AFG
70  !
80  !——— Initialize variables ———
90  DATA 42.94967E6,40E6,20E6,13.3333E6,305.176
100 READ Freq(*)
110  !
120  !——— Set up Counter ———
130  CLEAR SCREEN
140  PRINT "Set up Counter:"
150  PRINT
160  PRINT " Function -- Frequency"
170  PRINT " Input Impedance -- 50 ohms"
180  PRINT
190  PRINT "Connect the Counter to 'Marker Out' on the HP E1445A."
200  PRINT
210  DISP "Press 'Continue"
220  PAUSE
230  CLEAR SCREEN
240  !
```

(Continued on next page)
Test 2-7: Frequency Accuracy (cont'd)

Example Program (cont'd)

```
250 !-------- Set up AFG --------
260 OUTPUT @Afg,"RST"                  !Reset AFG
270 WAIT .5
280 !
290 !-------- Perform test --------
300 FOR I=1 TO 5
310 PRINT "Expected reading =";Freq(I)
320 PRINT
330 IF I=1 THEN
340 OUTPUT @Afg,"ROSC:SOUR INT1"       !ROSC = INT1
350 OUTPUT @Afg,"MARK:FEED "$"ROSC""    !Marker source = OSC
360 ELSE
370 OUTPUT @Afg,"ABORT"                !Abort waveform
380 OUTPUT @Afg,"ROSC:SOUR INT2"       !ROSC = INT2
390 IF Freq(I)=4.0E+7 THEN
400 OUTPUT @Afg,"MARK:FEED "$"ROSC""    !Marker source = OSC
410 ELSE
420 OUTPUT @Afg,"FUNC SQU;";           !Squarewave
430 !
440 //Square wave freq is 1/4 of marker freq
450 OUTPUT @Afg,"FREQ2 ";"VAL$(Freq(I)/4)";";
460 OUTPUT @Afg,"TRIG:STAR:SOUR INT2";TRIG source = INT2
470 OUTPUT @Afg,"MARK:FEED "$"TRIG""     !Marker source = TRIG
480 END IF
490 END IF
500 !
510 OUTPUT @Afg,"INIT: IMM"           !Initialize
520 WAIT 1
530 !
540 DISP "Record the Counter reading, then press 'Continue'
550 PAUSE
560 DISP
570 NEXT I
580 !
590 OUTPUT @Afg,"RST;CLS"             !Reset AFG
600 END
```
Test 2-8: Duty Cycle

Description

The purpose of this test is to verify that the AFG meets its specifications for square wave duty cycle. Duty cycle is determined by measuring positive pulse width.

Equipment Setup

- Connect equipment as shown in Figure 2-9
- Set Counter to: Pulse Width, DC coupling, 50Ω input impedance

![Equipment Setup Diagram]

Figure 2-9. Equipment Setup for Test 2-8

Test Procedure

1. Reset the AFG:

   *RST;*CLS

   Reset AFG and clear status registers

2. Set the AFG to output a square wave:

   FUNC SQU;
   :VOLT MAX

   Select squarewave
   Set to max amplitude

Perform steps 3 - 7 for each frequency listed in Table 2-8:

3. Abort the waveform if it has been previously initiated:

   ABORT
Test 2-8: Duty Cycle (cont’d)

Test Procedure (cont’d)

4. Set the AFG frequency range as specified in Table 2-8:

   FREQ:RANG MAX
   or
   FREQ:RANG MIN

   Enable doubling
   Disable doubling

5. Set AFG output frequency:

   FREQ <frequency>

   Set frequency

   where <frequency> is the value specified in Table 2-8.

6. Initiate the waveform:

   INIT:IMM

7. Measure positive pulse width (average at least 10 periods) with the Counter and record the reading in Table 2-11.

---

NOTE

If a percentage result is desired, measure the period (average at least 10 periods. Duty Cycle (%) = 100 x (Positive Pulse Width/Period)

---

Table 2-8. Duty Cycle Test Points

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Frequency Range</th>
<th>Test Limits (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 E3</td>
<td>MIN</td>
<td>5.0E-3 ± 1.0E-6</td>
</tr>
<tr>
<td>2.0 E3</td>
<td>MAX</td>
<td>2.5E-4 ± 3.0E-5</td>
</tr>
<tr>
<td>2.5 E5</td>
<td>MIN</td>
<td>2.0E-7 ± 3.4E-9</td>
</tr>
<tr>
<td>5.0 E5</td>
<td>MAX</td>
<td>1.0E-7 ± 1.5E-8</td>
</tr>
</tbody>
</table>
Example Program

This program performs the Duty Cycle Test.

```
10 ! RE-STORE "DUTY_CYCLE"
20 DIM Freq(1:4),Range$(1:4)[10]
30 !
40 !------ Set up I/O path and reset AFG ------
50 ASSIGN @Afg TO 70910
60 OUTPUT @Afg;"RST;CLS"
70 !
80 !------ Initialize variables -------
90 DATA 1E3,2E3,2.5E5,5E5
100 READ Freq(*)
110 !
120 DATA MIN,MAX,MIN,MAX
130 READ Range$(*)
140 !
150 !------ Set up Counter -------
160 CLEAR SCREEN
170 PRINT "Set up Counter;"
180 PRINT " Function -- Pulse Width"
190 PRINT " Coupling -- DC"
210 PRINT " Input Impedance -- 50 ohms"
220 PRINT "Connect Counter to AFG Output;"
240 DISP "Press 'Continue' when ready"
250 PAUSE
260 CLEAR SCREEN
270 !
280 !------ Set up AFG ------
290 OUTPUT @Afg;"RST"
300 OUTPUT @Afg;"FUNC SQU;"
310 OUTPUT @Afg;"VOLT MAX"
320 !
330 !------ Perform test ------
340 FOR l=1 TO 4
350 OUTPUT @Afg;"ABORT"
360 OUTPUT @Afg;"FREQ:RANG &Range$(l)&;"
370 OUTPUT @Afg;"FREQ &VALS(Freq(l))"
380 OUTPUT @Afg;"INIT:IMM"
390 WAIT 1
400 !
```

(Continued on next page)
Test 2-8: Duty Cycle (cont’d)

Example Program (cont’d)

```plaintext
410  !Take readings here
420  PRINT "Output Frequency =";Freq();" Hz"
430  PRINT
440  PRINT "Read positive pulse width (average at least 10 periods)."
450  INPUT "Enter positive pulse width (in sec):";Pos_width
460  !
470  PRINT "Set Counter to measure period (average at least 10 periods)."
480  INPUT "Enter period (in sec):";Period
490  !
500  !Calculate duty cycle
510  Duty_cycle=(Pos_width/(Period))*100
520  Duty_cycle=ROUND(Duty_cycle,2)
530  PRINT
540  PRINT "Positive Pulse Width = "&VAL$(Pos_width)
550  PRINT "Duty Cycle = "&VAL$(Duty_cycle)&"%"
560  !
570  DISP "Press 'Continue' when ready"
580  PAUSE
590  CLEAR SCREEN
600  NEXT I
610  !
620  OUTPUT @Afg;"*RST;*CLS" !Reset AFG
630  END
```
Test 2-9: Total Harmonic Distortion

Description

The purpose of this test is to verify that the AFG meets its specifications for sine wave total harmonic distortion (THD).

Equipment Setup

- Connect equipment as shown in Figure 2-10
- Set Spectrum Analyzer to:

  Ref Level = 25 dBm
  Freq Span = 1 kHz
  Resolution BW = 30 Hz
  Video BW = 30 Hz

NOTE

These are recommended settings only. Adjust your Spectrum Analyzer as necessary.

Figure 2-10. Equipment Setup for Test 2-9 and Test 2-10
Test 2-9: Total Harmonic Distortion (cont'd)

Test Procedure

1. Reset the AFG:
   
   *RST,*CLS  \hspace{3cm} \text{Reset AFG and clear status registers}

2. Set the AFG to output a sinewave with the 10 MHz filter enabled:

   \begin{align*}
   \text{VOLT} & \ 24\text{DBM} \\
   \text{OUTP: FILT: FREQ} & \ 10 \ \text{MHz} \\
   \text{OUTP: FILT ON} & \\
   \text{INIT: IMM}
   \end{align*}

   \hspace{3cm} \text{Set AFG amplitude} \hspace{1cm} \text{Set filter to 10 MHz} \hspace{1cm} \text{Enable filter} \hspace{1cm} \text{Initiate waveform}

Perform steps 3 - 6 for each frequency listed in Table 2-9:

3. Set AFG output frequency:

   \text{FREQ} \ <\text{frequency}> \\

   \hspace{3cm} \text{Set frequency}

   \text{where}<\text{frequency}> \ \text{is the value specified in Table 2-9.}

4. Set the Spectrum Analyzer center frequency to the output frequency of the AFG. Measure the peak amplitude of the fundamental in dBm. Note the result for use in step 6.

5. Set the Spectrum Analyzer center frequency to the second harmonic ( \(2 \times \text{fundamental frequency}\)). Measure the peak amplitude of the second harmonic in dBm.

6. Repeat step 5 for third through ninth harmonics. Calculate total harmonic distortion as shown below:

   \[
   \text{thd (dBc)} = 20 \cdot \log \left( \sqrt[9]{\text{result}_2^2 + \text{result}_3^2 + \ldots + \text{result}_9^2} \right)
   \]

   \hspace{3cm} \text{where}

   \[
   \text{result}_n \ = \ 10 \log \left( \text{n}^{\text{th}} \ \text{Harmonic (dBm)} - \ \text{Fundamental (dBm)} \right) / 20
   \]
Test 2-9: Total Harmonic Distortion (cont’d)

Test Procedure
(cont’d)

Table 2-9. THD Test Points

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Test Limits* (dBC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 E3</td>
<td>-60</td>
</tr>
<tr>
<td>250 E3</td>
<td>-60</td>
</tr>
<tr>
<td>1 E6</td>
<td>-48</td>
</tr>
<tr>
<td>4 E6</td>
<td>-36</td>
</tr>
<tr>
<td>10 E6</td>
<td>-36</td>
</tr>
</tbody>
</table>

* Through 9th harmonic

Example Program

This program performs the Total Harmonic Distortion Test.

```
10 ! RE-STORE "SINE_THD"
20 ! DIM Freq(1:5)
30 !
40 !----- Set up I/O path and reset AFG -----
50 ASSIGN @Afg TO 70910 !AFG I/O path
60 OUTPUT @Afg;"RST;"CLS" !Reset AFG
70 !
80 !----- Initialize variables ----- 
90 Dbm_out$="24DBM" !AFG output
100 !
110 DATA 100E3,250E3,1E6,4E6,10E6 !Read in freqs
120 READ Freq(*)
130 !
140 !----- Set up Spec Analyzer ------
150 CLEAR SCREEN
160 PRINT "Set up Spectrum Analyzer:"
170 PRINT
180 PRINT " Ref Level = 25 dBm"
190 PRINT " Span = 1 kHz"
200 PRINT " Resolution BW = 30 Hz"
210 PRINT " Video BW = 30 Hz"
220 PRINT

(Continued on next page)
```
Example Program (cont’d)

230 PRINT "Connect Spectrum Analyzer to AFG Output."
240 DISP "Press 'Continue' when ready"
250 PAUSE
260 !
270 !——— Set up AFG ———
280 OUTPUT @Afg;"RST" !Reset AFG
290 WAIT 1
300 OUTPUT @Afg;"VOLT ",&Dm_out$
310 OUTPUT @Afg;"OUTP:FFILT:FREQ 10MHZ" !Enable 10MHz filter
320 OUTPUT @Afg;"OUTP:FFILT ON"
330 OUTPUT @Afg;"INIT:IMM" !Initiate
340 !
350 !——— Perform test ———
360 FOR I=1 TO 5
370 OUTPUT @Afg;"FREQ ",&VAL$(Freq(I)) !Set frequency
380 !
390 CALL Meas_thd(Freq(I),Thd) !Measure THD
400 PRINT "Fundamental Frequency =",Freq(I)
410 PRINT "THD =",DBOUND(Thd,4),"dBc"
420 END
430 DISP "Press 'Continue' when ready"
440 PAUSE
450 !
460 NEXT I
470 !
480 OUTPUT @Afg;"RST","CLS" !Reset AFG
490 END
500 !
510 !
520 !——— Measurement subprogram ———
530 SUB Meas_thd(Frequency,Thd)
540 INTEGER Harmonic
550 CLEAR SCREEN
560 Harmonic=1
570 !
580 GOSUB Meas_fund !Get fundamental amplitude
590 !

(Continued on next page)
Test 2-9: Total Harmonic Distortion (cont’d)

Example Program (cont’d)

```
600   !Measure harmonics 2-9
610   Sum_amp_sqr=0
620   FOR Harmonic=2 TO 9
630       GOSUB Meas_amp
640       Sum_amp_sqr=Sum_amp_sqr+10^((Result/10))  !Sum of squared voltages
650       NEXT Harmonic
660       !
670       Thd=20*LOG(SQRT(Sum_amp_sqr))           !Calculate THD In dBc
680       SUBEXIT
690       !
700  Meas_fund:  !
710       PRINT "FUNDAMENTAL"
720       PRINT "Set Spectrum Analyzer Center Freq to: &VAL$(Frequency)&" Hz."
730       PRINT "Measure amplitude at the center frequency."
740       PRINT
750       INPUT "Enter amplitude (in dBm):",Baseline
760       RETURN
770       !
780  Meas_amp:  !
790       PRINT "HARMONIC =" ; Harmonic
800       PRINT "Set Spectrum Analyzer Center Freq to: &VAL$(Frequency*Harmonic)&" Hz."
810       PRINT "Measure amplitude at the center frequency."
820       PRINT
830       INPUT "Enter amplitude (in dBm):",Reading
840       Result=Reading-Baseline
850       RETURN
860   SUBEND
```
Test 2-10: Spurious/Non-Harmonic Distortion

Description

The purpose of this test is to verify that the AFG meets its specifications for non-harmonic and spurious distortion.

Equipment Setup

- Connect equipment as shown in Figure 2-9
- Set Spectrum Analyzer to:

  Ref Level = -5 dBm
  Resolution BW = 3 kHz
  Video BW = 3 kHz

NOTE

*These are recommended settings only. Adjust your Spectrum Analyzer as necessary.*

Test Procedure

1. Reset the AFG:

   *RST;*CLS

   Reset AFG and clear status registers

2. Set the AFG to output a -5 dBm, 10 MHz sinewave with the 10 MHz filter enabled:

   FREQ 1.0E7;
   :VOLT -5DBM
   OUTP:FILT:FREQ 10 MHZ
   OUTP:FILT ON
   INIT:IMM

   Set AFG frequency
   Set AFG amplitude
   Set filter to 10 MHz
   Enable filter
   Initiate waveform
Test Procedure (cont'd)

Perform steps 3 and 4 for each frequency range listed in Table 2-10:

3. Set the Spectrum Analyzer start frequency and stop frequency to the values listed in Table 2-10.

4. Measure the amplitude (in dBm) of the highest peak. Subtract the amplitude of the fundamental (-5 dBm) from the reading and record the result in Table 2-11:

\[
\text{result (dBc)} = \text{reading(dBm)} - (-5 \text{ dBm})
\]

Table 2-10. Spurious/Non-Harmonic Test Points

<table>
<thead>
<tr>
<th>Start Frequency (Hz)</th>
<th>Stop Frequency (Hz)</th>
<th>Test Limits (dBc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 E3</td>
<td>9.5 E6</td>
<td>-45</td>
</tr>
<tr>
<td>10.5 E6</td>
<td>19 E6</td>
<td>-45</td>
</tr>
<tr>
<td>21 E6</td>
<td>29 E6</td>
<td>-45</td>
</tr>
<tr>
<td>31 E6</td>
<td>39 E6</td>
<td>-45</td>
</tr>
<tr>
<td>41 E6</td>
<td>49 E6</td>
<td>-45</td>
</tr>
<tr>
<td>51 E6</td>
<td>75 E6</td>
<td>-45</td>
</tr>
<tr>
<td>75 E6</td>
<td>100 E6</td>
<td>-45</td>
</tr>
<tr>
<td>100 E6</td>
<td>125 E6</td>
<td>-45</td>
</tr>
<tr>
<td>125 E6</td>
<td>150 E6</td>
<td>-45</td>
</tr>
</tbody>
</table>
Test 2-10: Spurious/Non-Harmonic Distortion (cont’d)

Example Program

This program performs the Spurious/Non-harmonic Test.

```plaintext
10 ! RE-STORE "NON_HARM"
20 DIM Start_freq(1:9),Stop_freq(1:9),Max_ampl(1:9)
30 !
40 !--------- Set up I/O path and reset AFG ---------
50 ASSIGN @Afl TO 70910       !AFG I/O path
60 OUTPUT @Afl;"RST;"CLS"      !Reset AFG
70 !
80 !--------- Initialize variables ---------
90 Freq_out=1.0E+7              !Freq = 10 MHz
100 Dbm_out$="-5DBM"           !Amplitude = -5dBm
110 !
120 DATA 100E3,10.5E6,21E6,31E6,41E6,51E6,75E6,100E6,125E6
130 READ Start_freq(*)         !Read start freq
140 !
150 DATA 9.5E6,19E6,29E6,39E6,49E6,75E6,100E6,125E6,150E6
160 READ Stop_freq(*)          !Read stop freq
170 !
180 !--------- Set up Spec Analyzer ---------
190 CLEAR SCREEN
200 PRINT "Set up Spectrum Analyzer;"
210 PRINT
220 PRINT " Ref Level = -.5dBm"
230 PRINT " Resolution BW = 3 kHz"
240 PRINT " Video BW = 3 kHz"
250 PRINT
260 PRINT "Connect Spectrum Analyzer to AFG Output."
270 DISP "Press 'Continue' when ready"
280 PAUSE
290 CLEAR SCREEN
300 !
310 !--------- Set up AFG ---------
320 OUTPUT @Afl;"RST"           !Reset AFG
330 WAIT 1
340 OUTPUT @Afl;"FREQ &VAL$(Freq_out)$;";   !Set frequency
350 OUTPUT @Afl;"VOLT &Dbm_out$";         !Set amplitude
360 OUTPUT @Afl;"OUTP:FILT:FREQ 10MHZ";   !Enable 10MHz filter
370 OUTPUT @Afl;"OUTP:FILT ON;"        !
380 OUTPUT @Afl;"INIT:IMM"            !Initiate
390 !
```

(Continued on next page)
Example Program (cont'd)

400 !------ Perform test ------
410 FOR I=1 TO 9
420 CLEAR SCREEN
430 PRINT "Set Spectrum Analyzer Start Freq to: ",Start_freq(I);"Hz"
440 PRINT "Set Spectrum Analyzer Stop Freq to: ",Stop_freq(I);"Hz"
450 PRINT "Measure the amplitude of the highest peak."
460 PRINT
470 INPUT "Enter amplitude (in dBm):",Peak_ampl
480 PRINT "Result =",VAL(Dbm_out$)-Peak_ampl;"dBc"!Calculate result in dBc
490 DISP "Press 'Continue' when ready"
500 PAUSE
510 DISP
520 NEXT I
530 !
540 OUTPUT @Afg;"*RST,*CLS"!Reset AFG
550 END
Performance Test Record

Table 2-11, Performance Test Record for the HP E1445A AFG, is a form you can copy and use to record performance verification test results for the AFG. Table 2-11 shows AFG accuracy, measurement uncertainty, and test accuracy ratio (TAR) values.

AFG Test Limits

Test limits are defined using the specifications in Appendix A of the HP E1445A User's Manual. The specifications for Total Harmonic Distortion and Spurious/Non-harmonic Distortion are single-sided (i.e., there is an upper limit but no lower limit). In the Performance Test Record, the Minimum column will be blank.

Measurement Uncertainty

For the performance verification tests in this manual, the measurement uncertainties are based on the accuracy specifications for the following test equipment:

<table>
<thead>
<tr>
<th>Performance Test</th>
<th>Test Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. DC Zeros</td>
<td>HP 3458A</td>
</tr>
<tr>
<td>2. DC Accuracy</td>
<td>HP 3458A</td>
</tr>
<tr>
<td>3. DC Offset</td>
<td>HP 3458A</td>
</tr>
<tr>
<td>4. AC Accuracy</td>
<td>HP 3458A</td>
</tr>
<tr>
<td>5. AC Flatness (250 kHz filter)</td>
<td>HP 3458A</td>
</tr>
<tr>
<td>6. AC Flatness (10 MHz filter)*</td>
<td>HP 3458A</td>
</tr>
<tr>
<td></td>
<td>HP 8802A</td>
</tr>
<tr>
<td>7. Frequency Accuracy</td>
<td>HP 5334B</td>
</tr>
<tr>
<td>8. Duty Cycle</td>
<td>HP 5334B</td>
</tr>
<tr>
<td>9. Total Harmonic Distortion</td>
<td>HP 8566B</td>
</tr>
<tr>
<td>10. Spurious/Non-harmonic Distortion</td>
<td>HP 8566B</td>
</tr>
</tbody>
</table>

* Includes following uncertainties: HP 8902A Range linearity, HP 11722A Power Sensor Cal Factor uncertainty, HP 3458A accuracy at 100 kHz.
Test Accuracy Ratio (TAR) for the HP E1445A is defined as: AFG Accuracy/Measurement Uncertainty, i.e.,

\[
\text{TAR} = \frac{\text{Maximum - Expected Reading}}{\text{Measurement Uncertainty}}
\]

For single-sided measurements, Test Accuracy Ratio is not defined, so 'NA' (Not Applicable) will appear in the TAR column. For TARs that exceed 10:1, the entry is '>10:1'.
<table>
<thead>
<tr>
<th>Test Facility:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
</tr>
<tr>
<td>Address</td>
</tr>
<tr>
<td>City/State</td>
</tr>
<tr>
<td>Phone</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model</th>
<th>Ambient temperature °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serial No.</td>
<td>Relative humidity %</td>
</tr>
<tr>
<td>Options</td>
<td>Line frequency Hz (nominal)</td>
</tr>
<tr>
<td>Firmware Rev.</td>
<td></td>
</tr>
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Table 2-11. Performance Test Record for the HP E1445A (Page 2 of 7)

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* Since the arbitrary waveform consists of zeros, the expected reading is 0 V, regardless of the amplitude setting. The amplitude is changed in order to turn the various attenuators on and off.
### Table 2-11. Performance Test Record for the HP E1445A (Page 4 of 7)

<table>
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<th>Test Description</th>
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<th>TAR</th>
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<td>-10.1888</td>
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Table 2-11. Performance Test Record for the HP E1445A (Page 5 of 7)

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Test 2-5. AC Flatness Test - 250 kHz Filter (Values in dB error, relative to 1 kHz)
### Table 2-11. Performance Test Record for the HP E1445A (Page 6 of 7)

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<th>Test Description</th>
<th>Minimum</th>
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<th>Maximum</th>
<th>Meas Uncert</th>
<th>TAR</th>
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<td>0.20</td>
<td>0.0506 dB</td>
<td>4:1</td>
</tr>
<tr>
<td>1.6 MHz</td>
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<td>0.20</td>
<td>0.0506 dB</td>
<td>4:1</td>
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<td>0.0506 dB</td>
<td>4:1</td>
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<td>2.4 MHz</td>
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<td>0.0506 dB</td>
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<td>0.0506 dB</td>
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<td>-0.2</td>
<td></td>
<td>0.20</td>
<td>0.0506 dB</td>
<td>4:1</td>
</tr>
<tr>
<td>4.8 MHz</td>
<td>-0.2</td>
<td></td>
<td>0.20</td>
<td>0.0506 dB</td>
<td>4:1</td>
</tr>
<tr>
<td>5.2 MHz</td>
<td>-0.2</td>
<td></td>
<td>0.20</td>
<td>0.0506 dB</td>
<td>4:1</td>
</tr>
<tr>
<td>5.6 MHz</td>
<td>-0.2</td>
<td></td>
<td>0.20</td>
<td>0.0506 dB</td>
<td>4:1</td>
</tr>
<tr>
<td>6.0 MHz</td>
<td>-0.2</td>
<td></td>
<td>0.20</td>
<td>0.0506 dB</td>
<td>4:1</td>
</tr>
<tr>
<td>6.4 MHz</td>
<td>-0.2</td>
<td></td>
<td>0.20</td>
<td>0.0506 dB</td>
<td>4:1</td>
</tr>
<tr>
<td>6.8 MHz</td>
<td>-0.2</td>
<td></td>
<td>0.20</td>
<td>0.0536 dB</td>
<td>4:1</td>
</tr>
<tr>
<td>7.2 MHz</td>
<td>-0.2</td>
<td></td>
<td>0.20</td>
<td>0.0536 dB</td>
<td>4:1</td>
</tr>
<tr>
<td>7.6 MHz</td>
<td>-0.2</td>
<td></td>
<td>0.20</td>
<td>0.0536 dB</td>
<td>4:1</td>
</tr>
<tr>
<td>8.0 MHz</td>
<td>-0.2</td>
<td></td>
<td>0.20</td>
<td>0.0536 dB</td>
<td>4:1</td>
</tr>
<tr>
<td>8.4 MHz</td>
<td>-0.2</td>
<td></td>
<td>0.20</td>
<td>0.0536 dB</td>
<td>4:1</td>
</tr>
<tr>
<td>8.8 MHz</td>
<td>-0.2</td>
<td></td>
<td>0.20</td>
<td>0.0536 dB</td>
<td>4:1</td>
</tr>
<tr>
<td>9.2 MHz</td>
<td>-0.2</td>
<td></td>
<td>0.20</td>
<td>0.0536 dB</td>
<td>4:1</td>
</tr>
<tr>
<td>9.6 MHz</td>
<td>-0.2</td>
<td></td>
<td>0.20</td>
<td>0.0536 dB</td>
<td>4:1</td>
</tr>
<tr>
<td>10.0 MHz</td>
<td>-0.2</td>
<td></td>
<td>0.20</td>
<td>0.0536 dB</td>
<td>4:1</td>
</tr>
<tr>
<td>10.4 MHz</td>
<td>-0.2</td>
<td></td>
<td>0.20</td>
<td>0.0536 dB</td>
<td>4:1</td>
</tr>
<tr>
<td>10.8 MHz</td>
<td>-0.2</td>
<td></td>
<td>0.20</td>
<td>0.0536 dB</td>
<td>4:1</td>
</tr>
</tbody>
</table>
Table 2-11. Performance Test Record for the HP E1445A (Page 7 of 7)

<table>
<thead>
<tr>
<th>Test Description</th>
<th>Minimum</th>
<th>Measured Reading</th>
<th>Maximum</th>
<th>Meas Uncert</th>
<th>TAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 2-7. Frequency Accuracy Test (Values in Hz) *</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marker source is &quot;ROSC&quot;:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>42.9497 MHz</td>
<td>42.9467E6</td>
<td>42.9527E6</td>
<td>8.0</td>
<td>&gt;10:1</td>
<td></td>
</tr>
<tr>
<td>40.0 MHz</td>
<td>39.9972E6</td>
<td>40.0028E6</td>
<td>8.0</td>
<td>&gt;10:1</td>
<td></td>
</tr>
<tr>
<td>Marker source is &quot;TRIG&quot;:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20.0 MHz</td>
<td>19.9986E6</td>
<td>20.0014E6</td>
<td>5.0</td>
<td>&gt;10:1</td>
<td></td>
</tr>
<tr>
<td>13.3333 MHz</td>
<td>13.3324E6</td>
<td>13.3342E6</td>
<td>3.8</td>
<td>&gt;10:1</td>
<td></td>
</tr>
<tr>
<td>305.176 Hz</td>
<td>305.1546</td>
<td>305.1974</td>
<td>0.00305</td>
<td>7:1</td>
<td></td>
</tr>
<tr>
<td>Test 2-8. Duty Cycle Test (Values in nsec)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 kHz, .5 msec pulse width</td>
<td>4.99E-4</td>
<td>5.01E-4</td>
<td>2.1E-9</td>
<td>&gt;10:1</td>
<td></td>
</tr>
<tr>
<td>2 kHz, .25 msec pulse width</td>
<td>2.2E-4</td>
<td>2.8E-4</td>
<td>1.8E-9</td>
<td>&gt;10:1</td>
<td></td>
</tr>
<tr>
<td>250 kHz, 2 μsec pulse width</td>
<td>1.993E-6</td>
<td>2.007E-6</td>
<td>1.2E-9</td>
<td>6:1</td>
<td></td>
</tr>
<tr>
<td>500 kHz, 1 μsec pulse width</td>
<td>8.77E-7</td>
<td>1.123E-6</td>
<td>1.2E-9</td>
<td>&gt;10:1</td>
<td></td>
</tr>
<tr>
<td>Test 2-9. Total Harmonic Distortion Test (Values in dBC) **</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 dBm sinewave:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 kHz</td>
<td></td>
<td>-60 dBC</td>
<td>1.23 dB</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>250 kHz</td>
<td></td>
<td>-60 dBC</td>
<td>1.23 dB</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>1 MHz</td>
<td></td>
<td>-48 dBc</td>
<td>1.23 dB</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>4 MHz</td>
<td></td>
<td>-36 dBc</td>
<td>1.23 dB</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>10 MHz</td>
<td></td>
<td>-36 dBc</td>
<td>1.23 dB</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Test 2-10. Spurious/Non-harmonic Distortion Test (Values in dBC) **</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 MHz, -5 dBm sinewave:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 kHz - 9.5 MHz</td>
<td></td>
<td>-45 dBc</td>
<td>1.23 dB</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>10.5 MHz - 19 MHz</td>
<td></td>
<td>-45 dBc</td>
<td>1.23 dB</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>21 MHz - 29 MHz</td>
<td></td>
<td>-45 dBc</td>
<td>1.23 dB</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>31 MHz - 39 MHz</td>
<td></td>
<td>-45 dBc</td>
<td>1.23 dB</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>41 MHz - 49 MHz</td>
<td></td>
<td>-45 dBc</td>
<td>1.23 dB</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>51 MHz - 75 MHz</td>
<td></td>
<td>-45 dBc</td>
<td>1.23 dB</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>75 MHz - 100 MHz</td>
<td></td>
<td>-45 dBc</td>
<td>1.23 dB</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>100 MHz - 125 MHz</td>
<td></td>
<td>-45 dBc</td>
<td>1.23 dB</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>125 MHz - 150 MHz</td>
<td></td>
<td>-45 dBc</td>
<td>1.23 dB</td>
<td>NA</td>
<td></td>
</tr>
</tbody>
</table>

* Test limits assume 1 year of aging @ ±20 ppm/year
** Single-sided test -- Minimum is not applicable
Introduction

The procedures in this chapter show how to perform the following electronic adjustments for the AFG:

- DC Accuracy
- AC Flatness (250 kHz and 10MHz filters)
- Skew

NOTE

*The DC adjustment procedure should be performed before the AC flatness adjustment procedures.*

Required Equipment

See Table 1-1 for test equipment required for the procedures described in this chapter.

Recommended Environment

Before performing these procedures, allow the AFG to warm up for at least one hour. The temperature should be within $\pm 5^\circ C$ of $T_{cal}$ (the temperature of the most recent calibration), and between $18^\circ C$ and $28^\circ C$.

Calibration Commands

This section provides a brief description of commands that relate to calibration of the AFG. More information on these commands can be found in the Command Reference section of the *HP E1445A User's Manual*.

- **CALibration:COUNt?** returns the number of times that the AFG has been calibrated. Each adjustment procedure in this chapter increments the calibration number by 1.

- **CALibration:SECure:CODE <code>** sets the code that disables calibration security. The code is set at the factory to "E1445A". Calibration security must be disabled before changing the code.
Calibration Commands (cont’d)

- **CALibration:SECure[:STATE] <mode>,<code>** enables (<mode> = ON) or disables (<mode> = OFF) calibration security. The security code is required for CAL:SEC:STAT OFF, but the code is optional for CAL:SEC:STAT ON. The *RST command also enables calibration security.

- **CALibration[:DC]:BEGIN** starts the DC calibration sequence and sets up the AFG for the first calibration point.

- **CALibration[:DC]:POINT? <value>** sends a value to the AFG so that the appropriate calibration constant(s) can be calculated. The AFG returns two numbers: (1) the current calibration point, and (2) an error code (see Appendix B of the HP E1445A User's Manual for more information about AFG errors). Any non-zero error code indicates a failure. This command also sets up the AFG for the next calibration point.

- **CALibration:DATA[:DC] <block>** transfers the DC calibration constants to the AFG. The DC calibration procedure described in this chapter should be used in place of this command. The query form returns the current DC constants in IEEE-488.2 definite block data format.

- **CALibration:DATA:AC[1] <block>** transfers the AC calibration constants that are used with the 250 kHz filter. The query form returns the current constants in IEEE-488.2 definite block data format. See the AC Flatness Adjustment procedures for more information on the use of this command.

- **CALibration:DATA:AC2 <block>** transfers the AC calibration constants that are used with the 10 MHz filter. The query form returns the current constants in IEEE-488.2 definite block data format. See the AC Flatness Adjustment procedures for more information on the use of this command.
Calibration Commands (cont’d)

- **CALibration:DATA:FILTert <block>** transfers the two calibration constants that are used to determine the frequency points that will be calibrated for the 10 MHz filter. The query form returns the current constants in IEEE-488.2 definite block data format. See the AC Flatness Adjustment procedure for the 10 MHz filter for more information on the use of this command.

- **CALibration:DATA:SKEW <data>** transfers the calibration constant that is used by the skew DAC to synchronize the AFG’s DAC’s. The query form returns the current constant in IEEE-488.2 definite block data format. See the Skew DAC Adjustment procedure for more information on the use of this command.

---

**NOTE**

*The CAL:DATA:FILT and CAL:DATA:SKEW commands are available only on units with firmware rev A.02.00 or higher (use the *IDN? command to determine the AFG’s firmware revision).*

---

- **CALibration:STATet:AC <state>** enables or disables AC corrections using the calibration constants. If <state> is ON, corrections will be used. If <state> is OFF, corrections will not be used.

- **CALibration:STATet:DC <state>** enables or disables DC corrections using the calibration constants. If <state> is ON, corrections will be used. If <state> is OFF, corrections will not be used.

- **CALibration:STATet <state>** enables or disables both AC and DC corrections using the calibration constants. If <state> is ON, corrections will be used. If <state> is OFF, corrections will not be used.

- **PUD <data>** stores the specified data in non-volatile “protected user data” memory. The data must be sent in IEEE-488.2 definite or indefinite block format. The query form (*PUD?) returns the current protected user data in IEEE-488.2 definite block format.
Defeating Calibration Security

If the calibration security code is unknown, the security feature can be defeated by disassembling the AFG and moving the jumper on connector J104 (see Figure 3-1) to the unsecured position (left-most pins). To prevent accidental or unauthorized calibration, move the jumper back to the secured position (right-most pins) as soon as the security code has been set to the desired value (use the CALibration:SECure:CODE <code> command). Disassembly instructions can be found in Chapter 5.

Figure 3-1. Disabling Calibration Security
(shown in secured position)
DC Adjustment Procedure

Description

A DC adjustment is performed on the AFG by reading a series of voltages and resistances output by the AFG, then entering those values back into the AFG. After all measurements have been completed, new calibration constants are calculated and stored in non-volatile memory. To ensure accuracy, perform the DC calibration procedure at one year intervals.

This procedure uses a firmware routine to adjust the AFG’s DC calibration constants. The CALibration[:DC]:BEGIN command starts the DC calibration sequence and the CALibration[:DC]:POINT? command steps the AFG to the next calibration point. All AFG settings are performed by the firmware routine.

NOTE

If an error occurs at any time during the procedure, abort (*RST) and start over.

Equipment Setup

- Perform a complete autocalibration on the DMM (unless an autocal has been performed within the last 24 hours)
- Connect the equipment as shown in Figure 3-2

![Figure 3-2. DC Adjustment Setup](image_url)
DC Adjustment Procedure (cont’d)

Adjustment Procedure

1. Reset the AFG:

   *RST;*CLS

   \textit{Reset AFG and clear status registers}

2. Enable calibration on the AFG:

   CAL:SEC:STAT OFF, <security code>

   \textit{Cal security off}

   where \textit{<code>} is the AFG’s security code (factory-set to “E1445A”).

3. Send the command to start the DC adjustment routine and wait for the command to complete:

   CAL:DC:BEGIN

   *OPC?

   The AFG will return a "1" when ready.

\textit{Repeat steps 4 through 6 for calibration points 1 - 44:}

4. If the current calibration point is listed in Table 3-2, set up the DMM as specified. Otherwise, do not change the DMM settings. Note the special instructions for the following points:

   \textbf{Cal Point 31.} Immediately after performing the DMM measurement for cal point 30 (and before sending the reading to the AFG) set the DMM range to 10 V. This will prevent an overload when the AFG sets itself for the next reading.

   \textbf{Cal Point 41.} Immediately before setting up the DMM for cal point 41, take a reading using the DMM settings for cal point 40. This will provide a DC offset reading. Next, set up the DMM for cal point 41 as specified in Table 3-2. Then use the DC offset reading and Table 3-1 to determine the appropriate DMM range for subsequent calibration points.

   \textbf{Cal Point 43.} Same instructions as cal point 41.
DC Adjustment Procedure (cont’d)

Test Procedure (cont’d)

5. Trigger the DMM and note the reading.

6. Send the reading to the AFG:

```
CAL:DC:POINT? <reading>
```

where `<reading>` is the DMM reading from step 5. The AFG will return, in order, the number of the current cal point and an error code. Any non-zero error code indicates a failure.

<table>
<thead>
<tr>
<th>Absolute Value of DC Offset</th>
<th>DMM Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 10 mV</td>
<td>100 Ω</td>
</tr>
<tr>
<td>Between 10 mV and 100 mV</td>
<td>1000 Ω</td>
</tr>
<tr>
<td>Greater than 100 mV</td>
<td>Offset too high - abort cal</td>
</tr>
</tbody>
</table>

Table 3-2. DC Calibration Points

<table>
<thead>
<tr>
<th>Cal Point</th>
<th>DMM Settings (changes only)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DCV, 10 V range, 10 NPLC</td>
</tr>
<tr>
<td>29</td>
<td>1 V range, 20 NPLC</td>
</tr>
<tr>
<td>31</td>
<td>10 V*</td>
</tr>
<tr>
<td>33</td>
<td>100 mV range</td>
</tr>
<tr>
<td>41</td>
<td>4-wire ohms, offset comp on*</td>
</tr>
<tr>
<td>43</td>
<td>4-wire ohms, offset comp on*</td>
</tr>
</tbody>
</table>

*See Step 4 of the "DC Adjustment Procedure" for special instructions.
DC Adjustment Procedure (cont’d)

Example Program

10 ! RE-STORE "DC_ADJUST"
30 ! This program performs the firmware-guided DC adjustment procedure
40 ! for the HP E1445A Arbitrary Function Generator. An HP 3458A DMM
50 ! is required.
60 !
70 DIM Results(1:44)
80 INTEGER Cal_point,Max_cal_point,Problem,Err_num
90 !
100 !------------- Set up I/O paths -------------
110 ASSIGN @Afg TO 70910
120 ASSIGN @Dmm TO 722
130 !
140 !------------- Initialize variables -------------
150 Max_cal_point=44
160 Cal_point=0
170 Problem=0
180 Secure_code$="E1445A"
190 !
200 !------------- Initialize AFG and DMM -------------
210 OUTPUT @Afg;"RST;CLS"
220 OUTPUT @Dmm;"PRESET NORM"
230 !
240 !------------- Connections -------------
250 CLEAR SCREEN
260 PRINT "Connect the DMM to the AFG Output (4-wire connection)"
270 DISP "Press 'Continue' when ready"
280 PAUSE
290 CLEAR SCREEN
300 !
310 !------------- Setup AFG -------------
320 Cal_point=1
330 OUTPUT @Afg;"CAL:SEC:STATE OFF","&Secure_code$ !Disable cal security
340 OUTPUT @Afg;"CAL:DC:BEGIN" !Begin DC cal
350 OUTPUT @Afg;"*OPC?" !Wait for previous command to finish
360 ENTER @Afg;Not_busy
370 !
380 !------------- Start of loop -------------
390 REPEAT
400 DISP "DC Calibration in progress: Cal Point #"&VAL$(Cal_point)
410 !
420 GOSUB Setup_dmm !Change DMM settings, if necessary
430 GOSUB Read_dmm !Get reading
440 !

(Continued on next page)
DC Adjustment Procedure (cont'd)

Example Program (cont'd)

```
450 IF Cal_point=30 THEN  !Special case -- set range now
460 OUTPUT @Dmm;"RANGE 10"
470 END IF
480 !
490 OUTPUT @Afg;"CAL:DC:POINT? ";Reading  !Send cal value to AFG
500 ENTER @Afg;This_point,Err_num  !Returns current point, err code
510 WAIT .5
520 !
530 Results(Cal_point)=PROUN(D(Reading,.5))  !Increment Cal_point
540 Cal_point=Cal_point+1
550 UNTIL (Err_num<>0) OR (Cal_point>Max_cal_point)  !Increment Cal_point
560 !
570 !--------- End of loop ---------
580 !If error, print error number & cal point, else send PUD string
590 IF Err_num=0 THEN
600 PRINT "Calibration Successful"
610 !
620 !Store cal information if desired - place desired data inside quotes
630 !In following line and remove "s.
640 ! Pud$="63 CHARACTERS MAX"  !Change Pud$ as desired
650 ! OUTPUT @Afg;"PUD #0"&Pud$;CHR$(10);END
660 ELSE
670 PRINT "Calibration Error Number "&VAL$(Err_num)&" at Cal Point "&VAL$(Cal_point-1)
680 END IF
690 DISP
700 !
710 !--------- Quit -------
720 PAUSE
730 OUTPUT @Afg;"CAL:SEC:STATE ON"  !Enable cal security
740 OUTPUT @Afg;"RST"  !Reset AFG
750 OUTPUT @Dmm;"RESET"
760 LOCAL @Dmm  !Return DMM to local control
770 !
780 ASSIGN @Afg TO *
790 ASSIGN @Dmm TO *
800 STOP  !End of main program
810 !
820 !--------- Subroutines -------
830 !
840 Setup_dmm:  !
850 SELECT Cal_point
860 CASE =1  !Cal point 1
870 OUTPUT @Dmm;"FUNC DCV;RANGE 10;NPLC 10;OCOMP OFF"
880 CASE =29  !Cal point 29
890 OUTPUT @Dmm;"RANGE 1;NPLC 1"
```

(Continued on next page)
DC Adjustment Procedure (cont'd)

Example Program (cont'd)

```
900    CASE =31                                  !Cal point 31
910    OUTPUT @Dmm;"RANGE 10"
920    CASE =33                                  !Cal point 33
930    OUTPUT @Dmm;"RANGE .1"
940    CASE =41,=43                              !Cal point 41,43
950    OUTPUT @Dmm;"FUNC DCV;RANGE .1"
960    GOSUB Read_dmm                           !Read voltage - this will
970    !Determine ohms range for
980    !Measurements that follow
990    !
1000   OUTPUT @Dmm;"FUNC OHMF;OCOMP ON"
1010   !
1020   !Determine proper DMM range, using rdg from a few lines up
1030   SELECT ABS(Reading)                      !Use previous Rdg
1040   CASE <=1.0E-2                             !If Rdg<=10mV,
1050   OUTPUT @Dmm;"RANGE 100"
1060   CASE <=1.0E-1                             !IF 10mV<Rdg<=100mV,
1070   OUTPUT @Dmm;"RANGE 1000"
1080   CASE ELSE                                 !IF Rdg>100mV,
1090   Problem=1                                !Something is wrong
1100   END SELECT
1110   END SELECT
1120   RETURN
1130   !
1140   Read_dmm:                                 !
1150   OUTPUT @Dmm;"TRIG SGL"
1160   ENTER @Dmm;Reading                        !Get reading
1170   Reading=PROUND(Reading,-10)
1180   RETURN
1190   !
1200   END
```
AC Flatness Adjustment Procedure - 250 kHz Filter

Description

This procedure adjusts the AC calibration constants for the 250 kHz filter. The AC Flatness Test for the 250 kHz filter (see Chapter 2) is performed with AC corrections disabled. The results are used to calculate new calibration constants, which are then transferred to non-volatile memory.

Preliminary Procedure

- Perform a complete autocalibration on the DMM (unless an autocal has been performed within the last 24 hours).
- Determine the calibration constants by performing Test 2-5 (see Chapter 2), with the following modification: After resetting the AFG (step 1), turn off AC corrections using the CAL:STAT:AC OFF command.

Adjustment Procedure

1. Disable calibration security on the AFG:

   \texttt{CAL:SEC:STAT OFF, <security code>} \quad \textit{Cal security off}

   where \texttt{<code>} is the AFG’s security code (factory-set to "E1445A").

2. Verify that the calibration constants determined in the Preliminary Procedure are acceptable (see \texttt{SUB Valid_cons} in the example program).

3. Transfer the calibration constants to the AFG in arbitrary block data format:

   \texttt{CAL:DATA:AC1 <data>} \quad \textit{Transfer cal constants}

\underline{NOTE}

\textit{See \texttt{SUB Adj_flat} in the example program to see how step 3 is performed in \textit{HP BASIC}.}

Example Program

An example program that performs the AC flatness adjustment procedures for both filters is listed following the AC flatness adjustment procedure for the 10 MHz filter.
AC Flatness Adjustment Procedure - 10 MHz Filter

Description

This procedure adjusts the AC calibration constants for the 10 MHz filter. The AC Flatness Test for the 10 MHz filter (see Chapter 2) is performed with AC corrections disabled. The results are used to calculate new calibration constants, which are then transferred to non-volatile memory.

Preliminary Procedure

- Perform a complete autocalibration on the DMM (unless an autocal has been performed within the last 24 hours).
- Follow the manufacturer’s instructions for calibrating the Power Meter and correcting for the Power Sensor.
- Determine the calibration constants by performing Test 2-6 (see Chapter 2), with the following modification: After resetting the AFG (step 1), turn off AC corrections using the CAL:STAT:AC OFF command.

Adjustment Procedure

1. Disable calibration security on the AFG:

   CAL:SEC:STAT OFF, <security code>  \textit{Cal security off} \\

   where \texttt{<security code>} is the AFG’s security code (factory-set to "E1445A").

2. Verify that the calibration constants determined in the Preliminary Procedure are acceptable (see SUB Valid_cons in the example program).

3. If the firmware revision is A.02.00 or higher (use the *IDN? command to determine the firmware revision), transfer the two constants (4 and 25000) that determine the frequencies to be calibrated:

   CAL:DATA:FILT <data>

NOTE

\textit{See SUB Load_magic_num in the example program to see how step 3 is performed in HP BASIC.}
AC Flatness Adjustment Procedure - 10 MHz Filter  (cont’d)

Adjustment Procedure  
(cont’d)

NOTE

Rev A.02.00 (use the *IDN? command to determine the firmware revision) allows the 10 MHz filter to be replaced with a filter that has a lower cutoff frequency (the 10 MHz filter must be replaced at the factory). If the 10 MHz filter has been replaced, change the value for Max_freq in line 570 of the example program to the new cutoff frequency. Changing Max_freq may change the constants that are sent with the CAL:DATA:FILT command in step 3 (see SUB Load_magic_num).

4. Transfer the calibration constants to the AFG in arbitrary block data format:

CAL:DATA:AC2 <data>  
Transfer cal constants

NOTE

See SUB Adj_flat in the example program to see how step 4 is performed in HP BASIC.
AC Flatness Adjustment Procedure (cont'd)

Example Program

10 I RE-STORE "AC_FLAT"
30 I This program performs the AC flatness adjustment procedure for
40 I the HP E1445A Arbitrary Function Generator. An HP 3468A DMM
50 I and an HP 5902A Measuring Receiver are required.
60 I!
70 I To perform the flatness measurements without adjustments, change
80 I!Mode$ to "M" below.
90 I!
100 COM @Afg,@Dmm,@Pwr_mtr,@Analyzer,Secure_code$[12]
110 COM /Flat/ INTEGER Num_points,Max_con
120 CLEAR SCREEN
130 I!
140 I------------------- Set up I/O paths -------------------
150 ASSIGN @Afg TO 70910
160 ASSIGN @Dmm TO 722
170 ASSIGN @Pwr_mtr TO 714
180 Mode$="M"
190 Secure_code$="E1445A" !'M' means measure, 'A' means adjust
200 I! Calibration security code
210 CALL Flatness("250KHZ",Mode$)
220 CALL Flatness("10MHZ",Mode$)
230 I!
240 I---------------- QUIT ----------------
250 IRESET INSTRUMENTS
260 OUTPUT @Afg,"RST;"CLS"
270 OUTPUT @Pwr_mtr,"IP"
280 OUTPUT @Dmm,"RESET"
290 LOCAL @Dmm
300 LOCAL @Pwr_mtr
310 I!
320 ICLOSE I/O PATHS
330 ASSIGN @Afg TO *
340 ASSIGN @Dmm TO *
350 ASSIGN @Pwr_mtr TO *
360 STOP
370 I!
380 END
390 I!
400 I******************* End Of Main Program *******************
410 I!

(Continued on next page)
AC Flatness Adjustment Procedure (cont’d)

Example Program (cont’d)

420 Flatness:SUB Flatness(Filter$, Mode$)
430   COM @Afg, @Dmm, @Pwr_mtr, @Analyzer, Secure_code$
440   COM /Flat/ INTEGER Num_points, Max_con
450   INTEGER Filter, Ac_cal_int(1:2)
460   CLEAR SCREEN
470   !
480   !-------- Initialize variables --------
490   Ampl_dbm=24 ! AFG max amplitude
500   !
510   !-------- Main Program --------
520   IF Filter$="250KHZ" THEN
530     Num_points=25 ! Number of test points
540     Max_freq=2.50E+5
550     ELSE ! Else, 10M filter will be used
560     Num_points=27
570     Max_freq=1.08E+7
580     END IF
590   PRINT "FILTER = ", Filter$
600   !
610   ALLOCATE Test_freq(1:Num_points), Results(1:Num_points)
620   !
630   !Determine test frequencies
640   Step_size=Max_freq/Num_points
650   FOR I=1 TO Num_points
660     Test_freq(I)=Step_size*I
670     NEXT I
680   !
690   GOSUB Setup_afg
700   CALL Meas_flat(Test_freq($), Results($), Filter$)
710   !
720   IF Mode$="A" THEN
730     CALL Adj_flat(Results($), Filter$, Test_freq(Num_points))
740   END IF
750   !
760   DEALLOCATE Test_freq($), Results($)
770   SUBEXIT
780   !
790   Setup_afg: !
800   OUTPUT @Afg;"RST;"CLS"
810   WAIT .5
820   !

(Continued on next page)
AC Flatness Adjustment Procedure (cont’d)

Example Program (cont’d)

830 OUTPUT @Afg:"FUNC SIN:"; !Sine
840 OUTPUT @Afg:"VOLT "&VAL$(Amp_dbm)&"DBM:"; !Set amplitude
850 OUTPUT @Afg:"OUTP:LOAD 50" !50 ohm load
860 OUTPUT @Afg:"CAL:STATE:AC "&VAL$(Mode="M")" !Turn AC corrections
870 On if meas mode, or
880 Off if adjust mode
890 OUTPUT @Afg:"OUTP:FILT:FREQ "&Filter$ !Set filter
900 OUTPUT @Afg:"OUTP:FILT ON"
910 OUTPUT @Afg:"INIT:IMM"
920 WAIT 1
930 RETURN
940 SUBEND
950 !
960 Meas_flat:SUB Meas_flat(Test_freq(),Results(),Filter$)
970 COM @Afg,@Dmm,@Pwr_mtr,@Analyzer,Secure_code$
980 COM /Flat/ INTEGER Num_points,Max_con
990 INTEGER Dmm_setup,Pm_setup
1000 !
1010 !---------- Initialize variables ----------
1020 Ref_freq=1000 !Reference frequency
1030 Xover_freq=1E+5 !Crossover frequency
1040 Dmm_setup=1
1050 Pm_setup=1
1060 !
1070 !---------- Get ref readings ----------
1080 !
1090 PRINTER IS CRT
1100 !Get DMM reading at ref freq
1110 OUTPUT @Afg:"FREQ "&VAL$(Ref_freq)
1120 CALL Dmm_flat_rdq(Ref_freq,Dmm_ref,Dmm_setup)
1130 PRINT "DMM REF READING =";Dmm_ref
1140 !
1150 !If 10MHZ filter, get DMM & PWR MTR readings at crossover freq
1160 IF Filter$="10MHZ" THEN
1170 OUTPUT @Afg:"FREQ "&VAL$(Xover_freq)
1180 !
1190 CALL Dmm_flat_rdq(Xover_freq,Dmm_xover,Dmm_setup)
1200 PRINT "DMM XOVER READING =";Dmm_xover
1210 CALL Pm_flat_rdq(Xover_freq,Pm_xover,Pm_setup)
1220 Correct_factor=Dmm_xover/Pm_xover
1230 PRINT "POWER METER XOVER READING =";Pm_xover
1240 ELSE
1250 Correct_factor=1
1260 END IF

(Continued on next page)
Example Program (cont'd)

1270 Offset_factor=Dmm_ref
1280 PRINT "CORRECTION FACTOR =",Correct_factor
1290 PRINT
1300 PRINT
1310 PRINTER IS CRT
1320 !
1330 !
1340 !——— Perform measurements at test freqs ————
1350 !
1360 PRINT "  FREQ  READING (V)  ERROR (dBm)"
1370 PRINT "   ------  ------  -------"
1380 PRINT
1390 !
1400 FOR I=1 TO Num_points
1410 !Set AFG to test freq
1420 IF Test_freq(I)>1.073741824E+7 THEN  !SCPI can't do 10.8MHz
1430     GOSUB Max_afg_freq
1440 ELSE  !so use register commands
1450     OUTPUT @Afg:"FREQ "&VAL$(Test_freq(I))
1460 END IF
1470 !
1480 !Get reading
1490 IF Filter$="250KHZ" THEN  !If 250K filter,
1500     CALL Dmm_flat_rdg(Test_freq(I),Reading,Dmm_setup)
1510 ELSE  !If 10M filter,
1520     CALL Pm_flat_rdg(Test_freq(I),Reading,Pm_setup)
1530 END IF
1540 !Adjust reading  !Flat_result=Reading*Correct_factor
1550 !Convert to dBm error
1560 !Store result in array
1570 Results(I)=Flat_error_dbm  !Results(I)=(Test_freq(I)+13.0103E+2-(Offset_factor+13.0103E+2)
1580 !
1590 Freq$=FNFormat_num$(Test_freq(I),1.E+5,9,",M6","MD.2DESZ")
1600 Result_v$=FNFormat_num$(Flat_result,1.E+3,9,"M2D.5D","MD.3DESZ")
1610 Result_dbm$=FNFormat_num$(Flat_error_dbm,10,9,"M2D.5D","MD.3DESZ")
1620 PRINT USING "9A,5X,9A,5X,9A",Freq$,Result_v$,Result_dbm$
1630 NEXT I  !End of loop
1640 PRINT
1650 SUBEXIT
1660 !
1670 Max_afg_freq: !Set AFG to 10.8MHz with register level commands
1680 OUTPUT @Afg:"FREQ MAX"  !Get close with SCPI

(Continued on next page)
AC Flatness Adjustment Procedure (cont'd)

Example Program (cont'd)

1690 ! Use register commands to get to 10.8 MHz
1700 OUTPUT @Afg:"DIAG:POKE #HE000A1,8,0" ! PHASE_A1,0
1710 OUTPUT @Afg:"DIAG:POKE #HE000A3,8,126" ! PHASE_A2,126
1720 OUTPUT @Afg:"DIAG:POKE #HE000A5,8,95" ! PHASE_A3,95
1730 OUTPUT @Afg:"DIAG:POKE #HE000A7,8,64" ! PHASE_A4,64
1740 OUTPUT @Afg:"DIAG:POKE #HE0008D,8,0" ! LDSTBIND,0
1750 WAIT .1
1760 RETURN
1770 SUBEND
1780 !
1790 Adj_flat:SUB Adj_flat(Result$, Filter$, Max_freq)
1800 COM @Afg, @Dmm, @Pwr_mtr, @Analyzer, Secure_code$
1810 COM / Flat/ INTEGER Num_points, Max_con
1820 INTEGER Cal_problem, Problem
1830 !
1840 Cal_problem=0
1850 Scale_factor=1000
1860 STATUS @Afg, 3 ; Address ! Get path address
1870 !
1880 ALLOCATE INTEGER Ac_cal_cons(1:Num_points)
1890 FOR I=1 TO Num_points
1900 Ac_cal_cons(I)=Results(I)*Scale_factor ! Scale results array
1920 NEXT I
1930 !
1940 CALL Valid_cons(Results$( ),Cal_problem) ! Make sure constants are within range
1960 ! Transfer "magic numbers" if 10MHz filter
1970 IF Filter$="250KHZ" THEN
1980 Load_magic_num(Max_freq, Problem)
1990 IF Problem THEN
2000 PRINT "Problem occurred in Load_magic_num."
2010 Cal_problem=1
2020 END IF
2030 END IF
2040 !
2050 IF NOT Cal_problem THEN
2060 OUTPUT @Afg,"ABORT" ! Abort waveform
2070 !
2080 ! Store cal constants into eeprom (format off)
2090 OUTPUT @Afg,"CAL:SEC:STATE OFF,"&Secure_code$ ! Enable cal
2100 ASSIGN @Afg TO Address; FORMAT OFF
2110 IF Filter$="250KHZ" THEN
2120 PRINT "Changed 250KHz Cal constants"
2130 OUTPUT @Afg USING ",K","CAL:DATA:AC1 #0"
2140 ELSE
2150 PRINT "Changed 10MHz Cal constants"
2160 OUTPUT @Afg USING ",K","CAL:DATA:AC2 #0"
2170 END IF

(Continued on next page)
AC Flatness Adjustment Procedure (cont’d)

Example Program (cont’d)

```
2180 OUTPUT @Afg:Ac_cal_cons(*)    !Load array
2190 OUTPUT @Afg USING "#,K",CHR$(10),END    !LF,EOI
2200 !
2210 ASSIGN @Afg TO Address    !Back to default attributes
2220 OUTPUT @Afg;"CAL:SEC:STATE ON"    !Disable cal
2230 !
2240 PRINT "Flatness calibration constants stored to EEPROM"    !
2250 ELSE
2260 PRINT "Flatness calibration constants NOT stored to EEPROM"    !
2270 END IF
2280 !
2290 DISP "Press 'Continue' when ready"
2300 PAUSE
2310 DISP
2320 !
2330 DEALLOCATE Ac_cal_cons(*)
2340 SUBEND
2350 !
2360 Dmm_flat_rdgs:SUB Dmm_flat_rdgs(Freq,Rdg,INTEGER Dmm_setup)
2370 COM @Afg, @Dmm, @Pwr_mtr, @Analyzer, Secure_code$
2380 COM /Flat/ INTEGER Num_points, Max_con
2390 !
2400 IF Dmm_setup THEN    !If true, set up DMM
2410 !:otherwise, skip setup
2420 DISP "Connect DMM to AFG Output (with 50ohm termination), then press 'Continue""
2430 PAUSE
2440 DISP
2450 OUTPUT @Dmm;"PRESET NORM; FUNC ACV; SETACV SYNC; TRIG HOLD"
2460 OUTPUT @Dmm;"RANGE 10; DELAY .1"
2470 WAIT 1
2480 Dmm_setup=0    !Clear flag so setup is only performed once
2490 END IF
2500 !
2510 !
2520 OUTPUT @Dmm;"ACBAND "&VAL$(Freq*.9)&", "&VAL$(Freq*1.1)
2530 WAIT .5
2540 OUTPUT @Dmm;"TRIG SGL"
2550 ENTER @Dmm;Rdg
2560 SUBEND
2570 !
2580 Pm_flat_rdgs:SUB Pm_flat_rdgs(Freq,Rdg,INTEGER Pm_setup)
2590 COM @Afg, @Dmm, @Pwr_mtr, @Analyzer, Secure_code$
2600 COM /Flat/ INTEGER Num_points, Max_con
2610 !
2620 IF Pm_setup THEN    !If true, then set up Power Meter
2630 !:otherwise skip setup

(Continued on next page)
```
Example Program (cont’d)

2640 DISP "Connect Power Meter to AFG Output, then press 'Continue'"
2650 PAUSE
2660 DISP
2670 OUTPUT @Pwr_mtr;"IP" "Instrument preset"
2680 OUTPUT @Pwr_mtr;"AU M4 WT" "Auto operation, RF power, watts"
2690 WAIT .5
2700 Prn_setup=0 "Clear flag so that setup
2710 is only performed once
2720 END IF
2730 OUTPUT @Pwr_mtr;VAL$(Freq/1.E+6)&"MHZ" "Expected frequency"
2740 OUTPUT @Pwr_mtr;"T3" "Trigger Pwr Meter w/settling"
2750 ENTER @Pwr_mtr;Rdg "Get reading"
2760 !
2770 Rdg=SQRT(ABS(Rdg)*50) "Convert from watts to volts"
2780 SUBEND
2790 !
2800 Read_dc_cal_con:SUB Read_dc_cal_con(Cal_real())
2810 COM @Afg,@Dmm,@Pwr_mtr,@Analyzer,Secure_code$
2820 COM /Flat/ INTEGER Num_points,Max_con
2830 !
2840 Max_con=25
2850 ALLOCATE Scale(1:12),INTEGER Cal_reflect(1:Max_con)
2860 IF SIZE(Cal_real,1)<Max_con THEN
2870 PRINT "PASS PARAMETER NOT DIMENSIONED LARGE ENOUGH"
2880 BEEP
2890 END IF
2900 !
2910 !SET CAL CONSTANT SCALE FACTORS
2920 DATA 7E6 ,7E6 ,7E7 ,7E7 ,7E6
2930 ! M_plus,M_minus,M_adj,M_off,M_cust
2940 DATA 1E6 ,1E6 ,1E10 ,1E6 ,1E4
2950 ! Vpwr ,Vbuf ,M_sub, B_sum, dB ERROR
2960 DATA 4 ,0
2970 ! P&N BASE
2980 READ Scale(*)
2990 !
3000 OUTPUT @Afg,;"CAL:SEC:STATE OFF,"&Secure_code$
3010 !
3020 !Read cal constants back
3030 OUTPUT @Afg,;"CAL:DATA?"
3040 ENTER @Afg USING "4A,34(W)",Dummy$[1,4],Cal_reflect(*)
3050 !
3060 OUTPUT @Afg,;"CAL:SEC:STATE ON"
3070 !

(Continued on next page)
AC Flatness Adjustment Procedure (cont’d)

Example Program (cont’d)

FOR I=1 TO Max_con
Cal_real(I)=Cal_reflect(I)
IF I=1 THEN Cal_real(I)=Cal_reflect(I)/Scale(1)   ! M_plus
IF I=2 THEN Cal_real(I)=Cal_reflect(I)/Scale(11)  ! P_base
IF I=3 THEN Cal_real(I)=Cal_reflect(I)/Scale(2)   ! M_minus
IF I=4 THEN Cal_real(I)=Cal_reflect(I)/Scale(3)   ! M_adj
IF I=5 THEN Cal_real(I)=Cal_reflect(I)/Scale(11)  ! N_base
IF I>5 AND I<13 THEN Cal_real(I)=Cal_reflect(I)/Scale(10) ! Filter and
                      ! ATTN gain errors
IF I=13 THEN Cal_real(I)=Cal_reflect(I)/Scale(4)   ! M_off
IF I=14 THEN Cal_real(I)=Cal_reflect(I)/Scale(5)   ! M_cust
IF I=15 THEN Cal_real(I)=Cal_reflect(I)/Scale(6)   ! Vpwo
IF I=16 THEN Cal_real(I)=Cal_reflect(I)/Scale(7)   ! Vpwi
IF I=17 THEN Cal_real(I)=Cal_reflect(I)/Scale(8)   ! Vbxr
IF I=18 THEN Cal_real(I)=Cal_reflect(I)/Scale(9)   ! M_sum
IF I=19 THEN Cal_real(I)=Cal_reflect(I)/Scale(9)   ! B_sum
IF I>21 THEN Cal_real(I)=Cal_reflect(I)/Scale(10)  ! Zout gain errors
NEXT I
DEALLOCATE Scale(*), Cal_reflect(*)
SUBEND

Valid_cons:SUB Valid_cons(Results(*), INTEGER Cal_problem)
COM @Afp, @Dmm, @Pwr_mtr, @Analyzer, Secure_code$
COM /Flat/ INTEGER Num_points, Max_con
Max_con=25
Cal_problem=0
ALLOCATE Cal_real(1:Max_con)

CALL Read_dc_cal_con(Cal_real(*))
!CHECK FOR VALID CAL
M_plus=Cal_real(1)   ! key cal constant
P_base=Cal_real(2)   ! +base
M_minus=Cal_real(3)  ! key cal constant
M_adj=Cal_real(4)    ! key cal constant
N_base=Cal_real(5)   ! -base

!Check that cal constants are reasonable—if not, use nominal values
IF (M_plus<=-.005 OR M_plus>=-.003) THEN M_plus=-3.834E-3
IF (M_minus<=-.005 OR M_minus>=-.003) THEN M_minus=-3.834E-3
IF (M_adj<=-.0012 OR M_adj>=-.0009) THEN M_adj=-.001021
IF (P_base<3180 OR P_base>3889) THEN P_base=3535
IF (N_base<10 OR N_base>245) THEN N_base=128

(Continued on next page)
AC Flatness Adjustment Procedure (cont'd)

Example Program (cont'd)

```plaintext
!Check for valid cal
Max_filter_db=MAX(Cal_real(6),Cal_real(7),0)
Min_filter_db=MIN(Cal_real(6),Cal_real(7),0)
!
Max_attn_db=0
Min_attn_db=0
FOR I=8 TO 12
  IF Cal_real(I)>0 THEN
    Max_attn_db=Max_attn_db+Cal_real(I)
  ELSE
    Min_attn_db=Min_attn_db+Cal_real(I)
  END IF
NEXT I
!
Max_zout_db=MAX(Cal_real(22),Cal_real(23),Cal_real(24),Cal_real(25),0)
Min_zout_db=MIN(Cal_real(22),Cal_real(23),Cal_real(24),Cal_real(25),0)
!
Max_pos_gain_db=-1*MAX(Results(*,0)-(Max_filter_db+Max_attn_db+Max_zout_db)-1.02
Min_pos_gain_db=-1*MIN(Results(*,0)-(Min_filter_db+Min_attn_db+Min_zout_db)-1.02
!
!Calculate P_inc's and N_inc's
Max_p_inc=10^((Max_pos_gain_db)/20)-1/M_plus
Min_p_inc=10^((Min_pos_gain_db)/20)-1/M_plus
Max_n_inc=(Max_p_inc*(M_plus-M_minus))/M_adj
Min_n_inc=(Min_p_inc*(M_plus-M_minus))/M_adj
!
Max_gaindac=P_base+Max_p_inc
Min_gaindac=P_base+Min_p_inc
Max_todac=N_base+Max_n_inc
Min_todac=N_base+Min_n_inc
!
PRINT "GAIN DAC EXTREMES: MAX,MIN = "&VALS(PROUND(Max_gaindac,-1))&", "&VALS(PROUND(Max_gaindac,-1))"
PRINT "TURNOVER DAC EXTREMES: MAX,MIN = "&VALS(PROUND(Max_to_dac,-1))&", "&VALS(PROUND(Max_to_dac,-1))"
!
IF Max_gaindac>4075 OR Min_gaindac<20 THEN ! If out of range
  Cal_problem=1 ! Set flag
  PRINT "GAIN DAC OUT OF RANGE"
END IF
!
IF Max_to_dac>247 OR Min_to_dac<8 THEN ! If out of range
  Cal_problem=1 ! Don't store constants
  PRINT "TURNOVER DAC OUT OF RANGE"
END IF
!
 DEALLOCATE Cal_real(*)
SUBEND
! (Continued on next page)

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AC Flatness Adjustment Procedure (cont’d)

Example Program (cont’d)

```
4020 SUB Syst_err(Address)
4030 COM @Afg,@Dmm,@Pwr_mtr,@Analyzer,Secure_code$
4040 COM /Flat/ INTEGER Num_points,Max_con
4050 DIM Message$[256]
4060 REPEAT
4070   OUTPUT Address;"SYST:ERR?"
4080   ENTER Address;Code,Message$
4090   PRINT Code,Message$
4100 UNTIL NOT Code
4110 SUBEND
4120 !
4130 Load_magic_num:SUB Load_magic_num(Max_freq,OPTIONAL INTEGER Problem)
4140 COM @Afg,@Dmm,@Pwr_mtr,@Analyzer,Secure_code$
4150 COM /Flat/ INTEGER Num_points,Max_con
4160 INTEGER Num_cal_points,N,Div
4170 ALLOCATE Id$[50],INTEGER Block(1:2),Ac_int(1:2)
4180 !
4190 !Check firmware rev - if A.01.00 then exit
4200 OUTPUT @Afg;"*IDN?"
4210 ENTER @Afg;Id$
4220 IF POS(Id$,"A.01.00") THEN SUBEXIT
4230 !
4240 STATUS @Afg,3;Address                      !Get path address
4250 !
4260 IF NPAR>1 THEN Problem=0
4270 Num_cal_points=27
4280 !
4290 Cal_step=Max_freq/Num_cal_points              !Step size
4300 !
4310 !Calculate N
4320 N=INT(LGT(Cal_step/32768)/LGT(2))+1
4330 N=MAX(N,1)
4340 N=MIN(N,8)
4350 !
4360 !Calculate Div
4370 Div=Cal_step/(2^N)
4380 Div=MAX(Div,1)
4390 Div=MIN(Div,32767)
4400 !
4410 IF Cal_step->PROOUND((2^N)*Div),4) THEN
4420 IF NPAR>1 THEN Problem=1
```

(Continued on next page)
AC Flatness Adjustment Procedure (cont'd)

Example Program (cont'd)

4430 ELSE
4440 Block(1)=N
4450 Block(2)=Div
4460 !
4470 OUTPUT @Afg:"CAL:SEC:STATE OFF","&Secure_code$ !Enable cal
4480 ASSIGN @Afg TO Address;FORMAT OFF
4490 OUTPUT @Afg USING ",#K","CAL:DATA:FILTER 0"
4500 OUTPUT @Afg;Block(*)
4510 OUTPUT @Afg USING ",#K","CHRS$(10),END
4520 ASSIGN @Afg TO Address !Back to default attributes
4530 OUTPUT @Afg:"CAL:SEC:STATE ON" !Disable cal
4540 !
4550 PRINT "MAGIC NUMBERS STORED: ";N,Div
4560 PRINT
4580 END IF
4590 SUBEND
4600 !
4610 Read_ac_cal_int:SUB Read_ac_cal_int(INTEGER Ac_cal_int(*))
4620 COM @Afg,@Dmm,@Pwr_mtr,@Analyzer,Secure_code$
4630 COM /Flat/ INTEGER Num_points,Max_con
4640 !
4650 ALLOCATE Id$[50]
4660 !
4670 OUTPUT @Afg:"IDN?"
4680 ENTER @Afg;Id$
4690 !
4700 IF POS(Id$,"A.01.00") THEN
4710 Ac_cal_int(1)=4
4720 Ac_cal_int(2)=25000
4730 SUBEXIT
4740 END IF
4750 !
4760 Max_con=2
4770 !
4780 ! IF SIZE(Ac_cal_int,1)<=Max_con OR RANK(Ac_cal_int)<=1 THEN
4790 !
4800 STATUS @Afg,3;Address
4810 !
4820 OUTPUT @Afg:"CAL:SEC:STATE OFF","&Secure_code$
4830 OUTPUT @Afg:"CAL:DATA:FILTER?"
4840 ASSIGN @Afg TO Address;FORMAT OFF
4850 ENTER @Afg USING "3A,2(W);Dummy$(1,3),Ac_cal_int(*)
4860 ASSIGN @Afg TO Address
4870 OUTPUT @Afg:"CAL:SEC:STATE ON"
4880 !
4890 PRINT Ac_cal_int(*)
4900 SUBEND

(Continued on next page)
AC Flatness Adjustment Procedure (cont’d)

Example Program (cont’d)

4910  
4920  SUB Security_code  
4930  COM @Afg,@Dmm,@Pwr_mtr,@Analyzer,Secure_code$  
4940  COM /Flat/ INTEGER Num_points,Max_con  
4950  CLEAR SCREEN  
4960  OUTPUT @Afg,"**RST;**CLS"  
4970  !  
4980  Valid=0  
4990  REPEAT  
5000  Secure_code$="E1445A"  
5010  INPUT "Enter your security code <default is 'E1445A'>";Secure_code$  
5020  Secure_code$=TRIMS(Secure_code$)  
5030  Check_sec_code(Valid)  
5040  UNTIL Valid  
5050  SUBEND  
5060  !  
5070  !  
5080  SUB Check_sec_code(Valid)  
5090  COM @Afg,@Dmm,@Pwr_mtr,@Analyzer,Secure_code$  
5100  COM /Flat/ INTEGER Num_points,Max_con  
5110  DIM Message$[256]  
5120  Valid=0  
5130  CLEAR SCREEN  
5140  DISP "Verifying security code..."  
5150  WAIT 1  
5160  OUTPUT @Afg,"CAL:SEC:STAT OFF,"&Secure_code$  
5170  OUTPUT @Afg,"SYST:ERR?"  
5180  ENTER @Afg;Code.Message$  
5190  DISP  
5200  !  
5210  IF Code<>0 THEN  
5220  BEEP 1000,1  
5230  PRINT "Invalid security code -- try again"  
5240  OUTPUT @Afg,"**RST;**CLS"  
5250  DISP "Press 'Continue'"  
5260  PAUSE  
5270  SUBEXIT  
5280  ELSE  
5290  Valid=1  
5300  PRINT "Security code accepted"  
5310  WAIT 1  
5320  OUTPUT @Afg,"**RST;**CLS"  
5330  END IF  
5340  CLEAR SCREEN  
5350  SUBEND  
5360  !  
5370  !  

(Continued on next page)
AC Flatness Adjustment Procedure (cont'd)

Example Program (cont'd)

5380 Format_num:DEF FNFormat_num$(Value,Not_exp_max,INTEGER Length,Not_exp_img$,Exp_img$)
5390 INTEGER Diff
5400 SELECT ABS(Value)
5410 CASE <1.E-9,>=1.E+10
5420 IF NOT POS(Exp_img$,"Z") THEN
5430 OUTPUT String$ USING Exp_img$&"Z.#",Value
5440 ELSE
5450 OUTPUT String$ USING Exp_img$&"#",Value
5460 END IF
5470 CASE <1.E-4,>=Not_exp_max
5480 OUTPUT String$ USING Exp_img$&",#",Value
5490 CASE ELSE
5500 OUTPUT String$ USING Not_exp_img$&",#",Value
5510 END SELECT
5520 !
5530 Diff=Length-LEN(String$)
5540 IF Diff>0 THEN String$=RPT$(",Diff)&String$
5550 RETURN String$
5560 FNEND
5570 !
5580 !
Skew DAC Adjustment Procedure

Description

This procedure compensates for time delays between the AFG's two DACs. The skew setting which produces the lowest second harmonic amplitude is found and loaded into non-volatile memory.

Equipment Setup

- Connect the equipment as shown in Figure 3-3
- Set up the Spectrum Analyzer:
  
  Center Frequency = 8 MHz  
  Frequency Span = 3.2 kHz

![Diagram of equipment setup](image)

Figure 3-3. Skew DAC Adjustment Setup

Adjustment Procedure

1. Reset the AFG:

   *RST
Skew DAC Adjustment Procedure (cont’d)

Adjustment Procedure (cont’d)

2. Set up the AFG to output an 11 dBm, 4 MHz sinewave:

   FUNC SIN;
   :VOLT 11 DBM;
   :FREQ 4E6
   INIT: IMM

3. Load an initial value of 128 into the delay DAC:

   DIAG:POKE #HE0000B,8,2
   DIAG:POKE #HE0000D,8,128
   DIAG:POKE #HE0000B,8,7
   DIAG:POKE #HE0000D,8,8

4. With the Spectrum Analyzer, locate and center the second harmonic. Then, reduce the frequency span to 2 kHz.

5. Find the delay DAC setting that minimizes the amplitude of the second harmonic (see the example program).

6. Disable calibration security on the AFG:

   CAL:SEC:STAT OFF, <security code>  
   Cal security off

   where <code> is the AFG’s security code (factory-set to "E1445A").

7. Transfer the calibration constant (DAC setting) to the AFG in arbitrary block data format:

   CAL:DATA:SKEW <data >  
   Transfer cal constant

---

NOTE

See the example program to see how step 7 is performed in HP BASIC.

---

8. Enable calibration security on the AFG:

   CAL:SEC:STAT ON  
   Cal security on
Skew DAC Adjustment Procedure (cont’d)

Example Program

10 ! RE-STORE "SKEW_CAL"
20   COM @Afg, @Analyzer, Secure_code$[20]
30   INTEGER Dac_bits, Dac_word, Min_word, Max_word, Step_size, Harmonic
40   INTEGER Loc_min, Cal_word, Search_loop, Max_search_loop, Filter, Skew_con
50   DIM Id$[50]
60   !
70 !------- Assign I/O paths -------
80   ASSIGN @Afg TO 70910
90   ASSIGN @Analyzer TO 718
100 !
110 !------- Check firmware rev -------
120 !Rev A.01.00 does not support this cal procedure
130   OUTPUT @Afg;"""IDN?"
140   ENTER @Afg;id$
150 !
160   IF POS(id$,"A.01.00") THEN
170     PRINT "This rev does not support skew DAC calibration."
180     STOP
190   END IF
200 !
210 !------- Initialize variables -------
220   Secure_code$="E1445A"  !AFG security code
230   Harmonic=2  !Harmonic to be minimized
240   Filter=0  !No filter
250   Freq=4.E+6  !AFG frequency (Hz)
260   Amp_in_dbm=11  !AFG amplitude (dBm)
270   Search_span$=VAL$(Freq*Harmonic*4.00E-4)  !Initial Spec Analyzer span
280   Test_span$="2000"  !Span used for measurements
290 !
300   Dac_bits=8
310   Start_step_size=16
320   Step_size=Start_step_size
330   Max_search_loop=4
340   Dac_word=2**(Dac_bits-1)  !Initial Dac_word
350   Max_word=2**(Dac_bits)  !Initial max
360   Min_word=0  !Initial min
370 !
380 !------- Test connections -------
390   PRINT "Connect Spectrum Analyzer to AFG Ouput."
400   DISP "Press 'Continue' when ready"
410   PAUSE
420   CLEAR SCREEN
430 !

(Continued on next page)
Skew DAC Adjustment Procedure (cont'd)

Example Program (cont'd)

```plaintext
440 !------ Perform cal ------
450 OUTPUT @Afg:"RST;CLS;OPC?" !Reset AFG
460 ENTER @Afg:Result
470 !
480 !Set up Spec Analyzer
490 Setup_spec(VALS(Amp_in_dbm-2)"DM",VALS(Freq*Harmonic),Search_span$)
500 !
510 !Set up AFG
520 OUTPUT @Afg:"FUNC SIN;"
530 OUTPUT @Afg:"VOLT "&VALS(Amp_in_dbm)&"DBM;"
540 OUTPUT @Afg:"FREQ "&VALS(Freq)
550 OUTPUT @Afg:"INIT:IMM"
560 Load_delay_dac(Dac_word) !Load constant into register
570 !
580 !Capture and center 2nd harmonic
590 Get_2nd_harm(Test_span$)
600 !
610 !Begin cal search loop
620 Search_loop=1
630 REPEAT
640 ALLOCATE INTEGER Word_array(0:((Max_word-Min_word)/Step_size))
650 ALLOCATE REAL Meas_array(0:((Max_word-Min_word)/Step_size))
660 Array_counter=0
670 !
680 PRINT "LOOP =";Search_loop
690 PRINT
700 PRINT "CONSTANT"," READING"
710 PRINT "-----"," ----"
720 !
730 !Find constant that produces minimum 2nd harmonic
740 FOR I=Min_word TO Max_word STEP Step_size
750 IF I=256 THEN
760 Dac_word=255
770 ELSE
780 Dac_word=I
790 END IF
800 Load_delay_dac(Dac_word) !Load constant into register
810 Word_array(Array_counter)=Dac_word
820 !
830 !Measure 2nd_harmonic, store in array
840 Meas_2nd_harm(Word_array(Array_counter))
850 PRINT Word_array(Array_counter),DROUND(Meas_array(Array_counter),8)
860 Array_counter=Array_counter+1
870 NEXT I
880 !

(Continued on next page)
```
Skew DAC Adjustment Procedure (cont’d)

Example Program (cont’d)

```
890 ! Set variables for next loop
900   MAT SEARCH Meas_array,LOC MIN;Loc_min            ! Get location of min rdg
910   Cal_word=Word_array(Loc_min)
920   Min_word=Word_array(MAX(0,Loc_min-1))
930   Max_word=Word_array(MIN((SIZE(Word_array,1)-1),Loc_min+1))
940   Step_size=Step_size/INT(SQRT(Start_step_size)+.5)  ! Reduce step size
950   !
960   PRINT
970   PRINT
980   !
990   DEALLOCATE Meas_array(*),Word_array(*)
1000  Search_loop=Search_loop+1
1010  UNTIL Step_size<1
1020  !
1030  PRINT "CAL CONSTANT =";Cal_word
1040  PRINT
1050  Wrt_skew_con(Cal_word)                   ! Write word to eeprom
1060  !
1070  !------ Quit ------
1080  OUTPUT @Afg:"RST,"CLS"
1090  ASSIGN @Afg TO *
1100  ASSIGN @Analyzer TO *
1110  STOP
1120  END
1130  !
1140  Load_delay_dac:SUB Load_delay_dac(INTEGER Delay_dac)
1150   COM @Afg,@Analyzer,Secure_code$
1160   INTEGER Lower_8,Benign_chan1
1170   !
1180   Benign_chan1=1
1190   Lower_8=BINAND(Delay_dac,255)
1200   !
1210  OUTPUT @Afg:"DIAG:POKE #HE0000B,8,2"
1220  OUTPUT @Afg:"DIAG:POKE #HE0000D,8,"&VAL$(Lower_8)
1230  OUTPUT @Afg:"DIAG:POKE #HE0000B,8,7"
1240  OUTPUT @Afg:"DIAG:POKE #HE0000D,8,"&VAL$(Benign_chan1+7)
1250  WAIT .1
1260  SUBEND
1270  !

(Continued on next page)
```
Skew DAC Adjustment Procedure (cont’d)

Example Program (cont’d)

1280 WRt_skw_con:SUB WRt_skw_con(INTEGER Cal_word)
1290 COM @Afg.@Analyzer,Secure_code$
1300 DIM Id$[50]
1310 !
1320 !Check firmware rev
1330 OUTPUT @Afg;"IDN?"
1340 ENTER @Afg;Id$
1350 !
1360 IF POS(Id$,"A.01.00") THEN
1370 PRINT "This rev does not support skew DAC calibration."
1380 CALL Abort_error
1390 END IF
1400 !
1410 STATUS @Afg,3;Address !Get path address
1420 !
1430 OUTPUT @Afg;"CAL:SEC:STAT OFF,"&Secure_code$
1440 ASSIGN @Afg TO Address;FORMAT OFF
1450 OUTPUT @Afg USING "#K","CAL:DATA:SKEW #0"
1460 OUTPUT @Afg;Cal_word
1470 OUTPUT @Afg USING "#K",CHR$(10),END
1480 ASSIGN @Afg TO Address
1490 OUTPUT @Afg;"CAL:SEC:STAT ON"
1500 !
1510 PRINT "Skew constant written to AFG."
1520 SUBEND
1530 !
1540 Setup_spec:SUB Setup_spec(Amp_in_dbm$,Center$,Span$)
1550 COM @Afg.@Analyzer,Secure_code$
1560 OUTPUT @Analyzer;"IP;RB 100HZ;VB 100HZ" !Preset, set res & vid BW
1570 OUTPUT @Analyzer;"RL "&Amp_in_dbm$ !Set ref level
1580 OUTPUT @Analyzer;"SP "$&Span$&"HZ" !Set freq span
1590 OUTPUT @Analyzer;"CF "$&Center$ !Set center frequency
1600 SUBEND
1610 !
1620 Get_2nd_harm:SUB Get_2nd_harm(Test_span$)
1630 COM @Afg.@Analyzer,Secure_code$
1640 OUTPUT @Analyzer;"S2;TS;E1" !Peak search
1650 OUTPUT @Analyzer;"MKCF" !Center freq to marker
1660 OUTPUT @Analyzer;"SP "$&Test_span$&"HZ" !Narrow span
1670 SUBEND
1680 !

(Continued on next page)
Skew DAC Adjustment Procedure (cont'd)

Example Program (cont'd)

1690 Meas_2nd_harm:SUB Meas_2nd_harm(Reading)
1700  COM @Afg.@Analyzer,Secure_code$
1710  OUTPUT @Analyzer;"TS:E1" !Find peak
1720  OUTPUT @Analyzer;"MA" !Measure amplitude
1730  ENTER @Analyzer;Reading
1740  SUBEND
1750  !
1760  Read_skew_con:SUB Read_skew_con(INTEGER Skew_cal_con)
1770  COM @Afg.@Analyzer,Secure_code$
1780  ALLOCATE Id$[50]
1790  !
1800  OUTPUT @Afg;"IDN?"
1810  ENTER @Afg;Id$
1820  IF POS(Id$,"A.01.00") THEN
1830  Skew_cal_con=128
1840  SUBEXIT
1850  END IF
1860  !
1870  STATUS @Afg,3;Address
1880  !
1890  OUTPUT @Afg;"CAL:SEC:STAT OFF,&Secure_code$
1900  OUTPUT @Afg;"CAL:DATA:SKEW?"
1910  ASSIGN @Afg TO Address;FORMAT OFF
1920  ENTER @Afg USING "5A,1(W),Dummy$[1,3],Skew_cal_con
1930  ASSIGN @Afg TO Address
1940  OUTPUT @Afg;"CAL:SEC:STAT ON"
1950  SUBEND
Chapter 4
Replaceable Parts

Introduction
This chapter contains information for ordering replaceable parts for the HP E1445A AFG.

Exchange Assemblies
Table 4-1 lists assemblies that may be replaced on an exchange basis (NEW/EXCHANGE ASSEMBLIES). Exchange 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.

Ordering Information
To order a part listed in Table 4-1, 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 4-1 lists the user-replaceable parts for the HP E1445A AFG. See Figure 4-1 for locations of user-replaceable parts. Table 4-2 lists the reference designators for the AFG. Table 4-3 is the code list of manufacturers.
<table>
<thead>
<tr>
<th>Reference Designator</th>
<th>HP Part Number</th>
<th>Qty</th>
<th>Part Description</th>
<th>Mfr. Code</th>
<th>Mfr. Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDL1</td>
<td>E1400-45102*</td>
<td>1</td>
<td>HANDLE-BOTTOM METAL INJECTION MOLDING</td>
<td>28480</td>
<td>E1400-45102*</td>
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<tr>
<td>HDL2</td>
<td>E1400-45101*</td>
<td>1</td>
<td>HANDLE-TOP METAL INJECTION MOLDING</td>
<td>28480</td>
<td>E1400-45101*</td>
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<tr>
<td>HDW010</td>
<td>0380-1858</td>
<td>2</td>
<td>STANDOFF-HEX .312-IN-LG 4.4-40-THD</td>
<td>05791</td>
<td>SF1904-00</td>
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<tr>
<td>HDW011</td>
<td>2180-0004</td>
<td>2</td>
<td>WASHER-LK INTL T NO .4 .115-IN-ID</td>
<td>78189</td>
<td>SF1904-00</td>
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<tr>
<td>HDW11-HDW15</td>
<td>2950-0354</td>
<td>5</td>
<td>NUT-HEX-DBL-CHAM 1/2-28-THD 1/25-IN-THK</td>
<td>2950-0054</td>
<td>SF1904-00</td>
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<tr>
<td>HDW17-HDW21</td>
<td>5050-0324</td>
<td>5</td>
<td>WASHER- 7/16 IN .5-IN-ID .75-IN-OD</td>
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<td>MP1</td>
<td>8160-0686</td>
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<td>CLIP-RFI STRIP-FINGERS BE-CU SN-PL</td>
<td>30817</td>
<td>00786-185</td>
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<tr>
<td>MP2-MP5</td>
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<td>EMI STRIP</td>
<td>28480</td>
<td>E1400-01202</td>
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<tr>
<td>PNL1</td>
<td>E1445-00202*</td>
<td>1</td>
<td>FRONT PANEL</td>
<td>28480</td>
<td>E1445-00202*</td>
</tr>
<tr>
<td>SCR1-SCR8</td>
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<td>SCREW: MACHINE M3 X 0.5 25MM-LG-HD</td>
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<td>0515-0430</td>
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<tr>
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<td>TOP SHIELD</td>
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<tr>
<td>SHD2</td>
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<td>BOTTOM SHIELD</td>
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<td>E1445-00502*</td>
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<td>A1</td>
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<td>PCA- DAC MAIN</td>
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<tr>
<td>CR610-CR613</td>
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<td>5</td>
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<td>72619</td>
<td>535-0302</td>
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<tr>
<td>CR614</td>
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<td>72619</td>
<td>535-0321</td>
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<tr>
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<td>LED-LAMP ARRAY LUM-INT=1.5MCD, GREEN LENS</td>
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<td>535-0302</td>
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<td>1990-1507</td>
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<td>72619</td>
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<tr>
<td>F301-F305</td>
<td>2110-0699</td>
<td>5</td>
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<td>227676-1</td>
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<td>JM1-JM7</td>
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<td>JUMPER-REMOVABLE 2 POSITION, .250 IN</td>
<td>00779</td>
<td>531220-2</td>
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<td>SP301-SP302</td>
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<td>SWITCH-DIP ROCKER 8-1A 0.05A 30VDC</td>
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<td>75Y22318S</td>
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<td>U501</td>
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<td>1813-0831</td>
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<td>CLOCK-OSCILLATOR-XTAL 42.945672-MHz</td>
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</tr>
</tbody>
</table>

* These parts are not compatible with older versions of the E1445A that have plastic handles. To replace one of these parts on an older E1445A, you must order all five of the parts marked with a *.  

118 Replaceable Parts
HP E1445A Service Manual
Table 4-2. HP E1445A Reference Designators

<table>
<thead>
<tr>
<th>HP E1445A Reference Designators</th>
</tr>
</thead>
<tbody>
<tr>
<td>A .................................. assembly</td>
</tr>
<tr>
<td>CR .................................. diode</td>
</tr>
<tr>
<td>HDL .................................. handle</td>
</tr>
<tr>
<td>HDW .................................. hardware</td>
</tr>
<tr>
<td>J .................................. electrical connector (jack)</td>
</tr>
<tr>
<td>JM .................................. jumper</td>
</tr>
<tr>
<td>F .................................. fuse</td>
</tr>
<tr>
<td>MP .................................. mechanical part</td>
</tr>
<tr>
<td>PNL .................................. panel</td>
</tr>
<tr>
<td>SCR .................................. screw</td>
</tr>
<tr>
<td>SHD .................................. shield</td>
</tr>
<tr>
<td>SP .................................. switch</td>
</tr>
<tr>
<td>U .................................. integrated circuit</td>
</tr>
</tbody>
</table>

Table 4-3. HP E1445A Code List of Manufacturers

<table>
<thead>
<tr>
<th>Mfr. Code</th>
<th>Manufacturer's Name</th>
<th>Manufacturer's Address</th>
<th>Zip Code</th>
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<tr>
<td>00779</td>
<td>AMP INC</td>
<td>HARRISBURG, PA US</td>
<td>17111</td>
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<tr>
<td>05701</td>
<td>LYN-TRON INC</td>
<td>BURBANK, CA US</td>
<td>91505</td>
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<tr>
<td>18573</td>
<td>DUPONT E.I. DE NUMOURS &amp; CO CORPORATE</td>
<td>WILMINGTON, DE US</td>
<td>19801</td>
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<tr>
<td>28480</td>
<td>HEWLETT PACKARD COMPANY - CORPORATE</td>
<td>PALO ALTO, CA US</td>
<td>94304</td>
</tr>
<tr>
<td>30887</td>
<td>INSTRUMENT SPECIALTIES INC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>72619</td>
<td>DIALIGHT CORP</td>
<td>OAKWOOD, OH US</td>
<td></td>
</tr>
<tr>
<td>75915</td>
<td>LITTEL FUSE INC</td>
<td>BLOOMFIELD, NJ US</td>
<td>11237</td>
</tr>
<tr>
<td>78189</td>
<td>ILLINOIS TOOL WORKS INC</td>
<td>DES PLAINES, IL US</td>
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<td>SHAKEPROOF</td>
<td>ELGIN, IL US</td>
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<td>81073</td>
<td>GRAYHILL INC</td>
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<td>85466</td>
<td>ELCO INDUSTRIES INC</td>
<td>LA GRANGE, IL US</td>
<td>60525</td>
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<tr>
<td>86528</td>
<td>SEASTROM MFG CO</td>
<td>ROCKFORD, IL US</td>
<td>61125</td>
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<td></td>
<td></td>
<td>GLENDALE, CA US</td>
<td>91201</td>
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</table>
Figure 4-1. HP E1445A Replaceable Parts
Chapter 5
Service

Introduction

This chapter contains service information for the HP E1445A AFG, including troubleshooting guidelines and repair/maintenance guidelines.

WARNING

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

Equipment Required

Equipment required for AFG troubleshooting and repair is listed in Table 1-1, Recommended Test Equipment. Any equipment that satisfies the requirements given in the table may be substituted. To avoid damage to the screw head slots, use T8 and T10 Torx drivers as described in the disassembly instructions later in this chapter.

Service Aids

See Chapter 4 for descriptions and locations of HP E1445A replaceable parts. Service notes, manual updates, and service literature for the AFG may be available through Hewlett-Packard. For information, contact your nearest Hewlett-Packard Sales and Support Office.
Troubleshooting Techniques

Identifying the Problem

To troubleshoot an HP E1445A problem, you should first identify the problem, and then isolate the cause to a user-replaceable part.

AFG problems can be divided into three general categories:

- Operator errors
- Catastrophic failures
- Performance out of specification

Operator Errors

Apparent failures may result from operator errors. See Appendix B in the HP E1445A User's Manual for information on operator errors.

Catastrophic Failure

If a catastrophic failure occurs, see "Testing the Assembly" to troubleshoot the AFG.

Performance Out of Specification

If the AFG fails any of its Performance Tests, perform the adjustments described in Chapter 3, then repeat the Performance Tests.

Testing the Assembly

You can use the tests and checks in Table 5-1 to isolate the problem. See Figure 4-1 in Chapter 4 for locations of user-replaceable parts.

Table 5-1. HP E1445A Tests/Checks

<table>
<thead>
<tr>
<th>Test/Check</th>
<th>Reference Designator</th>
<th>Check:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Damage</td>
<td>-</td>
<td>Discolored PC boards</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Damaged insulation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Evidence of arcing</td>
</tr>
<tr>
<td>AFG/Jumper Settings</td>
<td>A1BG0 - A1BG3, A1SP301, A1SP302</td>
<td>Bus Request level setting</td>
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<tr>
<td></td>
<td></td>
<td>LADDR setting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Servant Area setting</td>
</tr>
<tr>
<td>AFG PCAs</td>
<td>A1F301 - A1F305</td>
<td>Fuse continuity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Damaged connectors</td>
</tr>
</tbody>
</table>
Checking for Heat Damage

Inspect the AFG 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 AFG until you have corrected the problem.

Checking Switches/Jumpers

Verify that the logical address setting is set correctly (factory set at 80). Verify that the bus request level and servant area settings are correct. See the HP E1445A User's Manual for information.

Checking the AFG PCAs

Check fuse continuity and inspect all connectors for bent pins or damaged contacts.

Disassembly

Use the following procedure to disassemble the AFG (see Figure 5-1):

1. Remove the nine T10 Torx screws on the right side panel.
2. Remove the front panel handles using a T-8 TORX driver.
3. Remove the hex standoffs and washers from the front panel digital port connector.
4. Remove the nuts and washers from the front panel BNC’s.

Figure 5-1. HP E1445A Disassembly
Removing BNC Connectors

Use the following steps to remove the AFG front panel BNC connectors (refer to Figure 5-2):

1. Unsolder wires
2. Remove the two T8 torx screws
3. Remove the BNC connector
4. Reverse the order to reinstall the connector

Figure 5-2. Removal of BNC Connectors
This section provides guidelines for repairing and maintaining the HP E1445A AFG, including:

- ESD precautions
- Soldering printed circuit boards
- Post-repair safety checks

**ESD Precautions**

Electrostatic discharge (ESD) may damage static sensitive devices in the HP E1445A AFG. This damage can range from slight parameter degradation to catastrophic failure. When handling AFG assemblies, follow these guidelines to avoid damaging AFG components:

- Always use a static-free work station with a pad of conductive rubber or similar material when handling AFG components.

- If a device requires soldering, be sure the assembly is placed on a pad of conductive material. Also, be sure that you, the pad, and the soldering iron tip are grounded to the assembly.

**Soldering Printed Circuit Boards**

When soldering to any circuit board, keep in mind the following guidelines:

- 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 that the equipment is properly grounded.

**Post-Repair Safety Checks**

After making repairs to the HP E1445A AFG, inspect the AFG 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 perform the Self-Test described in Chapter 2 to verify that the AFG is functional.