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Certification

Hewlett-Packard Company certifies that this product met its published specifications at the time of shipment from the factory. Hewlett-Packard further certifies that its calibration measurements are traceable to the United States National Institute of Standards and Technology (formerly National Bureau of Standards), to the extent allowed by that organization's calibration facility, and to the calibration facilities of other International Standards Organization members.

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Limitation Of Warranty

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HP E1445A User's Manual
Edition 3

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Documentation History

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

Edition 1 November 1991
Edition 2 November 1992
Edition 3 March 1997

Trademarks

Windows® is a U.S. registered trademark of Microsoft Corporation.
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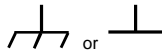
Safety Symbols



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



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



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



Alternating current (AC).



Direct current (DC).



Indicates hazardous voltages.

WARNING

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

CAUTION

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

WARNINGS

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

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

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

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

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

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

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

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

Declaration of Conformity
according to ISO/IEC Guide 22 and EN 45014

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

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

declares, that the product:

Product Name: Arbitrary Function Generator

Model Number: HP E1445A

Product Options: All

conforms to the following Product Specifications:

Safety: IEC 1010-1 (1990) Incl. Amend 2 (1995)/EN61010-1/A2 (1995)
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): 4 kVCD, 8 kVAD
IEC 801-3:1984/EN50082-1 (1992): 3 V/m
IEC 801-4:1988/EN50082-1 (1992): 1 kV Power Line
0.5 kV Signal Lines

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

Tested in a typical HP C-Size VXI Mainframe.

July 29, 1996



Jim White, QA Manager

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Notes

Chapter Contents

This chapter shows you how to configure, install, and begin using the HP E1445A Arbitrary Function Generator (AFG). The main sections of this chapter include:

- Preparation for Use Page 19
 - VXIbus Factory Settings Page 20
 - The AFG Logical Address Page 21
 - Addressing the AFG Page 22
 - Setting the AFG Servant Area Page 23
 - The AFG Bus Request Level Page 24
 - AFG Installation in a Mainframe Page 25
- Instrument Language (SCPI) Page 26
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Preparation for Use

This section contains the HP E1445A AFG VXIbus information required to configure the device and install it in the HP 75000 Series C mainframe.

Note The following VXIbus configuration information pertains to the HP E1445A Arbitrary Function Generator. For more (VXIbus) system configuration information, refer to the *C-Size VXIbus Systems Configuration Guide*.

VXibus Factory Settings

The HP E1445A AFG (shown in Figure 1-1) is configured at the factory as shown in Table 1-1.

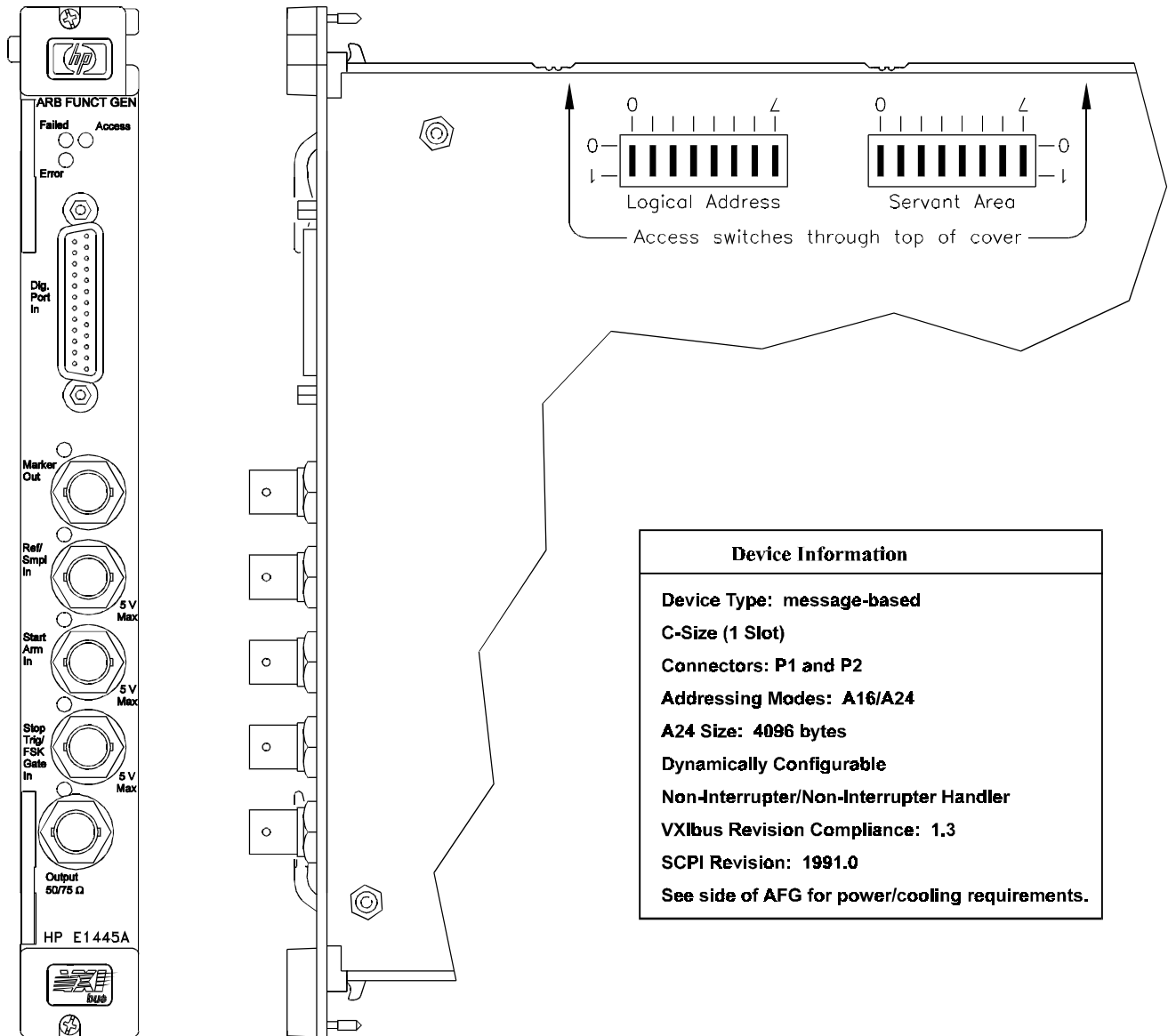


Figure 1-1. The HP E1445A Arbitrary Function Generator

Table 1-1. HP E1445A VXibus System Factory Settings

Parameter	Setting
Logical Address	80
Servant Area	0
Bus Request Level	3

Note Appendix A has the complete list of HP E1445A VXIbus system specifications.

The AFG Logical Address

The HP E1445A AFG logical address is used:

- to place the AFG in the servant area of a commander (HP E1406A Command Module or an embedded controller, for example);
- with the AFG servant area switch to set the AFG servant area;
- and to address the AFG (see “Addressing the AFG” on page 22 and “Using an Embedded Controller” on page 23.)

Assigning the AFG to a Commander

In a VXIbus system, every device must be in the servant area of a commander (with the exception of the top-level commander).

Note the following when assigning the HP E1445A AFG to a commander:

- A commander’s servant area is defined as:
Servant area = (logical address + 1) through
(logical address + servant area switch setting)
- The HP E1445A AFG is a message-based device. If an embedded controller and an HP E1406A Command Module are part of your VXIbus system, put the AFG in the servant area of the controller. This enables you to program the AFG at higher speeds across the VXIbus backplane, rather than over the Hewlett-Packard Interface Bus (HP-IB*) via the command module.
- If your system uses an external controller and the HP E1406A Command Module, put the AFG in the servant area of the command module. This enables the module to function as the HP-IB interface to the arbitrary function generator.

The HP E1406A Command Module has a factory set logical address of 0 and a servant area switch setting of 255. Using the factory settings, it is not necessary to change the logical address of the AFG (80) to place it in the servant area of the command module.

The HP E1445A AFG logical address switch is shown in Figure 1-2.

* HP-IB is Hewlett-Packard’s implementation of IEEE Std. 488.1-1978

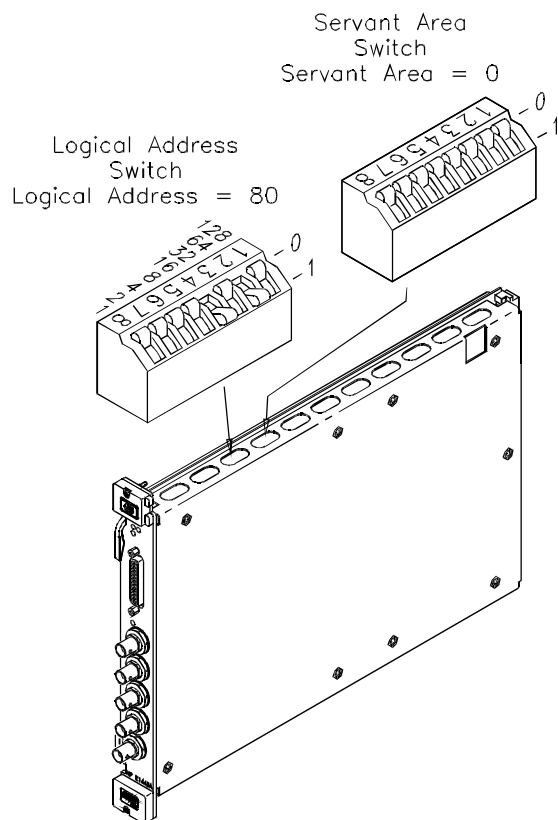


Figure 1-2. HP E1445A Logical Address and Servant Area Switch Location

Addressing the AFG (External Controller and PC)

Devices in the C-size mainframe and in the servant area of the HP E1406A Command Module are located by an HP-IB address. The HP-IB address is a combination of the controller's interface select code, the command module's primary HP-IB address, and the device's secondary HP-IB address. An address in this form in a HP BASIC statement appears as:

```
OUTPUT 70910;"SOUR:ROSC:SOUR INT1;;TRIG:STAR:SOUR INT1"
```

Interface Select Code (7): This code is determined by the address of the HP-IB interface card in the controller. In most Hewlett-Packard controllers, this card has a factory set address of 7, including the HP 82340/82341 HP-IB Interface Card (this card was used with an HP Vectra PC to create the Visual BASIC and Visual C/C++ example programs).

Primary HP-IB Address (09): This is the address of the HP-IB port on the command module. Valid addresses are 0 to 30. The module has a factory set address of 9.

Secondary HP-IB Address (10): This address is derived from the logical address of the device (AFG) by dividing the logical address by 8. Thus, for the HP E1445A AFG factory set logical address of 80, the secondary address is 10.

Using an Embedded Controller

As a message-based device, the HP E1445A can easily be programmed across the VXIbus backplane from an embedded controller. The select code of the VXI interface board in embedded controllers is typically 16. Since no secondary HP-IB address is required when programming over the backplane, the logical address of the HP E1445A is combined with the VXI interface select code.

For example, to send commands to the AFG with logical address 80, the OUTPUT statement in an HP BASIC program appears as:

```
OUTPUT 1680;"SOUR:ROSC:SOUR INT1;;TRIG:STAR:SOUR INT1"  
(for device logical addresses from 01 to 99)
```

or

```
OUTPUT 160xxx;"SOUR:ROSC:SOUR INT1;;TRIG:STAR:SOUR INT1"  
(for device logical addresses from 100 to 255)
```

Setting the AFG Servant Area

The HP E1445A servant area is set when the HP E1446A Summing Amplifier/DAC is used with the Arbitrary Function Generator. Note the following when setting the AFG servant area:

- The HP E1445A servant area need only be set when the HP E1446A Summing Amplifier/DAC is used with the AFG (factory setting = 0).
- The HP E1446A must be in the AFG servant area in order for the AFG to control the Summing Amplifier/DAC.
- The HP E1445A servant area is defined as:
Servant area = (logical address + 1) through
(logical address + servant area switch setting).
- The HP E1446A Summing Amplifier/DAC should be the only device in the AFG servant area. Other devices in the servant area would be inaccessible to other commanders (HP E1406A Command Module, for example).

The HP E1445A AFG servant area switch is shown in Figure 1-2.

The AFG Bus Request Level

The bus request level is a priority at which the HP E1445A can request the use of the Data Transfer Bus.

Bus Request Level Guidelines

- There are four bus request lines (BG0–BG3) from which one is selected (Figure 1-3). Bus request line 3 has the highest priority, bus request line 0 has the lowest priority.
- It is not necessary to change the bus request level setting (BG3) on the AFG. (More information on the Data Transfer Bus can be found in the *C-Size VXIbus Systems Configuration Guide*.)

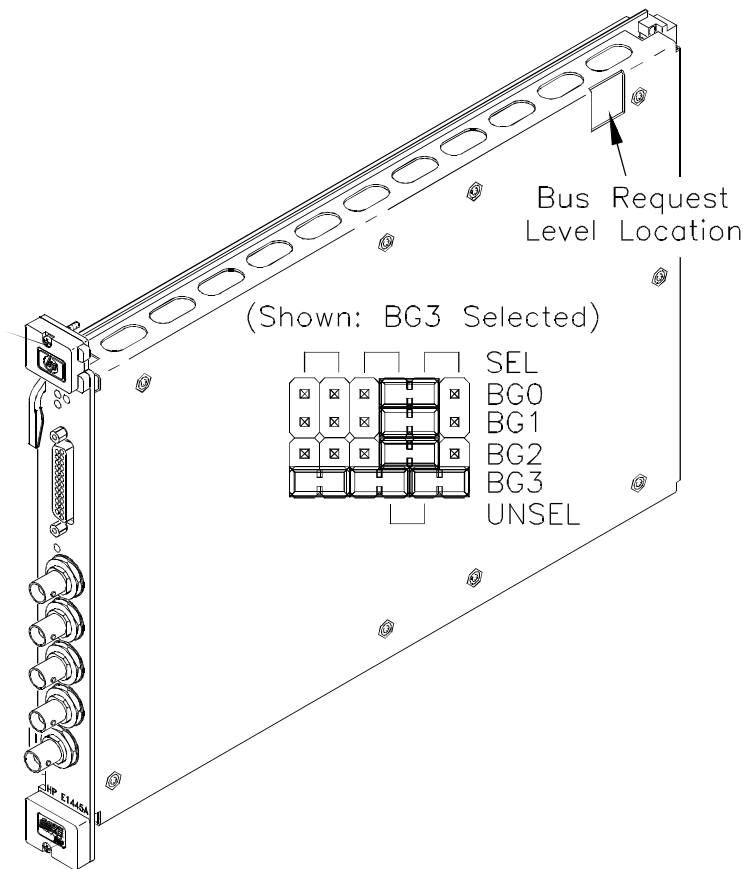


Figure 1-3. Setting the AFG Bus Request Level

AFG Installation in a Mainframe

The HP E1445A may be installed in any slot (except slot 0) in a C-size VXIbus mainframe. If an HP E1446A Summing Amplifier/DAC is part of your system, the amplifier *should* be installed in a slot next to the HP E1445A.

To install in a mainframe:

1. Set the extraction levers out. Slide the module into any slot (except slot 0) until the backplane connectors touch.
2. Seat the module by moving the levers toward each other.
3. Tighten the top and bottom screws to secure the module in the mainframe.

Note

For compliance with European EMI standards, order the Backplane Connector Shield Kit HP Part Number E1400-80920.

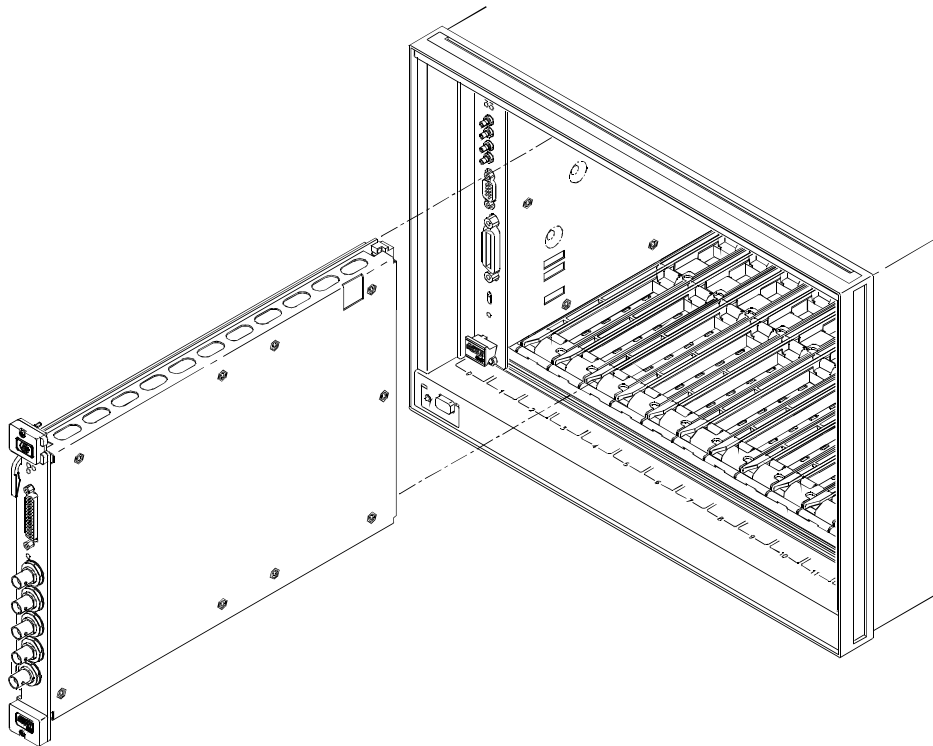


Figure 1-4. Installing the AFG Module in a VXIbus Mainframe

Removing a Module

To remove a module from a mainframe:

1. Loosen the top and bottom screws securing the module in the mainframe.
2. Move the extraction levers away from each other. As the levers are moved, the module will detach from the backplane connectors.
3. Slide the module out.

Note The extraction levers will not seat and unseat the backplane connectors on older HP VXibus mainframes and non-HP mainframes. You must manually seat the connectors by pushing the module into the mainframe until the front panel is flush with the front of the mainframe. The extraction levers may be used to guide or remove the module.

Instrument Language (SCPI)

The HP E1445A AFG uses the Standard Commands for Programmable Instruments (called SCPI) as the instrument control language. The programs shown in this manual are written in HP BASIC which uses the SCPI commands for instrument controls. These programs, and also programs in other languages, are contained on the CD that came with the instrument (see “Program Languages” on page 29 for more information).

SCPI Programming

SCPI (Standard Commands for Programmable Instruments) is an ASCII-based instrument command language designed for test and measurement instruments. The message-based AFG has an on-board microprocessor which interprets the ASCII command strings and returns ASCII formatted results.

SCPI Command Structure

The HP E1445A SCPI command set is found in Chapter 8. SCPI commands are based on a hierarchical structure, also known as a tree system. In this system, associated commands are grouped together under a common node or root, thus, forming subtrees or subsystems. An example is the HP E1445's ARM subsystem shown below.

```
ARM
  [:START]:SEquence[1]]
    [:LAYer[1]]
      :COUNT <number>
    :LAYer2
      :COUNT <number>
      [:IMMediate]           [no query]
      :SLOPe <edge>
      :SOURce <source>

  :SWEep]:SEquence3
    :COUNT <number>
    [:IMMediate]           [no query]
    :LINK <link>
    :SOURce <source>
```

ARM is the root keyword of the command, [:START]:SEquence[1]] and :SWEep]:SEquence3 are second-level keywords, [:LAYer[1]] and :LAYer2

are third-level keywords, and so on. A colon (:) always separates a command keyword from a lower-level keyword as shown below.

```
ARM:LAY2:SOUR EXT
```

A semicolon (;) is used to separate two commands within the same subsystem, and can also save typing. For example, sending this command message:

```
ARM:LAY2:SOUR EXT;SLOP POS;COUN 10
```

Is the same as sending these three commands:

```
ARM:LAY2:SOUR EXT  
ARM:LAY2:SLOP POS  
ARM:LAY2:COUN 10
```

Manual Format The typical format of commands listed in the command reference and throughout this manual is:

```
[SOURce:]FREQuency[1]:MODE <mode>
```

Command headers enclosed in square brackets ([]) are optional. Upper-case letters in the header are required, lower-case letters can be omitted.

Note The brackets are not part of the command and are not sent to the instrument.

To aid in learning the AFG command set, all headers are included in the example programs; however, the headers are abbreviated. In an example program, the previous statement with a <mode> parameter of FIX would appear as:

```
SOUR:FREQ1:MODE FIX
```

Command Coupling Many of the AFG SCPI commands are value coupled. This means that the value set by one command may affect the valid limits for the values of other commands. This can result in "Settings Conflict" errors when the program executes. To prevent these errors, the AFG commands must be executed in "Coupling Groups". The coupling groups are frequency and voltage. Some commands (like [SOURce:]FUNctio[n]:SHAPE) are associated with both groups. These commands are a bridge, linking (coupling) the two groups. Commands not in a coupling group must precede or follow commands in the coupling groups. Executing uncoupled commands in a coupling group breaks the coupling and can cause a "Settings Conflict" error.

The coupling groups and associated commands can be found in Table B-2 in Appendix B.

Executing Coupled Commands

Command coupling determines the AFG programming sequence. The high-level sequence, based on the coupling groups, is shown in Figure 1-5.

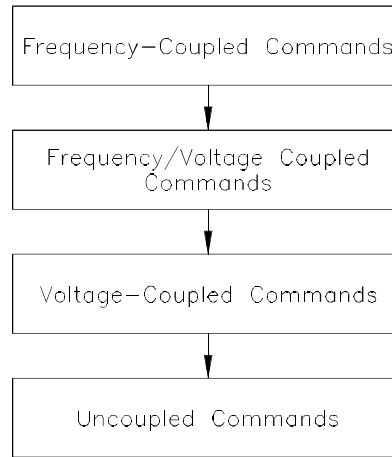


Figure 1-5. High-Level HP E1445A Programming Sequence

Coupled commands must be contiguous and executed in the same program statement. This is done by placing the commands in the same program line, or by suppressing the end-of-line terminator until the last (coupled) command has been sent.

To send multiple commands in a single line or in a single statement, the commands are linked with a semicolon (;) and a colon (:). This is illustrated in the following lines:

```
SOUR:ROSC:SOUR INT2;;TRIG:STAR:SOUR INT2
```

or

```
SOUR:ROSC:SOUR INT2;  
:TRIG:STAR:SOUR INT2
```

Both techniques are used in the programs found throughout this manual.

Note that the semicolon (;) *and* colon (:) link commands within different subsystems. Only a semicolon (;) is required to link commands within the same subsystem (see “SCPI Command Structure” on page 26).

Note See page 31 for information on suppressing the end-of-line terminator.

Program Languages

The program language shown in this manual is HP BASIC. This language was selected since it easily shows how to program the AFG.

However, the same programs (except where noted) are also supplied in Visual C/C++ and Visual BASIC using the HP Standard Instrument Control Library (SICL). The programs using SICL are Windows® programs. All programs are supplied on the CD that came with this manual (see next section).

Example Program CD

To determine the location of the different programs and the required libraries, read the “README” files. The different directories are:

- VBPROG for Visual BASIC programs
- VCPROG for Visual C/C++ programs

HP BASIC Language Programs

The following information identifies the system on which the HP BASIC programs were written and shows how the programs are structured.

System Configuration

Except where noted, the example programs in HP BASIC were developed on the following system:

Controller:	HP 9000 Series 300
Mainframe:	HP 75000 Series C
Slot 0/Resource Manager:	HP E1406A Command Module
HP E1445A Logical Address:	80
Instrument Language:	SCPI

Typical HP BASIC Example Program The structure of an example program in HP BASIC is shown below. This program enables output leveling by sweeping.

```

1  !RE-STORE"SWP_LEVEL"
2  !This program enables output leveling over the 0 Hz to 10 MHz sweep.
3  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 COM @Afg
40 !
50 !Set up error checking
60 ON INTR 7 CALL Errmsg
70 ENABLE INTR 7;2
80 OUTPUT @Afg;"*CLS"
90 OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms
130 CALL Rst
140 CALL Swp_level
150 !
160 WAIT .1 !allow interrupt to be serviced
170 OFF INTR 7
180 END
190 !
200 SUB Swp_level
210 Swp_level: !Subprogram which sets output leveling for sweeping from
220           !0 TO 10 MHz
230           COM @Afg
240           OUTPUT @Afg;"SOUR:FREQ1:MODE SWE;";           !sweep mode
250           OUTPUT @Afg;" :SOUR:FREQ1:STAR 0;";           !start frequency
260           OUTPUT @Afg;" :SOUR:FREQ1:STOP 10E6;";           !stop frequency
270           OUTPUT @Afg;" :SOUR:SWE:COUN INF;";           !sweep count
280           OUTPUT @Afg;" :SOUR:FUNC:SHAP SIN;";           !function
290           OUTPUT @Afg;" :SOUR:VOLT:LEV:IMM:AMPL 5 V";           !amplitude
300           OUTPUT @Afg;"OUTP1:FILT:LPAS:FREQ 10 MHZ";           !filter cutoff frequency
310           OUTPUT @Afg;"OUTP1:FILT:LPAS:STAT ON";           !enable output filter
320           OUTPUT @Afg;"INIT:IMM";           !wait-for-arm state
330           SUBEND
340           !
350           SUB Rst
360 Rst: !Subprogram which resets the E1445.
370           COM @Afg
380           OUTPUT @Afg;"*RST;*OPC?";           !reset the AFG
390           ENTER @Afg;Complete
400           SUBEND
410           !
420           SUB Errmsg
430 Errmsg: !Subprogram which displays E1445 programming errors
440           COM @Afg

```

Continued on Next Page

```

450     DIM Message$(256)
460     !Read AFG status byte register and clear service request bit
470     B=SPOLL(@Afg)
480     !End of statement if error occurs among coupled commands
490     OUTPUT @Afg;"
500     OUTPUT @Afg;"ABORT"                                !abort output waveform
510     REPEAT
520         OUTPUT @Afg;"SYST:ERR?"                        !read AFG error queue
530         ENTER @Afg;Code,Message$
540         PRINT Code,Message$
550     UNTIL Code=0
560     STOP
570     SUBEND

```

Turning Off (Suppressing) the End-Of-Line Terminator

As mentioned earlier, coupled commands must be contiguous and executed in the same program statement. By suppressing the end-of-line (EOL) terminator (Line Feed) on a command line, coupled commands can be sent on separate lines, yet as a single program statement.

In HP BASIC programs, the EOL terminator is suppressed by placing a semicolon (;) following the quotation mark (") which closes the command string. In the previous program, the commands in lines 240–270 are in the frequency coupling group, line 280 is in the frequency/voltage coupling group, and line 290 is in the voltage coupling group. The semicolons following the command strings in lines 240 through 280 suppress the EOL terminator; therefore lines 240–290 are sent as a single statement. Since the command in line 290 is not coupled to the commands in lines 300–320, the EOL terminator is not suppressed on line 290.

Visual BASIC Language Programs Using HP SICL

These example programs are written in the Visual BASIC language for the HP 82340/82341 HP-IB Interface Cards using the HP Standard Instrument Control Library (SICL).

The following identifies the system on which the programs are written, shows how to compile the programs, and gives a typical example program.

System Configuration

The Visual BASIC programs were developed on the following system:

Controller:	HP Vectra PC
HP-IB Interface Card:	HP 82341 HP-IB Interface with HP SICL
Required Program:	See “What’s Needed to Run the Programs” below
Mainframe:	HP 75000 Series C
Slot 0/Resource Manager:	HP E1406A Command Module
HP E1445A Logical Address:	80
Instrument Language:	SCPI

What’s Needed to Run the Programs

You need to include the “SICL.BAS” program file in your Visual BASIC project to run the example programs. To add the file, be sure you have opened a project you will be using. Then, Press Ctrl-D and enter the path and file name or select the “Add File” menu item under the “File” menu and select the SICL.BAS file (see the Visual BASIC documentation for more information).

How to Run a Program

You can run the example program in the Visual BASIC environment or compile it to make an executable file. Use the appropriate menu in the environment to compile the program (see the Visual BASIC documentation for more information). Note that the program can only operate under Windows®.

Typical Visual BASIC Example Program Using HP SICL

The following is an example program written in Visual BASIC using the HP Standard Instrument Control Library. The program:

- sends commands to the AFG to generate an arbitrary waveform;
- receives data from the AFG;
- shows how to send coupled commands;
- and performs error checking of the AFG.

Only program codes are given here. Refer to the actual program on the CD to see the data that generates the form, buttons, etc.

```
' ARBWAVE.FRM - This program generates a 100 points ramp. The data to generate  
' the ramp is transferred to the AFG as comma separated voltages
```

```
' Instrument HP-IB address  
Const ShowAddr = "hpib7,9,10"  
Dim Addr As Integer
```

```
Dim ChkName As String
```

```
Sub CheckError (SubName As String)  
' Check for any errors
```

```
Dim Actual As Long  
Dim RdErr As String * 256  
Dim Work As String  
Dim ErrNum As Integer  
Dim TempName As String
```

```
TempName = ChkName  
ChkName = "CheckError"
```

```
' Read error message  
Call iwrite(Addr, ByVal "SYSTem:ERRor?" + Chr$(10), 14, 1, Actual)  
Call iread(Addr, ByVal RdErr, 256, 0, Actual)
```

```
' If error was detected  
ErrNum = Val(RdErr)
```

```
If ErrNum <> 0 Then
```

```
    ' Store message only into Work string  
    Work = Mid$(RdErr, 1, Actual - 1)  
    Work = Work + " - in Sub " + SubName
```

```
    ' Enable and clear error list box  
    ShowErr.Enabled = True  
    ShowErr.Visible = True  
    ShowErr.Clear
```

Continued on Next Page

```

Action.Text = "The program generated the following error(s):"

    ' Show error message
ShowErr.AddItem Work

    ' Loop until error message is 0
Do

    ' Read error message
Call iwrite(Addr, ByVal "SYSTEM:ERRor?" + Chr$(10), 14, 1, Actual)
Call iread(Addr, ByVal RdErr, 256, 0, Actual)

    ' Store message only into Work string
Work = Mid$(RdErr, 1, Actual - 1)

    ' Get error number
ErrNum = Val(Work)

    ' If error, show error message
If ErrNum <> 0 Then
    Work = Work + " - in Sub " + SubName
    ShowErr.AddItem Work
End If

Loop Until (ErrNum = 0)

    ' Close communication with instrument
Call iclose(Addr)

    ' Clean up sicl
Call sicleanup

    ' Press to exit
DispErr = "The program detected errors in sub/function: " + SubName + Chr$(10)
DispErr = DispErr + Chr$(10) + ShowErr + "Press " + Chr$(34) + "OK" + Chr$(34) + " to exit!"
MsgBox DispErr, 64, "sw_vbs: CheckError"

End

End If

ChkName = TempName

End Sub

Sub CmdExe (Cmd() As String)
    ' This sub sends SCPI commands
Dim Cnt As Integer
Dim Actual As Long

```

Continued on Next Page

```

Cnt = 1

While Len(Cmd(Cnt))

    ' Send SCPI command
    Call iwrite(Addr, ByVal Cmd(Cnt) + Chr$(10), Len(Cmd(Cnt)) + 1, 1, Actual)

    Cnt = Cnt + 1
Wend

End Sub

Sub ExitProg_Click ()

    ' End program
    End

End Sub

Sub Form_Load ()

    ' Disable showing exit program button and lists
    ExitProg.Visible = False
    ShowQuery.Visible = False

    ' Show Action
    Action.Enabled = False
    Action.Visible = True

    ' Enable form
    Arbwave.Visible = True

    ' Call program to execute instrument
    Call Main

    ' Enable showing exit program button and make it the focus
    ExitProg.Visible = True
    ExitProg.SetFocus

End Sub

Sub GenSeg ()
    ' Setup AFG to generate an arbitrary waveform

    Static SetCommands(1 To 10) As String
    Static OutCommands(1 To 10) As String
    Dim SegCommand As String

```

Continued on Next Page

Dim Actual As Long

```
' Use the "SetCommands" array to setup the AFG
SetCommands(1) = "SOUR:LIST1:SSEQ:DEL:ALL" ' Clear sequence memory
SetCommands(2) = "SOUR:LIST1:SEGM:DEL:ALL" ' Clear segment memory

SetCommands(3) = "SOUR:ROSC:SOUR INT1;" ' Select the Ref. Oscillator
SetCommands(3) = SetCommands(3) + ":TRIG:STAR:SOUR INT1;" ' Select the sample source"
SetCommands(3) = SetCommands(3) + ":SOUR:FREQ1:FIX 100E3;" ' Set the sample frequency
SetCommands(3) = SetCommands(3) + ":SOUR:FUNC:SHAP USER;" ' Command to select the user
function
SetCommands(3) = SetCommands(3) + ":SOUR:VOLT:LEV:IMM:AMPL 5.1V" ' Set the amplitude

SetCommands(4) = "SOUR:LIST1:SEGM:SEL ramp" ' Define the "ramp" segment name
SetCommands(5) = "SOUR:LIST1:SEGM:DEF 100" ' Define the segment size

' Use the "OutCommands" array to generate output
OutCommands(1) = "SOUR:LIST1:SSEQ:SEL ramp_out" ' Define the sequence name as "ramp_out"
OutCommands(2) = "SOUR:LIST1:SSEQ:DEF 1" ' Define the sequence size
OutCommands(3) = "SOUR:LIST1:SSEQ:SEQ ramp" ' Set the segment execution order
OutCommands(4) = "SOUR:FUNC:USER ramp_out" ' Define the user name
OutCommands(5) = "INIT:IMM" ' Start waveform generation

' Use "SegCommand" to store segments
SegCommand = "SOUR:LIST1:SEGM:VOLT " ' Command to send volts data

' Setup the AFG
Call CmdExe(SetCommands())

' Call sub to check for AFG errors
Call CheckError("GenSeg (SetCommands)")

' Generating and storing segments into string
For I = 0 To 99
  If I = 99 Then
    SegCommand = SegCommand + Str$(I * .0505)
  Else
    SegCommand = SegCommand + Str$(I * .0505) + ","
  End If
Next I

' Send command with segment data
Call iwrite(Addr, ByVal SegCommand + Chr$(10), Len(SegCommand) + 1, 1, Actual)

' Call sub to check for AFG errors
Call CheckError("GenSeg (SegCommand)")

' Setup the AFG for output
Call CmdExe(OutCommands())
```

Continued on Next Page


```

' Call sub to check for AFG errors
Call CheckError("GenSeg (OutCommands)")

End Sub

Sub Main ()
' Main sub

Dim Actual As Long

' Set error routine
On Error GoTo AfgErr

ChkName = "Main"

' Open communication path
Addr = iopen(ShowAddr)

' Set timeout for 10 Sec
Call itimeout(Addr, 10000)

' Reset and clear the module
Action.Text = "Resetting the AFG; please wait"
ChkName = "RstClr"
Call RstClr

' Generate segment list and output sequence
Action.Text = "Generate Segments"
ChkName = "GenSeg"
Call GenSeg

' Query segment and segment/sequence memory
Action.Text = "Getting Memory Data"
ChkName = "RunQuery"
Call RunQuery

Action.Text = "DONE!"

' Close communication with instrument
Call iclose(Addr)

' Clean up sicl
Call sicleanup

Exit Sub

' In case of timeout
AfgErr:

```

Continued on Next Page

```

Call TimeOut

End Sub

Sub RstClr ()

Dim RdMsg As String * 10
Dim Actual As Long
Dim Length As Integer

Length = 10
' Executes the commands that resets the module and clears its error register
Call iwrite(Addr, ByVal "*RST;*OPC?" + Chr$(10), 11, 1, Actual)
Call iread(Addr, ByVal RdMsg, Length, 0, Actual)

Length = 10
Call iwrite(Addr, ByVal "*CLS;*OPC?" + Chr$(10), 11, 1, Actual)
Call iread(Addr, ByVal RdMsg, Length, 0, Actual)

End Sub

Sub RunQuery ()

Dim GetMem As String
Dim RdMsg As String * 100
Dim Actual As Long

ShowQuery.Visible = True
ShowQuery.Enabled = True

' Query segment memory
GetMem = "SOUR:LIST1:SEGM:FREE?"
Call iwrite(Addr, ByVal GetMem + Chr$(10), Len(GetMem) + 1, 1, Actual)
Call iread(Addr, ByVal RdMsg, 100, 0, Actual)

ShowQuery.AddItem "Segment Memory Available/Used: " + Mid$(RdMsg, 1, Actual - 1)

' Query sequence memory
GetMem = "SOUR:LIST1:SSEQ:FREE?"
Call iwrite(Addr, ByVal GetMem + Chr$(10), Len(GetMem) + 1, 1, Actual)
Call iread(Addr, ByVal RdMsg, 100, 0, Actual)

ShowQuery.AddItem "Sequence Memory Available/Used: " + Mid$(RdMsg, 1, Actual - 1)

End Sub

Sub TimeOut ()
' Shows timeout message and exits program

```

Continued on Next Page

```
Dim ShowTimeMsg As String
Dim ErrMsg As String

' Set error routine
On Error Resume Next

' Get error message
ErrMsg = igeterrstr(igeterrno())

ShowTimeMsg = "The program generated error message " + Chr$(34) + ErrMsg + Chr$(34) + Chr$(10)
ShowTimeMsg = ShowTimeMsg + "in Sub/Function: " + ChkName + Chr$(10) + Chr$(10)
ShowTimeMsg = ShowTimeMsg + "Press " + Chr$(34) + "OK" + Chr$(34) + " to exit"
MsgBox ShowTimeMsg, 64, "Verif: TimeOut"

' Close communication with instrument
Call iclose(Addr)

' Clean up sicl
Call sicleanup

' End program
End

End Sub
```

Visual C/C++ Language Programs Using HP SICL

These example programs are written in the Visual C/C++ language for the HP 82340/82341 HP-IB Interface Cards using the HP Standard Instrument Control Library (SICL).

The following identifies the system on which the programs are written, shows how to compile the programs, and gives a typical example program.

System Configuration

The Visual C/C++ programs were developed on the following system:

Controller:	HP Vectra PC
HP-IB Interface Card:	HP 82341 HP-IB Interface with HP SICL
Required Libraries:	See “What’s Needed to Compile the Programs” below
Mainframe:	HP 75000 Series C
Slot 0/Resource Manager:	HP E1406A Command Module
HP E1445A Logical Address:	80
Instrument Language:	SCPI

What’s Needed to Compile the Programs

You need the following libraries and header files. These are supplied with HP SICL.

- msapp16.lib - for Microsoft® Visual C and C++
- bcapp16.lib - Borland C and C++
- sicl16.lib
- sicl.h

Note

The programs must be compiled in the Large Memory Model

How to Run a Program

To run a program, first compile and link the program to make an executable file using the Large memory model. You can compile from the command line or the Windows™ interface. The two methods are:

From the Command Line

Make sure the program to be compiled and the appropriate libraries are in a project file. Do this in the C/C++ environment. Then do the following:

- For Borland compilers, type:

```
MAKE <project_name>>.MAK and press Enter
```

- For Microsoft® compilers used in Windows, type:

NMAKE <project_name>.MAK and press Enter

From the Windows Interface

Select the C/C++ Windows environment and make sure the program to be compiled and the appropriate libraries are in a project file. Then do the following:

- For Borland compilers, select:

Project | Open Project to open the project, then
Compile | Build All to compile the program

- For Microsoft compilers used in Windows, type:

Project | Open to open the project, then
Project | Re-build All to compile the program

Typical Visual C/C++ Example Program Using HP SICL

Following is an example program written in Visual C/C++ using the HP Standard Instrument Control Library. The program:

- sends commands to the AFG to generate an arbitrary waveform;
- receives data from the AFG;
- shows how to send coupled commands;
- and performs error checking of the AFG.

```
// ARBWAVE.C - This program generates a 100 points ramp. The data to generate
//            the ramp is transferred to the AFG as voltages
```

```
    // Include the following header files
```

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

```
#include <stdlib.h>
```

```
#include <string.h>
```

```
#include <malloc.h>        // Use "alloc.h" for Turbo C(c) or C++(c)
```

```
#include <sicl.h>         // Included with SICL
```

```
#define DEV_ADDR "hpib7,9,10" // Assign the HP-IB address
```

```
    // Functions
```

```
void gen_seg(void);
```

```
void cmd_exe(char *commands[], int length, char *func_tion);
```

```
void rst_clr(void);
```

```
void send_data(char *commands, float *Wave_seg, int num_size);
```

```
void run_query(void);
```

```
void check_error(char *func_tion);
```

```
void time_out(char *func_name);
```

Continued on Next Page

```

INST  addr; // HP-IB Address identifier

//*****
void main(void) // Run the program
{
    #if defined(__BORLANDC__) && !defined(__WIN_32)
        _InitEasyWin(); // Required for Borland EasyWin program
    #endif

    // Enable communication path to the module
    addr=iopen(DEV_ADDR);

    if (!addr)
    {
        printf("\n\tUnable to communicate with the module");
        printf("\n\nClose the window or press Alt-F4 to exit");
        exit(1);
    }

    // Set HP-IB Timeout to 10 seconds
    if(itimeout(addr, 10000))
        time_out("main - send timeout command");

    rst_clr(); // Reset the AFG
    gen_seg(); // Generate segment list and output sequence
    run_query(); // Query segment and segment/sequence memory

    // Close communication
    iclose(addr);

    // Release SICL resource allocation; not needed for Windows NT
    _sicleanup();

    printf("\n\nClose the window or press Alt-F4 to exit");

    exit(0);
}
//*****
void gen_seg(void)
{
    char *set_commands[] = // Use "set_commands" to setup the AFG
    {
        "SOUR:LIST1:SSEQ:DEL:ALL", // Clear sequence memory
        "SOUR:LIST1:SEGM:DEL:ALL", // Clear segment memory

        "SOUR:ROSC:SOUR INT1;" // Select the Ref. Oscillator
        ":TRIG:STAR:SOUR INT1;" // Select the sample source
        ":SOUR:FREQ1:FIX 100E3;" // Set the sample frequency
        ":SOUR:FUNC:SHAP USER;" // Command to select the user function

```

Continued on Next Page

```

":SOUR:VOLT:LEV:IMM:AMPL 5.1V",      // Set the amplitude

"SOUR:LIST1:SEGM:SEL ramp",          // Define the "ramp" segment name
"SOUR:LIST1:SEGM:DEF 100"           // Define the segment size
},

*seg_commands =                      // Use "seg_commands" to store segments

"SOUR:LIST1:SEGM:VOLT",              // Command to send volts data

*out_commands[] =                    // Use the "out_commands" array to generate output
{
"SOUR:LIST1:SSEQ:SEL ramp_out",      // Define the sequence name as "ramp_out"
"SOUR:LIST1:SSEQ:DEF 1",              // Define the sequence size
"SOUR:LIST1:SSEQ:SEQ ramp",          // Set the segment execution order
"SOUR:FUNC:USER ramp_out",           // Define the user name
"INIT:IMM"                            // Start waveform generation
};

float *Wave_seg;
int  loop,
     seg_size = 100;                  // Set the segment size to 100 points
char  send_str[50];

    // Allocate sufficient memory for storing the segments into computer memory
Wave_seg = (float*) malloc (seg_size * sizeof (float));

    // Setup the AFG
cmd_exe(set_commands, sizeof(set_commands) / sizeof(char*), "gen_seg (set_commands)");

    // Call routine to check for AFG errors
check_error("gen_seg (set_commands)");

    // Calculate the segments
for (loop = 0; loop < seg_size; loop ++)
    Wave_seg[loop] = (loop * .0505);

    // Setup for iprintf function
sprintf(send_str, "%s %%,%if\n", seg_commands, seg_size);

    // Call function to execute the final command with segment data
if(!iprintf(addr, send_str, Wave_seg))
    time_out("gen_seg (seg_commands)");

    // Call routine to check for AFG errors
check_error("gen_seg (seg_commands)");

    // Setup the AFG for output
cmd_exe(out_commands, sizeof(out_commands) / sizeof(char*), "gen_seg (out_commands)");

```

Continued on Next Page

```

        // Call routine to check for AFG errors
        check_error("gen_seg (out_commands)");

        // Free the allocated memory
        free (Wave_seg);
    }
//*****
void cmd_exe(char *commands[], int length, char *func_tion)
{
    int  loop;

    for (loop = 0; loop < length; loop++)
        if(!lprintf(addr, "%s\n", commands[loop]))
            time_out(func_tion);
}
//*****
void run_query(void)
{
    char  mem_size[21];

    // Query segment memory
    if(!lprintf(addr, "SOUR:LIST1:SEGM:FREE?\n", "%t", mem_size))
        time_out("run_query - seg memory");

    printf("\nSegment Memory Available/Used: %s", mem_size);

    // Query sequence memory
    if(!lprintf(addr, "SOUR:LIST1:SSEQ:FREE?\n", "%t", mem_size))
        time_out("run_query - seq memory");

    printf("\nSequence Memory Available/Used: %s", mem_size);
}
//*****
void rst_clr(void)
{
    int  into;

    // Executes the commands that resets the AFG and clears its error register
    if(!lprintf(addr, "*RST;*OPC?\n", "%i", &into))
        time_out("rst_clr - send *RST command");

    if(!lprintf(addr, "*CLS;*OPC?\n", "%i", &into))
        time_out("rst_clr - send *CLS command");
}
//*****
void check_error(char *func_tion)
{
    char  into[257];

```

Continued on Next Page


```

ipromptf(addr, "SYSTem:ERRor?\n", "%t", into); // Query error register

if (atoi(into)                // Determine if error is present
{                               // If errors present, print and exit

    printf("\n\nThe program detected the following error(s):\n\n");
    while (atoi(into))
    {
        printf("%s \t- in function %s\n", into, func_tion);
        ipromptf(addr, "SYSTem:ERRor?\n", "%t", into); // Query error register
    }
    // Close communication
    iclose(addr);

    // Release SICL resource allocation; not needed for Windows NT
    _sicleanup();

    printf("\n\nClose the window or press Alt-F4 to exit");
    exit(1);
}
}
//*****
void time_out(char *func_name)
{
    printf("\n\n\tThe program timed out in function: %s", func_name);
    // Close communication
    iclose(addr);

    // Release SICL resource allocation; not needed for Windows NT
    _sicleanup();

    printf("\n\nClose the window or press Alt-F4 to exit");

    exit(1);
}

```

Introductory Programs

The introductory programs in this section include:

- AFG Self-Test
- Resetting the AFG and clearing its status registers
- Querying the AFG power-on/reset settings
- Checking for Errors
- Generating a sine wave with a single command

AFG Self-Test The AFG self-test is executed with the command:

*TST?

The AFG parameters tested include:

- 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)

Upon completion of the test, one of the self-test codes listed in Table 1-2 is returned.

Table 1-2. HP E1445A Self-Test Codes

Self-Test Code	Description
0	Test passed
1	Test failed. An error message describes the failure.

HP BASIC Program Example (SLFTST)

```
1   !RE-STORE "SLFTST"
10  !Send the self-test command, enter and display the result.
20  DIM Message$(256)
30  OUTPUT 70910;"*TST?"
40  ENTER 70910;Rslt
50  IF Rslt <>0 THEN
60      REPEAT
70          OUTPUT 70910;"SYST:ERR?"
80          ENTER 70910;Code,Message$
90          PRINT Code,Message$
100     UNTIL Code=0
110  END IF
120  PRINT Rslt
130  END
```

Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, SLFTST.FRM, is in directory "VBPROG" and the Visual C/C++ example program, SLFTST.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Resetting and Clearing the AFG

The commands used to reset and clear the AFG are:

```
*RST
*CLS
```

Resetting the AFG sets it to its power-on configuration and clearing the AFG clears its Status Registers. Status Register programming is covered in Chapter 9.

HP BASIC Program Example (RSTCLS)

```
1   !RE-STORE"RSTCLS"
10  !Assign an I/O path between the computer and AFG.
20  ASSIGN @Afg TO 70910
30  COM @Afg
40  !Call the subprogram
50  CALL Rst_cls
60  END
70  !
80  SUB Rst_cls
90  Rst_cls: !subprogram which resets and clears the AFG.
100  COM @Afg
110  OUTPUT @Afg;"*RST;*CLS;*OPC?"      !reset and clear the AFG
120  ENTER @Afg;Complete
130  SUBEND
```

Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, RSTCLS.FRM, is in directory "VBPROG" and the Visual C/C++ example program, RSTCLS.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Querying the Power-On/Reset Configuration

After resetting the HP E1445A or cycling power, the AFG parameters are set to their power-on values. These values are listed in Table B-5 in Appendix B.

The command which queries each AFG parameter setting is:

```
*LRN?
```

HP BASIC Program Example (LRN)

```
1      !RE-STORE "LRN"
10     !Assign an I/O path between the computer and AFG.
20     ASSIGN @Afg to 70910
30     !Call the subprogram
40     Lrn_conf(@Afg)
50     END
60     !
70     SUB Lrn_conf(@Afg)
80 Lrn_conf: !subprogram which queries the AFG configuration
90     DIM Lrn$(5000)
100    OUTPUT @Afg;"*LRN?"
110    ENTER @Afg;Lrn$
120    Lrn$=Lrn$&";"
130    REPEAT
140        I=POS(Lrn$,";")
150        PRINT Lrn$[1;I-1]
160        Lrn$=Lrn$[I+1]
170    UNTIL Lrn$=""
180    SUBEND
```

Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, LRN.FRM, is in directory "VBPROG" and the Visual C/C++ example program, LRN.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Checking for Errors

The following HP BASIC program shows the lines and subprogram which are added to the HP BASIC programs to check for errors. Line 140 clears the AFG Standard Event Status Register. Lines 150 and 160 unmask the appropriate bits in the AFGs Status Byte Register and Standard Event Status Register.

When an error occurs, the subprogram "Errmsg" reads the AFG error queue and displays the code and message. Note that line 310 is used as an "end of statement" should a syntax error occur among coupled commands. Otherwise, line 320 would serve as the end of statement and the ABORT command would be ignored by the AFG parser.

Note An alternative HP BASIC error checking program can be found in the *C-Size VXibus Systems Configuration Guide*. Error checking routines for Visual C/C++ language and Visual BASIC programs are found in programs ARBWAVE.C and ARBWAVE.FRM, listed previously in this chapter.

HP BASIC Program Example (ERRORCHK)

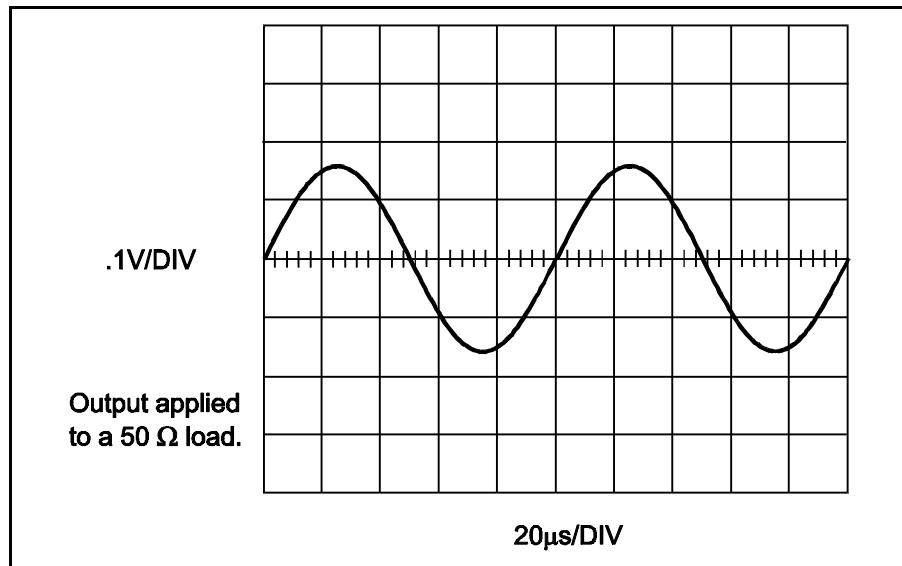
```
1  !RE-STORE"ERRORCHK"
2  !This program represents the method used to check for programming
3  !errors in HP BASIC programs.
4  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 COM @Afg
40 !Define branch to be taken when an E1445A error occurs.
50 !Enable HP-IB interface to generate an interrupt when an error
60 !occurs.
70 ON INTR 7 CALL Errmsg
80 ENABLE INTR 7;2
90 !Clear all bits in the standard event status register, unmask the
100 !standard event status group summary bit in the E1445A status byte
110 !register (decimal weight 32), unmask the query error, device
120 !dependent error, execution error, and command error bits
130 !(decimal sum 60) in the E1445A standard event status register.
140 OUTPUT @Afg;"*CLS"
150 OUTPUT @Afg;"*SRE 32"
160 OUTPUT @Afg;"*ESE 60"
170 !
180 !Subprogram calls would be here
190 !
200 WAIT .1 !allow error branch to occur before turning intr off
210 OFF INTR 7
220 END
```

Continued on Next Page

```
230  !
240  SUB Errmsg
250 Errmsg: !Subprogram which displays E1445 programming errors
260  COM @Afg
270  DIM Message$[256]
280  !Read AFG status byte register and clear service request bit
290  B=SPOLL(@Afg)
300  !End of statement if error occurs among coupled commands
310  OUTPUT @Afg;"
320  OUTPUT @Afg;"ABORT"          !abort output waveform
330  REPEAT
340    OUTPUT @Afg;"SYST:ERR?"    !read AFG error queue
350    ENTER @Afg;Code,Message$
360    PRINT Code,Message$
370  UNTIL Code=0
380  STOP
390  SUBEND
```

Generating Sine Waves

From the power-on/reset configuration you can output a 0.16187 Vp, 10 kHz sine wave by setting the AFG to the wait-for-arm state with the INITiate:IMMEDIATE command. This is done with the RSTSINE program.



HP BASIC Program Example (RSTSINE)

```
1  !RE-STORE"RSTSINE"
2  !This program outputs a sine wave based on the reset conditions
3  !of the AFG.
4  !
10 !Assign an I/O path between the computer and AFG.
20 ASSIGN @Afg TO 70910
30 COM @Afg
40 !
50 !Reset the AFG
60 CALL Rst
70 OUTPUT @Afg;"INIT:IMM"           !output sine wave using reset conditions
80 END
90 !
100 SUB Rst
110 Rst: !subprogram which resets the AFG.
120     COM @Afg
130     OUTPUT @Afg;"*RST;*OPC?"     !reset the AFG
140     ENTER @Afg;Complete
150     SUBEND
```

Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, RSTSINE.FRM, is in directory "VBPROG" and the Visual C/C++ example program, RSTSINE.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Notes

Chapter 2

Generating Standard Waveforms

Chapter Contents

This chapter shows how to generate standard waveforms (sinusoid, square, triangle, and ramps) using the HP E1445A 13-Bit Arbitrary Function Generator (called the "AFG").

The following sections show how to generate standard waveforms, how to setup the AFG for different output loads, how to select the output amplitude units (for example, V, V_{peak}, etc.), and how to set the waveform amplitude and offset. The sections are as follows:

- Standard Waveforms Flowchart Page 54
- Generating DC Voltages Page 56
- Generating Sine Waves Page 58
- Generating Square Waves Page 61
- Generating Triangle/Ramp Waves Page 65
- Selecting the Output Loads Page 69
- Selecting the Amplitude Levels and Output Units Page 72
- Using Phase Modulation Page 75
- Standard Waveform Program Comments Page 78
 - Sinusoid Function Requirements Page 78
 - Reference Oscillator Sources Page 78
 - Sample Sources Page 78
 - DDS Frequency Generator Ranges Page 79
 - Number of Points versus Frequency Page 79
 - Output Load Comments Page 79
 - Output Units Comments Page 80
 - Selecting the Deviation Units for
Phase Modulation. Page 80
 - Using MINimum and MAXimum Parameters Page 81

Note For information on how the AFG electronically generates the Standard Waveforms, refer to Chapter 10 of this manual.

Standard Waveforms Flowchart

The flowchart in Figure 2-1 shows the sequence used to generate standard waveforms. The reset (power-on) values of each command are also noted on the flowchart. The programs in this chapter begins with a reset (the IEEE 488.2 *RST command) which places the AFG into its power-on state. Thus, the programs do not execute all of the commands on the flowchart. Remove the flowchart from the binder for easy accessibility. Refer to the flowchart while doing the examples in this chapter, if desired.

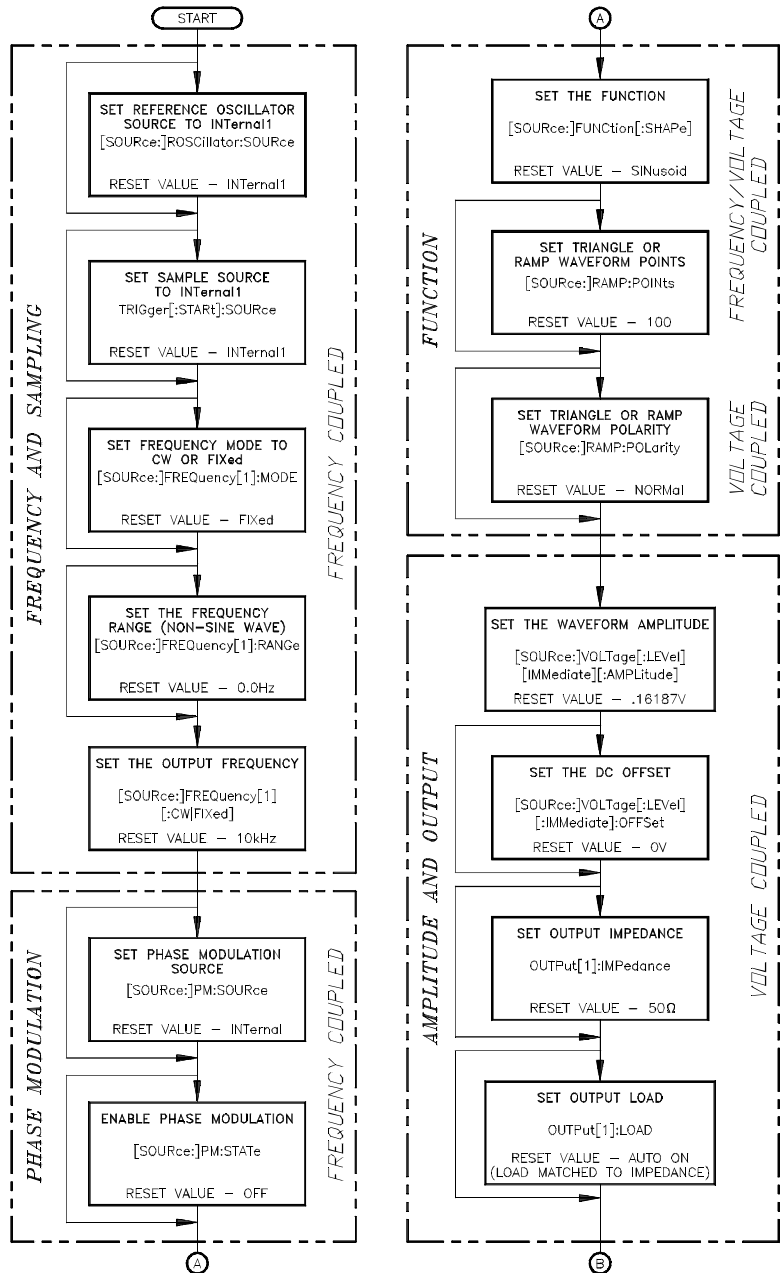


Figure 2-1. Commands for Generating Standard Waveforms
(continued on next page)

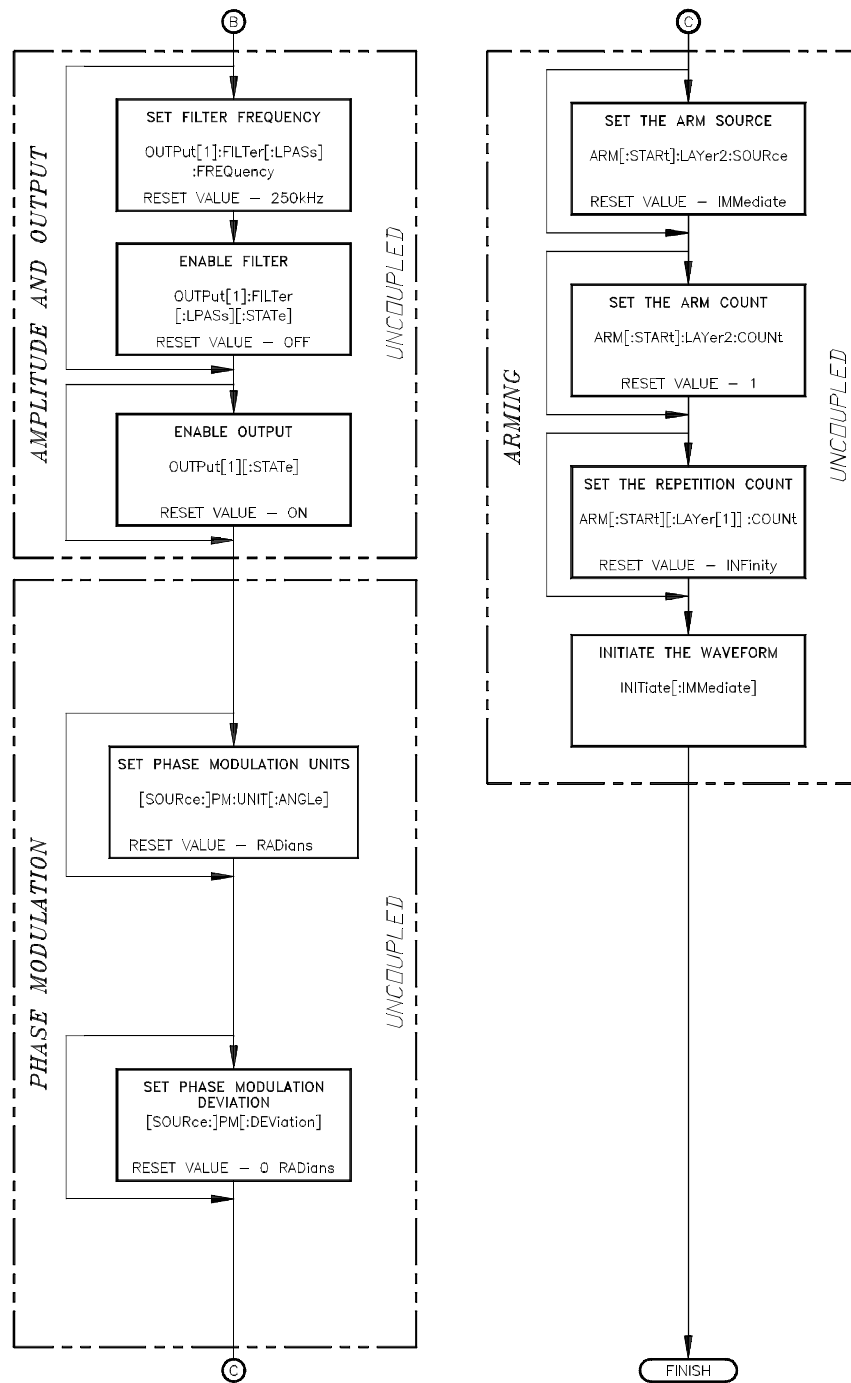


Figure 2-1. Commands for Generating Standard Waveforms
(continued from previous page)

Generating DC Voltages

The DCVOLTS program outputs a +5 Vdc voltage. The commands are:

1. **Reset the AFG**

*RST

This command aborts any waveform output and selects the sinusoid function, output impedance, and output load to 50 Ω .

2. **Select the Function**

[SOURce:]FUNCTion[:SHAPe] DC

This command selects the DC function.

3. **Set the Amplitude**

[SOURce:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude] <amplitude>

This command specifies the amplitude. Refer to the section called “Selecting the Amplitude Levels and Output Units” on page 72 for more information.

HP BASIC Program Example (DCVOLTS)

```
1   !RE-STORE“DCVOLTS”
2   !This program outputs a +5V DC voltage.
3   !
10  !Assign I/O path between the computer and E1445A.
20  ASSIGN @Afg TO 70910
30  COM @Afg
40  !
50  !Set up error checking
60  ON INTR 7 CALL Errmsg
70  ENABLE INTR 7;2
80  OUTPUT @Afg;“*CLS”
90  OUTPUT @Afg;“*SRE 32”
100 OUTPUT @Afg;“*ESE 60”
110 !
120 !Call the subprograms
130 CALL Rst
140 CALL Dc_volts
150 !
160 WAIT .1 !allow interrupt to be serviced
170 OFF INTR 7
180 END
190 !
200 SUB Dc_volts
210 Dc_volts: !subprogram which outputs a dc voltage
220     COM @Afg
230     OUTPUT @Afg;“SOUR:FUNC:SHAP DC;”;           !function
240     OUTPUT @Afg;“:SOUR:VOLT:LEV:IMM:AMPL 5V” !amplitude
```

Continued on Next Page

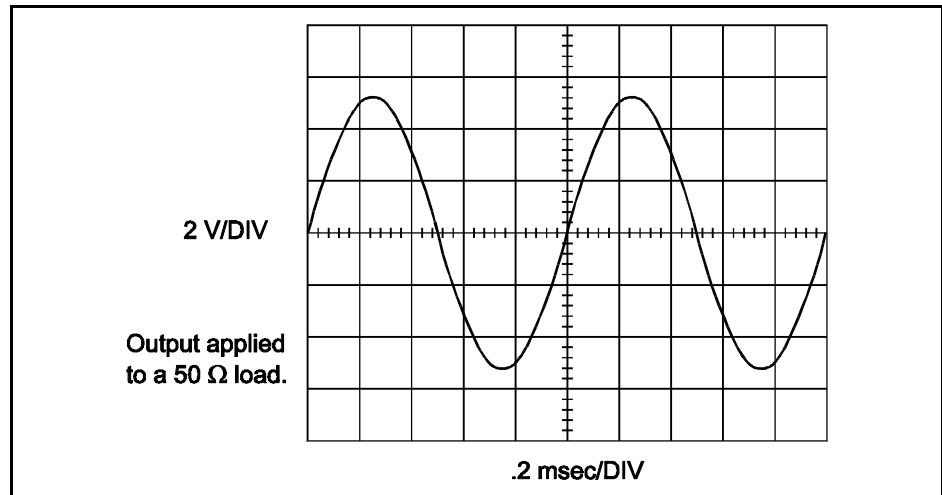
```

250 SUBEND
260 !
270 SUB Rst
280 Rst: !Subprogram which resets the E1445.
290 COM @Afg
300 OUTPUT @Afg;"*RST;*OPC?" !reset the AFG
310 ENTER @Afg;Complete
320 SUBEND
330 !
340 SUB Errmsg
350 Errmsg: !Subprogram which displays E1445 programming errors
360 COM @Afg
370 DIM Message$[256]
380 !Read AFG status byte register and clear service request bit
390 B=SPOLL(@Afg)
400 !End of statement if error occurs among coupled commands
410 OUTPUT @Afg;"
420 OUTPUT @Afg;"ABORT" !abort output waveform
430 REPEAT
440 OUTPUT @Afg;"SYST:ERR?" !read AFG error queue
450 ENTER @Afg;Code,Message$
460 PRINT Code,Message$
470 UNTIL Code=0
480 STOP
490 SUBEND

```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, DCVOLTS.FRM, is in directory "VBPROG" and the Visual C example program, DCVOLTS.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Generating Sine Waves



The SINEWAVE program outputs a Sine Wave at 1 kHz and 5 V output level. The commands are:

1. **Reset the AFG**

*RST

This command aborts any waveform output and selects the sinusoid function, output impedance, and output load to 50 Ω.

2. **Set the Waveform Frequency**

[SOURCE:]FREQUENCY[1][:FIXed] <frequency>

This command specifies the waveform frequency. You must use the direct synthesis frequency generator for the sinusoid function. Refer to Table B-3 in Appendix B for the frequency limits.

3. **Select the Function**

[SOURCE:]FUNCTION[:SHAPE] SINusoid

This command selects the sinusoid function. (Although *RST automatically selects this function, it is selected here for good programming practice.)

4. **Set the Amplitude**

[SOURCE:]VOLTage[:LEVel][IMMediate][:AMPLitude] <amplitude>

This command specifies the amplitude. Refer to the section called "Selecting the Amplitude Levels and Output Units" on page 72 for more information.

5. **Initiate the Waveform**

INITiate[:IMMediate]

This command generates an immediate output with the arm source set to IMMEDIATE. Refer to Chapter 5 for triggering information.

HP BASIC Program Example (SINEWAVE)

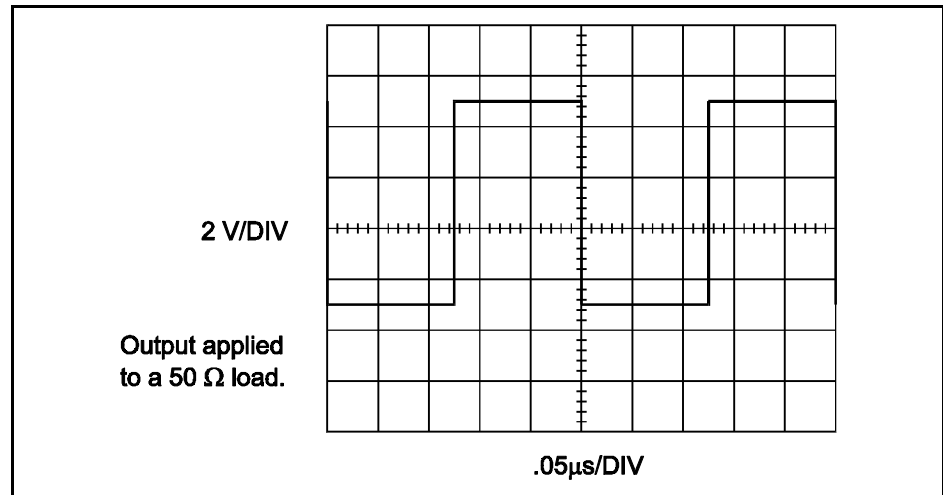
```
1  !RE-STORE"SINEWAVE"
2  !The following program generates a 1 kHz, 5 Vp sine wave.
3  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 COM @Afg
40 !
50 !Set up error checking
60 ON INTR 7 CALL Errmsg
70 ENABLE INTR 7;2
80 OUTPUT @Afg;"*CLS"
90 OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms
130 CALL Rst
140 CALL Sine_wave
150 !
160 WAIT .1 !allow interrupt to be serviced
170 OFF INTR 7
180 END
190 !
200 SUB Sine_wave
210 Sine_wave: !Subprogram which outputs a sine wave
220     COM @Afg
230     OUTPUT @Afg;"SOUR:FREQ1:FIX 1E3;";           !frequency
240     OUTPUT @Afg;"SOUR:FUNC:SHAP SIN;";         !function
250     OUTPUT @Afg;"SOUR:VOLT:LEV:IMM:AMPL 5V"     !amplitude
260     OUTPUT @Afg;"INIT:IMM"                     !wait-for-arm state
270 SUBEND
280 !
290 SUB Rst
300 Rst: !Subprogram which resets the E1445.
310     COM @Afg
320     OUTPUT @Afg;"*RST;*OPC?"                   !reset the AFG
330     ENTER @Afg;Complete
340 SUBEND
350 !
360 SUB Errmsg
370 Errmsg: !Subprogram which displays E1445 programming errors
380     COM @Afg
390     DIM Message$(256)
400     !Read AFG status byte register and clear service request bit
410     B=SPOLL(@Afg)
420     !End of statement if error occurs among coupled commands
430     OUTPUT @Afg;"
440     OUTPUT @Afg;"ABORT"                         !abort output waveform
450     REPEAT
```

Continued on Next Page

```
460      OUTPUT @Afg;"SYST:ERR?"           !read AFG error queue
470      ENTER @Afg;Code,Message$
480      PRINT  Code,Message$
490      UNTIL Code=0
500      STOP
510      SUBEND
```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, SINEWAVE.FRM, is in directory "VBPROG" and the Visual C example program, SINEWAVE.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Generating Square Waves



The SQUWAVE program outputs a square wave at 1 Mhz, 4 V output level, and +1 V offset. The commands are:

1. **Reset the AFG**

`*RST`

This command aborts any waveform output and selects the 42.9 MHz reference oscillator source, DDS sample source (that is, trigger start source), sinusoid function, arm start immediate, 0 V offset, and a 50 Ω output impedance and output load.

2. **Select the Reference Oscillator**

`[SOURCE:]ROSCillator:SOURCE INTERNAL[1]`

This command selects the reference oscillator source (see “Reference Oscillator Sources” on page 78). (Although *RST selects 42.9 MHz reference oscillator, it is selected here for good programming practice.)

3. **Select the Sample Source**

`TRIGGER:START:SOURCE INTERNAL[1]`

This command selects the sample source (that is, trigger start source). (Although *RST selects trigger start source that selects the DDS frequency generator, it is selected here for good programming practice.) The SQUARE function can use any of the trigger start sources (see “Sample Sources” on page 78).

4. **Set the Frequency Range**

`[SOURCE:]FREQUENCY[1]:RANGE <range>`

This command specifies the square wave upper frequency limit (see “DDS Frequency Generator Ranges” on page 79). (Since *RST automatically sets the range to the lower range, it is executed in this program for good programming practice.)

5. Set the Frequency

[SOURce:]FREQUency[1][:FIXed] <frequency>

This command specifies the frequency. Refer to Table B-3 in Appendix B for the frequency limits.

6. Select the Function

[SOURce:]FUNCtion[:SHAPE] SQUARE

This command selects the square wave function.

7. Select the Square Wave Polarity

[SOURce:]RAMP:POLarity INVERTed

This command selects the square wave polarity. For NORMAL, the initial voltage goes positive. For INVERTed, the initial voltage goes negative.

8. Set the Amplitude

[SOURce:]VOLTage[:LEVel][IMMediate][:AMPLitude] <amplitude>

This command specifies the amplitude. Refer to the section called “Selecting the Amplitude Levels and Output Units” on page 72 for more information.

9. Set the Offset

[SOURce:]VOLTage[:LEVel][IMMediate]OFFSet <offset>

This command specifies the offset. Refer to the section called “Selecting the Amplitude Levels and Output Units” on page 72 for more information.

10. Initiate the Waveform

INITiate[:IMMediate]

This command generates an immediate output with the arm source set to IMMEDIATE. Refer to Chapter 5 for triggering information.

HP BASIC Program Example (SQUWAVE)

```
1  !RE-STORE"SQUWAVE"
2  !This program outputs a 1 MHz, 4V square wave with a 1V DC offset.
3  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 COM @Afg
40 !
50 !Set up error checking
60 ON INTR 7 CALL Errmsg
70 ENABLE INTR 7;2
80 OUTPUT @Afg;"*CLS"
90 OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms
130 CALL Rst
140 CALL Squ_wave
150 !
160 WAIT .1 !allow interrupt to be serviced
170 OFF INTR
180 END
190 !
200 SUB Squ_wave
210 Squ_wave: !Subprogram which outputs a square wave
220   COM @Afg
230   OUTPUT @Afg;"SOUR:ROSC:SOUR INT1;";           !reference oscillator
240   OUTPUT @Afg;"TRIG:STAR:SOUR INT1;";         !trigger source
250   OUTPUT @Afg;"SOUR:FREQ:RANG 0;";           !frequency range
260   OUTPUT @Afg;"SOUR:FREQ:FIX 1E6;";         !frequency
270   OUTPUT @Afg;"SOUR:FUNC:SHAP SQU;";        !function
280   OUTPUT @Afg;"SOUR:RAMP:POL INV;";         !polarity (more negative)
290   OUTPUT @Afg;"SOUR:VOLT:LEV:IMM:AMPL 4V;";  !amplitude
300   OUTPUT @Afg;"SOUR:VOLT:LEV:IMM:OFFS 1V"    !dc offset
310   OUTPUT @Afg;"INIT:IMM"                    !wait-for-arm state
320 SUBEND
330 !
340 SUB Rst
350 Rst: !Subprogram which resets the E1445.
360   COM @Afg
370   OUTPUT @Afg;"*RST;*OPC?"                 !reset the AFG
380   ENTER @Afg;Complete
390 SUBEND
400 !
410 SUB Errmsg
420 Errmsg: !Subprogram which displays E1445 programming errors
430   COM @Afg
440   DIM Message$[256]
450   !Read AFG status byte register and clear service request bit
```

Continued on Next Page

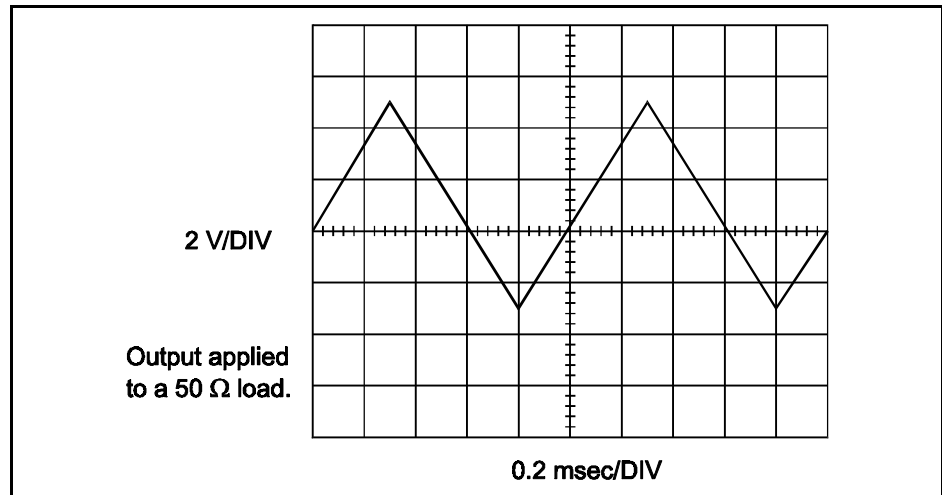
```

460     B=SPOLL(@Afg)
470     !End of statement if error occurs among coupled commands
480     OUTPUT @Afg;""
490     OUTPUT @Afg;"ABORT"           !abort output waveform
500     REPEAT
510         OUTPUT @Afg;"SYST:ERR?"   !read AFG error queue
520         ENTER @Afg;Code,Message$
530         PRINT Code,Message$
540     UNTIL Code=0
550     STOP
560     SUBEND

```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, SQUWAVE.FRM, is in directory “VBPROG” and the Visual C example program, SQUWAVE.C, is in directory “VCPROG” on the CD that came with your HP E1445A.

Generating Triangle/Ramp Waves



The TRIWAVE program outputs a triangle wave at 10 kHz, 4 V output level, and +1 V offset. The commands are:

1. **Reset the AFG**

`*RST`

This command aborts any waveform output and selects the 42.9 MHz reference oscillator source, DDS sample source (that is, trigger start source), sinusoid function, arm start immediate, 0 V offset, and a 50 Ω output impedance and output load.

2. **Select the Reference Oscillator**

`[SOURCE:]ROSCillator:SOURCE INTERNAL[1]`

This command selects the reference oscillator source (see “Reference Oscillator Sources” on page 78). (Although *RST selects 42.9 MHz reference oscillator, it is selected here for good programming practice.)

3. **Select the Sample Source**

`TRIGGER:START:SOURCE INTERNAL[1]`

This command selects the sample source (that is, trigger start source). (Although *RST selects trigger start source that selects the DDS frequency generator, it is selected here for good programming practice.) The TRIangle/RAMP functions can use any of the trigger start sources (see “Sample Sources” on page 78).

4. **Set the Frequency Range**

`[SOURCE:]FREQUENCY[1]:RANGE <range>`

This command specifies the triangle/ramp wave upper frequency limit (see “DDS Frequency Generator Ranges” on page 79). (Since *RST automatically sets the range to the lower range, it is executed in this program for good programming practice.)

5. Set the Frequency

[SOURce:]FREQUency[1][:FIXed] <frequency>

This command specifies the frequency. Refer to Table B-3 in Appendix B for the frequency limits.

6. Select the Function

[SOURce:]FUNCtion[:SHAPE] TRIangle

This command selects the TRIangle function. For the RAMP function, use the RAMP parameter instead of the TRIangle parameter.

7. Set the Number of Ramp Points

[SOURce:]RAMP:POINts <number>

This command specifies the number of ramp points. The more points give better resolution but lower frequency response.

8. Select the Triangle Wave Polarity

[SOURce:]RAMP:POLarity INVerted

This command selects the polarity of the TRIangle/RAMP wave. Use NORMal for the initial voltage to go positive. Use INVerted for the initial voltage to go negative.

9. Set the Amplitude

[SOURce:]VOLTage[:LEVel][IMMediate][:AMPLitude] <amplitude>

This command specifies the amplitude. Refer to the section called “Selecting the Amplitude Levels and Output Units” on page 72 for more information.

10. Set the Offset

[SOURce:]VOLTage[:LEVel][IMMediate]OFFSet <offset>

This command specifies the offset. Refer to the section called “Selecting the Amplitude Levels and Output Units” on page 72 for more information.

11. Initiate the Waveform

INITiate[:IMMediate]

This command generates an immediate output with the arm source set to IMMediate. Refer to Chapter 5 for triggering information.

HP BASIC Program Example (TRIWAVE)

```
1  !RE-STORE"TRIWAVE"
2  !This program outputs a 200 point, 10 kHz, 4V triangle wave
3  !with a 1V DC offset.
4  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 COM @Afg
40 !
50 !Set up error checking
60 ON INTR 7 CALL Errmsg
70 ENABLE INTR 7;2
80 OUTPUT @Afg;"*CLS"
90 OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms
130 CALL Rst
140 CALL Tri_wave
150 !
160 WAIT .1 !allow interrupt to be serviced
170 OFF INTR
180 END
190 !
200 SUB Tri_wave
210 Tri_wave: !Subprogram which outputs a triangle wave
220   COM @Afg
230   OUTPUT @Afg;"SOUR:ROSC:SOUR INT1;";           !reference oscillator
240   OUTPUT @Afg;"TRIG:STAR:SOUR INT1;";         !trigger source
250   OUTPUT @Afg;"SOUR:FREQ1:RANG 0;";          !frequency range
260   OUTPUT @Afg;"SOUR:FREQ1:FIX 10E3;";        !frequency
270   OUTPUT @Afg;"SOUR:FUNC:SHAP TRI;";         !function
280   OUTPUT @Afg;"SOUR:RAMP:POIN 200;";        !waveform points
290   OUTPUT @Afg;"SOUR:VOLT:LEV:IMM:AMPL 4V;";  !amplitude
300   OUTPUT @Afg;"SOUR:VOLT:LEV:IMM:OFFS 1V"    !dc offset
310   OUTPUT @Afg;"INIT:IMM"                    !wait-for-arm state
320 SUBEND
330 !
340 SUB Rst
350 Rst: !Subprogram which resets the E1445.
360   COM @Afg
370   OUTPUT @Afg;"*RST;*OPC?"                  !reset the AFG
380   ENTER @Afg;Complete
390 SUBEND
400 !
410 SUB Errmsg
420 Errmsg: !Subprogram which displays E1445 programming errors
430   COM @Afg
440   DIM Message$[256]
```

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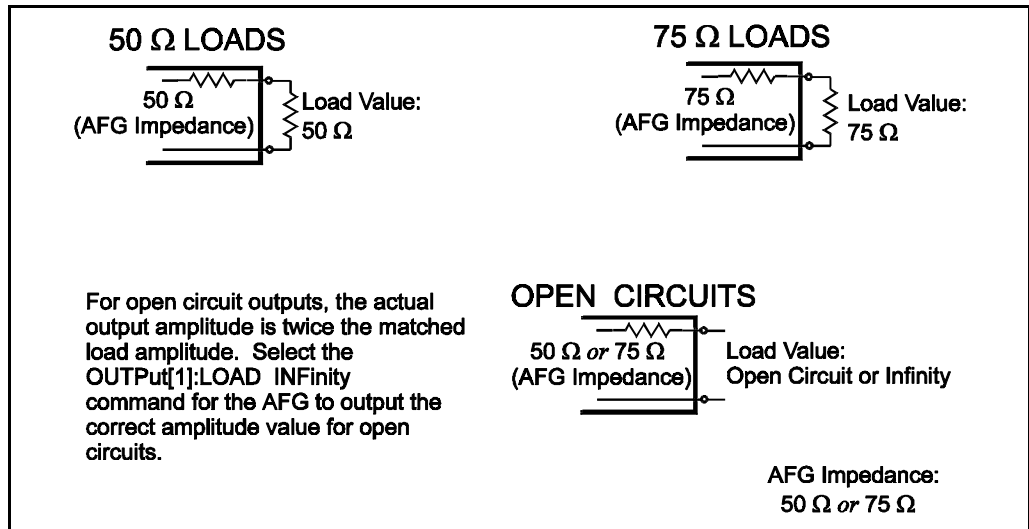
```

450      !Read AFG status byte register and clear service request bit
460      B=SPOLL(@Afg)
470      !End of statement if error occurs among coupled commands
480      OUTPUT @Afg;""
490      OUTPUT @Afg;"ABORT"           !abort output waveform
500      REPEAT
510          OUTPUT @Afg;"SYST:ERR?"   !read AFG error queue
520          ENTER @Afg;Code,Message$
530          PRINT Code,Message$
540      UNTIL Code=0
550      STOP
560      SUBEND

```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, TRIWAVE.FRM, is in directory “VBPROG” and the Visual C example program, TRIWAVE.C, is in directory “VCPROG” on the CD that came with your HP E1445A.

Selecting the Output Loads



The OUTPLOAD program sets the AFG's output impedance to the output load value of 75 Ω. The commands are:

1. Setup the AFG

`*RST`

Use the `*RST` command to setup the AFG. You can also use the commands listed in the previous sections of this chapter ("Generating Sine Waves" on page 58) to setup the AFG.

2. Set the Amplitude

`[SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude] <amplitude>`
This command specifies the amplitude. Refer to the section called "Selecting the Amplitude Levels and Output Units" on page 72 for more information.

3. Select the Auto Load On, Off, or Once

`OUTPut[1]:LOAD:AUTO <mode>`

With this command, the assumed load applied to the AFG's "Output 50/75 Ω" terminals tracks the AFG output impedance. The modes are:

ON – load value tracks output impedance

OFF – load value does not track output impedance

ONCE – load value tracks output impedance once and then goes to OFF

4. Select the Output Impedance

`OUTPut[1]:IMPedance <impedance>`

This command selects the AFG output impedance. The AFG output impedance can be either 50 Ω or 75 Ω.

5. Select the Output Load Value

OUTPut[1]:LOAD <load>

This command selects the load value expected at the "Output 50/75 Ω " terminals. The values are:

50 – for 50 Ω loads; must be same as output impedance.

75 – for 75 Ω loads; must be same as output impedance.

9.9E+37 or INFinity – for open circuit; output value is twice the normal matched load output value.

6. Initiate the Waveform

INITiate[:IMMEDIATE]

This command generates an immediate output with the arm source set to IMMEDIATE. Refer to Chapter 5 for triggering information.

HP BASIC Program Example (OUTPLOAD)

```
1  !RE-STORE"OUTPLOAD"
2  !This program sets the AFG's output impedance and output load
3  !to 75 ohms.
4  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910.
30 COM @Afg
40 !
50 !Set up error checking
60 ON INTR 7 CALL Errmsg
70 ENABLE INTR 7;2
80 OUTPUT @Afg;"*CLS"
90 OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms
130 CALL Rst
140 CALL Out_load
150 !
160 WAIT .1 !allow interrupt to be serviced
170 OFF INTR 7
180 END
190 !
200 SUB Out_load
210 Out_load: !Subprogram which sets the output load
220     COM @Afg
230     OUTPUT @Afg;"SOUR:VOLT:LEV:IMM:AMPL 5V;"; !amplitude
240     OUTPUT @Afg;":OUTP:LOAD:AUTO OFF;"; !decouple load from impedance
250     OUTPUT @Afg;":OUTP:IMP 75;"; !output impedance
260     OUTPUT @Afg;":OUTP:LOAD 75" !output load
270     OUTPUT @Afg;"INIT:IMM" !wait-for-arm state
280 SUBEND
290 !
```

Continued on Next Page

```

300 SUB Rst
310 Rst: !Subprogram which resets the E1445.
320 COM @Afg
330 OUTPUT @Afg;"*RST;*OPC?" !reset the AFG
340 ENTER @Afg;Complete
350 SUBEND
360 !
370 SUB Errmsg
380 Errmsg: !Subprogram which displays E1445 programming errors
390 COM @Afg
400 DIM Message$(256)
410 !Read AFG status byte register and clear service request bit
420 B=SPOLL(@Afg)
430 !End of statement if error occurs among coupled commands
440 OUTPUT @Afg;"
450 OUTPUT @Afg;"ABORT" !abort output waveform
460 REPEAT
470 OUTPUT @Afg;"SYST:ERR?" !read AFG error queue
480 ENTER @Afg;Code,Message$
490 PRINT Code,Message$
500 UNTIL Code=0
510 STOP
520 SUBEND

```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, OUTPLOAD.FRM, is in directory “VBPROG” and the Visual C example program, OUTPLOAD.C, is in directory “VCPROG” on the CD that came with your HP E1445A.

Selecting the Amplitude Levels and Output Units

The OUTPUNIT program shows how to set the output amplitude using the VPP (volts peak-to-peak) output unit. The commands are:

1. Reset the AFG

*RST

This command aborts any waveform output and selects the 42.9 MHz reference oscillator source, DDS sample source (that is, trigger start source), sinusoid function, arm start immediate, 0 V offset, and a 50 Ω output impedance and output load.

2. Select the Output Units

[SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude]:UNIT[:VOLTage] <units>

This command selects the following output *units*:

V = Volts

VPK = Volts peak

VPP = Volts peak-to-peak

VRMS = Volts rms

W = Watts

DBM | **DBMW** = dB referenced to 1 milliwatt

These units are assumed only if no other units are specified in the [SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude] <amplitude> command. The output units are only valid for amplitude and not offsets (volts is assumed for offsets).

3. Set the Amplitude and the Offset

[SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude] <amplitude>

[SOURce:]VOLTage[:LEVel][:IMMediate]:OFFSet <offset>

These commands specify the amplitude and offset. Refer to Table B-4 in Appendix B for the amplitude limits. The maximum value of the combined amplitude and offset voltages must remain within the 6.025 V limit.

4. Initiate the Waveform

INITiate[:IMMediate]

This command generates an immediate output with the arm source set to IMMEDIATE. Refer to Chapter 5 for triggering information.

HP BASIC Program Example (OUTPUNIT)

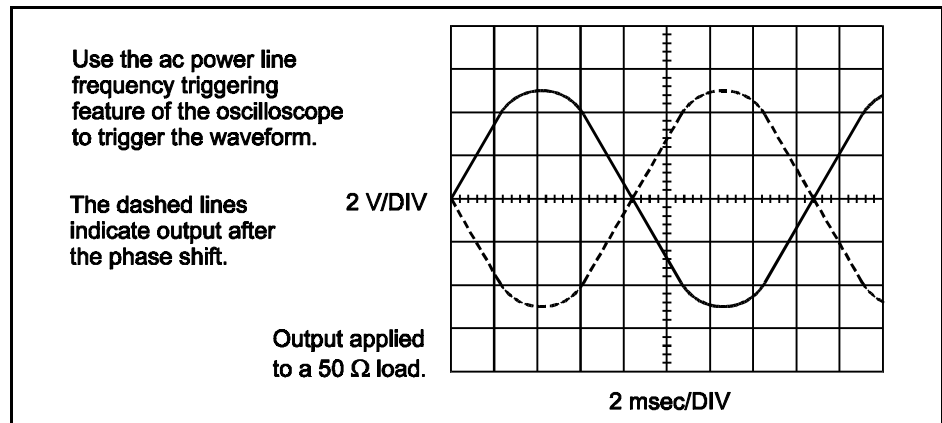
```
1   !RE-STORE"OUTPUNIT"
2   !This programs sets the output amplitude units to volts peak-to-peak
3   !
10  !Assign I/O path between the computer and E1445A.
20  ASSIGN @Afg TO 70910
30  COM @Afg
40  !
50  !Set up error checking
60  ON INTR 7 CALL Errmsg
70  ENABLE INTR 7;2
80  OUTPUT @Afg;"*CLS"
90  OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms
130 CALL Rst
140 CALL Out_unit
150 !
160 WAIT .1 !allow interrupt to be serviced
170 OFF INTR 7
180 END
190 !
200 SUB Out_unit
210 Out_unit: !Subprogram which sets the amplitude units
220     COM @Afg
230     OUTPUT @Afg;"SOUR:VOLT:LEV:IMM:AMPL:UNIT:VOLT VPP" !amplitude units
240     OUTPUT @Afg;"SOUR:VOLT:LEV:IMM:AMPL 8;" ;           !amplitude
250     OUTPUT @Afg;"SOUR:VOLT:LEV:IMM:OFFS 1"             !offset
260     OUTPUT @Afg;"INIT:IMM"                             !wait-for-arm state
270 SUBEND
280 !
290 SUB Rst
300 Rst: !Subprogram which resets the E1445.
310     COM @Afg
320     OUTPUT @Afg;"*RST;*OPC?"                           !reset the AFG
330     ENTER @Afg;Complete
340 SUBEND
350 !
360 SUB Errmsg
370 Errmsg: !Subprogram which displays E1445 programming errors
380     COM @Afg
390     DIM Message$(256)
400     !Read AFG status byte register and clear service request bit
410     B=SPOLL(@Afg)
420     !End of statement if error occurs among coupled commands
430     OUTPUT @Afg;"
440     OUTPUT @Afg;"ABORT"                                 !abort output waveform
450     REPEAT
```

Continued on Next Page

```
460     OUTPUT @Afg;"SYST:ERR?"           !read AFG error queue
470     ENTER @Afg;Code,Message$
480     PRINT Code,Message$
490     UNTIL Code=0
500     STOP
510     SUBEND
```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, OUTPUNIT.FRM, is in directory “VBPROG” and the Visual C example program, OUTPUNIT.C, is in directory “VCPROG” on the CD that came with your HP E1445A.

Using Phase Modulation



Phase modulation allows you to change the output deviation or phase of a sinusoid wave while it is output. This only works in the sinusoid function. The PHS_MOD program shows how change the deviation from 0° to 180°. The commands are:

1. **Reset the AFG**

*RST

This command aborts any waveform output and selects the 42.9 MHz reference oscillator source, DDS sample source (that is, trigger start source), sinusoid function, arm start immediate, 0 V offset, and a 50 Ω output impedance and output load.

2. **Set the Waveform Frequency**

[SOURCE:]FREQUENCY[1][:FIXed] <frequency>

This command specifies the waveform frequency. You must use the direct synthesis frequency generator for the sinusoid function. Refer to Table B-3 in Appendix B for the frequency limits.

3. **Select the Phase Modulation Source**

[SOURCE:]PM:SOURCE <source>

This command sets the phase modulation source. The command determines which source to use for a phase change. The available sources are:

INTERNAL – [SOURCE:]PM:DEVIATION sets the deviation angle (power-on value)

DPORT – The front panel “Dig Port” connector

LBUS – The VXI Local Bus

VXI – The VXI Backplane

4. **Enable Phase Modulation**

[SOURCE:]PM:STATE <mode>

This command turns phase modulation on or off. A "1" (one) or "ON" turns it on, and a "0" (zero) or "OFF" turns it off.

5. Select the Function

[SOURce:]FUNction[:SHAPE] SINusoid

This command selects the sinusoid function. (Although *RST automatically selects this function, it is selected here for good programming practice.)

6. Set the Amplitude

[SOURce:]VOLTage[:LEVel][IMMediate][:AMPLitude] <amplitude>

This command specifies the amplitude. Refer to the section called “Setting the Amplitude Levels and Output Units” on page 72 for more information.

7. Set the Phase Modulation Deviation

[SOURce:]PM:DEVIation <phase>

This command sets the deviation angle. The angle can either be in radians or degrees. The values can be from -3.14159265 to $+3.14159265$ radians ($-\Pi$ to $+\Pi$) or -180° to $+180^\circ$. (See “Selecting the Deviation Units for Phase Modulation” on page 80 to select the different units).

8. Initiate the Waveform

INITiate[:IMMediate]

This command generates an immediate output with the arm source set to IMMEDIATE. Refer to Chapter 5 for triggering information.

HP BASIC Program Example (PHS_MOD)

```
1  !RE-STORE“PHS_MOD”
2  !The following program shifts the phase of the output sine wave
3  !from 0 degrees to 180 degrees.
4  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 COM @Afg
40 !
50 !Set up error checking
60 ON INTR 7 CALL Errmsg
70 ENABLE INTR 7;2
80 OUTPUT @Afg;“*CLS”
90 OUTPUT @Afg;“*SRE 32”
100 OUTPUT @Afg;“*ESE 60”
110 !
120 !Call the subprograms
130 CALL Rst
140 CALL Phase_mod
150 !
160 WAIT .1 !allow interrupt to be serviced
170 OFF INTR 7
180 END
```

Continued on Next Page


```

190  !
200  SUB Phase_mod
210 Phase_mode: !Subprogram which outputs a sine wave
220    COM @Afg
230    OUTPUT @Afg;"SOUR:FREQ1:FIX 60;";           !frequency
240    OUTPUT @Afg;";SOUR:PM:SOUR INT;";         !phase modulation source
250    OUTPUT @Afg;";SOUR:PM:STAT ON;";         !enable phase modulation
260    OUTPUT @Afg;";SOUR:FUNC:SHAP SIN;";       !function
270    OUTPUT @Afg;";SOUR:VOLT:LEV:IMM:AMPL 5V"  !amplitude
280    OUTPUT @Afg;"SOUR:PM:DEV 0DEG"           !phase modulation
290    OUTPUT @Afg;"INIT:IMM"                   !wait-for-arm state
300    DISP "Press 'Continue' to shift phase 180 degrees"
310    PAUSE
320    OUTPUT @Afg;"SOUR:PM:DEV 180DEG"         !shift phase 180 degrees
330    DISP ""
340  SUBEND
350  !
360  SUB Rst
370 Rst: !Subprogram which resets the E1445.
380    COM @Afg
390    OUTPUT @Afg;"*RST;*OPC?";               !reset the AFG
400    ENTER @Afg;Complete
410  SUBEND
420  !
430  SUB Errmsg
440 Errmsg: !Subprogram which displays E1445 programming errors
450    COM @Afg
460    DIM Message$(256)
470    !Read AFG status byte register and clear service request bit
480    B=SPOLL(@Afg)
490    !End of statement if error occurs among coupled commands
500    OUTPUT @Afg;""
510    OUTPUT @Afg;"ABORT"                       !abort output waveform
520    REPEAT
530      OUTPUT @Afg;"SYST:ERR?";               !read AFG error queue
540      ENTER @Afg;Code,Message$
550      PRINT Code,Message$
560    UNTIL Code=0
570    STOP
580  SUBEND

```

Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, PHS_MOD.FRM, is in directory "VBPROG" and the Visual C example program, PHS_MOD.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Standard Waveform Program Comments

The following comments give additional details on the program examples in this chapter.

Sinusoid Function Requirements

The sinusoid requires that the sample source (see “Sample Sources” below) is set to **INTernal[1]** (that is, **TRIGger:START:SOURce INTernal[1]**). This selects the DDS frequency generator. No other sample source can generate a sinewave.

Reference Oscillator Sources

- The **SINusoid**, **SQUare**, **TRIangle**, and **RAMP** functions can use any of the reference oscillator sources. The sources selected by **[SOURce:]ROSCillator:SOURce** are:

INTernal[1] – 42.94967296 MHz (power-on value)

INTernal2 – 40 MHz

CLK10 – 10 MHz (the VXIbus CLK line)

EXTernal – User provided value (the front panel “Ref/Smpl In” BNC)

ECLTrg0 or 1 – User provided value (the VXIbus ECL trigger lines)

- If using either the **EXTernal** or **ECLTrg0 or 1** reference oscillator sources, enter the source frequency to the AFG using **[SOURce:]ROSCillator:FREQUENCY:EXTernal <frequency>**.
- For best frequency linearity, use the 42.9 MHz (that is, **INTernal[1]**) reference oscillator source with the DDS (frequency1) frequency generator. This combination provides .01 Hz resolution. For higher frequency values, use the 40 MHz (that is, **INTernal2**) reference oscillator source with the Divide-by-N (frequency2) frequency generator. Use the other sources for custom frequency values. However, any reference oscillator sources can be used with any frequency generator.

Sample Sources

- The **SINUsoid** function only operates with the **INTernal[1]** sample source.
- The **SQUare**, **TRIangle**, and **RAMP** functions operate with any of the sample sources selected by the **TRIGger:START:SOURce** command. The functions can use either the DDS (frequency1) frequency generator or the Divide-by-N (frequency2) frequency generator for waveform generation. However, the DDS frequency generator gives better frequency resolution and should be used for these functions. The Divide-by-N frequency generator should be used for arbitrary waveform generation where high frequency values are needed. The different sample sources are:

INTernal[1] (power-on value; selects the DDS frequency generator)

INTernal2 (selects the Divide-by-N frequency generator)

BUS (the HP-IB GET or *TRG commands)

EXTernal (the front panel “Ref/Smpl In” BNC)

ECLTrg0 or 1 (the VXIbus ECL trigger lines)
HOLD (suspends sample generation)
TTLTrg0 through 7 (the VXIbus TTL trigger lines)

DDS Frequency Generator Ranges

The [SOURce:]FREQUency[1]:RANGe command selects frequency doubling of the DDS frequency generator for the SQUare, TRIangle, and RAMP functions. This command is only used with DDS (frequency1) frequency generator.

The lower frequency setting (that is, normal setting) for the SQUare function is determined by:

- Reference Oscillator frequency / 16

The high frequency setting for the SQUare function is determined by:

- Reference Oscillator frequency / 8

The lower frequency setting (that is, normal setting) for the TRIangle and RAMP functions is determined by:

- Reference Oscillator frequency / 4 / number of points

The doubled frequency setting for the TRIangle and RAMP functions is determined by:

- Reference Oscillator frequency / 2 / number of points

The doubled setting worsens the frequency resolution by a factor of two and introduces some sample rate jitter.

Number of Points versus Frequency

The number of points ([SOURce:]RAMP:POINTs) determine the maximum frequency of the TRIangle and RAMP functions. The more points results in a lower maximum frequency, but with a better waveform shape. The fewer points results in a higher maximum frequency, but with lower resolution.

Output Load Comments

- For correct output amplitude values, the load applied to the AFG "Output 50/75 Ω " output terminals must be the same value as the selected AFG output impedance value.
- To output to an open circuit, execute OUTPut[1]:LOAD INFinity or 9.9E+37 (this sets the auto load value off). The HP E1445A then outputs the correct amplitude and offset for an open circuit. The amplitude and offset range are doubled while resolution worsens by a factor of 2.

Output Units Comments

- The selected unit type can be overridden by sending a unit suffix with the amplitude command. For example, if the selected unit is VPP, sending:
`[SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude] 5V`
changes the unit type to volts (that is, V) for that command. However, the default unit type remains in effect for subsequent amplitude commands that are sent without the unit suffix.
- The V (volts) suffix and VPK (volts peak) suffix generate the same amplitude values for all time varying waveforms like SINusoid, SQUare, TRIangle, and RAMPS.
- The default unit type only applies for amplitudes and not for offsets. The unit for offsets is always specified in V for volts. For example, executing:
`[SOURce:]VOLTage:OFFSet .1VPP`
causes an error. To prevent the error, execute either:
`[SOURce:]VOLTage:OFFSet 0.1`
or
`[SOURce:]VOLTage:OFFSet 0.1V`
- The W, DBM, and DBMW unit types references the amplitude levels to the 50 Ω or 75 Ω output load values (set by the OUTPut[1]:LOAD command). Thus, the W, DBM, and DBMW values are meaningless and not available when selecting an open circuit load.

Selecting the Deviation Units for Phase Modulation

Use either degrees or radians to change the phase in the phase modulation function. There are two ways to select the units, either send the unit type with the deviation command, like:

```
[SOURce:]PM:DEVIation -90DEG
```

or select the unit type with the unit command like:

```
[SOURce:]PM:UNIT:ANGLE DEG or [SOURce:]PM:DEVIation -90
```

Using MINimum and MAXimum Parameters

You can execute many commands (like [SOURce:]FREQuency[1][:CW]:FIXed) using the MINimum or MAXimum parameters instead of a number value. However, when using the parameters, the commands are immediately executed when received. This happens even if the commands are coupled to other commands in a coupling group. This is different than sending the commands with number values, where the commands are executed after a new coupling group is sent.

Thus, if a group of coupled commands are sent where the MINimum and MAXimum parameters conflict with the current AFG setting, the AFG generates an error. This happens even though the commands that follow may set the AFG to a state that does not conflict with the MINimum and MAXimum parameters.

For best results, use values in the commands and do not use the MINimum and MAXimum parameters.

Notes

Chapter 3

Generating Arbitrary Waveforms

Chapter Contents

This chapter shows how to generate arbitrary waveforms using the HP E1445A 13-Bit Arbitrary Function Generator (called the “AFG”).

The following sections show how to generate arbitrary waveforms. Also included are example programs that generate various arbitrary waveforms. The sections are as follows:

- Arbitrary Waveforms Flowchart Page 84
- How the AFG Generates Arbitrary Waveforms Page 86
- Generating a Simple Arbitrary Waveform Page 88
- Executing Several Waveform Segments Page 93
- Using Different Frequency Generators Page 99
- Sample Programs Page 104
 - Generating a Sin(X)/X Waveform Page 105
 - Generating a Damped Sine Wave Page 107
 - Generating an Exponential Change/Discharge Waveform. Page 108
 - Generating a Sine Wave with Spikes Page 109
 - Generating a ½ Rectified Sine Wave Page 111
 - Generating Noise Page 112
- Arbitrary Waveform Program Comments Page 113
 - Determining the Amount of Segment and Sequence Memory Page 113
 - How to Free Segment and Sequence Memory Page 113
 - Amplitude Effects on Voltage Lists Page 113
 - Using DAC Codes to Send Segment Data Page 114
 - Sending Segment Sequences Page 114
 - Reference Oscillator Sources Page 115
 - Sample Sources Page 115
 - Frequency1 Generator Range Page 116
 - Returning the Waveform Segment Names Page 116
 - Determining the Waveform Segment Size Page 116
 - Returning the Segment Sequence List Names Page 116
 - Returning the Repetition Count List Length. Page 116

Arbitrary Waveforms Flowchart

The flowchart in Figure 3-1 shows the commands and the command execution order to generate arbitrary waveforms. The reset (power-on) values of each command are also noted on the flowchart. Note that the IEEE 488.2 *RST command places the AFG into its power-on state. Thus, it may be unnecessary to execute all of the commands on the flowchart. Remove the flowchart from the binder for easy accessibility. Refer to the flowchart while doing the examples in this chapter, if desired.

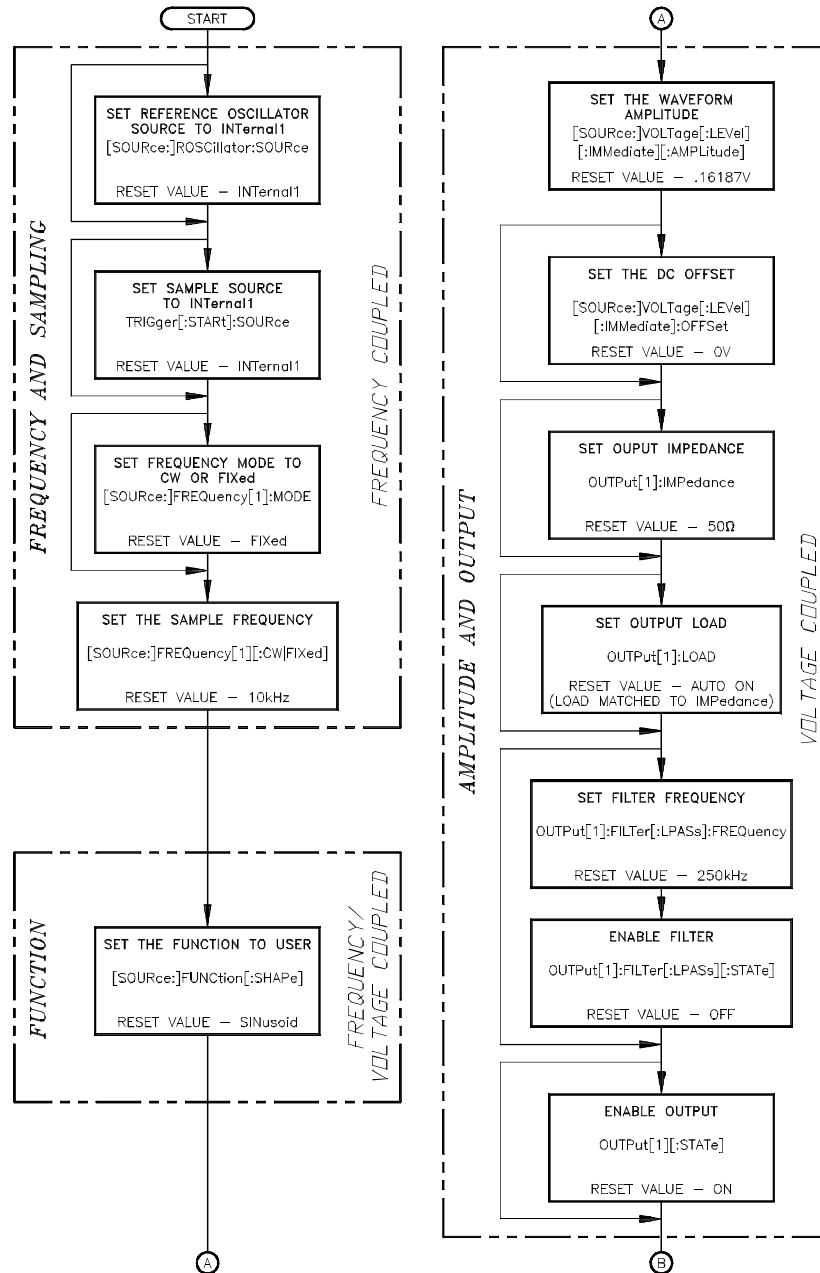


Figure 3-1. Commands for Generating Arbitrary Waveforms
(continued on next page)

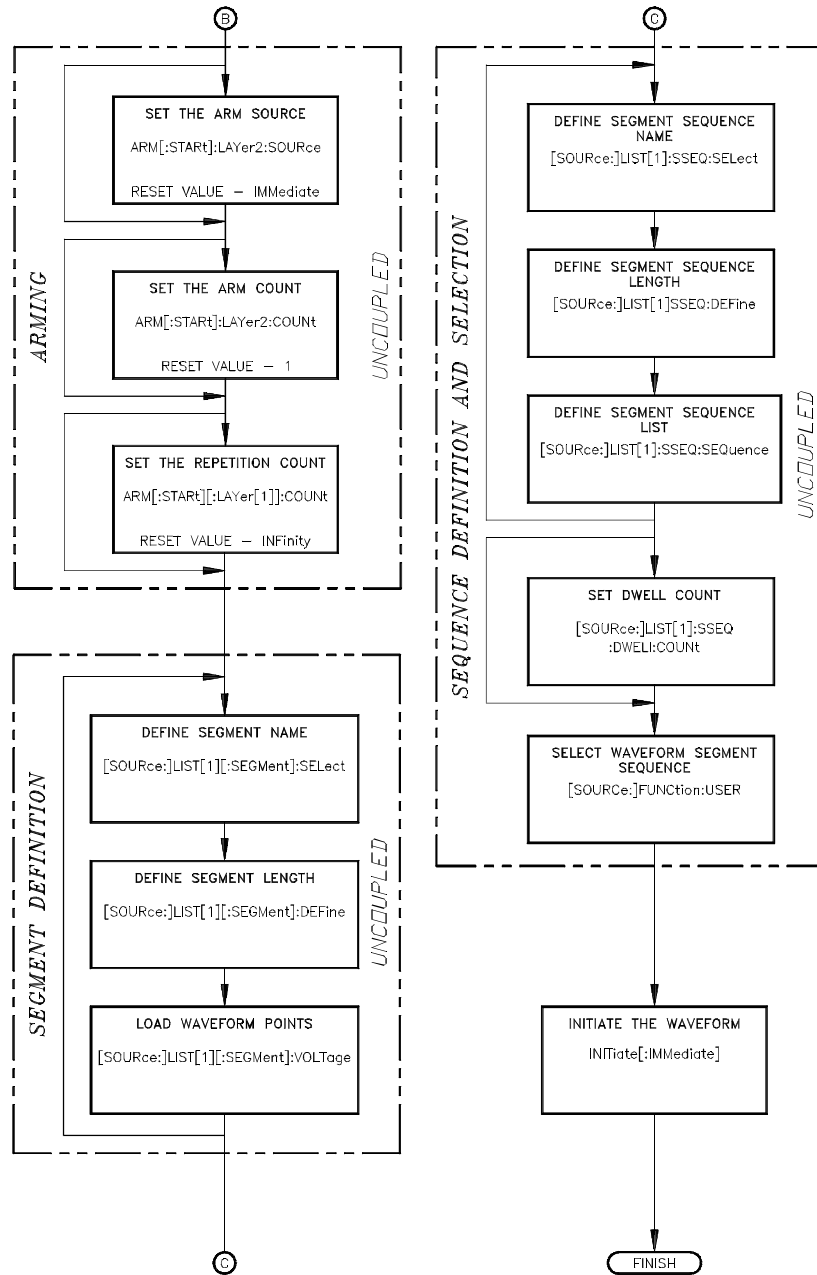


Figure 3-1. Commands for Generating Arbitrary Waveforms
(continued from previous page)

How the AFG Generates Arbitrary Waveforms

Refer to Figure 3-2. An arbitrary waveform consists of two parts, a waveform segment (or all points on a waveform) and a segment sequence. The segments are the actual voltage points of the waveform. The segment sequence determines the order in which one or more waveform segments are output.

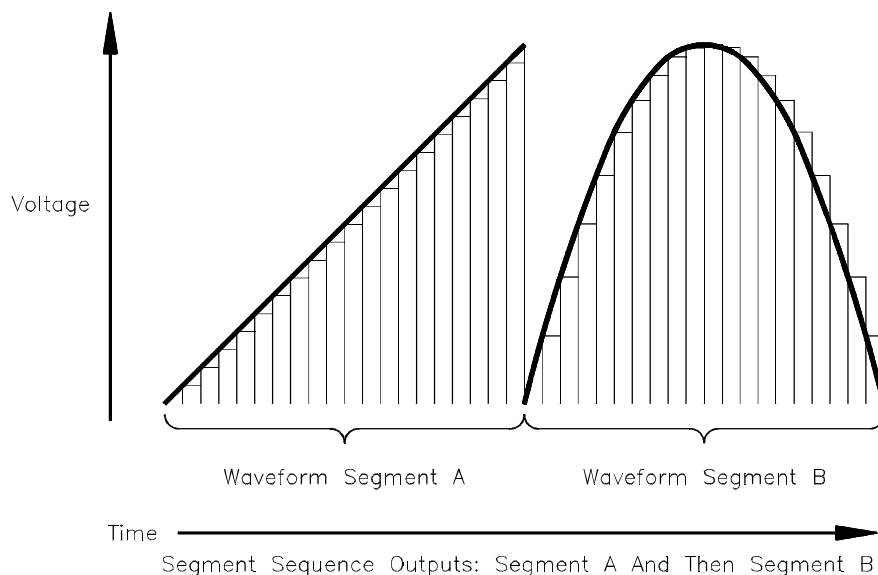


Figure 3-2. Generating Arbitrary Waveforms

To output a waveform, the waveform segment must be stored into the AFG's segment memory. To do this, you must assign a unique name (use `[SOURCE:]LIST[1]:SEGMENT:SElect <name>`) for each waveform segment to be stored into memory. This allows you to select one of many waveform segments, which may exist in memory, to be output. Legal names must start with an alphabetic character, but can contain alphabetic, numeric, and underscore (" _ ") characters. The names can have a maximum length of 12 characters. The AFG generates an error for duplicate names.

Besides the name, the AFG must also know the size (use `[SOURCE:]LIST[1]:SEGMENT:DEFine <length>`) of the waveform segment (that is, the number of points). The assigned segment size must be equal to or larger than the actual size of the waveform segment. The AFG generates an error if the waveform segment is larger than the size sent.

The segment values can be either sent as voltage values (use `[SOURCE:]LIST[1]:SEGMENT:VOLTage <voltage_list>`) or DAC (digital-to-analog converter) codes (use `[SOURCE:]LIST[1]:SEGMENT:VOLTage:DAC <voltage_list>`). If sent as voltage values, the AFG converts them to DAC codes before storing them in memory.

The segment sequence determines the order in which the waveform segments in memory are to be output, which order is assigned by the user (use [SOURCE:]LIST[1]:SSEQUENCE:SEQUENCE <segment_list>).

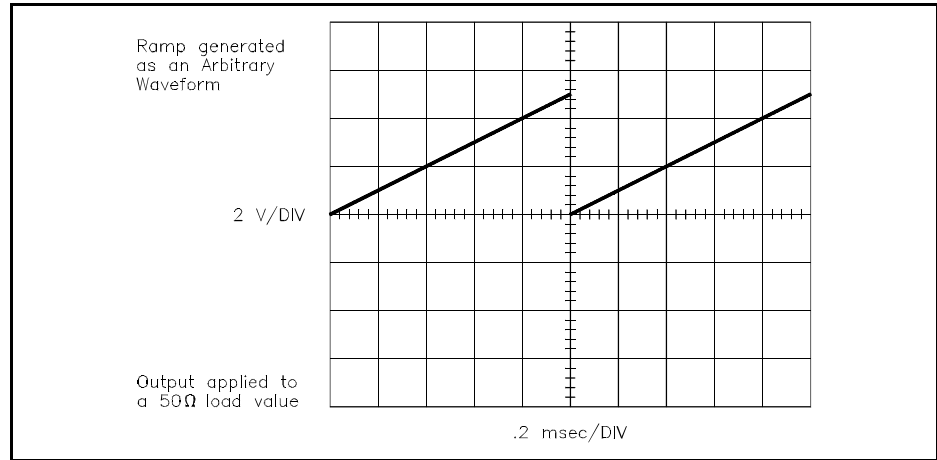
Each segment sequence must be stored into the AFG's sequence memory. To do this, you must assign a unique name (use [SOURCE:]LIST[1]:SSEQUENCE:SELECT <name>) for each segment sequence to be stored into memory. This allows you to select one of many segment sequences, which may exist in memory, to be output. Legal names must start with an alphabetic character, but can contain alphabetic, numeric, and underscore (" _ ") characters. The names can have a maximum length of 12 characters. The AFG generates an error for duplicate names.

The waveform segment names in a segment sequence can either be sent as names or as an address value (see Chapter 7 for more information).

To output a waveform, the AFG sets the DAC to the voltage value of each waveform segment in the segment sequence. The sample frequency determines the rate at which the DAC is set to the different voltage values. Depending on the sample source selected (by TRIGGER[:START]:SOURCE <source>), the sample rate is set by the DDS (frequency1) frequency generator ([SOURCE:]FREQUENCY[1]), Divide-by-N (frequency2) frequency generator ([SOURCE:]FREQUENCY2), or the samples rates of the external sample sources.

The sample rate and the number of points in the waveform segment determine the waveform repetition frequency. The repetition frequency is the sample rate / number of points.

Generating a Simple Arbitrary Waveform



The ARBWAVE program shows how to generate an arbitrary waveform with a single waveform segment. The example generates a 100 point ramp. The AFG stores the waveform segment into segment memory as voltage data points. The commands are:

1. **Reset the AFG**

`*RST`

The *RST command aborts any waveform output and sets the AFG to a defined state.

2. **Clear the AFG Memory of All Sequence Data**

`[SOURCE:]LIST[1]:SSEquence:DELeTe:ALL`

This command clears all segment sequence data stored in the sequence memory (see “How to Free Segment and Sequence Memory” on page 113 for more information).

3. **Clear the AFG Memory of All Segment Data**

`[SOURCE:]LIST[1]:SEGMENT:DELeTe:ALL`

This command clears all segment data stored in the segment memory (see “How to Free Segment and Sequence Memory” on page 113 for more information).

4. **Select the Reference Oscillator**

`[SOURCE:]ROSCillator:SOURCE <source>`

This command selects the reference oscillator source (see “Reference Oscillator Sources” on page 115).

5. Set the Segment Sample Rate

[SOURce:]FREQUency[1][:CW | :FIXed] *<frequency>*

This command sets the rate at which the points in a waveform segment are output by the AFG. The waveform frequency is determined by:

$$(\text{sample frequency}) / (\text{number of points})$$

Refer to Table B-3 in Appendix B for the frequency limits.

6. Select the Arbitrary Waveform Function

[SOURce:]FUNCtion[:SHAPE] USER

This command selects the arbitrary waveform function. Couple the command to the previous frequency command.

7. Set the Maximum Output Amplitude

[SOURce:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude] *<amplitude>*

This command specifies the maximum output amplitude. The amplitude must be equal to, or greater than the maximum voltage value of the waveform segment. Refer to Table B-4 in Appendix B for the amplitude limits.

8. Name the Waveform Segment

[SOURce:]LIST[1][:SEGment]:SElect *<name>*

This command names the waveform segment. Each waveform segment to be stored into memory must have a unique name. Legal names must start with an alphabetic character, but can contain alphabetic, numeric, and underscore (“_”) characters. The names can have a maximum length of 12 characters.

9. Set the Waveform Segment Size

[SOURce:]LIST[1][:SEGment]:DEFine *<length>*

This command defines the size of the number of voltages or points in the selected waveform segment. The size must be equal or greater than the number of points in the waveform segment (minimum value is 8 points). The command reserves enough memory needed for the waveform segment.

10. Store the Waveform Segment as Voltages

[SOURce:]LIST[1][:SEGment]:VOLTage *<voltage_list>*

This command stores the points of the waveform segment into the AFG’s segment memory. These points are sent to the AFG as volts which are the output voltage points that constitutes the waveform segment.

11. **Name the Segment Sequence**

[SOURCE:]LIST[1]:SSEquence:SElect <name>

This command names the segment sequence. Each sequence stored into memory must have a unique name. Legal names must start with an alphabetic character, but can contain alphabetic, numeric, and underscore (“_”) characters. The names can have a maximum length of 12 characters. The names **MUST** be different from any waveform segment names stored in memory.

12. **Set the Segment Sequence Length**

[SOURCE:]LIST[1]:SSEquence:DEFine <length>

This command defines the length of the selected segment sequence. The length must be equal to, or greater than the number of waveform segments in the sequence (next step).

13. **Define the Segment Sequence Order**

[SOURCE:]LIST[1]:SSEquence:SEquence <segment_list>

This command determines the order in which the waveform segments are to be executed. Each waveform segment name must be separated by a comma (for example, A,B,C). (see “Executing Several Waveform Segments” on page 93 for more information.)

14. **Select the User Name**

[SOURCE:]FUNCTION:USER <name>

This command selects the segment sequences to be output. Make the <name> in this command the same name as the stored segment sequence to be output.

15. **Initiate the Waveform**

INITiate[:IMMediate]

This command generates an immediate output with the arm source set to IMMEDIATE. Refer to Chapter 5 for triggering information.

16. **Query the Segment Memory (Optional)**

[SOURCE:]LIST[1]:SEGment:FREE?

This command returns the amount of segment memory remaining (first number) in the AFG and the amount of memory used (second number).

17. **Query the Segment Sequence Memory (Optional)**

[SOURCE:]LIST[1]:SSEquence:FREE?

This command returns the amount of segment memory remaining in the AFG (the first number) and the amount of memory used (the second number).

HP BASIC Program Example (ARBWAVE)

```
1  !RE-STORE"ARBWAVE"
2  !This program demonstrates the procedure for developing and
3  !outputting an arbitrary waveform.
4  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 COM @Afg,Seg_mem$[256],Seq_mem$[256]
40 !
50 !Set up error checking
60 ON INTR 7 CALL Errmsg
70 ENABLE INTR 7;2
80 OUTPUT @Afg;"*CLS"
90 OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms
130 CALL Rst
140 CALL Wf_del
150 !
160 OUTPUT @Afg;"SOUR:FREQ1:FIX 100E3;";           !frequency
170 OUTPUT @Afg;"SOUR:FUNC:SHAP USER;";           !function
180 OUTPUT @Afg;"SOUR:VOLT:LEV:IMM:AMPL 5.1V"      !amplitude
190 !
200 CALL Ramp_wave
210 !
220 OUTPUT @Afg;"SOUR:FUNC:USER RAMP_OUT"          !waveform sequence
230 OUTPUT @Afg;"INIT:IMM"                          !wait-for-arm state
240 !
250 PRINT "Segment memory points available, used: ";Seg_mem$
260 PRINT
270 PRINT "Sequence memory points available, used: ";Seq_mem$
280 !
290 WAIT .1 !allow interrupt to be serviced
300 OFF INTR 7
310 END
320 !
330 SUB Ramp_wave
340 Ramp_wave: !Subprogram which defines a ramp waveform and output
350             !sequence.
360     COM @Afg,Seg_mem$,Seq_mem$
370     DIM Waveform(1:100)                          !Calculate waveform points
380     FOR I=1 TO 100
390         Waveform(I)=I*.0505
400     NEXT I
410     !
420     OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL RAMP"        !segment name
430     OUTPUT @Afg;" SOUR:LIST1:SEGM:DEF 100"        !segment size
440     OUTPUT @Afg;" SOUR:LIST1:SEGM:VOLT ";Waveform(*) !waveform points
```

Continued on Next Page

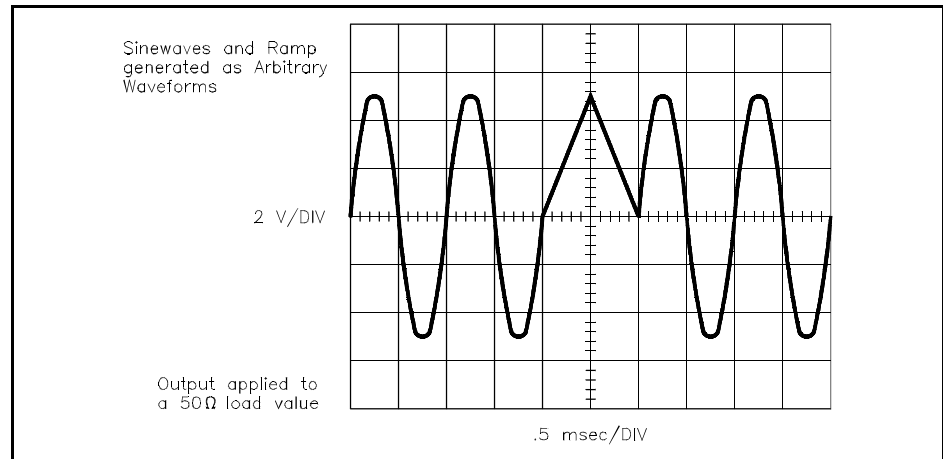
```

450     OUTPUT @Afg;" SOUR:LIST1:SEGM:FREE?"
460     ENTER @Afg;Seq_mem$
470     !
480     OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL RAMP_OUT" !sequence name
490     OUTPUT @Afg;" SOUR:LIST1:SSEQ:DEF 1" !sequence size
500     OUTPUT @Afg;" SOUR:LIST1:SSEQ:SEQ RAMP" !segment order
510     OUTPUT @Afg;" SOUR:LIST1:SSEQ:FREE?"
520     ENTER @Afg;Seq_mem$
530     SUBEND
540     !
550     SUB Rst
560 Rst: !Subprogram which resets the E1445.
570     COM @Afg,Seq_mem$,Seq_mem$
580     OUTPUT @Afg;"*RST:*OPC?" !reset the AFG
590     ENTER @Afg;Complete
600     SUBEND
610     !
620     SUB Wf_del
630 Wf_del: !Subprogram which deletes all sequences and segments.
640     COM @Afg,Seq_mem$,Seq_mem$
650     OUTPUT @Afg;"FUNC:USER NONE" !select no sequences
660     OUTPUT @Afg;"LIST:SSEQ:DEL:ALL" !Clear sequence memory
670     OUTPUT @Afg;"LIST:SEGM:DEL:ALL" !Clear segment memory
680     SUBEND
690     !
700     SUB Errmsg
710 Errmsg: !Subprogram which displays E1445 programming errors
720     COM @Afg,Seq_mem$,Seq_mem$
730     DIM Message$(256)
740     !Read AFG status byte register and clear service request bit
750     B=SPOLL(@Afg)
760     !End of statement if error occurs among coupled commands
770     OUTPUT @Afg;"
780     OUTPUT @Afg;"ABORT" !abort output waveform
790     REPEAT
800         OUTPUT @Afg;"SYST:ERR?" !read AFG error queue
810         ENTER @Afg;Code,Message$
820         PRINT Code,Message$
830     UNTIL Code=0
840     STOP
850     SUBEND

```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, ARBWAVE.FRM, is in directory "VBPROG" and the Visual C example program, ARBWAVE.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Executing Several Waveform Segments



The MULSEG program shows how to generate an arbitrary waveform using two different waveform segments. One waveform segment generates a 1 kHz, 5 V sine wave repeated twice. The other one generates a 1 kHz, 5 Vpeak triangle repeated once. The commands are:

1. **Reset the AFG**

`*RST`

The `*RST` command aborts waveform output and sets the AFG to a defined state.

2. **Clear the AFG Memory of All Sequence Data**

`[SOURCE:]LIST[1]:SSEquence:DELeTe:ALL`

This command clears all segment sequence data stored in the sequence memory.

3. **Clear the AFG Memory of All Segment Data**

`[SOURCE:]LIST[1]:DELeTe:ALL`

This command clears all segment data stored in the segment memory.

4. **Set the Sample Rate**

`[SOURCE:]FREQuency[1][:CW | :FIXed] <frequency>`

This command sets the rate at which the points are output by the AFG. The frequency is:

$$(\text{sample frequency}) / (\text{number of points})$$

Refer to Table B-3 in Appendix B for the frequency limits.

5. Select the Arbitrary Waveform Function

[SOURce:]FUNCTION[:SHAPE] USER

This command selects the arbitrary waveform function. Couple the command to the previous frequency command.

6. Set the Maximum Output Amplitude

[SOURce:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude] <amplitude>

This command specifies the maximum output amplitude. The amplitude must be equal or greater than the maximum voltage value of the waveform segment. Refer to Table B-4 in Appendix B for the amplitude limits.

7. Name the First Waveform Segment

[SOURce:]LIST[1][:SEGMENT]:SElect <name>

This command names the first waveform segment.

8. Set the First Waveform Segment Size

[SOURce:]LIST[1][:SEGMENT]:DEFine <length>

This command defines the size of the selected waveform segment.

9. Store the First Waveform Segment as Voltages

[SOURce:]LIST[1][:SEGMENT]:VOLTage <voltage_list>

This command stores the first waveform segment into the AFG's segment memory.

10. Name the Second Waveform Segment

[SOURce:]LIST[1][:SEGMENT]:SElect <name>

This command names the second waveform segment.

11. Set the Second Waveform Segment Size

[SOURce:]LIST[1][:SEGMENT]:DEFine <length>

This command defines the size of the selected waveform segment.

12. Store the Second Waveform Segment as Voltages

[SOURce:]LIST[1][:SEGMENT]:VOLTage <voltage_list>

This command stores the second waveform segment into the AFG's segment memory.

13. Name the Segment Sequence

[SOURce:]LIST[1]:SSEQUence:SElect <name>

This command names the segment sequence. The name must be different from any segment names stored in memory.

14. Set the Segment Sequence Length

[SOURce:]LIST[1]:SSEQUence:DEFine <length>

This command defines the length of the selected segment sequence. The length must be equal or greater than the number of the waveform segments stored in memory.

15. Define the Segment Sequence Order

[SOURCE:]LIST[1]:SSEQUENCE:SEQUENCE <segment_list>

This command determines the order in which the waveform segments are to be executed. The names of each waveform segment to be output must be separated by a comma (for example, A,B,C). See “Sending Segment Sequences” on page 114 for more information.

16. Define the Waveform Segments Repetition Count

[SOURCE:]LIST[1]:SSEQUENCE:DWELL:COUNT <repetition_list>

This command sets how many times each waveform segment is to be executed. See “Sending Segment Sequences” on page 114 for more information.

17. Select the User Name

[SOURCE:]FUNCTION:USER <name>

This command sets the AFG to output the selected segment sequence. The <name> in this command the same name as the stored segment sequence to be executed.

18. Initiate the Waveform

INITIATE[:IMMEDIATE]

This command generates an immediate output with the arm source set to IMMEDIATE. Refer to Chapter 5 for triggering information.

HP BASIC Program Example (MULSEG)

```
1  !RE-STORE"MULSEG"
2  !This program outputs an arbitrary waveform that is comprised of
3  !two waveform segments.
4  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 COM @Afg
40 !
50 !Set up error checking
60 ON INTR 7 CALL Errmsg
70 ENABLE INTR 7;2
80 OUTPUT @Afg;"*CLS"
90 OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms which reset the AFG and clear segment
130 !and sequence memory.
140 CALL Rst
150 CALL Wf_del
160 !Set the signal frequency, the function, and the amplitude.
170 OUTPUT @Afg;"SOUR:FREQ1:FIX 2.048E6;";
180 OUTPUT @Afg;":SOUR:FUNC:SHAP USER;";
190 OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL 5.1V"
200 !Call the subprograms which define the triangle wave, sine wave,
210 !and output waveform sequence.
220 CALL Tri_wave
230 CALL Sine_wave
240 CALL Seq_def
250 !Select the output sequence and start the waveform.
260 OUTPUT @Afg;"SOUR:FUNC:USER WAVE_OUT"
270 OUTPUT @Afg;"INIT:IMM"
280 !
290 WAIT .1 !allow interrupt to be serviced
300 OFF INTR 7
310 END
320 !
330 SUB Tri_wave
340 Tri_wave: !Subprogram which defines a triangle waveform and stores
350 !it in a segment
360 COM @Afg
370 DIM Waveform(1:2048) !Calculate waveform points
380 FOR I=1 TO 2048
390 IF I<1024 THEN
400 Waveform(I)=I*.0048828
410 ELSE
420 Waveform(I)=(2048-I)*.0048828
430 END IF
440 NEXT I
```

Continued on Next Page

```

450      !
460      OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL TRI"           !segment name
470      OUTPUT @Afg;" SOUR:LIST1:SEGM:DEF 2048"       !segment size
480      OUTPUT @Afg;" SOUR:LIST1:SEGM:VOLT";Waveform(*) !waveform points
490      SUBEND
500      !
510      SUB Sine_wave
520 Sine_wave: !Subprogram which computes a sine wave and stores
530             !it in a segment
540             COM @Afg
550             DIM Waveform(1:2048)                   !Calculate sine wave
560             FOR I=1 TO 2048
570                 Waveform(I)=5.*(SIN(2.*PI*(I/2048.)))
580             NEXT I
590             !
600             OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL SINEWAVE" !segment name
610             OUTPUT @Afg;" SOUR:LIST1:SEGM:DEF 2048"   !segment size
620             OUTPUT @Afg;" SOUR:LIST1:SEGM:VOLT";Waveform(*) !waveform points
630             SUBEND
640             !
650             SUB Seq_def
660 Seq_def: !Subprogram which defines the output sequence
670             COM @Afg
680             OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL WAVE_OUT" !sequence name
690             OUTPUT @Afg;"SOUR:LIST1:SSEQ:DEF 2"       !sequence size
700             OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEQ SINEWAVE,TRI" !execution order
710             OUTPUT @Afg;"SOUR:LIST1:SSEQ:DWEL:COUN 2,1" !segment dwell count
720             SUBEND
730             !
740             SUB Rst
750 Rst: !Subprogram which resets the E1445.
760             COM @Afg
770             OUTPUT @Afg;"*RST;*OPC?"                 !reset the AFG
780             ENTER @Afg;Complete
790             SUBEND
800             !
810             SUB Wf_del
820 Wf_del: !Subprogram which deletes all sequences and segments.
830             COM @Afg
840             OUTPUT @Afg;"FUNC:USER NONE"              !select no sequences
850             OUTPUT @Afg;"LIST:SSEQ:DEL:ALL"           !Clear sequence memory
860             OUTPUT @Afg;"LIST:SEGM:DEL:ALL"          !Clear segment memory
870             SUBEND
880             !
890             SUB Errmsg
900 Errmsg: !Subprogram which displays E1445 programming errors
910             COM @Afg
920             DIM Message$(256)
930             !Read AFG status byte register and clear service request bit
940             B=SPOLL(@Afg)

```

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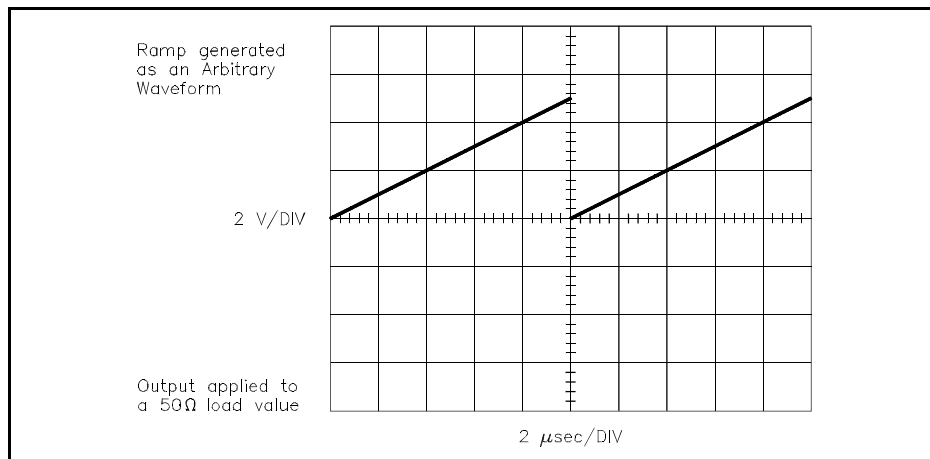
```

950      !End of statement if error occurs among coupled commands
960      OUTPUT @Afg;""
970      OUTPUT @Afg;"ABORT"           !abort output waveform
980      REPEAT
990          OUTPUT @Afg;"SYST:ERR?"   !read AFG error queue
1000         ENTER @Afg;Code,Message$
1010         PRINT  Code,Message$
1020     UNTIL Code=0
1030     STOP
1040     SUBEND

```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, MULSEG.FRM, is in directory “VBPROG” and the Visual C example program, MULSEG.C, is in directory “VCPROG” on the CD that came with your HP E1445A.

Using Different Frequency Generators



The AFG can use either the DDS (Frequency1) Frequency Generator or the Divide-by-N (Frequency2) Frequency Generator to generate arbitrary waveforms. The DDS generator gives lower frequency response with better resolution. The Divide-by-N generator gives higher frequency response with less resolution. For best operating practice, use the 42.9 MHz reference oscillator source (INTernal[1]) for the DDS generator; use the 40 MHz reference oscillator source (INTernal2) for the Divide-by-N generator. (See “Arbitrary Waveform Program Comments” on page 113 for more information.)

The AFGGEN1 program shows how to use the AFG’s DDS generator (selected at power-on) to generate waveforms. Use this generator for better frequency resolution and to perform frequency sweeping, frequency shifting, and so forth (see Chapter 4). See program AFGGEN2 for a frequency2 generator example. This program generates a 100 point ramp at 100 kHz. The commands are:

1. **Reset the AFG**

*RST

The *RST command aborts waveform output and sets the AFG to a defined state.

2. **Clear the AFG Memory of All Sequence Data**

[SOURCE:]LIST[1]:SSEQUence:DELEte:ALL

This command clears all segment sequence data stored in the sequence memory.

3. **Clear the AFG Memory of All Segment Data**

[SOURCE:]LIST[1]:DELEte:ALL

This command clears all segment data stored in the segment memory.

4. Select the Reference Oscillator

[SOURce:]ROSCillator:SOURce INTernal[1]

This command selects the 42.9 MHz (Internal1) reference oscillator source to be used with the DDS frequency generator (see “Reference Oscillator Sources” on page 115). (Although *RST selects the 42.9 MHz reference oscillator, it is selected here for good programming practice.)

If you wish to use the Divide-by-N frequency generator, use:

[SOURce:]ROSCillator:SOURce INTernal2

5. Select the Sample Source

TRIGger:START:SOURce INTernal[1]

This command selects the sample source for the DDS generator (that is, trigger start source INTernal[1]). (Although *RST selects this trigger start source, it is selected here for good programming practice.) The USER (that is, arbitrary waveform) function can use any of the trigger start sources (see “Sample Sources” on page 115).

If you wish to use the Divide-by-N generator, use:

TRIGger:START:SOURce INTernal2

6. Set the Sample Frequency Range

[SOURce:]FREQuency[1]:RANGe <range>

This command specifies the upper sample frequency limit (see “Frequency1 Generator Range” on page 116) for the DDS generator. Do not send this command if using the Divide-by-N generator.

7. Set the Segment Sample Rate

[SOURce:]FREQuency[1][:CW | :FIXed] <frequency>

This command sets the rate at which the points in a waveform segment are output by the AFG. The frequency is:

(sample frequency) / (number of points)

Refer to Table B-3 in Appendix B for the frequency limits.

8. Select the Arbitrary Waveform Function

[SOURce:]FUNCTion[:SHAPe] USER

This command selects the arbitrary waveform function. Couple the command to the previous frequency command.

9. Set the Maximum Output Amplitude

[SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude] <amplitude>

This command specifies the maximum output amplitude. The amplitude must be equal or greater than the maximum voltage value of the waveform segment. Refer to Table B-4 in Appendix B for the amplitude limits.

10. **Name the Waveform Segment**
[SOURce:]LIST[1]:SEGMENT:SElect <name>
This command names the waveform segment.
11. **Set the Waveform Segment Size**
[SOURce:]LIST[1]:SEGMENT:DEFine <length>
This command defines the size of the selected waveform segment.
12. **Store the Waveform Segment as Volts**
[SOURce:]LIST[1]:SEGMENT:VOLTage <voltage_list>
This command stores the segments into the AFG's segment memory.
13. **Name the Segment Sequence**
[SOURce:]LIST[1]:SSEQUence:SElect <name>
This command names the segment sequence.
14. **Set the Segment Sequence Length**
[SOURce:]LIST[1]:SSEQUence:DEFine <length>
This command defines the length of the selected segment sequence.
15. **Define the Segment Sequence Order**
[SOURce:]LIST[1]:SSEQUence:SEQUence <segment_list>
This command determines the order in which the waveform segments are to be executed.
16. **Select the User Name**
[SOURce:]FUNCTion:USER <name>
This command sets the AFG to output the selected segment sequence.
17. **Initiate the Waveform**
INITiate[:IMMEDIATE]
This command generates an immediate output with the arm source set to IMMEDIATE. Refer to Chapter 5 for triggering information.

HP BASIC Program Example (AFGGEN1)

```
1  !RE-STORE"AFGGEN1"
2  !This program outputs a ramp arbitrary waveform using the
3  !AFG's frequency1 generator.
4  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 COM @Afg
40 !
50 !Set up error checking
60 ON INTR 7 CALL Errmsg
70 ENABLE INTR 7;2
80 OUTPUT @Afg;"*CLS"
90 OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms which reset the AFG and which clear
130 !segment and sequence memory.
140 CALL Rst
150 CALL Wf_del
160 !Set waveform parameters
170 OUTPUT @Afg;"SOUR:ROSC:SOUR INT1;";
180 OUTPUT @Afg;".TRIG:STAR:SOUR INT1;";
190 OUTPUT @Afg;".SOUR:FREQ1:RANG 10E6;";
200 OUTPUT @Afg;".SOUR:FREQ1:FIX 10E6;";
210 OUTPUT @Afg;".SOUR:FUNC:SHAP USER;";
220 OUTPUT @Afg;".SOUR:VOLT:LEV:IMM:AMPL 5.1V"           !set amplitude to 5.1V
230 !Call subprogram which defines waveform segment and sequence
240 CALL Ramp_wave
250 !Select output sequence and initiate waveform
260 OUTPUT @Afg;"SOUR:FUNC:USER RAMP_OUT"
270 OUTPUT @Afg;"INIT:IMM"
280 !
290 WAIT .1 !allow interrupt to be serviced
300 OFF INTR 7
310 END
320 !
330 SUB Ramp_wave
340 Ramp_wave: !Subprogram which defines a ramp waveform
350   COM @Afg
360   DIM Waveform(1:100)           !Calculate waveform points
370   FOR I=1 TO 100
380     Waveform(I)=I*.0505
390   NEXT I
400   !
410   OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL RAMP"           !Define segment name
420   OUTPUT @Afg;" SOUR:LIST1:SEGM:DEF 100"           !Define segment size
430   OUTPUT @Afg;" SOUR:LIST1:SEGM:VOLT";Waveform(*) !load waveform points
440   !
```

Continued on Next Page

```

450     OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL RAMP_OUT"
460     OUTPUT @Afg;" SOUR:LIST1:SSEQ:DEF 1"
470     OUTPUT @Afg;" SOUR:LIST1:SSEQ:SEQ RAMP"
480     SUBEND
490     !
500     SUB Rst
510 Rst: !Subprogram which resets the E1445.
520     COM @Afg
530     OUTPUT @Afg;"*RST;*OPC?"                !reset the AFG
540     ENTER @Afg;Complete
550     SUBEND
560     !
570     SUB Wf_del
580 Wf_del: !Subprogram which deletes all sequences and segments.
590     COM @Afg
600     OUTPUT @Afg;"FUNC:USER NONE"            !select no sequences
610     OUTPUT @Afg;"LIST:SSEQ:DEL:ALL"        !Clear sequence memory
620     OUTPUT @Afg;"LIST:SEGM:DEL:ALL"        !Clear segment memory
630     SUBEND
640     !
650     SUB Errmsg
660 Errmsg: !Subprogram which displays E1445 programming errors
670     COM @Afg
680     DIM Message$[256]
690     !Read AFG status byte register and clear service request bit
700     B=SPOLL(@Afg)
710     !End of statement if error occurs among coupled commands
720     OUTPUT @Afg;"
730     OUTPUT @Afg;"ABORT"                    !abort output waveform
740     REPEAT
750         OUTPUT @Afg;"SYST:ERR?"            !read AFG error queue
760         ENTER @Afg;Code,Message$
770         PRINT Code,Message$
780     UNTIL Code=0
790     STOP

```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, AFGGEN1.FRM, is in directory "VBPROG" and the Visual C example program, AFGGEN1.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

HP BASIC Program Example (AFGGEN2)

This program is similar to the AFGGEN1 program on page 102 except it selects different reference oscillator and sample sources. The differences are as follows:

```
1  !RE-STORE"AFGGEN2"
2  !This program outputs a ramp arbitrary waveform using the
3  !AFG's frequency2 generator.

160 !Set waveform parameters
170 OUTPUT @Afg;"SOUR:ROSC:SOUR INT2;";
180 OUTPUT @Afg;":TRIG:STAR:SOUR INT2;";
190 OUTPUT @Afg;":SOUR:FREQ2:RANG 40E6;";
200 OUTPUT @Afg;":SOUR:FREQ2:FIX 40E6;";
```

Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, AFGGEN2.FRM, is in directory "VBPROG" and the Visual C example program, AFGGEN2.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

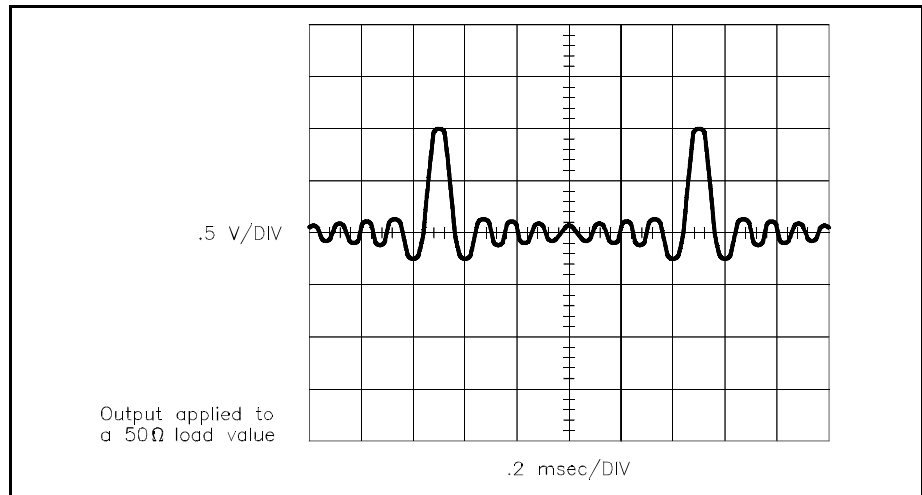
Sample Programs

The programs in this section generate various arbitrary waveforms. All programs output waveforms at a 1 kHz repetition frequency and 5 V amplitude. These programs do not delete any waveform segments and segment sequences stored in memory. Thus, once a program is executed, it generates Error +1100, "Illegal segment name" and Error +1110, "Illegal sequence name", if executed again.

Due to the similarity of all the programs, only the first program is completely presented here. Only the differences are shown by the other programs.

Generating a Sin(X)/X Waveform

The SIN_X program generates a Sin(X)/X waveform using 4096 segments or points.



HP BASIC Program Example (SIN_X)

```
1  !RE-STORE "SIN_X"
2  !This program generates the arbitrary waveform Sin(x)/x.
3  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 COM @Afg
40 !
50 !Set up error checking
60 ON INTR 7 CALL Errmsg
70 ENABLE INTR 7;2
80 OUTPUT @Afg;"*CLS"
90 OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprogram which resets and clears the AFG.
130 CALL Rst
140 !Set the signal frequency, function, and amplitude.
150 OUTPUT @Afg;"SOUR:FREQ1:FIX 4.096E6;";
160 OUTPUT @Afg;":SOUR:FUNC:SHAP USER;";
170 OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL 1.1V"
180 !Call the subprogram which defines the Sin(x)/x waveform and
190 !output sequence.
200 CALL Sinx_def
210 !Select the output sequence and start the waveform.
220 OUTPUT @Afg;"SOUR:FUNC:USER SIN_X_OUT"
230 OUTPUT @Afg;"INIT:IMM"
240 !
250 WAIT .1 !allow interrupt to be serviced
260 OFF INTR 7
270 END
```

Continued on Next Page

```

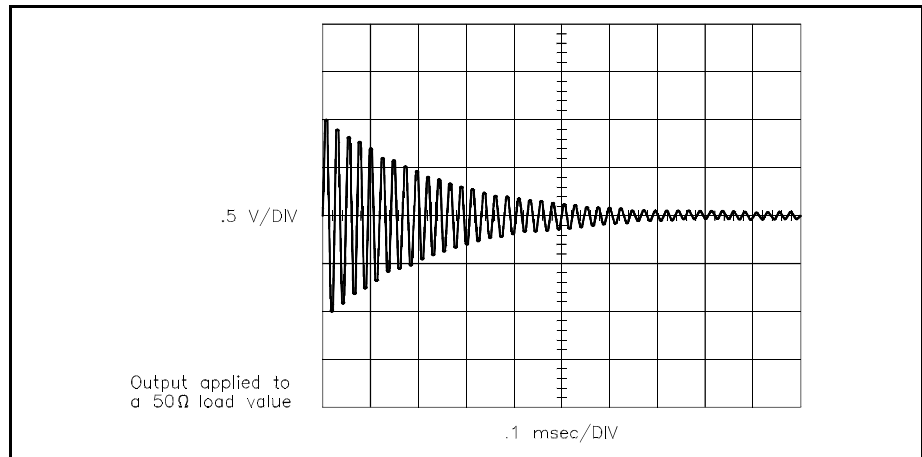
280 SUB Sinx_def
290 Sinx_def: !Define Sin(x)/x waveform and output sequence.
300 COM @Afg
310 DIM Waveform(1:4096)
320 FOR I=-2047 TO 2048
330 IF I=0 THEN I=1.E-38
340 Waveform(I+2048)=((SIN(2*PI*.53125*I/256)))/(.53125*I/256)*.159154943092)
350 NEXT I
360 !
370 OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL SIN_X" !select segment to be defined
380 OUTPUT @Afg;"SOUR:LIST1:SEGM:DEF 4096" !reserve memory for segment
390 OUTPUT @Afg;"SOUR:LIST1:SEGM:VOLT";Waveform(*) !load waveform points
400 !
410 OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL SIN_X_OUT" !select sequence to be defined
420 OUTPUT @Afg;"SOUR:LIST1:SSEQ:DEF 1" !specify # segments in sequence
430 OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEQ SIN_X" !set segment order in sequence
440 SUBEND
450 !
460 SUB Rst
470 Rst: !Subprogram which resets the E1445.
480 COM @Afg
490 OUTPUT @Afg;"*RST;*OPC?" !reset the AFG
500 ENTER @Afg;Complete
510 SUBEND
520 !
530 SUB Errmsg
540 Errmsg: !Subprogram which displays E1445 programming errors
550 COM @Afg
560 DIM Message$(256)
570 !Read AFG status byte register and clear service request bit
580 B=SPOLL(@Afg)
590 !End of statement if error occurs among coupled commands
600 OUTPUT @Afg;"
610 OUTPUT @Afg;"ABORT" !abort output waveform
620 REPEAT
630 OUTPUT @Afg;"SYST:ERR?" !read AFG error queue
640 ENTER @Afg;Code,Message$
650 PRINT Code,Message$
660 UNTIL Code=0
670 STOP
680 SUBEND

```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, SIN_X.FRM, is in directory "VBPROG" and the Visual C example program, SIN_X.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Generating a Damped Sine Wave

The SIN_D program generates a Damped sine wave using 4096 segments or points.



HP BASIC Program Example (SIN_D)

This program is similar to the "SIN_X" BASIC program on page 105, with the following differences:

```
1   IRE-STORE "SIN_D"
2   !This program outputs a damped sine wave arbitrary waveform.

180  !Call the subprogram which defines a damped sine wave and
190  !the output sequence.
200  CALL Sind_def
210  !Select the output sequence and start the waveform.
220  OUTPUT @Afg;"SOUR:FUNC:USER SIN_D_OUT"
230  OUTPUT @Afg;"INIT:IMM"

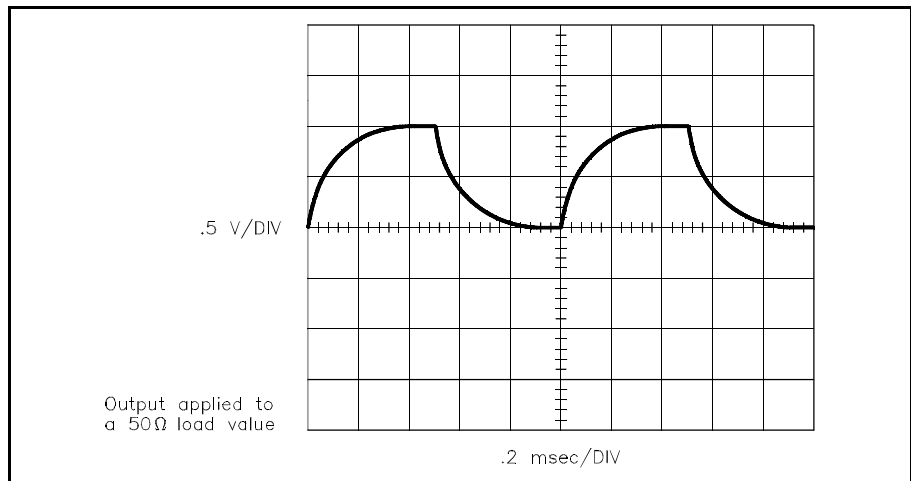
290  SUB Sind_def
300  Sind_def: !Compute waveform (damped sine wave) and define segment.
310    COM @Afg
320    DIM Waveform(1:4096)
330    A=4/4096
340    W=(2*PI)/50
350    FOR T=1 TO 4096
360      Waveform(T)=EXP(-A*T)*SIN(W*T)
370    NEXT T
380    OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL SIN_D" !select segment to be defined
390    OUTPUT @Afg;"SOUR:LIST1:SEGM:DEF 4096" !set segment size
400    OUTPUT @Afg;"SOUR:LIST1:SEGM:VOLT";Waveform(*) !load waveform points
410    !
420    OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL SIN_D_OUT" !Define sequence name
430    OUTPUT @Afg;"SOUR:LIST1:SSEQ:DEF 1" !Define sequence size
440    OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEQ SIN_D" !Set segment execution order
450  SUBEND
```

Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, SIN_D.FRM, is in directory "VBPROG" and the Visual C example program, SIN_D.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Generating an Exponential Charge/Discharge Waveform

The CHARGE program generates an Exponential Charge/Discharge waveform with 4096 segments or points.



HP BASIC Program Example (CHARGE)

This program is similar to the "SIN_X" BASIC program on page 105, with the following differences:

```
1  !RE-STORE "CHARGE"
2  !This program generates an exponential charge/discharge waveform
3  !as an arbitrary waveform.

180 !Call the subprogram which defines the exponential charge/
190 !discharge waveform and output sequence.
200 CALL Charge_def
210 !Select the output sequence and start the waveform.
220 OUTPUT @Afg;"SOUR:FUNC:USER CHARGE_OUT"
230 OUTPUT @Afg;"INIT:IMM"

280 SUB Charge_def
290 Charge_def:!Compute waveform (exponential) and define segment and
300 !sequence.
310 COM @Afg
320 DIM Waveform(1:4096)
330 Rc=400
340 FOR T=1 TO 4096
350 IF T>=0 AND T<2047 THEN
360 Waveform(T)=1*(1-EXP(-T/Rc))
370 END IF
```

Continued on Next Page


```

380     IF T>=2047 THEN
390         Waveform(T)=1*(1-EXP(-2048/Rc))-1*(1-EXP(-(T-2047)/Rc))
400     END IF
410     NEXT T
420     OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL CHARGE" !select segment to be defined
430     OUTPUT @Afg;"SOUR:LIST1:SEGM:DEF 4096"     !reserve memory for segment
440     OUTPUT @Afg;"SOUR:LIST1:SEGM:VOLT";Waveform(*) !load waveform points
450     !
460     OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL CHARGE_OUT" !Define sequence name
470     OUTPUT @Afg;"SOUR:LIST1:SSEQ:DEF 1"         !Define sequence size
480     OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEQ CHARGE"    !Set execution order
490     SUBEND

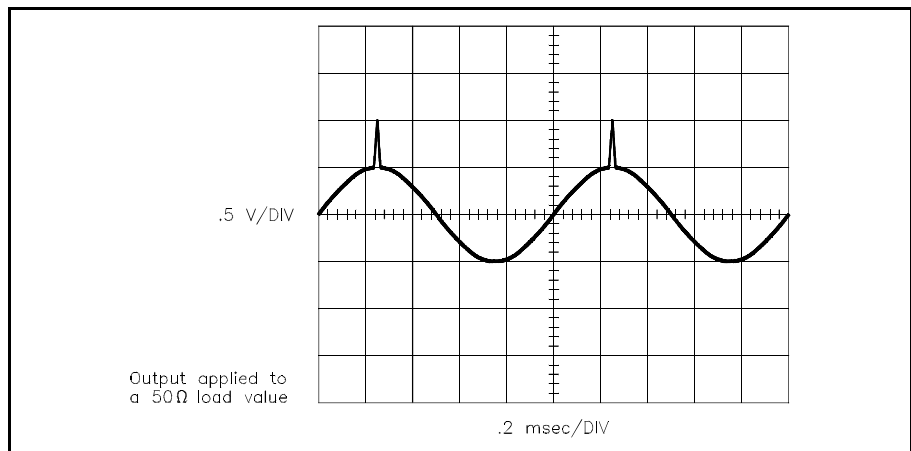
```

Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, CHARGE.FRM, is in directory “VBPROG” and the Visual C example program, CHARGE.C, is in directory “VCPROG” on the CD that came with your HP E1445A.

Generating a Sine Wave with Spikes

The SPIKES program generates a sine wave with spikes using 4096 segments or points.



HP BASIC Program Example (SPIKES)

This program is similar to the “SIN_X” BASIC program on page 105, with the following differences:

```

1     IRE-STORE "SPIKES"
2     !This program generates a spiked sine wave as an arbitrary waveform.

180    !Call the subprogram which defines a sine wave with a spike and
190    !the output sequence.
200    CALL Spike_def
210    !Select the output sequence and start the waveform.
220    OUTPUT @Afg;"SOUR:FUNC:USER SPIKES_OUT"
230    OUTPUT @Afg;"INIT:IMM"

290    SUB Spike_def

```

Continued on Next Page

```

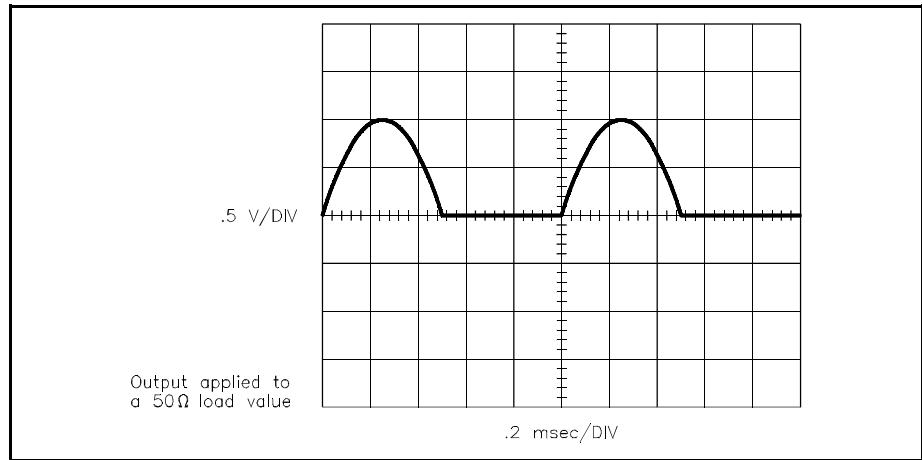
300 Spike_def: !Compute waveform (sine wave with spike) and define segment.
310     COM @Afg
320     DIM Waveform(1:4096)
330     FOR I=1 TO 4096
340         Waveform(I)=SIN(2*PI*(I/4096))
350     NEXT I
360     Width=50
370     FOR J=1 TO Width/2
380         Waveform(J+1024)=Waveform(J+1024)+J*.04
390     NEXT J
400     FOR J=1 TO Width/2
410         Waveform(J+1024+Width/2)=Waveform(J+1024+Width/2)+1-(J*.04)
420     NEXT J
430     OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL SPIKES" !select segment to be defined
440     OUTPUT @Afg;"SOUR:LIST1:SEGM:DEF 4096" !reserve memory for segment
450     OUTPUT @Afg;"SOUR:LIST1:SEGM:VOLT";Waveform(*) !load waveform points
460     !
470     OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL SPIKES_OUT" !Define sequence name
480     OUTPUT @Afg;"SOUR:LIST1:SSEQ:DEF 1" !Define sequence size
490     OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEQ SPIKES" !Define segment execution order
500     SUBEND

```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, SPIKES.FRM, is in directory "VBPROG" and the Visual C example program, SPIKES.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Generating a 1/2 Rectified Sine Wave

The SIN_R program generates a Rectified sine wave using 4096 segments or points.



HP BASIC Program Example (SIN_R)

This program is similar to the “SIN_X” BASIC program on page 105, with the following differences:

```
1  IRE-STORE "SIN_R"
2  !This program outputs a rectified sine wave as an arbitrary waveform.

180 !Call the subprogram which defines a rectified sine wave and
190 !the output sequence.
200 CALL Sinr_def
210 !Select the output sequence and start the waveform.
220 OUTPUT @Afg;"SOUR:FUNC:USER SIN_R_OUT"
230 OUTPUT @Afg;"INIT:IMM"

280 SUB Sinr_def
290 Sinr_def: !Compute waveform (rectified sine wave) and define segment.
300 COM @Afg
310 DIM Waveform(1:4096)
320 FOR I=1 TO 4096
330 Waveform(I)=SIN(2*PI*(I/4096))
340 NEXT I
350 FOR I=2048 TO 4096
360 Waveform(I)=0
370 NEXT I
380 OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL SIN_R" !Define segment name
390 OUTPUT @Afg;"SOUR:LIST1:SEGM:DEF 4096" !Define segment size
400 OUTPUT @Afg;"SOUR:LIST1:SEGM:VOLT";Waveform(*) !load waveform points
410 !
420 OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL SIN_R_OUT" !Define sequence name
430 OUTPUT @Afg;"SOUR:LIST1:SSEQ:DEF 1" !Define sequence size
440 OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEQ SIN_R" !Set segment execution order
450 SUBEND
```

Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, SIN_R.FRM, is in directory "VBPROG" and the Visual C example program, SIN_R.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Generating Noise

The NOISE program generates pseudo-noise.

HP BASIC Program Example (NOISE)

This program is similar to the "SIN_X" BASIC program on page 105, with the following differences:

```
1  !RE-STORE "NOISE"
2  !This program outputs a pseudo random noise waveform as an
3  !arbitrary waveform.

180 !Call the subprogram which defines the noise signal and
190 !output sequence.
200 CALL Noise_def
210 !Select the output sequence and start the waveform.
220 OUTPUT @Afg;"SOUR:FUNC:USER NOISE_OUT"
230 OUTPUT @Afg;"INIT:IMM"

280  SUB Noise_def
290 Noise_def: !Subprogram which defines the noise signal and output
300             !sequence.
310             COM @Afg
320             DIM Waveform(1:4096)
330             FOR I=1 TO 4096
340               Waveform(I)=2.*RND-1
350             NEXT I
360             OUTPUT @Afg;"LIST:SEGM:SEL NOISE"           !select segment to be defined
370             OUTPUT @Afg;" LIST:SEGM:DEF 4096"           !reserve memory for segment
380             OUTPUT @Afg;" LIST:SEGM:VOLT";Waveform(*)   !load waveform points
390             !
400             OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL NOISE_OUT" !define sequence
410             OUTPUT @Afg;"SOUR:LIST1:SSEQ:DEF 1"         !number segments in sequence
420             OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEQ NOISE"     !segment order
430             SUBEND
```

Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, NOISE.FRM, is in directory "VBPROG" and the Visual C example program, NOISE.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Arbitrary Waveform Program Comments

The following comments give additional details on the program examples in this chapter.

Determining the Amount of Segment and Sequence Memory

- To determine the amount of segment sequence data remaining in the AFG and the amount of data used, execute the [SOURCE:]LIST[1]:SSEQUENCE:FREE? command. The command returns two number values. The first number shows, in points, the amount of segment sequence memory available. The second number shows, in points, the amount of segment sequence memory used.
- To determine the amount of segment data remaining in the AFG and the amount of segment data used, execute the [SOURCE:]LIST[1]:SEGMENT:FREE? command. The command returns two number values. The first number shows, in points, the amount of segment memory available. The second number shows, in points, the amount of segment memory used.

How to Free Segment and Sequence Memory

- Use [SOURCE:]LIST[1]:SSEQUENCE:DELETE[:SELECTED] to delete the currently selected segment sequence data that was last selected by the [SOURCE:]LIST[1]:SSEQUENCE:SELECT command.
- [SOURCE:]LIST[1]:SSEQUENCE:DELETE:ALL deletes all segment sequence data stored in the AFG's sequence memory. Use the command if there is insufficient segment sequence memory available to store new segment sequences. Note that a segment sequence cannot be deleted if it is currently selected by the [SOURCE:]FUNCTION:USER <name> command.
- Use [SOURCE:]LIST[1]:SEGMENT:DELETE[:SELECTED] to delete the currently selected segment data that was last selected by the [SOURCE:]LIST[1]:SEGMENT:SELECT command.
- [SOURCE:]LIST[1]:SEGMENT:DELETE:ALL deletes all segment data currently in the segment memory. Use the command if there is insufficient segment memory available to store new segments.

Amplitude Effects on Voltage Lists

If the segment data is sent as voltage values, the AFG changes the data into digital-to-analog converter (DAC) codes. This requires that the voltage value of the segment data MUST NOT exceed the AFG's current amplitude level (set by [SOURCE:]VOLTAGE[:LEVEL][:IMMEDIATE][:AMPLITUDE]). If it does, the AFG generates an error.

Using DAC Codes to Send Segment Data

Besides sending the points in a waveform segment as voltage data, they can also be sent as signed or unsigned DAC codes data. Since the AFG always stores DAC codes into memory, setting the amplitude levels is not necessary if sending segment data as DAC codes instead of voltages. See Chapter 7 on how to store DAC codes.

Sending Segment Sequences

- [SOURce:]LIST[1]:SSEquence:SEquence <segment_list> selects the sequence in which the waveform segments are to be executed. The waveform segments must be in memory, or the AFG generates an error. Each waveform segment name to be executed must be separated by a comma (“,”). For example, to execute the “sine” and “tri” waveform segments, send the command as:
SOUR:LIST1:SSEQ:SEQ sine,tri

- A waveform segment can be executed more than once in a single segment sequence. There are two different methods. In one method, a waveform segment is placed in the [SOURce:]LIST[1]:SSEquence:SEquence <segment_list> command several times. The other method uses an additional command, the [SOURce:]LIST[1]:SSEquence:DWELl:COUNT <repetition_list> command. The following examples illustrate the two methods. The examples show how to execute waveform segment “sine” three times and segment list “tri” once.

Method 1:

```
[SOURce:]LIST[1]:SSEquence:SEquence sine,sine,sine,tri
```

Method 2:

```
[SOURce:]LIST[1]:SSEquence:SEquence sine, tri  
[SOURce:]LIST[1]:SSEquence:DWELl:COUNT 3,1
```

Method 1 requires more memory since the minimum segment sequence length ([SOURce:]LIST[1]:SSEquence:DEFine <length>) must be at least the number of waveform segments in the sequence (i.e., sine,sin,sine,tri = a length of 4). Since in Method 2 the waveform segments consist of “sine,tri”, the sequence length is only 2.

Method 1 is required if the marker outputs (set by the [SOURce:]LIST[1]:SSEquence:MARKer command) are to be different for the various repetitions (see Chapters 6 and 7 for marker output information).

Reference Oscillator Sources

- The USER function can use any of the reference oscillator sources selected by the [SOURCE:]ROSCillator:SOURce command. The reference oscillator sources are:
 - INTernal[1]** – 42.94967296 MHz (power-on value)
 - INTernal2** – 40 MHz
 - CLK10** – 10 MHz (the VXIbus CLK line)
 - EXTernal** – User provided value (the front panel “Ref/Smpl In” BNC)
 - ECLTrg0 or 1** – User provided value (the VXIbus ECL trigger lines)
- If using either the EXTernal or ECLTrg0 or 1 reference oscillator sources, enter the source frequency to the AFG using [SOURCE:]ROSCillator:FREQUENCY:EXTernal <frequency>.
- For best frequency linearity, use the 42.9 MHz (i.e., INTernal[1]) reference oscillator source with the DDS (frequency1) frequency generator. This combination provides .01 Hz resolution. For higher frequency values, use the 40 MHz (i.e., INTernal2) reference oscillator source with the Divide-by-N (frequency2) frequency generator. Use the EXTernal or ECLTrg0 or ECLTrg1 sources for custom frequency values. However, any reference oscillator source can be used with any frequency generator.

Sample Sources

- The USER function operates with any of the sample sources selected by the TRIGger:START:SOURce command. The INTernal[1] source automatically selects the DDS frequency generator. The INTernal2 source selects the Divide_by_N frequency generator. The other sources are not used with any frequency generator. The sample frequency thus depends on the externally generated sample signal. The different sample sources are:
 - INTernal[1]** (power-on value; selects the DDS frequency generator)
 - INTernal2** (selects the Divide-by-N frequency generator)
 - BUS** (the HP-IB GET or *TRG commands)
 - EXTernal** (the front panel “Ref/Smpl In” BNC)
 - ECLTrg0 or ECLTrg1** (the VXIbus ECL trigger lines)
 - HOLD** (suspends sample generation)
 - TTLTrg0 through 7** (the VXIbus TTL trigger lines)

Frequency1 Generator Range

- The [SOURCE:]FREQUENCY[1]:RANGE command allows for higher sample frequency operations of the USER function. This command is only used with frequency1 generator. If set to 0 (MINimum), the normal setting, the maximum sample frequency is the

Reference Oscillator frequency / 4

- If set to MAXimum, the maximum sample frequency is the

Reference Oscillator frequency / 2

The MAXimum setting worsens the frequency resolution by a factor of two and introduces some sample rate jitter.

Returning the Waveform Segment Names

Use [SOURCE:]LIST[1]:SEGMENT:CATALOG? to return the names of the different waveform segments stored in memory. The command returns comma-separated strings that contain the names of the segment lists.

Determining the Waveform Segment Size

Use [SOURCE:]LIST[1]:SEGMENT:VOLTAGE:POINTS? to determine the size, in number of waveform segments or points, of the currently selected waveform segment.

Returning the Segment Sequence List Names

Use [SOURCE:]LIST[1]:SSEQUENCE:CATALOG? to return the names of the different segment sequence lists stored in memory. The command returns comma-separated strings that contain the names of the segment sequence lists.

Returning the Repetition Count List Length

Use [SOURCE:]LIST[1]:SSEQUENCE:DWELL:COUNT:POINTS? to determine the length of the currently selected segment sequence's repetition count list.

Chapter 4

Sweeping and Frequency-Shift Keying

Chapter Contents

This chapter covers the sweeping, frequency list, and frequency-shift keying (FSK) features of the HP E1445A 13-Bit Arbitrary Function Generator (called the “AFG”). The chapter is organized as follows:

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 - FSK Command Reference Page 120

- Sweeping and Frequency Lists Page 120
 - Sweeping Using Start and Stop Frequencies Page 121
 - Specifying a Frequency List Page 124
 - Sweeping Using Start and Span Frequencies Page 127
 - Frequency Lists Using Definite and Indefinite Length Arbitrary Blocks Page 130
 - Logarithmic Sweeping Page 133
 - Sweep Points Versus Time Page 135
 - Frequency Lists Versus Time Page 138
 - Sweeping Arbitrary Waveforms Page 141
 - AC Output Leveling Page 144

- Frequency-Shift Keying Page 147
 - FSK Using the “FSK” Control Source Page 147
 - FSK Using the TTLTrg<n> Control Source Page 150
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- Sweeping and FSK Program Comments Page 154
 - Reference Oscillator Sources Page 154
 - Sample Sources Page 154
 - AFG Frequency Modes Page 155
 - Frequency Range: Sweeping and Sampling Page 155
 - Frequency Range: Frequency Lists and FSK Page 155
 - Sweep Count and Frequency List Repetition Count Page 156
 - Arbitrary Block Data Page 156
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 - Sweep Time Page 158
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 - AC Leveling Page 160
 - FSK Control Sources Page 161
 - Frequency-Shift Delay Page 162
 - Driving the TTLTrg<n> Trigger Lines Page 162

FSK Programming Flowchart

The flowchart in Figure 4-1 shows the commands used to program the AFG for frequency sweeps, frequency lists, and for frequency-shift keying. Shown with each command is its power-on/reset setting. Since each example program begins by resetting the AFG, many of the default settings are used. Thus, the examples, which follow the sequence, do not execute every command shown on the flowchart. Remove the flowchart from the binder for easy accessibility. Refer to the flowchart while doing the examples in this chapter, if desired.

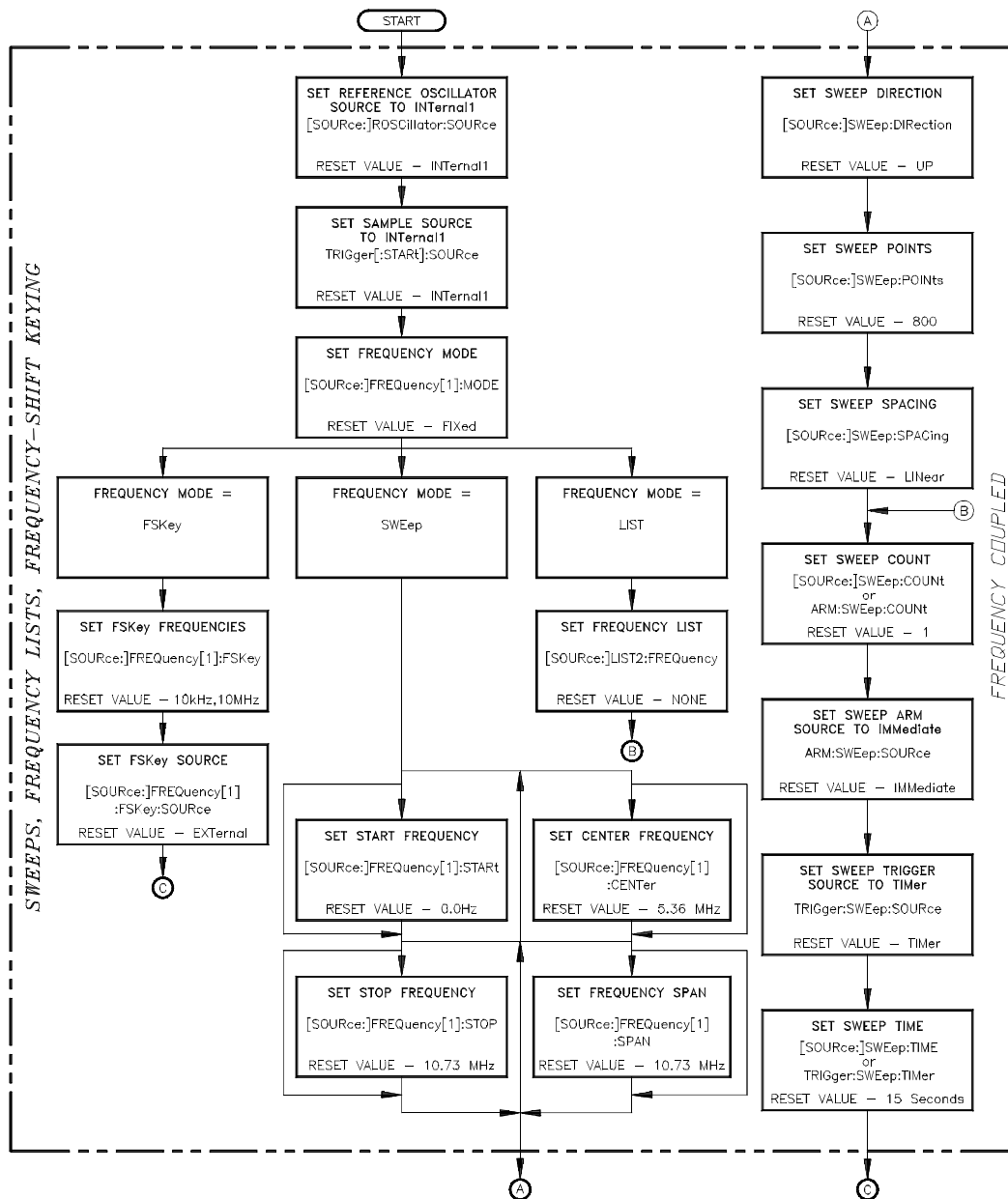


Figure 4-1. Commands for Frequency Sweeps, Frequency Lists, and FSK Keying
(continued on next page)

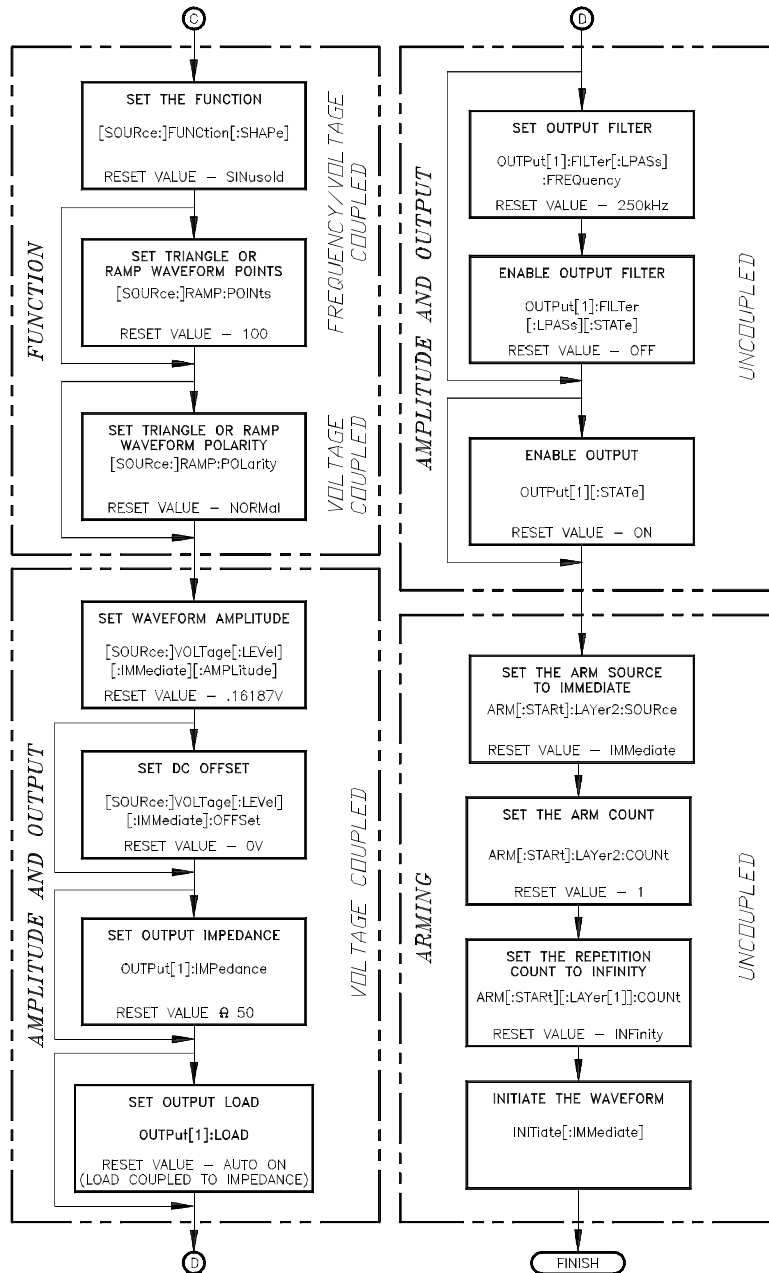


Figure 4-1. Commands for Frequency Sweeps, Frequency Lists, and FSK Keying (continued from previous page)

FSK Command Reference

Detailed information on the commands introduced in this chapter can be found in Chapter 8, “Command Reference”. The commands in this chapter are shown in their entirety (optional headers included) to help you locate them in the reference.

Sweeping and Frequency Lists

The AFG offers linear frequency sweeping of standard waveforms (that is, sine, square, triangle, ramp) and arbitrary waveforms from 0.0 Hz to 10.73741824 MHz, and logarithmic sweeping of standard and arbitrary waveforms from 0.01 Hz to 10.73741824 MHz.

The AFG can also “frequency hop” — where the AFG outputs a sequence of discrete frequencies from a pre-defined list. Up to 256 frequencies from 0.0 Hz to 10.73741824 MHz can be specified in a single list, and the AFG can sequence through the list at up to 800 frequencies per second.

Sweeps and frequency lists are programmed with the same commands. The command subsystems covered in this section include:

- [SOURce:]ROSCillator
- TRIGger
- [SOURce:]FREQuency[1]
 - Sweep mode and related commands
 - Frequency list mode and related commands
- [SOURce:]SWEep
- ARM:SWEep

The following programs show how to perform sweeps and frequency lists.

Sweeping Using Start and Stop Frequencies

The SMPLSWP1 program specifies a start frequency and a stop frequency and continuously sweeps between 0 and 1 MHz. The program also queries the start frequency, stop frequency, center frequency, and frequency span to show the relationship between them.

Using the flowchart in Figure 4-1 as a guide, the steps of this program are:

1. **Select the 42.9 MHz reference oscillator**
[SOURce:]ROSCillator:SOURce <source>
2. **Select the frequency generator that allows frequency sweeping**
TRIGger[:START]:SOURce <source>
3. **Select the frequency sweep mode**
[SOURce:]FREQUency[1]:MODE <mode>
4. **Set the start frequency**
[SOURce:]FREQUency[1]:START <start_freq>
5. **Set the stop frequency**
[SOURce:]FREQUency[1]:STOP <stop_freq>
6. **Set the number of sweeps**
[SOURce:]SWEep:COUNT <number>
7. **Set the output function**
[SOURce:]FUNCTion[:SHAPE] <shape>
8. **Set the signal amplitude**
[SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude] <amplitude>
9. **Place the AFG in the wait-for-arm state**
INITiate[:IMMediate]

HP BASIC Program Example (SMPLSWP1)

```
1  !RE-STORE"SMPLSWP1"
2  !This program specifies start and stop frequencies to sweep
3  !a sine wave from 0 to 1 MHz.
4  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 COM @Afg
40 !
50 !Set up error checking
60 ON INTR 7 CALL Errmsg
70 ENABLE INTR 7;2
80 OUTPUT @Afg;"*CLS"
90 OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms
130 CALL Rst
140 CALL Sweep1
150 CALL Query
160 !
170 WAIT .1 !allow interrupt to be serviced
180 OFF INTR 7
190 END
200 !
210 SUB Sweep1
220 Sweep1: !Subprogram which outputs a swept sine wave from 0 Hz to 1 MHz
230     COM @Afg
240     OUTPUT @Afg;"SOUR:ROSC:SOUR INT1;";           !reference oscillator
250     OUTPUT @Afg;":TRIG:STAR:SOUR INT1;";         !frequency1 generator (DDS)
260     OUTPUT @Afg;":SOUR:FREQ1:MODE SWE;";         !sweep mode
270     OUTPUT @Afg;":SOUR:FREQ1:STAR 0;";           !start frequency
280     OUTPUT @Afg;":SOUR:FREQ1:STOP 1E6;";         !stop frequency
290     OUTPUT @Afg;":SOUR:SWE:COUN INF;";           !sweep count
300     OUTPUT @Afg;":SOUR:FUNC:SHAP SIN;";         !function
310     OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL 5 V";   !amplitude
320     OUTPUT @Afg;"INIT:IMM"                       !wait-for-arm state
330 SUBEND
340 !
350 SUB Rst
360 Rst: !Subprogram which resets the E1445.
370     COM @Afg
380     OUTPUT @Afg;"*RST;*OPC?";                   !reset the AFG
390     ENTER @Afg;Complete
400 SUBEND
410 !
420 SUB Query
430 Query: !Subprogram which queries sweep parameters
440     COM @Afg
```

Continued on Next Page

```

450     OUTPUT @Afg;"SOUR:FREQ1:CENT?"
460     ENTER @Afg;Center$
470     OUTPUT @Afg;"SOUR:FREQ1:SPAN?"
480     ENTER @Afg;Span$
490     OUTPUT @Afg;"SOUR:FREQ1:STAR?"
500     ENTER @Afg;Start$
510     OUTPUT @Afg;"SOUR:FREQ1:STOP?"
520     ENTER @Afg;Stop$
530     DISP "START = ";Start$, "STOP = ";Stop$, "CENTER = ";Center$, "SPAN = ";Span$
540     SUBEND
550     !
560     SUB Errmsg
570 Errmsg: !Subprogram which displays E1445 programming errors
580     COM @Afg
590     DIM Message$[256]
600     !Read AFG status byte register and clear service request bit
610     B=SPOLL(@Afg)
620     !End of statement if error occurs among coupled commands
630     OUTPUT @Afg;"
640     OUTPUT @Afg;"ABORT"                !abort output waveform
650     REPEAT
660         OUTPUT @Afg;"SYST:ERR?"        !read AFG error queue
670         ENTER @Afg;Code,Message$
680         PRINT Code,Message$
690     UNTIL Code=0
700     STOP
710     SUBEND

```

The start, stop, center, and span values returned are:

```

START = +0.000000000E+000  STOP = +1.000000000E+006
CENTER = +5.000000000E+005  SPAN = +1.000000000E+006

```

**Visual BASIC and
Visual C/C++ Program
Versions**

The Visual BASIC example program, SMPLSWP1.FRM, is in directory “VBPROG” and the Visual C example program, SMPLSWP1.C, is in directory “VCPROG” on the CD that came with your HP E1445A.

Specifying a Frequency List

The LIST1 program shows the basic steps involved in setting up and “hopping” through a frequency list. The program also shows how to query the number of frequencies in the list.

Using the flowchart in Figure 4-1 as a guide, the steps of this program are:

1. **Select the 42.9 MHz reference oscillator**
[SOURce:]ROSCillator:SOURce <source>
2. **Select the frequency generator which allows frequency lists (hopping)**
TRIGger[:START]:SOURce <source>
3. **Select the frequency list mode**
[SOURce:]FREQuency[1]:MODE <mode>
4. **Specify the frequency list**
[SOURce:]LIST2:FREQuency <freq_list>
5. **Set the output function**
[SOURce:]FUNCTion[:SHAPE] <shape>
6. **Set the signal amplitude**
[SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude] <amplitude>
7. **Place the AFG in the wait-for-arm state**
INITiate[:IMMediate]

HP BASIC Program Example (LIST1)

```
1  !RE-STORE "LIST1"
2  !The following program outputs the frequencies 1 kHz, 10 kHz,
3  !100 kHz, and 1 MHz in a (default) period of 1 second.
4  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 COM @Afg
40 !
50 !Set up error checking
60 ON INTR 7 CALL Errmsg
70 ENABLE INTR 7;2
80 OUTPUT @Afg;"*CLS"
90 OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms
130 CALL Rst
140 CALL List1
150 CALL List_length
160 !
170 WAIT .1 !allow interrupt to be serviced
180 OFF INTR 7
190 END
200 !
210 SUB List1
220 List1: !Subprogram which outputs a frequency list
230     COM @Afg
240     OUTPUT @Afg;"SOUR:ROSC:SOUR INT1;";           !reference oscillator
250     OUTPUT @Afg;":TRIG:STAR:SOUR INT1;";         !frequency1 generator
260     OUTPUT @Afg;":SOUR:FREQ1:MODE LIST;";         !list mode
270     OUTPUT @Afg;":SOUR:LIST2:FREQ 1E3,10E3,100E3,1E6;"; !freq list
280     OUTPUT @Afg;":SOUR:FUNC:SHAP SIN;";           !function
290     OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL 5 V"     !amplitude
300     OUTPUT @Afg;"INIT:IMM"                         !wait-for-arm state
310 SUBEND
320 !
330 SUB Rst
340 Rst: !Subprogram which resets the E1445.
350     COM @Afg
360     OUTPUT @Afg;"*RST;*OPC?"                       !reset the AFG
370     ENTER @Afg;Complete
380 SUBEND
390 !
400 SUB List_length
410 List_length: !Subprogram which queries frequency list length
420     COM @Afg
430     OUTPUT @Afg;"SOUR:LIST2:FREQ:POIN?"
```

Continued on Next Page

```

440     ENTER @Afg;Points$
450     DISP "Number of frequencies in list: ";Points$
460     SUBEND
470     !
480     SUB Errmsg
490 Errmsg: !Subprogram which displays E1445 programming errors
500     COM @Afg
510     DIM Message$(256)
520     !Read AFG status byte register and clear service request bit
530     B=SPOLL(@Afg)
540     !End of statement if error occurs among coupled commands
550     OUTPUT @Afg;"
560     OUTPUT @Afg;"ABORT"                !abort output waveform
570     REPEAT
580         OUTPUT @Afg;"SYST:ERR?"        !read AFG error queue
590         ENTER @Afg;Code,Message$
600         PRINT Code,Message$
610     UNTIL Code=0
620     STOP
630     SUBEND

```

Upon completion, the program displays:

```
"Number of frequencies in list: +4"
```

**Visual BASIC and
Visual C/C++ Program
Versions**

The Visual BASIC example program, LIST1.FRM, is in directory "VBPROG" and the Visual C example program, LIST1.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Sweeping Using Start and Span Frequencies

The SMPLSWP2 program specifies a start frequency and a frequency span to continuously sweep from 1 kHz to 21 kHz. The program also queries the start frequency, stop frequency, center frequency, and frequency span to show the relationship between them.

Using the flowchart in Figure 4-1 as a guide, the steps of this program are:

1. **Set the frequency sweep mode**
[SOURce:]FREQUency[1]:MODE *<mode>*
2. **Set the start frequency**
[SOURce:]FREQUency[1]:START *<start_freq>*
3. **Set the frequency span**
[SOURce:]FREQUency[1]:SPAN *<freq_span>*
4. **Set the number of sweeps**
[SOURce:]SWEep:COUNT *<number>*
5. **Set the output function**
[SOURce:]FUNCTion[:SHAPE] *<shape>*
6. **Set the signal amplitude**
[SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude] *<amplitude>*
7. **Place the AFG in the wait-for-arm state**
INITiate[:IMMediate]

HP BASIC Program Example (SMPLSWP2)

```
1  !RE-STORE"SMPLSWP2"
2  !This program continuously sweeps from 1 kHz to 21 kHz and specifies
3  !a start frequency and a frequency span.
4  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 COM @Afg
40 !
50 !Set up error checking
60 ON INTR 7 CALL Errmsg
70 ENABLE INTR 7;2
80 OUTPUT @Afg;"*CLS"
90 OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms
130 CALL Rst
140 CALL Sweep2
150 CALL Query
160 !
170 WAIT .1 !allow interrupt to be serviced
180 OFF INTR 7
190 END
200 !
210 SUB Sweep2
220 Sweep2: !Subprogram which outputs a swept sine wave from 1 kHz to
230         !21 kHz.
240     COM @Afg
250     OUTPUT @Afg;"SOUR:FREQ1:MODE SWE;";           !sweep mode
260     OUTPUT @Afg;" :SOUR:FREQ1:STAR 1E3;";       !start frequency
270     OUTPUT @Afg;" :SOUR:FREQ1:SPAN 20E3;";      !frequency span
280     OUTPUT @Afg;" :SOUR:SWE:COUN INF;";         !sweep count
290     OUTPUT @Afg;" :SOUR:FUNC:SHAP SIN;";        !function
300     OUTPUT @Afg;" :SOUR:VOLT:LEV:IMM:AMPL 5 V"  !amplitude
310     OUTPUT @Afg;"INIT:IMM"                       !wait-for-arm state
320 SUBEND
330 !
340 SUB Rst
350 Rst: !Subprogram which resets the E1445.
360     COM @Afg
370     OUTPUT @Afg;"*RST;*OPC?"                     !reset the AFG
380     ENTER @Afg;Complete
390 SUBEND
400 !
410 SUB Query
420 Query: !Subprogram which queries sweep parameters
430     COM @Afg
440     OUTPUT @Afg;"SOUR:FREQ1:CENT?"
```

Continued on Next Page

```

450     ENTER @Afg;Center$
460     OUTPUT @Afg;"SOUR:FREQ1:SPAN?"
470     ENTER @Afg;Span$
480     OUTPUT @Afg;"SOUR:FREQ1:STAR?"
490     ENTER @Afg;Start$
500     OUTPUT @Afg;"SOUR:FREQ1:STOP?"
510     ENTER @Afg;Stop$
520     DISP "START = ";Start$,"STOP = ";Stop$,"CENTER = ";Center$,"SPAN = ";Span$
530 SUBEND
540 !
550 SUB Errmsg
560 Errmsg: !Subprogram which displays E1445 programming errors
570     COM @Afg
580     DIM Message$[256]
590     !Read AFG status byte register and clear service request bit
600     B=SPOLL(@Afg)
610     !End of statement if error occurs among coupled commands
620     OUTPUT @Afg;"
630     OUTPUT @Afg;"ABORT"                !abort output waveform
640     REPEAT
650         OUTPUT @Afg;"SYST:ERR?"        !read AFG error queue
660         ENTER @Afg;Code,Message$
670         PRINT Code,Message$
680     UNTIL Code=0
690     STOP
700 SUBEND

```

The start, stop, center, and span values returned are:

```

START = +1.000000000E+003      STOP = +2.100000000E+004
CENTER = +1.100000000E+004     SPAN = +2.000000000E+004

```

Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, SMPLSWP2.FRM, is in directory "VBPROG" and the Visual C example program, SMPLSWP2.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Frequency Lists Using Definite and Indefinite Length Arbitrary Blocks

When specifying a large frequency list (up to 256 frequencies), the ease in which the list is specified and the speed at which data is loaded into the AFG is enhanced by using definite or indefinite length arbitrary blocks. The data in an arbitrary block is in IEEE-754 64-bit floating point format.

The LISTDEF program sends a definite length arbitrary block of 100 frequencies to the AFG. Once the frequencies are received, the AFG steps through the list at one frequency per second.

At the end of the listing are program modifications for sending the data in an indefinite length arbitrary block.

Using the flowchart in Figure 4-1 as a guide, the steps of this program are:

1. **Select the reference oscillator**
[SOURce:]ROSCillator:SOURce <source>
2. **Select the frequency generator which allows frequency lists (hopping)**
TRIGger[:START]:SOURce <source>
3. **Select the frequency list mode**
[SOURce:]FREQuency[1]:MODE <mode>
4. **Download the frequency list**
[SOURce:]LIST2:FREQuency <freq_list>
5. **Set the duration of the list**
[SOURce:]SWEep:TIME <number>
6. **Set the output function**
[SOURce:]FUNctioN[:SHAPE] <shape>
7. **Set the signal amplitude**
[SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude] <amplitude>
8. **Place the AFG in the wait-for-arm state**
INITiate[:IMMediate]

HP BASIC Program Example (LISTDEF)

```
1   !RE-STORE"LISTDEF"
2   !This program sends a definite length arbitrary block of frequencies
3   !to the AFG. Once the AFG receives the frequencies, it steps through
4   !the list at a rate of one frequency per second.
5   !
10  !Assign I/O paths between the computer and E1445A. One path sends
20  !data in ASCII format to the AFG, the other path sends frequency
30  !list data to the AFG in binary format.
40  COM @Afg,@Afg1
50  ASSIGN @Afg TO 70910 !path for ASCII data
60  ASSIGN @Afg1 TO 70910;FORMAT OFF           !path for binary data
70  !
80  !Set up error checking
90  ON INTR 7 CALL Errmsg
100 ENABLE INTR 7;2
110 OUTPUT @Afg;"*CLS"
120 OUTPUT @Afg;"*SRE 32"
130 OUTPUT @Afg;"*ESE 60"
140 !
150 !Call the subprograms
160 CALL Rst
170 CALL List1
180 !
190 WAIT .1 !allow interrupt to be serviced
200 OFF INTR 7
210 END
220 !
230 SUB List1
240 List1: !Subprogram which downloads a list of 100 frequencies
250      !(1 kHz to 100 kHz) in a definite length arbitrary block.
260      COM @Afg,@Afg1
270      DIM Freqlist(1:100)
280      FOR I=1 TO 100
290          Freqlist(I)=1000.*I
300      NEXT I
310      !
320      OUTPUT @Afg;"SOUR:ROSC:SOUR INT1;";           !reference oscillator
330      OUTPUT @Afg;":TRIG:STAR:SOUR INT1;";         !frequency1 generator
340      OUTPUT @Afg;":SOUR:FREQ1:MODE LIST;";        !frequency list mode
350      OUTPUT @Afg USING "#,K";":SOUR:LIST2:FREQ #3800"!download freqs
360      OUTPUT @Afg1;Freqlist(*)                     !^ 800 bytes - 3 digits
370      OUTPUT @Afg                                  !CR LF
380      OUTPUT @Afg;"SOUR:SWE:TIME 100;";           !time (seconds) through list
390      OUTPUT @Afg;":SOUR:FUNC:SHAP SIN;";         !function
400      OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL 5 V"    !amplitude
410      OUTPUT @Afg;"INIT:IMM"                       !wait-for-arm state
420 SUBEND
430 !
```

Continued on Next Page

```

440   SUB Rst
450 Rst: !Subprogram which resets the E1445.
460     COM @Afg,Afg1
470     OUTPUT @Afg;"*RST;*OPC?"           !reset the AFG
480     ENTER @Afg;Complete
490   SUBEND
500   !
510   SUB Errmsg
520 Errmsg: !Subprogram which displays E1445 programming errors
530     COM @Afg,Afg1
540     DIM Message$(256)
550     !Read AFG status byte register and clear service request bit
560     B=SPOLL(@Afg)
570     !End of statement if error occurs among coupled commands
580     OUTPUT @Afg;"
590     OUTPUT @Afg;"ABORT"               !abort output waveform
600     REPEAT
610         OUTPUT @Afg;"SYST:ERR?"       !read AFG error queue
620         ENTER @Afg;Code,Message$
630         PRINT Code,Message$
640     UNTIL Code=0
650     STOP
660   SUBEND

```

Program Modifications In order to download the frequency list as an **indefinite length** arbitrary block, modify lines 350 through 370 as follows:

```

350     OUTPUT @Afg USING "#,K";".SOUR:LIST2:FREQ #0"  !download freqs
360     OUTPUT @Afg1;Freqlist(*)
370     OUTPUT @Afg;CHR$(10);END           !LF EOI (NL END)

```

Additional information on definite and indefinite length arbitrary blocks is located under “Arbitrary Block Data” on page 156.

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, LISTDEF.FRM, is in directory “VBPROG” and the Visual C example program, LISTDEF.C, is in directory “VCPROG” on the CD that came with your HP E1445A.

Logarithmic Sweeping

The LOG_SWP program shows you how to select logarithmic spacing between the frequencies in a frequency sweep. The program sets up a seven point logarithmic frequency sweep from 1 Hz to 1 MHz. Thus, the swept frequencies are: 1 Hz, 10 Hz, 100 Hz, 1 kHz, 10 kHz, 100 kHz, 1 MHz.

Using the flowchart in Figure 4-1 as a guide, the steps of this program are:

1. **Set the frequency sweep mode**
[SOURce:]FREQUency[1]:MODE *<mode>*
2. **Set the start frequency**
[SOURce:]FREQUency[1]:STARt *<start_freq>*
3. **Set the stop frequency**
[SOURce:]FREQUency[1]:STOP *<stop_freq>*
4. **Set the number of points (frequencies) in the frequency sweep**
[SOURce:]SWEep:POINts *<number>*
5. **Set linear or logarithmic spacing**
[SOURce:]SWEep:SPACing *<mode>*
6. **Set the number of sweeps**
[SOURce:]SWEep:COUNT *<number>*
7. **Set the output function**
[SOURce:]FUNCTion[:SHAPe] *<shape>*
8. **Set the signal amplitude**
[SOURce:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude] *<amplitude>*
9. **Place the AFG in the wait-for-arm state**
INITiate[:IMMEDIATE]

HP BASIC Program Example (LOG_SWP)

```
1  !RE-STORE"LOG_SWP"
2  !This program logarithmically sweeps from 1 Hz to 1 MHz in seven
3  !points.
4  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 COM @Afg
40 !
50 !Set up error checking
60 ON INTR 7 CALL Errmsg
70 ENABLE INTR 7;2
80 OUTPUT @Afg;"*CLS"
90 OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
```

Continued on Next Page

```

110  !
120  !Call the subprograms
130  CALL Rst
140  CALL Swp_pvss
150  !
160  WAIT .1 !allow interrupt to be serviced
170  OFF INTR 7
180  END
190  !
200  SUB Swp_pvss
210  Swp_pvss: !Subprogram which sets a logarithmic sweep
220      COM @Afg
230      OUTPUT @Afg;"SOUR:FREQ1:MODE SWE;";           !sweep mode
240      OUTPUT @Afg;" :SOUR:FREQ1:STAR 1;";           !start frequency
250      OUTPUT @Afg;" :SOUR:FREQ1:STOP 1E6;";         !stop frequency
260      OUTPUT @Afg;" :SOUR:SWE:POIN 7;";             !sweep points
270      OUTPUT @Afg;" :SOUR:SWE:SPAC LOG;";           !logarithmic sweep
280      OUTPUT @Afg;" :SOUR:SWE:COUN INF;";           !sweep count
290      OUTPUT @Afg;" :SOUR:FUNC:SHAP SIN;";         !function
300      OUTPUT @Afg;" :SOUR:VOLT:LEV:IMM:AMPL 5 V"    !amplitude
310      OUTPUT @Afg;"INIT:IMM"                        !wait-for-arm state
320  SUBEND
330  !
340  SUB Rst
350  Rst: !Subprogram which resets the E1445.
360      COM @Afg
370      OUTPUT @Afg;"*RST;*OPC?";                     !reset the AFG
380      ENTER @Afg;Complete
390  SUBEND
400  !
410  SUB Errmsg
420  Errmsg: !Subprogram which displays E1445 programming errors
430      COM @Afg
440      DIM Message$(256)
450      !Read AFG status byte register and clear service request bit
460      B=SPOLL(@Afg)
470      !End of statement if error occurs among coupled commands
480      OUTPUT @Afg;"
490      OUTPUT @Afg;"ABORT";                           !abort output waveform
500      REPEAT
510          OUTPUT @Afg;"SYST:ERR?";                   !read AFG error queue
520          ENTER @Afg;Code,Message$
530          PRINT Code,Message$
540      UNTIL Code=0
550      STOP
560  SUBEND

```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, LOG_SWP.FRM, is in directory "VBPROG" and the Visual C example program, LOG_SWP.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Sweep Points Versus Time

To demonstrate the relationship between the number of points (frequencies) in a frequency sweep and the time of the sweep, the SWP_PVST program uses 100 frequency points to continuously sweep from 5 kHz to 15 kHz in 0.125 seconds. The program also shows you how to control the direction of a sweep.

Using the flowchart in Figure 4-1 as a guide, the steps of this program are:

1. **Select the frequency sweep mode**
[SOURce:]FREQuency[1]:MODE *<mode>*
2. **Set the start frequency**
[SOURce:]FREQuency[1]:STARt *<start_freq>*
3. **Set the stop frequency**
[SOURce:]FREQuency[1]:STOP *<stop_freq>*
4. **Set the direction (up or down) of the frequency sweep**
[SOURce:]SWEep:DIRection *<direction>*
5. **Set the number of points (frequencies) in the frequency sweep**
[SOURce:]SWEep:POINts *<number>*
6. **Set the number of sweeps**
[SOURce:]SWEep:COUNT *<number>*
7. **Set the frequency advance source**
TRIGger:SWEep:SOURce *<source>*
8. **Set the duration of the sweep**
[SOURce:]SWEep:TIME *<number>*
9. **Set the output function**
[SOURce:]FUNctIon[:SHAPe] *<shape>*
10. **Set the signal amplitude**
[SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude] *<amplitude>*
11. **Place the AFG in the wait-for-arm state**
INITiate[:IMMediate]

HP BASIC Program Example (SWP_PVST)

```
1   !RE-STORE"SWP_PVST"
2   !This program sweeps from 5 kHz to 15 kHz in 0.1 seconds to
3   !demonstrate how to set the sweep time. The program also sets
4   !the direction of the sweep.
5   !
10  !Assign I/O path between the computer and E1445A.
20  ASSIGN @Afg TO 70910
30  COM @Afg
40  !
50  !Set up error checking
60  ON INTR 7 CALL Errmsg
70  ENABLE INTR 7;2
80  OUTPUT @Afg;"*CLS"
90  OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms
130 CALL Rst
140 CALL Swp_pvst
150 !
160 WAIT .1 !allow interrupt to be serviced
170 OFF INTR 7
180 END
190 !
200 SUB Swp_pvst
210 Swp_pvst: !Subprogram which sets sweep direction, points, and time
220   COM @Afg
230   OUTPUT @Afg;"SOUR:FREQ1:MODE SWE;";           !sweep mode
240   OUTPUT @Afg;" :SOUR:FREQ1:STAR 5E3;";         !start frequency
250   OUTPUT @Afg;" :SOUR:FREQ1:STOP 15E3;";        !stop frequency
260   OUTPUT @Afg;" :SOUR:SWEEP:DIR DOWN;";         !sweep direction
270   OUTPUT @Afg;" :SOUR:SWEEP:POIN 100;";         !sweep points
280   OUTPUT @Afg;" :SOUR:SWE:COUN INF;";           !sweep count
290   OUTPUT @Afg;" :TRIG:SWE:SOUR TIM;";           !sweep advance source
300   OUTPUT @Afg;" :SOUR:SWE:TIME .12375;";        !sweep time
310   OUTPUT @Afg;" :SOUR:FUNC:SHAP SIN;";          !function
320   OUTPUT @Afg;" :SOUR:VOLT:LEV:IMM:AMPL 5 V"    !amplitude
330   OUTPUT @Afg;"INIT:IMM"                        !wait-for-trigger state
340 SUBEND
350 !
360 SUB Rst
370 Rst: !Subprogram which resets the E1445.
380   COM @Afg
390   OUTPUT @Afg;"*RST;*OPC?";                     !reset the AFG
400   ENTER @Afg;Complete
410 SUBEND
420 !
430 SUB Errmsg
```

Continued on Next Page

```

440 Errmsg: !Subprogram which displays E1445 programming errors
450     COM @Afg
460     DIM Message$[256]
470     !Read AFG status byte register and clear service request bit
480     B=SPOLL(@Afg)
490     !End of statement if error occurs among coupled commands
500     OUTPUT @Afg;"
510     OUTPUT @Afg;"ABORT"                                !abort output waveform
520     REPEAT
530         OUTPUT @Afg;"SYST:ERR?"                        !read AFG error queue
540         ENTER @Afg;Code,Message$
550         PRINT Code,Message$
560     UNTIL Code=0
570     STOP
560     SUBEND

```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, SWP_PVST.FRM, is in directory “VBPROG” and the Visual C example program, SWP_PVST.C, is in directory “VCPROG” on the CD that came with your HP E1445A.

Frequency Lists Versus Time

To demonstrate the relationship between the number of frequencies in a frequency list and the time to hop through the list, program LIST_TME makes continuous passes through a frequency list where the frequencies are spaced 1 second apart.

Using the flowchart in Figure 4-1 as a guide, the steps of this program are:

1. **Select the frequency list mode**
[SOURce:]FREQuency[1]:MODE <mode>
2. **Specify the frequency list**
[SOURce:]LIST2:FREQuency <freq_list>
3. **Set the list repetition count**
[SOURce:]SWEep:COUNT <number>
4. **Set the frequency advance source**
TRIGger:SWEep:SOURce <source>
5. **Set the frequency hop rate**
[SOURce:]SWEep:TIME <number>
6. **Set the output function**
[SOURce:]FUNctio[n]:SHAPE <shape>
7. **Set the number of waveform points (triangle wave)**
[SOURce:]RAMP:POINts <number>
8. **Set the signal amplitude**
[SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude] <amplitude>
9. **Place the AFG in the wait-for-arm state**
INITiate[:IMMediate]

HP BASIC Program Example (LIST_TME)

```
1  !RE-STORE"LIST_TME"
2  !The following program steps through a frequency list at a rate
3  !such that a new frequency is output every 1 second.
4  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 COM @Afg
40 !
50 !Set up error checking
60 ON INTR 7 CALL Errmsg
70 ENABLE INTR 7;2
80 OUTPUT @Afg;"*CLS"
90 OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms
130 CALL Rst
140 CALL List_time
150 !
160 WAIT .1 !allow interrupt to be serviced
170 OFF INTR 7
180 END
190 !
200 SUB List_time
210 List_count: !Subprogram which continuously outputs a frequency list
220             !in which the frequencies are 1s apart
230     COM @Afg
240     OUTPUT @Afg;"SOUR:FREQ1:MODE LIST;";           !list mode
250     OUTPUT @Afg;" :SOUR:LIST2:FREQ 2.5E3,5E3,7.5E3,10E3;";!freq list
260     OUTPUT @Afg;" :SOUR:SWE:COUN INF;";           !hop through list continuously
270     OUTPUT @Afg;" :TRIG:SWE:SOUR TIM;";           !list advance source
280     OUTPUT @Afg;" :SOUR:SWE:TIME 3;";           !time through list
290     OUTPUT @Afg;" :SOUR:FUNC:SHAP TRI;";           !function
300     OUTPUT @Afg;" :SOUR:RAMP:POIN 1E3;";           !1000 point waveform
310     OUTPUT @Afg;" :SOUR:VOLT:LEV:IMM:AMPL 5 V"     !amplitude
320     OUTPUT @Afg;"INIT:IMM"                       !wait-for-arm state
330 SUBEND
340 !
350 SUB Rst
360 Rst: !Subprogram which resets the E1445.
370     COM @Afg
380     OUTPUT @Afg;"*RST;*OPC?"                       !reset the AFG
390     ENTER @Afg;Complete
400 SUBEND
410 !
420 SUB Errmsg
430 Errmsg: !Subprogram which displays E1445 programming errors
440     COM @Afg
```

Continued on Next Page

```

450     DIM Message$(256)
460     !Read AFG status byte register and clear service request bit
470     B=SPOLL(@Afg)
480     !End of statement if error occurs among coupled commands
490     OUTPUT @Afg;""
500     OUTPUT @Afg;"ABORT"                                !abort output waveform
510     REPEAT
520         OUTPUT @Afg;"SYST:ERR?"                        !read AFG error queue
530         ENTER @Afg;Code,Message$
540         PRINT Code,Message$
550     UNTIL Code=0
560     STOP
570     SUBEND

```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, LIST_TME.FRM, is in directory “VBPROG” and the Visual C example program, LIST_TME.C, is in directory “VCPROG” on the CD that came with your HP E1445A.

Sweeping Arbitrary Waveforms

When sweeping arbitrary waveforms, the start and stop frequencies specified are start and stop sample rates. The corresponding output frequency is the sample rate divided by the number of points in the waveform. The following programs demonstrate how to sweep arbitrary waveforms by specifying starting and stopping sample rates.

Sweeping Sin(x)/x and Pseudo-Random Noise Signals

The SWP_ARB program computes a 4096 point, 8½ cycle, phase-continuous Sin(x)/x waveform with a peak amplitude of 1V; and a 4096 point pseudo-random noise signal.

By sweeping the Sin(x)/x signal, the different frequencies of the signal are swept simultaneously. Starting and stopping sample rates are specified such that Sin(x)/x is swept from 1 kHz to 2 kHz.

The noise signal is a “comb” of frequencies separated by the repetition rate of the signal. The pseudo-random signal is repetitive. Sweeping this signal effectively decreases the repetition rate by increasing the length of the signal. The sampling bandwidth is 40 kHz with an effective bandwidth of 20 kHz. The output is swept from 10 Hz to 20 Hz.

HP BASIC Program Example (SWP_ARB)

```
1  !RE-STORE"SWP_ARB"
2  !This program sweeps two arbitrary waveforms: sin(x)/x and pseudo
3  !random noise. The 4096 point waveforms are swept from 4.096 MHz to
4  !8.192 MHz which results in an output frequency sweep from 1 kHz to
5  !2 kHz.
6  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 COM @Afg
40 !
50 !Set up error checking
60 ON INTR 7 CALL Errmsg
70 ENABLE INTR 7;2
80 OUTPUT @Afg;"*CLS"
90 OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms
130 CALL Wwfm_manage
140 !Abort the current waveform, select and initiate either the sin(x)/x
150 !(S1) or noise waveform (N1) sequence. Comment out (!) the line of
160 !the one you DO NOT want to select.
170 OUTPUT @Afg;"ABORT"
180 OUTPUT @Afg;"SOUR:FUNC:USER S1"           !select waveform sequence (Sin(x))
190 OUTPUT @Afg;"SOUR:FUNC:USER N1"           !select waveform sequence (Noise)
200 OUTPUT @Afg;"INIT:IMM"                     !wait-for-arm state
```

Continued on Next Page

```

210  !
220  WAIT .1 !allow interrupt to be serviced
230  OFF INTR 7
240  END
250  !
260  SUB Wvfm_manage
270  Wvfm_manage:  !Subprogram which calls the subprograms which delete
280                !all existing waveforms and define Sin(x)/x and
290                !pseudo random noise.
300      COM @Afg
310      CALL Rst
320      CALL Wf_del
330      CALL Sinx_def  !Comment out this line if line 180 is commented
340      CALL Noise_def !Comment out this line if line 190 is commented
350  SUBEND
360  !
370  SUB Sinx_def
380  Sinx_def !Set sweep mode, specify start and stop sample rates for a
390          !1 kHz to 2 kHz sweep, set arbitrary waveform function.
400          !Compute waveform (Sin(x)/x), define waveform segment and
410          !sequence.
420      COM @Afg
430      OUTPUT @Afg;"SOUR:FREQ1:MODE SWE";          !sweep mode
440      OUTPUT @Afg;" :SOUR:FREQ1:STAR 4.096E6";    !start sample rate
450      OUTPUT @Afg;" :SOUR:FREQ1:STOP 8.192E6";    !stop sample rate
460      OUTPUT @Afg;" :SOUR:SWE:COUN INF";          !sweep count
470      OUTPUT @Afg;" :SOUR:FUNC:SHAP USER";        !function (arbitrary)
480      OUTPUT @Afg;" :SOUR:VOLT:LEV:IMM:AMPL 1.1V" !scale arb values
490      !
500      DIM Waveform(1:4096)
510      FOR I=-2047 TO 2048
520          IF I=0 THEN I=1.E-38
530          Waveform(I+2048)=((SIN(2*PI*.53125*I/256)))/(.53125*I/256)*.159154943092)
540      NEXT I
550      !
560      OUTPUT @Afg;"LIST:SEGM:SEL SIN_X"           !select segment
570      OUTPUT @Afg;" LIST:SEGM:DEF 4096"           !reserve memory
580      OUTPUT @Afg;" LIST:SEGM:VOLT";Waveform(*)   !load points
590      !
600      OUTPUT @Afg;"LIST:SSEQ:SEL S1"              !select sequence
610      OUTPUT @Afg;" LIST:SSEQ:DEF 1"              !number of segments
620      OUTPUT @Afg;" LIST:SSEQ:SEQ SIN_X"          !segment order in sequence
630  SUBEND
640  !
650  SUB Noise_def
660  Noise_def: !Set sweep mode, specify start and stop sample rates for a
670            !10 Hz to 20 Hz sweep, set arbitrary waveform function.
680            !Compute waveform (Noise), define waveform segment and
690            !sequence.
700      COM @Afg

```

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```

710     OUTPUT @Afg;"SOUR:FREQ1:MODE SWE;";           !sweep mode
720     OUTPUT @Afg;" :SOUR:FREQ1:STAR 40.96E3;";     !start sample rate
730     OUTPUT @Afg;" :SOUR:FREQ1:STOP 81.92E3;";     !stop sample rate
740     OUTPUT @Afg;" :SOUR:SWE:COUN INF;";           !sweep count
750     OUTPUT @Afg;" :SOUR:FUNC:SHAP USER;";         !function (arbitrary)
760     OUTPUT @Afg;" :SOUR:VOLT:LEV:IMM:AMPL 1.1V"    !scale arb values
770     !
780     DIM Waveform(1:4096)
790     FOR I=1 TO 4096
800         Waveform(I)=2*RND-1.
810     NEXT I
820     OUTPUT @Afg;"LIST:SEGM:SEL NOISE"             !select segment
830     OUTPUT @Afg;" LIST:SEGM:DEF 4096"           !reserve memory
840     OUTPUT @Afg;" LIST:SEGM:VOLT ";Waveform(*)   !load points
850     !
860     OUTPUT @Afg;"LIST:SSEQ:SEL N1"               !select sequence
870     OUTPUT @Afg;" LIST:SSEQ:DEF 1"              !number of segments
880     OUTPUT @Afg;" LIST:SSEQ:SEQ NOISE"          !segment order in sequence
890     SUBEND
900     !
910     SUB Rst
920 Rst: !Subprogram which resets the E1445.
930     COM @Afg
940     OUTPUT @Afg;"*RST;*OPC?"                    !reset the AFG
950     ENTER @Afg;Complete
960     SUBEND
970     !
980     SUB Wf_del
990 Wf_del: !Subprogram which deletes all sequences and segments.
1000    COM @Afg
1010    OUTPUT @Afg;"FUNC:USER NONE"                !select no sequences
1020    OUTPUT @Afg;"LIST:SSEQ:DEL:ALL"             !delete all sequences
1020    OUTPUT @Afg;"LIST:SEGM:DEL:ALL"            !delete all waveform segments
1040    SUBEND
1050    !
1060    SUB Errmsg
1070 Errmsg: !Subprogram which displays E1445 programming errors
1080    COM @Afg
1090    DIM Message$(256)
1100    !Read AFG status byte register and clear service request bit
1110    B=SPOLL(@Afg)
1120    !End of statement if error occurs among coupled commands
1130    OUTPUT @Afg;"
1140    OUTPUT @Afg;"ABORT"                          !abort output waveform
1150    REPEAT
1160        OUTPUT @Afg;"SYST:ERR?"                !read AFG error queue
1170        ENTER @Afg;Code,Message$
1180        PRINT Code,Message$
1190    UNTIL Code=0
1200    STOP
1210    SUBEND

```

Program Modifications

To select another waveform, comment out (!) line 180 or 190 depending on the waveform sequence (S1 or N1) you DO NOT want to output. You must also comment out line 330 if line 180 is commented, or line 340 if line 190 is commented.

Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, SWP_ARB.FRM, is in directory “VBPROG” and the Visual C example program, SWP_ARB.C, is in directory “VCPROG” on the CD that came with your HP E1445A.

AC Output Leveling

The SWP_LEVL program sets up a sine wave frequency sweep from 0 Hz to 10 MHz and uses the AFG’s 10 MHz filter and AC output leveling to maintain a constant amplitude over the span.

With the flowchart in Figure 4-1 as a guide, the steps of this program are:

1. **Select the frequency sweep mode**
[SOURce:]FREQUency[1]:MODE *<mode>*
2. **Set the start frequency**
[SOURce:]FREQUency[1]:START *<start_freq>*
3. **Set the stop frequency**
[SOURce:]FREQUency[1]:STOP *<stop_freq>*
4. **Set the number of sweeps**
[SOURce:]SWEep:COUNT *<number>*
5. **Set the output function**
[SOURce:]FUNCTion[:SHAPE] *<shape>*
6. **Set the signal amplitude**
[SOURce:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude] *<amplitude>*
7. **Select the output filter**
OUTPut[1]:FILTer[:LPASs]:FREQUency *<frequency>*
8. **Enable the output filter**
OUTPut[1]:FILTer[:LPASs][:STATe] *<mode>*
9. **Place the AFG in the wait-for-arm state**
INITiate[:IMMEDIATE]

HP BASIC Program Example (SWP_LEVEL)

```
1  !RE-STORE"SWP_LEVEL"
2  !This program enables output leveling over the 0 Hz to 10 MHz
3  !sweep.
4  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 COM @Afg
40 !
50 !Set up error checking
60 ON INTR 7 CALL Errmsg
70 ENABLE INTR 7;2
80 OUTPUT @Afg;"*CLS"
90 OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms
130 CALL Rst
140 CALL Swp_level
150 !
160 WAIT .1 !allow interrupt to be serviced
170 OFF INTR 7
180 END
190 !
200 SUB Swp_level
210 Swp_level: !Subprogram which sets output leveling for sweeping from
220           !0 TO 10 MHz
230     COM @Afg
240     OUTPUT @Afg;"SOUR:FREQ1:MODE SWE;";           !sweep mode
250     OUTPUT @Afg;" :SOUR:FREQ1:STAR 0;";           !start frequency
260     OUTPUT @Afg;" :SOUR:FREQ1:STOP 10E6;";       !stop frequency
270     OUTPUT @Afg;" :SOUR:SWE:COUN INF;";           !sweep count
280     OUTPUT @Afg;" :SOUR:FUNC:SHAP SIN;";           !function
290     OUTPUT @Afg;" :SOUR:VOLT:LEV:IMM:AMPL 5 V"     !amplitude
300     OUTPUT @Afg;"OUTP1:FILT:LPAS:FREQ 10 MHZ"     !filter cutoff frequency
310     OUTPUT @Afg;"OUTP1:FILT:LPAS:STAT ON"         !enable output filter
320     OUTPUT @Afg;"INIT:IMM"                       !wait-for-arm state
330 SUBEND
340 !
350 SUB Rst
360 Rst: !Subprogram which resets the E1445.
370     COM @Afg
380     OUTPUT @Afg;"*RST;*OPC?"                       !reset the AFG
390     ENTER @Afg;Complete
400 SUBEND
410 !
420 SUB Errmsg
430 Errmsg: !Subprogram which displays E1445 programming errors
440     COM @Afg
```

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```

450     DIM Message$(256)
460     !Read AFG status byte register and clear service request bit
470     B=SPOLL(@Afg)
480     !End of statement if error occurs among coupled commands
490     OUTPUT @Afg;""
500     OUTPUT @Afg;"ABORT"                                !abort output waveform
510     REPEAT
520         OUTPUT @Afg;"SYST:ERR?"                        !read AFG error queue
530         ENTER @Afg;Code,Message$
540         PRINT Code,Message$
550     UNTIL Code=0
560     STOP
570     SUBEND

```

**Visual BASIC and
Visual C/C++ Program
Versions**

The Visual BASIC example program, SWP_LEVEL.FRM, is in directory "VBPROG" and the Visual C example program, SWP_LEVEL.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Frequency-Shift Keying

Frequency-shift keying (FSK) changes the frequency of the output waveform or sample rate based on the signal level of the frequency-shift keying control source. FSK frequencies can range from 0.0 Hz to 10 MHz.

The command subsystems associated with frequency-shift keying include:

- [SOURce:]ROSCillator
- TRIGger
- [SOURce:]FREQuency[1]
 - FSK mode and related commands

FSK Using the “FSK” Control Source

The FSK1 program shows the basic steps involved in setting up and using the frequency-shift keying function of the AFG. A 5 V, 1 MHz square wave control signal is applied to the AFG’s front panel “FSK” port. Output frequencies of 5 MHz and 10 MHz occur as the level of the 1 MHz signal changes.

Note

When the frequency shifts, there is a delay of 20 reference oscillator clock cycles before the frequency is active. This delay occurs with all reference oscillator sources.

Using the flowchart in Figure 4-1 as a guide, the steps of this program are:

1. **Select the 42.9 MHz reference oscillator**
[SOURce:]ROSCillator:SOURce <source>
2. **Select the frequency generator which allows frequency-shift keying**
TRIGger[:START]:SOURce <source>
3. **Select the frequency-shift keying mode**
[SOURce:]FREQuency[1]:MODE <mode>
4. **Select the FSK frequencies**
[SOURce:]FREQuency[1]:FSKey <frequency1>,<frequency2>
5. **Select the FSK control source**
[SOURce:]FREQuency[1]:FSKey:SOURce <source>
6. **Set the output function**
[SOURce:]FUNCTION[:SHAPE] <shape>

7. Set the signal amplitude

[SOURce:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude] <amplitude>

8. Place the AFG in the wait-for-arm state

INITiate[:IMMEDIATE]

HP BASIC Program Example (FSK1)

```
1  !RE-STORE "FSK1"
2  !This program shifts between 5 MHz and 10 MHz based on a 1 MHz
3  !control signal applied to the "FSK" control source. The
4  !program also queries the FSK frequencies and the FSK control
5  !source.
6  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 COM @Afg
40 !
50 !Set up error checking
60 ON INTR 7 CALL Errmsg
70 ENABLE INTR 7;2
80 OUTPUT @Afg;"*CLS"
90 OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms
130 CALL Rst
140 CALL Fsk
150 CALL Fsk_info
160 !
170 WAIT .1 !allow interrupt to be serviced
180 OFF INTR 7
190 END
200 !
210 SUB Fsk
220 Fsk: !Subprogram which sets up frequency-shift keying and the front
230 !panel FSK In BNC as the control source.
240 COM @Afg
250 OUTPUT @Afg;"SOUR:ROSC:SOUR INT1;"; !reference oscillator
260 OUTPUT @Afg;":TRIG:STAR:SOUR INT1;"; !frequency1 generator
270 OUTPUT @Afg;":SOUR:FREQ1:MODE FSK;"; !FSK mode
280 OUTPUT @Afg;" :SOUR:FREQ1:FSK 5E6,10E6;"; !FSK frequencies
290 OUTPUT @Afg;" :SOUR:FREQ1:FSK:SOUR EXT;"; !FSK source
300 OUTPUT @Afg;":SOUR:FUNC:SHAP SIN;"; !function
310 OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL 5 V" !amplitude
320 OUTPUT @Afg;"OUTP1:FILT:LPAS:FREQ 10 MHZ" !filter
330 OUTPUT @Afg;"OUTP1:FILT:LPAS:STAT ON" !enable filter
340 OUTPUT @Afg;"INIT:IMM" !wait-for-arm state
350 SUBEND
360 !
```

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```

370 SUB Rst
380 Rst: !Subprogram which resets the E1445.
390 COM @Afg
400 OUTPUT @Afg;"*RST;*OPC?" !reset the AFG
410 ENTER @Afg;Complete
420 SUBEND
430 !
440 SUB Fsk_info
450 Fsk_info: !Subprogram which queries FSK frequencies and source
460 COM @Afg
470 DIM Frequencies$(80)
480 OUTPUT @Afg;"SOUR:FREQ1:FSK?" !query FSK frequencies
490 ENTER @Afg;Frequencies$
500 OUTPUT @Afg;"SOUR:FREQ:FSK:SOUR?" !query FSK source
510 ENTER @Afg;Source$
520 PRINT "FSK frequencies are: ";Frequencies$
530 PRINT "FSK control source is: ";Source$
540 SUBEND
550 !
560 SUB Errmsg
570 Errmsg: !Subprogram which displays E1445 programming errors
580 COM @Afg
590 DIM Message$(256)
600 !Read AFG status byte register and clear service request bit
610 B=SPOLL(@Afg)
620 !End of statement if error occurs among coupled commands
630 OUTPUT @Afg;"
640 OUTPUT @Afg;"ABORT" !abort output waveform
650 REPEAT
660 OUTPUT @Afg;"SYST:ERR?" !read AFG error queue
670 ENTER @Afg;Code,Message$
680 PRINT Code,Message$
690 UNTIL Code=0
700 STOP
710 SUBEND

```

Upon completion, the program displays:

```

FSK frequencies are:
+5.000000000E+006,+1.000000000E+007
FSK control source is: EXT

```

Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, FSK1.FRM, is in directory "VBPROG" and the Visual C example program, FSK1.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

FSK Using the TTLTrg<n> Control Source

The FSK2 program sets up frequency-shift keying using a TTLTrg<n> trigger line as the control source. The TTLTrg trigger line is driven by the HP E1406A Command Module.

Using the flowchart in Figure 4-1 as a guide, the steps of this program are:

1. **Select the frequency-shift keying mode**
[SOURce:]FREQUency[1]:MODE <mode>
2. **Select the FSK frequencies**
[SOURce:]FREQUency[1]:FSKey <frequency1>,<frequency2>
3. **Select the FSK control source**
[SOURce:]FREQUency[1]:FSKey:SOURce <source>
4. **Set the output function**
[SOURce:]FUNCTion[:SHAPe] <shape>
5. **Set the signal amplitude**
[SOURce:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude] <amplitude>
6. **Place the AFG in the wait-for-arm state**
INITiate[:IMMEDIATE]

HP BASIC Program Example (FSK2)

```
1  !RE-STORE "FSK2"
2  !This program shifts between 1 MHz and 2 MHz based on a control
3  !signal supplied by the HP E1406 Command Module on TTLTRG
4  !trigger line 5.
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 ASSIGN @Cmd_mod TO 70900
40 COM @Afg,@Cmd_mod
50 !
60 !Set up error checking
70 ON INTR 7 CALL Errmsg
80 ENABLE INTR 7;2
90 OUTPUT @Afg;"*CLS"
100 OUTPUT @Afg;"*SRE 32"
110 OUTPUT @Afg;"*ESE 60"
120 !
130 !Call the subprograms which reset the AFG, set up frequency-shift
140 !keying, and which set up the TTLTrg5 trigger line.
150 CALL Rst
160 CALL Fsk_ttl
170 CALL Setup_ttl5
180 WAIT .1 !allow interrupt to be serviced
190 OFF INTR 7
```

Continued on Next Page

```

200 END
210 !
220 SUB Fsk_ttl
230 Fsk_ttl: !Subprogram which sets up frequency-shift keying and trigger
240 !line TTLTRG 5 as the control source.
250 COM @Afg,@Cmd_mod
260 OUTPUT @Afg;"SOUR:FREQ1:MODE FSK;"; !FSK mode
270 OUTPUT @Afg;" :SOUR:FREQ1:FSK 1E6,2E6;"; !FSK frequencies
280 OUTPUT @Afg;" :SOUR:FREQ:FSK:SOUR TTLT5;"; !FSK source
290 OUTPUT @Afg;" :SOUR:FUNC:SHAP SIN;"; !function
300 OUTPUT @Afg;" :SOUR:VOLT:LEV:IMM:AMPL 5 V" !amplitude
310 OUTPUT @Afg;"INIT:IMM" !wait-for-trigger state
320 SUBEND
330 !
340 SUB Setup_ttl5
350 Setup_ttl5: !Subprogram which sets up trigger line TTLTrg5 to
360 !change the AFG frequency-shift keying frequencies.
370 COM @Afg,@Cmd_mod
380 OUTPUT @Cmd_mod;"OUTP:TTLT5:STAT ON" !enable line TTLTrg5
390 OUTPUT @Cmd_mod;"OUTP:TTLT5:SOUR INT" !drive TTLTrg5 internally
400 !Loop which shifts frequency
410 DISP "Press 'Continue' to shift frequency"
420 PAUSE
430 DISP ""
440 FOR I=1 TO 10
450 IF BIT(I,0) THEN
460 OUTPUT @Cmd_mod;"OUTP:TTLT5:LEV:IMM 1" !level is electrically low
470 ELSE
480 OUTPUT @Cmd_mod;"OUTP:TTLT5:LEV:IMM 0" !level is electrically high
490 END IF
500 WAIT 1
510 NEXT I
520 SUBEND
530 !
540 SUB Rst
550 Rst: !Subprogram which resets the E1445.
560 COM @Afg
570 OUTPUT @Afg;"*RST;*OPC?" !reset the AFG
580 ENTER @Afg;Complete
590 SUBEND
600 !
610 SUB Errmsg
620 Errmsg: !Subprogram which displays E1445 programming errors
630 COM @Afg,@Cmd_mod
640 DIM Message$[256]
650 !Read AFG status byte register and clear service request bit
660 B=SPOLL(@Afg)
670 !End of statement if error occurs among coupled commands
680 OUTPUT @Afg;"
690 OUTPUT @Afg;"ABORT" !abort output waveform

```

Continued on Next Page

```

700 REPEAT
710     OUTPUT @Afg;"SYST:ERR?"           !read AFG error queue
720     ENTER @Afg;Code,Message$
730     PRINT Code,Message$
740     UNTIL Code=0
750     STOP
760 SUBEND

```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, FSK2.FRM, is in directory "VBPROG" and the Visual C example program, FSK2.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

FSK Using an Arbitrary Waveform The FSK_ARB program uses frequency-shift keying with an arbitrary waveform to shift between two sample rates. The control source is a 5 V signal applied to the AFG's front panel "FSK In" BNC connector.

HP BASIC Program Example (FSK_ARB)

```

1  !RE-STORE "FSK_ARB"
2  !This program shifts the frequency of an arbitrary waveform
3  !based on a control signal applied to the "FSK In" BNC connector.
4  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 COM @Afg
40 !
50 !Set up error checking
60 ON INTR 7 CALL Errmsg
70 ENABLE INTR 7;2
80 OUTPUT @Afg;"*CLS"
90 OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprogram which resets and clears the AFG.
130 CALL Rst
140 CALL Wf_del
150 !Set the FSK mode, the FSK sample frequencies for 1 kHz and
160 !2 kHz output frequencies, the FSK source, the function, and
170 !output level.
180 OUTPUT @Afg;"SOUR:FREQ1:MODE FSK;";           !FSK mode
190 OUTPUT @Afg;" :SOUR:FREQ1:FSK 4.096E6,8.192E6;"; !sample frequencies
200 OUTPUT @Afg;" :SOUR:FREQ1:FSK:SOUR EXT;";     !FSK source
210 OUTPUT @Afg;" :SOUR:FUNC:SHAP USER;";        !function
220 OUTPUT @Afg;" :SOUR:VOLT:LEV:IMM:AMPL 1.1V"   !amplitude
230 !Call the subprogram which defines the Sin(x)/x waveform and
240 !output sequence.
250 CALL Sinx_def
260 !Select the output sequence and start the waveform.

```

Continued on Next Page

```

270 OUTPUT @Afg;"SOUR:FUNC:USER SIN_X_OUT"
280 OUTPUT @Afg;"INIT:IMM"
290 !
300 WAIT .1 !allow interrupt to be serviced
310 OFF INTR 7
320 END
330 SUB Sinx_def
340 Sinx_def: !Define Sin(x)/x waveform and output sequence.
350 COM @Afg
360 DIM Waveform(1:4096)
370 FOR I=-2047 TO 2048
380 IF I=0 THEN I=1.E-38
390 Waveform(I+2048)=((SIN(2*PI*.53125*I/256)))/(.53125*I/256)*.159154943092)
400 NEXT I
410 !
420 OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL SIN_X" !select segment
430 OUTPUT @Afg;"SOUR:LIST1:SEGM:DEF 4096" !reserve memory
440 OUTPUT @Afg;"SOUR:LIST1:SEGM:VOLT";Waveform(*) !load points
450 !
460 OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL SIN_X_OUT" !select sequence
470 OUTPUT @Afg;"SOUR:LIST1:SSEQ:DEF 1" !number of segments
480 OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEQ SIN_X" !segment order
490 SUBEND
500 !
510 SUB Rst
520 Rst: !Subprogram which resets the E1445.
530 COM @Afg
540 OUTPUT @Afg;"*RST;*OPC?" !reset the AFG
550 ENTER @Afg;Complete
560 SUBEND
570 !
580 SUB Wf_del
590 Wf_del: !Subprogram which deletes all sequences and segments.
600 COM @Afg
610 OUTPUT @Afg;"FUNC:USER NONE" !select no sequences
620 OUTPUT @Afg;"LIST:SSEQ:DEL:ALL" !delete all sequences
630 OUTPUT @Afg;"LIST:SEGM:DEL:ALL" !delete all segments
640 SUBEND
650 !
660 SUB Errmsg
670 Errmsg: !Subprogram which displays E1445 programming errors
680 COM @Afg
690 DIM Message$[256]
700 !Read AFG status byte register and clear service request bit
710 B=SPOLL(@Afg)
720 !End of statement if error occurs among coupled commands
730 OUTPUT @Afg;"
740 OUTPUT @Afg;"ABORT" !abort output waveform
750 REPEAT
760 OUTPUT @Afg;"SYST:ERR?" !read AFG error queue

```

Continued on Next Page

```

770      ENTER @Afg;Code,Message$
780      PRINT Code,Message$
790      UNTIL Code=0
800      STOP
810      SUBEND

```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, FSK_ARB.FRM, is in directory “VBPROG” and the Visual C example program, FSK_ARB.C, is in directory “VCPROG” on the CD that came with your HP E1445A.

Sweeping and FSK Program Comments

The following information is associated with sweeping, frequency lists, and frequency-shift keying. Included are details on the operation of these functions, and on the various modes, ranges, etc., used in the programs in this chapter.

Reference Oscillator Sources

There are five reference oscillator sources for the AFG which are selected by the [SOURCE:]ROSCillator:SOURCE command:

- **CLK10** – The VXIbus CLK10 (10 MHz) line.
- **EXternal** – The AFG’s front panel “Ref/Smpl In” BNC.
- **ECLTrg0 or 1** – The VXIbus ECL trigger lines.
- **INTERNAL[1]** – The internal 42.94967296 MHz oscillator.
- **INTERNAL2** – The internal 40 MHz oscillator.

The INTERNAL[1] reference oscillator is recommended for use with the Direct-Digital-Synthesis (DDS) time base ([SOURCE:]FREQUENCY[1] subsystem) for high resolution and frequency range.

INTERNAL[1] is the default reference oscillator source. Thus, in many programs, the source is not specified.

Sample Sources

Sweeping, frequency lists, and frequency-shift keying are only available using the direct-digital-synthesis (DDS) frequency synthesis method ([SOURCE:]FREQUENCY[1] subsystem). The method by which the output is advanced to the next sample point is selected with the TRIGGER[:START]:SOURCE command. The available sources are:

- **BUS** – The HP-IB Group Execute Trigger (GET command) or the IEEE-488.2 *TRG common command.
- **ECLTrg0 or ECLTrg1** – The VXIbus ECL trigger lines.
- **EXternal** – The AFG’s front panel “Ref/Smpl In” BNC.
- **HOLD** – Suspends sample generation.
- **INTERNAL[1]** – The [SOURCE:]FREQUENCY[1] subsystem DDS frequency synthesis.
- **INTERNAL2** – The [SOURCE:]FREQUENCY2 subsystem Divide-by-n frequency synthesis.

- **TTLTrg0 through 7** – The VXIbus TTL trigger lines.

INTernal[1] is the source selected at power-on or following a reset, but is specified in the programs to emphasize that sweeping, frequency lists, and frequency-shift keying are only allowed when INTernal[1] is the source.

AFG Frequency Modes

There are four frequency “modes” available using the INTernal1 sample source (DDS timebase). The modes selected by the [SOURce:]FREQUENCY[1]:MODE command are:

- **CW | FIXed** – single frequency mode
- **FSKey** – frequency shift keying mode
- **LIST** – frequency list mode
- **SWEep** – frequency sweep mode

Frequency Range: Sweeping and Sampling

The frequency range for sweeping or sampling depends on the reference oscillator used. However, for the INTernal1 42.94967296 MHz oscillator, the range for swept sine, square, triangle, and ramp waveforms, and the swept sampling range for arbitrary waveforms is 0 Hz to 10.73741824 MHz.

Frequency Range: Frequency Lists and FSK

The maximum number of frequencies in a frequency list is 256. The range of frequencies allowed in a frequency list or for frequency-shift keying depends on the output function:

- **Sine Wave and Arbitrary Waveforms:** The minimum frequency is 0 Hz; the maximum frequency is the selected reference oscillator frequency divided by 4.
- **Square Waves:** The minimum frequency is 0 Hz; the maximum frequency is the selected reference oscillator frequency divided by 16.
- **Ramp and Triangle Waveforms:** The minimum frequency is 0 Hz; the maximum frequency is the selected reference oscillator frequency divided by four multiplied by the number of waveform points ($R_{osc}/(4 * n_{pts})$).

Frequency Doubling

For all waveforms except sine waves, the sweeping or sampling range can be doubled using the [SOURce:]FREQUENCY[1]:RANGE command. **Frequency doubling is enabled by specifying a range that is greater than the maximum “undoubled” frequency allowed for a given waveform.** The maximum undoubled frequencies for the various waveforms are given below.

- **Arbitrary Waveforms:** The maximum undoubled frequency is the current reference oscillator frequency divided by 4.
- **Square Waves:** The maximum undoubled frequency is the current reference oscillator frequency divided by 16.

- **Triangle and Ramp Waves:** The maximum undoubled frequency is the current reference oscillator frequency divided by 4, further divided by the [SOURce:]RAMP:POINts value.

Sweep Count and Frequency List Repetition Count

The sweep count specifies the number of sweeps to occur, or the number of passes through the frequency list before the AFG returns to the idle state from the wait-for-arm state (see Chapter 5).

The sweep count, set with the [SOURce:]SWEep:COUNT command has a range from 1 to 2,147,483,647 or INFinity. The default count is 1. Continuous sweeps, or loops through a frequency list can be stopped with the ABORt command.

Arbitrary Block Data

Data sent to the AFG in an arbitrary block is in a binary format. The encoding syntax for downloading frequency list data in this format is shown Figure 4-2.

In a definite length arbitrary block:

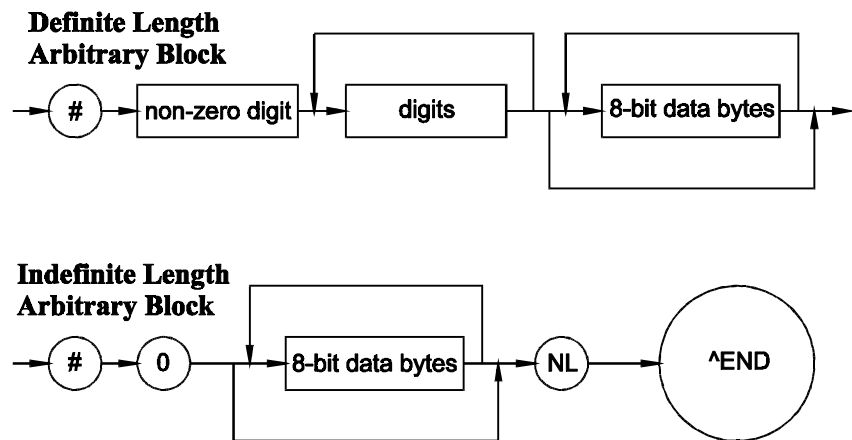


Figure 4-2. Arbitrary Block Data Diagram

- “#” indicates the data to be sent is in an arbitrary block
- “non-zero digit” is a single digit number which shows the number of digits contained in “digits”. For example, if the “digits” value is 100 or 2000, the “non-zero digit” value is 3 or 4, respectively.
- “8-bit data bytes” is the data (i.e. frequencies) sent to the AFG. Note that there are eight bytes per frequency list frequency.

In the LISTDEF program on page 131, a list of 100 frequencies is downloaded using the definite length block format. In the definite length encoding syntax, “digit” specifies the number of bytes downloaded (800). Since ‘800’ is three characters, “non-zero digit” is ‘3’.

In an indefinite length arbitrary block:

- “#” indicates the data to be sent is in an arbitrary block.
- “0” indicates that an indefinite length block of data is to be sent.
- “8-bit data bytes” is the data (i.e. frequencies) sent to the AFG. There are eight bytes per frequency list frequency.
- NL ^END means a line feed (LF) is sent with END (EOI) asserted. It indicates to the AFG that the end of the data block has been reached.

Additional information on arbitrary block data can be found in *ANSI/IEEE Standard 488.2-1987 IEEE Standard Codes, Formats, Protocols, and Common Commands*.

Frequency Points

The number of frequencies generated (points) in a frequency sweep can be from 2 to 1,073,741,824. The default number is 800. The number of points is set with the [SOURce:]SWEep:POINts command and applies to sweeps only.

Sweep Spacing

The spacing between the frequencies (points) in a sweep can be either linear or logarithmic as set by [SOURce:]SWEep:SPACing. Linear sweeps can start at 0 Hz. Logarithmic sweeps can start at the reference oscillator frequency/4,294,967,296/npts. The number of waveform points (npts) for sine waves and arbitrary waveforms is 1, for square waves npts is 4, for ramp and triangle waves npts is the number of ramp points.

Sweep Direction

The direction of the frequency sweep can be up or down. When the direction is up, the sweep begins at the specified start frequency and stops at the specified stop frequency. When the direction is down, the sweep begins at the stop frequency and stops at the start frequency. You must stop (abort) the sweep before changing direction.

For arbitrary waveforms when the direction is up, sampling begins at the start frequency and stops at the stop frequency. When the direction is down, sampling begins at the stop frequency and stops at the start frequency. You must stop (abort) sampling before changing direction.

Frequency lists begin with the first frequency in the list and end with the last frequency. There is no directional control.

Sweep Time

The number of frequencies (points) in a sweep and the number of frequencies in a frequency list change the duration of the sweep or pass through the list. The relationship between the sweep or list time ([SOURCE:]SWEep:TIME), the time between frequencies (TRIGger:SWEep:TIMer), and the number of frequencies (points) is shown below:

$$\text{TIME} = \text{TIMer} * (\text{points} - 1)$$

Changing the number of points keeps the value set by the last command sent (either [SOURCE:]SWEep:TIME or TRIGger:SWEep:TIMer) and changes the other. Changing TIME or TIMer affects the other.

Sweep Advance Source

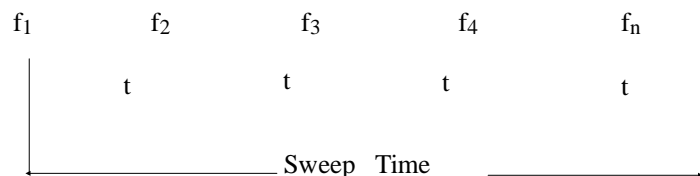
The source which advances the sweep or list to the next frequency is set with the TRIGger:SWEep:SOURce command. The available sources are:

- **BUS** – The HP-IB Group Execute Trigger (GET) command or the IEEE-488.2 *TRG common command.
- **HOLD** – Suspend sweep or frequency list advance triggering. Advance to the next frequency (sweeping or in a list) using TRIGger:SWEep:IMMEDIATE.
- **LINK** – The next valid start arm advances the sweep or list.
- **TIMer** – The [SOURCE:]SWEep:TIME and/or TRIGger:SWEep:TIMer commands control the sweep and frequency list advance timing (default source).
- **TTLTrg0 through TTLTrg7** – The VXIbus TTL trigger lines.

More information on the sweep advance source can be found in Chapter 5, “Arming and Triggering”.

Specifying a Sweep Time

The sweep time (set by [SOURCE:]SWEep:TIME) is the period from the **generation** of the first frequency in the sweep or list to the **generation** of the last frequency (see below).



The duration (t) of each frequency (except the last (f_n)) is:

$$\text{specified sweep time}/(\text{frequency points} - 1)$$

For multiple sweeps or repetitions through the list, the duration of the last frequency (f_n) is also t. To maintain a constant rate between sweeps or repetitions, the duration of f_n must be accounted for as follows:

$$\text{Sweep time}_{\text{specified}} = \text{Sweep repetition time}_{\text{desired}} * ((\text{points} - 1)/\text{points})$$

Sweep Points Versus Time

In SWP_PVST (Sweep Points Versus Time) on page 136, the program continually sweeps 100 frequency points in 0.125 seconds. To maintain this rate continuously, the time between the last frequency point and the first point is accounted for as follows:

$$\text{Sweep time}_{\text{specified}} = 0.125 * (99/100) = 0.125 * 0.99 = 0.12375$$

Thus, the actual sweep time specified is 0.12375 seconds.

Frequency Lists Versus Time

In the LIST_TME program (Frequency Lists Versus Time) on page 139, the program outputs a new frequency every 1 second. To maintain this rate continuously, the time between the last frequency in the list and the first frequency is accounted for as follows:

$$\text{Repetition rate}_{\text{specified}} = 4 * (3/4) = 4 * 0.75 = 3$$

Thus, the actual repetition rate specified is 3 (seconds).

The minimum and maximum sweep times and frequency list repetition rates are based on the number of points and frequencies, and are calculated as follows:

$$\begin{aligned} \text{MINimum} &= 1.25 \text{ mS} * (\text{points} - 1) \\ \text{MAXimum} &= 4.19430375 \text{ S} * (\text{points} - 1) \end{aligned}$$

Again, for continuous sweeping list repetitions, the desired (minimum or maximum) time must be multiplied by the quantity:

$$(\text{points} - 1) / \text{points}$$

The default sweep time is 1 second for any number of points or frequencies specified.

The function in this program is a 1,000 point triangle wave. The maximum frequency allowed in the frequency list is the reference oscillator frequency divided by the quantity four multiplied by the number of waveform points:

$$\text{Rosc} / (4 * \text{npts}) = 42.94967296\text{E6} / (4 * 1000) = 10.7374 \text{ kHz}$$

Output Frequency and Sample Rate

The output frequency of an arbitrary waveform is defined as:

$$F_O = \text{sample rate}/\text{waveform_points}$$

For frequency sweeps the sample rate(s) are the start and stop frequencies. For example, with an arbitrary waveform with 4096 amplitude points, a start frequency of 4.096E6 and a stop frequency of 8.192E6 produces a sweep from 1 kHz to 2 kHz.

For frequency-shift keying the sample rates are *frequency1* and *frequency2* specified by the [SOURCE:]FREQUENCY[1]:FSKey command. The output frequencies are the sample rates divided by the number of amplitude points in the arbitrary waveform.

AC Leveling

The AFG has a 250 kHz output filter and a 10 MHz output filter. When the filter has been selected and enabled, AC output leveling maintains the amplitude at a constant level over the frequency sweep or frequency list. AC leveling, which is performed by the CALibration:STATE:AC ON command (reset setting), applies to the sine wave function only.

AC Leveling Amplitude Errors

When AC leveling is enabled during a sweep or frequency list, errors in the output amplitude still occur during a frequency change. In most cases, the errors are negligible. However, in applications where the step-to-step frequency changes are large (10% or greater), or when frequency changes occur near the filter's cutoff frequency, the error is such that settling times on the order of milliseconds are required for the output to settle to the correct amplitude.

Table 4-1 shows typical (non-warranted) amplitude errors versus settling times when a frequency change occurs. These “worst case” settling times represent frequency changes (freq1 to freq2) of 10% and 1% from the filter's cutoff frequency.

Table 4-1. Amplitude Errors Versus Settling Times

Amplitude = 5 Vpk, 10 MHz filter, frequency change =10 %, Freq ₁ = 10.7 MHz, Freq ₂ = 0.9 * Freq ₁			
Error in Volts	Settling Time (ms)	% Error	dB Error
0.532	0.01	10.6	0.878
0.5	0.48	10.0	0.828
0.25	1.16	5.0	0.424
0.1	2.04	2.0	0.172
0.05	2.62	1.0	0.086
Amplitude = 5 Vpk, 10 MHz filter, frequency change =1%, Freq ₁ = 10.7 MHz, Freq ₂ = 0.99 * Freq ₁			
Error in Volts	Settling Time (ms)	% Error	dB Error
0.056	0.01	1.12	0.097
0.05	0.48	1.0	0.086
0.025	1.10	0.5	0.043
Amplitude = 5 Vpk, 250 kHz filter, frequency change =10 %, Freq ₁ = 250 kHz, Freq ₂ = 0.9 * Freq ₁			
Error in Volts	Settling Time (ms)	% Error	dB Error
0.256	0.01	5.12	0.433
0.25	0.39	5.0	0.424
0.10	1.22	2.0	0.172
0.05	1.84	1.0	0.086
0.025	2.60	0.5	0.043
Amplitude = 5 Vpk, 250 kHz filter, frequency change =1%, Freq ₁ = 250 kHz, Freq ₂ = 0.99 * Freq ₁			
Error in Volts	Settling Time (ms)	% Error	dB Error
0.025	0.32	0.5	0.043
0.01	1.20	0.2	0.0174

FSK Control Sources

The frequency-shift keying control sources are:

EXTernal – The HP E1445A AFG’s front panel “Stop Trig/FSK/Gate In” BNC connector (TTL levels).

TTLTrg<n> – The VXIbus TTL trigger lines TTLTrg0 through TTLTrg7.



Both the “FSK” BNC connector and the TTLTrg<n> trigger lines use TTL compatible signal levels. A “high” level on the BNC or trigger line selects *frequency1*, a “low” level selects *frequency2*.

Frequency-Shift Delay

Once the control signal to shift the frequency is received, there is a delay of 20 reference oscillator clock cycles before the frequency is active. This delay occurs with all reference oscillator sources.

Driving the TTLTrg<n> Trigger Lines

When driving the TTLTrg<n> trigger lines with the HP E1406A Command Module, note that the module uses negative-true logic. Thus, writing a logic '1' to a trigger line sets the line to an electrically low level. This would select FSK *frequency2*. Writing a logic '0' to a trigger line sets the line to an electrically high level which selects *frequency1*. Refer to your Command Module manual for more information on setting up and enabling the TTLTrg trigger lines.

Chapter 5

Arming and Triggering

Chapter Contents

This chapter shows you how to arm and trigger the HP E1445A AFG in order to start and advance standard and arbitrary waveforms. The sections of this chapter include:

- The ARM-TRIG Configuration Page 164
 - The ARM-TRIG States Page 164
- Initiating Waveforms Page 165
- Arming the AFG Page 165
 - Arming Commands Page 165
 - Setting Arming Sources Page 166
 - Setting the Arm and Waveform Cycle Count Page 169
- Triggering the AFG Page 172
 - Triggering Commands Page 172
 - Using the Divide-by-N Frequency Generator Page 174
 - Lock-Stepping Multiple AFGs Page 176
 - Using Stop Triggers Page 180
 - Gating Trigger Signals Page 183
- Arming and Triggering Frequency Sweeps and Lists Page 186
 - Frequency Sweeps Using Triggers Page 186
 - Arming and Triggering a Frequency Sweep Page 190
 - Arming and Triggering a Frequency List Page 193
- Aborting Waveforms Page 196
 - Using ABORt, Stop Triggers, or Gating Page 196
- Arming and Triggering Program Comments Page 197
 - Reference Oscillator Sources Page 197
 - AFG Frequency Synthesis Modes Page 197
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 - AFG Gating Sources Page 200
 - AFG Gate Polarity Page 200
 - Enabling the Gate Page 200
 - Frequency Sweep/List Arming Page 201
 - Frequency Sweep/List Advance Trigger Page 201

The ARM-TRIG Configuration

Each standard and arbitrary waveform is a series of discrete amplitude points (digital-to-analog (DAC) codes). The HP E1445A AFG uses an ARM-TRIG triggering configuration to output these points. When initiated, an arm signal enables the AFG to output one amplitude point each time a trigger signal is received. The “arm-trigger” model is shown in Figure 5-1.

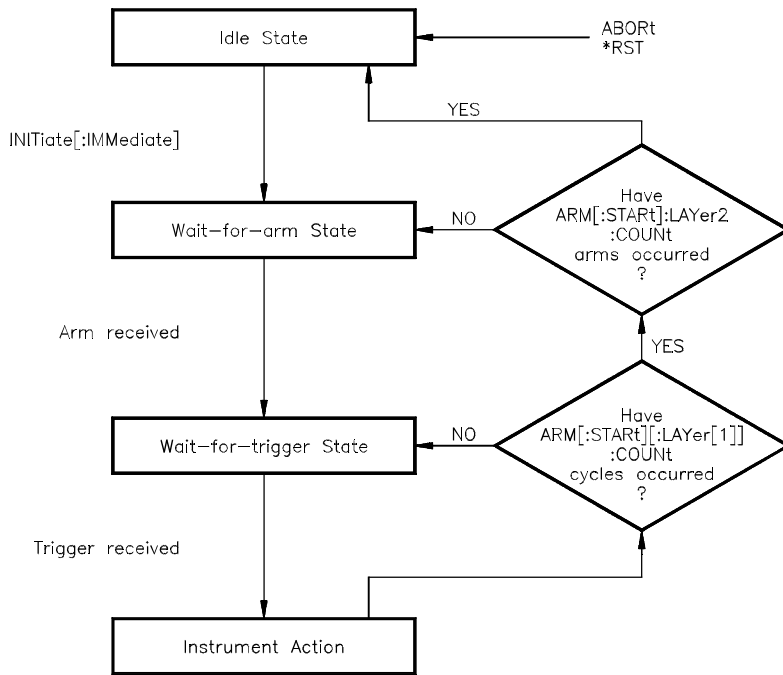


Figure 5-1. The ARM-TRIG Triggering Model

The ARM-TRIG States

The AFG operates within four states: Idle, Wait-for-Arm, Wait-for-Trigger, and Instrument Action (see Figure 5-1).

When power is applied or following a reset or an abort, the AFG is in the Idle state. The AFG is set to the Wait-for-Arm state with the INITiate[:IMMediate] command.

The AFG moves to the Wait-for-Trigger state when an arm from the specified arm source is received. The AFG moves to the Instrument Action state when a trigger is received.

After the Instrument Action (amplitude point is output) occurs, the AFG returns to the Wait-for-Trigger state until the next trigger occurs. When enough triggers have occurred such that the specified waveform cycle (repetition) count has been reached, the AFG returns to the Wait-for-Arm state until the next arm occurs. When the specified arm count has been reached, the AFG returns to the Idle state.

Initiating Waveforms

After the AFG has been configured to output the desired waveform, the AFG is set to the Wait-for-Arm state with the command:

```
INITiate[:IMMEDIATE]
```

INITiate is an uncoupled command and is generally the last command executed before a waveform is output:

```
SUB Sine_wave
Sine_wave: !Subprogram which outputs a sine wave
COM @Afg
OUTPUT @Afg;"SOUR:FREQ1:FIX 1E3";           !frequency
OUTPUT @Afg;":SOUR:FUNC:SHAP SIN;";       !function
OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL 5 V"  !amplitude
OUTPUT @Afg;"INIT:IMM"                  !wait-for-arm state
SUBEND
```

If INITiate[:IMMEDIATE] is executed when the AFG is not in the Idle state, Error -213, "Init ignored" is generated.

Arming the AFG

In order for the AFG to accept trigger signals which output the amplitude points of the waveform, the AFG must be armed. The information in this section covers the commands and programming sequence used to arm the AFG for fixed frequency waveform generation.

Arming Commands

The commands which arm the AFG allow you to specify the following:

- the arm source
- the slope of an external arm signal
- the number of arms per INITiate[:IMMEDIATE] command
- the number of waveform cycles per arm

The arming commands include:

```
ARM
[:START | SEQUENCE[1]]
[:LAYER[1]]
:COUNT <number>
:LAYER2
:COUNT <number>
[:IMMEDIATE]
:SLOPE <edge>
:SOURCE <source>
```

The arming commands for continuous waveforms are uncoupled commands. They are executed relative to other AFG commands in the sequence of Figure 5-2.

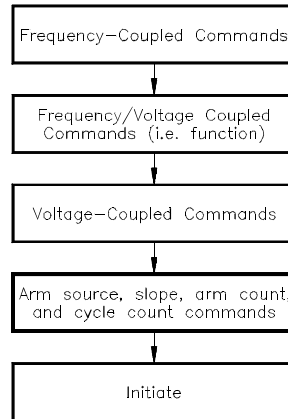


Figure 5-2. AFG Arming Command Sequence

Note

Detailed information on the commands introduced in this chapter can be found in Chapter 8, “Command Reference”. The commands in this chapter are shown in their entirety (optional headers included) to help you locate them in the reference.

Setting Arming Sources

The EXT_ARM program shows how to select the source which arms the AFG. The program selects the AFG’s “Start Arm In” BNC connector as the arming source. When an arming signal is received, a 10 kHz, 1 Vpp square wave is output.

The steps of this program are:

1. **Select the FIXed frequency mode**
[SOURce:]FREQuency[1]:MODE <mode>
2. **Set the output frequency**
[SOURce:]FREQuency[1][:CW | :FIXed] <frequency>
3. **Set the output function**
[SOURce:]FUNctio[n][:SHAPE] <shape>
4. **Set the signal amplitude**
[SOURce:]VOLtag[e][:LEVel][:IMMediate][:AMPLitude] <amplitude>

5. **Set the arm source**

ARM[:START]:LAYer2:SOURce <source>

6. **Set the trigger edge of the external trigger signal**

ARM[:START]:LAYer2:SLOPe <edge>

7. **Place the AFG in the wait-for-arm state**

INITiate[:IMMEDIATE]

HP BASIC Program Example (EXT_ARM)

```
1  !RE-STORE"EXT_ARM"
2  !This program arms the AFG with an external signal applied to the
3  !AFG Start Arm In port. When armed, a 10 kHz, 1 VPP square wave is
4  !output
5  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 COM @Afg
40 !
50 !Set up error checking
60 ON INTR 7 CALL Errmsg
70 ENABLE INTR 7;2
80 OUTPUT @Afg;"*CLS"
90 OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms
130 CALL Rst
140 CALL External_arm
150 !
160 WAIT .1 !allow interrupt to be serviced
170 OFF INTR 7
180 END
190 !
200 SUB External_arm
210 External_arm: !Subprogram which externally arms the AFG and outputs
220 !a square wave.
230 COM @Afg
240 OUTPUT @Afg;"SOUR:FREQ1:MODE FIX;"; !frequency mode
250 OUTPUT @Afg;"SOUR:FREQ1:FIX 3;"; !frequency
260 OUTPUT @Afg;"SOUR:FUNC:SHAP SQU;"; !function
270 OUTPUT @Afg;"SOUR:VOLT:LEV:IMM:AMPL 1VPP" !amplitude
280 OUTPUT @Afg;"ARM:STAR:LAY2:SOUR EXT" !arm source
290 OUTPUT @Afg;"ARM:STAR:LAY2:SLOP NEG" !signal edge
300 OUTPUT @Afg;"INIT:IMM" !wait-for-arm state
310 SUBEND
320 !
330 SUB Rst
```

Continued on Next Page

```

340 Rst: !Subprogram which resets the E1445.
350     COM @Afg
360     OUTPUT @Afg;"*RST;*OPC?"           !reset the AFG
370     ENTER @Afg;Complete
380     SUBEND
390     !
400     SUB Errmsg
410 Errmsg: !Subprogram which displays E1445 programming errors
420     COM @Afg
430     DIM Message$(256)
440     !Read AFG status byte register and clear service request bit
450     B=SPOLL(@Afg)
460     !End of statement if error occurs among coupled commands
470     OUTPUT @Afg;"
480     OUTPUT @Afg;"ABORT"               !abort output waveform
490     REPEAT
500         OUTPUT @Afg;"SYST:ERR?"       !read AFG error queue
510         ENTER @Afg;Code,Message$
520         PRINT Code,Message$
530     UNTIL Code=0
540     STOP
550     SUBEND

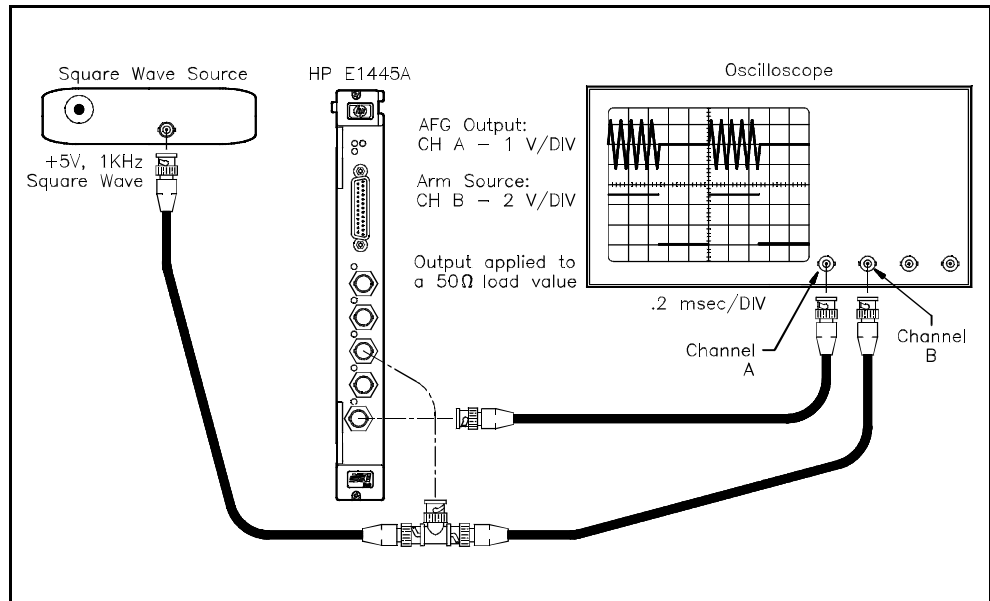
```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, EXT_ARM.FRM, is in directory "VBPROG" and the Visual C example program, EXT_ARM.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Setting the Arm and Waveform Cycle Count

The BURST program shows you how to set the number of arms the AFG is to receive before returning to the Idle state, and how to set the number of waveform cycles (repetitions) per arm.

The program sets a five cycle burst that occurs each time an external arm is received.



The steps of this program are:

1. **Set the output (burst) frequency**
[SOURce:]FREQuency[1][:CW | :FIXed] <frequency>
2. **Set the output function**
[SOURce:]FUNCtion[:SHAPe] <shape>
3. **Set the signal amplitude**
[SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude] <amplitude>
4. **Set the arm source**
ARM[:START]:LAYer2:SOURce <source>
5. **Set the slope of the external arm signal**
ARM[:START]:LAYer2:SLOPe <edge>
6. **Set the arm count**
ARM[:START]:LAYer2:COUNt <number>
7. **Set the number of waveform cycles (burst count)**
ARM[:START][:LAYer[1]]:COUNt <number>
8. **Place the AFG in the wait-for-arm state**
INITiate[:IMMediate]

HP BASIC Program Example (BURST)

```
1   !RE-STORE"BURST"
2   !This program sets the arm count to infinity, and the cycle count
3   !count to 5. The arm source is set to external and a 1 kHz square
4   !wave is applied to the AFG's "Start Arm In" BNC connector. The
5   !AFG outputs a 5 cycle burst on each positive edge of the external
6   !arm signal.
7   !
10  !Assign I/O path between the computer and E1445A.
20  ASSIGN @Afg TO 70910
30  COM @Afg
40  !
50  !Set up error checking
60  ON INTR 7 CALL Errmsg
70  ENABLE INTR 7;2
80  OUTPUT @Afg;"*CLS"
90  OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms
130 CALL Rst
140 CALL Burst_arm
150 !
160 WAIT .1 !allow interrupt to be serviced
170 OFF INTR 7
180 END
190 !
200 SUB Burst_arm
210 Burst_arm: !Subprogram which outputs a 5 cycle burst on each
220             !positive edge of an external arm signal.
230     COM @Afg
240     OUTPUT @Afg;"SOUR:FREQ1:FIX 10E3;";           !burst frequency
250     OUTPUT @Afg;":SOUR:FUNC:SHAP SIN;";         !function
260     OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL 2.5VPP" !amplitude
270     OUTPUT @Afg;"ARM:STAR:LAY2:SOUR EXT"        !arm source
280     OUTPUT @Afg;"ARM:STAR:LAY2:SLOP POS"       !arm slope
290     OUTPUT @Afg;" ARM:STAR:LAY2:COUN INF"      !arm count
300     OUTPUT @Afg;" ARM:STAR:LAY1:COUN 5"       !cycle count
310     OUTPUT @Afg;"INIT:IMM"                    !wait-for-arm state
320 SUBEND
330 !
340 SUB Rst
350 Rst: !Subprogram which resets the E1445.
360     COM @Afg
370     OUTPUT @Afg;" *RST;*OPC?"                 !reset the AFG
380     ENTER @Afg;Complete
390 SUBEND
400 !
410 SUB Errmsg
```

Continued on Next Page

```

420 Errmsg: !Subprogram which displays E1445 programming errors
430     COM @Afg
440     DIM Message$[256]
450     !Read AFG status byte register and clear service request bit
460     B=SPOLL(@Afg)
470     !End of statement if error occurs among coupled commands
480     OUTPUT @Afg;"
490     OUTPUT @Afg;"ABORT"                                !abort output waveform
500     REPEAT
510         OUTPUT @Afg;"SYST:ERR?"                        !read AFG error queue
520         ENTER @Afg;Code,Message$
530         PRINT Code,Message$
540     UNTIL Code=0
550     STOP
560 SUBEND

```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, BURST.FRM, is in directory "VBPROG" and the Visual C example program, BURST.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Triggering the AFG

Arming the AFG places the device in the Wait-for-Trigger state (Figure 5-1). When a trigger occurs, the AFG digital-to-analog converter (DAC) outputs one waveform amplitude point.

The information in this section covers the commands and programming sequence used to trigger the AFG when outputting fixed frequency waveforms.

Triggering Commands

The commands which trigger the AFG allow you to specify the following:

- the (start) trigger source
- the slope of an external (start) trigger signal
- the stop trigger source
- the slope of an external stop trigger signal
- the sample gating source
- the polarity of an external gating signal
- to enable sample gating

The triggering commands include:

```
TRIGger
[:START|SEQUence[1]]
:COUNT <number>
:GATE
    :POLarity <polarity>
    :SOURce <source>
    :STATe <state>
[:IMMediate]
:SLOPe <edge>
:SOURce <source>

:STOP|SEQUence2
[:IMMediate]
:SLOPe <edge>
:SOURce <source>
```

Note The trigger count (TRIGger[:START]:COUNT) is always equal to the number of amplitude points in the current waveform, multiplied by the number of waveform cycles. This value is not programmable (other than 9.91E37), but is included for SCPI compatibility purposes only.

The commands in the TRIGger subsystem are frequency coupled. They are executed relative to other AFG commands in the sequence shown in Figure 5-3.

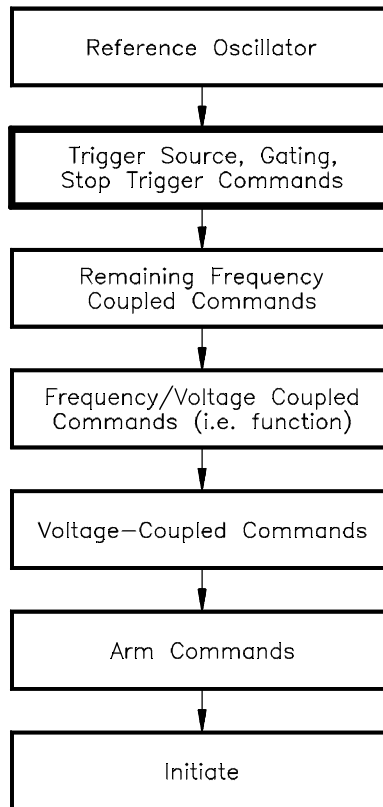


Figure 5-3. AFG Triggering Command Sequence

Using the Divide-by-N Frequency Generator

The DIV_N program shows how to set the AFG trigger source. The program selects the AFG's divide-by-N frequency generator ([SOURce:]FREQuency2 subsystem). This generator is recommended for use with the AFG's 40 MHz reference oscillator (also selected in the program) to produce exact frequencies such as 10 MHz, 20 MHz, etc.,

The steps of this program are:

1. **Select the 40 MHz reference oscillator**
[SOURce:]ROSCillator:SOURce <source>
2. **Select the divide-by-N time base**
TRIGger[:START]:SOURce <source>
3. **Set the output frequency**
[SOURce:]FREQuency2[:CW | :FIXed] <frequency>
4. **Set the output function**
[SOURce:]FUNCtion[:SHAPE] <shape>
5. **Set the signal amplitude**
[SOURce:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude] <amplitude>
6. **Place the AFG in the wait-for-arm state**
INITiate[:IMMEDIATE]

HP BASIC Program Example (DIV_N)

```
1  !RE-STORE"DIV_N"
2  !This program selects the 40 MHz reference oscillator and the
3  !SOURce:FREQuency2 subsystem (divide-by-N frequency synthesis) to
4  !generate an "exact" square wave frequency of 10 MHz.
5  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 COM @Afg
40 !
50 !Set up error checking
60 ON INTR 7 CALL Errmsg
70 ENABLE INTR 7;2
80 OUTPUT @Afg;"*CLS"
90 OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms which reset the AFG and which
130 !generate the square wave.
140 CALL Rst
150 CALL Squ_wave
```

Continued on Next Page

```

160 WAIT .1 !allow interrupt to be serviced
170 OFF INTR 7
180 END
190 !
200 SUB Squ_wave
210 Squ_wave: !Subprogram which selects reference oscillator source
220           !INTernal2, trigger source INTernal2, and the output
230           !frequency, function, and amplitude.
240     COM @Afg
250     OUTPUT @Afg;"SOUR:ROSC:SOUR INT2;";           !reference oscillator
260     OUTPUT @Afg;":TRIG:STAR:SOUR INT2;";         !trigger source
270     OUTPUT @Afg;":SOUR:FREQ2:FIX 10E6;";         !output frequency
280     OUTPUT @Afg;":SOUR:FUNC:SHAP SQU;";         !output function
290     OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL 1VPP"    !amplitude
300     OUTPUT @Afg;"INIT:IMM"                       !wait-for-arm state
310 SUBEND
320 !
330 SUB Rst
340 Rst: !Subprogram which resets the E1445.
350     COM @Afg
360     OUTPUT @Afg;" *RST;*OPC?                     !reset the AFG
370     ENTER @Afg;Complete
380 SUBEND
390 !
400 SUB Errmsg
410 Errmsg: !Subprogram which displays E1445 programming errors
420     COM @Afg
430     DIM Message$(256)
440     !Read AFG status byte register and clear service request bit
450     B=SPOLL(@Afg)
460     !End of statement if error occurs among coupled commands
470     OUTPUT @Afg;""
480     OUTPUT @Afg;"ABORT"                          !abort output waveform
490     REPEAT
500         OUTPUT @Afg;"SYST:ERR?"                  !read AFG error queue
510         ENTER @Afg;Code,Message$
520         PRINT Code,Message$
530     UNTIL Code=0
540     STOP
550 SUBEND

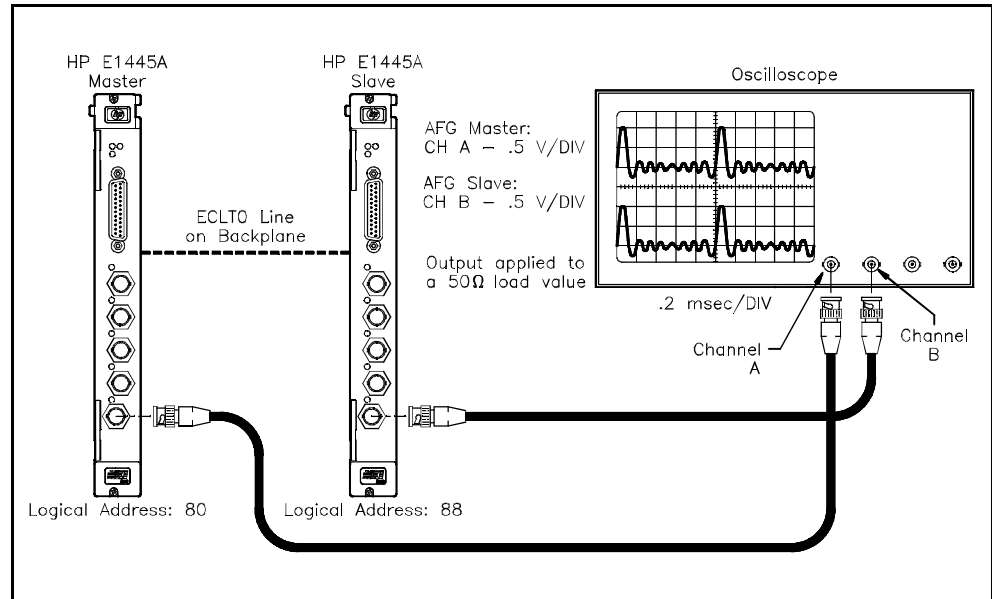
```

**Visual BASIC and
Visual C/C++ Program
Versions**

The Visual BASIC example program, DIV_N.FRM, is in directory "VBPROG" and the Visual C example program, DIV_N.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Lock-Stepping Multiple AFGs

The LOCKSTEP program configures two AFGs such that they share the same trigger source. A “master” AFG is programmed to output its triggers on ECLTrg trigger line 0. The trigger source of a “servant” AFG is set to ECLTrg 0. Thus, both AFGs output waveforms (sin(x)/x) at the same frequency, and changing the frequency of the master changes the frequency of the servant simultaneously.



The programming sequence for lock-stepping multiple AFGs is given below:

1. **Set the reference oscillator source for the master and slave as desired or use the default source**
`[SOURce:]ROSCillator:SOURce <source>`
2. **Set the trigger source of the master AFG as desired. Set the trigger source of the slave AFG to the source driven by the master**
`TRIGger[:START]:SOURce <source>`
3. **Set the frequency mode**
`[SOURce:]FREQuency[1]:MODE <mode>`
4. **Set the output frequency of the master**
`[SOURce:]FREQuency[1][:CW | :FIXed] <frequency>`
or
`[SOURce:]FREQuency2[:CW | :FIXed] <frequency>`
5. **Set the output function**
`[SOURce:]FUNCtion[:SHAPE] <shape>`
6. **Set the signal amplitude**
`[SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude] <amplitude>`

7. **Feed the master AFG trigger to the trigger source of the slave AFG**
[SOURCE:]MARKER:ECLTrg<n>:FEED <source>
8. **Enable the routing of the trigger signal**
[SOURCE:]MARKER:ECLTrg<n>[:STATE] <mode>
9. **Place the AFG in the wait-for-arm state**
INITiate[:IMMEDIATE]

HP BASIC Program Example (LOCKSTEP)

```

1  !RE-STORE"LOCKSTEP"
2  !This program "lock-steps" two AFGs. The trigger source which
3  !advances the waveform of the master AFG (DDS time base) is shared by
4  !the slave AFG. Thus, changing the frequency of the master AFG
5  !changes the frequency of the slave AFG simultaneously.
6  !
10 !Assign I/O path between the computer and E1445A, dimension an array
20 !variable for the sin(x)/x waveform amplitude points.
30 ASSIGN @Afg_m TO 70910
40 ASSIGN @Afg_s TO 70911
50 COM @Afg_m,@Afg_s,REAL Waveform(1:4096)
60 !
70 !Set up error checking
80 ON INTR 7 CALL Errmsg
90 ENABLE INTR 7;2
100 OUTPUT @Afg_m;"*CLS"
110 OUTPUT @Afg_m;"*SRE 32"
120 OUTPUT @Afg_m;"*ESE 60"
130 !
140 OUTPUT @Afg_s;"*CLS"
150 OUTPUT @Afg_s;"*SRE 32"
160 OUTPUT @Afg_s;"*ESE 60"
170 !
180 !Call the subprograms which reset the AFGs, delete all
190 !existing waveform segments and sequences, and which set up the
200 !AFGs to output arbitrary waveforms.
210 CALL Rst
220 CALL Wf_del
230 CALL Sinx_def
240 CALL Sinx_m
250 CALL Sinx_s
260 !
270 !Select the waveform sequence of the master AFG, place the
280 !master AFG in the Wait-for-arm state.
290 OUTPUT @Afg_m;"SOUR:FUNC:USER SINX_M"
300 OUTPUT @Afg_m;"INIT:IMM"
310 !
320 WAIT .1 !allow interrupt to be serviced
330 OFF INTR 7

```

Continued on Next Page

```

340 END
350 !
360 SUB Sinx_def
370 Sinx_def: !Subprogram which computes the sin(x)/x waveform amplitudes
380 !used by both AFGs.
390 COM @Afg_m,@Afg_s,Waveform(*)
400 FOR I=-2047 TO 2048
410 IF I=0 THEN I=1.E-38
420 Waveform(I+2048)=((SIN(2*PI*.53125*I/256)))/(.53125*I/256)*.159154943092)
430 NEXT I
440 SUBEND
450 !
460 SUB Sinx_m
470 COM @Afg_m,@Afg_s,Waveform(*)
480 Sinx_m: !Set the reference oscillator source, trigger source,
490 !frequency mode/frequency, and amplitude for the master
500 !AFG waveform. Feed the master trigger source to the slave
510 !AFG via ECL trigger line ECLT0.
520 OUTPUT @Afg_m,"SOUR:ROSC:SOUR INT1;";
530 OUTPUT @Afg_m,":TRIG:STAR:SOUR INT1;";
540 OUTPUT @Afg_m,":SOUR:FREQ1:MODE FIXED;";
550 OUTPUT @Afg_m,":SOUR:FREQ1:FIX 4.096E6;";
560 OUTPUT @Afg_m,":SOUR:FUNC:SHAP USER;";
570 OUTPUT @Afg_m,":SOUR:VOLT:LEV:IMM:AMPL 1.1V"
580 OUTPUT @Afg_m,"SOUR:MARK:ECLT0:FEED ""TRIG:STAR""
590 OUTPUT @Afg_m,"SOUR:MARK:ECLT0:STAT ON"
600 !
610 !Define the waveform segment and download the amplitude points.
620 !Define the output waveform sequence.
630 OUTPUT @Afg_m,"SOUR:LIST1:SEGM:SEL SIN_X" !select segment
640 OUTPUT @Afg_m,"SOUR:LIST1:SEGM:DEF 4096" !reserve memory
650 OUTPUT @Afg_m,"SOUR:LIST1:SEGM:VOLT";Waveform(*) !load points
660 !
670 OUTPUT @Afg_m,"SOUR:LIST1:SSEQ:SEL SINX_M" !select sequence
680 OUTPUT @Afg_m,"SOUR:LIST1:SSEQ:DEF 1" !specify segments
690 OUTPUT @Afg_m,"SOUR:LIST1:SSEQ:SEQ SIN_X" !segment order
700 SUBEND
710 !
720 SUB Sinx_s
730 Sinx_s: !Set the trigger source, frequency mode, function, and
740 !amplitude for the slave AFG waveform.
750 COM @Afg_m,@Afg_s,Waveform(*)
760 OUTPUT @Afg_s,"TRIG:STAR:SOUR ECLT0;";
770 OUTPUT @Afg_s,":SOUR:FREQ1:MODE FIXED;";
780 OUTPUT @Afg_s,":SOUR:FUNC:SHAP USER;";
790 OUTPUT @Afg_s,":SOUR:VOLT:LEV:IMM:AMPL 1.1V"
800 !
810 !Define the waveform segment and download the amplitude points.
820 !Define the output waveform sequence. Select the sequence for
830 !output and place the slave AFG in the Wait-for-arm state.

```

Continued on Next Page

```

840     OUTPUT @Afg_s;"SOUR:LIST1:SEGM:SEL SIN_X"
850     OUTPUT @Afg_s;"SOUR:LIST1:SEGM:DEF 4096"
860     OUTPUT @Afg_s;"SOUR:LIST1:SEGM:VOLT";Waveform(*)
870     !
880     OUTPUT @Afg_s;"SOUR:LIST1:SSEQ:SEL SINX_S"
890     OUTPUT @Afg_s;"SOUR:LIST1:SSEQ:DEF 1"
900     OUTPUT @Afg_s;"SOUR:LIST1:SSEQ:SEQ SIN_X"
910     OUTPUT @Afg_s;"SOUR:FUNC:USER SINX_S"
920     !
930     OUTPUT @Afg_s;"INIT:IMM"
940     SUBEND
950     !
960     SUB Rst
970 Rst: !Subprogram which resets the master and slave AFGs.
980     COM @Afg_m,@Afg_s,Waveform(*)
990     OUTPUT @Afg_m;"*RST;*OPC?" !reset master AFG
1000    ENTER @Afg_m;Complete
1010    !
1020    OUTPUT @Afg_s;"*RST;*OPC?" !reset servant AFG
1030    ENTER @Afg_s;Complete
1040    SUBEND
1050    !
1060    SUB Wf_del
1070 Wf_del: !Subprogram which deletes all sequences and segments.
1080    COM @Afg_m,@Afg_s,Waveform(*)
1090    OUTPUT @Afg_m;"FUNC:USER NONE" !select no sequences
1100    OUTPUT @Afg_m;"LIST:SSEQ:DEL:ALL" !delete all sequences
1110    OUTPUT @Afg_m;"LIST:SEGM:DEL:ALL" !delete all segments
1120    !
1130    OUTPUT @Afg_s;"FUNC:USER NONE" !select no sequences
1140    OUTPUT @Afg_s;"LIST:SSEQ:DEL:ALL" !delete all sequences
1150    OUTPUT @Afg_s;"LIST:SEGM:DEL:ALL" !delete all segments
1160    SUBEND
1170    !
1180    SUB Errmsg
1190 Errmsg: !Subprogram which displays E1445 programming errors
1200    COM @Afg_m,@Afg_s,Waveform(*)
1210    DIM Message$[256]
1220    !Read master AFG status byte register, clear service request bit
1230    B=SPOLL(@Afg_m)
1240    !End of statement if error occurs among coupled commands
1250    OUTPUT @Afg_m;" "
1260    OUTPUT @Afg_m;"ABORT" !abort output waveform
1270    REPEAT
1280        OUTPUT @Afg_m;"SYST:ERR?" !read master AFG error queue
1290        ENTER @Afg_m;Code,Message$
1300        PRINT Code,Message$
1310    UNTIL Code=0
1320    !
1330    !Read servant AFG status byte register, clear service request bit

```

Continued on Next Page

```

1340     B=SPOLL(@Afg_s)
1350     !End of statement if error occurs among coupled commands
1360     OUTPUT @Afg_s;""
1370     OUTPUT @Afg_s;"ABORT"                !abort output waveform
1380     REPEAT
1390         OUTPUT @Afg_s;"SYST:ERR?"        !read servant AFG error queue
1400         ENTER @Afg_s;Code,Message$
1410         PRINT Code,Message$
1420     UNTIL Code=0
1430     STOP
1440 SUBEND

```

Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, LOCKSTEP.FRM, is in directory “VBPROG” and the Visual C example program, LOCKSTEP.C, is in directory “VCPROG” on the CD that came with your HP E1445A.

Using Stop Triggers

The STOPTRIG program shows you how to use stop triggers to abort the remaining cycles of a cycle count (ARM[:START][:LAYer[1]]:COUNT). The program sets up five, 5,000 cycle bursts. Stop triggers are used to abort the burst before all of the 5,000 cycles occurs. An external arm is used to start the bursts. A stop trigger aborts a burst at the end of the current cycle.

The steps of the program are:

1. **Set the (start) trigger source**
TRIGger[:START]:SOURce <source>
2. **Set the stop trigger source**
TRIGger:STOP:SOURce <source>
3. **Set the (external) stop trigger slope**
TRIGger:STOP:SLOPe <edge>
4. **Set the output frequency**
[SOURce:]FREQuency[1][:CW | :FIXed] <frequency>
5. **Set the output function**
[SOURce:]FUNCTion[:SHAPE] <shape>
6. **Set the signal amplitude**
[SOURce:]VOLTage[:LEVel][:IMMEdiate][:AMPLitude] <amplitude>
7. **Set the arm source**
ARM[:START]:LAYer2:SOURce <source>
8. **Set the (external) arm slope**
ARM[:START]:LAYer2:SLOPe <edge>
9. **Set the arm count**
ARM[:START]:LAYer2:COUNt <number>

10. Set the number of waveform cycles

ARM[:START][:LAYer[1]]:COUNT <number>

11. Place the AFG in the wait-for-arm state

INITiate[:IMMEDIATE]

HP BASIC Program Example (STOPTRIG)

```
1  !RE-STORE"STOPTRIG"
2  !This program sets the arm count to 5 and the repetition count to
3  !5,000. A stop trigger applied to the "Stop Trig" BNC connector
4  !aborts the remaining cycles of the current burst. An arm signal
5  !applied to the "Start Arm In" BNC re-arms the AFG which then
6  !outputs the next burst.
7  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 COM @Afg
40 !
50 !Set up error checking
60 ON INTR 7 CALL Errmsg
70 ENABLE INTR 7;2
80 OUTPUT @Afg;"*CLS"
90 OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms
130 CALL Rst
140 CALL Stop_trig
150 WAIT .1 !allow interrupt to be serviced
160 OFF INTR 7
170 END
180 !
190 SUB Stop_trig
200 Stop_trig: !Subprogram which sets up the AFG to output 5, 5,000
210           !cycle bursts. Sets the trigger source to INTernal1,
220           !the stop trigger source to EXTernal, the stop trigger
230           !slope to NEGative. The arm source is also set to
240           !EXTernal.
250           COM @Afg
260           OUTPUT @Afg;"TRIG:STAR:SOUR INT1;";           !trigger source
270           OUTPUT @Afg;" :TRIG:STOP:SOUR EXT;";           !stop trigger source
280           OUTPUT @Afg;" :TRIG:STOP:SLOP NEG;";           !stop trigger slope
290           OUTPUT @Afg;" :SOUR:FREQ1:FIX 100;";           !output frequency
300           OUTPUT @Afg;" :SOUR:FUNC:SHAP SIN;";           !output function
310           OUTPUT @Afg;" :SOUR:VOLT:LEV:IMM:AMPL 5VPP"           !amplitude
320           OUTPUT @Afg;"ARM:STAR:LAY2:SOUR EXT"           !arm source
```

Continued on Next Page

```

330     OUTPUT @Afg;" ARM:STAR:LAY2:SLOP POS"           !arm slope
340     OUTPUT @Afg;" ARM:STAR:LAY2:COUN 5"           !arm count
350     OUTPUT @Afg;" ARM:STAR:LAY1:COUN 5E3"         !repetition count
360     OUTPUT @Afg;"INIT:IMM"                       !wait-for-arm state
370     SUBEND
380     !
390     SUB Rst
400 Rst: !Subprogram which resets the E1445.
410     COM @Afg
420     OUTPUT @Afg;" *RST;*OPC?"                   !reset the AFG
430     ENTER @Afg;Complete
440     SUBEND
450     !
460     SUB Errmsg
470 Errmsg: !Subprogram which displays E1445 programming errors
480     COM @Afg
490     DIM Message$[256]
500     !Read AFG status byte register and clear service request bit
510     B=SPOLL(@Afg)
520     !End of statement if error occurs among coupled commands
530     OUTPUT @Afg;"
540     OUTPUT @Afg;"ABORT"                         !abort output waveform
550     REPEAT
560         OUTPUT @Afg;"SYST:ERR?"                 !read AFG error queue
570         ENTER @Afg;Code,Message$
580         PRINT Code,Message$
590     UNTIL Code=0
600     STOP
610     SUBEND

```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, STOPTRIG.FRM, is in directory "VBPROG" and the Visual C example program, STOPTRIG.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Gating Trigger Signals

Gating is the process of suspending the output waveform. When the gate is active, AFG triggering is suspended. The output remains at the last amplitude point triggered. When the gate is inactive, the output resumes with the next amplitude point.

The gating commands are frequency coupled and are executed relative to other AFG commands as shown in Figure 5-3.

The GATE example shows how to use the AFG's "Gate In" BNC to suspend AFG triggering and thus, generation of the output signal. A high (TTL levels) on the BNC activates the gate.

The steps of program are as follows:

1. **Set the reference oscillator source**
[SOURce:]ROSCillator:SOURce <source>
2. **Set the (start) trigger source**
TRIGger[:STARt]:SOURce <source>
3. **Set the trigger gating source**
TRIGger[:STARt]:GATE:SOURce <source>
4. **Set the gating signal polarity**
TRIGger[:STARt]:GATE:POLarity <polarity>
5. **Enable trigger gating**
TRIGger[:STARt]:GATE:STATe <mode>
6. **Set the output frequency**
[SOURce:]FREQuency[1][:CW | :FIXed] <frequency>
7. **Set the output function**
[SOURce:]FUNCtion[:SHAPE] <shape>
8. **Set the number of waveform points**
[SOURce:]RAMP:POINts <number>
9. **Set the signal amplitude**
[SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude] <amplitude>
10. **Place the AFG in the wait-for-arm state**
INITiate[:IMMediate]

HP BASIC Program Example (GATE)

```
1   !RE-STORE"GATE"
2   !The following program gates the output of a 40 point triangle
3   !wave whose frequency is 1 MHz. When the signal on the "Gate In" BNC
4   !is high, the gate is active and the output is suspended at the last
5   !amplitude point triggered. When the signal is low, the gate is inactive
6   !and the waveform resumes.
7   !
10  !Assign I/O path between the computer and E1445A.
20  ASSIGN @Afg TO 70910
30  COM @Afg
40  !
50  !Set up error checking
60  ON INTR 7 CALL Errmsg
70  ENABLE INTR 7;2
80  OUTPUT @Afg;"*CLS"
90  OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms
130 CALL Rst
140 CALL Tri_wave
150 !
160 WAIT .1 !allow interrupt to be serviced
170 OFF INTR 7
180 END
190 !
200 SUB Tri_wave
210 Tri_wave: !Subprogram which outputs a triangle wave
220   COM @Afg
230   OUTPUT @Afg;"SOUR:ROSC:SOUR INT2;";           !reference oscillator
240   OUTPUT @Afg;" :TRIG:STAR:SOUR INT2;";         !frequency2 generator
250   OUTPUT @Afg;" :TRIG:STAR:GATE:SOUR EXT;";     !gate source
260   OUTPUT @Afg;" :TRIG:STAR:GATE:POL NORM;";     !gate polarity
270   OUTPUT @Afg;" :TRIG:STAR:GATE:STAT ON;";     !enable gate
280   OUTPUT @Afg;" :SOUR:FREQ2:FIX 1E6;";         !frequency
290   OUTPUT @Afg;" :SOUR:FUNC:SHAP TRI;";         !function
300   OUTPUT @Afg;" :SOUR:RAMP:POIN 40;";         !waveform points
310   OUTPUT @Afg;" :SOUR:VOLT:LEV:IMM:AMPL 5V"    !amplitude
320   OUTPUT @Afg;"INIT:IMM"                       !wait-for-arm state
330   SUBEND
340   !
350   SUB Rst
360 Rst: !Subprogram which resets the E1445.
370   COM @Afg
380   OUTPUT @Afg;" *RST;*OPC?                     !reset the AFG
390   ENTER @Afg;Complete
400   SUBEND
410   !
```

Continued on Next Page

```

420   SUB Errmsg
430 Errmsg: !Subprogram which displays E1445 programming errors
440     COM @Afg
450     DIM Message$[256]
460     !Read AFG status byte register and clear service request bit
470     B=SPOLL(@Afg)
480     !End of statement if error occurs among coupled commands
490     OUTPUT @Afg;"
500     OUTPUT @Afg;"ABORT"                !abort output waveform
510     REPEAT
520         OUTPUT @Afg;"SYST:ERR?"        !read AFG error queue
530         ENTER @Afg;Code,Message$
540         PRINT Code,Message$
550     UNTIL Code=0
560     STOP
570   SUBEND

```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, GATE.FRM, is in directory “VBPROG” and the Visual C example program, GATE.C, is in directory “VCPROG” on the CD that came with your HP E1445A.

Arming and Triggering Frequency Sweeps and Lists

Frequency sweeps and lists are started and advanced using the arm and trigger signals described in this section. The commands used to set up the arming and triggering of sweeps and lists are:

```
ARM
:SWEEp|SEQuence3
:COUNT <number>
[:IMMEDIATE]
:LINK <link>
:SOURce <source>

TRIGger
:SWEEp|SEQuence3
[:IMMEDIATE]
:LINK <link>
:SOURce <source>
:TIMer <period>
```

The frequency sweep and frequency list arming and triggering commands are frequency coupled. Thus, they are executed in the sequence shown in the flowchart in Figure 4-1 on page 118.

Frequency Sweeps Using Triggers

The AFG can output frequency sweeps each time it is triggered. However, the maximum sweep time and frequency steps depend on the number of waveform repetitions and the average sweep frequency.

To determine the maximum sweep time ([SOURce:]SWEEp:TIME <number>), divide the number of waveform repetitions to be output (i.e., maximum is 66536) by the average frequency. For example:

START frequency is: 1 kHz
STOP frequency is: 1 MHz

then

$$\text{sweep time} = 66536 / ((1000 + 1000000) / 2) = 66536 / 500,500 = .1329$$

To determine the maximum number of frequency steps (or points) ([SOURce:]SWEEp:POINTS <number>), divide the sweep time by the minimum time between frequency points (i.e., .00125 S). For example, using the above calculated time:

$$.1329 / .00125 = 106 \text{ points}$$

The SWP_TRIG program shows how to output a sweep using a user selected trigger mode.

The steps of this program are:

1. **Set the sweep mode**
[SOURce:]FREQUency[1]:MODE SWEEp
2. **Set the start frequency**
[SOURce:]FREQUency[1]:STARt <start_freq>
3. **Set the stop frequency**
[SOURce:]FREQUency[1]:STOP <stop_freq>
4. **Set the number of sweeps**
[SOURce:]SWEep:COUNT INFinity
5. **Set the number of points in a sweep**
[SOURce:]SWEep:POINts <number>
6. **Set the sweep time**
[SOURce:]SWEep:TIME <number>
7. **Select the source to start a sweep**
ARM:SWEep:SOURce LINK
8. **Set the number of waveform repetitions**
ARM[:STARt]:LAYer[1]:COUNT <number>
9. **Set the number of waveform arm starts**
ARM[:STARt]:LAYer2:COUNT <number>
10. **Select the source to start waveform output**
ARM[:STARt]:LAYer2:SOURce <source>
11. **Set the output function**
[SOURce:]FUNctio[n]:SHAPE <shape>
12. **Set the signal amplitude**
[SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude] <amplitude>
13. **Place the AFG in the wait-for-arm state**
INITiate[:IMMediate]
14. **Trigger the AFG to start a sweep**
use the source selected above in Step 10

HP BASIC Program Example (SWP_TRIG)

```

1  !RE-STORE"SWP_TRIG"
2  !This program triggers a sweep using the Group Execute
3  !Trigger command. The sweep is from 1 kHz to 1 MHz.
4  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 80910.
30 COM @Afg
40 !
50 !Set up error checking
60 ON INTR 8 CALL Errmsg
70 ENABLE INTR 8;2
80 OUTPUT @Afg;"*CLS"
90 OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms
130 CALL Rst
140 CALL Swp_trig
150 !
160 WAIT .1 !allow interrupt to be serviced
170 OFF INTR 8
180 END
190 !
200 SUB Swp_trig
210 Swp_trig: !Subprogram that triggers a sweep
220   COM @Afg
230   OUTPUT @Afg;"SOUR:FREQ1:MODE SWE;";           !Sweep mode
240   OUTPUT @Afg;" :SOUR:FREQ1:STAR 1E3;";         !start frequency
250   OUTPUT @Afg;" :SOUR:FREQ1:STOP 1E6;";         !stop frequency
260   OUTPUT @Afg;" :SOUR:SWE:COUN INF;";           !repetition count
270   OUTPUT @Afg;" :SOUR:SWE:POIN 100;";          !frequency points
280   OUTPUT @Afg;" :SOUR:SWE:TIME .13"            !sweep time
290   OUTPUT @Afg;"ARM:SWE:SOUR LINK"              !trigger mode
300   OUTPUT @Afg;"ARM:STAR:LAY1:COUN 65536"       !waveform repetitions
310   OUTPUT @Afg;"ARM:STAR:LAY2:COUN INF"         !waveform starts
320   OUTPUT @Afg;"ARM:STAR:LAY2:SOUR BUS"        !trigger source
330   OUTPUT @Afg;" :SOUR:FUNC:SHAP SIN;";         !function
340   OUTPUT @Afg;" :SOUR:VOLT:LEV:IMM:AMPL 5 V"   !amplitude
350   OUTPUT @Afg;"INIT:IMM"                       !wait-for-arm state
360   CALL Step
370 SUBEND
380 !
390 SUB Step
400 Step: !Subprogram which starts sweep
410   COM @Afg
420   DISP "Press 'Continue' when ready to start a sweep"
430   PAUSE
440   TRIGGER @Afg                                 !trigger AFG

```

Continued on Next Page


```

450     FOR I=1 TO 10
460         DISP "Wait until sweep completes, then press 'Continue' to start a new sweep"
470         PAUSE
480         TRIGGER @Afg !trigger AFG
490     NEXT I
500     DISP ""
510 SUBEND
520 !
530 SUB Rst
540 Rst: !Subprogram which resets the E1445.
550     COM @Afg
560     OUTPUT @Afg;" *RST;*OPC?                !reset the AFG
570     ENTER @Afg;Complete
580 SUBEND
590 !
600 SUB Errmsg
610 Errmsg: !Subprogram which displays E1445 programming errors
620     COM @Afg
630     DIM Message$(256)
640     !Read AFG status byte register and clear service request bit
650     B=SPOLL(@Afg)
660     !End of statement if error occurs among coupled commands
670     OUTPUT @Afg;"
680     OUTPUT @Afg;"ABORT"                    !abort output waveform
690     REPEAT
700         OUTPUT @Afg;"SYST:ERR?"          !read AFG error queue
710         ENTER @Afg;Code,Message$
720         PRINT Code,Message$
730     UNTIL Code=0
740     STOP
750 SUBEND

```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, SWP_TRIG.FRM, is in directory "VBPROG" and the Visual C example program, SWP_TRIG.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Arming and Triggering a Frequency Sweep

The SWP_STEP program show you how to control the start and advancing of a frequency sweep. The program sets the sweep arm and sweep trigger sources to HOLD. The AFG is armed, and advances to the next frequency in the sweep using the ARM:SWEep[:IMMEDIATE] and TRIGger:SWEep[:IMMEDIATE] commands respectively.

Using the flowchart in Figure 4-1 on page 118 as a guide, the steps of the program are:

1. **Select the frequency generator that allows frequency sweeping**
TRIGger[:START]:SOURce <source>
2. **Select the frequency sweep mode**
[SOURce:]FREQuency[1]:MODE <mode>
3. **Set the start frequency**
[SOURce:]FREQuency[1]:STARt <start_freq>
4. **Set the stop frequency**
[SOURce:]FREQuency[1]:STOP <stop_freq>
5. **Set the number of points (frequencies) in the frequency sweep**
[SOURce:]SWEep:POINts <number>
6. **Set the source which starts the frequency sweep**
ARM:SWEep:SOURce <source>
7. **Set the source which advances the sweep to the next frequency**
TRIGger:SWEep:SOURce <source>
8. **Set the output function**
[SOURce:]FUNCTion[:SHAPE] <shape>
9. **Set the signal amplitude**
[SOURce:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude] <amplitude>
10. **Place the AFG in the wait-for-arm state**
INITiate[:IMMEDIATE]

HP BASIC Program Example (SWP_STEP)

```
1  !RE-STORE"SWP_STEP"
2  !This program sets the AFG arm source and trigger source to
3  !HOLD. The AFG is armed and advanced through the sweep points
4  !using "arm immediate" and "trigger immediate" commands.
5  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 COM @Afg,Pts
40 !
50 !Set up error checking
60 ON INTR 7 CALL Errmsg
70 ENABLE INTR 7;2
80 OUTPUT @Afg;"*CLS"
90 OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms
130 CALL Rst
140 CALL Swp_step
150 !
160 WAIT .1 !allow interrupt to be serviced
170 OFF INTR 7
180 END
190 !
200 SUB Swp_step
210 Swp_step: !Subprogram which sets up a sweep from 1 kHz to 10 kHz
220           !which is armed and advanced on "IMMediate" command.
230     COM @Afg,Pts
240     OUTPUT @Afg;"TRIG:STAR:SOUR INT1;";           !DDS time base
250     OUTPUT @Afg;":SOUR:FREQ1:MODE SWE;";         !sweep mode
260     OUTPUT @Afg;":SOUR:FREQ1:STAR 1E3;";         !start frequency
270     OUTPUT @Afg;":SOUR:FREQ1:STOP 10E3;";       !stop frequency
280     OUTPUT @Afg;":SOUR:SWE:POIN 10;";           !frequency points
290     OUTPUT @Afg;":ARM:SWE:SOUR HOLD;";          !suspend sweep arm
300     OUTPUT @Afg;":TRIG:SWE:SOUR HOLD;";        !suspend sweep trigger
310     OUTPUT @Afg;":SOUR:FUNC:SHAP SIN;";         !function
320     OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL 5 V"    !amplitude
330     OUTPUT @Afg;"INIT:IMM"                       !wait-for-arm state
340     CALL Step
350 SUBEND
360 !
370 SUB Step
380 Step: !Subprogram which starts and advances sweep
390     COM @Afg,Pts
400     DISP "Press 'Continue' to arm trigger system"
410     PAUSE
420     OUTPUT @Afg;"ARM:SWE:IMM"                    !start sweep (sweep does not advance)
430     OUTPUT @Afg;"SOUR:SWE:POIN?"                !query number of waveform points
```

Continued on Next Page

```

440     ENTER @Afg;Pts
450     FOR I=1 TO (Pts-1)
460         DISP "Press 'Continue' to advance to next frequency"
470         PAUSE
480         OUTPUT @Afg;"TRIG:SWE:IMM"           !step to next frequency
490     NEXT I
500     DISP ""
510 SUBEND
520 !
530 SUB Rst
540 Rst: !Subprogram which resets the E1445.
550     COM @Afg;Pts
560     OUTPUT @Afg;" *RST;*OPC?"           !reset the AFG
570     ENTER @Afg;Complete
580 SUBEND
590 !
600 SUB Errmsg
610 Errmsg: !Subprogram which displays E1445 programming errors
620     COM @Afg;Pts
630     DIM Message$(256)
640     !Read AFG status byte register and clear service request bit
650     B=SPOLL(@Afg)
660     !End of statement if error occurs among coupled commands
670     OUTPUT @Afg;""
680     OUTPUT @Afg;"ABORT"                 !abort output waveform
690     REPEAT
700         OUTPUT @Afg;"SYST:ERR?"         !read AFG error queue
710         ENTER @Afg;Code,Message$
720         PRINT Code,Message$
730     UNTIL Code=0
740     STOP
750 SUBEND

```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, SWP_STEP.FRM, is in directory "VBPROG" and the Visual C example program, SWP_STEP.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Arming and Triggering a Frequency List

Frequency lists are started and advanced using the same arming and triggering commands used for sweeps. The LIST_STP program sets the arm and list advance sources to BUS. Thus, the AFG is armed and advanced through the frequency list using the HP-IB group execute trigger command TRIGGER 7.

Using the flowchart in Figure 4-1 on page 118 as a guide, the steps of this program are:

1. **Select the frequency generator which allows frequency lists (hopping)**
TRIGger[:STARt]:SOURce <source>
2. **Select the frequency list mode**
[SOURce:]FREQuency[1]:MODE <mode>
3. **Set the frequency list**
[SOURce:]LIST[2]:FREQuency <freq_list>
4. **Set the source which starts the frequency list**
ARM:SWEp:SOURce <source>
5. **Set the source which advances the list to the next frequency**
TRIGger:SWEp:SOURce <source>
6. **Set the output function**
[SOURce:]FUNCtion[:SHAPE] <shape>
7. **Set the signal amplitude**
[SOURce:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude] <amplitude>
8. **Place the AFG in the wait-for-arm state**
INITiate[:IMMEDIATE]

HP BASIC Program Example (LIST_STP)

```
1   !RE-STORE"LIST_STP"
2   !The following program configures the AFG to step through a
3   !frequency list when an HP-IB group execute trigger is received.
4   !
10  !Assign I/O path between the computer and E1445A.
20  ASSIGN @Afg TO 70910
30  COM @Afg,Pts
40  !
50  !Set up error checking
60  ON INTR 7 CALL Errmsg
70  ENABLE INTR 7;2
80  OUTPUT @Afg;"*CLS"
90  OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms
130 CALL Rst
140 CALL List_stp
150 !
160 WAIT .1 !allow interrupt to be serviced
170 OFF INTR 7
180 END
190 !
200 SUB List_stp
210 List_stp: !Subprogram which sets up a frequency list which is armed
220           !and advanced with HP-IB group execute triggers (TRIGGER 7).
230   COM @Afg,Pts
240   OUTPUT @Afg;"TRIG:STAR:SOUR INT1;";           !DDS time base
250   OUTPUT @Afg;":SOUR:FREQ1:MODE LIST;";         !frequency list mode
260   OUTPUT @Afg;":SOUR:LIST2:FREQ 10E3,20E3,30E3,40E3,50E3;"; !freq list
270   OUTPUT @Afg;":ARM:SWE:SOUR BUS;";             !arm on HP-IB trigger
280   OUTPUT @Afg;":TRIG:SWE:SOUR BUS;";           !advance on HP-IB trigger
290   OUTPUT @Afg;":SOUR:FUNC:SHAP SQU;";         !function
300   OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL 1 V"     !amplitude
310   OUTPUT @Afg;"INIT:IMM"                       !wait-for-arm state (10 kHz is output)
320   WAIT .1 !wait in case of error
330   CALL Step
340 SUBEND
350 !
360 SUB Step
370 Step: !Subprogram which starts and advances frequency list
380   COM @Afg,Pts
390   DISP "Press 'Continue' to arm trigger system"
400   PAUSE
410   TRIGGER 7                                     !start frequency list (10 kHz is still output)
420   FOR I=1 TO 4                                  !Triggers for the four remaining frequencies
430     DISP "Press 'Continue' to advance to next frequency"
440     PAUSE
```

Continued on Next Page

```

450      TRIGGER 7                               !advance to next frequency
460      NEXT I
470      DISP ""
480      SUBEND
490      !
500      SUB Rst
510 Rst: !Subprogram which resets the E1445.
520      COM @Afg,Pts
530      OUTPUT @Afg;" *RST;*OPC?               !reset the AFG
540      ENTER @Afg;Complete
550      SUBEND
560      !
570      SUB Errmsg
580 Errmsg: !Subprogram which displays E1445 programming errors
590      COM @Afg,Pts
600      DIM Message$[256]
610      !Read AFG status byte register and clear service request bit
620      B=SPOLL(@Afg)
630      !End of statement if error occurs among coupled commands
640      OUTPUT @Afg;"
650      OUTPUT @Afg;"ABORT"                     !abort output waveform
660      REPEAT
670          OUTPUT @Afg;"SYST:ERR?"           !read AFG error queue
680          ENTER @Afg;Code,Message$
690          PRINT Code,Message$
700      UNTIL Code=0
710      STOP
720      SUBEND

```

**Visual BASIC and
Visual C/C++ Program
Versions**

The Visual BASIC example program, LIST_STP.FRM, is in directory "VBPROG" and the Visual C example program, LIST_STP.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Aborting Waveforms

Aborting a waveform places the AFG in the Idle state (Figure 5-4). The waveform is halted and the output remains at the last amplitude point triggered when the abort was executed. The command which aborts a waveform is:

ABORt

Using ABORt, Stop Triggers, or Gating

Figure 5-4 compares the effects of aborting a waveform, or using stop triggers or gating to stop or suspend the output.

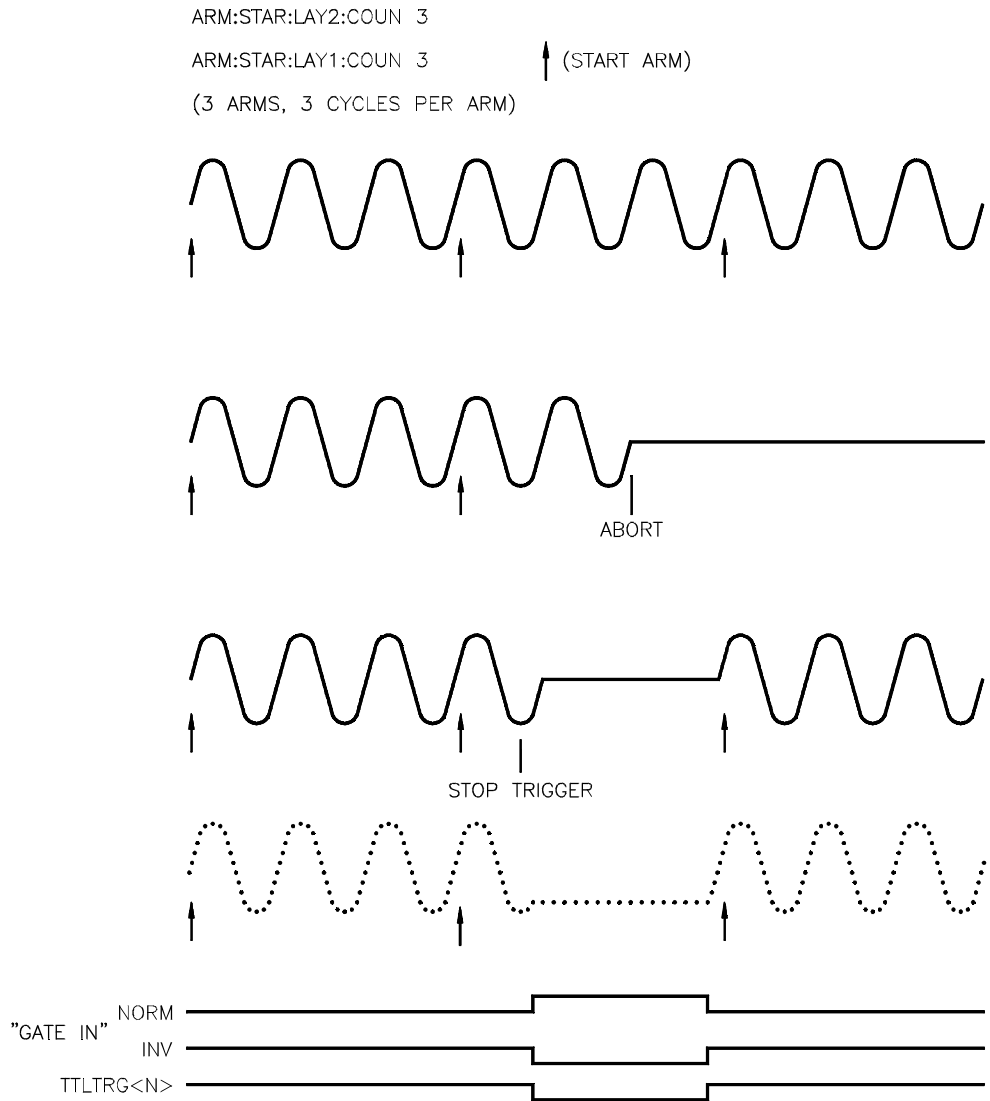


Figure 5-4. Effects of ABORt, Stop Triggers, and Gating

Arming and Triggering Program Comments

The following information is associated with arming and triggering the AFG. Included are details on the operation of the AFG's arming and triggering functions, and on the various modes, ranges, etc., used in the programs in this chapter.

Reference Oscillator Sources

There are five reference oscillator sources for the AFG which are selected by the [SOURCE:]ROSCillator:SOURCE command:

- **CLK10** – The VXIbus CLK10 (10 MHz) line.
- **EXTERNAL** – The AFG's front panel "Ref/Smpl In" BNC (TTL levels).
- **ECLTrg0 or 1** – The VXIbus ECL trigger lines.
- **INTERNAL[1]** – The internal 42.94967296 MHz oscillator (default source).
- **INTERNAL2** – The internal 40 MHz oscillator.

The INTERNAL[1] reference oscillator is recommended for use with the Direct-Digital-Synthesis (DDS) time base ([SOURCE:]FREQUENCY[1] subsystem) for high resolution and frequency range. The INTERNAL2 reference oscillator is recommended for use with the divide-by-n time base ([SOURCE:]FREQUENCY2 subsystem) to produce exact frequencies such as 10 MHz, 20 MHz, etc.,.

AFG Frequency Synthesis Modes

When outputting a fixed (continuous) frequency signal, the DDS time base ([SOURCE:]FREQUENCY[1]) or the divide-by-N time base ([SOURCE:]FREQUENCY2) are the most often used. In addition to these time bases, other sources which can be selected with the TRIGGER[:START]:SOURCE command are:

- **BUS** (the HP-IB Group Execute Trigger (GET command) or the IEEE-488.2 *TRG common command)
- **ECLTrg0 or ECLTrg1** (the VXIbus ECL trigger lines)
- **EXTERNAL** (the AFG's front panel "Ref/Smpl In" BNC)
- **HOLD** (suspends sample generation)
- **INTERNAL[1]** (the [SOURCE:]FREQUENCY[1] subsystem DDS frequency synthesis)
- **INTERNAL2** (the [SOURCE:]FREQUENCY2 subsystem Divide-by-n frequency synthesis)
- **TTLTrg0 through 7** (the VXIbus TTL trigger lines)

In programs where the time base (trigger source) is not specified, the default DDS time base ([SOURCE:]FREQUENCY[1]) is used.

Note Direct frequency control (that is, the [SOURCE:]FREQUENCY commands) is only available with the INTERNAL1 and INTERNAL2 time base sources. For all other sources, the output frequency depends upon the frequency of the time base source. [SOURCE:]FREQUENCY commands will be accepted with other time base sources, but become effective when the source is changed to INTERNAL1 or INTERNAL2.

Divide-by-N Frequency Synthesis Fixed frequency (continuous) waveforms are the only signals allowed by the Divide-by-N frequency synthesis method ([SOURCE:]FREQUENCY2 subsystem). **All waveforms except standard function sine waves can be output using Divide-by-N frequency synthesis.**

AFG Frequency Modes There are four frequency “modes” available using the DDS time base ([SOURCE:]FREQUENCY[1]). The modes selected by the [SOURCE:]FREQUENCY[1]:MODE command are:

- **CW | FIXed** – single frequency mode.
- **FSKey** – frequency shift keying mode
- **LIST** – frequency list mode
- **SWEep** – frequency sweep mode

CW or **FIXed** is the default mode but is specified in many of the programs to emphasize that the arm source specified by ARM[:START]:LAYER2:SOURCE <source> is for fixed (continuous) frequency waveforms.

Frequency Sweeping and Lists Frequency sweeping and frequency lists are only available using the DDS time base. When setting the frequency mode, SWEep must be selected for frequency sweeps and LIST must be selected for frequency lists.

AFG Arming Sources

The arming sources set by the `ARM[:START]:LAYer2:SOURce <source>` command are:

- **BUS** – The HP-IB Group Execute Trigger (GET) command or the IEEE-488.2 *TRG common command.
- **ECLTrg0 and ECLTrg1** – The VXIbus ECL trigger lines.
- **EXternal** – The HP E1445A's front panel "Start Arm In" BNC connector (TTL levels).
- **HOLD** – Suspend arming. Use the `ARM:START:LAYer2:IMMediate` command to start the waveform.
- **IMMediate** – Immediate arming. An arm is internally generated two to three reference oscillator cycles after the start trigger sequence enters the wait-for-arm state.
- **TTLTrg0 through TTLTrg7** – The VXIbus TTL trigger lines.

AFG Arm Count

The arm count specifies the number of arms the AFG is to receive before it returns to the Idle state. The arm count is set with the `ARM[:START]:LAYer2:COUNT` command. The range is 1 through 65535, or INFINITY. The default value is 1.

Waveform Repetition Count

The waveform repetition (cycle) count specifies the number of cycles per arm. The cycle count is specified with the `ARM[:START][:LAYer[1]]:COUNT <number>` command. The range for the cycle count is 1 through 65536, or INFINITY. The default value is INFINITY.

Stop Trigger Sources

Stop triggers abort the waveform cycle (repetition) count at the end of the current cycle. The stop trigger sources set with the `TRIGger:STOP:SOURce` command are:

- **BUS** – The HP-IB Group Execute Trigger (GET) command or the IEEE-488.2 *TRG common command.
- **EXternal** – The AFG's front panel "Stop Trigger/FSK/Gate In" BNC connector (TTL levels).
- **HOLD** – Suspend stop triggering. Use the `TRIGger:STOP:IMMediate` command to terminate a start arm cycle (default source).
- **TTLTrg0 through TTLTrg7** – The VXIbus TTL trigger lines.

External Stop Trigger Slope

An external stop trigger signal is applied to the AFG's "Stop Trig/FSK/Gate In" BNC connector. The edge of the signal on which the AFG is triggered is set with the TRIGger:STOP:SLOPe command. The edges are:

- **POSitive** – Selects the rising edge of the signal.
- **NEGative** – Selects the falling edge of the signal.

AFG Gating Sources

The source which gates the triggers is specified with the TRIGger[:START]:GATE:SOURce command. The available sources are:

- **EXTernal** – The HP E1445A's front panel "Stop Trig/FSK/Gate In" BNC connector (default source). This BNC is driven by TTL levels.
- **TTLTrg0 through TTLTrg7** – The VXIbus TTL trigger lines.

AFG Gate Polarity

The polarity of the signal which gates the output is specified with the TRIGger[:START]:GATE:POLarity command. The polarities which can be selected are:

- **NORMal** – Selects an "active high" gate. When the gate signal is high, the gate is active and the output is suspended at the last amplitude point triggered. When the gate is low (inactive), the output resumes with the next point.
- **INVerted** – Selects an "active low" gate (default polarity). When the gate signal is low, the gate is active and the output is suspended at the last amplitude point triggered. When the gate is high (inactive), the output resumes with the next point.

The gate polarity applies only to the EXTernal gate source (front panel "Gate In" BNC). If you are using a TTLTrg0 through TTLTrg7 trigger line as a gating source, the gate is always "active low".

Gating and Signal Phase

Gating the triggers suspends the output at the last amplitude point triggered. When the gate is inactive, the waveform resumes with the next amplitude point. Thus, the phase of the signal remains continuous.

Enabling the Gate

Before the AFG triggers can be gated, the gate must be enabled. This is done with the TRIGger[:START]:GATE:STATe command. When the mode is ON, gating is enabled. When OFF, gating is disabled.

Frequency Sweep/ List Arming

The source which arms the frequency sweep or list is set with the ARM:SWEep:SOURce command. The available sources are:

- **BUS** – The HP-IB Group Execute Trigger (GET) command or the IEEE-488.2 *TRG common command.
- **HOLD** – Suspend sweep or frequency list arming. Arm using ARM:SWEep[:IMMediate].
- **IMMediate** – Immediate sweep or frequency list arming. If the sweep or frequency list advance trigger (TRIGger:SWEep:SOURce) is set to TIMer, the sweep or list starts when the first start arm is received. If the sweep or frequency list advance source is set to any other source, the sweep or list starts when INITiate[:IMMediate] is executed.
- **LINK** – The next valid start arm starts the sweep or frequency list.
- **TTLTrg0 through TTLTrg7** – The VXIbus TTL trigger lines.

After the AFG is armed, the first frequency in the sweep or list is output. Trigger signals output the remaining frequencies.

Frequency Sweep/ List Advance Trigger

The source which advances the sweep or frequency list to the next frequency is set with the TRIGger:SWEep:SOURce command. The available sources are:

- **BUS** – The HP-IB Group Execute Trigger (GET) command or the IEEE-488.2 *TRG common command.
- **HOLD** – Suspend sweep or frequency list advance triggering. Advance to the next frequency using TRIGger:SWEep:IMMediate.
- **LINK** – The next valid start arm advances the sweep or frequency list.
- **TIMer** – The SOURce:SWEep:TIME and TRIGger:SWEep:TIMer commands control the sweep and frequency list advance timing (default source).
- **TTLTrg0 through TTLTrg7** – The VXIbus TTL trigger lines.

Placing the AFG in the wait-for-arm state (INITiate[:IMMediate]) puts the first frequency in the sweep or list at the output. Trigger signals output the remaining frequencies. Thus, for multiple sweeps or passes through the frequency list, n-1 triggers are required for the first pass and n triggers are required for all subsequent passes (n = number of points = number of triggers).

Immediate Arming and Triggering

When the sweep and frequency list arming and triggering sources are set to HOLD, the starting frequency is output when the AFG is set to the wait-for-arm state (INITiate[:IMMediate]). Once the sweep or frequency list arm is received ARM:SWEep[:IMMediate], the sweep or list can be advanced when a sweep or list advance trigger (TRIGger:SWEep:IMMediate) is received.

Notes

Chapter 6

Marker Outputs/Multiple AFG Operations

Chapter Contents

This chapter shows how to generate the different signals at the front panel's "Marker Out" BNC and how to select the ECL trigger lines. Use these signals and trigger lines to synchronize multiple AFGs, generate trigger pulses, etc. The sections are as follows:

- Marker Pulse Enable Flowchart Page 204
- Available Marker Sources Page 205
- Arbitrary Generated Marker Pulses Page 206
 - Generating Marker Pulses for Arbitrary Waveforms Page 206
 - Generating Multiple Marker Pulses in Multiple Segment Lists Page 207
 - Generating Single Marker Pulses in Single Waveform Segments Page 212
- Generating Marker Pulses for Each Waveform Point Page 214
- Operating Multiple AFGs Together. Page 218
- Marker Program Comments. Page 222
 - Determining the Number of Marker Points of a Waveform Segment Page 222
 - Determining the Number of Marker Points of a Segment Sequence Page 222

Marker Pulse Enable Flowchart

The flowchart in Figure 6-1 shows how to select and output the different marker pulses at the front panel “Marker Out” BNC and the ECL trigger lines. Remove the flowchart from the binder for easy accessibility. Refer to the flowchart while doing the examples in this chapter, if desired.

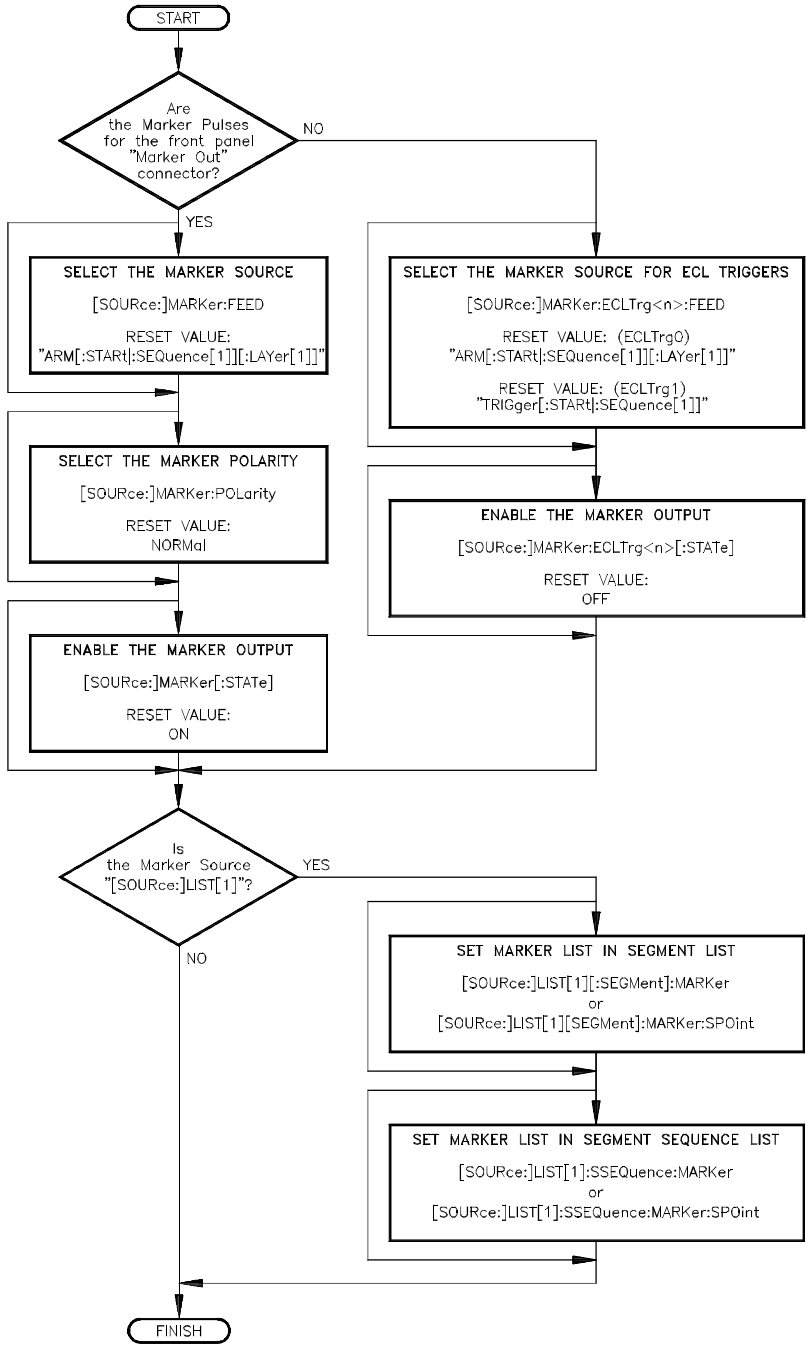


Figure 6-1. Commands for Marker Pulses

Available Marker Sources

There are six marker sources available for output at the AFG's front panel "Marker Out" BNC and the ECL Trigger Lines. Use the [SOURCE:]MARKer:FEED <source> command to select the "Marker Out" BNC; use [SOURCE:]MARKer:ECLTrg<n>:FEED <source> command to select the ECL trigger lines.

The sources for the "Marker Out" BNC, not the ECL trigger lines, can output the marker pulses as either active high (NORMAL) or active low (INVERTed). Use the [SOURCE:]MARKer:POLarity <polarity> command to select the polarity.

The different marker sources are as follows:

ARM[:START]:SEQUence[1][:LAYer[1]]

For arbitrary waveforms, the marker level changes with the first point on the waveform of the first waveform repetition. The source then outputs a marker pulse at the last waveform point of each repetition. For SINUsoid outputs, the marker is a 50% duty cycle square wave at the waveform frequency.

ARM[:START]:SEQUence[1]:LAYer2

The AFG asserts a marker when triggering the first amplitude point after receiving a start arm. The AFG unasserts a marker with the last amplitude point of the last waveform repetition, or following an ABORT.

[SOURCE:]FREQUency[1]:CHANge

The source outputs a one sample period wide marker pulse after a frequency change occurs. This shows that the steady state frequency was reached.

[SOURCE:]LIST[1]

The source outputs marker pulses specified by the [SOURCE:]LIST[1]:SEGMENT:MARKer and [SOURCE:]LIST[1]:SSEQUence:MARKer commands. Increase the pulse size by selecting marker output for consecutive points on the waveform. Can only be used with arbitrary waveforms (see Chapters 3 and 7 on how to generate arbitrary waveforms).

[SOURCE:]PM:DEViation:CHANge

This source outputs a one sample period wide marker pulse after a phase change occurs. This shows that the new phase was reached.

[SOURce:]ROSCillator

The source outputs the reference oscillator selected by [SOURce:]ROSCillator:SOURce.

TRIGger[:START]:SEQuence[1]

The source outputs a nominal 12 nS marker pulse for each point of a waveform segment.

Arbitrary Generated Marker Pulses

To generate marker pulses for arbitrary waveforms, do the following:

- Select the “[SOURce:]LIST[1]” source for the front panel “Marker Out” BNC connector using [SOURce:]MARKer:FEED “[SOURce:]LIST[1]”.
- Select the marker pulse polarity using [SOURce:]MARKer:POLarity <polarity>.
- Enable the AFG to output a marker list using [SOURce:]MARKer:STATe <mode>.
- Define a marker list in a waveform segment using [SOURce:]LIST[1]:SEGMENT:MARKer <marker_list> or [SOURce:]LIST[1]:SEGMENT:MARKer:SPOint <point>.
- Enable the waveform segment in a segment sequence to output the marker list using [SOURce:]LIST[1]:SSEQUENCE:MARKer <marker_list> or [SOURce:]LIST[1]:SSEQUENCE:MARKer:SPOint <point>.

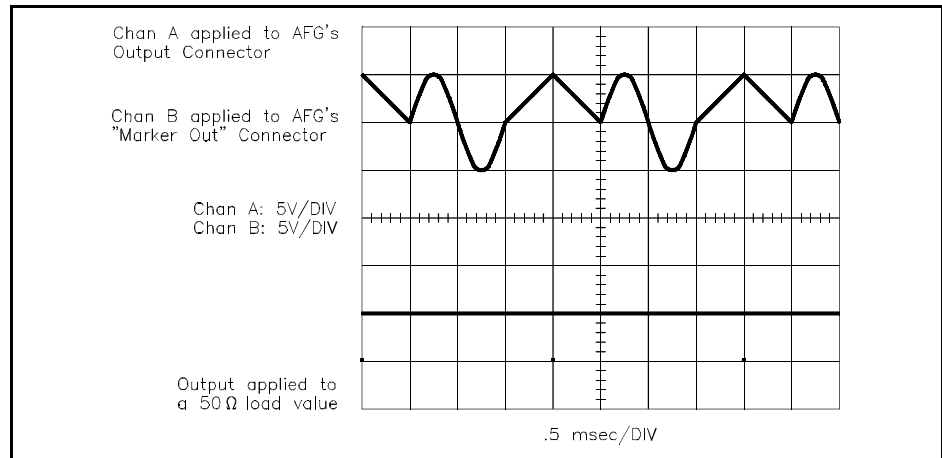
Generating Marker Pulses for Arbitrary Waveforms

The following programs show how to generate the marker pulses using two different methods. The two methods are:

1. [SOURce:]LIST[1]:SEGMENT:MARKer defines for each point in a waveform segment where a marker is to be output. Likewise, [SOURce:]LIST[1]:SSEQUENCE:MARKer enables (or disables) marker outputs for each waveform segment in a segment sequence.
2. [SOURce:]LIST[1]:SEGMENT:MARKer:SPOint defines a single segment or point in a waveform segment where the marker pulse is to be output. Likewise, [SOURce:]LIST[1]:SSEQUENCE:MARKer:SPOint enables a marker output for a single waveform segment in a segment sequence.

Generating Multiple Marker Pulses in Multiple Segment Lists

The MARKSEG1 program shows how to generate marker pulses using [SOURCE:]LIST[1]:SEGMENT:MARKER and [SOURCE:]LIST[1]:SEQUENCE:MARKER. The program generates a sine wave and triangle wave. It generates a 10 points wide active low marker pulses starting at the center of the triangle waveform. The program generates a 512 point, 5 V sine wave and 5 V triangle wave.



The commands are:

- 1. Reset the AFG**
*RST
- 2. Clear the AFG Memory of All Sequence and Segment Data**
[SOURCE:]LIST[1]:SEQUENCE:DELETE:ALL
[SOURCE:]LIST[1]:SEGMENT:DELETE:ALL
- 3. Setup the AFG for Output**
[SOURCE:]FREQUENCY[1]:CW | :FIXed] <frequency>
[SOURCE:]FUNCTION[:SHAPE] USER
[SOURCE:]VOLTAGE[:LEVEL][:IMMEDIATE][:AMPLITUDE] <amplitude>
- 4. Select the Marker Source**
[SOURCE:]MARKER:FEED "[SOURCE:]LIST[1]"
This command selects the marker source for the front panel's "Marker Out" connector to output marker pulses generated by arbitrary waveforms. (See "Available Marker Sources" on page 205 for the different sources.)
- 5. Select the Marker Polarity**
[SOURCE:]MARKER:POLARITY <polarity>
NORMAL <polarity> selects active high marker pulses;
INVERTED selects active low marker pulses.

6. Enable Marker Outputs

[SOURce:]MARKer[:STATe] ON

This command enables the AFG to output marker pulses. However, before the marker pulses can be output, they must be selected in the waveform segment and the waveform segment must be selected for marker output in the segment sequence. (Although *RST automatically enables the AFG for marker outputs, it is given here for good programming practice.)

7. Setup the First Waveform Segment

[SOURce:]LIST[1][:SEGment]:SElect <name>

[SOURce:]LIST[1][:SEGment]:DEFine <length>

8. Store the First Waveform Segment as Voltage Data Points

[SOURce:]LIST[1][:SEGment]:VOLTage <voltage_list>

9. Setup the Second Waveform Segment

[SOURce:]LIST[1][:SEGment]:SElect <name>

[SOURce:]LIST[1][:SEGment]:DEFine <length>

10. Store the Second Waveform Segment as Voltage Data Points

[SOURce:]LIST[1][:SEGment]:VOLTage <voltage_list>

11. Store the Marker List for the Second Waveform Segment

[SOURce:]LIST[1][:SEGment]:MARKer <marker_list>

This command stores the marker list into memory as a comma (“,”) separated list. A “1” selects a marker pulse and a “0” does not. (You can also send this list as Definite or Indefinite Length Arbitrary Block Data, as explained in Chapter 7.)

12. Setup the Segment Sequence

[SOURce:]LIST[1]:SSEquence:SElect <name>

[SOURce:]LIST[1]:SSEquence:DEFine <length>

[SOURce:]LIST[1]:SSEquence:SEquence <segment_list>

13. Select the Waveform Segment for Marker Output

[SOURce:]LIST[1]:SSEquence:MARKer <marker_list>

This command selects the waveform segment in a segment sequence that is to output the marker pulses. The marker pulses must be selected by

[SOURce:]LIST[1][:SEGment]:MARKer <marker_list> or

[SOURce:]LIST[1][:SEGment]:MARKer:SPOint <point> before they are output.

14. Generate the Output

[SOURce:]FUNCTION:USER <name>

INITiate[:IMMEDIATE]

HP BASIC Program Example (MARKSEG1)

```
1   !RE-STORE"MARKSEG1"
2   !This program computes a sine wave and a triangle wave as arbitrary
3   !waveforms. A corresponding marker list is defined for the triangle
4   !wave. The program sets the output sequence to consist of both
5   !waveforms, and enables marker pulses to be output with selected
6   !triangle waveform amplitude points.
7!
10  !Assign I/O path between the computer and E1445A.
20  ASSIGN @Afg TO 70910
30  COM @Afg
40  !
50  !Set up error checking
60  ON INTR 7 CALL Errmsg
70  ENABLE INTR 7;2
80  OUTPUT @Afg;"*CLS"
90  OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms which reset the AFG and delete all existing
130 !waveform segments and sequences.
140 CALL Rst
150 CALL Wf_del
160 !
170 !Set up the AFG
180 OUTPUT @Afg;"SOUR:FREQ1:FIX 512E3;";           !frequency
190 OUTPUT @Afg;":SOUR:FUNC:SHAP USER;";         !function
200 OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL 5.1V"    !amplitude
210 OUTPUT @Afg;"SOUR:MARK:FEED ""SOUR:LIST1""    !marker source
220 OUTPUT @Afg;"SOUR:MARK:POL INV"              !marker polarity
230 OUTPUT @Afg;"SOUR:MARK:STAT ON"              !enable marker
240 !
250 CALL Sine_wave
260 CALL Tri_wave
270 CALL Seq_list
280 !
290 OUTPUT @Afg;"SOUR:FUNC:USER WAVE_OUT"         !waveform sequence
300 OUTPUT @Afg;"INIT:IMM"                       !wait-for-arm state
310 !
320 WAIT .1 !allow interrupt to be serviced
330 OFF INTR 7
340 END
350 !
360 SUB Sine_wave
370 Sine_wave: !Subprogram which computes a sine wave.
380   COM @Afg
390   DIM Waveform(1:512)                         !Calculate sine wave
400   FOR I=1 TO 512
410     Waveform(I)=5.*(SIN(2.*PI*(I/512.)))
```

Continued on Next Page

```

420     NEXT I
430     !
440     OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL SINE"           !segment name
450     OUTPUT @Afg;" SOUR:LIST1:SEGM:DEF 512"         !segment size
460     OUTPUT @Afg;"SOUR:LIST1:SEGM:VOLT ";Waveform(*) !amplitude points
470 SUBEND
480     !
490 SUB Tri_wave
500 Tri_wave: !Subprogram which computes a triangle wave and marker list.
510     COM @Afg
520     DIM Waveform(1:512),Marker_list(1:512)
530     FOR I=1 TO 256                                     !Calculate triangle wave
540         Waveform(I)=*.0195313
550     NEXT I
560     FOR I=257 TO 512
570         Waveform(I)=(512-I)*.0195313
580     NEXT I
590     !
600     FOR I=256 TO 266                                     !Define marker list
610         Marker_list(I)=1
620     NEXT I
630     !
640     !Load waveform points and marker list
650     OUTPUT @Afg;"SOUR:MARK:FEED ""SOUR:LIST1""      !markers at fp BNC
660     OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL TRI"          !segment name
670     OUTPUT @Afg;" SOUR:LIST1:SEGM:DEF 512"         !segment size
680     OUTPUT @Afg;"SOUR:LIST1:SEGM:VOLT ";Waveform(*) !amplitude points
690     OUTPUT @Afg;"SOUR:LIST1:SEGM:MARK ";Marker_list(*) !marker list
700 SUBEND
710     !
720 SUB Seq_list
730 Seq_list: !This subprogram defines the sequence list and enables
740     !marker signals to be output with the triangle wave
750     !segment.
760     COM @Afg
770     OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL WAVE_OUT"     !sequence name
780     OUTPUT @Afg;"SOUR:LIST1:SSEQ:DEF 2"           !number of segments
790     OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEQ SINE,TRI"     !segments in sequence
800     OUTPUT @Afg;"SOUR:LIST1:SSEQ:MARK 0,1"        !enable marker on segment TRI
810 SUBEND
820     !
830 SUB Rst
840 Rst: !Subprogram which resets the E1445.
850     COM @Afg
860     OUTPUT @Afg;"*RST;*OPC?"                       !reset the AFG
870     ENTER @Afg;Complete
880 SUBEND
890     !
900 SUB Wf_del

```

Continued on Next Page

```

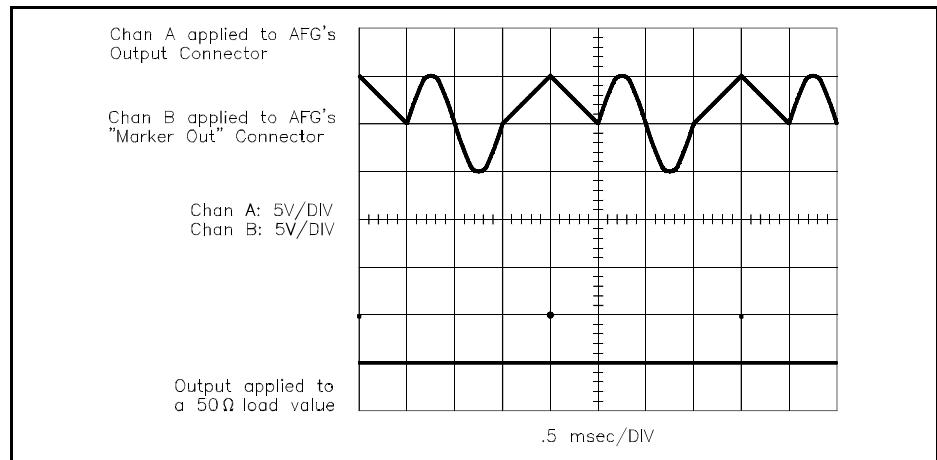
910 Wf_del: !Subprogram which deletes all sequences and segments.
920     COM @Afg
930     OUTPUT @Afg;"FUNC:USER NONE"           !select no sequences
940     OUTPUT @Afg;"LIST:SSEQ:DEL:ALL"       !Clear sequence memory
950     OUTPUT @Afg;"LIST:SEGM:DEL:ALL"      !Clear segment memory
960 SUBEND
970 !
980 SUB Errmsg
990 Errmsg:!Subprogram which displays E1445 programming errors
1000    COM @Afg,Seg_mem$,Seq_mem$
1010    DIM Message$(256)
1020    !Read AFG status byte register and clear service request bit
1030    B=SPOLL(@Afg)
1040    !End of statement if error occurs among coupled commands
1050    OUTPUT @Afg;" "
1060    OUTPUT @Afg;"ABORT"                   !abort output waveform
1070    REPEAT
1080        OUTPUT @Afg;"SYST:ERR?"           !read AFG error queue
1090        ENTER @Afg;Code,Message$
1100        PRINT Code,Message$
1110    UNTIL Code=0
1120    STOP
1130 SUBEND

```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, MARKSEG1.FRM, is in directory "VBPROG" and the Visual C example program, MARKSEG1.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Generating Single Marker Pulses in Single Waveform Segments

The MARKSEG2 program shows how to generate marker pulses using [SOURCE:]LIST[1]:SEGMENT:MARKER:SPOINT and [SOURCE:]LIST[1]:SSEQUENCE:MARKER:SPOINT. The program generates a sine wave and triangle wave. It outputs Active high marker pulse at the center of the triangle waveform. The program generates a 512 point, 5 V sine wave and 5 V triangle wave.



The commands are the same ones listed in “Generating Multiple Marker Pulses in Multiple Waveform Segment Lists” on page 207, except they only select single point-wide marker pulses. The exceptions are as follows:

10. **Store the Marker Pulse Location for the Second Waveform Segment**
 [SOURCE:]LIST[1]:SEGMENT:MARKER:SPOINT *<point>*
 This command selects the segment or point on a waveform where the marker pulse is to be output. For example, to output a marker pulse at point 5 of a 10 point waveform, execute
 [SOURCE:]LIST[1]:SEGMENT:MARKER:SPOINT 5.

12. **Select the Waveform Segment for Marker Output**
 [SOURCE:]LIST[1]:SSEQUENCE:MARKER:SPOINT *<point>*
 This command selects the waveform segment in a segment sequence that is to output the marker pulses. The marker pulses must be selected by
 [SOURCE:]LIST[1]:SEGMENT:MARKER:SPOINT *<point>* or
 [SOURCE:]LIST[1]:SEGMENT:MARKER *<marker_list>* before they are output.

HP BASIC Program Example (MARKSEG2)

The MARKSEG2 program is the same as the MARKSEG1 program on page 209 except it selects the marker pulses differently. The differences are as follows:

```
1  !RE-STORE"MARKSEG2"
2  !This program computes a sine wave and a triangle wave as arbitrary
3  !waveforms. A single marker pulse is output with amplitude point 256
4  !of the triangle wave.

170 !Set up the AFG
180 OUTPUT @Afg;"SOUR:FREQ1:FIX 512E3;"           !frequency
190 OUTPUT @Afg;"SOUR:FUNC:SHAP USER;"           !function
200 OUTPUT @Afg;"SOUR:VOLT:LEV:IMM:AMPL 5.1V"     !amplitude
210 OUTPUT @Afg;"SOUR:MARK:FEED ""SOUR:LIST1""    !marker source
220 OUTPUT @Afg;"SOUR:MARK:POL NORM"              !marker polarity
230 OUTPUT @Afg;"SOUR:MARK:STAT ON"               !enable marker

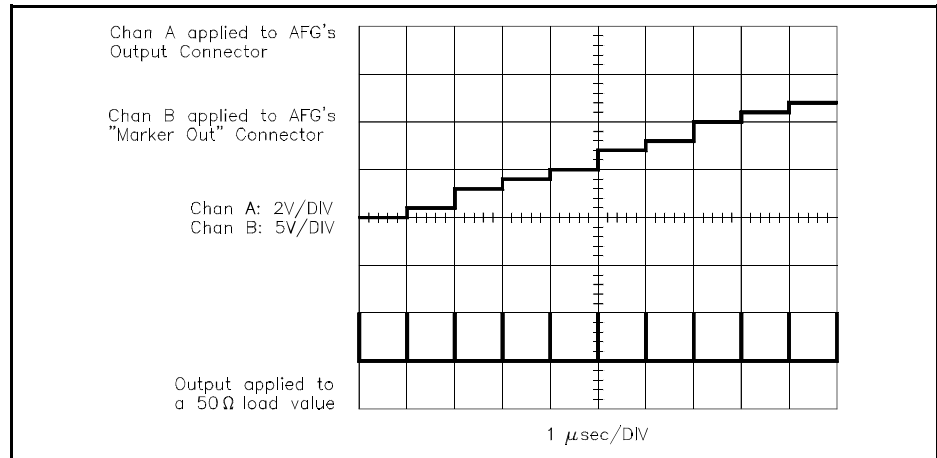
500 Tri_wave: !Subprogram which computes a triangle wave and specifies
510             !a marker pulse to be output with amplitude point 256.
520     COM @Afg
530     DIM Waveform(1:512)
540     FOR I=1 TO 256                               !Calculate triangle wave
550         Waveform(I)=*.0195313
560     NEXT I
570     FOR I=257 TO 512
580         Waveform(I)=(512-I)*.0195313
590     NEXT I
600     !
610     !Load waveform points and specify a single marker pulse
620     OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL TRI"       !segment name
630     OUTPUT @Afg;" SOUR:LIST1:SEGM:DEF 512"     !segment size
640     OUTPUT @Afg;"SOUR:LIST1:SEGM:VOLT ";Waveform(*)!amplitude points
650     OUTPUT @Afg;"SOUR:LIST1:SEGM:MARK:SPO 256" !marker on point 256
660     SUBEND
670     !
680     SUB Seq_list
690 Seq_list: !This subprogram defines the sequence list and enables
700             !a marker signal to be output with the triangle wave
710             !segment.
720     COM @Afg
730     OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL WAVE_OUT" !sequence name
740     OUTPUT @Afg;"SOUR:LIST1:SSEQ:DEF 2"        !number of segments
750     OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEQ SINE,TRI" !segments in sequence
760     OUTPUT @Afg;"SOUR:LIST1:SSEQ:MARK:SPO 2" !enable marker on segment TRI
770     SUBEND
```

Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, MARKSEG2.FRM, is in directory "VBPROG" and the Visual C example program, MARKSEG2.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Generating Marker Pulses for Each Waveform Point

The MARKTRG program shows how to generate and output a 12 nS wide marker pulse at each point of the waveform. The pulses are output at the “Marker Out” BNC. Since the pulses are output each time a segment is output, the pulse rate is the same as the sample rate (you can use this function as another way to lockstep multiple AFGs). The example generates a 10 point, +5 V ramp. Although this example generates an arbitrary waveform, the pulses can be generated in any function and sample source.



The commands are:

- 1. Reset the AFG**
`*RST`
- 2. Clear the AFG Memory of All Sequence and Segment Data**
`[SOURce:]LIST[1]:SSEquence:DELEte:ALL`
`[SOURce:]LIST[1]:SEGMENT:DELEte:ALL`
- 3. Setup the AFG for Output**
`[SOURce:]FREQuency[1][:CW | :FIXed] <frequency>`
`[SOURce:]FUNCTion[:SHAPe] USER`
`[SOURce:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude] <amplitude>`
- 4. Select the Marker Source**
`[SOURce:]MARKer:FEED "TRIGger[:START]:SEQUence[1]"`
This command selects the marker source for the front panel's "Marker Out" connector to output marker pulses at the sample rate. (See "Available Marker Sources" on page 205 for the different sources.)

5. **Select the Marker Polarity**

[SOURce:]MARKer:POLarity <polarity>
NORMal <polarity> selects active high marker pulses;
INVerted selects active low marker pulses.

6. **Enable Marker Outputs**

[SOURce:]MARKer[:STATe] ON
This commands enables the AFG to output marker pulses. (Although *RST automatically enables the AFG for marker outputs, it is given here for good programming practice.)

7. **Setup the Waveform Segment; Store it as Voltage Data Points**

[SOURce:]LIST[1][:SEGment]:SElect <name>
[SOURce:]LIST[1][:SEGment]:DEFine <length>
[SOURce:]LIST[1][:SEGment]:VOLTage <voltage_list>

8. **Setup the Sequence and Generate the Output**

[SOURce:]LIST[1]:SSEquence:SElect <name>
[SOURce:]LIST[1]:SSEquence:DEFine <length>
[SOURce:]LIST[1]:SSEquence:SEquence <segment_list>
[SOURce:]FUNction:USER <name>
INITiate[:!MMediate]

HP BASIC Program Example (MARKTRG)

```
1  !RE-STORE"MARKTRG"  
2  !This program computes a ramp wave as an arbitrary waveform, and  
3  !outputs a marker pulse with each waveform amplitude point.  
4  !  
10 !Assign I/O path between the computer and E1445A.  
20 ASSIGN @Afg TO 70910  
30 COM @Afg  
40 !  
50 !Set up error checking  
60 ON INTR 7 CALL Errmsg  
70 ENABLE INTR 7;2  
80 OUTPUT @Afg;"*CLS"  
90 OUTPUT @Afg;"*SRE 32"  
100 OUTPUT @Afg;"*ESE 60"  
110 !  
120 !Call the subprograms which reset the AFG and delete all existing  
130 !waveform segments and sequences.  
140 CALL Rst  
150 CALL Wf_del  
160 !  
170 !Set up the AFG  
180 OUTPUT @Afg;"SOUR:FREQ1:FIX 1E6;";           !frequency
```

Continued on Next Page

```

190 OUTPUT @Afg;":SOUR:FUNC:SHAP USER;";           !function
200 OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL 5.1V"      !amplitude
210 OUTPUT @Afg;"SOUR:MARK:FEED ""TRIG:STAR""      !marker source
220 OUTPUT @Afg;"SOUR:MARK:POL NORM"              !marker polarity
230 OUTPUT @Afg;"SOUR:MARK:STAT ON"                !enable marker
240 !
250 CALL Ramp_wave
260 !
270 OUTPUT @Afg;"SOUR:FUNC:USER RAMP_OUT"          !waveform sequence
280 OUTPUT @Afg;"INIT:IMM"                          !wait-for-arm state
290 !
300 WAIT .1 !allow interrupt to be serviced
310 OFF INTR 7
320 END
330 !
340 SUB Ramp_wave
350 Ramp_wave: !Subprogram which computes a ramp wave and sets the
351             !output sequence.
360     COM @Afg
370     DIM Waveform(1:10)                          !Calculate ramp wave
380     FOR I=1 TO 10
390         Waveform(I)=I*.5
400     NEXT I
410     !
420     OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL RAMP"      !segment name
430     OUTPUT @Afg;" SOUR:LIST1:SEGM:DEF 10"       !segment size
440     OUTPUT @Afg;"SOUR:LIST1:SEGM:VOLT ";Waveform(*)!amplitude points
450     !
460     OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL RAMP_OUT"  !sequence name
470     OUTPUT @Afg;"SOUR:LIST1:SSEQ:DEF 1"        !number of segments
480     OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEQ RAMP"     !segments in sequence
490 SUBEND
500 !
510 SUB Rst
520 Rst: !Subprogram which resets the E1445.
530     COM @Afg
540     OUTPUT @Afg;"*RST;*OPC?"                  !reset the AFG
550     ENTER @Afg;Complete
560 SUBEND
570 !
580 SUB Wf_del
590 Wf_del: !Subprogram which deletes all sequences and segments.
600     COM @Afg
610     OUTPUT @Afg;"FUNC:USER NONE"              !select no sequences
620     OUTPUT @Afg;"LIST:SSEQ:DEL:ALL"           !Clear sequence memory
630     OUTPUT @Afg;"LIST:SEGM:DEL:ALL"          !Clear segment memory
640 SUBEND
650 !
660 SUB Errmsg

```

Continued on Next Page

```

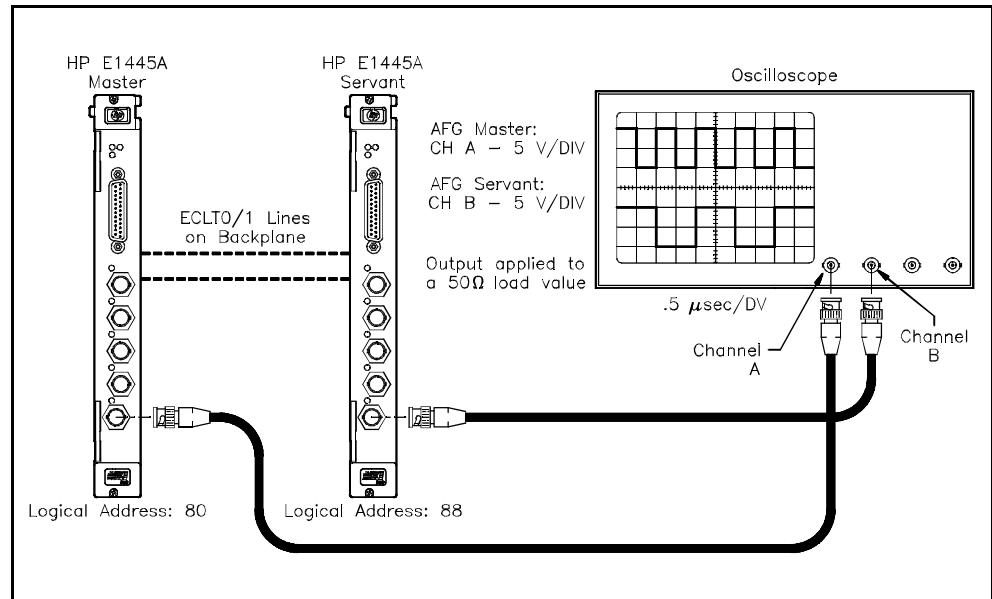
670 Errmsg: !Subprogram which displays E1445 programming errors
680     COM @Afg
690     DIM Message$[256]
700     !Read AFG status byte register and clear service request bit
710     B=SPOLL(@Afg)
720     !End of statement if error occurs among coupled commands
730     OUTPUT @Afg;"
740     OUTPUT @Afg;"ABORT"                                !abort output waveform
750     REPEAT
760         OUTPUT @Afg;"SYST:ERR?"                        !read AFG error queue
770         ENTER @Afg;Code,Message$
780         PRINT Code,Message$
790     UNTIL Code=0
800     STOP
810     SUBEND

```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, MARKTRG.FRM, is in directory “VBPROG” and the Visual C example program, MARKTRG.C, is in directory “VCPROG” on the CD that came with your HP E1445A.

Operating Multiple AFGs Together

The DRIFT program shows how to operate multiple AFGs together to synchronize their outputs to each other. One AFG (the master AFG) uses its Reference Oscillator Output as the Reference Oscillator source for the second AFG (the servant AFG). Thus, any frequency change caused by drift of the master AFG reference results in the same amount of change in the servant AFG. The master AFG generates a 1 MHz square wave; the servant, a 500 KHz square wave.



The commands are:

- 1. Reset the Master and Servant AFGs**
`*RST`
- 2. Setup the Master AFG For Output**
`[SOURce:]ROSCillator:SOURce INT2`
`TRIGger[:START]:SOURce INTERNAL2`
`[SOURce:]FREQuency[1]:FIXed <frequency>`
`[SOURce:]FUNCTion[:SHAPE] SQUARE`
`[SOURce:]VOLTage[:LEVEL][:IMMEDIATE][:AMPLitude] <amplitude>`
- 3. Select the Master AFG's Marker Source**
`[SOURce:]MARKer:ECLTrg<n>:FEED`
`"[SOURce:]ROSCillator"`
This command selects the marker source for the ECLTrg0 trigger line to output the Reference Oscillator clock pulses.

4. **Enable the ECLTrg0 Line**
 [SOURce:]MARKer:ECLTrg0[:STATe] ON
 This enables the marker output on the ECLTrg0 trigger line.
 (Although *RST automatically enables the AFG for marker outputs, it is given here for good programming practice.)
5. **Select the Master AFG's ECLTrg1 Feed Trigger Source**
 [SOURce:]MARKer:ECLTrg1:FEED <source>
 "ARM:START:LAYer2"
 This source outputs a marker pulse when the master's waveform output starts. The marker is output on the ECLTrg1 trigger line.
6. **Enable the ECLTrg1 Line**
 [SOURce:]MARKer:ECLTrg1[:STATe] ON
 This enables the arm output on the ECLTrg1 trigger line.
7. **Select the Servant AFG's Reference Oscillator Source**
 [SOURce:]ROSCillator:SOURce ECLTrg<n>
 [SOURce:]ROSCillator:FREQUENCY:EXTernal 40M
 This command selects the Reference Oscillator Source. To synchronize the servant AFG with the master, select the ECLTrg0 trigger line. (The ECLTRG0 line is a 40 MHz clock.)
8. **Select the Servant AFG's Sample Source**
 TRIGger[:START]:SEQuence[1]:SOURce INT2
 Select the Divide-by-n time base for the sample source.
9. **Setup the Servant AFG For a 5 V Square Wave Output**
 [SOURce:]FREQUENCY[1]:FIXed <frequency>
 [SOURce:]FUNCTion[:SHAPE] SQUare
10. **Setup the Servant AFG Arm Source to be the ECLTrg1 Line**
 ARM[:START]:LAYer2:SOURce ECLTrg1
 This command tells the servant AFG to start on the arm signal from the master AFG.
11. **Generate the Servant AFG's Output**
 INITiate[:IMMEDIATE]
12. **Wait for the Servant AFG to Complete its Setup**
 STATus:OPC:INITiate OFF;*OPC?
13. **Generate the Master AFG's Output**
 INITiate[:IMMEDIATE]

HP BASIC Program Example (DRIFT)

```
1  !RE-STORE"DRIFT"
2  !This program sets up two AFG's to output 1 MHz square waves.
3  !To prevent these signals from drifting and creating a phase
4  !difference, the reference oscillator of a "master" AFG is shared
5  !by a "servant" AFG. The master's reference oscillator signal is
6  !output on VXI backplane trigger line ECLT0.
10 !Assign I/O paths between the computer and the AFGs.
20 ASSIGN @Afg_m TO 70910           !master AFG
30 ASSIGN @Afg_s TO 70911           !servant AFG
40 COM @Afg_m,@Afg_s
50 !
60 !Set up error checking
70 CALL Rst
80 OUTPUT @Afg_m;"*CLS"             !master
90 OUTPUT @Afg_m;"*SRE 32"
100 OUTPUT @Afg_m;"*ESE 60"
110 OUTPUT @Afg_m;"*OPC?"
120 ENTER @Afg_m;Complete
130 !
140 OUTPUT @Afg_s;"*CLS"            !servant
150 OUTPUT @Afg_s;"*SRE 32"
160 OUTPUT @Afg_s;"*ESE 60"
170 OUTPUT @Afg_s;"*OPC?"
180 ENTER @Afg_s;Complete
190 ON INTR 7 CALL Errmsg
200 ENABLE INTR 7;2
210 !
220 !Call the subprograms which reset the AFGs output sine waves 180
230 !degrees out of phase.
240 CALL Square_wave_m
250 CALL Square_wave_s
260 !
270 !Set master AFG to wait-for-arm state
280 OUTPUT @Afg_m;"INIT:IMM"        !start waveform
290 !
300 WAIT .1 !allow interrupt to be serviced
310 OFF INTR 7
320 END
330 !
340 SUB Square_wave_m
350 Square_wave_m: !Subprogram which sets up master AFG
360   COM @Afg_m,@Afg_s
370   OUTPUT @Afg_m;"SOUR:ROSC:SOUR INT2;"; !reference osc. source
380   OUTPUT @Afg_m;"TRIG:STAR:SOUR INT2;"; !trigger source
390   OUTPUT @Afg_m;"SOUR:FREQ2:FIX 1E6;"; !frequency
400   OUTPUT @Afg_m;"SOUR:FUNC:SHAP SQU;"; !function
410   OUTPUT @Afg_m;"SOUR:VOLT:LEV:IMM:AMPL 5V" !amplitude
```

Continued on Next Page


```

420     OUTPUT @Afg_m;"SOUR:MARK:ECLT0:FEED "SOUR:ROSC""      !feed ref osc
430     OUTPUT @Afg_m;"SOUR:MARK:ECLT0:STAT ON"      !enable ECLT0 trig line
440     OUTPUT @Afg_m;"SOUR:MARK:ECLT1:FEED "ARM:STAR:LAY2"" !feed arm source
450     OUTPUT @Afg_m;"SOUR:MARK:ECLT1:STAT ON"      !enable ECLT1 trig line
460     SUBEND
470     !
480     SUB Square_wave_s
490 Square_wave_s:  !Subprogram which sets up servant AFG: square wave
500                 !in phase with master AFG, reference oscillator source
510                 !external.
520     COM @Afg_m,@Afg_s
530     OUTPUT @Afg_s;"SOUR:ROSC:SOUR ECLT0;";          !reference source
540     OUTPUT @Afg_s;":SOUR:ROSC:FREQ:EXT 40E6;";      !reference frequency
550     OUTPUT @Afg_s;":TRIG:STAR:SOUR INT2;";         !trigger source
560     OUTPUT @Afg_s;":SOUR:FREQ2:FIX .5E6;";         !frequency
570     OUTPUT @Afg_s;":SOUR:FUNC:SHAP SQU;";          !function
580     OUTPUT @Afg_s;":SOUR:VOLT:LEV:IMM:AMPL 5V"      !amplitude
590     OUTPUT @Afg_s;":ARM:STAR:LAY2:SOUR ECLT1"      !arm source
600     !
610     OUTPUT @Afg_s;"INIT:IMM"                       !wait-for-arm state
620     OUTPUT @Afg_s;"STAT:OPC:INIT OFF;*OPC?"      !allow setup to complete
630     ENTER @Afg_s;Complete
640     SUBEND
650     !
660     SUB Rst
670 Rst:  !Subprogram which resets the AFGs.
680     COM @Afg_m,@Afg_s
690     OUTPUT @Afg_m;"*RST;*OPC?"                    !reset the master AFG
700     ENTER @Afg_m;Complete
710     !
720     OUTPUT @Afg_s;"*RST;*OPC?"                    !reset the servant AFG
730     ENTER @Afg_s;Complete
740     SUBEND
750     !
760     SUB Errmsg
770 Errmsg: !Subprogram which displays E1445 programming errors
780     COM @Afg_m,@Afg_s
790     DIM Message$[256]
800     !Read AFG status byte register and clear service request bit
810     B=SPOLL(@Afg_m)
820     IF B THEN                                       !master error
830     !End of statement if error occurs among coupled commands
840     OUTPUT @Afg_m;""
850     OUTPUT @Afg_m;"ABORT"                          !abort output waveform
860     PRINT "Master AFG"
870     PRINT
880     REPEAT
890     OUTPUT @Afg_m;"SYST:ERR?"                      !read AFG error queue
900     ENTER @Afg_m;Code,Message$

```

Continued on Next Page

```

910         PRINT Code,Message$
920     UNTIL Code=0
930     STOP
940     ELSE                                     !servant error
950     B=SPOLL(@Afg_s)
960     !End of statement if error occurs among coupled commands
970     OUTPUT @Afg_s;"
980     OUTPUT @Afg_s;"ABORT"                   !abort output waveform
990     PRINT "Servant AFG"
1000    PRINT
1010    REPEAT
1020        OUTPUT @Afg_s;"SYST:ERR?"           !read AFG error queue
1030        ENTER @Afg_s;Code,Message$
1040        PRINT Code,Message$
1050    UNTIL Code=0
1060    STOP
1070    END IF
1080    SUBEND

```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, DRIFT.FRM, is in directory “VBPROG” and the Visual C example program, DRIFT.C, is in directory “VCPROG” on the CD that came with your HP E1445A.

Marker Program Comments

The following program comments give additional details on the program examples in this chapter.

Determining the Number of Marker Points of a Waveform Segment

Use [SOURCE:]LIST[1]:MARKer:POINTs? to determine the length of the marker pulse list selected by [SOURCE:]LIST[1]:MARKer. The command returns the marker list size of the currently selected waveform segment.

Determining the Number of Marker Points of a Segment Sequence

Use [SOURCE:]LIST[1]:SSEquence:MARKer:POINTs? to determine the length of the marker pulse list selected by [SOURCE:]LIST[1]:SSEquence:MARKer. The command returns the marker list size of the currently selected segment sequence.

Chapter 7

High Speed Operation

Chapter Contents

This chapter explains how to use the HP E1445A Arbitrary Function Generator at faster speeds and other operations.

Chapter 3 shows how to transfer waveform segments and segment sequences to the AFG as voltage values and ASCII data, respectively. This is the slowest method to transfer the lists to the AFG. This chapter shows faster ways to transfer the lists to the AFG. The sections are as follows:

- Data Transfer Methods and Speed Comparisons Page 224
- Using Signed Data to Generate Waveforms Page 225
 - Using the Signed Number Format. Page 225
- Using Unsigned Data to Generate Waveforms Page 229
 - Using the Unsigned Number Format Page 229
- Using Definite Length Arbitrary Blocks to Transfer Data Page 231
 - Definite Length Block Data Format Page 231
 - Data Byte Size Page 231
- Using Indefinite Length Arbitrary Blocks to Transfer Data Page 235
 - Indefinite Length Block Data Format Page 235
 - Data Byte Size Page 235
- Using Combined Signed Data Page 239
 - Combined Segment List Format Page 239
 - Using the Combined List with the Signed Number Format Page 240
- Using Combined Unsigned Data Page 245
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- Using Combined Waveform Segments and Segment Sequences Page 250
 - Combined Segment Sequence List Format. Page 250
- Using the VXIbus Backplane. Page 259
 - Downloading Segment Data Page 259
 - Downloading Segment Data into Memory Page 259
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- Using the Front Panel’s “Digital Port In” Connector Page 272
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- High Speed Program Comments Page 280
 - Amplitude Effects on DAC Codes Page 280
 - Incorrect AFG Operation from Incorrect DAC Codes Page 280
 - DAC Sources Page 280
 - Download Sources Page 280
 - Determining the Size of the Combined Segment List Page 280
 - Determining the Size of the Combined Segment Sequence List Page 280

Data Transfer Methods and Speed Comparisons

Table 7-1 shows the timing relationship of the different data transfer methods used. The table lists the relative timing in descending order with the slowest method on top.

Table 7-1. Speed Relationships of Data Transfer Methods

Method	Command	Approximate Time Savings*
Segment Voltage List	[SOURCE]:LIST[1]:SEGMENT:VOLTage	0
Segment DAC Code List	[SOURCE]:LIST[1]:SEGMENT:VOLTage:DAC	35%
Segment Combined List	[SOURCE]:LIST[1]:SEGMENT:COMBined	35%
Segment DAC Codes as Block Data	[SOURCE]:LIST[1]:SEGMENT:VOLTage:DAC	88%
Segment Combined List as Block Data	[SOURCE]:LIST[1]:SEGMENT:COMBined	94%
Segment/Sequence Combined List as Block Data	[SOURCE]:LIST[1]:SEGMENT:COMBined/ [SOURCE]:LIST[1]:SSEQUence:COMBined	94%

*The time saving percentages are referenced to the speed of the Segment Voltage List method

Using Signed Data to Generate Waveforms

Transferring waveform segments as Digital-to-Analog Converter (DAC) Codes to the AFG is faster than transferring a voltage list. This section shows how to transfer the lists as DAC codes using the Signed number format. The DAC codes are transferred to the AFG as a comma (“,”) separated list.

Note The AFG can only accept a single number format at a time. Thus, if the AFG currently contains Unsigned data and you wish to send Signed data, you **MUST** delete the data in memory first before enabling the AFG to receive Signed data.

Using the Signed Number Format

This section shows how to setup the AFG to receive DAC codes in the Signed number format and how to calculate the codes from voltage values.

Transferring DAC Codes in the Signed Number Format

With the AFG set to receive DAC codes in the Signed number format, it receives the codes in 16-bit two’s complement numbers. Use the [SOURce:]ARbitrary:DAC:FORMat SIGNED command to select the format.

Determining DAC Codes in the Signed Number Format

For outputs into matched loads and with the amplitude set to maximum (+5.11875V), the following DAC codes generate the following outputs:

- Code **0** outputs 0 V
- Code **-4096** outputs -5.12 V or negative full scale voltage
- Code **+4095** outputs +5.11875 V or positive full scale voltage

To calculate DAC codes from voltage values, use the formula:

$$\text{DAC Code} = \text{voltage value} / .00125$$

For example, to output -2V:

$$\text{DAC Code} = -2 / .00125 = -1600$$

The SIGN_DAT program shows how to store a waveform segment (i.e., points of an arbitrary waveform) into the AFG’s segment memory. The points are stored in the Signed DAC number format. The data is transferred to the AFG as a comma (“,”) separated list. The example generates a 200 point -5 V to +5 V positive going ramp.

The commands are:

- 1. Reset the AFG**
*RST
- 2. Clear the AFG Memory of All Sequence and Segment Data**
[SOURce:]LIST[1]:SSEquence:DELEte:ALL
[SOURce:]LIST[1]:SEGMeNt]:DELEte:ALL
- 3. Setup the AFG for Output**
[SOURce:]FREQuency[1][:CW | :FIXed] <frequency>
[SOURce:]FUNctioN[:SHAPE] USER
[SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude] <amplitude>
- 4. Select the DAC Data Source**
[SOURce:]ARBitrary:DAC:SOURce INTernal
This command selects the source that transfers data to the DAC (see “DAC Sources” on page 280). Use INTernal to transfer the data using the [SOURce:]LIST[1] subsystem.
- 5. Select the DAC Data Format**
[SOURce:]ARBitrary:DAC:FORMat SIGNed
This command selects the SIGNed number format.
- 6. Setup the Waveform Segment**
[SOURce:]LIST[1]:SEGMeNt]:SELEct <name>
[SOURce:]LIST[1]:SEGMeNt]:DEFine <length>
- 7. Store the Waveform Segment as Signed DAC Data**
[SOURce:]LIST[1]:SEGMeNt]:VOLTage:DAC <voltage_list>
This command stores the waveform segment into segment memory using the Signed number format set by the [SOURce:]ARBitrary:DAC:FORMat SIGNed command.
- 8. Setup the Segment Sequence and Generate Output**
[SOURce:]LIST[1]:SSEquence:SELEct <name>
[SOURce:]LIST[1]:SSEquence:DEFine <length>
[SOURce:]LIST[1]:SSEquence:SEQuence <segment_list>
[SOURce:]FUNctioN:USER <name>
INITiate[:IMMediate]

HP BASIC Program Example (SIGN_DAT)

The SIGN_DAT program is very similar to the example programs used in Chapter 3. The only difference is that this program generates (in line 360) and transfers (in line 430) segment data as DAC codes in the Signed number format instead of voltage values.

```
1  IRE-STORE"SIGN_DAT"
2  !This program downloads arbitrary waveform data as signed
3  !(2's complement) DAC codes. The waveform defined is a 200 point,
4  !-5V to +5V ramp wave.
5  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 COM @Afg
40 !
50 !Set up error checking
60 ON INTR 7 CALL Errmsg
70 ENABLE INTR 7;2
80 OUTPUT @Afg;"*CLS"
90 OUTPUT @Afg;"*SRE 32"
100 OUTPUT @Afg;"*ESE 60"
110 !
120 !Call the subprograms which reset the AFG and erase all waveform
130 !segments and sequences.
140 CALL Rst
150 CALL Wf_del
160 !
170 OUTPUT @Afg;"SOUR:FREQ1:FIX 200E3;";           !frequency
180 OUTPUT @Afg;":SOUR:FUNC:SHAP USER;";         !function (arbitrary)
190 OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL 5.11875V" !amplitude
200 !
210 CALL Ramp_wave
220 !
230 OUTPUT @Afg;"SOUR:FUNC:USER RAMP_OUT"         !waveform sequence
240 OUTPUT @Afg;"INIT:IMM"                        !wait-for-arm state
250 !
260 WAIT .1!allow interrupt to be serviced
270 OFF INTR 7
280 END
290 !
300 SUB Ramp_wave
310 Ramp_wave: !Subprogram which defines a ramp waveform and output
320 !sequence.
330 COM @Afg
340 DIM Waveform(1:200)                          !Calculate waveform points as dac codes
350 FOR I=-100 TO 99
360 Waveform(I+101)=(I*.050505)/.00125
370 NEXT I
380 !
```

Continued on Next Page

```

390     OUTPUT @Afg;"SOUR:ARB:DAC:SOUR INT"           !dac data source
400     OUTPUT @Afg;"SOUR:ARB:DAC:FORM SIGN"         !dac data format (signed)
410     OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL RAMP"       !segment name
420     OUTPUT @Afg;" SOUR:LIST1:SEGM:DEF 200"       !segment size
430     OUTPUT @Afg;" SOUR:LIST1:SEGM:VOLT:DAC ";Waveform(*) !waveform pts
440     !
450     OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL RAMP_OUT"   !sequence name
460     OUTPUT @Afg;" SOUR:LIST1:SSEQ:DEF 1"         !sequence size
470     OUTPUT @Afg;" SOUR:LIST1:SSEQ:SEQ RAMP"      !segment order
480     SUBEND
490     !
500     SUB Rst
510 Rst: !Subprogram which resets the E1445.
520     COM @Afg
530     OUTPUT @Afg;"*RST;*OPC?"                   !reset the AFG
540     ENTER @Afg;Complete
550     SUBEND
560     !
570     SUB Wf_del
580 Wf_del: !Subprogram which deletes all sequences and segments.
590     COM @Afg
600     OUTPUT @Afg;"FUNC:USER NONE"                !select no sequences
610     OUTPUT @Afg;"LIST:SSEQ:DEL:ALL"             !Clear sequence memory
620     OUTPUT @Afg;"LIST:SEGM:DEL:ALL"            !Clear segment memory
630     SUBEND
640     !
650     SUB Errmsg
660 Errmsg: !Subprogram which displays E1445 programming errors
670     COM @Afg
680     DIM Message$(256)
690     !Read AFG status byte register and clear service request bit
700     B=SPOLL(@Afg)
710     !End of statement if error occurs among coupled commands
720     OUTPUT @Afg;"
730     OUTPUT @Afg;"ABORT"                          !abort output waveform
740     REPEAT
750         OUTPUT @Afg;"SYST:ERR?"                  !read AFG error queue
760         ENTER @Afg;Code,Message$
770         PRINT Code,Message$
780     UNTIL Code=0
790     STOP
800     SUBEND

```

Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, SIGN_DAT.FRM, is in directory "VBPROG" and the Visual C example program, SIGN_DAT.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

These programs are very similar to the example programs used in Chapter 3. The only difference is that this program transfers the segment data as DAC codes in the Signed number format instead of voltage values.

Using Unsigned Data to Generate Waveforms

Transferring waveform segments as Digital-to-Analog Converter (DAC) Codes to the AFG is faster than transferring a voltage list. This section shows how to transfer the lists as DAC codes using the Unsigned number format. The DAC codes are transferred to the AFG as a comma (“,”) separated list.

Note The AFG can only accept a single number format at a time. Thus, if the AFG currently contains Unsigned data and you wish to send Signed data, you **MUST** delete the data in memory first before enabling the AFG to receive Signed data.

Using the Unsigned Number Format

This section shows how to setup the AFG to receive DAC codes in the Unsigned number format and how to generate the codes from voltage values.

Transferring DAC Codes in the Unsigned Number Format

With the AFG set to receive DAC codes in the UNSigned number format, it receives the codes as unsigned or offset binary numbers. Use the [SOURce:]ARbitrary:DAC:FORMat UNSigned command to select the format.

Determining DAC Codes in the Unsigned Number Format

For outputs into matched loads and with the amplitude set to maximum (+5.11875V), the following DAC codes generate the following outputs:

Code **0** outputs -5.12 V or negative full scale voltage
Code **+4096** outputs 0 V
Code **+8191** outputs +5.11875 V or positive full scale voltage

To calculate DAC codes from voltage values, use the formula:

$$\text{DAC Code} = (\text{voltage value} / .00125) + 4096$$

For example, to output -2V:

$$\text{DAC Code} = (-2 / .00125) + 4096 = -1600 + 4096 = 2496$$

The UNS_DAT program shows how to store a waveform segment (i.e., points of an arbitrary waveform) into the AFG’s segment memory. The waveform segment is stored in the Unsigned number format. The data is transferred to the AFG as a comma (“,”) separated list. The example generates a 200 point +5 V to -5 V negative going ramp.

The commands are the same ones listed on page 226, except on how to select the Unsigned format and how generate the data. These exceptions are as follows:

5. **Select the DAC Data Format**

[SOURce:]ARbitrary:DAC:FORMat UNSigned

This command selects the UNSigned number format.

7. **Store the Waveform Segment as Unsigned DAC Data**

[SOURce:]LIST[1][:SEGment]:VOLTage:DAC <voltage_list>

This command stores the waveform segment into segment memory according to the Unsigned number format set by the

[SOURce:]ARbitrary:DAC:FORMat UNSigned command.

HP BASIC Program Example (UNS_DAT)

Use the same BASIC program as the “SIGN_DAT” program beginning on page 227. The only difference is that this program generates (in line 360) and transfers (in line 400) the segment data as DAC codes in the Unsigned number format instead of the Signed format. The following lines show the differences of the two program examples:

```
1   !RE-STORE"UNS_DAT"

300  SUB Ramp_wave
310 Ramp_wave:  !Subprogram which defines a ramp waveform and output
320             !sequence.
330  COM @Afg
340  DIM Waveform(1:200) !Calculate waveform points as dac codes
350  FOR I=-100 TO 99
360      Waveform(I+101)=((I*.050505)/.00125)+4096
370  NEXT I
380  !
390  OUTPUT @Afg;"SOUR:ARB:DAC:SOUR INT"      !dac data source
400  OUTPUT @Afg;"SOUR:ARB:DAC:FORM UNS"      !dac data format (unsigned)
410  OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL RAMP"    !segment name
420  OUTPUT @Afg;" SOUR:LIST1:SEGM:DEF 200"    !segment size
430  OUTPUT @Afg;" SOUR:LIST1:SEGM:VOLT:DAC ";Waveform(*) !waveform pts
440  !
450  OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL RAMP_OUT" !sequence name
460  OUTPUT @Afg;" SOUR:LIST1:SSEQ:DEF 1"      !sequence size
470  OUTPUT @Afg;" SOUR:LIST1:SSEQ:SEQ RAMP"    !segment order
480  SUBEND
```

Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, UNS_DAT.FRM, is in directory “VBPROG” and the Visual C example program, UNS_DAT.C, is in directory “VCPROG” on the CD that came with your HP E1445A.

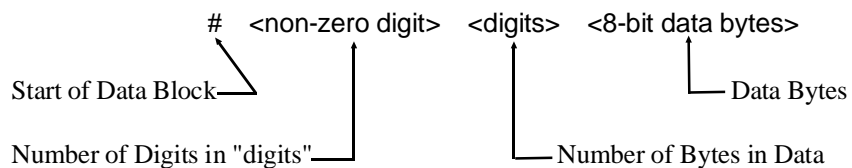
This program is very similar to the example programs used in Chapter 3. The only difference is that this program transfers the segment data as DAC codes in the Unsigned number format instead of voltage values.

Using Definite Length Arbitrary Blocks to Transfer Data

The AFG can receive DAC codes as Definite Length Arbitrary Block Data using either the Signed or Unsigned number format. This is a much faster method to transfer data than using a comma (“,”) separated list that was used in “Using Signed Data to Generate Waveforms” on page 225 and “Using Unsigned Data to Generate Waveforms” on page 229. (The speed is about the same as the method used in “Using Indefinite Length Arbitrary Blocks to Transfer Data” on page 235.)

Definite Length Block Data Format

A typical data block using the definite length format consists of:



where:

- “#” – Shows that the data to be sent is in an arbitrary block format.
- “<non-zero digit>” – is a single digit number that shows the number of digits contained in <digits>; for example, if the <digits> value equals 100 or 2000, the <non-zero digit> value equals 3 or 4, respectively.
- “<digits>” – Shows the number of data bytes to be sent; for example, if 100 data bytes are to be sent, <digits> equals 100 (see “Data Byte Size” below).
- “<8-bit data bytes>” – Is the data (i.e., DAC codes) sent to the AFG.
- A typical example of a data block sending 2000 8-bit data bytes is:

#42000<data bytes>

Data Byte Size

The DAC codes are transferred to the AFG as 16-bit integer values that meet the coding set by the IEEE 488.2 standard. Since IEEE 488.2 requires an 8-bit code, the 16-bit integer must be sent as 2 8-bit values for each 16-bit integer.

For example, to send a waveform segment consisting of 1000 DAC codes (1000 points), the actual number of “digits” and “8-bit data bytes” equals:

$$1000 * 2 = 2000$$

HP BASIC Program Example (DACBLOK1)

The DACBLOK1 program shows how to store a waveform segment (i.e., points of an arbitrary waveform) into the AFG's segment memory. The waveform segment is stored as DAC codes in the Signed number format. This program is the same program as SIGN_DAT beginning on page 227, except the data is transferred to the AFG using the Definite Length Arbitrary Block method. The example generates a 200 point -5 V to +5 V positive going ramp.

To transfer Definite Length Block Data to the AFG requires that the data sent with the [SOURCE:]LIST[1]:SEGMENT:VOLTage:DAC command must be contiguous. To do this, sent no carriage return (CR) and line feed (LF) before all the data is transferred. The format in line 440 disables the CR and LF. The CR and LF sent in line 460 tells the AFG that the data transfer is complete.

```
1  !RE-STORE"DACBLOK1"
2  !This program downloads arbitrary waveform data as signed
3  !(2's complement) DAC codes. The data is sent in an IEEE-488.2
4  !definite length block in 16-bit integer format. The waveform is
5  !a 200 point, -5V to +5V ramp wave.
6  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 ASSIGN @Afg1 TO 70910.;FORMAT OFF !path for binary data
40 COM @Afg,@Afg1
50 !
60 !Set up error checking
70 ON INTR 7 CALL Errmsg
80 ENABLE INTR 7;2
90 OUTPUT @Afg;"*CLS"
100 OUTPUT @Afg;"*SRE 32"
110 OUTPUT @Afg;"*ESE 60"
120 !
130 !Call the subprograms which reset the AFG and erase all waveform
140 !segments and sequences.
150 CALL Rst
160 CALL Wf_del
170 !
180 OUTPUT @Afg;"SOUR:FREQ1:FIX 200E3;"; !frequency
190 OUTPUT @Afg;"SOUR:FUNC:SHAP USER;"; !function
200 OUTPUT @Afg;"SOUR:VOLT:LEV:IMM:AMPL 5.11875V" !amplitude
210 !
220 CALL Ramp_wave
230 !
240 OUTPUT @Afg;"SOUR:FUNC:USER RAMP_OUT" !waveform sequence
250 OUTPUT @Afg;"INIT:IMM" !wait-for-arm state
260 !
270 WAIT .1!allow interrupt to be serviced
280 OFF INTR 7
```

Continued on Next Page

```

290 END
300 !
310 SUB Ramp_wave
320 Ramp_wave: !Subprogram which defines a ramp waveform and output
330 !sequence.
340 COM @Afg,@Afg1
350 INTEGER Waveform(1:200) !Calculate waveform points as dac codes
360 FOR I=-100 TO 99
370 Waveform(I+101)=(I*.050505)/.00125
380 NEXT I
390 !
400 OUTPUT @Afg;"SOUR:ARB:DAC:SOUR INT" !dac data source
410 OUTPUT @Afg;"SOUR:ARB:DAC:FORM SIGN" !dac data format (signed)
420 OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL RAMP" !segment name
430 OUTPUT @Afg;" SOUR:LIST1:SEGM:DEF 200" !segment size
440 OUTPUT @Afg USING "#,K";"SOUR:LIST1:SEGM:VOLT:DAC #3400"
450 OUTPUT @Afg1;Waveform(*) !400 bytes: 3 digits (2 bytes/ampl point)
460 OUTPUT @Afg !CR LF
470 !
480 OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL RAMP_OUT" !sequence name
490 OUTPUT @Afg;" SOUR:LIST1:SSEQ:DEF 1" !sequence size
500 OUTPUT @Afg;" SOUR:LIST1:SSEQ:SEQ RAMP" !segment order
510 SUBEND
520 !
530 SUB Rst
540 Rst: !Subprogram which resets the E1445.
550 COM @Afg,Afg1
560 OUTPUT @Afg;"*RST;*OPC?" !reset the AFG
570 ENTER @Afg;Complete
580 SUBEND
590 !
600 SUB Wf_del
610 Wf_del: !Subprogram which deletes all sequences and segments.
620 COM @Afg,Afg1
630 OUTPUT @Afg;"FUNC:USER NONE" !select no sequences
640 OUTPUT @Afg;"LIST:SSEQ:DEL:ALL" !Clear sequence memory
650 OUTPUT @Afg;"LIST:SEGM:DEL:ALL" !Clear segment memory
660 SUBEND
670 !
680 SUB Errmsg
690 Errmsg: !Subprogram which displays E1445 programming errors
700 COM @Afg,Afg1
710 DIM Message$(256)
720 !Read AFG status byte register and clear service request bit
730 B=SPOLL(@Afg)
740 !End of statement if error occurs among coupled commands
750 OUTPUT @Afg;"
760 OUTPUT @Afg;"ABORT" !abort output waveform
770 REPEAT
780 OUTPUT @Afg;"SYST:ERR?" !read AFG error queue

```

Continued on Next Page

```
790     ENTER @Afg;Code,Message$
800     PRINT Code,Message$
810     UNTIL Code=0
820     STOP
830     SUBEND
```

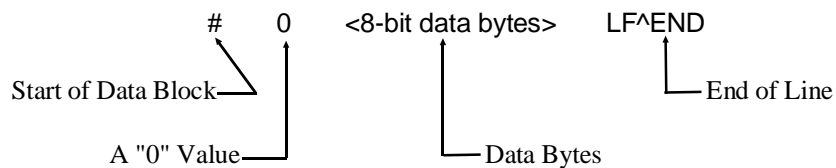
**Visual BASIC and
Visual C/C++ Program
Versions** The Visual BASIC example program, DACBLOK1.FRM, is in directory “VBPROG” and the Visual C example program, DACBLOK1.C, is in directory “VCPROG” on the CD that came with your HP E1445A.

Using Indefinite Length Arbitrary Blocks to Transfer Data

The AFG can receive DAC codes as Indefinite Length Arbitrary Block Data using either the Signed or Unsigned number format. This is a much faster method to transfer data than using a comma (“,”) separated list that was used in “Using Signed Data to Generate Waveforms” on page 225 and “Using Unsigned Data to Generate Waveforms” on page 229. (The speed is about the same as the method used in “Using Definite Length Arbitrary Blocks to Transfer Data” on page 231.)

Indefinite Length Block Data Format

A typical data block using the indefinite length format consists of:



where:

- “#” – Shows that the data to be sent is in an arbitrary block format.
- “0” – Shows that the format is an indefinite length arbitrary block format; the “0” number must be sent since a different number shows the definite length arbitrary block format.
- “<8-bit data bytes>” – Is the data (i.e., DAC codes) sent to the AFG.
- “LF^END” – Means line feed (LF) sent with END (EOI) asserted. It indicates to the AFG that the end of data has been reached.

Data Byte Size

The DAC codes are transferred to the AFG as 16-bit integer values that meet the coding set by the IEEE 488.2 standard. Since IEEE 488.2 requires an 8-bit code, the 16-bit integer must be sent as 2 8-bit values for each 16-bit integer.

For example, to send a waveform segment consisting of 1000 DAC codes (1000 points), the actual number of “digits” and “8-bit data bytes” equals:

$$1000 * 2 = 2000$$

HP BASIC Program Example (DACBLOK2)

The DACBLOK2 program shows how to store a waveform segment (i.e., points of an arbitrary waveform) into the AFG's segment memory. The waveform segment is stored as DAC codes in the Unsigned number format. This program is the same program as UNS_DAT beginning on page 230.

The data is transferred to the AFG using the Indefinite Length Arbitrary Block method. The example generates a 200 point +5 V to -5 V negative going ramp.

To transfer Indefinite Length Block Data to the AFG requires that the data sent with the [SOURCE:]LIST[1]:SEGMENT:VOLTAGE:DAC command must be contiguous. To do this, sent no carriage return (CR) and line feed (LF) before all the data is transferred. Also, since EOL is a data terminating string, it must not be sent before the data transfer is complete. The format in line 440 disables the CR, LF, and EOL. The LF character and EOL string sent in line 460 tells the AFG that the data transfer is complete.

```
1  !RE-STORE"DACBLOK2"
2  !This program downloads arbitrary waveform data as unsigned
3  !DAC codes. The data is sent in an IEEE-488.2 indefinite length
4  !block in 16-bit integer format. The waveform is a 200 point,
5  !+5V to -5V ramp wave.
6  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 ASSIGN @Afg1 TO 70910.;FORMAT OFF !path for binary data
40 COM @Afg,@Afg1
50 !
60 !Set up error checking
70 ON INTR 7 CALL Errmsg
80 ENABLE INTR 7;2
90 OUTPUT @Afg;"*CLS"
100 OUTPUT @Afg;"*SRE 32"
110 OUTPUT @Afg;"*ESE 60"
120 !
130 !Call the subprograms which reset the AFG and erase all waveform
140 !segments and sequences.
150 CALL Rst
160 CALL Wf_del
170 !
180 OUTPUT @Afg;"SOUR:FREQ1:FIX 200E3;"; !frequency
190 OUTPUT @Afg;":SOUR:FUNC:SHAP USER;"; !function
200 OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL 5.11875V" !amplitude
210 !
220 CALL Ramp_wave
230 !
240 OUTPUT @Afg;"SOUR:FUNC:USER RAMP_OUT" !waveform sequence
250 OUTPUT @Afg;"INIT:IMM" !wait-for-arm state
```

Continued on Next Page


```

260      !
270      WAIT .1!allow interrupt to be serviced
280      OFF INTR 7
290      END
300      !
310      SUB Ramp_wave
320 Ramp_wave: !Subprogram which defines a ramp waveform and output
330             !sequence.
340             COM @Afg,@Afg1
350             INTEGER Waveform(1:200)             !Calculate waveform points as dac codes
360             FOR I=100 TO -99 STEP -1
370                 Waveform(101-I)=((I*.050505)/.00125)+4096
380             NEXT I
390             !
400             OUTPUT @Afg;"SOUR:ARB:DAC:SOUR INT"             !dac data source
410             OUTPUT @Afg;"SOUR:ARB:DAC:FORM UNS"             !dac data format (unsigned)
420             OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL RAMP"             !segment name
430             OUTPUT @Afg;" SOUR:LIST1:SEGM:DEF 200"             !segment size
440             OUTPUT @Afg USING "#,K";"SOUR:LIST1:SEGM:VOLT:DAC #0"
450             OUTPUT @Afg1;Waveform(*)
460             OUTPUT @Afg;CHR$(10);END             !terminate with line feed (LF) and EOI
470             !
480             OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL RAMP_OUT"             !sequence name
490             OUTPUT @Afg;" SOUR:LIST1:SSEQ:DEF 1"             !sequence size
500             OUTPUT @Afg;" SOUR:LIST1:SSEQ:SEQ RAMP"             !segment order
510      SUBEND
520      !
530      SUB Rst
540 Rst: !Subprogram which resets the E1445.
550             COM @Afg,Afg1
560             OUTPUT @Afg;"*RST;*OPC?"             !reset the AFG
570             ENTER @Afg;Complete
580      SUBEND
590      !
600      SUB Wf_del
610 Wf_del: !Subprogram which deletes all sequences and segments.
620             COM @Afg,Afg1
630             OUTPUT @Afg;"FUNC:USER NONE"             !select no sequences
640             OUTPUT @Afg;"LIST:SSEQ:DEL:ALL"             !Clear sequence memory
650             OUTPUT @Afg;"LIST:SEGM:DEL:ALL"             !Clear segment memory
660      SUBEND
670      !
680      SUB Errmsg
690 Errmsg: !Subprogram which displays E1445 programming errors
700             COM @Afg,Afg1
710             DIM Message$[256]
720             !Read AFG status byte register and clear service request bit
730             B=SPOLL(@Afg)
740             !End of statement if error occurs among coupled commands
750             OUTPUT @Afg;"

```

Continued on Next Page

```
760     OUTPUT @Afg;"ABORT"                !abort output waveform
770     REPEAT
780         OUTPUT @Afg;"SYST:ERR?"        !read AFG error queue
790         ENTER @Afg;Code,Message$
800         PRINT Code,Message$
810     UNTIL Code=0
820     STOP
830 SUBEND
```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, DACBLOK2.FRM, is in directory "VBPROG" and the Visual C example program, DACBLOK2.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Using Combined Signed Data

The Combined Segment Lists transfers both the arbitrary waveform segment data and marker pulses to the AFG (see Chapter 6 for information on marker pulses). You can use either the Signed or Unsigned number format for the list.

The Combined Segment List can be sent as a comma separated list (see “Using Signed Data to Generate Waveforms” on page 225), or as Definite Length or Indefinite Length Arbitrary Block Data (see “Using Definite Length Arbitrary Blocks to Transfer Data” on page 231 and “Using Indefinite Length Arbitrary Blocks to Transfer Data” on page 235, respectively).

This section shows how to transfer the lists as DAC codes using the Signed number format.

Note The AFG can only accept a single number format at a time. Thus, if the AFG currently contains Signed data and you wish to send Unsigned data, you **MUST** delete the data in memory first before enabling the AFG to receive Unsigned data.

Combined Segment List Format

Refer to Figure 7-1 for the 16-bit Integer Combined Segment List. Bit 1 (bit value 2) sets the marker pulse. Bits 3 to 15 are the DAC codes.

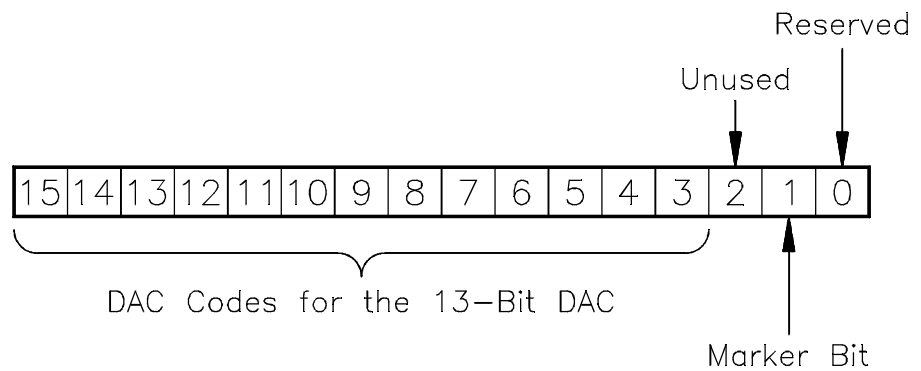


Figure 7-1. Combined List Format

Using the Combined List with the Signed Number Format

This section shows how to setup the AFG to receive a combined list in the Signed number format and how to generate the list from voltage values.

Transferring the List in the Signed Number Format

With the AFG set to receive codes in the Signed number format, it receives the codes in 16-bit two's complement numbers. Use the [SOURce:]ARbitrary:DAC:FORMat SIGNed command to select the format.

Determining Codes in the Signed Number Format

For outputs into matched loads and with the amplitude set to maximum (+5.11875V), the following codes generate the following outputs:

Code **0** outputs 0 V

Code **-32768** outputs -5.12 V or negative full scale voltage

Code **+32760** outputs +5.11875 V or positive full scale voltage

To calculate combined DAC codes from voltage values, use the formula:

$$\text{Code} = (\text{voltage value} / .00125) \text{ shift left by } 3$$

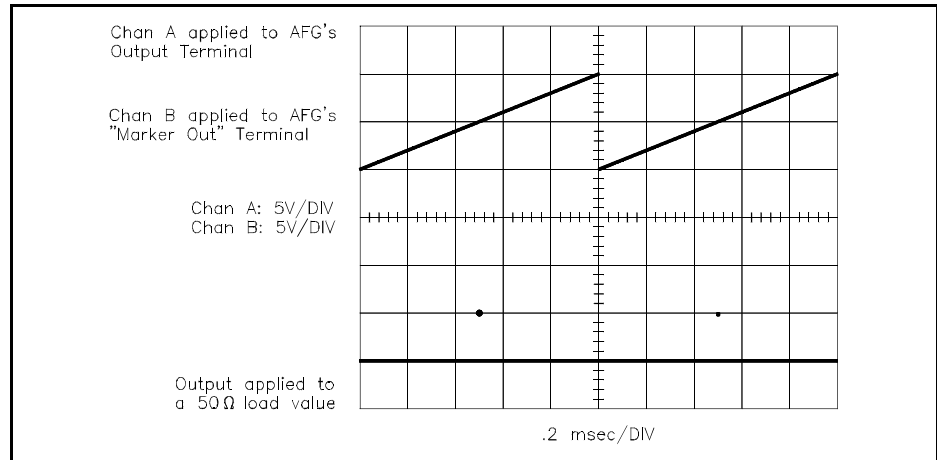
For example, to output -2V:

$$\text{DAC Code} = (-2 / .00125) \text{ shift left by } 3 = -12800$$

To output a marker at a particular point of a waveform, add "2" to the combined list DAC code value of the point. For example, to add a marker bit of a point with a voltage value of 5 V:

$$\text{Code} = ((5 / .00125) \text{ shift left by } 3) + 2 = 32000 + 2 = 32002$$

The COMBSIGN program shows how to store a combined list (i.e., points and/or marker bit of an arbitrary waveform) into the AFG's segment memory. The list is stored in the Signed number format. The data is transferred to the AFG using the Definite Length Arbitrary Block Data method. The example generates a 200 point -5 V to +5 V positive going ramp. A marker is output at the zero crossing (or center) of the ramp.



The commands are:

1. **Reset the AFG**

*RST

2. **Clear the AFG Memory of All Sequence and Segment Data**

[SOURCE:]LIST[1]:SSEquence:DELEte:ALL

[SOURCE:]LIST[1]:SEGMent:DELEte:ALL

3. **Setup the AFG for Output**

[SOURCE:]FREQuency[1][:CW | :FIXed] <frequency>

[SOURCE:]FUNCTion[:SHAPE] USER

[SOURCE:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude] <amplitude>

4. **Select the DAC Data Source**

[SOURCE:]ARBitrary:DAC:SOURce INTernal

This command selects the source that transfers data to the DAC

(see "DAC Sources" on page 280). Use INTernal to transfer the data

using the [SOURCE:]LIST[1] subsystem.

5. **Select the DAC Data Format**

[SOURCE:]ARBitrary:DAC:FORMat SIGNed

This command selects the SIGNed data number format.

6. Set the Marker Output Source

```
[SOURce:]MARKer:FEED "[SOURce:]LIST[1]"
```

This command selects the LIST[1] source as the source that outputs a marker pulse at the "Marker Out" front panel terminals (see Chapter 6 for information on other sources).

7. Setup the Waveform Segment

```
[SOURce:]LIST[1]:SEGMENT:SElect <name>
```

```
[SOURce:]LIST[1]:SEGMENT:DEFine <length>
```

8. Store the Waveform Segment as Combined Signed DAC Data

```
[SOURce:]LIST[1]:SEGMENT:COMBined <combined_list>
```

This command stores the waveform segment into segment memory in the Signed format set by the [SOURce:]ARbitrary:DAC:FORMat SIGNed command. The data is sent as a combined list with the marker bit selected.

9. Setup the Sequence and Generate Output

```
[SOURce:]LIST[1]:SSEquence:SElect <name>
```

```
[SOURce:]LIST[1]:SSEquence:DEFine <length>
```

```
[SOURce:]LIST[1]:SSEquence:SEquence <segment_list>
```

```
[SOURce:]FUNCtion:USER <name>
```

```
INITiate[:IMMEDIATE]
```

HP BASIC Program Example (COMBSIGN)

```
1  IRE-STORE"COMBSIGN"
2  !This program downloads an arbitrary waveform as a combined
3  !(voltage and marker) list of signed (2's complement) DAC codes.
4  !The data is sent in an IEEE-488.2 definite length block in 16-bit
5  !integer format. The waveform is a 200 point, -5V to +5V ramp wave.
6  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 ASSIGN @Afg1 TO 70910;FORMAT OFF           !path for binary data
40 COM @Afg,@Afg1
50 !
60 !Set up error checking
70 ON INTR 7 CALL Errmsg
80 ENABLE INTR 7;2
90 OUTPUT @Afg;"*CLS"
100 OUTPUT @Afg;"*SRE 32"
110 OUTPUT @Afg;"*ESE 60"
120 !
130 !Call the subprograms which reset the AFG and erase all waveform
140 !segments and sequences.
150 CALL Rst
```

Continued on Next Page

```

160 CALL Wf_del
170 !
180 OUTPUT @Afg;"SOUR:FREQ1:FIX 200E3;"; !frequency
190 OUTPUT @Afg;":SOUR:FUNC:SHAP USER;"; !function
200 OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL 5.11875V" !amplitude
210 !
220 CALL Ramp_wave
230 !
240 OUTPUT @Afg;"SOUR:FUNC:USER RAMP_OUT" !waveform sequence
250 OUTPUT @Afg;"INIT:IMM" !wait-for-arm state
260 !
270 WAIT .1!allow interrupt to be serviced
280 OFF INTR 7
290 END
300 !
310 SUB Ramp_wave
320 Ramp_wave: !Subprogram which defines a ramp waveform and output
330 !sequence.
340 COM @Afg,@Afg1
350 INTEGER Waveform(1:200) !Calculate waveform points as dac codes
360 FOR I=-100 TO 99
370 IF I=0 THEN
380 Waveform(I+101)=0+2 !set marker bit with this amplitude point
390 ELSE
400 Waveform(I+101)=(I*.050505)/.00125
410 !shift bits to dac code positions
420 Waveform(I+101)=SHIFT(Waveform(I+101),-3)
430 END IF
440 NEXT I
450 !
460 OUTPUT @Afg;"SOUR:ARB:DAC:SOUR INT" !dac data source
470 OUTPUT @Afg;"SOUR:ARB:DAC:FORM SIGN" !dac data format (signed)
480 !output marker as defined by segment list
490 OUTPUT @Afg;"SOUR:MARK:FEED ""SOUR:LIST1""
500 OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL RAMP" !segment name
510 OUTPUT @Afg;" SOUR:LIST1:SEGM:DEF 200" !segment size
520 OUTPUT @Afg USING "#,K";"SOUR:LIST1:SEGM:COMB #3402"
530 OUTPUT @Afg1;Waveform(*) !400 bytes: 3 digits (2 bytes/ampl point)
540 OUTPUT @Afg !CR LF
550 !
560 OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL RAMP_OUT" !sequence name
570 OUTPUT @Afg;" SOUR:LIST1:SSEQ:DEF 1" !sequence size
580 OUTPUT @Afg;" SOUR:LIST1:SSEQ:SEQ RAMP" !segment order
590 SUBEND
600 !
610 SUB Rst
620 Rst: !Subprogram which resets the E1445.
630 COM @Afg,Afg1
640 OUTPUT @Afg;"*RST;*OPC?" !reset the AFG
650 ENTER @Afg;Complete

```

Continued on Next Page

```

660 SUBEND
670 !
680 SUB Wf_del
690 Wf_del: !Subprogram which deletes all sequences and segments.
700 COM @Afg,Afg1
710 OUTPUT @Afg;"FUNC:USER NONE" !select no sequences
720 OUTPUT @Afg;"LIST:SSEQ:DEL:ALL" !Clear sequence memory
630 OUTPUT @Afg;"LIST:SEGM:DEL:ALL" !Clear segment memory
740 SUBEND
750 !
760 SUB Errmsg
770 Errmsg: !Subprogram which displays E1445 programming errors
780 COM @Afg,Afg1
790 DIM Message$(256)
800 !Read AFG status byte register and clear service request bit
810 B=SPOLL(@Afg)
820 !End of statement if error occurs among coupled commands
830 OUTPUT @Afg;"
840 OUTPUT @Afg;"ABORT" !abort output waveform
850 REPEAT
860 OUTPUT @Afg;"SYST:ERR?" !read AFG error queue
870 ENTER @Afg;Code,Message$
880 PRINT Code,Message$
890 UNTIL Code=0
900 STOP
910 SUBEND

```

**Visual BASIC and
Visual C/C++ Program
Versions**

The Visual BASIC example program, COMBSIGN.FRM, is in directory "VBPROG" and the Visual C example program, COMBSIGN.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

This program sends the combined list using Signed data as Definite Length Arbitrary Block Data. It is thus very similar to the SIGN_DAT program beginning on page 227 and DACBLOK1 example program beginning on page 232.

Using Combined Unsigned Data

The Combined Segment Lists transfers both the arbitrary waveform segment data and marker pulses to the AFG (see Chapter 6 for information on marker pulses). You can use either the Signed or Unsigned number format for the list.

The Combined Segment List can be sent as a comma separated list (see “Using Signed Data to Generate Waveforms” on page 225), or as Definite Length or Indefinite Length Arbitrary Block Data (see “Using Definite Length Arbitrary Blocks to Transfer Data” on page 231 and “Using Indefinite Length Arbitrary Blocks to Transfer Data” on page 235, respectively).

This section shows how to transfer the lists as DAC codes using the Unsigned number format.

Note The AFG can only accept a single number format at a time. Thus, if the AFG currently contains Signed data and you wish to send Unsigned data, you **MUST** delete the data in memory first before enabling the AFG to receive Unsigned data.

Using the Combined List with the Unsigned Number Format

This section shows how to setup the AFG to receive a combined list in the Unsigned number format and how to generate the list from voltage values.

Transferring the List in the Unsigned Number Format

With the AFG set to receive codes in the Unsigned number format, it receives the codes as unsigned or offset binary numbers. Use the `[SOURce:]ARbitrary:DAC:FORMat UNSigned` command to select the format.

Determining the Codes in the Unsigned Number Format

For outputs into matched loads and with the amplitude set to maximum (+5.11875V), the following DAC codes generate the following outputs:

Code **-32768** outputs 0 V
Code **0** outputs -5.12 V or negative full scale voltage
Code **-8** outputs +5.11875 V or positive full scale voltage

To calculate combined list codes from NEGATIVE voltage values, use the formula:

$$\text{DAC Code} = ((\text{voltage value} / .00125) \text{ shift left by } 3) + 32768$$

For example, to output -2V:

$$\text{DAC Code} = ((-2 / .00125) \text{ shift left by } 3) + 32768 = -12800 + 32768 = 19968$$

To calculate combined list codes from POSITIVE voltage values, use the formula:

$$\text{DAC Code} = ((\text{voltage value} / .00125) \text{ shift left by } 3) - 32768$$

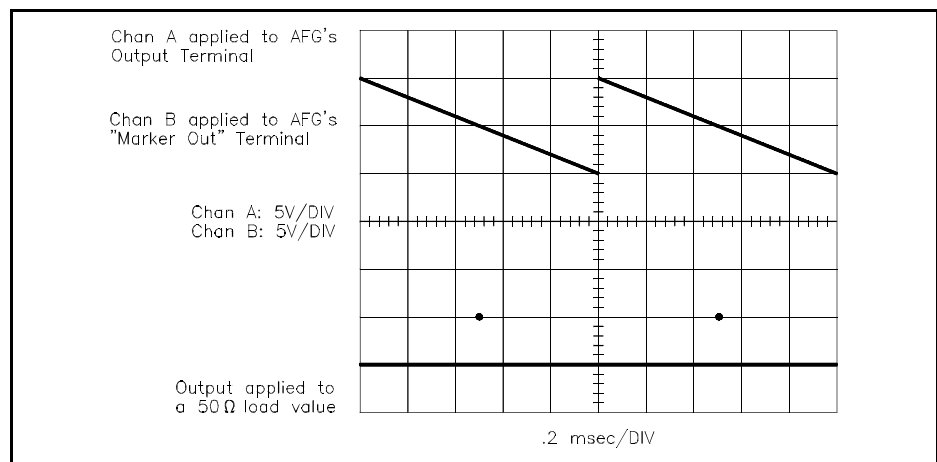
For example, to output +5V:

$$\text{DAC Code} = ((5 / .00125) \text{ shift left by } 3) - 32768 = 32000 - 32768 = -768$$

To output a marker at a particular point, add "2" to the combined list DAC code value of the point. For example, to add a marker bit of a point with a voltage value of 5 V:

$$\text{Code} = ((5 / .00125) \text{ shift left by } 3) - 32768 + 2 = 32000 - 32768 + 2 = -766$$

The COMBUNS program shows how to store a combined list (i.e., waveform segment and/or marker bit of an arbitrary waveform) into the AFG's segment memory. The list is stored in the Unsigned number format. The data is transferred to the AFG using the Indefinite Length Arbitrary Block Data method. The example generates a 200 point +5 V to -5 V negative going ramp. A marker is output at the zero crossing (or center) of the ramp.



The commands are the same ones listed on page 241, except on how to select the Unsigned format and how to generate the data. These exceptions are as follows:

5. **Select the DAC Data Format**

[SOURce:]ARbitrary:DAC:FORMat UNSigned

This command selects the UNSigned data number format.

8. **Store the Waveform Segment as Combined Signed DAC Data**

[SOURce:]LIST[1][:SEGment]:COMBined *<combined_list>*

This command stores the waveform segment into segment memory in the Unsigned format set by the

[SOURce:]ARbitrary:DAC:FORMat UNSigned command.

The data is sent as a comma separated combined list with the marker bit selected.

HP BASIC Program Example (COMBUNS)

The COMBUNS program is similar to the “COMBSIGN” program on page 242. The only differences are that this program generates and transfers the combined list using the Unsigned number format instead of the Signed format, and the list is transferred as Indefinite Length Arbitrary Block Data.

```

1  IRE-STORE"COMBUNS"
2  !This program downloads an arbitrary waveform as a combined
3  !(voltage and marker) list of unsigned DAC codes. The data is sent
4  !in an IEEE-488.2 indefinite length block in 16-bit integer format.
5  !The waveform is a 200 point, +5V to -5V ramp wave.
6  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 ASSIGN @Afg1 TO 70910;FORMAT OFF           !path for binary data
40 COM @Afg,@Afg1
50 !
60 !Set up error checking
70 ON INTR 7 CALL Errmsg
80 ENABLE INTR 7;2
90 OUTPUT @Afg;"*CLS"
100 OUTPUT @Afg;"*SRE 32"
110 OUTPUT @Afg;"*ESE 60"
120 !
130 !Call the subprograms which reset the AFG and erase all waveform
140 !segments and sequences.
150 CALL Rst
160 CALL Wf_del
170 !

```

Continued on Next Page

```

180 OUTPUT @Afg;"SOUR:FREQ1:FIX 200E3;";           !frequency
190 OUTPUT @Afg;":SOUR:FUNC:SHAP USER;";         !function
200 OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL 5.11875V" !amplitude
210 !
220 CALL Ramp_wave
230 !
240 OUTPUT @Afg;"SOUR:FUNC:USER RAMP_OUT"         !waveform sequence
250 OUTPUT @Afg;"INIT:IMM"                       !wait-for-arm state
260 !
270 WAIT .1!allow interrupt to be serviced
280 OFF INTR 7
290 END
300 !
310 SUB Ramp_wave
320 Ramp_wave: !Subprogram which defines a ramp waveform with a marker
330             !pulse and the output sequence.
340     COM @Afg,@Afg1
350     INTEGER Waveform(1:200)                   !Calculate waveform points as dac codes
360     FOR I=100 TO -99 STEP -1
370         IF I<0 THEN                            !dac codes for voltages < 0V
380             Waveform(101-I)=(I*.050505)/.00125
390             !shift bits to dac code positions
400             Waveform(101-I)=(SHIFT(Waveform(101-I),-3))+32768.
410         END IF
420         IF I=0 THEN                             !0V dac code and marker pulse
430             Waveform(101)=-32766                !set marker bit with this amplitude point
440         END IF
450         IF I>0 THEN                             !dac codes for voltages > 0V
460             Waveform(101-I)=(I*.050505)/.00125
470             !shift bits to dac code positions
480             Waveform(101-I)=(SHIFT(Waveform(101-I),-3))-32768.
490         END IF
500     NEXT I
510     !
520     OUTPUT @Afg;"SOUR:ARB:DAC:SOUR INT"         !dac data source
530     OUTPUT @Afg;"SOUR:ARB:DAC:FORM UNS"        !dac data format (unsigned)
540     OUTPUT @Afg;"SOUR:MARK:FEED ""SOUR:LIST1 """" !define marker output
550     OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL RAMP"     !segment name
560     OUTPUT @Afg;" SOUR:LIST1:SEGM:DEF 200"    !segment size
570     OUTPUT @Afg USING "#,K";"SOUR:LIST1:SEGM:COMB #0"
580     OUTPUT @Afg1;Waveform(*)                  !indefinite length block
590     OUTPUT @Afg;CHR$(10);END                  !terminate with line feed (LF) and EOI
600     !
610     OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL RAMP_OUT" !sequence name
620     OUTPUT @Afg;" SOUR:LIST1:SSEQ:DEF 1"      !sequence size
630     OUTPUT @Afg;" SOUR:LIST1:SSEQ:SEQ RAMP"   !segment order
640 SUBEND
650 !
660 SUB Rst
670 Rst: !Subprogram which resets the E1445.

```

Continued on Next Page

```

680     COM @Afg,Afg1
690     OUTPUT @Afg;"*RST;*OPC?"           !reset the AFG
700     ENTER @Afg;Complete
710     SUBEND
720     !
730     SUB Wf_del
740 Wf_del: !Subprogram which deletes all sequences and segments.
750     COM @Afg,Afg1
760     OUTPUT @Afg;"FUNC:USER NONE"       !select no sequences
770     OUTPUT @Afg;"LIST:SSEQ:DEL:ALL"    !Clear sequence memory
780     OUTPUT @Afg;"LIST:SEGM:DEL:ALL"    !Clear segment memory
790     SUBEND
800     !
810     SUB Errmsg
820 Errmsg: !Subprogram which displays E1445 programming errors
830     COM @Afg,Afg1
840     DIM Message$(256)
850     !Read AFG status byte register and clear service request bit
860     B=SPOLL(@Afg)
870     !End of statement if error occurs among coupled commands
880     OUTPUT @Afg;"
890     OUTPUT @Afg;"ABORT"                 !abort output waveform
900     REPEAT
910         OUTPUT @Afg;"SYST:ERR?"        !read AFG error queue
920         ENTER @Afg;Code,Message$
930         PRINT Code,Message$
940     UNTIL Code=0
950     STOP
960     SUBEND

```

Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, COMBUNS.FRM, is in directory "VBPROG" and the Visual C example program, COMBUNS.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

This program sends the combined list using Unsigned data as Indefinite Length Arbitrary Block Data. It is thus very similar to the UNS_DAT program beginning on page 230 and the DACBLOK2 program beginning on page 236.

Using Combined Waveform Segments and Segment Sequences

Using Combined Segment Lists and Combined Segment Sequence Lists to generate arbitrary waveforms is one of the fastest methods to download or transfer waveform segments and segment sequences to the AFG. Both can be downloaded to the AFG either as Definite Length or Indefinite Length Arbitrary Block Data.

The Combined Segment Lists transfers both the arbitrary waveform segment data and marker pulses to the AFG. The lists are sent as **16-bit Integers** in either the Signed or Unsigned number format. (See “Using Combined Signed Data” on page 239 for more information.)

The Combined Segment Sequence List selects the waveform segments, enables the marker output, and sets the repetition count for each waveform segment to be output. Each data code in a Combined Segment Sequence List is sent as a **32-bit Integer** in the Unsigned number format.

Combined Segment Sequence List Format

Figure 7-2 shows a single 32-bit integer used for a Combined Segment Sequence List. Bits 0 through 16 select the combined or regular waveform segments for output, bit 18 enables the marker output, and bits 20 through 31 sets the repetition count.

A Combined Segment Sequence List determines the order and how often a waveform segment is to be executed. Thus, each waveform segment, marker enable, and repetition count has a unique data code.

32-Bit Combined List that defines the segment lists to be executed, enables the marker, and defines the repetition count for the segment lists.

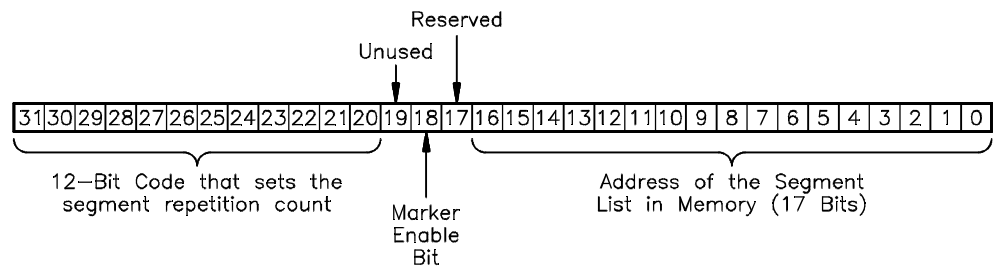


Figure 7-2. Combined Sequence List Format

Selecting the Waveform Segments

To select a waveform segment, determine the address of the waveform segment and include the address in the Combined Sequence List. Do the following to determine the address:

1. **Select the Waveform Segment**

Use the [SOURCE:]LIST[1][SEGMENT]:SElect <name> command, where <name> is the name of the waveform segment to be output.

2. **Get the Selected Waveform Segment Address**

Use the [SOURCE:]LIST[1][:SEGMENT]:ADDRESS? query command to get the address. The address is the start location of the waveform segment in segment memory.

To use the returned value in the Combined Sequence List, divide the returned value by 8. For example, if the returned value is 2048, the actual address is $2048 / 8 = 256$. This is necessary due to the hardware requirements of the AFG.

3. **Add the Address to a Data Value in the Combined Segment Sequence List**

Selecting the Marker Enable

To select the marker enable, add the value of bit 18 to the Data Byte in the Combined Segment Sequence List.

Selecting the Repetition Count

Bits 20 through 31 select the repetition count. Do the following to set the repetition count:

1. **Select the Repetition Count Value**

The repetition count bit value = $4096 - \text{desired repetition count}$.
For example, 2 repetition counts = $4096 - 2 = 4094$.

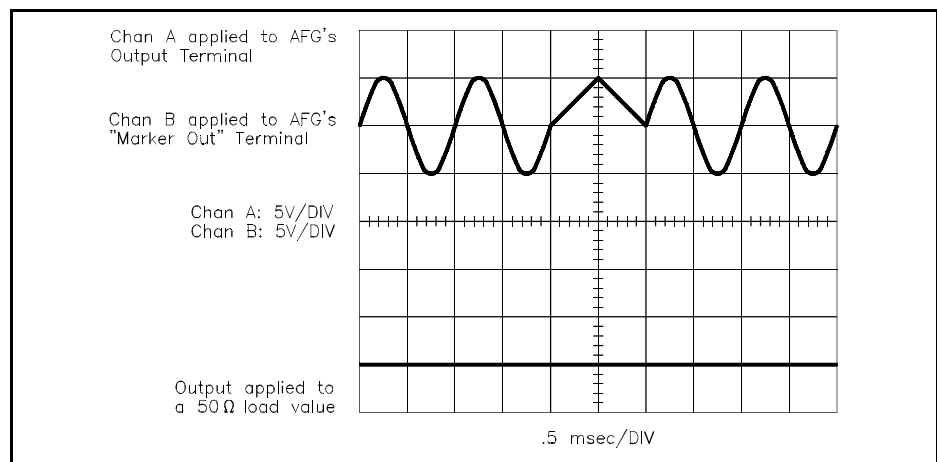
2. **Shift the Repetition Count Value left by 20**

3. **Add the Shifted Repetition Count Value to the Data Byte in the Combined Segment Sequence List**

The COMBSEQ program shows how to transfer multiple Combined Segment Lists (i.e., waveform segments and/or marker bit of an arbitrary waveform) and a Combined Sequence List (waveform segments to be executed, marker enables, and repetition counts) into the AFG's memory.

The waveform segments are transferred in the Signed number format and transferred as Definite Length Arbitrary Block Data. The segment sequence is transferred as Indefinite Length Arbitrary Block Data in the Unsigned number format.

The example generates two 5 V sine waves and a single 0 V to +5 V triangle wave. A marker is output at the center of the triangle.



The commands are:

1. **Reset the AFG**
*RST
2. **Clear the AFG Memory of All Sequence and Segment Data**
[SOURce:]LIST[1]:SSEquence:DELEte:ALL
[SOURce:]LIST[1]:SEGMENT:DELEte:ALL
3. **Setup the AFG for Output**
[SOURce:]FREQuency[1]::CW | :FIXed] <frequency>
[SOURce:]FUNctioN[:SHAPE] USER
[SOURce:]VOLTage[:LEVel]:IMMEdiate[:AMPLitude] <amplitude>
4. **Select the DAC Data Source**
[SOURce:]ARbitrary:DAC:SOURce INTERNAL
This command selects the source that transfers data to the DAC (see "DAC Sources" on page 280). Use INTERNAL to transfer the data using the [SOURce:]LIST[1] subsystem.

5. Select the DAC Data Format

[SOURce:]ARbitrary:DAC:FORMat SIGNed

This command selects the SIGNed data (or UNSigned) data format.

6. Setup the First Waveform Segment

[SOURce:]LIST[1]:SEGment:SElect <name>

[SOURce:]LIST[1]:SEGment:DEFine <length>

7. Store the First Waveform Segment as Signed Combined Data

[SOURce:]LIST[1]:SEGment:VOLTage:DAC <voltage_list>

This command stores the waveform segment into segment memory in the format set by the [SOURce:]ARbitrary:DAC:FORMat command.

The data is sent as Definite Length Arbitrary Block Data (can also be sent as Indefinite Length Arbitrary Block Data).

8. Setup the Second Waveform Segment

[SOURce:]LIST[1]:SEGment:SElect <name>

[SOURce:]LIST[1]:SEGment:DEFine <length>

9. Store the Second Waveform Segment as Signed Combined Data

[SOURce:]LIST[1]:SEGment:VOLTage:DAC <voltage_list>

This command stores the waveform segment and marker bit into segment memory in the Signed format set by the

[SOURce:]ARbitrary:DAC:FORMat SIGNed command. The data is

sent as Definite Length Arbitrary Block Data (can also be sent as

Indefinite Length Arbitrary Block Data). In this example, the marker bit is set at the center of the triangle.

10. Select the First Waveform Segment and Return its Address

[SOURce:]LIST[1]:SEGment:SElect <name>

[SOURce:]LIST[1]:SEGment:ADDRess?

These commands selects the first waveform segment and then returns the address. Divide the address by 8 and store it into the first element of the 32-bit Integer data array that is used to transfer the sequence list to the AFG.

11. Add the First Waveform Segment's Repetition Count

Add the repetition count (number of times the waveform segment is to be executed) of the first waveform segment to the value in the first element of the data array.

12. Select the Second Waveform Segment and Return its Address

[SOURce:]LIST[1]:SEGment:SElect <name>

[SOURce:]LIST[1]:SEGment:ADDRess?

These commands selects the second waveform segment and then returns the address. Divide the address by 8 and store it into the second element of the data array.

13. **Add the Marker Enable**
Add the value of the marker enable bit of the second waveform segment to the value in the second element of the data array.
14. **Add the Second Waveform Segment's Repetition Count**
Add the repetition count (number of times the waveform segment is to be executed) of the second waveform segment to the value in the second element of the data array.
15. **Setup the Sequence List**
[SOURce:]LIST[1]:SSEquence:SElect <name>
[SOURce:]LIST[1]:SSEquence:DEFine <length>
16. **Store the Segment Sequence as Unsigned Combined Data**
[SOURce:]LIST[1]:SSEquence:COMBined <combined_list>
This command stores the segment sequence in the data array into sequence memory. The list is in the Unsigned format and sent as Indefinite Length Arbitrary Block Data (can also be sent as Definite Length Arbitrary Block Data).
17. **Generate the Output**
[SOURce:]FUNction:USER <name>
INITiate[:IMMEDIATE]

HP BASIC Program Example (COMBSEQ)

Sending the Combined Segment Lists is similar to the other HP BASIC programs in this chapter. However, since HP BASIC does not support 32-Bit Integer variables, sending a Combined Segment Sequence List is done differently.

How HP BASIC Transfers 32-Bit Integer Data

The Combined Segment Sequence List must be treated in HP BASIC as 2, 16-Bit Integers. The first integer contains the repetition count, marker enable, and the most significant bit (MSB) of and the segment address. The second bit contains the rest of the segment address. For example, Figure 7-3 shows two 16-Bit Integers for a combined sequence that contains a waveform segment with an address of 256, the marker enable bit set, and 2 repetition counts.

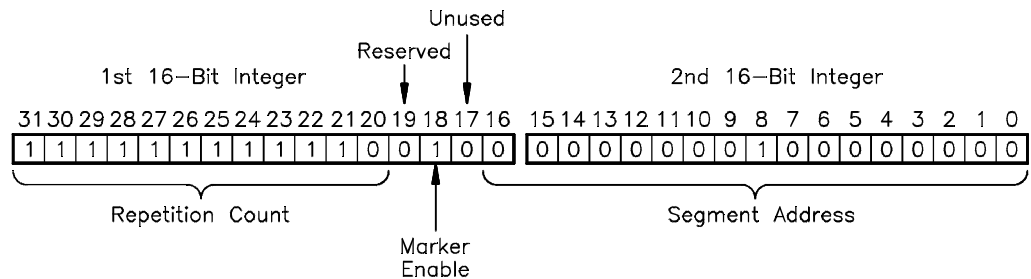


Figure 7-3. Sending 32-Bit Integers in HP BASIC

HP BASIC determines the value for the first integer as follows:

$$\text{Repetition Count/Marker} = (\text{SHIFT}(4096 - \langle \text{repetition count} \rangle, -4) + \langle \text{segment address} \rangle \text{ DIV } 65536) + 4$$

HP BASIC determines the value for the second integer as follows:

$$\text{Segment Address} = \langle \text{segment address} \rangle \text{ MOD } 65536 - 65536 * (\langle \text{segment address} \rangle \text{ MOD } 65536 > 32767)$$

DIV returns the integer portion of the Dividend. MOD returns the remainder of the division.

```

1  !RE-STORE"COMBSEQ"
2  !This program downloads two arbitrary waveforms as combined lists
3  !(voltage and marker) of signed (2's complement) DAC codes. The
4  !lists are downloaded in definite length arbitrary blocks. The
5  !output sequence is a combined list (repetition count, marker, and
6  !waveform segment address) downloaded in an indefinite length
7  !arbitrary block.
8  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 70910
30 ASSIGN @Afg1 TO 70910;FORMAT OFF          !path for binary (block) data

```

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```

40  COM @Afg,@Afg1
50  !
60  !Set up error checking
70  ON INTR 7 CALL Errmsg
80  ENABLE INTR 7;2
90  OUTPUT @Afg;"*CLS"
100 OUTPUT @Afg;"*SRE 32"
110 OUTPUT @Afg;"*ESE 60"
120 !
130 !Call the subprograms
140 CALL Rst
150 CALL Wf_del
160 !
170 OUTPUT @Afg;"SOUR:FREQ1:FIX 2.048E6;";           !frequency
180 OUTPUT @Afg;"SOUR:FUNC:SHAP USER;";           !function
190 OUTPUT @Afg;"SOUR:VOLT:LEV:IMM:AMPL 5.11875V"  !amplitude
200 OUTPUT @Afg;"SOUR:ARB:DAC:SOUR INT"           !dac data source
210 OUTPUT @Afg;"SOUR:ARB:DAC:FORM SIGN"         !dac data format (signed)
220 !
230 CALL Sine_wave
240 CALL Tri_wave
250 CALL Seq_list
260 !
270 OUTPUT @Afg;"SOUR:FUNC:USER M_OUT"           !waveform sequence
280 OUTPUT @Afg;"INIT:IMM"                       !wait-for-arm state
290 !
300 WAIT .1!allow interrupt to be serviced
310 OFF INTR 7
320 END
330 !
340 SUB Sine_wave
350 Sine_wave: !Subprogram which computes a sine wave and downloads
360             !the corresponding dac codes as signed numbers (in a
370             !definite length block) to segment memory. A combined list
380             !is used but no marker pulse is specified.
390  COM @Afg,@Afg1
400  INTEGER Waveform(1:2048)                   !Calculate sine wave (dac codes)
410  FOR I=1 TO 2048
420    Waveform(I)=5.*(SIN(2.*PI*(I/2048.)))/.00125
430    Waveform(I)=SHIFT(Waveform(I),-3)       !shift bits to dac code positions
440  NEXT I
450  !
460  OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL M1"       !segment name
470  OUTPUT @Afg;" SOUR:LIST1:SEGM:DEF 2048"   !segment size
480  OUTPUT @Afg USING "#,K";"SOUR:LIST1:SEGM:COMB #44096"
490  OUTPUT @Afg1;Waveform(*)                 !4096 bytes: 4 digits (2 bytes/ampl point)
500  OUTPUT @Afg                               !CR LF
510  SUBEND
520  !
530  SUB Tri_wave

```

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```

540 Tri_wave: !Subprogram which computes a triangle wave and downloads
550           !the corresponding dac codes as signed numbers (in a
560           !definite length block) to segment memory. Marker pulses
570           !coincide with the output voltages of Waveform(1024)
580           !through Waveform(1033).
590   COM @Afg,@Afg1
600   INTEGER Waveform(1:2048)           !Calculate triangle wave (dac codes)
610   FOR I=1 TO 1023
620     Waveform(I)=*.0048828/.00125
630     Waveform(I)=SHIFT(Waveform(I),-3)           !shift bits to code positions
640   NEXT I
650   FOR I=1024 TO 1033
660     Waveform(I)=*.0048828/.00125
670     Waveform(I)=(SHIFT(Waveform(I),-3))+2       !shift bits, set marker bit
680   NEXT I
690   FOR I=1034 TO 2048
700     Waveform(I)=(2048-I)*.0048828/.00125
710     Waveform(I)=SHIFT(Waveform(I),-3)           !shift bits to code positions
720   NEXT I
730   !
740   !Output marker as defined by segment and sequence list
750   OUTPUT @Afg;"SOUR:MARK:FEED ""SOUR:LIST1""
760   OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL M2"           !segment name
770   OUTPUT @Afg;" SOUR:LIST1:SEGM:DEF 2048"       !segment size
780   OUTPUT @Afg USING "#,K";"SOUR:LIST1:SEGM:COMB #44096"
790   OUTPUT @Afg1;Waveform(*)           !4096 bytes: 4 digits (2 bytes/ampl point)
800   OUTPUT @Afg           !CR LF
810   SUBEND
820   !
830   SUB Seq_list
840   Seq_list: !This subprogram downloads the sequence list as a combined
850             !(repetition count, marker, segment address) list in an
860             !indefinite length arbitrary block.
870   INTEGER Sequence(1:2,1:2)
880   REAL Addr1,Addr2
890   COM @Afg,@Afg1
900   OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL M1"           !determine segment address
910   OUTPUT @Afg;"SOUR:LIST1:SEGM:ADDR?"
920   ENTER @Afg;Addr1
930   Addr1=Addr1/4           ! /4 to set starting address (boundary) of segment
940   !
950   !Sequence (1,1) is the repetition count and marker enable for
960   !segment M1. Sequence (1,2) is the starting address of segment M1.
970   Sequence(1,1)=SHIFT(4096-2,-4)+Addr1 DIV 65536
980   Sequence(1,2)=Addr1 MOD 65536-65536*(Addr1 MOD 65536>32767)
990   !
1000  OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL M2"           !determine segment address
1010  OUTPUT @Afg;"SOUR:LIST1:SEGM:ADDR?"
1020  ENTER @Afg;Addr2
1030  Addr2=Addr2/4           ! /4 to set starting address (boundary) of segment

```

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```

1040      !
1050      !Sequence (2,1) is the repetition count and marker enable for
1060      !segment M2. Sequence (2,2) is the starting address of segment M2.
1070      Sequence(2,1)=(SHIFT(4096-1,-4)+Addrm2 DIV 65536)+4 !enable marker
1080      Sequence(2,2)=Addrm2 MOD 65536-65536*(Addrm2 MOD 65536>32767)
1090      !
1100      OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL M_OUT"          !sequence name
1110      OUTPUT @Afg;"SOUR:LIST1:SSEQ:DEF 2"            !segments in sequence
1120      OUTPUT @Afg USING "#,K";"SOUR:LIST1:SSEQ:COMB #0"
1130      OUTPUT @Afg1;Sequence(*)                      !sequence list in indefinite length block
1140      OUTPUT @Afg;CHR$(10);END                      !terminate with Line Feed (LF) and EOI
1150      SUBEND
1160      !
1170      SUB Rst
1180      Rst: !Subprogram which resets the E1445.
1190      COM @Afg,Afg1
1200      OUTPUT @Afg;"*RST;*OPC?"                      !reset the AFG
1210      ENTER @Afg;Complete
1220      SUBEND
1230      !
1240      SUB Wf_del
1250      Wf_del: !Subprogram which deletes all sequences and segments.
1260      COM @Afg,Afg1
1270      OUTPUT @Afg;"FUNC:USER NONE"                  !select no sequences
1280      OUTPUT @Afg;"LIST:SSEQ:DEL:ALL"              !Clear sequence memory
1290      OUTPUT @Afg;"LIST:SEGM:DEL:ALL"             !Clear segment memory
1300      SUBEND
1310      !
1320      SUB Errmsg
1330      Errmsg: !Subprogram which displays E1445 programming errors
1340      COM @Afg,Afg1
1350      DIM Message$(256)
1360      !Read AFG status byte register and clear service request bit
1370      B=SPOLL(@Afg)
1380      !End of statement if error occurs among coupled commands
1390      OUTPUT @Afg;"
1400      OUTPUT @Afg;"ABORT"                            !abort output waveform
1410      REPEAT
1420      OUTPUT @Afg;"SYST:ERR?"                      !read AFG error queue
1430      ENTER @Afg;Code,Message$
1440      PRINT Code,Message$
1450      UNTIL Code=0
1460      STOP
1470      SUBEND

```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, COMBSEQ.FRM, is in directory "VBPROG" and the Visual C example program, COMBSEQ.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Using the VXIbus Backplane

You can use the VXIbus backplane to download or transfer segment and sequence data to the AFG, and to set the phase modulation angle.

Downloading Segment Data

There are two ways to use the VXIbus backplane to download the data:

- downloading the list into memory to be executed later
- downloading directly to the DAC for immediate execution

Downloading Segment Data into Memory

Download a Combined Segment List and a Combined Sequence List into memory using the requirements in this section.

Combined Waveform Segment List Format

Figure 7-4 shows a single 16-bit integer used to download a Combined Waveform Segment List. Bits 3 through 15 are the DAC codes for the waveform voltage values, bit 1 is the marker bit, and bit 0 the last point.

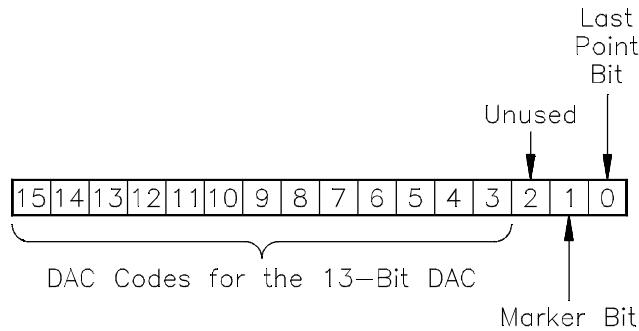


Figure 7-4. Combined List Format for Downloading

- Store the list either as Signed or Unsigned Combined Segment Lists into memory. Use either Definite Length or Indefinite Length Arbitrary Block Data to store the data. The list uses a 16-bit word for each point of the waveform segment.
- Download the segment data directly into the AFG's High Speed Data Register. The data must go to the register address with a 38 decimal (26 hex) offset in the AFG's A24 address space.
- Be sure to set the last point bit (bit 0) in the list. This indicates to the AFG that all the segment data has been transferred. Set the bit at the third-to-last point of the waveform segments (the actual last point = -3). For example, for a Combined list with a size of 2048, set the bit at point number $2048 - 3 = 2045$.

Combined Segment Sequence List Format

Figure 7-5 shows a single 32-bit integer used to download a Combined Segment Sequence List. Bits 0 through 16 select the combined waveform segments for output, bit 18 enables the marker output, and bits 20 through 31 sets the repetition count.

32-bit combined list that defines the segment lists to be executed, enables the marker, enables the last point, and defines the repetition count for the segment lists.

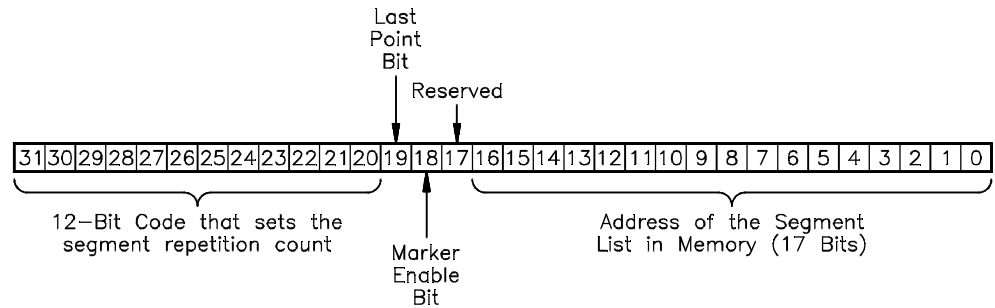


Figure 7-5. Combined Sequence List Format

- A Combined Segment Sequence List determines the order and how often a waveform segment is to be executed. Thus, each waveform segment, marker enable, and repetition count has a unique data code.
- Select the combined waveform segments using their starting addresses in memory. Add the address to the Combined Segment Sequence List.
- Set bit 18 to enable the marker output for a segment sequence. Add the bit value to the Combined Segment Sequence List.
- Determine the repetition count using: $4096 - \text{the repetition count value}$. Add the repetition count to the Combined Segment Sequence List.
- Store the list as a 32-bit wide value for each waveform segment in the list. Send the value as two 16-bit words with the most significant bit (MSB) sent first. Download the word with the most significant bit into the AFG's Sequence Register with a 34 decimal (22 hex) offset in the AFG's A24 address space. Download the word with the least significant bit into the AFG's Sequence Register with a 36 decimal (24 hex) offset in the AFG's A24 address space (see Appendix C for information on registers).

The VXIDOWN program shows how to download multiple Combined Segment Lists (i.e., waveform segment and/or marker bit of an arbitrary waveform) and a single Combined Segment Sequence List (waveform segments to be executed, marker enables, and repetition counts) into the AFG's memory using the VXIbus backplane.

The combined segment lists are downloaded in the Signed format and as Definite Length Arbitrary Block Data.

The example generates two 5 V sine waves and a single 0 to +5 V triangle wave. A marker is output at the center of the triangle.

The commands are:

- 1. Reset the AFG**
*RST
- 2. Clear the AFG Memory of All Sequence and Segment Data**
[SOURCE:]LIST[1]:SSEQUence:DELEte:ALL
[SOURCE:]LIST[1]:SEGMENT:DELEte:ALL
- 3. Setup the AFG for Output**
[SOURCE:]FREQuency[1][:CW | :FIXed] <frequency>
[SOURCE:]FUNction[:SHAPE] USER
[SOURCE:]VOLTage[:LEVel][:IMMediate][:AMPLitude] <amplitude>
- 4. Select the DAC Data Format**
[SOURCE:]ARbitrary:DAC:FORMat SIGNed
This command selects the SIGNed (or UNSIGNed) number format.
- 5. Set the Marker Output Source**
[SOURCE:]MARKer:FEED “[SOURCE:]LIST[1]”
This command selects the LIST[1] source as the source that outputs a marker pulse at the “Marker Out” front panel terminals (see Chapter 6 for information on other sources).
- 6. Setup the First Combined Segment List**
[SOURCE:]LIST[1]:SEGMENT:SELEct <name>
[SOURCE:]LIST[1]:SEGMENT:DEFine <length>
- 7. Select the Download Source for the First Combined Segment List**
[SOURCE:]ARbitrary:DOWNload <source>,<dest>,<length>
This command selects the source used to download DAC data into segment memory (see “DAC Sources” on page 280). The <source> parameter selects the download source, <dest> contains the name of the waveform segment to be downloaded, and <length> contains the size of the waveform segment in number of points (i.e., the same size set in [SOURCE:]LIST[1]:SEGMENT:DEFine <length>).

8. Place the AFG into Hold Until All Commands are Executed

***OPC?**

This command prevents the AFG from receiving data over the VXIbus until it executes all the previous commands. If *OPC? is not sent, the AFG will try to receive data, and thus generate an error, even before it completes executing the previous commands.

9. Generate, Download, and Store the First Waveform Segment as a Combined Signed List

This step stores the Combined waveform segment into segment memory using the Signed number format set by the [SOURCE:]ARbitrary:DAC:FORMat SIGNed command. The command or downloading method used depends on the device that downloads the data. For example, the device may be an embedded controller. (You can also use the command module, like the HP E1406A Command Module, but at a slower data transfer rate.)

Be sure to set the last point bit at the appropriate point on the waveform.

10. Notify the AFG that Downloading is Completed

[SOURCE:]ARbitrary:DOWNload:COMplete

Send this command to the AFG after all data is downloaded.

11. Setup the Second Combined Segment List

[SOURCE:]LIST[1][:SEGment]:SElect <name>

[SOURCE:]LIST[1][:SEGment]:DEFine <length>

12. Select the Download Source for the Second Segment List

[SOURCE:]ARbitrary:DOWNload <source>,<dest>,<length>

This command selects the source used to download DAC data into segment memory (see “DAC Sources” on page 280). The <source> parameter selects the download source, <dest> contains the name of the waveform segment to be downloaded, and <length> contains the size of the waveform segment in number of points (i.e., the same size set in [SOURCE:]LIST[1][:SEGment]:DEFine <length>).

13. Place the AFG Into Hold Until All Commands are Executed

***OPC?**

This command prevents the AFG from receiving data over the VXIbus until it executes all the previous commands. If *OPC? is not sent, the AFG will try to receive data, and thus generate an error, even before it completes executing the previous commands.

14. Generate, Download, and Store the Second Waveform Segment as a Combined Signed List

This step stores the Combined waveform segment into segment memory using the Signed number format set by the [SOURCE:]ARbitrary:DAC:FORMat SIGNed command. The command or downloading method used depends on the device that downloads the data. For example, the device may be an embedded

controller. (You can also use the command module, like the HP E1406A Command Module, but at a slower data transfer rate.)

Be sure to set the last point bit and marker bits at the appropriate points on the waveform.

15. Notify the AFG that Downloading is Completed

[SOURce:]ARbitrary:DOWNload:COMplete

Send this command to the AFG after all data is downloaded.

16. Select the First Waveform Segment and Return its Address

[SOURce:]LIST[1]:SEGment:SElect <name>

[SOURce:]LIST[1]:SEGment:ADDRess?

These commands select the first waveform segment and then returns its address. Divide the address by 8; store it into the second element of the first 16-bit word array. Add the most significant bit of the segment address to the first element of the first 16-bit word array.

17. Add the First Segment List's Repetition Count

Add the repetition count (number of times the waveform segment is to be executed) of the first element of the first 16-bit word array.

18. Select the Second Waveform Segment and Return its Address

[SOURce:]LIST[1]:SEGment:SElect <name>

[SOURce:]LIST[1]:SEGment:ADDRess?

These commands select the second waveform segment and then returns its address. Divide the address by 8; store it into the second element of the second 16-bit word array. Add the most significant bit of the segment address to the first element of the second 16-bit word array.

19. Add the Marker Enable

Add the value of the marker enable bit of the second waveform segment to the value in the first element of the second 16-bit word array.

20. Add the Second Segment List's Repetition Count

Add the repetition count (number of times the waveform segment is to be executed) of the first element of the second 16-bit word array.

21. Add the Last Point

Add the value of the last point bit to the first element of the second 16-bit word array.

22. Setup the Sequence List

[SOURce:]LIST[1]:SSEquence:SElect <name>

[SOURce:]LIST[1]:SSEquence:DEFine <length>

23. Select the Download Source for the Segment Sequence List

[SOURce:]ARbitrary:DOWNload <source>,<dest>,<length>

This command selects the source used to download DAC data into segment sequence memory (see "DAC Sources" on page 280). The <source> parameter selects the download source, <dest> contains the

name of the segment sequence list to be downloaded, and *<length>* contains the size of the segment sequence list in number of segment lists (i.e., the same size set in [SOURCE:]LIST[1]:SSEQUENCE:DEFine *<length>*).

24. Place the AFG into Hold Until All Commands are Executed

*OPC?

This command prevents the AFG from receiving data over the VXIbus until it executes all the previous commands. If *OPC? is not sent, the AFG will try to receive data, and thus generate an error, even before it completes executing the previous commands.

25. Download and Store the Segment Sequence List as a Combined List

This step stores the segment sequence list into memory. The command or downloading method used depends on the device that downloads the data. For example, the device may be an embedded controller. (You can also use the command module, like the HP E1406A Command Module, but at a slower data transfer rate.)

26. Notify the AFG that Downloading is Completed

[SOURCE:]ARbitrary:DOWNload:COMplete

Send this command to the AFG after all data is downloaded.

27. Generate the Output

INITiate[:IMMediate]

HP BASIC Program Example (VXIDOWN)

This program is similar to the COMBSEQ program beginning on page 255, except on how the data is transferred to the AFG. The program uses a V360 Controller to download the data using the VXIbus instead of transferring it directly to the AFG using HP-IB.

```
1  IRE-STORE"VXIDOWN"
2  !This program downloads two arbitrary waveforms from the VXIbus
3  !backplane. The program loads segment memory by writing to the
4  !AFG's high-speed data register, and loads sequence memory by
5  !writing to the Sequence register. The program is written for a
6  !HP E1480 V/360 embedded controller, which allows direct access to
7  !the registers via the VXIbus.
8  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 1680
30 COM @Afg,Base_addr
40 !
50 !Set up error checking for the SCPI commands.
60 ON INTR 16 CALL Errmsg
70 ENABLE INTR 16;32
80 OUTPUT @Afg;"*CLS"
```

Continued on Next Page

```

90   OUTPUT @Afg;"*SRE 32"
100  OUTPUT @Afg;"*ESE 60"
110  !
120  !Call the subprograms
130  CALL Rst
140  CALL Wf_del
150  CALL A24_offset
160  !
170  OUTPUT @Afg;"SOUR:FREQ1:FIX 2.048E6;";           !frequency
180  OUTPUT @Afg;":SOUR:FUNC:SHAP USER;";           !function
190  OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL 5.11875V"  !amplitude
200  OUTPUT @Afg;"SOUR:ARB:DAC:FORM SIGN"           !dac data format (signed)
210  OUTPUT @Afg;"SOUR:MARK:FEED ""SOUR:LIST1""      !marker pulse source
220  !
230  CALL Sine_wave
240  CALL Tri_wave
250  CALL Seq_list
260  !
270  OUTPUT @Afg;"SOUR:FUNC:USER WAVE_OUT"          !waveform sequence
280  OUTPUT @Afg;"INIT:IMM"                          !wait-for-arm state
290  !
300  WAIT .1 !allow interrupt to be serviced
310  OFF INTR 16
320  END
330  !
340  SUB Sine_wave
350  Sine_wave: !Subprogram which computes a sine wave and downloads
360             !the corresponding dac codes to segment memory over the
370             !VXIbus. A combined list is used but no marker pulse is
380             !specified.
390             COM @Afg,Base_addr
400             CONTROL 16,25;3 !access A24 space with WRITEIO
410             OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL SINE" !segment name
420             OUTPUT @Afg;"SOUR:LIST1:SEGM:DEF 2048" !segment size
430             !
440             INTEGER Waveform(1:2048)
450             !Calculate sine wave (dac codes) and shift bits to dac code positions
460             FOR I=1 TO 2048
470                 Waveform(I)=5.*(SIN(2.*PI*(I/2048.)))/.00125
480                 Waveform(I)=SHIFT(Waveform(I),-3)
490             NEXT I
500             !Set last point bit (actual last point - 3)
510             Waveform(2045)=Waveform(2045)+1
520             !
530             !Enable downloading from the VXIbus
540             OUTPUT @Afg;"ARB:DOWN VXI,SINE,2048"
550             OUTPUT @Afg;"*OPC?"
560             ENTER @Afg;Ready
570             !

```

Continued on Next Page

```

580      !Download the waveform segment to segment memory using WRITEIO and
590      !the AFG's high-speed data register. The register's address is
600      !located in A24 address space.
610      FOR I=1 TO 2048
620          WRITEIO -16,Base_addr+IVAL("26",16);Waveform(I)
630          NEXT I
640      OUTPUT @Afg;"SOUR:ARB:DOWN:COMP"          !disable downloading
650  SUBEND
660  !
670  SUB Tri_wave
680 Tri_wave: !Subprogram which computes a triangle wave and downloads
690           !the corresponding dac codes to segment memory over the
700           !VXIbus. Marker pulses coincide with the output voltages
710           !Waveform(1024) through Waveform(1033).
720      COM @Afg,Base_addr
730      CONTROL 16,25;3      !access A24 space with WRITEIO
740      OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL TRI"      !segment name
750      OUTPUT @Afg;" SOUR:LIST1:SEGM:DEF 2048"    !segment size
760      !
770      !Calculate triangle wave (dac codes) and shift bits to code positions
780      INTEGER Waveform(1:2048)
790      FOR I=1 TO 1023
800          Waveform(I)=*.0048828/.00125
810          Waveform(I)=SHIFT(Waveform(I),-3)
820      NEXT I
830      FOR I=1024 TO 1033
840          Waveform(I)=I*.0048828/.00125
850          Waveform(I)=SHIFT(Waveform(I),-3)+2    !include marker bit
860      NEXT I
870      FOR I=1034 TO 2048
880          Waveform(I)=(2048-I)*.0048828/.00125
890          Waveform(I)=SHIFT(Waveform(I),-3)
900      NEXT I
910      !
920      !Set last point bit (actual last point - 3)
930      Waveform(2045)=Waveform(2045)+1
940      !
950      !Enable downloading from the VXIbus
960      OUTPUT @Afg;"ARB:DOWN VXI,TRI,2048"
970      OUTPUT @Afg;"*OPC?"
980      ENTER @Afg;Ready
990      !
1000     !Download the waveform segment to segment memory using WRITEIO and
1010     !the AFG's high-speed data register. The register's address is
1020     !located in A24 address space.
1030     FOR I=1 TO 2048
1040         WRITEIO -16,Base_addr+IVAL("26",16);Waveform(I)
1050         NEXT I
1060     OUTPUT @Afg;"SOUR:ARB:DOWN:COMP"          !disable downloading
1070  SUBEND

```

Continued on Next Page

```

1080  !
1090  SUB Seq_list
1100 Seq_list: !This subprogram downloads the sequence list (repetition
1110             !count, marker, segment address) to sequence memory over
1120             !the VXIbus.
1130     INTEGER Sequence(1:2,1:2)
1140     REAL Addr1,Addr2
1150     COM @Afg,Base_addr
1160     CONTROL 16,25;3!access A24 space with WRITEIO
1170     OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL SINE"      !determine segment address
1180     OUTPUT @Afg;"SOUR:LIST1:SEGM:ADDR?"
1190     ENTER @Afg;Addr1
1200     Addr1=Addr1/8                               ! /8 to set starting address (boundary) of segment
1210     !
1220     !Sequence (1,1) is the repetition count and marker enable for
1230     !segment SINE. Sequence (1,2) is the starting address of segment SINE.
1240     Sequence(1,1)=(SHIFT(4096-2,-4)+Addr1 DIV 65536)
1250     Sequence(1,2)=(Addr1 MOD 65536-65536*(Addr1 MOD 65536>32767))
1260     !
1270     OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL TRI"      !determine segment address
1280     OUTPUT @Afg;"SOUR:LIST1:SEGM:ADDR?"
1290     ENTER @Afg;Addr2
1300     Addr2=Addr2/8                               ! /8 to set starting address (boundary) of segment
1310     !
1320     !Sequence (2,1) is the repetition count, marker enable, and last point
1330     !indication for the segment sequence. Sequence (2,2) is the starting
1340     !address of segment TRI.
1350     Sequence(2,1)=(SHIFT(4096-1,-4)+Addr2 DIV 65536)+12
1360     Sequence(2,2)=Addr2 MOD 65536-65536*(Addr2 MOD 65536>32767)
1370     !
1380     OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL WAVE_OUT" !sequence name
1390     OUTPUT @Afg;"SOUR:LIST1:SSEQ:DEF 2"        !segments in sequence
1400     OUTPUT @Afg;"SOUR:ARB:DOWN VXI,WAVE_OUT,2"
1410     OUTPUT @Afg;"*OPC?"
1420     ENTER @Afg;Ready
1430     !
1440     !Download the waveform sequence to sequence memory using WRITEIO
1450     !and the AFG's Sequence register. The register's address is
1460     !located in A24 address space.
1470     WRITEIO -16,Base_addr+IVAL("22",16);Sequence(1,1) !16 MS Bits
1480     WRITEIO -16,Base_addr+IVAL("24",16);Sequence(1,2) !16 LS Bits
1490     WRITEIO -16,Base_addr+IVAL("22",16);Sequence(2,1) !16 MS Bits
1500     WRITEIO -16,Base_addr+IVAL("24",16);Sequence(2,2) !16 LS Bits
1510     OUTPUT @Afg;"SOUR:ARB:DOWN:COMP"          !disable downloading
1520  SUBEND
1530  !
1540  SUB A24_offset
1550 A24_offset:!Subprogram which determines the base address for
1560             !the AFG registers in A24 address space.
1570     COM @Afg,Base_addr

```

Continued on Next Page

```

1580     CONTROL 16,25;2           !access A16 space with READIO and WRITEIO
1590     A16_addr=DVAL("D400",16) !AFG A16 base address
1600     Offset=READIO(-16,A16_addr+6) !read AFG offset register
1610     Base_addr=Offset*256       !shift offset for 24-bit address
1620 SUBEND
1630 !
1640 SUB Rst
1650 Rst: !Subprogram which resets the E1445.
1660     COM @Afg,Base_addr
1670     OUTPUT @Afg;"*RST;*OPC?"           !reset the AFG
1680     ENTER @Afg;Complete
1690 SUBEND
1700 !
1710 SUB Wf_del
1720 Wf_del: !Subprogram which deletes all sequences and segments.
1730     COM @Afg,Base_addr
1740     OUTPUT @Afg;"FUNC:USER NONE"       !select no sequences
1750     OUTPUT @Afg;"LIST:SSEQ:DEL:ALL"    !Clear sequence memory
1760     OUTPUT @Afg;"LIST:SEGM:DEL:ALL"    !Clear segment memory
1770 SUBEND
1780 !
1790 SUB Errmsg
1800 Errmsg: !Subprogram which displays E1445 programming errors
1810     COM @Afg,Base_addr
1820     DIM Message$(256)
1830     !Read AFG status byte register and clear service request bit
1840     B=SPOLL(@Afg)
1850     !End of statement if error occurs among coupled commands
1860     OUTPUT @Afg;" "
1870     OUTPUT @Afg;"ABORT"               !abort output waveform
1880     REPEAT
1890         OUTPUT @Afg;"SYST:ERR?"       !read AFG error queue
1900         ENTER @Afg;Code,Message$
1910         PRINT Code,Message$
1920     UNTIL Code=0
1930 STOP
1940 SUBEND

```

Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, VXIDOWN.FRM, is in directory "VBPROG" and the Visual C example program, VXIDOWN.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

The above example programs use the HP E1406A Command Module to download the data into memory. However, the command module is only used to demonstrate the downloading method for those programs. A better method is to use an embedded controller. If you wish to use the HP E1406A Command Module to download data, use the method described in "Using Combined Waveform Segments and Segment Sequences" on page 250.

Downloading Data Directly into the DAC

This method disables the AFG's ARM subsystem and immediately outputs the DAC data point when received. The DAC code received by the AFG only sets the DAC to output to the received value. It thus does not disable the AFG's DAC code format, triggering, marker selection and enabling, and amplitude setting. Send the DAC codes as Combined lists.

- The lists can be downloaded either in the Signed or Unsigned number formats, and as Definite Length or Indefinite Length Arbitrary Block Data.
- Since the AFG stores no data into memory, do not set the last point bit in the list.
- Download the segment data directly into the AFG's High Speed Data Register. The data must go to the register address with a 38 decimal (26 hex) offset in the AFG's A24 address space (see Appendix C for information on registers).

The VXISRCE program shows how to download segment data directly to the DAC. The program downloads the lists using the VXIbus.

The segment lists are downloaded in the Signed number format and as Indefinite Length Arbitrary Block Data. The example generates a 0 to +5 V triangle wave. The frequency of the triangle depends on the speed at which downloading occurs. The commands are:

1. **Reset the AFG**
*RST
2. **Set the AFG's Output Amplitude**
[SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude] <amplitude>
3. **Select the DAC Data Format**
[SOURce:]ARbitrary:DAC:FORMat SIGNED
This command selects the SIGNED (or UNSIGNED) number format.
4. **Select the DAC Data Source**
[SOURce:]ARbitrary:DAC:SOURce VXI
This command selects the source that transfers data to the DAC (see "DAC Sources" on page 280). Use "VXI" to transfer data using the VXIbus.
5. **Place the AFG Into Hold Until All Commands are Executed**
*OPC?
This command prevents the AFG from receiving data over the VXIbus until it executes all the previous commands. If *OPC? is not sent, the AFG will try to receive data, and thus generate an error, even before it completes executing the previous commands.
6. **Download the Waveform Segment as a Combined Signed List**
This step directly downloads the Combined Waveform Segment List to the DAC using the Signed number format set by the

[SOURCE:]ARbitrary:DAC:FORMat SIGNed command. The downloading method used depends on the device that downloads the data. For example, the device may be an embedded controller or a command module. The AFG output depends on the data received by the DAC and the currently selected amplitude.

HP BASIC Program Example (VXISRCE)

The program uses the V360 Controller to download the data using the VXIbus instead of transferring it directly to the AFG using HP-IB.

```

1  !RE-STORE"VXISRCE"
2  !This program uses the V/360 embedded controller to send waveform
3  !data directly to the AFG dac over the VXIbus backplane.
4  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 1680
30 COM @Afg,Addr
40 !
50 !Call the subprograms which reset the AFG and determine the base
60 !address of the registers in A24 address space.
70 CALL Rst
80 CALL A24_offset
90 !
100 !Scale the amplitude, set the dac data format and dac data source.
110 OUTPUT @Afg;"SOUR:VOLT:LEV:IMM:AMPL 5.11875V"      !amplitude
120 OUTPUT @Afg;"SOUR:ARB:DAC:FORM SIGN"              !dac data format (signed)
130 OUTPUT @Afg;"SOUR:ARB:DAC:SOUR VXI"               !dac data source
140 OUTPUT @Afg;"*OPC?"                               !Wait for the SCPI commands to complete
150 ENTER @Afg;Complete
160 !
170 !Call the subprogram which sends data directly to the dac.
180 CALL Dac_drive
190 END
200 !
210 SUB A24_offset
220 A24_offset: !Subprogram which determines the base address for
230             !the AFG registers in A24 address space, then adds the
240             !offset and register number to the base to get the
250             !complete address.
260             COM @Afg,Addr
270             !CONTROL 16,25;2                       !access A16 space with READIO and WRITEIO
280             A16_addr=DVAL("D400",16)              !AFG A16 base address
290             Offset=READIO(-16,A16_addr+6)         !read AFG offset register
300             Base_addr=Offset*256                  !shift offset for 24-bit address
310             !Add the register number of the high speed data register
320             !to the A24 base address.
330             Addr=Base_addr+IVAL("26",16)
340 SUBEND

```

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```

350    !
360    SUB Dac_drive
370 Dac_drive: !Subprogram which computes a 128 point, 5 Vpp triangle wave and
380             !writes the corresponding codes directly to the DAC via
390             !the VXIbus and High Speed Data register.
400    COM @Afg,Addr
410    !CONTROL 16,25;3                               !access A24 space with WRITEIO
420    !
430    INTEGER I,Waveform(1:128)                       !Calculate triangle wave (dac codes)
440    FOR I=1 TO 64
450        Waveform(I)=*.0755/.00125
460        Waveform(I)=SHIFT(Waveform(I),-3)           !shift bits to dac code positions
470    NEXT I
480    FOR I=65 TO 128
490        Waveform(I)=(128-I)*.0755/.00125
500        Waveform(I)=SHIFT(Waveform(I),-3)           !shift bits to dac code positions
510    NEXT I
520    !
530    !Continuously write data (in 16-bit words) to the dac via the
540    !VXIbus and High Speed Data register.
550    LOOP
560        FOR I=1 TO 128
570            WRITEIO -16,Addr;Waveform(I)
580        NEXT I
590    END LOOP
600    SUBEND
610    !
620    SUB Rst
630 Rst: !Subprogram which resets the E1445.
640    COM @Afg,Addr
650    OUTPUT @Afg;"*RST;*OPC?"                       !reset the AFG
660    ENTER @Afg;Complete
670    SUBEND

```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, VXISRCE.FRM, is in directory “VBPROG” and the Visual C example program, VXISRCE.C, is in directory “VCPROG” on the CD that came with your HP E1445A.

The above example programs use the HP E1406A Command Module to download the data to the DAC. However, the command module is only used to demonstrate the downloading method for those programs. A better method is to use an embedded controller.

Using the Front Panel's "Digital Port In" Connector

You can use the "Digital Port In" connector to download data to the segment memory ([SOURce:]ARbitrary:DOWNload command), to change segment sequences without aborting the present operation, or to drive the DAC directly ([SOURce:]ARbitrary:DAC:SOURce command).

The WAVSELFP program selects three different sequences using the "Digital Port In" connector. Sequence 1 is a Sin (X)/X waveform, sequence 2 is a damped sine waveform, and sequence 3 is a sine wave with spikes waveform. The program downloads segment data as indefinite length arbitrary block data using the [SOURce:]LIST[1]:SEGMENT:COMBined command. Select the sequences as follows:

FPCLK is clocked, other data lines open – Sequence 3
FPCLK is clocked, FP000 to low – Sequence 2
FPCLK is clocked, FP001 to low – Sequence 1

HP BASIC Program Example (WAVSELFP)

```
1  !RE-STORE "WAVSELFP"
2  !This program changes the output waveform sequence once the AFG has been
3  !INITiated by writing the location of a sequence's base address to the
4  !Waveform Select register. All register reads and writes are 16 bit.
5  !The program uses the front panel 'Digital Port In' connector to
6  !change the sequences, as follows:
7  !FPCLK is clocked, other data lines open – Sequence 3
8  !FPCLK is clocked, FP000 to low – Sequence 2
9  !FPCLK is clocked, FP001 to low – Sequence 1
10 !
20 !Assign an I/O path between the computer and the AFG
30 ASSIGN @Cmd TO 80900
40 ASSIGN @Afg TO 80910
50 ASSIGN @Afg1 TO 80910;FORMAT OFF !path for binary data
60 Laddr=80 !logical address for AFG
70 COM @Cmd,@Afg,@Afg1,Base_addr,Seq1_addr,Seq2_addr,Seq3_addr
80 !
90 !Subprograms which reset the AFG and erase all existing waveforms.
100 CALL Rst
110 CALL Wf_del
120 !
130 !SCPI commands which configure the AFG
140 OUTPUT @Afg;"SOUR:FREQ1:FIX 4.096E6;"; !Sample rate
150 OUTPUT @Afg;":SOUR:FUNC:SHAP USER;"; !function
160 OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL 2.1V" !amplitude
170 OUTPUT @Afg;"SOUR:ARB:DAC:SOUR INT" !dac data source
180 OUTPUT @Afg;"SOUR:ARB:DAC:FORM SIGN" !dac data format
190 !
```

Continued on Next Page

```

200 !Subprograms which define waveforms and load them into segment
210 !and sequence memory, which determine the AFG's register locations
220 !in A24, and which configure the AFG's sequence base memory.
230 CALL Waveform_def
240 CALL A24_offset(Laddr)
250 CALL Build_ram
260 !
270 !Select an output sequence, and initiate (start) waveform output.
280 OUTPUT @Afg;"SOUR:FUNC:USER SEQ1" !waveform sequence
290 OUTPUT @Afg;"INIT:IMM" !wait-for-arm state
300 !
310 !Wait for AFG to start output
320 OUTPUT @Afg;"STAT:OPC:INIT OFF;*OPC?"
330 ENTER @Afg;A
340 !
350 !Enable FP DPORT to control sequence selection
360 OUTPUT @Cmd;"DIAG:PEEK? ";Base_addr+8;"",16"
370 ENTER @Cmd;Traffic
380 Traffic=BINIOR(BINAND(Traffic,IVAL("3FFF",16)),IVAL("4000",16))
390 OUTPUT @Cmd;"DIAG:POKE ";Base_addr+8;"",16,"";Traffic
400 END
410 !
420 SUB Waveform_def
430 COM @Cmd,@Afg,@Afg1,Base_addr,Seq1_addr,Seq2_addr,Seq3_addr
440 CALL Sinx_def
450 CALL Sind_def
460 CALL Spike_def
470 SUBEND
480 !
490 SUB A24_offset(Laddr)
500 A24_offset: !Subprogram which determines the base address for
510 !the AFG registers in A24 address space.
520 COM @Cmd,@Afg,@Afg1,Base_addr,Seq1_addr,Seq2_addr,Seq3_addr
530 OUTPUT @Cmd;"DIAG:PEEK? ";DVAL("1FC000",16)+64*Laddr+6;"",16"
540 ENTER @Cmd;Offset !AFG A24 base address
550 Base_addr=Offset*256 !shift offset for 24-bit address
560 SUBEND
570 !
580 SUB Build_ram
590 Build_ram: !This subprogram configures the AFG's sequence base memory
600 !such that there are valid sequence base addresses in memory
610 !before the AFG is INITiated and waveforms are selected.
620 COM @Cmd,@Afg,@Afg1,Base_addr,Seq1_addr,Seq2_addr,Seq3_addr
630 !
640 !Preserve Traffic register contents. Set bits 15-14 to 1 0 to set
650 !the Waveform Select register as the source which selects the output
660 !waveform sequence.
670 OUTPUT @Cmd;"DIAG:PEEK? ";Base_addr+8;"",16"
680 ENTER @Cmd;Traffic
690 Traffic=BINIOR(BINAND(Traffic,IVAL("3FFF",16)),IVAL("8000",16))

```

Continued on Next Page

```

700     OUTPUT @Cmd;"DIAG:POKE ";Base_addr+8;" ,16,";Traffic
710     !
720     !Write the location of the sequence base address (waveform index)
730     !to the Waveform Select register. Write the base address of
740     !of the sequence in sequence memory to the Sequence Base register.
750     !
760     OUTPUT @Cmd;"DIAG:POKE ";Base_addr+10;" ,8,252"
770     OUTPUT @Cmd;"DIAG:POKE ";Base_addr+32;" ,16,";Seq3_addr
780     !
790     OUTPUT @Cmd;"DIAG:POKE ";Base_addr+10;" ,8,253"
800     OUTPUT @Cmd;"DIAG:POKE ";Base_addr+32;" ,16,";Seq1_addr
810     !
820     OUTPUT @Cmd;"DIAG:POKE ";Base_addr+10;" ,8,254"
830     OUTPUT @Cmd;"DIAG:POKE ";Base_addr+32;" ,16,";Seq2_addr
840     !
850     OUTPUT @Cmd;"DIAG:POKE ";Base_addr+10;" ,8,255"
860     OUTPUT @Cmd;"DIAG:POKE ";Base_addr+32;" ,16,";Seq3_addr
870     !
880     OUTPUT @Cmd;"DIAG:POKE ";Base_addr+10;" ,8,0"
890     SUBEND
900     !
910     SUB Sinx_def
920 Sinx_def:  !Define the waveform Sin(x)/x. Download the waveform data
930             !as a combined list (voltage and marker) of signed numbers
940             !in an indefinite length block. Download the sequence as a
950             !combined list (repetition count, marker, and segment address)
960             !in an indefinite length arbitrary block.
970     COM @Cmd,@Afg,@Afg1,Base_addr,Seq1_addr,Seq2_addr,Seq3_addr
980     INTEGER Waveform(1:4096)
990     INTEGER Sequence(1:2)
1000    REAL Addr_seg1
1010    FOR I=-2047 TO 2048
1020        IF I=0 THEN I=1.E-38
1030        Waveform(I+2048)=((SIN(2*PI*.53125*I/256)))/(.53125*I/256)*.159154943092)/.00125
1040        !shift bits to dac code positions
1050        Waveform(I+2048)=SHIFT(Waveform(I+2048),-3)
1060    NEXT I
1070    !
1080    OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL SIN_X"           !segment name
1090    OUTPUT @Afg;"SOUR:LIST1:SEGM:DEF 4096"           !segment size
1100    OUTPUT @Afg USING "#,K";"SOUR:LIST1:SEGM:COMB #0" !waveform points
1110    OUTPUT @Afg1;Waveform(*)                         !indefinite length block
1120    OUTPUT @Afg;CHR$(10);END                         !terminate with line feed (LF) and EOI
1130    !
1140    OUTPUT @Afg;"SOUR:LIST1:SEGM:ADDR?"
1150    ENTER @Afg;Addr_seg1
1160    Addr_seg1=Addr_seg1/8                            ! /8 to set starting address (boundary) of segment
1170    !
1180    !Sequence (1) is the repetition count and marker enable for
1190    !segment SIN_X. Sequence (2) is the starting address of segment SIN_X.

```

Continued on Next Page

```

1200 Sequence(1)=SHIFT(4096-1,-4)+Addr_seg1 DIV 65536
1210 Sequence(2)=Addr_seg1 MOD 65536-65536*(Addr_seg1 MOD 65536.32767)
1220 !
1230 OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL SEQ1" !sequence name
1240 OUTPUT @Afg;"SOUR:LIST1:SSEQ:DEF 1" !sequence size
1250 OUTPUT @Afg USING "#,K";"SOUR:LIST1:SSEQ:COMB #0" !segment execution order
1260 OUTPUT @Afg1;Sequence(*) !sequence list in indefinite length block
1270 OUTPUT @Afg;CHR$(10);END !terminate with Line Feed (LF) and EOI
1280 !
1290 OUTPUT @Afg;"SOUR:LIST1:SSEQ:ADDR?" !sequence location
1300 ENTER @Afg;Seq1_addr
1310 SUBEND
1320 !
1330 SUB Sind_def
1340 Sind_def: !Compute the damped sine waveform. Download the data
1350 !as a combined list (voltage and marker) of signed numbers
1360 !in an indefinite length block. Download the sequence as a
1370 !combined list (repetition count, marker, and segment address)
1380 !in an indefinite length arbitrary block.
1390 COM @Cmd,@Afg,@Afg1,Base_addr,Seq1_addr,Seq2_addr,Seq3_addr
1400 INTEGER Waveform(1:4096)
1410 INTEGER Sequence(1:2)
1420 REAL Addr_seg2
1430 A=4/4096
1440 W=(2*PI)/50
1450 FOR T=1 TO 4096
1460 Waveform(T)=EXP(-A*T)*SIN(W*T)/.00125
1470 !shift bits to dac code positions
1480 Waveform(T)=SHIFT(Waveform(T),-3)
1490 NEXT T
1500 !
1510 OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL SIN_D" !segment name
1520 OUTPUT @Afg;"SOUR:LIST1:SEGM:DEF 4096" !segment size
1530 OUTPUT @Afg USING "#,K";"SOUR:LIST1:SEGM:COMB #0" !waveform points
1540 OUTPUT @Afg1;Waveform(*) !indefinite length block
1550 OUTPUT @Afg;CHR$(10);END !terminate with line feed (LF) and EOI
1560 !
1570 OUTPUT @Afg;"SOUR:LIST1:SEGM:ADDR?"
1580 ENTER @Afg;Addr_seg2
1590 Addr_seg2=Addr_seg2/8 ! /8 to set starting address (boundary) of segment
1600 !
1610 !Sequence (1) is the repetition count and marker enable for
1620 !segment SIN_D. Sequence (2) is the starting address of segment SIN_D.
1630 Sequence(1)=SHIFT(4096-1,-4)+Addr_seg1 DIV 65536
1640 Sequence(2)=Addr_seg2 MOD 65536-65536*(Addr_seg2 MOD 65536.32767)
1650 !
1660 OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL SEQ2" !sequence name
1670 OUTPUT @Afg;"SOUR:LIST1:SSEQ:DEF 1" !sequence size
1680 OUTPUT @Afg USING "#,K";"SOUR:LIST1:SSEQ:COMB #0"!segment execution order
1690 OUTPUT @Afg1;Sequence(*) !sequence list in indefinite length block

```

Continued on Next Page

```

1700     OUTPUT @Afg;CHR$(10);END           !terminate with Line Feed (LF) and EOI
1710     !
1720     OUTPUT @Afg;"SOUR:LIST1:SSEQ:ADDR?"      !sequence location
1730     ENTER @Afg;Seq2_addr
1740 SUBEND
1750     !
1760 SUB Spike_def
1770 Spike_def: !Compute the waveform (sine wave with spike). Download the
1780     !data as a combined list (voltage and marker) of signed
1790     !numbers in an indefinite length block. Download the sequence as
1800     !a combined list (repetition count, marker, and segment address)
1810     !in an indefinite length arbitrary block.
1820     COM @Cmd,@Afg,@Afg1,Base_addr,Seq1_addr,Seq2_addr,Seq3_addr
1830     INTEGER Waveform(1:4096)
1840     INTEGER Sequence(1:2)
1850     REAL Addr_seg3
1860     FOR I=1 TO 4096
1870         Waveform(I)=SIN(2*PI*(I/4096))/0.00125
1880     NEXT I
1890     Width=50
1900     FOR J=1 TO Width
1910         I=1024-Width+J
1920         Waveform(I)=Waveform(I)+.9*J/Width/0.00125
1930     NEXT J
1940     FOR J=1 TO Width-1
1950         I=1024+Width-J
1960         Waveform(I)=Waveform(I)+.9*J/Width/0.00125
1970     NEXT J
1980     !
1990     !shift bits to dac code positions
2000     FOR I=1 TO 4096
2010         Waveform(I)=SHIFT(Waveform(I),-3)
2020     NEXT I
2030     !
2040     OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL SPIKE"      !segment name
2050     OUTPUT @Afg;"SOUR:LIST1:SEGM:DEF 4096"      !segment size
2060     OUTPUT @Afg USING "#,K";"SOUR:LIST1:SEGM:COMB #0"!waveform points
2070     OUTPUT @Afg1;Waveform(*)                    !indefinite length block
2080     OUTPUT @Afg;CHR$(10);END                    !terminate with line feed (LF) and EOI
2090     !
2100     OUTPUT @Afg;"SOUR:LIST1:SEGM:ADDR?"
2110     ENTER @Afg;Addr_seg3
2120     Addr_seg3=Addr_seg3/8                        !/8 to set starting address (boundary) of segment
2130     !
2140     !Sequence (1) is the repetition count and marker enable for
2150     !segment SPIKE. Sequence (2) is the starting address of segment SPIKE.
2160     Sequence(1)=SHIFT(4096-1,-4)+Addr_seg3 DIV 65536
2170     Sequence(2)=Addr_seg3 MOD 65536.-65536.*(Addr_seg3 MOD 65536.32767)
2180     !
2190     OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL SEQ3"      !sequence name

```

Continued on Next Page


```

2200     OUTPUT @Afg;"SOUR:LIST1:SSEQ:DEF 1"           !sequence size
2210     OUTPUT @Afg USING "#,K";"SOUR:LIST1:SSEQ:COMB #0" !segm execution order
2220     OUTPUT @Afg1;Sequence(*)                   !sequence list in indefinite length block
2230     OUTPUT @Afg;CHR$(10);END                   !terminate with Line Feed (LF) and EOI
2240     !
2250     OUTPUT @Afg;"SOUR:LIST1:SSEQ:ADDR?"         !sequence location
2260     ENTER @Afg;Seq3_addr
2270     SUBEND
2280     !
2290     SUB Rst
2300 Rst: !Subprogram which resets the E1445.
2310     COM @Cmd,@Afg,@Afg1,Base_addr,Seq1_addr,Seq2_addr,Seq3_addr
2320     OUTPUT @Afg;"*RST;*CLS;*OPC?"             !reset the AFG
2330     ENTER @Afg;Complete
2340     SUBEND
2350     !
2360     SUB Wf_del
2370 Wf_del: !Subprogram which deletes all sequences and segments.
2380     COM @Cmd,@Afg,@Afg1,Base_addr,Seq1_addr,Seq2_addr,Seq3_addr
2390     OUTPUT @Afg;"FUNC:USER NONE"              !select no sequences
2400     OUTPUT @Afg;"LIST:SSEQ:DEL:ALL"           !Clear sequence memory
2410     OUTPUT @Afg;"LIST:SEGM:DEL:ALL"          !Clear segment memory
2420     SUBEND

```

Visual BASIC and Visual C/C++ Program Versions The Visual BASIC example program, WAVSELFP.FRM, is in directory “VBPROG” and the Visual C example program, WAVSELFP.C, is in directory “VCPROG” on the CD that came with your HP E1445A.

“Digital Port In” Connector Pinout

Figure 7-6 shows a pinout of the “Digital Port In” connector.

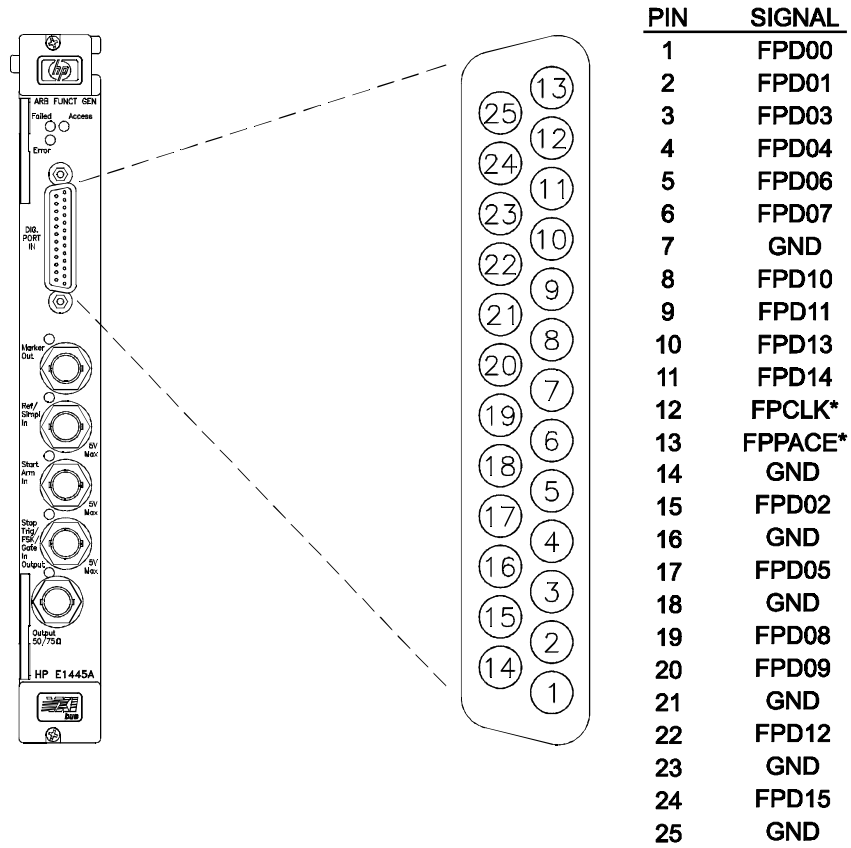


Figure 7-6. HP E1445A “Digital Port In” Connector

Using the “Digital Port In” Connector to Select a Sequence

Figure 7-7 shows the timing relationship to select a segment sequence.

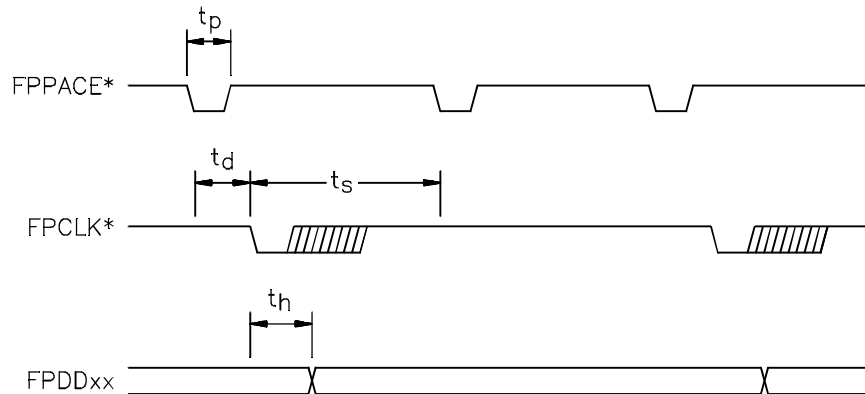


Figure 7-7. "Digital Port In" Data Timing

The following explains the relationship.

1. The AFG generates an **FPPACE*** signal after the next segment sequence has been selected, but before completing its output.
2. The AFG is now ready for a new segment sequence. Set the **FPCLK*** line low to select a new segment sequence. If the line remains high, the AFG re-uses the last selected sequence.
3. The AFG now latches the least significant byte on the **FPDxx** (i.e., FPD00 through FPD15) data lines to select a new sequence. These data lines contain the address of the sequence to be selected.
4. Once the AFG uses the data to select a new sequence, it generates a new **FPPACE*** signal and the process completes.

For correct operation, the **FPCLK*** should occur 150 nS before the next **FPPACE*** occurs. The minimum response delay (t_s) is 0 as is also the minimum data hold time (t_s). The minimum **FPPACE*** pulse width (t_p) is 20 nS; its width depends on the selected sample rate.

To change the sequence, the sequence base memory must be loaded. See the “WAVSELFP” example program beginning on page 272 to determine how to load the memory with the sequences.

Using the “Digital Port In” Connector to Download Data

To download data, ignore the **FPPACE*** line but provide a **FPCLK*** for each data point to be downloaded. The timing relationship between **FPCLK*** and **FPDDxx** is as shown in Figure 7-7, except without the **FPPACE*** line. The data format is the same that is used to download segment data using the [SOURCE:]ARbitrary:DOWNload command.

High Speed Operation Program Comments

The following comments give additional details on the program examples in this chapter.

Amplitude Effects on DAC Codes

The AFG stores the Signed or Unsigned DAC codes directly into memory. Thus, the amplitude setting has no effect on the codes. Unlike sending a voltage list, the output amplitude can be set to any of the values listed in Appendix B. The amplitude does not have to be \geq to the maximum DAC code value.

Incorrect AFG Operation from Incorrect DAC Codes

The AFG requires that the data it receives must be correct, or it will not execute it correctly. Unlike using other data transfer methods, the AFG does not perform any error checking on the data when it is directly downloaded.

DAC Sources

The AFG has the following DAC sources available to download data to the DAC:

INTernal – The [SOURCE:]LIST[1] subsystem/built-in waveforms.

DPORT – The front panel’s “Digital Port In” connector

LBUS – The VXIbus Local Bus

VXI – The VXIbus backplane

Download Sources

The AFG has the following sources available to download waveform segments and segment sequences into memory:

DPORT – The front panel’s “Digital Port In” connector.

LBUS – The VXIbus Local Bus.

VXI – The VXIbus backplane.

Determining the Size of the Combined Segment List

Use [SOURCE:]LIST[1]:SEGMENT:COMBINED:POINTS? to determine the size of the number of points of the waveform segment and marker pulse list of the currently selected waveform segment.

Determining the Size of the Combined Segment Sequence List

Use [SOURCE:]LIST[1]:SEQUENCE:COMBINED:POINTS? to determine the size of the number of waveform segments, marker pulse enable lists, and repetition count lists of the currently selected segment sequence.

Chapter 8

Command Reference

Chapter Contents

This chapter describes the **Standard Commands for Programmable Instruments** (SCPI) command set and the **IEEE 488.2 Common Commands** for the HP E1445A Arbitrary Function Generator (AFG). Included in this chapter are the following sections:

- Command Types Page 284
- SCPI Command Format Page 284
- SCPI Command Parameters Page 286
- SCPI Command Execution Page 288
- SCPI Command Reference Page 289
- SCPI Command Quick Reference Page 409
- SCPI Conformance Information Page 414
- IEEE 488.2 Common Commands Page 416
- Common Commands Quick Reference Page 428

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--	---

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Command Types

Commands are separated into two types: IEEE 488.2 Common Commands and SCPI Commands.

Common Command Format

The IEEE 488.2 standard defines the Common Commands that perform functions like reset, self-test, status byte query, etc. Common commands are four or five characters in length, always begin with the asterisk character (*), and may include one or more parameters. The command keyword is separated from the first parameter by a space character. Some examples of Common Commands are shown below:

*RST, *CLS, *ESE <unmask>, *OPC?, *STB?

SCPI Command Format

The functions of the AFG are programmed using SCPI commands. SCPI commands are based on a hierarchical structure, also known as a tree system. In this system, associated commands are grouped together under a common node or root, thus, forming subtrees or subsystems. An example is the AFG's ARM subsystem.

```
ARM
  [:START|:SEquence[1]]
    [:LAYer[1]]
      :COUNT <number>
    :LAYer2
      :COUNT <number>
      [:IMMediate] [no query]
      :SLOPe <edge>
      :SOURce <source>

  :SWEep|:SEquence3
    :COUNT <number>
    [:IMMediate] [no query]
    :LINK <link>
    :SOURce <source>
```

ARM is the root keyword of the command, :START|:SEquence1 and :SWEep|:SEquence3 are second level keywords, :LAYer1 and :LAYer2 are third level keywords, and so on.

Command Separator

A colon (:) always separates one command keyword from a lower level command keyword as shown below:

```
ARM:LAY2:SOUR EXT
```

Abbreviated Commands

The command syntax shows most commands as a mixture of upper and lower case letters. The upper case letters indicate the abbreviated spelling for the command. For shorter program lines, send the abbreviated form. For better program readability, you may send the entire command. The AFG will accept either the abbreviated form or the entire command.

For example, if a command's syntax contains the keyword COUNT, then COUN and COUNT are acceptable forms. Other forms of COUNT such as COU will generate an error.

You can use upper or lower case letters. Therefore, COUNT, coun, or Coun are all acceptable.

Implied (Optional) Commands

Implied or optional commands are those which appear in square brackets ([]) in the command syntax. The brackets are not part of the command, and are not sent to the AFG. Suppose you send the following command:

```
ARM:COUN 100
```

In this case, the AFG responds as if you had executed the command as:

```
ARM:STARt:LAYer1:COUNT 100
```

Variable Command Syntax

Some commands will have what appears to be a variable syntax. For example:

```
[SOURce:]MARKer:ECLTrg<n>[:STATe] <mode>
```

In this command, <n> is replaced by a number. No space is left between the keyword (ECLTrg) and the number because the number is part of the keyword.

SCPI Command Parameters

Parameters are enclosed in greater than/less than symbols (< >) in the command syntax and *must* always be separated from the keywords by a space. When more than one parameter is allowed, the parameters are separated by a vertical line (|).

The following information contains explanations and examples of the parameter types found in this chapter.

Parameter Types, Explanations, and Examples

- Numeric

Accepts all commonly used decimal representations of numbers including optional signs, decimal points, and scientific notation:

123, 123E2, -123, -1.23E2, .123, 1.23E-2, 1.23000E-01.

Special cases include MINimum, MAXimum, and INFinity. The Comments section within the Command Reference will state whether a numeric parameter can also be specified in hex, octal, and/or binary:

#H7B, #Q173, #B1111011

- Boolean

Represents a single binary condition that is either true or false. Any non-zero value is considered true:

ON, OFF, 1, 0

- Discrete

Selects from a finite number of values. These parameters use mnemonics to represent each valid setting. An example is the TRIGger[:STARt]:SOURce <source> command where source can be BUS, ECLTrg0, ECLTrg1, EXTernal, HOLD, INTernal[1], INTernal[2], or TTLTrg0 through TTLTrg1.

- Arbitrary Block Program Data

This parameter type is used to transfer a block of data in the form of bytes. The block of data bytes is preceded by a header which indicates either

1. The number of data bytes which follow (definite length block), or
2. That the following data block will be terminated upon receipt of a New Line message with the EOI signal true (indefinite length block).

The syntax for data in the blocks is as follows:

Definite length block:

#<non-zero digit><digit(s)><data byte(s)>

Where the value of <non-zero digit> equals the number of <digit(s)>. The value of <digit(s)> taken as a decimal integer indicates the number of <data byte(s)> in the block.

Indefinite length block:

#0<data byte(s)><NL^END>

Examples of sending 4 data bytes:

#14<byte><byte><byte><byte>
#3004<byte><byte><byte><byte>
#0<byte><byte><byte><byte><NL^END>

Optional Parameters

Command parameters shown within square brackets ([]) are optional. The brackets are not part of the parameter, and are not sent to the AFG. If you do not specify a value for an optional parameter, the instrument chooses a default value.

For example, consider the ARM[:START]:LAYer[1]:COUNT? [<MIN | MAX | INF>] command. If you send the command without specifying a parameter, the present ARM[:START]:LAYer[1]:COUNT value is returned. If you send the MIN parameter, the command returns the minimum count available. If you send the MAX parameter, the command returns the maximum count available. There must be a space between the command and the parameter.

Querying Parameter Settings

Unless otherwise noted in the reference section, parameter settings can be queried by adding a question mark (?) to the command which set the parameter. For example:

SOUR:FREQ1:FIX 20E3

sets the frequency to 20 kHz. The value can be queried by executing:

SOUR:FREQ1:FIX?

The MINimum or MAXimum value of a parameter is determined as follows:

SOUR:FREQ1:FIX? MIN
SOUR:FREQ1:FIX? MAX

The minimum and maximum values returned are based on the settings of other AFG commands at that time.

SCPI Command Execution

The following information should be remembered when executing SCPI commands.

Command Coupling

Many of the AFG SCPI commands are value coupled. This means that sending a command can change parameter values set by previous commands. Often, this results in “Settings Conflict” errors when the program executes. To prevent these errors, the AFG commands must be executed in “Coupling Groups”. The coupling groups and associated commands are listed in Table B-2 in Appendix B.

The coupling groups identified in Table B-2 are frequency and voltage. Some commands (like [SOURCE:]FUNCTION[:SHAPE]) are associated with both groups. These commands are a bridge linking (coupling) the two groups. Commands not in a coupling group must precede or follow commands in the coupling groups. Executing un-coupled commands in a coupling group breaks the coupling and can cause a “Settings Conflict” error. Command queries (commands with ?) are uncoupled commands and should be executed before or after coupled commands.

See “Executing Coupled Commands” on page 28 for information on executing coupled commands.

MIN and MAX Parameters in Coupling Groups

When MINimum or MAXimum is the parameter of a command in a coupling group, that command should be the last command executed in the group. Unlike other parameters that are set when an end-of-line indication is received, MIN and MAX are evaluated by the AFG processor when the command is parsed. Thus, the value of MIN or MAX is based on the values of the other (coupling group) commands at that time. “Settings conflict” errors will occur if the current values are incompatible with an intended MIN or MAX value. As a result, MIN and MAX are **not recommended** for specifying the value of a parameter.

Linking Commands

Linking IEEE 488.2 Common Commands.

Use a semicolon between the commands. For example:

```
*RST;*CLS;*OPC?
```

Linking Multiple SCPI Commands.

Use both a semicolon and a colon between the commands. For example:

```
SOUR:ROSC:SOUR INT1;;TRIG:STAR:SOUR INT1
```

Command Choices

Some commands are listed as two commands separated with a vertical bar (“|”). This means that either command name can be used. For example, use either :CW or :FIXed when :CW|:FIXed is shown.

SCPI Command Reference

This section describes the SCPI commands for the HP E1445A Arbitrary Function Generator. Commands are listed alphabetically by subsystem and also within each subsystem. A command guide is printed in the top margin of each page. The guide indicates the subsystem listed on that page.

The ABORt command places the TRIGger subsystem in the idle state, regardless of any other settings. The command halts waveform generation, but keeps the output voltage at the value generated when ABORt was executed. Only another INITiate:IMMediate command will restart waveform output.

Subsystem Syntax ABORt [no query]

- Comments**
- ABORt does not affect any other settings of the HP E1445A.
 - The Pending Operation Flag set true by the INITiate:IMMediate command will be set false as a consequence of entering the trigger idle state. Subsequent *OPC, *OPC?, and *WAI commands will therefore complete immediately.
 - **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** *OPC, *OPC?, *WAI, INITiate:IMMediate
 - ***RST Condition:** *RST places the HP E1445A in the trigger idle state, as if executing an ABORt command.

Example **Aborting a Waveform**

ABOR

Places HP E1445A in idle state.

The ARM subsystem operates with the TRIGger subsystem to control the starting of waveform output and frequency sweeps or list generation, as follows:

- The source and slope for arming (starting) waveform generation.
- The number of waveform start arms the HP E1445A will accept before trigger system returns to the idle state.
- The number of repetitions of a waveform that will be output for each start arm accepted.
- The number of sweep arms the HP E1445A will accept before the sweep system returns to the idle state.
- The source and slope for arming (starting) a frequency sweep or list generation.

Subsystem Syntax

```

ARM
  [:START]:SEquence[1]
    [:LAYer[1]]
      :COUNT <number>
    :LAYer2
      :COUNT <number>
      [:IMMediate]           [no query]
      :SLOPe <edge>
      :SOURce <source>

  :SWEep]:SEquence3
    :COUNT <number>
    [:IMMediate]           [no query]
    :LINK <link>
    :SOURce <source>

```

[:START][:LAYer[1]]:COUNT

ARM[:START][:LAYer[1]]:COUNT <number> selects the number of waveform repetitions to be output for each start arm accepted.

Parameter Name	Parameter Type	Range of Values	Default Units
<number>	numeric	1 through 65536 9.9E+37 INFinity MINimum MAXimum	none
MINimum selects 1 repetitions; MAXimum selects 65536 repetitions. 9.9E+37 is equivalent to INFinity.			

- Comments**
- Use the ABORt or TRIGger:STOP[:IMMediate] command to terminate the output when ARM:START:LAYer1:COUNT is set to INFinity or 9.9E+37.
 - For standard function sine waves, the actual number of cycles which appear at the output relative to the programmed count is approximate, and is not specified.

ARM

- **Executable when Initiated:** Query form only
- **Coupling Group:** None
- **Related Commands:** ABORt, TRIGger:STOP[:IMMediate]
- ***RST Condition:** ARM:STARt:LAYer1:COUNT INFIinity

Example Setting Waveform Repetitions per Arm

ARM:COUN 10 *Sets 10 repetitions/arm.*

[:STARt]:LAYer2:COUNT

ARM[:STARt]:LAYer2:COUNT *<number>* specifies the number of waveform start arms the HP E1445A will accept after an INITiate:IMMediate command before returning the trigger system to the idle state.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<number>	numeric	1 through 65535 MINimum MAXimum 9.9E+37 INFIinity	none
MINimum selects 1 arms; MAXimum selects 65535 arms. 9.9E+37 is equivalent to INFIinity.			

- Comments**
- Use the ABORt command to return the trigger system to the idle state when ARM[:STARt]:LAYer2:COUNT set to INFIinity or 9.9E+37.
 - **Executable when Initiated:** Query form only
 - **Coupling Group:** None
 - **Related Commands:** ABORt, INITiate[:IMMediate]
 - ***RST Condition:** ARM:STARt:LAYer2:COUNT 1

Example Setting the Start Arm Count

ARM:LAY2:COUN 10 *Sets 10 start arms per INITiate.*

[[:START]:LAYer2[:IMMediate]

ARM[:START]:LAYer2[:IMMediate] immediately arms the waveform regardless of the selected arm source. The trigger system must be initiated and the start trigger sequence must be in the wait-for-arm state. The selected start arm source remains unchanged.

- Comments**
- Executing this command with the start trigger sequence not in the wait-for-arm state generates Error -212, "Arm ignored".
 - **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** INITiate[:IMMediate]
 - ***RST Condition:** None

Example Starting a Waveform

```
ARM:LAY2:SOUR HOLD           Sets manual arm source.
INIT                          Initiates trigger system.
ARM:LAY2                       Starts waveform.
```

[[:START]:LAYer2:SLOPe

ARM[:START]:LAYer2:SLOPe <edge> selects the edge (rising or falling) on the HP E1445A's front panel "Start Arm In" BNC which starts waveform generation. This edge is significant only with ARM[:START]:LAYer2:SOURce set to EXTERNAL. The programmed value is retained but not used when other sources are selected.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<edge>	discrete	NEGative POSitive	none

- Comments**
- **Executable when Initiated:** Query form only
 - **Coupling Group:** None
 - **Related Commands:** ARM[:START]:LAYer2:SOURce
 - ***RST Condition:** ARM:START:LAYer2:SLOPe POSitive

Example Setting the Start Arm Slope

```
ARM:LAY2:SLOP NEG           Sets negative start arm slope.
```

[:START]:LAYer2:SOURce

ARM[:START]:LAYer2:SOURce *<source>* selects the source that will start waveform output. The available sources are:

BUS – The Group Execute Trigger (GET) HP-IB command or the IEEE-488.2 *TRG common command.

ECLTrg0 and **ECLTrg1** – The VXIbus ECL trigger lines.

EXTernal – The HP E1445A’s front panel “Start Arm In” BNC connector.

HOLD – Suspend arming. Use the ARM[:START]:LAYer2[:IMMediate] command to start the waveform.

IMMediate – Immediate arming. An arm is internally generated two to three reference oscillator cycles after the start trigger sequence enters the wait-for-arm state.

TTLTrg0 through **TTLTrg7** – The VXIbus TTL trigger lines.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><source></i>	discrete	BUS ECLTrg0 ECLTrg1 EXTernal HOLD IMMediate TTLTrg0 through TTLTrg7	none

- Comments**
- Use the ARM:START:LAYer2:SLOPe command to select the active edge for the front panel “Start Arm In” BNC when used as the start arm source.
 - **Executable when Initiated:** Query form only
 - **Coupling Group:** None
 - **Related Commands:** ARM[:START]:LAYer2:SLOPe
 - ***RST Condition:** ARM:START:LAYer2:SOURce IMMediate

Example Setting the Start Arm Source

ARM:LAY2:SOUR EXT

Start arm source is front panel’s “Start Arm In” BNC.

:SWEep:COUNT

ARM:SWEep:COUNT *<number>* specifies the number of sweep arms the HP E1445A will accept after an INITiate:IMMEDIATE command before the sweep trigger sequence returns to the idle state. This command is equivalent to the [SOURCE:]SWEep:COUNT command; either command may be used, and executing either one changes the value of the other.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><number></i>	numeric	1 through 2147483647 9.9E+37 INFINITY	none
MINimum selects 1 arm; MAXimum selects 2147483647 arms. 9.9E+37 is equivalent to INFINITY.			

- Comments**
- **Executable when Initiated:** Query form only
 - **Coupling Group:** Frequency
 - **Related Commands:** INITiate[:IMMEDIATE]
 - ***RST Condition:** ARM:SWEep:COUNT 1

Example Setting the Sweep Arm Count

ARM:SWE:COUNT 10

Sets 10 sweep arms per INITiate.

:SWEep[:IMMEDIATE]

ARM:SWEep[:IMMEDIATE] starts a frequency sweep or list regardless of the selected sweep arm source. The trigger system must be initiated and the sweep trigger sequence must be in the wait-for-arm state. The selected sweep arm source remains unchanged.

- Comments**
- Executing this command when frequency sweeps or lists are not enabled, or with the sweep trigger sequence not in the wait-for-arm state generates Error -212, "Arm ignored".
 - **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** INITiate[:IMMEDIATE], [SOURCE:]SWEep
 - ***RST Condition:** None

ARM

Example Starting a Frequency Sweep

SWE:START 1E3;STOP 10E3	<i>Sets sweep frequency limits.</i>
SWE:POIN 10	<i>Sets 1 kHz steps.</i>
ARM:SOUR IMM	<i>Sets output to start immediately.</i>
ARM:SWE:SOUR HOLD	<i>Sets manual sweep arm.</i>
INIT	<i>Initiates trigger system.</i>
ARM:SWE	<i>Starts sweep.</i>

:SWEep:LINK

ARM:SWEep:LINK <link> selects the internal event that starts a frequency sweep or list when ARM:SWEep:SOURce is set to LINK. The only defined internal event to start a sweep or list is “ARM[:START | :SEquence[1]]:LAYer2”.

There is no need to send this command since there is only one defined internal event. The command is included for SCPI compatibility purposes only.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<link>	string	“ARM[:START :SEquence[1]]:LAYer2”	none

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** ARM:SWEep:SOURce
 - ***RST Condition:** ARM:SWEep:LINK “ARM[:START | :SEquence[1]]:LAYer2”

Example Linking the Sweep Arm

ARM:SWE:SOUR LINK	<i>Links sweep arm to start arm.</i>
ARM:SWE:LINK “ARM”	

:SWEep:SOURce

ARM:SWEep:SOURce <source> selects the source that starts a frequency sweep or list. The available sources are:

BUS – The Group Execute Trigger (GET) HP-IB command or the IEEE-488.2 *TRG common command.

HOLD – Suspend sweep or list arming. Use ARM:SWEep[:IMMediate] to start the frequency sweep or list.

IMMediate – Immediate sweep or list arming. If the sweep advance trigger source (TRIGger:SWEep:SOURce command) is set to TIMer, the first frequency sweep or list starts when the first start arm is received. For multiple sweeps or lists, the last frequency point of each sweep or list is output for the same TRIGger:SWEep:TIMer time as between all other points of the sweep or list.

If TRIGger:SWEep:SOURce is set to any other source, the frequency sweep or list starts when the INITiate:IMMediate command is executed. For multiple sweeps or lists, a last frequency is output until the next sweep advance trigger is received.

LINK – The next valid start arm starts a sweep or list.

TTLTrg0 through **TTLTrg7** – The VXIbus TTL trigger lines.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<source>	discrete	BUS HOLD IMMediate LINK TTLTrg0 through TTLTrg7	none

Comments

- If ARM:SWEep:SOURce is set to TTLTrg<n> and you want to set TRIGger:SWEep:SOURce to TTLTrg<n>, both must be set to the same trigger line <n>.

- **Executable when Initiated:** Query form only
- **Coupling Group:** Frequency
- **Related Commands:** ARM[:START]:LAYer2:SOURce
- ***RST Condition:** ARM:SWEep:SOURce IMMediate

Example Setting the Sweep Arm Source

ARM:SWE:SOUR TTLT1

Selects VXIbus trigger line TTLTRG1 as sweep arm source.*

The CALibration subsystem has commands that calibrate the HP E1445A. The subsystem also includes commands to prevent and detect accidental or unauthorized calibration of the HP E1445A. The calibration procedure using these commands is located in the *HP E1445A Service Manual*.

Subsystem Syntax

```

CALibration
:COUNT?                [query only]
:DATA
  :AC[1] <block>
  :AC2 <block>
  [:DC] <block>
[:DC]
  :BEGin                [no query]
  :POINT? <value>      [query only]
:SECure
  :CODE <code>          [no query]
  [:STATe] <mode[,<code>]
:STATe <state>
  :AC <state>
  :DC <state>

```

:COUNT?

CALibration:COUNT? returns a number that shows how often the HP E1445A has been calibrated. Since executing CALibration:DATA:AC1, AC2, and DC commands and the CALibration:POINT? query (upon completion of the calibration procedure) increment the number, the CALibration:COUNT? command may be used to detect any accidental or unauthorized HP E1445A calibration.

- Comments**
- The HP E1445A was calibrated before it left the factory. Before using, read the calibration count to determine its initial value.
 - The HP E1445A stores the calibration number in its non-volatile calibration memory which remains intact even with power off.
 - The maximum value of the number is 2,147,483,647, after which it wraps around to 0.
 - **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** CALibration:SECure[:STATe], CALibration[:DC]:BEGin
 - ***RST Condition:** Unaffected

Example Querying the Calibration Count**CAL:COUN?***Queries calibration count.***:DATA:AC[1]**

CALibration:DATA:AC[1] <block> transfers the 250 kHz filter portion of the HP E1445A's calibration constants in IEEE-488.2 arbitrary block program data format. The query form returns this portion of the calibration constants in IEEE-488.2 definite block data format. Both forms require that calibration security have been previously disabled. See the *HP E1445 Service Manual* for detailed information on the use of this command.

- Comments**
- Executing this command with calibration security disabled increments the calibration count (CALibration:COUN? query).
 - **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** CALibration:COUNt?, CALibration:SECure[:STATe]
 - ***RST Condition:** Unaffected

:DATA:AC2

CALibration:DATA:AC2 <block> transfers the 10 MHz filter portion of the HP E1445A's calibration constants in IEEE-488.2 arbitrary block program data format. The query form returns this portion of the calibration constants in IEEE-488.2 definite block data format. Both forms require that calibration security have been previously disabled.

- Comments**
- Executing this command with calibration security disabled increments the calibration count (CALibration:COUN? query).
 - **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** CALibration:COUNt?, CALibration:SECure[:STATe]
 - ***RST Condition:** Unaffected

:DATA[:DC]

CALibration:DATA[:DC] *<block>* transfers the DC portion of the HP E1445A's calibration constants in IEEE-488.2 arbitrary block program data format. The query form returns the current DC portion of the calibration constants in IEEE-488.2 definite block data format. Both forms require that calibration security have been previously disabled. See the *HP E1445A Service Manual* for detailed information on the use of this command.

- Comments**
- Executing this command with calibration security disabled increments the calibration count (CALibration:COUNT? query).
 - **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** CALibration:COUNT?, CALibration:SECure[:STATe]
 - ***RST Condition:** Unaffected

[:DC]:BEGin

CALibration[:DC]:BEGin starts the DC calibration procedure for the HP E1445A. It sets the HP E1445A up for the first of the 44 measurements in the procedure. Calibration security must have been previously disabled. See the *HP E1445A Service Manual* for detailed information on the use of this command.

- Comments**
- Most of the HP E1445A's commands cannot be executed while calibration is in progress. The *RST command may be used to prematurely terminate the calibration procedure without affecting the stored calibration constants.
 - **Executable when Initiated:** No
 - **Coupling Group:** None
 - **Related Commands:** CALibration[:DC]:POINT, CALibration:SECure[:STATe]
 - ***RST Condition:** None

[[:DC]:POINT?

CALibration[:DC]:POINT? *<value>* takes the measured value for the current DC calibration point, computes needed calibration constants, and sets up the HP E1445A for the next measurement. When all measurements have been made, the calibration constants are checked for validity. If the validity check passes, the constants are stored in the HP E1445A's non-volatile calibration memory and the calibration count (CALibration:COUNT? query) is incremented.

The *RST command should be sent after completing the calibration procedure to restore normal operation.

Calibration security must have been previously disabled. See the *HP E1445A Service Manual* for detailed information on the use of this command.

- Comments**
- Most of the HP E1445A's commands cannot be executed while calibration is in progress. The *RST command may be used to prematurely terminate the calibration procedure without affecting the stored calibration constants.
 - **Executable when Initiated:** No
 - **Coupling Group:** None
 - **Related Commands:** CALibration[:DC]:BEGin, CALibration:SECure[:STATe]
 - ***RST Condition:** None

:SECure:CODE

CALibration:SECure:CODE *<code>* sets the code which is required to disable calibration security. Calibration security must have been previously disabled.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><code></i>	character data	0 through 12 characters	none

The code must start with a letter (“A” through “Z”) and may contain letters, digits, and underscores. Lower case letters are converted to upper case.

- Comments**
- Executing this command with calibration security enabled (CALibration:SECure[:STATe] ON set), generates the Error +1002, "Calibration security enabled". Disabling calibration security requires knowledge of the previous security code.
 - Before shipping, the factory sets the calibration security code to “E1445A”. You should change it before you use your HP E1445A to prevent unauthorized calibration. Record the new security code and store it in a secure place. If you forget the new code, defeating the security involves instrument disassembly. See the *HP E1445A Service Manual* if this is required.
 - The HP E1445A stores the security code in its non-volatile calibration memory which remains intact even with power off.
 - **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** CALibration:SECure[:STATe]
 - ***RST Condition:** Unaffected

Example Changing the Factory-shipped Security Password

```
CAL:SEC:STAT OFF,E1445A           Disables security.  
CAL:SEC:CODE NEWCODE             Sets new security code.  
CAL:SEC ON                       Re-enables security.
```

:SECure[:STATe]

CALibration:SECure[:STATe] <mode>[,<code>] enables or disables calibration security. Calibration security must be disabled to calibrate the HP E1445A, read or write calibration data, change the security code, or change the protected user data.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<mode>	boolean	OFF 0 ON 1	none
<code>	string	0 through 15 characters	none

- Comments**
- Attempting to disable calibration security without providing the <code> parameter generates Error -109, "Missing parameter". The value supplied must match the currently programmed security code or Error -224, "Illegal parameter value" will be generated. The HP E1445A will then wait 1 second before executing any subsequent commands.
 - To enable security, the <code> parameter is *not* not required, but is checked if it is present.
 - **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** CALibration[:DC]:BEGin, CALibration:DATA:AC[1], CALibration:DATA:AC2, CALibration:SECure:CODE, *PUD
 - ***RST Condition:** Unaffected
 - **Power-On Condition:** CALibration:SECure[:STATe] ON

Example Disabling Calibration Security

CAL:SEC:STATe OFF,E1445A

Disables security assuming factory-set security code.

CALibration

:STATe

CALibration:STATe *<state>* specifies whether corrections using the calibration constants are made or not. If STATe is OFF, then no corrections are made. If STATe is ON, DC and/or AC corrections will be made or not according to the states of the CALibration:STATE:DC and AC commands.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><state></i>	boolean	OFF 0 ON 1	none

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** CALibration:STATE:AC, CALibration:STATE:DC
 - ***RST Condition:** CALibration:STATe ON

Example Disabling Calibration Corrections

CAL:STAT OFF *Disables corrections.*

:STATE:AC

CALibration:STATE:AC *<state>* specifies whether AC corrections using the calibration constants are made or not. If *state* is OFF, then no AC corrections are made. If *state* is ON, AC corrections will be made if CALibration:STATe ON is also set.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><state></i>	boolean	OFF 0 ON 1	none

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** CALibration:STATE
 - ***RST Condition:** CALibration:STATE:AC ON

Example Disabling AC Calibration Corrections

CAL:STAT:AC OFF *Disables AC corrections.*

:STATe:DC

CALibration:STATe:DC *<state>* specifies whether DC corrections using the calibration constants are made or not. If *state* is OFF, then no DC corrections are made. If *state* is ON, DC corrections will be made if CALibration:STATe ON is also set.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><state></i>	boolean	OFF 0 ON 1	none

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** CALibration:STATe
 - ***RST Condition:** CALibration:STATe:DC ON

Example Disabling DC Calibration Corrections

CAL:STAT:DC OFF

Disables DC corrections.

The INITiate subsystem initiates the trigger subsystem and prepares the HP E1445A for waveform generation. Once initiated, a start arm received from the programmed arm source (TRIGger:STARt:SOURce command) starts the waveform output.

For frequency sweeping, the initial sample or waveform frequency is the START frequency when [SOURce:]FREQUENCY[1]:MODE SWEep is set, or the first frequency in the frequency list when [SOURce:]FREQUENCY[1]:MODE LIST is set.

Subsystem Syntax

INITiate
[:IMMEDIATE] [no query]

[:IMMEDIATE]

INITiate[:IMMEDIATE] initiates the trigger system and places all trigger sequences in the wait-for arm or wait-for-trigger state, as appropriate. Waveform generation begins when the next start arm is received. When ARM[:STARt]:LAYer2:COUNT full arm cycles complete, the trigger system returns to the idle state, and waveform generation halts.

This command is an overlapped command as described by IEEE-488.2, Section 12. The exit from the idle state caused by INITiate:IMMEDIATE shall cause its Pending Operation Flag to be set true. This Pending Operation Flag will be set false when the idle state is re-entered, either when the trigger cycle completes or when an ABORt or *RST command is executed.

The STATus:OPC:INITiate command controls whether *OPC, *OPC? and *WAI will test the Pending Operation Flag and wait until it is false (trigger system in the idle state).

- Comments**
- Use the **ABORt** command to prematurely halt the waveform generation and place the trigger system in the idle state.
 - Waveform output begins immediately if **ARM[:START]:LAYer2:SOURce IMMEDIATE** is set.
 - Executing this command when **[SOURce:]FUNCTion[:SHAPE] DC** is set, when **[SOURce:]ARBitrary:DAC:SOURce** is not set to **INTernal**, or the trigger system is not in the idle state, Error -213, "Init ignored" is generated.
 - **Executable when Initiated:** No
 - **Coupling Group:** None
 - **Related Commands:** *OPC, *OPC?, *RST, *WAI, **ABORt**, ARM subsystem, **STATus:OPC:INITiate**, **TRIGger** subsystem
 - ***RST Condition:** The trigger system is in the idle state.

Example Initiating Waveform Generation

INIT

Initiates waveform generation.

The OUTPut[1] subsystem controls the characteristics of the output waveform. The subsystem sets the low-pass output filter, sets the output source impedance, and enables or disables the output.

Subsystem Syntax

```

OUTPut[1]
:FILTER
  [:LPASs]
    :FREQuency <frequency>
    [:STATe] <mode>
:IMPedance<impedance>
:LOAD <load>
:AUTO <mode>
[:STATe] <mode>
    
```

:FILTER[:LPASs]:FREQuency

OUTPut[1]:FILTER[:LPASs]:FREQuency <frequency> sets the output filter’s cutoff frequency to either 250 kHz or 10 MHz.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<frequency>	numeric	250 kHz 10 MHz MINimum MAXimum	Hz
MINimum selects the 250 kHz filter; MAXimum selects the 10 MHz filter.			

- Comments**
- Selecting the cutoff frequency does not enable the output filter. Use the OUTPut[1]:FILTER[:LPASs][:STATe] command to enable or disable the output filter.
 - **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** OUTPut[1]:FILTER[:LPASs][:STATe]
 - ***RST Condition:** OUTPut1:FILTER:LPASs:FREQuency 250 KHZ

Example Setting the Low-pass Filter to 10 MHz

```

OUTP:FILT:FREQ 10 MHZ           Selects 10 MHz output filter.
OUTP:FILT ON                   Enables output filtering.
    
```


:FILTer[:LPASs][:STATe]

OUTPut[1]:FILTer[:LPASs][:STATe] *<mode>* enables or disables the output filter.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><mode></i>	boolean	OFF 0 ON 1	none

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** OUTPut[1]:FILTer[:LPASs]:FREQuency
 - ***RST Condition:** OUTPut1:FILTer:LPASs:STATe OFF

Example Enabling the 10 MHz Low-pass Filter

OUTP:FILT:FREQ 10 MHZ *Selects 10 MHz output filter.*
 OUTP:FILT ON *Enables output filtering.*

:IMPedance

OUTPut[1]:IMPedance *<impedance>* sets the HP E1445A's output impedance to either 50Ω or 75Ω.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><impedance></i>	numeric	50 75 MINimum MAXimum	Ohms
MINimum selects 50Ω output impedance; MAXimum selects 75Ω.			

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** Voltage
 - **Related Commands:** OUTPut[1]:LOAD, OUTPut[1]:LOAD:AUTO
 - ***RST Condition:** OUTPut1:IMPedance 50

Example Setting 75 Ω Output Impedance

OUTP:IMP 75 *Sets 75 Ω output impedance.*

:LOAD

OUTPut[1]:LOAD *<load>* indicates whether the actual load applied to the HP E1445A's "Output 50/75Ω" is either matched to the output impedance specified by OUTPut[1]:IMPedance or is an open circuit. The output voltage into an open circuit is twice that into a matched load. Setting OUTPut[1]:LOAD INFINITY compensates for this effect so that the [SOURce:]LIST[1][:SEGMENT]:VOLTage and [SOURce:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude] and OFFSet commands will output the specified voltages into an open circuit.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><load></i>	numeric	50 75 9.9E+37 INFINITY MINimum MAXimum	Ohms
MINimum selects 50 Ω load impedance; MAXimum selects 75 Ω. Use 9.9E+37 or INFINITY to indicate an open circuit output.			

- Comments**
- The *<load>* value specified by this command either must be the same as that specified by OUTPut[1]:IMPedance or must be 9.9E+37 or INFINITY, or Error -221, "Settings conflict" will be generated.
 - With OUTPut[1]:LOAD:AUTO ON set, the OUTPut[1]:LOAD value is coupled to (tracks) the OUTPut[1]:IMPedance value. Changing the IMPedance changes the LOAD value. Specifying a value for LOAD sets AUTO OFF.
 - **Executable when Initiated:** Yes
 - **Coupling Group:** Voltage
 - **Related Commands:** OUTPut[1]:IMPedance, OUTPut[1]:LOAD:AUTO, [SOURce:]LIST subsystem, [SOURce:]VOLTage subsystem
 - ***RST Condition:** OUTPut[1]:LOAD:AUTO ON is set, and the OUTPut[1]:LOAD value is coupled to the OUTPut[1]:IMPedance value.

Example Indicating Open Circuit Output Load

OUTP:LOAD INF

Indicates open circuit.

:LOAD:AUTO

OUTPut[1]:LOAD:AUTO *<mode>* indicates whether the OUTPut[1]:LOAD value should be coupled to (track) the OUTPut[1]:IMPedance value.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><mode></i>	boolean	OFF 0 ON 1 ONCE	none

Comments

- With OUTPut[1]:LOAD:AUTO ON set, the OUTPut[1]:LOAD value is coupled to the OUTPut[1]:IMPedance value. Changing the IMPedance changes the LOAD value. Specifying a value for LOAD sets AUTO OFF. AUTO ONCE sets the LOAD value to the IMPedance value and sets AUTO OFF.

- **Executable when Initiated:** Yes
- **Coupling Group:** Voltage
- **Related Commands:** OUTPut[1]:IMPedance, OUTPut[1]:LOAD
- ***RST Condition:** OUTPut1:LOAD:AUTO ON

Example Uncoupling OUTPut[1]:IMPedance and OUTPut[1]:LOAD

OUTP:LOAD:AUTO OFF *Uncouples impedance and load.*

[:STATe]

OUTPut[1][:STATe] *<mode>* closes or opens the HP E1445A's output relay to enable or disable the analog output. Disabling the output does not stop waveform generation; however, the output appears as an open circuit.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><mode></i>	boolean	OFF 0 ON 1	none

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - ***RST Condition:** OUTPut1:STATe ON (not SCPI compliant)

Example Disabling the Output

OUTP OFF *Disables output.*

The [SOURce:] subsystem is divided into multiple sections, each of which control a particular aspect of the HP E1445A. Each section of the subsystem is separately documented in the following sections of the command reference.

The [SOURce:] node itself is optional.

Subsystem Syntax The first level [SOURce:] syntax tree is:

[SOURce:]	
ARBitrary	Page 313
FREQuency[1]	Page 319
FREQuency2	Page 330
FUNCtion	Page 332
LIST[1]	Page 334
LIST2	Page 358
MARKer	Page 361
PM	Page 365
RAMP	Page 368
ROSCillator	Page 370
SWEep	Page 372
VOLTage	Page 377

The [SOURce:]ARBitrary subsystem controls:

- The data format for the digital-to-analog converter (DAC).
- The DAC data source.
- Direct downloading of DAC data to the waveform segment memory.

Subsystem Syntax

```
[SOURce:]
ARBitrary
:DAC
:FORMat <format>
:SOURce <source>
:DOWNload <source>,<dest>,<length> [no query]
:COMPLete [no query]
```

:DAC:FORMat

[SOURce:]ARBitrary:DAC:FORMat <format> specifies the format for the DAC codes. The format controls how to send and receive DAC codes, and how the HP E1445A stores and interprets the waveform segment memory data.

Note The DAC code format cannot be changed after storing the waveform segment data. Use [SOURce:]LIST[1]::SEGment]:DELeTe:ALL to delete waveform segment data before changing the DAC code format.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<format>	discrete	SIGNed UNSigned	none

- Comments**
- The available formats are:
 - **SIGNed:** Selects the two's-complement format. The DAC code is a two's complement number where 0 represents 0 V output, -4096 represents negative full scale output, +4095 represents positive full scale. The positive full scale output value is specified by the [SOURce:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude] command.
 - **UNSIGNed:** Selects the unsigned format. The DAC code is an unsigned number where 0 represents negative full scale output and 8191 represents positive full scale.

- There is no need to specify the DAC format with waveforms programmed in volts. The format should be specified if you are:
 - a. Programming waveforms in DAC codes ([SOURce:]LIST[1][:SEGMENT]:COMBined or [SOURce:]LIST[1][:SEGMENT]:VOLTage:DAC commands).
 - b. Driving the DAC directly ([SOURce:]ARbitrary:DAC:SOURce).
 - c. Directly downloading waveform segments ([SOURce:]ARbitrary:DOWNload).
- **Related Commands:** [SOURce:]ARbitrary:DAC:SOURce, [SOURce:]ARbitrary:DOWNload, [SOURce:]LIST[1][:SEGMENT]:COMBined, [SOURce:]LIST[1][:SEGMENT]:VOLTage:DAC
- **Executable when Initiated:** Query form only
- **Coupling Group:** None
- ***RST Condition:** Unaffected
- **Power-On Condition:** [SOURce:]ARbitrary:DAC:FORMat SIGNed

Example Setting Unsigned DAC Code Format**ARB:DAC:FORM UNS***Sets unsigned format.*

:DAC:SOURce

[SOURce:]ARBitrary:DAC:SOURce <source> selects the DAC's data source.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<source>	discrete	DPORt INTernal LBUS VXI	none

- Comments**
- The available sources are:
 - **DPORt:** The HP E1445A's front panel "Digital Port In" connector.
 - **LBUS:** The VXIbus local bus.
 - **INTernal:** The [SOURce:]LIST[1] subsystem or built-in waveforms.
 - **VXI:** The VXIbus data transfer bus.
 - When driving the DAC from the VXIbus data transfer bus, the address for writing the data is offset 38 decimal (26 hex) in the HP E1445A's A24 address space.
 - Setting the DAC data source to a setting other than INTernal disables the ARM subsystem, the INITiate command, the [SOURce:] subsystem except for the [SOURce:]ARBitrary, [SOURce:]MARKer, and [SOURce:]VOLTage subsystems, and the TRIGger subsystem. The HP E1445A immediately outputs each DAC data point when received. Also, the output amplitude must be specified in terms of volts or volts peak (V or VPK).
 - Use the [SOURce:]ARBitrary:DAC:FORMat command to select the format of the data (two's-complement or unsigned) when directly driving the DAC from the VXIbus local bus, the front panel "Digital Port", or the VXI backplane, or when programming waveforms using DAC codes via the [SOURce:]ARBitrary:DOWNload, [SOURce:]LIST[1]:SEGMent:COMBined, or [SOURce:]LIST[1]:SEGMent:VOLTage:DAC commands.
 - **Executable when Initiated:** Query form only
 - **Coupling Group:** Frequency and voltage
 - **Related Commands:** VINstrument[:CONFigure]:LBUS[:MODE]
 - ***RST Condition:** SOURce:ARBitrary:DAC:SOURce INTernal

Example Setting the DAC Data Source

ARB:DAC:SOUR DPOR

Selects front panel "Digital Port" connector as source.

:DOWNload

[SOURce:]ARbitrary:DOWNload *<source>*,*<dest>*,*<length>* enables the direct download mode to the waveform segment or segment sequence memory. It selects the download source, waveform segment or segment sequence name, and number of points. The available download sources are:

- **DPORt:** The HP E1445A’s front panel “Digital Port In” connector. Only waveform segment memory may be downloaded via this source.
- **LBUS:** The VXIbus local bus. Only waveform segment memory may be downloaded via this source.
- **VXI:** The VXIbus data transfer bus.

Waveform Segment Data The waveform segment data consists of a single 16-bit word for each voltage point. The format for downloaded waveform segment data is:

Bits 15–3	Bit 2	Bit 1	Bit 0
DAC code	unused	marker	last point

The *DAC code* is a 13-bit two’s complement or unsigned number (see the [SOURce:]ARbitrary:DAC:FORMat command on page 313). With [SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude] 5.11875 V set and a matched output load, the least significant bit (LSB) represents 1.25 mV. If the *marker* bit is 1, a marker pulse will be output with this point if the *marker* bit in the segment sequence memory location generating this segment is also a 1. *Last point* is 1 for the waveform segment’s third-to-last point (actual last point - 3).

When downloading waveform segment data from the VXIbus data transfer bus, the address for writing the data is offset 38 decimal (26 hex) in the HP E1445A’s A24 address space.

Segment Sequence Data The segment sequence data consists of a 32-bit wide value for each segment in the sequence. The value should be sent as two 16-bit words with the most significant word sent first. The format for downloaded segment sequence data is:

Bits 31–20	Bit 19	Bit 18	Bit 17	Bits 16–0
repetition count	last point	marker enable	unused	segment address

The *repetition count* is 12-bit unsigned value that is (4096 - the desired repetition count): a value of 4095 in these bits indicates 1 repetition; a value of 0 indicates 4096 repetitions. *Last point* is 1 for the segment sequence’s last point. *Marker enable* is 1 to enable marker pulse generation for that waveform segment. *Segment address* is the starting address of the segment divided by 8. Use the [SOURce:]LIST[1][:SEGment]:ADDRess? query to obtain the address of a waveform segment.

[SOURce:]ARBitrary

When downloading segment sequence data from the VXIbus data transfer bus, the most significant 16 bits should be written to offset 34 decimal (22 hex) in the HP E1445A's A24 address space. The least significant 16 bits should be written to offset 36 decimal (24 hex).

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<source>	discrete	DPORT LBUS VXI	none
<dest>	char	defined waveform segment or segment sequence name	none
<length>	numeric	see below MINimum MAXimum	none

For waveform segments, the *length*, in terms of points, must be greater than or equal to 4 and less than or equal to the defined waveform segment length. The current waveform segment length is set to this length.

MINimum selects 4 points; MAXimum selects the defined waveform segment length.

For segment sequences, the *length*, in terms of points, must be greater than or equal to 1 and less than or equal to the defined segment sequence length. The current segment sequence length is set to this length.

MINimum selects 1 point; MAXimum selects the defined waveform segment or segment sequence length.

- Comments**
- The waveform segment or segment sequence must have been previously defined (see the [SOURce:]LIST[1]:SEGMENT:DEFine and [SOURce:]LIST[1]:SSEQUENCE:DEFine commands).
 - When downloading is complete, use the [SOURce:]ARBitrary:DOWNload:COMplete command to restore normal operation.
 - No error checking is performed on downloaded data. Erratic operation may occur if invalid data (length or format) is downloaded.
 - **Executable when Initiated:** No
 - **Coupling Group:** None
 - **Related Commands:** [SOURce:]LIST[1] commands
 - ***RST Condition:** Downloading disabled

Example Set up to download 512 points from the VXI backplane to waveform segment "ABC"

LIST:SEL ABC	<i>Creates segment name.</i>
LIST:DEF 512	<i>Reserves 512 points of segment memory.</i>
ARB:DOWN VXI,ABC,512	<i>Sets up for download.</i>
<i>download data</i>	
ARB:DOWN:COMP	<i>Indicates download complete.</i>

:DOWNload:COMplete

[SOURCE:]ARBITRARY:DOWNload:COMplete disables direct downloading mode. Send it when downloading is complete.

- Comments**
- **Executable when Initiated:** No
 - **Coupling Group:** None
 - **Related Commands:** [SOURCE:]ARBITRARY:DOWNload
 - ***RST Condition:** Downloading disabled

Example Set up to download 512 points from the VXIbus to waveform segment “ABC”

LIST:SEL ABC	<i>Creates segment name.</i>
LIST:DEF 512	<i>Reserves 512 points of segment memory.</i>
ARB:DOWN VXI,ABC,512	<i>Sets up for download.</i>
<i>download data</i>	
ARB:DOWN:COMP	<i>Indicates download complete.</i>

The [SOURce:]FREQUency[1] subsystem controls the first of the HP E1445A's two frequency generators. ([SOURce:]FREQUency2 controls the second generator.)

The first generator uses a direct digital synthesis (NCO) technique to generate the specified frequencies. It has an upper frequency limit of the reference oscillator frequency divided by 4 (the second generator operates up to the reference oscillator frequency). This generator has excellent resolution (.01 Hz with the 42.94 MHz reference oscillator) and allows frequency sweeping. Sine wave output is possible only with this generator. The second generator has better phase noise characteristics and permits higher frequency operation.

The values programmed by this subsystem are only used when TRIGger[:START]:SOURce is set to INTernal1.

Coupling Rules The swept commands START, STOP, CENTER, and SPAN are coupled commands. When sending these commands, the following rules apply:

- If either START or STOP is sent singly, the value of the other is preserved, but the CENTER and SPAN values will change according to the following equations:

$$\begin{aligned}\text{CENTer} &= (\text{START} + \text{STOP})/2 \\ \text{SPAN} &= \text{STOP} - \text{START}\end{aligned}$$

- If either CENTER or SPAN is sent singly, the value of the other is preserved, but the START and STOP values will change according to the following equations:

$$\begin{aligned}\text{START} &= \text{CENTer} - (\text{SPAN}/2) \\ \text{STOP} &= \text{CENTer} + (\text{SPAN}/2)\end{aligned}$$

- If any two commands are sent as part of a frequency-coupled group within a single program message, then these two will be set as specified, and the other two will change. If more than two are sent in the group, the sweep will be determined by the *last* two received.

When MINimum and MAXimum are used with these commands, the values that will be set are the minimum and maximum values that will not cause any of the START, STOP, CENTER, and SPAN values to go beyond the minimum and maximum possible frequencies, given the coupling equations above. For example, if SPAN is currently set to 1 MHz, FREQUency1:CENTer MINimum would set 500 kHz.

The minimum possible frequency is 0 Hz, except in the case of logarithmic frequency sweeps. For logarithmic frequency sweeps, the minimum frequency is the maximum possible frequency divided by 1,073,741,824. The maximum possible frequency depends on the frequency of the currently selected reference oscillator source ([SOURce:]ROSCillator:SOURce), the waveform shape

([SOURce:]FUNCTION[:SHAPE]), and whether or not frequency doubling is enabled ([SOURce:]FREQUency[1]:RANGE), according to the following rules:

- **Arbitrary Waveforms and Sine Wave Outputs:** the maximum possible frequency is the current reference oscillator frequency divided by 4.
- **Square Wave Outputs:** the maximum possible frequency is the current reference oscillator frequency divided by 16.
- **Ramps and Triangle Outputs:** the maximum possible frequency is the current reference oscillator frequency divided by 4 further divided by the [SOURce:]RAMP:POINTS value.

For non-sine wave outputs, multiply the above values by 2 if frequency doubling is in effect (see the [SOURce:]FREQUency[1]:RANGE command on page 326).

Subsystem Syntax

```
[SOURce:]
FREQUency[1]
:CENTer <center_freq>
[:CW]:FIXed <frequency>
:FSKey <frequency1>,<frequency2>
:SOURce <source>
:MODE <mode>
:RANGE <range>
:SPAN <freq_span>
:START <start_freq>
:STOP <stop_freq>
```

:CENTer

[SOURce:]FREQUENCY[1]:CENTer *<center_freq>* sets the center sample rate or waveform frequency for a frequency-swept waveform.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><center_freq></i>	numeric	see below MINimum MAXimum	Hz
The legal range for <i><center_freq></i> , as well as the MINimum and MAXimum values, are context-dependent. See "Coupling Rules" on page 319 for a description of the coupling between START, STOP, CENTER, and SPAN.			

- Comments**
- **Executable when Initiated:** Query form only
 - **Coupling Group:** Frequency
 - **Related Commands:** TRIGger[:START]:SOURce, [SOURce:]FREQUENCY[1]:MODE, RANGE, SPAN, START, and STOP, [SOURce:]FUNCTION[:SHAPE], [SOURce:]ROSCillator commands
 - ***RST Condition:** SOURce:FREQUENCY1:CENTer 5.36870912 MHz

Example Setting the Center Frequency

FREQ:CENT 1E3

Sets the center frequency to 1000 Hz.

[:CW]:FIXed

[SOURce:]FREQUency[1][:CW]:FIXed *<frequency>* selects the non-swept sample rate for arbitrary waveforms or waveform frequency for the built-in waveforms (sine, square, etc.).

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><frequency></i>	numeric	see below MINimum MAXimum	Hz
MINimum selects 0 Hz. Arbitrary Waveforms and Sine Wave Outputs: MAXimum selects the current reference oscillator frequency divided by 4. Square Wave Outputs: MAXimum selects the current reference oscillator frequency divided by 16. Ramps and Triangle Outputs: MAXimum selects the current reference oscillator frequency divided by 4 further divided by the [SOURce:]RAMP:POINTS value. For non-sine wave outputs, multiply the MAXimum value by 2 if frequency doubling is in effect (see the [SOURce:]FREQUency[1]:RANGe command). The above values bound the legal range for <i><frequency></i> .			

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** Frequency
 - **Related Commands:** TRIGger[:START]:SOURce, [SOURce:]FREQUency[1]:MODE, [SOURce:]FUNCTION[:SHAPE], [SOURce:]ROSCillator commands
 - ***RST Condition:** SOURce:FREQUency1:FIXed 10 kHz

Example Setting the Sample Rate or Waveform Frequency

FREQ 1E3

Sets the frequency to 1000 Hz.

[SOURce:]FREQUency[1]

:FSKey

[SOURce:]FREQUency[1]:FSKey *<frequency1>*,*<frequency2>* sets the two sample rates or waveform frequencies for frequency-shift keying.

[SOURce:]FREQUency[1]:FSKey:SOURce sets the source which selects between the two sample rates or waveform frequencies. A TTL high level on the selected source generates *frequency1*; a TTL low level generates *frequency2*.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><frequency1></i> <i><frequency2></i>	numeric	see below MINimum MAXimum	Hz
MINimum selects 0 Hz.			
Arbitrary Waveforms and Sine Wave Outputs: MAXimum selects the current reference oscillator frequency divided by 4.			
Square Wave Outputs: MAXimum selects the current reference oscillator frequency divided by 16.			
Ramps and Triangle Outputs: MAXimum selects the current reference oscillator frequency divided by 4 further divided by the [SOURce:]RAMP:POINTS value.			
For non-sine wave outputs, multiply the MAXimum value by 2 if frequency doubling is in effect (see the [SOURce:]FREQUency[1]:RANGe command).			
The above values bound the legal range for <i><frequency1></i> and <i><frequency2></i> .			

- Comments**
- **Executable when Initiated:** Yes. However, the frequency being generated will not change until the FSK control source changes levels.
 - **Coupling Group:** Frequency
 - **Related Commands:** TRIGger[:]STARt[:]SOURce, [SOURce:]FREQUency[1]:MODE, [SOURce:]FREQUency[1]:RANGe, [SOURce:]FUNCTion[:]SHAPE, [SOURce:]ROSCillator commands
 - ***RST Condition:** SOURce:FREQUency1:FSKey 10 kHz, 10 MHz

Example Setting the Frequency-Shift Frequencies

FREQ:FSK 1E6,1 KHZ

Sets 1 MHz and 1 kHz frequencies.

:FSKey:SOURce

[SOURce:]FREQUency[1]:FSKey:SOURce *<source>* sets the source which will control which of the two FSKey sample rates or waveform frequencies is generated when [SOURce:]FREQUency[1]:MODE FSKey is selected. A high level on the source selects [SOURce:]FREQUency[1]:FSKey *<frequency1>*; a low level selects *<frequency2>*.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><source></i>	discrete	EXternal TTLTrg0 through TTLTrg7	none

- Comments**
- The available sources are:
 - **EXternal:** The HP E1445A’s front panel “Stop Trig/FSK/Gate In” BNC connector.
 - **TTLTrg0** through **TTLTrg7:** The VXibus TTL trigger lines.
 - The front panel’s “Stop Trig/FSK/Gate In” BNC is a three-use connector; for FSK control, as a stop trigger source, or as a sample gate source. Only one of these uses may be active at any time.
 - If a VXibus TTLTrg trigger line is used for FSK control, then no TTLTrg trigger lines can be used as a stop trigger source or as a sample gate source.
 - **Executable when Initiated:** Query form only
 - **Coupling Group:** Frequency
 - **Related Commands:** [SOURce:]FREQUency[1]:FSKey, [SOURce:]FREQUency[1]:MODE
 - ***RST Condition:** SOURce:FSKey:SOURce EXternal

Example Setting the FSK Control Source

FREQ:FSK:SOUR TTLT0

Selects VXibus trigger line TTLTRG0 as FSK control source.*

:MODE

[SOURce:]FREQUENCY[1]:MODE *<mode>* determines which set of commands control the frequency subsystem.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><mode></i>	discrete	CW FIXed FSKey LIST SWEep	none

Comments • The *<mode>* parameter has the following meanings:

- **CW** or **FIXed**: Selects single-frequency mode. [SOURce:]FREQUENCY[1]:CW | :FIXed] selects the sample rate or waveform frequency. CW and FIXed are equivalent.
- **FSKey**: Selects frequency shift keying mode. [SOURce:]FREQUENCY[1]:FSKey and the front panel's "Stop Trig/FSK/Gate In" BNC select the two sample rate or waveform frequencies.
- **LIST**: Selects frequency list mode. [SOURce:]LIST2:FREQUENCY sets the sample rate or waveform frequencies.
- **SWEep**: Selects frequency sweep mode. [SOURce:]FREQUENCY[1]:CENTer, SPAN, START and STOP commands set the sample or waveform frequency range. The [SOURce:]SWEep, ARM:SWEep, and TRIGger:SWEep subsystems control the sweep.

• **Executable when Initiated**: Query form only

• **Coupling Group**: Frequency

• **Related Commands**: TRIGger[:START]:SOURce, [SOURce:]FREQUENCY[1] subsystem, [SOURce:]LIST2 subsystem, [SOURce:]SWEep subsystem

• ***RST Condition**: SOURce:FREQUENCY1:MODE FIXed

Example Setting the Frequency Sweep Mode

FREQ:MODE LIST

Sets the frequency sweep mode.

:RANGe

[SOURce:]FREQUency[1]:RANGe <range> enables or disables frequency doubling for non-sine wave outputs. When doubling is enabled, the waveform is advanced on both edges, instead of one edge, of the square wave generated by the direct digital synthesis chip, thus doubling the maximum sample output rate. However, since the square wave symmetry is not perfect, doubling introduces some systematic jitter in the sample rate. Also, in doubled mode, the frequency resolution worsens by a factor of two.

Setting <range> to any value less than or equal to the maximum undoubled frequency, specified below, disables frequency doubling. Values greater than the maximum undoubled frequency enable frequency doubling.

- **Arbitrary Waveforms:** The maximum undoubled frequency is the current reference oscillator frequency divided by 4.
- **Square Wave Outputs:** The maximum undoubled frequency is the current reference oscillator frequency divided by 16.
- **Ramps and Triangle Outputs:** The maximum undoubled frequency is the current reference oscillator frequency divided by 4 further divided by the [SOURce:]RAMP:POINTs value.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<range>	numeric	see below MINimum MAXimum	Hz
MINimum selects 0 Hz; MAXimum selects twice the maximum undoubled frequency. The above values bound the legal range for <range>.			

- Comments**
- Since the maximum undoubled frequency depends on waveform shape and the reference oscillator frequency, frequency doubling may be alternately enabled and disabled as these settings change if <range> is greater than 0. Setting SOURce:FREQUency1:RANGe 0 is a good way to guarantee that frequency doubling is always disabled.
 - **Executable when Initiated:** Query form only
 - **Coupling Group:** Frequency
 - **Related Commands:** TRIGger[:START]:SOURce, [SOURce:]FREQUency[1]:CENTer, MODE, START, and STOP, [SOURce:]FUNCTION[:SHAPE], [SOURce:]ROSCillator commands
 - ***RST Condition:** SOURce:FREQUency1:RANGe 0.0 Hz

[SOURce:]FREQUency[1]

Example Enabling Frequency Doubling

FUNC:SHAP SQU *Selects square wave output.*
ROSC:SOUR INT1 *Selects 42.94 MHz oscillator.*
FREQ:RANG 5MHZ *Sets frequency range to 5 MHz.*

:SPAN

[SOURce:]FREQUency[1]:SPAN *<freq_span>* sets the sample rate or waveform frequency span for a frequency-swept waveform.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><freq_span></i>	numeric	see below MINimum MAXimum	Hz
The legal range for <i><freq_span></i> , as well as the MINimum and MAXimum values, are context-dependent. See "Coupling Rules" on page 319 for a description of the coupling between START, STOP, CENTER, and SPAN.			

- Comments**
- **Executable when Initiated:** Query form only
 - **Coupling Group:** Frequency
 - **Related Commands:** TRIGger[:START]:SOURce, [SOURce:]FREQUency[1]:CENTer, MODE, RANGE, START, and STOP, [SOURce:]FUNCtion[:SHAPE], [SOURce:]ROSCillator commands
 - ***RST Condition:** SOURce:FREQUency1:SPAN 10.73741824 MHz

Example Setting the Frequency Span

FREQ:SPAN 1E3 *Sets the frequency span to 1000 Hz.*

:START

[SOURce:]FREQUENCY[1]:START *<start_freq>* sets the starting sample rate or waveform frequency for a frequency-swept waveform.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><start_freq></i>	numeric	see below MINimum MAXimum	Hz
The legal range for <i><start_freq></i> , as well as the MINimum and MAXimum values, are context-dependent. See "Coupling Rules" on page 319 for a description of the coupling between START, STOP, CENTER, and SPAN.			

- Comments**
- **Executable when Initiated:** Query form only
 - **Coupling Group:** Frequency
 - **Related Commands:** TRIGger[:START]:SOURce, [SOURce:]FREQUENCY[1]:CENTer, MODE, RANGE, SPAN, and STOP, [SOURce:]FUNCTION[:SHAPE], [SOURce:]ROSCillator commands
 - ***RST Condition:** SOURce:FREQUENCY1:START 0.0 Hz

Example Setting the Starting Frequency

FREQ:STAR 1 KHZ

Sets the starting frequency to 1000 Hz.

[SOURce:]FREQUENCY[1]

:STOP

[SOURce:]FREQUENCY[1]:STOP *<stop_freq>* sets the stopping sample rate or waveform frequency for a frequency-swept waveform.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><stop_freq></i>	numeric	see below MINimum MAXimum	Hz
The legal range for <i><stop_freq></i> , as well as the MINimum and MAXimum values, are context-dependent. See "Coupling Rules" on page 319 for a description of the coupling between START, STOP, CENTER, and SPAN.			

- Comments**
- **Executable when Initiated:** Query form only
 - **Coupling Group:** Frequency
 - **Related Commands:** TRIGger[:START]:SOURce, [SOURce:]FREQUENCY[1]:CENTer, MODE, RANGE, SPAN, and START, [SOURce:]FUNCTION[:SHAPE], [SOURce:]ROSCillator commands
 - ***RST Condition:** SOURce:FREQUENCY1:STOP 10.73741824 MHz

Example Setting the Stopping Frequency

FREQ:STOP 1E3

Sets the stopping frequency to 1000 Hz.

[SOURce:]FREQuency2

The [SOURce:]FREQuency2 subsystem controls the second of the HP E1445A's two frequency generators. ([SOURce:]FREQuency[1] controls the first generator.)

This second generator consists of a simple divide-by- n of the currently selected reference oscillator source, where n may be 1, 2, 3, or any even value between 4 and 131,072. This generator has better phase noise characteristics and permits higher frequency operation than the direct digital synthesis (NCO) technique used by the first generator. The first generator has finer resolution and frequency sweeping capability. Also, sine wave output is possible only with the first generator. Either generator may be used for square, ramp, triangle and arbitrary waveform output.

The values programmed by this subsystem are only used when TRIGger:STARt:SOURce is set to INTernal2.

Subsystem Syntax

```
[SOURce:]  
FREQuency2  
[:CW]:FIXed] <frequency>
```

[SOURce:]FREQUency2

[:CW | :FIXed]

[SOURce:]FREQUency2[:CW]:FIXed *<frequency>* selects the sample rate for arbitrary waveforms or the frequency for the standard waveforms (square, ramp, triangle).

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><frequency></i>	numeric	see below MINimum MAXimum	Hz
Arbitrary Waveforms: MINimum selects the current reference oscillator frequency divided by 131,072; MAXimum selects the current reference oscillator frequency.			
Square Wave Outputs: MINimum selects the current reference oscillator frequency divided by 524,288; MAXimum selects the current reference oscillator frequency divided by 4.			
Ramps and Triangles Outputs: MINimum selects the current reference oscillator frequency divided by 131,072 further divided by the SOURce:RAMP:POINts value; MAXimum selects the current reference oscillator frequency divided by the SOURce:RAMP:POINts value.			
The above values bound the valid range for <i><frequency></i> . The <i><frequency></i> value is rounded to the nearest frequency that can be produced using the divide-by-n technique of this generator.			

- Comments**
- If the actual frequency generated differs from the specified frequency by greater than 1%, the Frequency bit of the Questionable Signal Status Register will be set. See the STATus subsystem for more information.
 - **Executable when Initiated:** Yes
 - **Coupling Group:** Frequency
 - **Related Commands:** TRIGger[:STARt]:SOURce, [SOURce:]FUNCTio[n]:SHAPE], [SOURce:]ROSCillator commands, STATus subsystem
 - ***RST Condition:** SOURce:FREQUency2:FIXed 10E3

Example Setting the Sample Rate or Waveform Frequency

FREQ2 1E3

Sets frequency to 1000 Hz.

[SOURce:]FUNCTION

The [SOURce:]FUNCTION subsystem controls what waveform shape (arbitrary, sinusoid, etc.) the HP E1445A generates. For arbitrary waveforms generation, the subsystem controls which of the 128 possible segment sequences are selected.

Subsystem Syntax

```
[SOURce]
:FUNCTION
[:SHAPE] <shape>
:USER <name>
```

[:SHAPE]

[SOURce:]FUNCTION[:SHAPE] <shape> selects what waveform shape the HP E1445A generates.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<shape>	discrete	DC RAMP SINusoid SQUare TRiangle USER	none

- Comments**
- The <shape> parameter values are shown as follows:
 - **DC:** Generates a DC output voltage.
 - **RAMP:** Generates a stepped ramp. The [SOURce:]RAMP subsystem controls the polarity and number of points.
 - **SINusoid:** Generates a sinusoidal voltage. SINusoid requires that TRIGger[:START]:SOURce INTernal1 be selected.
 - **SQUare:** Generates a square wave. The [SOURce:]RAMP:POLarity command controls the polarity.
 - **TRiangle:** Generates a stepped triangle wave. The [SOURce:]RAMP subsystem controls the polarity and number of points.
 - **USER:** Generates an arbitrary waveform. The [SOURce:]FUNCTION:USER command selects the segment sequence to be generated.
 - **For the DC function:** The voltage level is specified by [SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude].
 - **For the RAMP, SINusoid, SQUare, TRiangle, and USER functions:**
 - Use [SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude] to set output amplitude. For arbitrary (USER) waveforms, this command specifies the full-scale output voltage.
 - [SOURce:]VOLTage[:LEVel][:IMMediate]:OFFSet specifies the offset voltage.

[SOURce:]FUNCTioN

- TRIGger[:START:]SOURce selects the sample source. SINusoid requires that TRIGger[:START:]SOURce INTernal1 be selected.
- The [SOURce:]FREQUency[1] or [SOURce:]FREQUency2 subsystems specify the signal frequency for RAMP, SINusoid, SQUare, and TRIangle waveforms. They specify the sample rate for arbitrary (USER) waveforms.
- When [SOURce:]FUNCTioN[:SHAPe] RAMP or TRIangle is selected, the greater of the SOURce:RAMP:POINts value and 8 points of contiguous waveform segment memory must be available. When [SOURce:]FUNCTioN[:SHAPe] SQUare is selected, 8 points of contiguous waveform segment memory must be available. Attempting to select one of these functions with less contiguous waveform segment memory available, or to set [SOURce:]RAMP:POINts to a value larger than the largest contiguous amount of available waveform segment memory when ramp or triangle wave output is selected, will generate Error +1000,"Out of memory".
- **Executable when Initiated:** Query form only
- **Coupling Group:** Frequency and voltage
- ***RST Condition:** SOURce:FUNCTioN:SHAPe SINusoid

Example Selecting Square Wave Generation Mode

FUNC SQU *Selects square wave mode.*

:USER

[SOURce:]FUNCTioN:USER <name> selects which one of the 128 possible stored segment sequences the HP E1445A generates when arbitrary waveform generation is selected by [SOURce:]FUNCTioN[:SHAPe] USER.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<name>	character data	defined waveform sequence name NONE	none
NONE selects no segment sequence			

- Comments**
- **Executable when Initiated:** Query form only
 - **Coupling Group:** None
 - **Related Commands:** [SOURce:]FUNCTioN[:SHAPe]
 - ***RST Condition:** SOURce:FUNCTioN:USER NONE

Example Selecting an Arbitrary Waveform

FUNC USER *Selects arbitrary waveform mode.*

FUNC:USER ABC *Selects segment sequence.*

[SOURce:]LIST[1]

The [SOURce:]LIST[1] subsystem defines the waveform segments and segment sequence for arbitrary waveform generation. The HP E1445A can simultaneously store up to 256 waveform segments and up to 128 segment sequences.

Subsystem syntax

```
[SOURce:]
LIST[1]
:FORMat
    [:DATA] <format>[,<length>]

[:SEGment]
:ADDRess?                [query only]
:CATalog?                [query only]
:COMBined <combined_list>
    :POINTs?            [query only]
:DEFine <length>
:DELete
    :ALL                [no query]
    [:SELected]        [no query]
:FREE?                  [query only]
:MARKer <marker_list>
    :POINTs?            [query only]
    :SPOint <point>    [no query]
:SELect <name>
:VOLTage <voltage_list>
    :DAC <voltage_list>
    :POINTs?            [query only]

:SSEquence
:ADDRess?                [query only]
:CATalog?                [query only]
:COMBined <combined_list>
    :POINTs?            [query only]
:DEFine <length>
:DELete
    :ALL                [no query]
    [:SELected]        [no query]
:DWELI
    :COUNT <repetition_list>
    :POINTs?            [query only]
:FREE?                  [query only]
:MARKer <marker_list>
    :POINTs?            [query only]
    :SPOint <point>    [no query]
:SELect <name>
:SEquence <segment_list>
    :SEGMents?         [query only]
```

[SOURce:]LIST[1]

:FORMat[:DATA]

[SOURce:]LIST[1]:FORMat[:DATA] *<format>* [, *<length>*] specifies the format of numeric waveform segment and segment sequence list return data in the [SOURce:]LIST[1] subsystem. The available numeric list return data formats are:

ASCIi: Returns numeric data as an NR1 or NR3 number as defined in IEEE-488.2.

PACKed: Returns data in IEEE-488.2 definite block format. Internal to the block, the format depends on the query being executed, as list below. The most significant byte of each value is always sent first.

- [SOURce:]LIST[1][:SEGment]:COMBined?: The data is returned in the format described under the [SOURce:]LIST[1][:SEGment]:COMBined command.
- [SOURce:]LIST[1][:SEGment]:MARKer?: The data is returned in 16-bit integer format.
- [SOURce:]LIST[1][:SEGment]:VOLTage?: The data is returned in IEEE-754 64-bit floating point format.
- [SOURce:]LIST[1][:SEGment]:VOLTage:DAC?: The data is returned as 16-bit signed or unsigned DAC codes as specified by the [SOURce:]ARbitrary:DAC:FORMat command.
- [SOURce:]LIST[1]:SSEquence:DWELI:COUNT?: The data is returned in 16-bit integer format.
- [SOURce:]LIST[1]:SSEquence:COMBined?: The data is returned in the format described under the [SOURce:]LIST[1]:SSEquence:COMBined command.
- [SOURce:]LIST[1]:SSEquence:MARKer?: The data is returned in 16-bit integer format.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><format></i>	discrete	ASCIi PACKed	none
<i><length></i>	numeric	see below MINimum MAXimum	none

If ASCII format is specified, *<length>* must either be omitted or must be 9 (or MINimum or MAXimum). Packed format ignores the *<length>* parameter.

- Comments**
- **Executable when Initiated:** Query form only
 - **Coupling Group:** None
 - **Related Commands:** [SOURce:]LIST[1][:SEGment] commands, [SOURce:]LIST[1]:SSEquence commands
 - ***RST Condition:** SOURce:LIST1:FORMat:DATA ASCII

Example Setting PACKed Return Data Format

LIST:FORM PACK

Sets packed format.

[[:SEGMENT]:ADDRESS?

[SOURce:]LIST[1][:SEGMENT]:ADDRESS? returns the address in the waveform segment memory at which the currently selected waveform segment is located.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - ***RST Condition:** No waveform segment is selected
 - **Power-On Condition:** No waveform segments are defined

Example Query Waveform Segment Memory Address

LIST:SEGM:ADDR? *Queries segment address.*

[[:SEGMENT]:CATALOG?

[SOURce:]LIST[1][:SEGMENT]:CATALOG? returns a comma-separated list of quoted strings, each containing the name of a defined waveform segment. If no waveform segment names are defined, a single null string ("") is returned.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - ***RST Condition:** None
 - **Power-On Condition:** No waveform segment names are defined

Example Cataloging Waveform Segment Names

LIST:CAT? *Catalog waveform segments.*

[:SEGMENT]:COMBined

[SOURce:]LIST[1][:SEGMENT]:COMBined *<combined_list>* defines in one step both the output voltage and marker pulse lists that constitute a waveform segment.

Parameters The *<combined_list>* may be either a comma-separated list of values or an IEEE-488.2 definite or indefinite length block containing the values in 16-bit integer format. Each value has the following format:

Bits 15–3	Bit 2	Bit 1	Bit 0
DAC code	unused	marker	reserved

The *DAC code* is a 13-bit two's complement or unsigned number (see the [SOURce:]ARbitrary:DAC:FORMat command). With [SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude] 5.11875 V set and a matched output load, the least significant bit (LSB) represents 1.25 mV. If the *marker* bit is 1, a marker pulse will be output with this point if the *marker* bit in the segment sequence memory location generating this segment is also a 1.

MINimum and MAXimum cannot be used with this command.

- Comments**
- If the comma-separated list of values format is used, the values must be in two's complement format, i.e., values should range from -32768 to +32767. If block format is used, the most significant byte of each value must be sent first.
 - The combined list must be at least four points long but no longer than the reserved length specified by [SOURce:]LIST[1][:SEGMENT]:DEFine. If the combined list length is less than the reserved length, only the number of points specified by the combined list is generated when outputting the waveform segment.
 - Executing the query form of this command with voltage point and marker pulse lists defined with different lengths generates Error -221, "Settings conflict" unless the marker pulse list has a length of 1.
 - Using combined lists is faster than separately defining the voltage point and marker pulse lists.
 - **Executable when Initiated:** No
 - **Coupling Group:** None
 - **Related Commands:** [SOURce:]LIST[1][:SEGMENT]:MARKer, [SOURce:]LIST[1][:SEGMENT]:VOLTage, [SOURce:]LIST[1][:SEGMENT]:VOLTage:DAC
 - ***RST Condition:** Unaffected
 - **Power-On Condition:** No waveform segments are defined

Example Defining a Waveform Segment Combined List

LIST:SEL ABC	<i>Selects waveform segment ABC.</i>
LIST:DEF 8	<i>ABC is 8 points long.</i>
LIST:COMB 16000,32000,16000,0,-16000,-32000,-16000,0	<i>Defines waveform segment.</i>

[[:SEGMENT]:COMBined:POINts?

[SOURce:]LIST[1][[:SEGMENT]:COMBined:POINts? returns a number indicating the length of the currently selected waveform segment's combined voltage point and marker pulse list.

- Comments**
- Executing this command with voltage point and marker pulse lists defined with different lengths generates Error -221, "Settings conflict" unless the marker pulse list has a length of 1. In this case, the length of the voltage point list is returned.
 - **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - ***RST Condition:** None
 - **Power-On Condition:** No waveform segments are defined

Example Query Combined Point List Length

LIST:SEL ABC	<i>Selects waveform segment ABC.</i>
LIST:COMB:POIN?	<i>Queries combined point list length.</i>

[:SEGMENT]:DEFine

[SOURce:]LIST[1][:SEGMENT]:DEFine *<length>* reserves enough waveform segment memory for a waveform segment of *length* points for the segment currently selected by [SOURce:]LIST[1][:SEGMENT]:SElect.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><length></i>	numeric	see below MINimum MAXimum	none
<p>The length will be rounded up, if needed, to a multiple of 8 points. All defined waveform segments share the waveform segment memory. Any one segment may use any part of or all of this memory.</p> <p>MINimum reserves 8 points; MAXimum reserves the largest available contiguous piece of waveform segment memory (up to 262,144 points if no waveforms other than standard function sine waves exist).</p>			

- Comments**
- Once a waveform segment has been DEFined, it must be deleted ([SOURce:]LIST[1][:SEGMENT]:DElete[:SElected] command) before its reserved length may be redefined. The voltage point and marker pulse list values and length may be changed repeatedly without re-executing the DEFine command.
 - [SOURce:]LIST[1][:SEGMENT]:DEFine initializes the waveform segment voltage point list to zero length and the marker pulse list to a length of 1 with a value of 0 (no markers will be generated).
 - While the reserved length must be a multiple of 8, rounded up if necessary, the only restriction on the current waveform segment length (number of voltage points stored) is that it be at least four points long.
 - **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** [SOURce:]LIST[1][:SEGMENT]:SElect
 - ***RST Condition:** Unaffected
 - **Power-On Condition:** No waveform segments are defined

Example Reserving Memory for a Waveform Segment

```
LIST:SEL ABC           Selects waveform segment ABC.
LIST:DEF 1024         Reserves 1024 points for ABC.
```

[[:SEGMENT]:DELEte:ALL

[SOURce:]LIST[1][:SEGMENT]:DELEte:ALL deletes all defined waveform segment definitions from memory and makes all of the waveform memory available for new waveform segment definitions.

- Comments**
- If any waveform segment is used in any segment sequence, executing this command generates Error +1102, "Segment in use". No waveform segments will be deleted.
 - Use [SOURce:]LIST[1][:SEGMENT]:DELEte[:SELEcted] to delete only the currently selected waveform segment definition.
 - **Executable when Initiated:** No
 - **Coupling Group:** None
 - **Related Commands:** [SOURce:]LIST[1][:SEGMENT]:DELEte[:SELEcted]
 - ***RST Condition:** None
 - **Power-On Condition:** No waveform segments are defined

Example Deleting All Waveform Segments

LIST:DEL:ALL

Deletes all segments.

[[:SEGMENT]:DELEte[:SELEcted]

[SOURce:]LIST[1][:SEGMENT]:DELEte[:SELEcted] deletes the currently selected waveform segment definition and makes its memory available for new waveform segment definitions.

- Comments**
- If the waveform segment is used in any segment sequence, executing this command generates Error +1102, "Segment in use". The waveform segment will not be deleted.
 - After deleting the currently selected waveform segment, no waveform segment is SELEcted.
 - Use [SOURce:]LIST[1][:SEGMENT]:DELEte:ALL to delete all waveform segment definitions with one command.
 - **Executable when Initiated:** No
 - **Coupling Group:** None
 - **Related Commands:** [SOURce:]LIST[1][:SEGMENT]:DELEte:ALL, [SOURce:]LIST[1][:SEGMENT]:SELEct
 - ***RST Condition:** None

[SOURce:]LIST[1]

- **Power-On Condition:** No waveform segments are defined

Example Deleting a Waveform

LIST:SEL ABC *Selects waveform segment ABC.*
LIST:DEL *Deletes segment.*

[[:SEGMENT]:FREE?

[SOURce:]LIST[1][:SEGMENT]:FREE? returns information on waveform segment memory availability and usage. The return data format is:

<numeric_value>,<numeric_value>

The first numeric value shows the amount of waveform segment memory available in points; the second, the amount of waveform segment memory used in points.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - ***RST Condition:** None
 - **Power-On Condition:** All of the waveform segment memory is available

Example Querying Waveform Segment Memory Usage

LIST:FREE? *Queries segment memory usage.*

[:SEGMENT]:MARKer

[SOURce:]LIST[1][:SEGMENT]:MARKer *<marker_list>* defines, for each voltage point of a waveform segment, whether the HP E1445A may output a marker pulse. To actually output a marker pulse, the marker enable list value for the segment sequence entry for the segment must also be set to 1. [SOURce:]MARKer:FEED must be set to "SOURce:LIST" to output the marker pulse on the "Marker Out" BNC; [SOURce:]MARKer:ECLTrg<n>:FEED must be set to "SOURce:LIST" to output the marker pulse on the corresponding VXibus ECLTRG* line.

Parameters The *<marker_list>* may be either a comma-separated list of values or an IEEE-488.2 definite or indefinite length block containing the values in 16-bit integer format. A value of 0 generates no marker pulse; any non-zero value enables marker pulse generation.

MINimum and MAXimum cannot be used with this command.

- Comments**
- If block format is used, the most significant byte of each value must be sent first.
 - Marker pulses are one sample period wide (nominally 25 nS at 40 MHz clock rate). To widen the pulses, enable marker pulse generation on consecutive points.
 - Usually, marker pulse generation is enabled on no more than one point of a waveform segment. The [SOURce:]LIST[1][:SEGMENT]:MARKer:SPOint command is the most efficient way to enable marker pulse generation on a single point.
 - The waveform segment's marker pulse list length must be the same length as its voltage point list or must have a length of 1. If not, executing the INITiate:IMMediate command generates Error +1104, "Segment lists of different lengths".
 - A marker pulse list of length 1 is treated as though it were the same length as the voltage point list, with all marker pulse values the same as the specified value.
 - The marker pulse list length must be no longer than the reserved length specified by [SOURce:]LIST[1][:SEGMENT]:DEFine. If the marker pulse list length is less than the reserved length, only the number of points specified by the most recent marker pulse and voltage point lists is generated when the waveform segment is output.
 - Changing marker pulse values preserves the waveform segment's voltage point list, and vice versa.
 - **Executable when Initiated:** No
 - **Coupling Group:** None
 - **Related Commands:** [SOURce:]LIST[1][:SEGMENT]:COMBined
 - ***RST Condition:** Unaffected
 - **Power-On Condition:** No waveform segments are defined

[SOURce:]LIST[1]

Example Defining a Waveform Segment Marker Pulse List

LIST:SEL ABC	<i>Selects waveform segment ABC.</i>
LIST:DEF 8	<i>ABC is 8 points long.</i>
LIST:VOLT -1,.5,.5,.5,.5,0,-.5,-1	<i>Defines waveform voltages.</i>
LIST:MARK 1,0,0,0,1,0,0,0	<i>Outputs a marker pulse on first and fifth voltage points.</i>

[:SEGMENT]:MARKer:POINts?

[SOURce:]LIST[1][:SEGMENT]:MARKer:POINts? returns a number indicating the length of the currently selected waveform segment's marker pulse list.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - ***RST Condition:** None
 - **Power-On Condition:** No waveform segments are defined

Example Query Marker Pulse List Length

LIST:SEL ABC	<i>Selects waveform segment ABC.</i>
LIST:MARK:POIN?	<i>Queries the marker pulse list length.</i>

[:SEGMENT]:MARKer:SPOint

[SOURce:]LIST[1][:SEGMENT]:MARKer:SPOint *<point>* is a short-cut method for defining a marker list with marker pulse generation enabled on a single point. It creates a marker list whose length is the same as the current voltage point list, and which enables marker generation only on the point specified. The voltage point list must have been previously defined.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><point></i>	numeric	see below MINimum MAXimum	none
The valid range for <i><point></i> is 1 through the length of the current voltage point list. MINimum selects the first point of the current voltage point list; MAXimum selects the last point.			

- Comments**
- **Executable when Initiated:** No
 - **Coupling Group:** None
 - **Related Commands:** [SOURce:]LIST[1][:SEGMENT]:MARKer

- ***RST Condition:** Unaffected
- **Power-On Condition:** No waveform segments are defined

Example Creating a Single Point Marker List

LIST:SEL ABC	<i>Selects waveform segment ABC.</i>
LIST:DEF 8	<i>ABC is 8 points long.</i>
LIST:VOLT -1,.5,.5,.5,.5,0,-.5,-1	<i>Defines waveform voltages.</i>
LIST:MARK:SPO 5	<i>Outputs a marker pulse on the fifth voltage point.</i>

[[:SEGMENT]:SELEct

[SOURce:]LIST[1][:SEGMENT]:SELEct <name> selects a waveform segment for subsequent [SOURce:]LIST[1][:SEGMENT] subsystem commands. This command will define the waveform segment name if it is undefined, but does not reserve any waveform segment memory.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<name>	character data	1 through 12 characters NONE	none
NONE selects no waveform segment			

- Comments**
- Legal names must start with an alphabetic character and contain only alphabetic, numeric, and underscore ("_") characters. Alphabetic character case (upper versus lower) is ignored. No waveform segment may have the same name as any segment sequence.
 - A maximum of 256 waveform segment names may be defined at any time. Use the [SOURce:]LIST[1][:SEGMENT]:DELEte:ALL or SELEcted commands to delete names that are no longer needed.
 - **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - ***RST Condition:** Unaffected

Example Selecting a Waveform Segment

LIST:SEL ABC	<i>Selects waveform segment ABC.</i>
---------------------	--------------------------------------

[[:SEGMENT]:VOLTage

[SOURce:]LIST[1][:SEGMENT]:VOLTage *<voltage_list>* defines the series of output voltage points that constitute a waveform segment. The points are specified in terms of volts.

Parameters The *<voltage_list>* may be either a comma-separated list of voltage values or an IEEE-488.2 definite or indefinite length block containing the values in IEEE-754 64-bit floating-point format.

The legal range for voltage values is specified by the [SOURce:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude] command. Default units are volts.

MINimum and MAXimum cannot be used with this command.

- Comments**
- If block format is used, the most significant byte of each value must be sent first.
 - The voltage point list length must be at least four points long but no longer than the reserved length specified by [SOURce:]LIST[1][:SEGMENT]:DEFine. If the voltage point list length is less than the reserved length, only the number of points specified by the most recent voltage point and marker pulse list is generated when the waveform segment is output.
 - The waveform segment's marker pulse list length must be the same length as its voltage point list, or must have a length of 1. If not, executing the INITiate:IMMEDIATE command generates Error +1104, "Segment lists of different lengths".
 - Changing marker pulse values preserves the waveform segment's voltage point list, and vice versa.
 - The voltage values specified by this command are scaled relative to the full-scale output voltage specified by [SOURce:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude] in effect at the time the voltage point list is created. Subsequently changing the full-scale output voltage will change the actual output voltages that are generated, and also the values returned by the query form of this command.
 - **Executable when Initiated:** No
 - **Coupling Group:** None
 - **Related Commands:** [SOURce:]LIST[1][:SEGMENT]:COMBined, [SOURce:]LIST[1][:SEGMENT]:VOLTage:DAC, [SOURce:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude]
 - ***RST Condition:** Unaffected
 - **Power-On Condition:** No waveform segments are defined

Example Defining a Waveform Segment Voltage Point List

LIST:SEL ABC	<i>Selects waveform segment ABC.</i>
LIST:DEF 8	<i>ABC is 8 points long.</i>
LIST:VOLT .5,1,.5,0,-.5,-1,-.5,0	<i>Defines waveform voltages.</i>

[[:SEGMENT]:VOLTage:DAC

[SOURce:]LIST[1][:SEGMENT]:VOLTage:DAC *<voltage_list>* defines the series of output voltage points that constitute a waveform segment. The points are specified in terms of digital-to-analog converter (DAC) codes.

Parameters The *<voltage_list>* may be either a comma-separated list of DAC codes or an IEEE-488.2 definite or indefinite length block containing the DAC codes in 16-bit integer format.

The DAC code is a 16-bit two's complement or unsigned number (see the [SOURce:]ARbitrary:DAC:FORMat command). With [SOURce:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude] 5.11875 V set and a matched output load, the least significant bit (LSB) represents 1.25 mV. The legal range for the DAC codes is -4096 through +4095 for signed numbers, 0 through +8191 for unsigned numbers.

MINimum and MAXimum cannot be used with this command.

- Comments**
- If block format is used, the most significant byte of each value must be sent first.
 - The voltage point list length must be at least four points long but no longer than the reserved length specified by [SOURce:]LIST[1][:SEGMENT]:DEFine. If the voltage point list length is less than the reserved length, only the number of points specified by the most recent voltage point and marker pulse list is generated when the waveform segment is output.
 - The waveform segment's marker pulse list length must be the same length as its voltage point list or must have a length of 1. If not, executing the INITiate:IMMEDIATE command generates Error +1104, "Segment lists of different lengths".
 - Changing marker pulse values preserves the waveform segment's voltage point list, and vice versa.
 - **Executable when Initiated:** No
 - **Coupling Group:** None
 - **Related Commands:** [SOURce:]LIST[1][:SEGMENT]:VOLTage, [SOURce:]LIST[1][:SEGMENT]:COMBined, [SOURce:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude]
 - ***RST Condition:** Unaffected

[SOURce:]LIST[1]

- **Power-On Condition:** No waveform segments are defined

Example Defining a Waveform Segment Voltage Point List

ARB:DAC:FORM SIGN	<i>Selects signed DAC code format.</i>
LIST:SEL ABC	<i>Selects waveform segment ABC.</i>
LIST:DEF 8	<i>ABC is 8 points long.</i>
LIST:VOLT:DAC 400,800,400,0,-400,-800,-400,0	<i>Defines waveform voltages.</i>

[:SEGMENT]:VOLTage:POINTs?

[SOURce:]LIST[1][:SEGMENT]:VOLTage:POINTs? returns a number indicating the length of the currently selected waveform segment's voltage point list.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - ***RST Condition:** None
 - **Power-On Condition:** No waveform segments are defined

Example Query Voltage Point List Length

LIST:SEL ABC	<i>Selects waveform segment ABC.</i>
LIST:VOLT:POIN?	<i>Queries voltage point list length.</i>

:SSEquence:ADDRess?

[SOURce:]LIST[1]:SSEquence:ADDRess? returns the address in the segment sequence memory at which the currently selected segment sequence is located.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - ***RST Condition:** None
 - **Power-On Condition:** No segment sequences are defined

Example Query Segment Sequence Memory Address

LIST:SSEQ:ADDR?	<i>Queries sequence address.</i>
-----------------	----------------------------------

:SSEquence:CATalog?

[SOURCE:]LIST[1]:SSEquence:CATalog? returns a comma-separated list of quoted strings, each containing the name of a defined segment sequence. If no segment sequence names are defined, a single null string ("") is returned.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - ***RST Condition:** None
 - **Power-On Condition:** No segment sequence names are defined

Example Cataloging Segment Sequence Names

LIST:SSEQ:CAT?

Catalogs segment sequence names.

:SSEquence:COMBined

[SOURCE:]LIST[1]:SSEquence:COMBined <*combined_list*> defines in one step the waveform segment, marker enable, and repetition count lists that constitute a segment sequence.

Parameters The <*combined_list*> may be either a comma-separated list of values or an IEEE-488.2 definite or indefinite length block containing the values in 32-bit integer format. Each value has the following format:

Bits 31–20	Bit 19	Bit 18	Bit 17	Bits 16–0
repetition count	reserved	marker enable	unused	segment address

The *repetition count* is 12-bit unsigned value that is (4096 - the desired repetition count): a value of 4095 in these bits indicates 1 repetition; a value of 0 indicates 4096 repetitions. *Marker enable* is 1 to enable marker pulse generation for that waveform segment. *Segment address* is the starting address of the segment divided by 8. Use the [SOURCE:]LIST[1]:SEGMent:ADDRess? query to obtain the address of a waveform segment.

MINimum and MAXimum cannot be used with this command.

- Comments**
- If the comma-separated list of values format is used, the values must be in two's complement format (i.e., values should range from -2147483648 to +2147483647). If block format is used, the most significant byte of each value must be sent first.
 - The combined list must be no longer than the reserved length specified by [SOURCE:]LIST[1]:SSEquence:DEFine. If the combined list length is less than the reserved length, only the number of points specified by the combined list is generated when outputting the segment sequence.

[SOURce:]LIST[1]

- Using combined lists is faster than separately defining the waveform segment, marker enable, and repetition count lists.
- Executing this command with waveform segment, marker pulse, and repetition count lists defined with different lengths generates Error -221, "Settings conflict" unless the different length lists are the marker pulse and/or repetition count list and have a length of 1.
- **Executable when Initiated:** No
- **Coupling Group:** None
- **Related Commands:** [SOURce:]LIST[1]:SSEquence:DWELI:COUNT, [SOURce:]LIST[1]:SSEquence:MARKer, [SOURce:]LIST[1]:SSEquence:SESequence
- ***RST Condition:** Unaffected
- **Power-On Condition:** No segment sequences are defined

Example Defining a Segment Sequence Combined List

LIST:SSEQ:SEL ABC	<i>Selects sequence ABC.</i>
LIST:SSEQ:DEF 1	<i>ABC is 1 point long.</i>
LIST:SSEQ:COMB -786432	<i>Outputs segment at address 0 one time with markers enabled.</i>

:SSEquence:COMBined:POINts?

[SOURce:]LIST[1]:SSEquence:COMBined:POINts? returns a number indicating the length of the currently selected segment sequence's combined waveform segment, marker pulse, and repetition count list.

- Comments**
- Executing this command with waveform segment, marker pulse, and repetition count lists defined with different lengths generates Error -221, "Settings conflict" unless the different length lists are the marker pulse and/or repetition count list and have a length of 1. In this case, the length of the waveform segment list is returned.
 - **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - ***RST Condition:** None
 - **Power-On Condition:** No waveform segments are defined

Example Query Combined Point List Length

LIST:SSEQ:SEL ABC	<i>Selects sequence ABC.</i>
LIST:SSEQ:COMB:POIN?	<i>Queries combined point list length.</i>

:SSEquence:DEFine

[SOURCE:]LIST[1]:SSEquence:DEFine *<length>* reserves enough segment sequence memory for a segment sequence of *length* segment names for the sequence currently selected by [SOURCE:]LIST[1]:SSEquence:SElect.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><length></i>	numeric	see below MINimum MAXimum	none
The segment sequence memory can store a maximum of 32,768 points (32,767 points if a square, ramp, or triangle wave exists). All defined segment sequences share this memory. Any one sequence can use any part of or all of this memory.			
MINimum reserves 1 point; MAXimum reserves the largest available contiguous piece of segment sequence memory.			

- Comments**
- Once a segment sequence has been DEFINed, it must be deleted ([SOURCE:]LIST[1]:SSEquence:DELeTe[:SElected] command) before its reserved length may be redefined. The contents and length of the list may be changed repeatedly without re-executing the DEFine command.
 - By using the [SOURCE:]LIST[1]:SSEquence:DWEL:COUNT command, up to 4096 repetitions of a waveform segment can take only one point in the segment sequence memory. This factor should be considered when reserving segment sequence memory space.
 - [SOURCE:]LIST[1]:SSEquence:DEFine initializes the segment sequence's waveform segment list to a zero current length and the repetition count and marker enable lists to a length of 1 with a value of 1 (single repetition of each segment, marker pulse generation enabled for all segments).
 - **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** [SOURCE:]LIST[1]:SSEquence:SElect
 - ***RST Condition:** Unaffected
 - **Power-on Condition:** No segment sequences are defined.

Example Reserving Memory for a Segment Sequence

LIST:SSEQ:SEL ABC

Selects sequence ABC.

LIST:SSEQ:DEF 1024

Reserves 1024 points for ABC.

[SOURCE:]LIST[1]

:SSEquence:DELeTe:ALL

[SOURCE:]LIST[1]:SSEquence:DELeTe:ALL deletes all defined segment sequence definitions from memory and makes all of the sequence memory available for new segment sequence definitions. "In use" sequences cannot be deleted.

- Comments**
- Use [SOURCE:]LIST[1]:SSEquence:DELeTe[:SELeCted] to delete a single segment sequence definition.
 - **Executable when Initiated:** No
 - **Coupling Group:** None
 - **Related Commands:** [SOURCE:]LIST[1]:SSEquence:DELeTe[:SELeCted]
 - ***RST Condition:** None
 - **Power-On Condition:** No segment sequences are defined

Example Deleting All Segment Sequences

LIST:SSEQ:DEL:ALL

Deletes all segments.

:SSEquence:DELeTe[:SELeCted]

[SOURCE:]LIST[1]:SSEquence:DELeTe[:SELeCted] deletes a single segment sequence definition and makes its memory available for new segment sequence definitions.

- Comments**
- Use [SOURCE:]LIST[1]:SSEquence:DELeTe:ALL to delete all segment sequence definitions with one command.
 - **Executable when Initiated:** No
 - **Coupling Group:** None
 - **Related Commands:** [SOURCE:]LIST[1]:SSEquence:DELeTe:ALL, [SOURCE:]LIST[1]:SSEquence:SELeCt
 - ***RST Condition:** None
 - **Power-On Condition:** No segment sequences are defined

Example Deleting a Segment Sequence

LIST:SSEQ:SEL ABC

Selects segment sequence ABC.

LIST:SSEQ:DEL

Deletes segment.

:SSEquence:DWEL:COUNT

[SOURce:]LIST[1]:SSEquence:DWEL:COUNT *<repetition_list>* defines, for each waveform segment of a segment sequence, how many times the waveform segment will be output before advancing to the next segment in the sequence.

Parameters The *<repetition_list>* may be either a comma-separated list of repetition counts or an IEEE-488.2 definite or indefinite length block containing the counts in 16-bit integer format. The legal range for the counts is 1 to 4096.

MINimum and MAXimum cannot be used with this command.

- Comments**
- If block format is used, the most significant byte of each value must be sent first.
 - The segment sequence's repetition count list length must be the same length as its waveform segment and marker enable lists or must have a length of 1. If not, executing INITiate:IMMEDIATE generates Error +1114, "Sequence lists of different lengths".
 - A repetition count list of length 1 is treated as though it were the same length as the waveform segment list, with all repetition count values the same as the specified value.
 - Changing repetition count values preserves the waveform segment and marker enable lists, and vice versa.
 - **Executable when Initiated:** No
 - **Coupling Group:** None
 - **Related Commands:** [SOURce:]LIST[1]:SSEquence:COMBined
 - ***RST Condition:** Unaffected
 - **Power-On Condition:** No segment sequences are defined

Example Defining a Segment Sequence Repetition Count List

```
LIST:SSEQ:SEL ABC           Selects sequence ABC.
LIST:SSEQ:DEF 8            ABC is 8 points long.
LIST:SSEQ:SEQ A,B,C,D,E,F,G,H Defines segment sequence.
LIST:SSEQ:DWEL:COUN 6,1,1,1,1,1,1 Outputs segment A six times, others once.
```

:SSEquence:DWELI:COUNT:POINTs?

[SOURCE:]LIST[1]:SSEquence:DWELI:COUNT:POINTs? returns a number indicating the length of the currently selected segment sequence's repetition count list.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - ***RST Condition:** None
 - **Power-On Condition:** No segment sequences are defined

Example Query Repetition Count List Length

LIST:SSEQ:SEL ABC	<i>Selects segment sequence ABC.</i>
LIST:SSEQ:DWEL:COUNT:POINTs?	<i>Queries repetition count list length.</i>

:SSEquence:FREE?

[SOURCE:]LIST[1]:SSEquence:FREE? returns information on segment sequence memory availability and usage. The return data format is:

<numeric_value>,<numeric_value>

The first numeric value shows the amount of segment sequence memory available in points; the second, the amount of segment sequence memory used in points.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - ***RST Condition:** None
 - **Power-On Condition:** All of the segment sequence memory is available

Example Querying Segment Sequence Memory Usage

LIST:SSEQ:FREE?	<i>Queries segment memory usage.</i>
-----------------	--------------------------------------

:SSEquence:MARKer

[SOURce:]LIST[1]:SSEquence:MARKer *<marker_list>* defines, for each waveform segment of a segment sequence, whether the HP E1445A may output the marker pulses defined by the marker list for that waveform segment.

Parameters The *<marker_list>* may be either a comma-separated list of values or an IEEE-488.2 definite or indefinite length block containing the values in 16-bit integer format. A value of 0 disables marker pulse generation for the waveform segment; any non-zero value enables marker pulse generation.

MINimum and MAXimum cannot be used with this command.

- Comments**
- If block format is used, the most significant byte of each value must be sent first.
 - Frequently, marker pulse generation is enabled on no more than one waveform segment of a segment sequence. The [SOURce:]LIST[1]:SSEquence:MARKer:SPOint command is the most efficient way to enable marker pulse generation for a single waveform segment.
 - The segment sequence's marker enable list length must be the same length as its waveform segment and repetition count lists or must have a length of 1. If not, executing INITiate:IMMEDIATE generates Error +1114, "Sequence lists of different lengths".
 - A marker enable list of length 1 is treated as though it were the same length as the waveform segment list, with all marker enable values the same as the specified value.
 - Changing marker enable values preserves the waveform segment and repetition count lists, and vice versa.
 - **Executable when Initiated:** No
 - **Coupling Group:** None
 - **Related Commands:** [SOURce:]LIST[1]:SSEquence:COMBined
 - ***RST Condition:** Unaffected
 - **Power-On Condition:** No segment sequences are defined

Example Defining a Segment Sequence Marker Enable List

LIST:SSEQ:SEL ABC	<i>Selects sequence ABC.</i>
LIST:SSEQ:DEF 8	<i>ABC is 8 points long.</i>
LIST:SSEQ:SEQ A,B,C,D,E,F,G,H	<i>Defines segment sequence.</i>
LIST:SSEQ:MARK 1,0,0,0,1,0,0,0	<i>Enables marker output on segments A and E.</i>

:SSEquence:MARKer:POINts?

[SOURce:]LIST[1]:SSEquence:MARKer:POINts? returns a number indicating the length of the currently selected segment sequence's marker pulse list.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - ***RST Condition:** None
 - **Power-On Condition:** No segment sequences are defined

Example Query Marker Pulse List Length

LIST:SSEQ:SEL ABC *Selects segment sequence ABC.*
 LIST:SSEQ:MARK:POIN? *Queries marker pulse list length.*

:SSEquence:MARKer:SPOint

[SOURce:]LIST[1]:SSEquence:MARKer:SPOint *<point>* is a short-cut method for defining a marker list with marker pulse generation enabled on a single waveform segment. It creates a marker list whose length is the same as the current waveform segment list, and which enables marker pulse generation only on the segment specified. The waveform segment list must have been previously defined.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><point></i>	numeric	see below MINimum MAXimum	none
The valid range for <i><point></i> is 1 through the length of the current waveform segment list.			
MINimum selects the first segment of the current waveform segment list; MAXimum selects the last segment.			

- Comments**
- **Executable when Initiated:** No
 - **Coupling Group:** None
 - **Related Commands:** [SOURce:]LIST[1]:SSEquence:MARKer
 - ***RST Condition:** Unaffected
 - **Power-On Condition:** No segment sequences are defined

Example Creating a Single-Segment Marker List

LIST:SSEQ:SEL ABC *Selects segment sequence ABC.*
 LIST:SSEQ:DEF 8 *ABC is 8 points long.*
 LIST:SSEQ:SEQ A,B,C,D,E,F,G,H *Defines segment sequence.*
 LIST:SSEQ:MARK:SPO 3 *Enables marker pulse on segment C.*

:SSEquence:SElect

[SOURCE:]LIST[1]:SSEquence:SElect <name> selects a segment sequence for subsequent [SOURCE:]LIST[1]:SSEquence subsystem commands. This command will define the segment sequence name if it is undefined, but does not reserve any segment sequence memory.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<name>	character data	1 through 12 characters NONE	none
NONE selects no segment sequence			

- Comments**
- Legal names must start with an alphabetic character and contain only alphabetic, numeric, and underscore ("_") characters. Alphabetic character case (upper versus lower) is ignored. No segment sequence may have the same name as any waveform segment.
 - A maximum of 128 segment sequence names may exist at any time. Use the [SOURCE:]LIST[1]:SSEquence:DElete:ALL or SElected commands to delete names that are no longer needed.
 - **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Power-On Condition:** SOURCE:LIST1:SSEquence:SElect NONE
 - ***RST Condition:** Unaffected

Example Selecting a Segment Sequence

```
LIST:SSEQ:SEL ABC
```

Selects segment sequence ABC

[SOURce:]LIST[1]

:SSEquence:SEQuence

[SOURce:]LIST[1]:SSEquence:SEQuence *<segment_list>* defines the ordered sequence of waveform segments that constitute a full waveform.

Parameters The *<segment_list>* is a comma-separated list of waveform segment names. The waveform segment names must have been previously defined.

Comments

- The maximum length of the segment sequence is 32,768 points. By using the [SOURce:]LIST[1]:SSEquence:DWELL:COUNT command, up to 4096 repetitions of a segment sequence name take only one point in the segment sequence memory.

- **Executable when Initiated:** No

- **Coupling Group:** None

- ***RST Condition:** Unaffected

Example Defining a Segment Sequence

```
LIST:SSEQ:SEQ A,B,C
```

Defines segment sequence.

:SSEquence:SEQuence:SEGMents?

[SOURce:]LIST[1]:SSEquence:SEQuence:SEGMents? returns a number indicating the length of the currently selected segment sequence's waveform segment list.

Comments

- **Executable when Initiated:** Yes

- **Coupling Group:** None

- ***RST Condition:** None

- **Power-On Condition:** No segment sequences are defined

Example Query Segment Sequence Length

```
LIST:SSEQ:SEQ:SEGM?
```

Queries segment sequence length.

[SOURce:]LIST2

The [SOURce:]LIST2 subsystem defines the sample rate or frequencies list to be generated when [SOURce:]FREQUENCY[1]:MODE is set to LIST. Frequency list generation requires that TRIGGER[:START]:SOURce INTERNAL1 and [SOURce:]FREQUENCY[1]:MODE LIST be set. Frequency list generation is started by a sweep arm (ARM:SWEep subsystem) and is advanced by a sweep advance trigger (TRIGGER:SWEep subsystem).

Subsystem Syntax

```
[SOURce:]
LIST2
:FORMat
    [:DATA] <format>[,<length>]
:FREquency <freq_list>
:POINts?                                [query only]
```

:FORMat[:DATA]

[SOURce:]LIST2:FORMat[:DATA] <format>[,<length>] specifies the format of frequency list return data for the SOURce:LIST2:FREQUENCY command. The available frequency list return data formats are:

- **ASCii:** Returns the frequency list as NR3 numbers as defined in IEEE-488.2.
- **REAL:** Returns data in IEEE-488.2 definite block format containing the frequency values in IEEE-754 64-bit floating-point format.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<format>	discrete	ASCii REAL	none
<length>	numeric	see below MINimum MAXimum	none

If ASCII format is specified, <length> must either be omitted or must be 10 (or MINimum or MAXimum). If REAL format is specified, <length> must either be omitted or must be 64 (or MINimum or MAXimum).

- Comments**
- **Executable when Initiated:** Query form only
 - **Coupling Group:** None
 - **Related Commands:** [SOURce:]LIST2:FREQUENCY
 - ***RST Condition:** SOURce:LIST2:FORMat:DATA ASCii

Example Setting REAL Return Data Format

```
LIST:FORM REAL                                Sets real format.
```

:FREQUENCY

[SOURce:]LIST2:FREQUENCY *<freq_list>* defines the list of sample rates or frequencies to be generated when [SOURce:]FREQUENCY[1]:MODE is set to LIST.

Parameters The *<freq_list>* has one of the two following formats:

1. A comma-separated list of frequency values.
2. An IEEE-488.2 definite or indefinite length block containing the frequency values in IEEE-754 64-bit floating-point format.

The maximum length of the list is 256 frequency values.

The legal range for frequency values is given below. Default units are hertz. MINimum and MAXimum cannot be used with this command.

The minimum frequency is 0 Hz for all waveform shapes.

- **Arbitrary Waveforms and Sine Wave Outputs:** The maximum frequency is the current reference oscillator frequency divided by 4.
- **Square Wave Outputs:** The maximum frequency is the current reference oscillator frequency divided by 16.
- **Ramps and Triangle Outputs:** The maximum frequency is the current reference oscillator frequency divided by 4 further divided by the [SOURce:]RAMP:POINTS value.

For non-sine wave outputs,, multiply the maximum frequency by 2 if frequency doubling is in effect (see the [SOURce:]FREQUENCY[1]:RANGE command).

- Comments**
- When changing the frequency list length when [SOURce:]FREQUENCY[1]:MODE LIST is set, the [SOURce:]SWEp:TIME or the TRIGger:SWEp:TIMer value remains the same, depending on which command was most recently sent. The other value is changed based on the new frequency list length.
 - **Executable when Initiated:** Query form only
 - **Coupling Group:** Frequency
 - **Related Commands:** TRIGger[:START]:SOURce, [SOURce:]FREQUENCY[1]:MODE, [SOURce:]SWEp
 - ***RST Condition:** Unaffected
 - **Power-On Condition:** No frequency list is defined

Example Defining a Frequency List

LIST2:FREQ 1000,10e3,100e3,1 MHz *Defines the frequency list.*

:FREQuency:POINts?

[SOURce:]LIST2:FREQuency:POINts? returns a number that shows the length of the currently defined frequency list.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - ***RST Condition:** Unaffected
 - **Power-On Condition:** No frequency list is defined

Example Query the Frequency List Length

LIST:FREQ2:POIN?

Queries frequency list length.

[SOURce:]MARKer

The [SOURce:]MARKer subsystem controls:

- Which signal is routed to the “Marker Out” BNC.
- The polarity of the “Marker Out” BNC signal.
- Which signals, if any, are routed to the VXIbus ECL trigger lines.

Subsystem Syntax

```
[SOURce:]MARKer
: ECLTrg<n>
: FEED <source>
[ :STATe] <mode>
: FEED <source>
: POLarity <polarity>
[ :STATe] <mode>
```

:ECLTrg<n>:FEED

[SOURce:]MARKer:ECLTrg<n>:FEED <source> selects the marker source for the specified VXIbus ECL trigger line (ECLTRG0 or ECLTRG1). The available sources are:

- **“ARM[:START]:SEQUENCE[1][:LAYER[1]]”**: For arbitrary waveforms, the marker level changes with the first waveform point of the first repetition. A marker pulse is then output with the last waveform point of each repetition. For sine waves, the marker is a 50% duty cycle square wave at the sine wave frequency.
- **“ARM[:START]:SEQUENCE[1]:LAYER2”**: Once a start arm is received, the marker is asserted when the first amplitude point is triggered. The marker is unasserted with the last amplitude point of the last waveform repetition, or following an ABORT.
- **“[SOURce:]FREQUENCY[1]:CHANGE”**: Outputs a one sample period wide marker pulse that is output after a frequency change occurs. This shows that the new steady state frequency has been reached.
- **“[SOURce:]LIST[1]”**: Outputs marker pulses specified by the [SOURce:]LIST[1][:SEGMENT]:MARKer and SSEQUENCE:MARKer commands. The pulse is normally one sample period wide, but may be widened by placing markers on consecutive output points. This source is only useful with [SOURce:]FUNCTION[:SHAPE] USER (i.e., arbitrary waveform output).
- **“[SOURce:]PM:DEVIATION:CHANGE”**: Outputs a one sample period wide marker pulse that is output after a phase change occurs. This shows that the new phase has been reached.
- **“[SOURce:]ROSCillator”**: The reference oscillator as selected by [SOURce:]ROSCillator:SOURce.
- **“TRIGGER[:START]:SEQUENCE[1]”**: Outputs a nominal 12 nS marker pulse for each point of the segment list.

[SOURce:]MARKer

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<source>	string	“ARM[:START]:SEQuence[1][:LAYer[1]]” “ARM[:START]:SEQuence[1][:LAYer2]” “[SOURce:]FREQuency[1]:CHANge” “[SOURce:]LIST[1]” “[SOURce:]PM:DEVIation:CHANge” “[SOURce:]ROSCillator” “TRIGger[:START]:SEQuence[1]”	none

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** [SOURce:]MARKer:ECLTrg<n>[:STATe]
 - ***RST Condition:**
[SOURce:]MARKer:ECLTrg0:FEED “ARM[:START]:SEQuence[1][:LAYer[1]]”,
[SOURce:]MARKer:ECLTrg1:FEED “TRIGger[:START]:SEQuence[1]”

Example Setting the VXI ECLTRG0 Trigger Line Source

MARK:ECLT0:FEED “SOUR:LIST” *Sets marker list as source.*

:ECLTrg<n>[:STATe]

[SOURce:]MARKer:ECLTrg<n>[:STATe] <mode> enables or disables the routing of the selected marker signal ([SOURce:]MARKer:ECLTrg<n>:FEED command) to the specified VXIbus ECL trigger line (ECLTRG0 or ECLTRG1).

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<mode>	boolean	OFF 0 ON 1	none

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** [SOURce:]MARKer:ECLTrg<n>:FEED
 - ***RST Condition:** SOURce:MARKer:ECLTrg<n>:STATe OFF

Example Enabling Marker Output to ECLTRG0*

MARK:ECLT0 ON *Enables ECLTRG0*.*

:FEED

[SOURCE:]MARKer:FEED <source> selects the source for the front panel “Marker Out” BNC. The available sources are:

- **“ARM[:START]:SEquence[1][:LAYer[1]]”**: For arbitrary waveforms, the marker level changes with the first waveform point of the first repetition. A marker pulse is then output with the next-to-last waveform point of each repetition. For sine waves, the marker is a 50% duty cycle square wave at the sine wave frequency.
- **“ARM[:START]:SEquence[1][:LAYer2]”**: Once a start arm is received, the marker is asserted when the first amplitude point is triggered. The marker is unasserted with the last amplitude point of the last waveform repetition, or following an ABORT.
- **“[SOURCE:]FREQuency[1]:CHANge”**: Outputs a one sample period wide marker pulse that is output after a frequency change occurs. This shows that the new steady state frequency has been reached.
- **“[SOURCE:]LIST[1]”**: Outputs marker pulses specified by the [SOURCE:]LIST[1][:SEGment]:MARKer and SSEquence:MARKer commands. The pulse is normally one sample period wide, but may be widened by placing markers on consecutive output points. This source is only useful with [SOURCE:]FUNction:SHAPE USER (i.e., arbitrary waveform output).
- **“[SOURCE:]PM:DEVIation:CHANge”**: Outputs a one sample period wide marker pulse that is output after a phase change occurs. This shows that the new phase has been reached.
- **“[SOURCE:]ROSCillator”**: The reference oscillator as selected by [SOURCE:]ROSCillator:SOURce.
- **“TRIGger[:START]:SEquence[1]”**: Outputs a nominal 12 nS marker pulse for each point of the segment list.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<source>	string	“ARM[:START]:SEquence[1][:LAYer[1]]” “ARM[:START]:SEquence[1][:LAYer2]” “[SOURCE:]FREQuency[1]:CHANge” “[SOURCE:]LIST[1]” “[SOURCE:]PM:DEVIation:CHANge” “[SOURCE:]ROSCillator” “TRIGger[:START]:SEquence[1]”	none

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** [SOURCE:]MARKer:POLarity, [SOURCE:]MARKer:STATe]
 - ***RST Condition:**
SOURCE:MARKer:FEED “ARM[:START]:SEquence[1][:LAYer[1]]”

[SOURce:]MARKer

Example Setting the “Marker Out” BNC Source

MARK:FEED “SOUR:LIST” *Sets marker list as source.*

:POLarity

[SOURce:]MARKer:POLarity <polarity> selects the polarity of the marker signal at the front panel “Marker Out” BNC. NORMAL polarity selects an active high marker output; INVERTed an active low output.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<polarity>	discrete	INVERTed NORMAl	none

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** [SOURce:]MARKer:FEED, [SOURce:]MARKer[:STATe]
 - ***RST Condition:** SOURce:MARKer:POLarity NORMAl

Example Setting the “Marker Out” BNC Polarity

MARK:POL INV *Sets active low output.*

[:STATe]

[SOURce:]MARKer[:STATe] <mode> enables or disables the routing of the currently selected marker signal ([SOURce:]MARKer:FEED command) to the front panel “Marker Out” BNC.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<mode>	boolean	OFF 0 ON 1	none

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** [SOURce:]MARKer:FEED, [SOURce:]MARKer:POLarity
 - ***RST Condition:** SOURce:MARKer:STATe ON

Example Enabling Marker Output to “Marker Out” BNC

MARK ON *Enables “Marker Out” BNC.*

[SOURce:]PM

The [SOURce:]PM (Phase Modulation) subsystem controls the modulation for sine wave output (only). Phase modulation is not possible with other waveform shapes.

Subsystem Syntax

```
[SOURce:]
  PM
  [:DEVIation] <phase>
  :SOURce <source>
  :STATe <mode>
  :UNIT
  [:ANGLe] <units>
```

[:DEVIation]

[SOURce:]PM[:DEVIation] <phase> sets the modulation DEVIation for a sine wave output when [SOURce:]PM:SOURce is set to INTERNAL.

The query form returns the amplitude in terms of the default units, specified by the [SOURce:]PM:UNIT[:ANGLe] command.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<phase>	numeric	- π through π MINimum MAXimum	see below
MINimum selects $-\pi$; MAXimum selects π .			
The default units for DEVIation are specified by the [SOURce:]PM:UNIT[:ANGLe] command.			

Acceptable units are <suffix_multiplier>RAD (radians) and <suffix_multiplier>DEG (degrees).

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** [SOURce:]PM:SOURce, [SOURce:]PM:UNIT[:ANGLe]
 - ***RST Condition:** SOURce:PM:DEVIation 0

Example Setting Phase Deviation

```
PM:DEV 180 DEG
```

Sets deviation to 180°.

:SOURce

[SOURce:]PM:SOURce <source> selects the source for phase modulation data.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<source>	discrete	DPORt INTernal LBUS VXI	none

Comments The available sources are:

- **DPORt:** The HP E1445A’s front panel “Digital Port In” connector.
 - **LBUS:** The VXIbus local bus.
 - **INTernal:** The [SOURce:]PM[:DEViation] command.
 - **VXI:** The VXIbus data transfer bus.
- When the source for phase deviation data is the VXIbus data transfer bus, the least significant byte of the data should be written either in the least significant bits of a word to offset 176 decimal (B0 hex). The most significant byte should be written in the least significant bits of a word to offset 178 decimal (B2 hex). After both bytes are written, a word write of any data to offset 138 decimal (8A hex) is required to activate the new phase deviation.
 - Phase deviation may be changed at a maximum rate of one change every 5 reference oscillator cycles or 2 MHz, whichever is less.
 - **Executable when Initiated:** Yes
 - **Coupling Group:** Frequency
 - **Related Commands:** [SOURce:]PM[:DEViation], [SOURce:]PM:STATe
 - ***RST Condition:** SOURce:PM:SOURce INTernal

Example Setting Modulation Source

PM:SOUR DPOR

Sets “Digital Port In” connector as modulation source.

:STATe

[SOURce:]PM:STATe *<mode>* enables or disables phase modulation for sine wave output. Phase modulation is always disabled for other waveform shapes.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><mode></i>	boolean	OFF 0 ON 1	none

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** Frequency
 - **Related Commands:** [SOURce:]FUNCTio[n][:SHAPE]
 - ***RST Condition:** SOURce:PM:STATe OFF

Example Enabling Phase Modulation

```

FUNC:SHAP SIN           Selects sine wave output.
PM:STAT ON             Enables phase modulation.
INIT                   Starts output.
PM:DEV .78648          Sets deviation to  $\pi/4$ .

```

:UNIT[:ANGLE]

[SOURce:]PM:UNIT[:ANGLE] *<units>* sets the default angle units for subsequent [SOURce:]PM[:DEVIation] commands. The available default units are:

- **DEG:** Degrees
- **RAD:** Radians

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><units></i>	discrete	DEG RAD	none

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** [SOURce:]PM[:DEVIation]
 - ***RST Condition:** SOURce:PM:UNIT:ANGLE RAD

Example Setting the Default Angle Units

```

PM:UNIT:ANGL DEG       Sets default units to degrees.

```

The [SOURce:]RAMP subsystem selects the polarity of ramp waveforms, and the number of points on generated ramps and triangle waveforms.

Subsystem Syntax

```
[SOURce:]
RAMP
:POINTs <number>
:POLarity <polarity>
```

:POINTs

[SOURce:]RAMP:POINTs <number> specifies the number of points to be used to generate the stepped ramp or triangle waveform.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<number>	numeric	see below MINimum MAXimum	none
The valid range for <number> is 4 through the length of the largest available contiguous piece of waveform segment memory.			
MINimum selects 4 points; MAXimum selects the largest available contiguous piece of waveform segment memory or 262,144 points, whichever is less (4 points minimum).			

- Comments**
- For triangle waves, make <number> a multiple of 4 for best waveform shape.
 - When [SOURce:]FUNCTION[:SHAPE] RAMP or TRIangle is selected, the greater of the [SOURce:]RAMP:POINTs value and 8 points of contiguous waveform segment memory must be available. When [SOURce:]FUNCTION[:SHAPE] SQUARE is selected, 8 points of contiguous waveform segment memory must be available. Attempting to select one of these functions with less contiguous waveform segment memory available, or to set [SOURce:]RAMP:POINTs to a value larger than the largest contiguous amount of available waveform segment memory when ramp or triangle wave output is selected, will generate Error +1000,"Out of memory".
 - **Executable when Initiated:** Query form only
 - **Coupling Group:** Frequency and voltage
 - **Related Commands:** [SOURce:]FUNCTION[:SHAPE]
 - ***RST Condition:** SOURce:RAMP:POINTs 100

Example Setting Ramp Length

```
RAMP:POIN 1000
```

Sets ramp length.

:POLarity

[SOURce:]RAMP:POLarity *<polarity>* selects the polarity of the ramp, triangle, or square wave. For ramps, **NORMAL** generates a positive-going ramp; **INVERTed** generates a negative-going ramp. For triangles, **NORMAL** generates a triangle with an initial positive-going slope; **INVERTed** generates an initial negative-going slope. For square waves, **NORMAL** generates a waveform with initial voltage being the more positive voltage; **INVERTed** generates the more negative voltage first.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><polarity></i>	discrete	INVERTed NORMAL	none

- Comments**
- **Executable when Initiated:** Query form only
 - **Coupling Group:** Voltage
 - **Related Commands:** [SOURce:]FUNCTion[:SHAPE]
 - ***RST Condition:** SOURce:RAMP:POLarity NORMAL

Example Selecting Ramp Polarity

FUNC:SHAP RAMP
RAMP:POL INV

Selects ramp output.

Selects negative-going ramp.

The [SOURce:]ROSCillator subsystem controls the reference oscillator's source and indicates the frequency of an external oscillator. The HP E1445A uses the source and frequency information to generate sample output rate for arbitrary waveforms or waveform frequency for ramp, sine, square, and triangle wave output.

Subsystem Syntax

```
[SOURce:]
ROSCillator
:FREQUENCY
:EXTernal <frequency>
:SOURce <source>
```

:FREQUENCY:EXTernal

[SOURce:]ROSCillator:FREQUENCY:EXTernal <frequency> indicates to the HP E1445A the frequency of an external reference oscillator source. The [SOURce:]FREQUENCY[1] and [SOURce:]FREQUENCY2 subsystems use this value to generate sample rate and waveform frequencies when [SOURce:]ROSCillator:SOURce is set to EXTernal or ECLTrgn.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<frequency>	numeric	1 Hz through 42.94967296 MHz MINimum MAXimum	Hz
MINimum selects 1 Hz; MAXimum selects 42.94967296 MHz.			

- Comments**
- Indicating an incorrect frequency for an external reference oscillator will cause incorrect sample rate and waveform frequencies to be generated by the [SOURce:]FREQUENCY[1] and [SOURce:]FREQUENCY2 subsystems.
 - **Executable when Initiated:** Query form only
 - **Coupling Group:** Frequency
 - ***RST Condition:** SOURce:ROSCillator:FREQUENCY:EXTernal 42.94967296 MHz

Example Specifying the External Reference Oscillator Frequency

```
ROSC:FREQ:EXT 5 MHZ
```

External oscillator is 5 MHz.

:SOURce

[SOURce:]ROSCillator:SOURce <source> selects the reference oscillator source.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<source>	discrete	CLK10 ECLTrg0 ECLTrg1 EXTernal INTernal[1] INTernal2	none

Comments • The available sources are:

- **CLK10:** The VXIbus CLK10 (10 MHz) line.
 - **EXTernal:** The HP E1445A’s front panel “Ref/Sample In” BNC.
 - **ECLTrg0** and **ECLTrg1:** The VXIbus ECL trigger lines.
 - **INTernal[1]:** The internal 42.94967296 MHz oscillator. Using this oscillator in conjunction with the [SOURce:]FREQUENCY[1] subsystem gives a resolution of .01 Hz for sine waves and arbitrary waveform sample rates.
 - **INTernal2:** The internal 40 MHz oscillator. Using this oscillator in conjunction with the [SOURce:]FREQUENCY2 subsystem allows that subsystem to exactly produce frequencies such as 1, 5, 10, and 20 MHz for arbitrary waveform sample rates.
- The reference oscillator is used to generate the sample rate and waveform frequencies specified in the [SOURce:]FREQUENCY[1] and [SOURce:]FREQUENCY2 subsystems.
 - Use [SOURce:]ROSCillator:FREQUENCY:EXTernal to indicate the frequency of an external reference oscillator.
 - **Executable when Initiated:** Query form only
 - **Coupling Group:** Frequency
 - **Related Commands:** [SOURce:]ROSCillator:FREQUENCY:EXTernal, [SOURce:]FREQUENCY[1] commands, [SOURce:]FREQUENCY2 commands
 - ***RST Condition:** SOURce:ROSCillator:SOURce INTernal1

Example Setting the Reference Oscillator Source

ROSC:SOUR CLK10

Selects VXI CLK10 line as oscillator source.

The [SOURce:]SWEep subsystem selects:

- The number of frequency sweeps or repetitions of a frequency list to be performed.
- The direction of a frequency sweep.
- The number of points in a frequency sweep.
- A linear or logarithmic frequency sweep with respect to time.
- The sweep rate for frequency sweeps and frequency lists when TRIGger:SWEep:SOURce TIMer is set.

Frequency sweeping generation requires that TRIGger[:START:]SOURce INTerna1 and [SOURce:]FREQuency[1]:MODE SWEep be set. A sweep is started by a sweep arm (ARM:SWEep subsystem) and is advanced by a sweep advance trigger (TRIGger:SWEep subsystem).

Subsystem Syntax

```
[SOURce:]
SWEep
:COUNT <number>
:DIRection <direction>
:POINts <number>
:SPACing <mode>
:TIME <time>
```

SWEep:COUNT

[SOURce:]SWEep:COUNT <number> specifies the number of sweeps or repetitions of a frequency list the HP E1445A will perform after an INITiate:IMMediate command before the sweep subsystem returns to the idle state. This command is equivalent to the ARM:SWEep:COUNT command; either command may be used, and executing either one changes the value of the other.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<number>	numeric	1 through 2147483647 9.9E+37 INFinity	none
MINimum selects 1 sweep; MAXimum selects 2147483647 sweeps. 9.9E+37 is equivalent to INFinity.			

- Comments**
- **Executable when Initiated:** Query form only
 - **Coupling Group:** Frequency
 - **Related Commands:** INITiate:IMMediate

- ***RST Condition:** SOURce:SWEep:COUNT 1

Example Setting the Sweep Count

SWE:COUN 10

Sets 10 sweeps per INITiate.

:DIRection

[SOURce:]SWEep:DIRection *<direction>* selects the direction of the frequency sweep.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><direction></i>	discrete	DOWN UP	none

- Comments**
- The available directions are:
 - **DOWN:** The sweep starts at the stop frequency specified by [SOURce:]FREQuency[1]:STARt and STOP, or CENTER and SPAN and ends at the start frequency.
 - **UP:** The sweep starts at the start frequency specified by [SOURce:]FREQuency[1]:STARt and STOP, or CENTER and SPAN and ends at the stop frequency.
 - **Executable when Initiated:** Query form only
 - **Coupling Group:** Frequency
 - **Related Commands:** [SOURce:]FREQuency[1]:CENTer, MODE, SPAN, START, and STOP, [SOURce:]SWEep:POINts and SPACing
 - ***RST Condition:** SOURce:SWEep:DIRection UP

Example Setting the Sweep Direction

SWE:DIR DOWN

Sweeps down in frequency.

:POINts

[SOURce:]SWEep:POINts *<number>* selects the number of points in a frequency sweep.

The frequencies generated by the sweep are evenly spaced linearly or logarithmically, depending on the [SOURce:]SWEep:SPACing setting, between the frequencies specified by [SOURce:]FREQUency[1]:STARt and STOP, or CENTer and SPAN, inclusive.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><number></i>	numeric	2 through 1073741824 MINimum MAXimum	none
MINimum selects 2 points; MAXimum selects 1073741824 points.			

- Comments**
- [SOURce:]SWEep:POINts specifies the number of points with [SOURce:]FREQUency[1]:MODE set to SWEep; the length of the [SOURce:]LIST2:FREQUency list specifies the points with [SOURce:]FREQUency[1]:MODE set to LIST.
 - When changing the [SOURce:]SWEep:POINts value when [SOURce:]FREQUency[1]:MODE SWEep set, the [SOURce:]SWEep:TIME or the TRIGger:SWEep:TIMer value remains the same, depending on which command was most recently sent. The other value is changed based on the new SWEep:POINts value.
 - **Executable when Initiated:** Query form only
 - **Coupling Group:** Frequency
 - **Related Commands:** [SOURce:]FREQUency[1]:CENTer, MODE, SPAN, START, and STOP, [SOURce:]SWEep:DIRection and SPACing
 - ***RST Condition:** SOURce:SWEep:POINts 800

Example Setting the Number of Points in the Sweep

SWE:POIN 100 *Sets 100 points in sweep.*

:SPACing

[SOURce:]SWEep:SPACing *<mode>* selects either linear or logarithmic frequency sweep mode.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><mode></i>	discrete	LINear LOGarithmic	none

Comments

- The available modes are:
 - **LINear:** Selects the linear sweep mode. The sample rate or waveform frequency increases or decreases linearly between the start and stop frequencies selected by [SOURce:]FREQUENCY[1]:START and STOP, or CENTER and SPAN.
 - **LOGarithmic:** Selects the logarithmic sweep mode. The sample rate or waveform frequency increases or decreases logarithmically between the start and stop frequencies selected by [SOURce:]FREQUENCY[1]:START and STOP, or CENTER and SPAN.
- **Executable when Initiated:** Query form only
- **Coupling Group:** Frequency
- **Related Commands:** [SOURce:]FREQUENCY[1]:CENTER, MODE, SPAN, START, and STOP, [SOURce:]SWEep:DIRection and POINTs
- ***RST Condition:** SOURce:SWEep:SPACing LINear

Example Setting the Frequency Sweep Spacing

SWE:SPAC LOG

Selects logarithmic spacing.

:TIME

[SOURce:]SWEep:TIME <number> selects the duration of the sweep or frequency list generation when TRIGger:SWEep:SOURce is set to TIMer. The duration is the time from the start of the sweep or list until when the last frequency begins to be output. The value set by this command is coupled to the TRIGger:SWEep:TIMer command value by the following equation:

$$\text{TIME} = \text{TIMer} * (\text{points} - 1)$$

where *points* is the [SOURce:]SWEep:POINts value for frequency sweeps, or the length of the frequency list for frequency list generation.

When changing the frequency list length when [SOURce:]FREQuency[1]:MODE LIST is set, or the [SOURce:]SWEep:POINts value when any other MODE is set, the TIME or TIMer value remains the same, depending on which command, [SOURce:]SWEep:TIME or TRIGger:SWEep:TIMer respectively, was most recently sent. The other value is changed based on the new *points* value.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<time>	numeric	see below MINimum MAXimum	seconds
MINimum selects 1.25 mS * (points - 1); MAXimum selects 4.19430375 S * (points - 1). The above values bound the valid range for time.			

- Comments**
- When performing multiple sweeps or list generations with ARM:SWEep:SOURce IMMEDIATE set, the last frequency point is output for the same length of time as all other points. The SWEep:TIME value is the time from the start of the sweep or list until the last frequency begins to be output and does not include the time for the last frequency point. Therefore, if a specific sweep repetition time is desired, SWEep:TIME should be set according to the following equation:

$$\text{SWEep:TIME} = \text{time} * (\text{points} - 1) / \text{points}$$

Thus, to set a repetition time of 1 S for a 5 point sweep, SWEep:TIME should be set to .8 S.

- **Executable when Initiated:** Query form only
- **Coupling Group:** Frequency
- **Related Commands:** [SOURce:]LIST2:FREQuency, [SOURce:]SWEep:POINts, TRIGger:SWEep:SOURce, TRIGger:SWEep:TIMer
- ***RST Condition:** SOURce:SWEep:TIME 1

Example Setting the Duration of the Sweep

SWE:TIME 10

Sets sweep to take 10 seconds.

[SOURce:]VOLTage

The [SOURce:]VOLTage subsystem controls the amplitude and offset values for all output waveform shapes.

Subsystem Syntax

```
[SOURce:]
  VOLTage
    [:LEVel]
      [:IMMediate]
        [:AMPLitude] <amplitude>
          :UNIT
            [:VOLTage] <units>
              :OFFSet <offset>
```

[:LEVel][:IMMediate][:AMPLitude]

[SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude] <amplitude> sets the output amplitude when SOURce:FUNCTION[:SHAPe] is set to DC, RAMP, SINusoid, SQUare, or TRIangle. It sets the positive full-scale output amplitude for arbitrary waveforms (SOURce:FUNCTION[:SHAPe] USER set); the least significant DAC code bit represents 1/4095 of this value.

Output amplitude for ramp, sine, square and triangle wave output may be programmed in volts, peak volts, peak-to-peak volts, RMS volts, or dBm. Output amplitude for DC must be programmed in volts; for arbitrary waveform output, volts or peak volts.

The query form returns the amplitude in terms of the default units, specified by the SOURce:VOLTage[:LEVel][:IMMediate][:AMPLitude]:UNIT[:VOLTage] command.

[SOURce:]VOLTage

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<amplitude>	numeric	see below MINimum MAXimum	see below
<p>DC Output: When a matched load has been specified, MINimum selects -5.12 V; MAXimum selects 5.11875 V.</p> <p>Arbitrary Waveform, Ramp, Sine, Square, and Triangle Outputs: When a matched load has been specified, if the current offset voltage is less than or equal to 1 V, MINimum selects the equivalent of .16187 V (peak) in the default voltage units; if the current offset voltage is greater than 1 V, MINimum selects the equivalent of 1.02486 V in the current voltage units. MAXimum selects the equivalent of the lesser of (+6.025 V - [output offset value]) [rounded down to a value that is a multiple of .01 dB from 5.11875] and +5.11875 V.</p> <p>For all waveform shapes, when an open circuit load has been specified, double the all the above voltages.</p> <p>These values bound the legal range of values for <amplitude>.</p> <p>Default units are specified by the [SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude]:UNIT[:VOLTage] command.</p>			

For all waveform shapes other than DC output, output amplitude control is implemented as a 0 to 30 dB attenuator with .01 dB resolution. For DC output, the amplitude is generated using the DAC; resolution is .00125 V into a matched load, .0025 V into an open circuit.

For DC output, acceptable units are V (volts). For arbitrary waveform output, acceptable units are V (volts) and VPK. For ramp, sine, square, and triangle outputs, acceptable units are V (volts), VPK (volts peak), VPP (volts peak-to-peak), VRMS (volts RMS), W (watts) and DBM or DBMW (dB referenced to 1 milliwatt). For W, DBM, and DBMW, the amplitude is referenced to the OUTPUT[1]:LOAD value; they are meaningless and therefore unavailable if OUTPUT[1]:LOAD INFINITY is set.

- Comments**
- **Related Commands:** OUTPUT[1]:LOAD, [SOURce:]FUNCTION[:SHAPE], [SOURce:]VOLTage[:LEVel][:IMMediate]:OFFSet
 - **Executable when Initiated:** Yes
 - **Coupling Group:** Voltage
 - ***RST Condition:**
SOURce:VOLTage:LEVel:IMMediate:AMPLitude .16187 V

Example Setting Output Voltage

VOLT 5 VPP

Sets output amplitude to 5 volts peak-to-peak.

[:LEVel][:IMMediate][:AMPLitude]:UNIT[:VOLTage]

[SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude]:UNIT[:VOLTage] *<units>*
 sets the default units for subsequent
 [SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude] commands.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><units></i>	discrete	DBM DBMW V VPK VPP VRMS W	none

Comments • The available default units are:

- **DBM | DBMW:** dB referenced to 1 milliwatt.
- **V:** Volts. This is equivalent to VPK for time-varying waveforms.
- **VPK:** Volts peak
- **VPP:** Volts peak-to-peak
- **VRMS:** Volts RMS
- **W:** Watts

For W, DBM, and DBMW, the amplitude is referenced to the OUTPUT[1]:LOAD value; they are meaningless and therefore unavailable if OUTPUT[1]:LOAD INFINITY is set.

- **Executable when Initiated:** Yes
- **Coupling Group:** None
- **Related Commands:** OUTPUT[1]:IMPedance, OUTPUT[1]:LOAD, [SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude]
- ***RST Condition:**
 SOURce:VOLTage:LEVel:IMMediate:AMPLitude:UNIT:VOLTage V

Example Setting the Default Voltage Units

VOLT:UNIT:VOLT VPP

Sets default units to volts peak-to-peak.

[SOURce:]VOLTage

[[:LEVel]][[:IMMediate]:OFFSet

[SOURce:]VOLTage[:LEVel]][[:IMMediate]:OFFSet *<offset>* sets the output offset voltage for all waveform shapes except DC. Output offset amplitude is programmed in volts.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><offset></i>	numeric	see below MINimum MAXimum	volts
DC Output: When a matched load has been specified, MINimum selects -5.0 V; MAXimum selects +5.0 V.			
Arbitrary Waveform, Ramp, Sine, Square, and Triangle Outputs: When a matched load has been specified, if the output amplitude, in volts, is greater than 1.02426 V (peak), MINimum selects the greater of (-6.025 V + output amplitude value) and -5.0 V, rounded down if needed to a multiple of 2.5 mV; MAXimum selects the lesser of (+6.025 V - output amplitude value) and +5.0 V, again rounded down. If the output amplitude in volts, is less than or equal to 1.02426 V, MINimum selects the greater of (-1.205 V + output amplitude value) and -.99993 V rounded down if needed to a multiple of .499966 mV; MAXimum selects the lesser of (+1.205 V - output amplitude value) and +.99993 V, again rounded down.			
For all waveform shapes, when an open circuit load has been specified, double all the above voltages.			
The above values bound the legal range for <i><offset></i> .			

- Comments**
- **Related Commands:** [SOURce:]VOLTage[:LEVel]][[:IMMediate]][[:AMPLitude]
 - **Executable when Initiated:** Yes
 - **Coupling Group:** Voltage
 - ***RST Condition:** SOURce:VOLTage:LEVel:IMMediate:OFFSet 0 V

Example Setting Offset Voltage

VOLT:OFFS 3

Sets offset voltage to 3 volts.

The STATus subsystem controls the SCPI-defined Operation and Questionable Signal status registers. Each is comprised of a Condition Register, an Event Register, an enable mask, and negative and positive transition filters.

Each Status Register works as follows:

When a condition occurs, the appropriate bit in the Condition Register is set or cleared. If the corresponding transition filter is enabled for that bit, the same bit is set in the associated Event Register. The contents of the Event Register and the enable mask are logically ANDed bit-for-bit; if any bit of the result is set, the Summary bit for that register is set in the status byte. The Status Byte Summary bit for the Operation Status Register is bit 7; for the Questionable Signal Status Register, bit 3.

Operation Status Register Only bits 0 (calibrating), 3 (sweeping), 6 (waiting for arm), and 8 (initiated) are defined for the HP E1445A. All other bits are always zero.

Bit 0 - Calibrating: Set (1) during the execution of the CALibration[:DC]:BEGin command. Cleared (0) at the end of DC calibration or if calibration is aborted.

Bit 3 - Sweeping: Set (1) while a frequency sweep or list is in progress. Cleared (0) when waveform generation is halted, when frequency sweeping or lists are not selected, and at the end of each sweep or list.

Bit 6 - Waiting for Arm:ARM Set (1) when waiting for a start arm. Cleared (0) when a start arm is accepted or when waveform generation is aborted.

Bit 8 - Initiated: Set (1) by the INITiate:IMMEDIATE command. Cleared (0) when waveform generation is complete and the trigger subsystem returns to the idle state.

Questionable Signal Status Register Only bits 5 (frequency) and 8 (calibration) are defined. All other bits are always 0.

Bit 5 - Frequency: Set (1) when the [SOURce:]FREQUENCY2 divide-by-n frequency generator is selected and the generated frequency differs from the specified frequency by greater than 1%. Cleared (0) otherwise.

Bit 8 - Calibration: Set (1) if an error has been detected in the non-volatile calibration memory. Cleared (0) otherwise.

STATus

Subsystem Syntax

```
STATus
:OPC
  :INITiate <state>
:OPERation
  :CONDition? [query only]
  :ENABle <unmask>
  [:EVENT]? [query only]
  :NTRansition <unmask>
  :PTRansition <unmask>
:PRESet [no query]
:QUESTionable
  :CONDition? [query only]
  :ENABle <unmask>
  [:EVENT]? [query only]
  :NTRansition <unmask>
  :PTRansition <unmask>
```

:OPC:INITiate

STATus:OPC:INITiate <state> controls whether the *OPC, *OPC?, and *WAI commands will complete immediately or whether they will wait for waveform generation to complete. With *state* OFF set, these commands will complete immediately. With *state* ON set, they will wait for the Pending Operation Flag set true by INITiate:IMMEDIATE to return false, indicating that the trigger system is in the idle state and that waveform generation has completed or been aborted by the ABORT or *RST commands.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<state>	boolean	OFF 0 ON 1	none

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** *OPC, *OPC?, *RST, *WAI, ABORT, INITiate:IMMEDIATE, STATus:PRESet
 - ***RST Condition:** Unaffected
 - **Power-on Condition:** STATus:OPC:INITiate ON

Example Setting Immediate Completion Mode

STAT:OPC:INIT OFF *Completes immediately for *OPC, etc.*

:OPERation:CONDition?

STATUS:OPERation:CONDition? returns the contents of the Operation Condition Register. Reading the register does not affect its contents.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** STATUS commands, *SRE, *STB?
 - ***RST Condition:** All bits of the Operation Condition Register are cleared as a result of the state present after *RST.

Example Querying the Operation Condition Register

STAT:OPER:COND? *Queries the Operation Condition Register.*

:OPERation:ENABLE

STATUS:OPERation:ENABLE <unmask> specifies which bits of the Operation Event Register are included in its Summary bit. The Summary bit is the bit-for-bit logical AND of the Event Register and the unmasked bit(s).

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<unmask>	numeric or non-decimal numeric	0 through +32767	none

The non-decimal numeric forms are the #H, #Q, or #B formats specified by IEEE-488.2.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** STATUS commands, *SRE, *STB?
 - ***RST Condition:** Unaffected
 - **Power-on Condition:** STATUS:OPERation:ENABLE 0

Example Setting the Operation Register Enable Mask

STAT:OPER:ENAB #H0040 *Enables summary on Waiting for Arm bit.*

:OPERation[:EVENT]?

STATUS:OPERation[:EVENT]? returns the contents of the Operation Event Register. Reading the register clears it to 0.

- Comments**
- The Operation Event Register is also cleared to 0 by the *CLS common command.
 - **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** STATUS commands, *SRE, *STB?
 - ***RST Condition:** Unaffected
 - **Power-on Condition:** Operation Event Registers are cleared to 0.

Example Querying the Operation Event Register

STAT:OPER:EVEN? *Queries the Operation Event Register.*

:OPERation:NTRansition

STATUS:OPERation:NTRansition <unmask> sets the negative transition mask. For each bit unmasked, a 1-to-0 transition of that bit in the Operation Condition Register will set the same bit in the Operation Event Register.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<unmask>	numeric or non-decimal numeric	0 through +32767	none

The non-decimal numeric forms are the #H, #Q, or #B formats specified by IEEE-488.2.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** STATUS commands, *SRE, *STB?
 - ***RST Condition:** Unaffected
 - **Power-on Condition:** STATUS:OPERation:NTRansition 0

Example Setting the Operation Register Negative Transition Mask

STAT:OPER:NTR #H0008 *Sets the Event bit when sweeping condition is cleared.*

:OPERation:PTRansition

STATUS:OPERation:PTRansition <unmask> sets the positive transition mask. For each bit unmasked, a 0-to-1 transition of that bit in the Operation Condition Register will set the same bit in the Operation Event Register.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<unmask>	numeric or non-decimal numeric	0 through +32767	none

The non-decimal numeric forms are the #H, #Q, or #B formats specified by IEEE-488.2.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** STATUS commands, *SRE, *STB?
 - ***RST Condition:** Unaffected
 - **Power-on Condition:** STATUS:OPERation:PTRansition 32767

Example Setting the Operation Register Positive Transition Mask

STAT:OPER:PTR #H0040

Sets the event bit when Waiting for Arm condition is set.

:PRESet

STATUS:PRESet initializes the Enable Registers and transition masks for the Operation Status and Questionable Signal Status Registers and sets STATUS:OPC:INITiate ON. For both Status Registers, the Enable Registers are set to 0, the negative transition masks are set to 0, and the positive transition masks are set to 32767.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** STATUS commands, *SRE, *STB?
 - ***RST Condition:** None

Example Presetting the Status Subsystem

STAT:PRES

Presets the status subsystem.

:QUESTionable:CONDition?

STATus:QUESTionable:CONDition? returns the contents of the Questionable Signal Condition Register. Reading the register does not affect its contents.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** STATus commands, *SRE, *STB?
 - ***RST Condition:** All bits of the Condition Register are cleared as a result of the state present after *RST, except for the Calibration bit, which will remain set if the condition persists.

Example Querying the Questionable Signal Condition Register

STAT:QUES:COND? *Queries Questionable Signal Condition Register.*

:QUESTionable:ENABLE

STATus:QUESTionable:ENABLE <unmask> specifies which bits of the Questionable Signal Event Register are included in its Summary bit. The Summary bit is the bit-for-bit logical AND of the Event Register and the unmasked bit(s).

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<unmask>	numeric or non-decimal numeric	0 through +32767	none

The non-decimal numeric forms are the #H, #Q, or #B formats specified by IEEE-488.2.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** STATus commands, *SRE, *STB?
 - ***RST Condition:** Unaffected
 - **Power-on Condition:** STATus:QUESTionable:ENABLE 0

Example Setting the Questionable Signal Register Enable Mask

STAT:QUES:ENAB #H0040 *Enables summary on Waiting for Arm bit.*

:QUESTionable[:EVENT]?

STATus:QUESTionable[:EVENT]? returns the contents of the Questionable Signal Event Register. Reading the register clears it to 0.

- Comments**
- The Event Register is also cleared to 0 by the *CLS common command.
 - **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** STATus commands, *SRE, *STB?
 - ***RST Condition:** Unaffected
 - **Power-on Condition:** The Event Register is cleared to 0.

Example Querying the Questionable Signal Event Register

STAT:QUES:EVEN? *Queries the Questionable Signal Event Register.*

:QUESTionable:NTRansition

STATus:QUESTionable:NTRansition <unmask> sets the negative transition mask. For each bit unmasked, a 1-to-0 transition of that bit in the Questionable Signal Condition Register will set the same bit in the Questionable Signal Event Register.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<unmask>	numeric or non-decimal numeric	0 through +32767	none

The non-decimal numeric forms are the #H, #Q, or #B formats specified by IEEE-488.2.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** STATus commands, *SRE, *STB?
 - ***RST Condition:** Unaffected
 - **Power-on Condition:** STATus:QUESTionable:NTRansition 0

Example Setting the Questionable Signal Register Negative Transition Mask

STAT:QUES:NTR #H0008 *Sets the Event bit when sweeping condition is cleared.*

:QUESTIONable:PTRansition

STATUS:QUESTIONable:PTRansition <unmask> sets the positive transition mask. For each bit unmasked, a 0-to-1 transition of that bit in the Questionable Signal Condition Register will set the same bit in the Questionable Signal Event Register.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<unmask>	numeric or non-decimal numeric	0 through +32767	none

The non-decimal numeric forms are the #H, #Q, or #B formats specified by IEEE-488.2.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** STATUS commands, *SRE, *STB?
 - ***RST Condition:** Unaffected
 - **Power-on Condition:** STATUS:QUESTIONable:PTRansition 32767

Example Setting the Questionable Signal Register Positive Transition Mask

STAT:QUES:PTR #H0040

Sets the event bit when Waiting for Arm condition is set.

The SYSTem subsystem returns error messages and the SCPI version number to which the HP E1445A complies.

Subsystem Syntax	SYSTem	
	:ERRor?	[query only]
	:VERSion?	[query only]

:ERRor?

SYSTem:ERRor? returns the error messages in the error queue. See Table B-6 in Appendix B for a listing of possible error numbers and messages.

- Comments**
- The HP E1445A places any generated errors into the error queue. The queue is first-in, first out. With several errors waiting in the queue, the SYSTem:ERRor? command returns the oldest unread error message first.
 - The error queue can hold 30 error messages. If the HP E1445A generates more than 30 messages that are not read, it replaces the last error message in the queue with Error -350, "Too many errors". No additional messages are placed into the queue until SYSTem:ERRor? reads some messages or the *CLS (clear status) command clears the queue.
 - When the error queue is empty, SYSTem:ERRor? returns +0, "No error".
 - **Executable when Initiated:** Yes
 - ***RST Condition:** Unaffected
 - **Power-On Condition:** No errors are in the error queue

Example Reading the Error Queue

SYST:ERR? *Queries the error queue.*

SYSTem

:VERSion?

SYSTem:VERSion? returns the SCPI version number to which the HP E1445A complies: “1991.0”.

- Comment**
- **Executable when Initiated:** Yes
 - ***RST Condition:** None

Example Querying the SCPI Revision

SYST:VERS?

Queries SCPI revision.

The TRIGger subsystem operates with the ARM subsystem to control the behavior of the trigger system, as follows:

- The source and slope for generating the individual samples of a waveform.
- The source and slope of the signal that may gate sample generation.
- The source and slope for prematurely stopping one trigger cycle, without aborting the entire trigger system.
- The source for advancing a frequency sweep or list.

Subsystem Syntax

```

TRIGger
[:START]:SEquence[1]]
:COUNT <number>
:GATE
:POLarity <polarity>
:SOURce <source>
:STATe <state>
[:IMMEDIATE] [no query]
:SLOPe <edge>
:SOURce <source>

:STOP]:SEquence2
[:IMMEDIATE] [no query]
:SLOPe <edge>
:SOURce <source>

:SWEep]:SEquence3
[:IMMEDIATE] [no query]
:LINK <link>
:SOURce <source>
:TIMer <period>

```

TRIGger

[[:STARTt]:COUNT

TRIGger[:STARTt]:COUNT *<number>* would normally specify the number of triggers the HP E1445A would accept after an INITiate:IMMEDIATE command before returning the start trigger sequence to the wait-for-arm state. However, since this is equal to the length of the current waveform, and is not configurable here, the only legal value for this command is 9.91e37 or NaN (not a number).

There is no need to send this command. It is included for SCPI compatibility purposes only.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><number></i>	numeric	9.91e37 NAN MINimum MAXimum	none
MINimum and MAXimum select 9.91e37 triggers. 9.91E+37 is equivalent to NAN.			

- Comments**
- **Executable when Initiated:** Query form only
 - **Coupling Group:** None
 - **Related Commands:** ABORt, INITiate:IMMEDIATE
 - ***RST Condition:** TRIGger:STARt:COUNT 9.91e37

Example Setting the Start Trigger Count

TRIG:COUN NAN

[:START]:GATE:POLarity

TRIGger[:START]:GATE:POLarity *<polarity>* selects the polarity of the HP E1445A's front panel "Stop Trig/FSK/Gate In" BNC which gates the TRIGger:STARt subsystem. NORMal polarity selects an active high gate; INVerted polarity selects an active low gate. This polarity is significant only when TRIGger[:START]:GATE SOURce is set to EXTernal. The programmed value is retained but not used when other sources are selected.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><polarity></i>	discrete	INVerted NORMal	none

- Comments**
- **Executable when Initiated:** Query form only
 - **Coupling Group:** Frequency
 - **Related Commands:** TRIGger[:START]:GATE:SOURce
 - ***RST Condition:** TRIGger:STARt:GATE:POLarity INVerted

Example Setting the Sample Gate Polarity

TRIG:STARt:GATE:POL NORM *Sets active high gate.*

[:START]:GATE:SOURce

TRIGger[:START]:GATE:SOURce *<source>* selects the source which gates the TRIGger[:START] subsystem. The TRIGger[:START] subsystem is suspended (no new samples are generated) while the selected gate source is asserted. Normal sample generation resumes when the gate is unasserted.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><source></i>	discrete	EXTernal TTLTrg0 through TTLTrg7	none

- Comments**
- The available sources are:
 - **EXTernal:** The HP E1445A's front panel "Stop Trig/FSK/Gate In" BNC connector.
 - **TTLTrg0** through **TTLTrg7:** The VXIbus TTL trigger lines.
 - When a VXIbus TTLTrg<n> line is selected as the gate source, the low level on the line asserts the gate. The TRIGger[:START]:GATE:POLarity command selects

TRIGger

the active level for the front panel's "Stop Trig/FSK/Gate In" BNC when used as the gate source.

- The front panel's "Stop Trig/FSK/Gate In" BNC is a three-use connector; for FSK control, as a stop trigger source, or as a sample gate source. Only one of these uses may be active at any time.
- If a VXIbus TTLTrg trigger line is used as the sample gate source, then no TTLTrg trigger lines can be used for FSK control or as a stop trigger source.
- **Executable when Initiated:** Query form only
- **Coupling Group:** Frequency
- **Related Commands:** TRIGger[:START]:GATE:POLarity, [SOURce:]FREQUENCY[1]:FSK:SOURce, TRIGger:STOP:SOURce
- ***RST Condition:** TRIGger:START:GATE:SOURce EXTERNAL

Example Setting the Sample Gate Source

TRIG:GATE:SOUR TTLT0

Selects VXIbus trigger line TTLTRG0 as sample gate source.*

[:START]:GATE:STATE

TRIGger[:START]:GATE:STATE <mode> enables or disables sample gating. When enabled, the TRIGger[:START] subsystem is suspended (no new samples are generated) while the gate source selected by TRIGger[:START]:GATE:SOURce is asserted. Normal sample generation resumes when the gate is unasserted.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<mode>	boolean	OFF 0 ON 1	none

- Comments**
- **Executable when Initiated:** Query form only
 - **Coupling Group:** Frequency
 - **Related Commands:** TRIGger[:START]:GATE:SOURce
 - ***RST Condition:** TRIGger:START:GATE:STATE OFF

Example Enabling Sample Gating

TRIG:GATE:STAT ON

Enables sample gating.

[[:START]:IMMEDIATE]

TRIGger[:START]:IMMEDIATE immediately advances to the next sample in a waveform regardless of the selected trigger source, provided that the trigger system has been initiated and a start arm received. The selected trigger source remains unchanged.

- Comments**
- Executing this command with the start trigger sequence not in the wait-for-trigger state generates Error -211, "Trigger ignored".
 - **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** INITiate[:IMMEDIATE], TRIGger
 - ***RST Condition:** None

Example Single Stepping a Waveform

ARM:LAY2:SOUR IMM	<i>Sets immediate arming.</i>
TRIG:SOUR HOLD	<i>Sets manual sample generation.</i>
INIT	<i>Initiates trigger system.</i>
TRIG	<i>Advances waveform.</i>

[[:START]:SLOPE]

TRIGger[:START]:SLOPE *<edge>* selects the edge (rising or falling) at the HP E1445A's front panel "Ref/Sample In" BNC to advance the waveform. This edge is significant only with TRIGger[:START]:SOURce set to EXTERNAL. The programmed value is retained but not used when other sources are selected.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><edge></i>	discrete	NEGative POSitive	none

- Comments**
- **Executable when Initiated:** Query form only
 - **Coupling Group:** None
 - **Related Commands:** TRIGger[:START]:SOURce
 - ***RST Condition:** TRIGger:START:SLOPE POSitive

Example Setting the Start Trigger Slope

TRIG:SLOP NEG	<i>Sets negative trigger slope.</i>
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[[:START]:SOURce

TRIGger[:START]:SOURce *<source>* selects the source that advances the waveform to the next sample point.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><source></i>	discrete	BUS ECLTrg0 ECLTrg1 EXternal HOLD INTERNAL[1] INTERNAL2 TTLTrg0 through TTLTrg7	none

- Comments**
- The sources available are:
 - **BUS:** The Group Execute Trigger (GET) HP-IB command or the IEEE-488.2 *TRG common command.
 - **ECLTrg0** and **ECLTrg1:** The VXibus ECL trigger lines.
 - **EXternal:** The HP E1445A’s front panel “Ref/Sample In” BNC connector.
 - **HOLD:** Suspends sample generation. Use the TRIGger[:START][:IMMEDIATE] command to advance the waveform.
 - **INTERNAL[1]:** The [SOURce:]FREQUENCY[1] subsystem. Sine wave output ([SOURce:]FUNCTION[:SHAPE] SINusoid set) requires that this source be selected.
 - **INTERNAL2:** The [SOURce:]FREQUENCY2 subsystem.
 - **TTLTrg0** through **TTLTrg7:** The VXibus TTL trigger lines.
 - Use the TRIGger[:START]:SLOPe command to select the active edge for the front panel “Ref/Sample In” BNC when used as the start trigger source.
 - **Executable when Initiated:** No
 - **Coupling Group:** Frequency
 - **Related Commands:** TRIGger[:START]:SLOPe
 - ***RST Condition:** TRIGger:START:SOURce INTERNAL1

Example Setting the Start Trigger Source

TRIG:SOUR EXT

Trigger source is front panel’s “Ref/Sample In” BNC.

:STOP[:IMMEDIATE]

TRIGger:STOP[:IMMEDIATE] terminates the current start arm cycle at the end of the current waveform repetition regardless of the selected stop trigger source. The command aborts the remaining ARM[:START][:LAYer[1]]:COUNT repetitions of the current trigger cycle. The start trigger sequence is placed into the wait-for-arm state at the end of the current waveform repetition. The selected stop trigger source remains unchanged.

- Comments**
- Executing this command with the start trigger sequence in the idle or wait-for-arm states generates Error -211, "Trigger ignored".
 - If the start trigger sequence is on the last of ARM[:START]:LAYer2:COUNT trigger cycles, or if ARM[:START]:LAYer2:COUNT 1 is set, TRIGger:STOP[:IMMEDIATE] places the trigger system in the idle state at the end of the current waveform repetition. An INITiate:IMMEDIATE command must be executed to restart waveform generation.
 - TRIGger:STOP[:IMMEDIATE] differs from ABORt in that ABORt terminates all start arm cycles immediately, whereas TRIGger:STOP[:IMMEDIATE] terminates only the current arm cycle, at the end of the current waveform repetition.
 - **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** ABORt, INITiate[:IMMEDIATE], TRIGger[:START]:COUNT
 - ***RST Condition:** None

Example Stopping an Arm Cycle

ARM:LAY2:COUN 5	<i>Allows 5 arms.</i>
ARM:LAY2:SOUR HOLD	<i>Sets manual start arm.</i>
ARM:COUN 100	<i>Sets 100 repetitions per arm.</i>
INIT	<i>Initiates trigger system.</i>
ARM:LAY2	<i>Starts arm waveform.</i>
TRIG:STOP	<i>Terminates arm cycle at end of waveform repetition.</i>
ARM:LAY2	<i>Starts arm waveform again.</i>

:STOP:SLOPe

TRIGger:STOP:SLOPe *<edge>* selects the edge (rising or falling) on the HP E1445A's front panel "Stop Trig/FSK/Gate In" BNC which terminates the current start arm cycle at the end of the current waveform repetition. This edge is significant only with TRIGger:STOP:SOURce set to EXTERNAL. The programmed value is retained but not used when other sources are selected.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><edge></i>	discrete	NEGative POSitive	none

- Comments**
- **Executable when Initiated:** Query form only
 - **Coupling Group:** Frequency
 - **Related Commands:** TRIGger:STOP:SOURce
 - ***RST Condition:** TRIGger:STOP:SLOPe POSitive

Example Setting the Stop Trigger Slope

TRIG:STOP:SLOP NEG *Sets negative stop trigger slope.*

:STOP:SOURce

TRIGger:STOP:SOURce *<source>* selects the source that can terminate the current start arm cycle at the end of the current waveform repetition. When the HP E1445A receives a stop trigger, the start trigger sequence is placed into the wait-for-arm state at the end of the current waveform repetition, aborting the remaining ARM[:START[:LAYER[1]]:COUNT repetitions of the current arm cycle.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><source></i>	discrete	BUS EXTERNAL HOLD TTLTrg0 through TTLTrg7	none

- Comments**
- The available sources are:
 - **BUS:** The Group Execute Trigger (GET) HP-IB command or the IEEE-488.2 *TRG common command.
 - **EXTERNAL:** The HP E1445A's front panel "Stop Trigger/FSK/Gate In" BNC connector.
 - **HOLD:** Suspend stop triggering. Use the TRIGger:STOP[:IMMEDIATE] command to terminate a start arm cycle.
 - **TTLTrg0 through TTLTrg7:** The VXIbus TTL trigger lines.

- If a stop trigger is received while the start trigger sequence is in the idle or wait-for-arm states, it is ignored with no error generated.
- If the start trigger sequence is on the last of ARM[:START]:LAYer2:COUNT arm cycles, a stop trigger places the trigger system in the idle state at the end of the current waveform repetition.
- A stop trigger differs from the ABORt command in that ABORt terminates all start arm cycles immediately, whereas a stop trigger terminates only the current arm cycle, at the end of the current waveform repetition.
- Use the TRIGger:STOP:SLOPe command to select the active edge (rising or falling) for the front panel “Stop Trig/FSK/Gate In” BNC when used as the stop trigger source.
- The front panel “Stop Trig/FSK/Gate In” BNC is a three-use connector; for FSK control, as a stop trigger source, or as a sample gate source. Only one of these uses may be active at any time.
- If a VXIbus TTLTrg trigger line is used as the stop trigger source, then no TTLTrg trigger lines can be used for FSK control or as the gating source.
- **Executable when Initiated:** Query form only
- **Coupling Group:** Frequency
- **Related Commands:** ABORt, INITiate[:IMMediate], TRIGger[:START]:COUNT
- ***RST Condition:** TRIGger:STOP:SOURce HOLD

Example Setting the Stop Trigger Source

TRIG:STOP:SOUR TTLT1

Selects VXIbus trigger line TTLTRG1 as source.*

:SWEep[:IMMediate]

TRIGger:SWEep[:IMMediate] advances a frequency sweep or list to the next frequency regardless of the selected trigger source. The trigger system must have been initiated and the sweep trigger sequence must be in the wait-for-trigger state. The selected trigger source remains unchanged.

- Comments**
- Executing this command when frequency sweeps or lists are not enabled, or with the sweep trigger sequence not in the wait-for-trigger state generates Error -211, "Trigger ignored".
 - **Executable when Initiated:** Yes
 - **Coupling Group:** none
 - **Related Commands:** INITiate:IMMediate, [SOURce:]SWEep commands

TRIGger

- ***RST Condition:** None

Example Advancing a Frequency Sweep

SWE:STAR 1E3;STOP 10E3	<i>Sets sweep frequency limits.</i>
SWE:POIN 10	<i>Sets 1 kHz steps.</i>
ARM:LAY2:SOUR IMM	<i>Sets output to start immediately.</i>
ARM:SWE:SOUR IMM	<i>Sets sweep to start immediately.</i>
TRIG:SWE:SOUR HOLD	<i>Sets sweep to advance sweep manually.</i>
INIT	<i>Initiates trigger system.</i>
TRIG:SWE	<i>Advances to next frequency.</i>

:SWEep:LINK

TRIGger:SWEep:LINK *<link>* selects the internal event that advances a frequency sweep or list when TRIGger:SWEep:SOURce is set to LINK. The only defined internal event to advance a sweep or list is “ARM[:START]:SEQuence[1]:LAYer2”.

There is no need to send this command since there is only one defined internal event. The command is included for SCPI compatibility purposes only.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><link></i>	string	“ARM[:START]:SEQuence1]:LAYer2”	none

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** TRIGger:SWEep:SOURce
 - ***RST Condition:** TRIGger:SWEep:LINK “ARM[:START]:SEQuence[1]:LAYer2”

Example Linking the Sweep Advance Trigger

TRIG:SWE LINK	<i>Links sweep advance trigger to start arm.</i>
TRIG:SWE:LINK "ARM:LAY2"	

:SWEep:SOURce

TRIGger:SWEep:SOURce *<source>* selects the source that causes a frequency sweep or list to advance to the next frequency.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<source>	discrete	BUS HOLD LINK TImEr TTLTrg0 through TTLTrg7	none

- Comments**
- The available sources are:
 - **BUS:** The Group Execute Trigger (GET) HP-IB command or the IEEE-488.2 *TRG common command.
 - **HOLD:** Suspend sweep or list frequency advance triggering. Use TRIGger:SWEep[:IMMediate] to advance to the next frequency.
 - **LINK:** The next valid start arm advances the sweep or list. Thus, the frequency change always occurs at the start of ARM[:STARt][:LAYer[1]]:COUnT repetitions of the waveform.
 - **TImEr:** The [SOURce:]SWEep:TIME and TRIGger:SWEep:TImEr commands control the sweep or list frequency advance timing.
 - **TTLTrg0** through **TTLTrg1:** The VXIbus TTL trigger lines.
 - If TRIGger:SWEep:SOURce is set to TTLTrg<n> and you want to set ARM:SWEep:SOURce to TTLTrg<n>, both must be set to the same trigger line <n>.
 - **Executable when Initiated:** Query form only
 - **Coupling Group:** Frequency
 - **Related Commands:** [SOURce:]SWEep:TIME
 - ***RST Condition:** TRIGger:SWEep:SOURce TImEr

Example Setting the Sweep Advance Trigger Source

TRIG:SWE:SOUR TTLT1

Selects VXIbus trigger line TTLTRG1 as sweep advance source.*

:SWEep:TIMer

TRIGger:SWEep:TIMer *<period>* selects the time between frequency values for sweep or frequency list generation when TRIGger:SWEep:SOURce is set to TIMer. This value set by command is coupled to the [SOURce:]SWEep:TIME command value by the following equation:

$$\text{TIME} = \text{TIMer} * (\text{points} - 1)$$

where *points* is the [SOURce:]SWEep:POINts value for frequency sweeps, or the length of the frequency list for frequency list generation.

When changing the frequency list length when [SOURce:]FREQUency[1]:MODE LIST is set, or the [SOURce:]SWEep:POINts value when any other MODE is set, the TIME or TIMer value remains the same, depending on which command, [SOURce:]SWEep:TIME or TRIGger:SWEep:TIMer respectively, was most recently sent. The other value is changed based on the new *points* value.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><period></i>	numeric	.00125 through 4.19430375 MINimum MAXimum	seconds
MINimum selects 1.25 mS; MAXimum selects 4.19430375 S. The above values bound the valid range for <i><period></i>			

- Comments**
- **Executable when Initiated:** Query form only
 - **Coupling Group:** Frequency
 - **Related Commands:** [SOURce:]LIST2:FREQUency, [SOURce:]SWEep:POINts, [SOURce:]SWEep:TIME, TRIGger:SWEep:SOURce
 - ***RST Condition:** SOURce:SWEep:TIME 1 is set; TRIGger:SWEep:TIMer is the dependent value.

Example Setting the Sweep Advance Period

TRIG:SWE:TIM .1

Sets .1 S per frequency value.

VINstrument

The VINstrument subsystem operates with the [SOURce:]ARbitrary and [SOURce:]PM subsystems to control the virtual instrument features of the HP E1445A. These features include the ability to use the VXIbus Local Bus and normal data transfer bus to download data to the segment and segment sequence memories, directly drive the main output DAC, and provide phase deviations for sine waves.

Subsystem Syntax

```
VINstrument
  [:CONFigure]
    :LBUS
      [:MODE] <mode>
        :AUTO <state>
    :TEST
      :CONFigure <length>           [no query]
      :DATA?                         [query only]
    :VME
      :RECeive
        :ADDRess
          :DATA?                     [query only]
          :READy?                    [query only]
        [:MODE] <edge>
    :IDENtity?
```

[:CONFigure]:LBUS[:MODE]

VINstrument[:CONFigure]:LBUS[:MODE] <mode> selects the operating mode for the VXIbus Local Bus.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<mode>	discrete	CONSumE OFF PIPeline	none

- Comments**
- The available modes are:
 - CONSumE:** Local Bus data is used and not passed through. This mode must be selected when downloading segment and segment sequence memory data, directly driving the main output DAC, and providing phase deviations for sine waves.
 - OFF:** The Local Bus interface is disabled. Local Bus data is neither used nor passed through.
 - PIPeline:** Local Bus data is passed through and not used. Select this mode when data should be transparently passed through the HP E1445A.

- With `VINstrument[:CONFigure]:LBUS[:MODE]:AUTO` ON set, the Local Bus operation mode is automatically set to CONSUME when downloading segment or segment sequence data (`[SOURce:]ARbitrary:DOWNload` LBUS command), directly driving the main output DAC (`[SOURce:]ARbitrary:DAC:SOURce` LBUS command), or providing phase deviation data (`[SOURce:]PM:SOURce` LBUS command); the mode is set to OFF when none of these are active.

Executing the `VINstrument[:CONFigure]:LBUS[:MODE]` command sets `VINstrument[:CONFigure]:LBUS[:MODE]:AUTO` OFF.

- **Executable when Initiated:** Yes
- **Coupling Group:** None
- **Related Commands:** `[SOURce:]ARbitrary:DAC:SOURce`, `[SOURce:]ARbitrary:DOWNload`, `[SOURce:]PM:SOURce`, `VINstrument[:CONFigure]:LBUS[:MODE]:AUTO`
- ***RST Condition:** `VINstrument:CONFigure:LBUS:MODE` OFF

Example Setting the Local Bus Operation Mode

`VINS:CONF:LBUS PIP`

Sets pipeline (pass through) mode.

`[:CONFigure]:LBUS[:MODE]:AUTO`

`VINstrument[:CONFigure]:LBUS[:MODE]:AUTO <mode>` indicates whether the VXIbus Local Bus operation mode should be automatically set to CONSUME when downloading segment or segment sequence data (`[SOURce:]ARbitrary:DOWNload` LBUS command), directly driving the main output DAC (`[SOURce:]ARbitrary:DAC:SOURce` LBUS command), or providing phase deviation data (`[SOURce:]PM:SOURce` LBUS command), and set to OFF when none of these are active. If `AUTO ON` is set, the Local Bus operation mode is changed as needed; if `OFF` is set, the mode must be explicitly set by the `VINstrument[:CONFigure]:LBUS[:MODE]` command.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<code><mode></code>	boolean	OFF 0 ON 1	none

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** `[SOURce:]ARbitrary:DAC:SOURce`, `[SOURce:]ARbitrary:DOWNload`, `[SOURce:]PM:SOURce`, `VINstrument[:CONFigure]:LBUS[:MODE]`

- ***RST Condition:** VINstrument:CONFigure:LBUS:MODE:AUTO ON

Example Uncoupling Local Bus Operation Mode

VINS:CONF:LBUS:AUTO OFF *Uncouple operation mode.*

[:CONFigure]:TEST:CONFigure

VINstrument[:CONFigure]:TEST:CONFigure *<length>* configures the HP E1445A for Local Bus testing. The *<length>* parameter indicates that, during the test, that number of bytes will be sent to the HP E1445A. The data will be placed into unused waveform segment memory. When all data has been sent, use the VINstrument[:CONFigure]:TEST:DATA? query to retrieve what the HP E1445A received.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<i><length></i>	numeric	see below	none
The valid range for <i><length></i> is 2 through the size of largest available contiguous piece of waveform segment memory in bytes (2 bytes per point). <i><length></i> must be an even number.			

MINimum and MAXimum cannot be used with this command.

- Comments**
- **Executable when Initiated:** Query form only
 - **Coupling Group:** None
 - **Related Commands:** VINstrument[:CONFigure]:TEST:DATA?
 - ***RST Condition:** None
 - **Power-On Condition:** Local Bus testing not configured

Example Testing Local Bus Operation

VINS:CONF:TEST:CONF 100 *Configures for 100 byte test.*

send data

VINS:CONF:TEST:DATA? *Reads back test data.*

[[:CONFigure]:TEST:DATA?

VINstrument[:CONFigure]:TEST:DATA? returns the received VXIbus Local Bus test data. The data is returned in 16-bit integer format in an IEEE-488.2 definite block.

- Comments**
- **Executable when Initiated:** No
 - **Coupling Group:** None
 - **Related Commands:** VINstrument[:CONFigure]:TEST:CONFigure
 - ***RST Condition:** None
 - **Power-On Condition:** Local Bus testing not configured

Example Testing Local Bus Operation

```
VINS:CONF:TEST:CONF 100           Configure for 100 byte test
send data
VINS:CONF:TEST:DATA?             Read back test data.
```

[[:CONFigure]:VME[:MODE]

VINstrument[:CONFigure]:VME[:MODE] <mode> selects the operating mode for the VXIbus data transfer bus. The only available mode is CONSume.

There is no need to send this command since there is only one available mode. The command is only included for compatibility with the HP Virtual Instrument/Local Bus System Specification.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<mode>	discrete	CONSume	none

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - ***RST Condition:** VINstrument:CONFigure:VME:MODE CONSume

Example Setting the VXIbus Data Transfer Bus Operation Mode

```
VINS:VME CONS                     Sets CONSume mode.
```

[[:CONFIgure]:VME:RECEive:ADDRess:DATA?

VINstrument[:CONFIgure]:VME:RECEive:ADDRess:DATA? returns two values: *A24,offset*. *A24* indicates that the HP E1445A's A24 address space should be used for writing waveform segment, segment sequence, DAC, or phase deviation data, and *offset* is the offset into the A24 address space to be written to. The *offset* returned depends on which of the above operations is active when the **ADDRess:DATA?** query is executed. If none are active, Error +1022, "VXI data transfer bus not active" is generated.

- Comments**
- For segment sequence and phase deviation data, the offset returned is the offset of the first of the two words that must be written.
 - **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** [SOURce:]ARbitrary:DAC:SOURce, [SOURce:]ARbitrary:DOWNload, [SOURce:]PM:SOURce
 - ***RST Condition:** The VXI data transfer bus is not active

Example Querying the A24 Address Space Offset

LIST:SEL ABC;DEF 100	<i>Creates waveform segment.</i>
ARB:DOWN VXI,ABC,100	<i>Starts download to segment.</i>
VINS:VME:REC:ADDR:DATA?	<i>Queries A24 offset for data writes.</i>

[[:CONFIgure]:VME:RECEive:ADDRess:READY?

VINstrument[:CONFIgure]:VME:RECEive:ADDRess:READY? returns two values: *A24,112*. *A24* indicates that the HP E1445A's A24 address space when writing waveform segment, segment sequence, DAC, or phase deviation data, and *112* is the offset into the A24 address space to be checked.

Actually, this indicated Status Register need never be checked. The HP E1445A will always handshake any data written to it; however, the data will be ignored if none of the above operations are active. Nevertheless, bit 1 of the Status Register indicates whether the HP E1445A is in the initiated state or the idle state: 1 indicates initiated, 0 indicates idle. This may useful when writing DAC and phase deviation data as it can be checked to indicate when these types of data will be ignored.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** [SOURce:]ARbitrary:DAC:SOURce, [SOURce:]ARbitrary:DOWNload, [SOURce:]PM:SOURce

- ***RST Condition:** None

Example Querying the A24 Address Space Ready Indication Offset

VINS:VME:REC:ADDR:READ? *Queries A24 offset for ready indication.*

:IDENTity?

VINstrument:IDENTity? returns a response consisting of 4 fields, indicating the virtual instrument capability of the HP E1445A:

```
HEWLETT-PACKARD VIRTUAL INSTRUMENT,ANY DTOA,0,A.01.00
```

The first and last fields indicate that the HP E1445A conforms to revision A.01.00 of HP's Virtual Instrument/Local Bus System Specification. The second field indicates that the HP E1445A is a digital-to-analog converter. The third field is reserved for future use.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - ***RST Condition:** None

Example Querying Virtual Instrument Capability

VINS:IDEN? *Queries capability.*

SCPI Command Quick Reference

Table 8-1. HP E1445A SCPI Commands

Subsystem	Commands
TRIGger	ABORt
ARM	ARM[:STARt][:LAYer[1]]:COUNT <number> ARM[:STARt]:LAYer2:COUNT <number> ARM[:STARt]:LAYer2[:IMMediate] ARM[:STARt]:LAYer2:SLOPe <edge> ARM[:STARt]:LAYer2:SOURce <source> ARM:SWEEp:COUNT <number> ARM:SWEEp[:IMMediate] ARM:SWEEp:LINK <link> ARM:SWEEp:SOURce <source>
CALibration	CALibration:COUNT CALibration:DATA:AC[1] <block> CALibration:DATA:AC2 <block> CALibration:DATA[:DC] <block> CALibration[:DC]:BEGin CALibration[:DC]:POINt? <value> CALibration:SECure:CODE <code> CALibration:SECure[:STATe]<mode>[,<code>] CALibration:STATe <state> CALibration:STATe:AC <state> CALibration:STATe:DC <state>
INITiate	INITiate[:IMMediate]
OUTPut[1]	OUTPut[1]:FILTer[:LPASs]:FREQuency <frequency> OUTPut[1]:FILTer[:LPASs][:STATe] <mode> OUTPut[1]:IMPedance <impedance> OUTPut[1]:LOAD <load> OUTPut[1]:LOAD:AUTO <mode> OUTPut[1][:STATe] <mode>

Table 8-1. HP E1445A SCPI Commands (continued)

Subsystem	Commands
[SOURCE:]ARbitrary	[SOURCE:]ARbitrary:DAC:FORMat <format> [SOURCE:]ARbitrary:DAC:SOURce <source> [SOURCE:]ARbitrary:DOWNload <source>,<dest>,<length> [SOURCE:]ARbitrary:DOWNload:COMPLete
[SOURCE:]FREQuency[1]	[SOURCE:]FREQuency[1]:CENTer <center_freq> [SOURCE:]FREQuency[1]:CW FIXed <frequency> [SOURCE:]FREQuency[1]:FSKey <frequency1>,<frequency2> [SOURCE:]FREQuency[1]:FSKey:SOURce <source> [SOURCE:]FREQuency[1]:MODE <mode> [SOURCE:]FREQuency[1]:RANGe <range> [SOURCE:]FREQuency[1]:SPAN <freq_span> [SOURCE:]FREQuency[1]:STARt <start_freq> [SOURCE:]FREQuency[1]:STOP <stop_freq>
[SOURCE:]FREQuency2	[SOURCE:]FREQuency2[:CW FIXed] <frequency>
[SOURCE:]FUNction	[SOURCE:]FUNction[:SHAPE] <shape> [SOURCE:]FUNction:USER <name>
[SOURCE:]LIST[1]	[SOURCE:]LIST[1]:FORMat[:DATA] <format> [,<length>] [SOURCE:]LIST[1][:SEGMENT]:ADDRess? [SOURCE:]LIST[1][:SEGMENT]:CATalog? [SOURCE:]LIST[1][:SEGMENT]:COMBined <combined list> [SOURCE:]LIST[1][:SEGMENT]:COMBined:POINTs? [SOURCE:]LIST[1][:SEGMENT]:DEFine <length> [SOURCE:]LIST[1][:SEGMENT]:DELete:ALL [SOURCE:]LIST[1][:SEGMENT]:DELete[:SELected] [SOURCE:]LIST[1][:SEGMENT]:FREE?

Table 8-1. HP E1445A SCPI Commands (continued)

Subsystem	Commands
[SOURCE:]LIST[1] (Cont'd)	[SOURCE:]LIST[1]:SEGMENT:MARKER <marker_list> [SOURCE:]LIST[1]:SEGMENT:MARKER:POINTS? [SOURCE:]LIST[1]:SEGMENT:MARKER:SPOINT <point> [SOURCE:]LIST[1]:SEGMENT:SELECT <name> [SOURCE:]LIST[1]:SEGMENT:VOLTAGE <voltage_list> [SOURCE:]LIST[1]:SEGMENT:VOLTAGE:DAC <voltage_list> [SOURCE:]LIST[1]:SEGMENT:VOLTAGE:POINTS? [SOURCE:]LIST[1]:SEQUENCE:ADDRESS? [SOURCE:]LIST[1]:SEQUENCE:CATALOG? [SOURCE:]LIST[1]:SEQUENCE:COMBINED <combined_list> [SOURCE:]LIST[1]:SEQUENCE:COMBINED:POINTS? [SOURCE:]LIST[1]:SEQUENCE:DEFINE <length> [SOURCE:]LIST[1]:SEQUENCE:DELETE:ALL [SOURCE:]LIST[1]:SEQUENCE:DELETE[:SELECTED] [SOURCE:]LIST[1]:SEQUENCE:DWELL:COUNT <repetition list> [SOURCE:]LIST[1]:SEQUENCE:DWELL:COUNT:POINTS? [SOURCE:]LIST[1]:SEQUENCE:FREE? [SOURCE:]LIST[1]:SEQUENCE:MARKER <marker_list> [SOURCE:]LIST[1]:SEQUENCE:MARKER:POINTS? [SOURCE:]LIST[1]:SEQUENCE:MARKER:SPOINT <point> [SOURCE:]LIST[1]:SEQUENCE:SELECT <name> [SOURCE:]LIST[1]:SEQUENCE:SEQUENCE <segment_list> [SOURCE:]LIST[1]:SEQUENCE:SEQUENCE:SEGMENTS?
[SOURCE:]LIST2	[SOURCE:]LIST2:FORMAT[:DATA] <format> [,<length> [SOURCE:]LIST2:FREQUENCY <freq_list> [SOURCE:]LIST2:FREQUENCY:POINTS?

Table 8-1. HP E1445A SCPI Commands (continued)

Subsystem	Commands
[SOURce:]MARKer	[SOURce:]MARKer:ECLTrg<n>:FEED <source> [SOURce:]MARKer:ECLTrg<n>[STATe] <mode> [SOURce:]MARKer:FEED <source> [SOURce:]MARKer:POLarity <polarity> [SOURce:]MARKer[:STATe] <mode>
[SOURce:]PM	[SOURce:]PM[:DEViation] <phase> [SOURce:]PM:SOURce <source> [SOURce:]PM:STATe <mode> [SOURce:]PM:UNIT[:ANGLE] <units>
[SOURce:]RAMP	[SOURce:]RAMP:POLarity <polarity> [SOURce:]RAMP:POINts <number>
[SOURce:]ROSCillator	[SOURce:]ROSCillator:FREQuency:EXTernal <frequency> [SOURce:]ROSCillator:SOURce <source>
[SOURce:]SWEep	[SOURce:]SWEep:COUNT <number> [SOURce:]SWEep:DIRection <direction> [SOURce:]SWEep:POINts <number> [SOURce:]SWEep:SPACing <mode> [SOURce:]SWEep:TIME <number>
[SOURce:]VOLTage	[SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude] <amplitude> [SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude]:UNIT[:VOLTage] <units> [SOURce:]VOLTage[:LEVel][:IMMediate]:OFFSet <offset>
STATus	STATus:OPC:INITiate <state> STATus:OPERation[:QUESTionable:CONDition? STATus:OPERation[:QUESTionable:ENABLE <unmask> STATus:OPERation[:QUESTionable[:EVENT]? STATus:OPERation[:QUESTionable:NTRansition <unmask> STATus:OPERation[:QUESTionable:PTRansition <unmask> STATus:PRESet

Table 8-1. HP E1445A SCPI Commands (continued)

Subsystem	Commands
SYSTem	SYSTem:ERRor? SYSTem:VERsion?
TRIGger	TRIGger[:STARt]:GATE:POLarity < <i>polarity</i> > TRIGger[:STARt]:GATE:SOURce < <i>source</i> > TRIGger[:STARt]:GATE:STATe < <i>mode</i> > TRIGger[:STARt][:IMMediate] TRIGger[:STARt]:SLOPe < <i>edge</i> > TRIGger[:STARt]:SOURce < <i>source</i> > TRIGger:STOP[:IMMediate] TRIGger:STOP:SLOPe < <i>edge</i> > TRIGger:STOP:SOURce < <i>source</i> > TRIGger:SWEep[:IMMediate] TRIGger:SWEep:LINK < <i>link</i> > TRIGger:SWEep:SOURce < <i>source</i> > TRIGger:SWEep:TIMer < <i>period</i> >
VINstrument	VINstrument[:CONFigure]:LBUS[:MODE] < <i>mode</i> > VINstrument[:CONFigure]:LBUS[:MODE]:AUTO < <i>mode</i> > VINstrument[:CONFigure]:TEST:CONFigure < <i>length</i> > VINstrument[:CONFigure]:TEST:DATA? VINstrument[:CONFigure]:VME[:MODE] < <i>mode</i> > VINstrument[:CONFigure]:VME:RECeive:ADDRess:DATA? VINstrument[:CONFigure]:VME:RECeive:ADDRess:READY? VINstrument:IDENTity?

SCPI Conformance Information

The HP E1445A Arbitrary Function Generator conforms to the SCPI-1991.0 standard.

Table 8-2 and 8-3 list all the SCPI confirmed, approved, and non-SCPI commands that the HP E1445A can execute.

Table 8-2. SCPI Confirmed Commands

ABORt	[SOURce:]
ARM	MARKer
[:START]:SEquence[1]]	[:STATe] <mode>
[:LAYer[1]]	PM
:COUNT <number>	[:DEVIation] <phase>
:LAYer2	:SOURce <source>
:COUNT <number>	:STATe <mode>
[:IMMediate]	:UNIT
:SLOPe <edge>	[:ANGLE] <units>
:SOURce <source>	ROSCillator
:SWEEp]:SEquence3]	:SOURce <source>
:COUNT <number>	SWEep
[:IMMediate]	:COUNT <number>
:LINK <link>	:DIRection <direction>
:SOURce <source>	:POINts <number>
	:SPACing <mode>
	:TIME <time>
INITiate	
[:IMMediate]	STATus
	:OPERation
OUTPut[1]	:CONDition?
:FILTer	:ENABle <mask>
[:LPASs]	:NTRansition <mask>
:FREQuency <frequency>	:PTRansition <mask>
[:STATe] <mode>	:PRESet
:IMPedance <impedance>	:QUESTionable
[:STATe] <mode>	:CONDition?
	:ENABle <mask>
[SOURce:]	:NTRansition <mask>
FREQuency[1]	:PTRansition <mask>
:CENTer <center_freq>	
[:CW]:FIXed] <frequency>	SYSTem
:MODE <mode>	:ERRor?
:SPAN <freq_span>	:VERSion?
:STARt <start_freq>	
:STOP <stop_freq>	TRIGger
FREQuency2	[:START]:SEquence[1]]
[:CW]:FIXed] <frequency>	:COUNT <number>
FUNction	[:IMMediate]
[:SHAPE] <shape>	:SLOPe <edge>
LIST2	:SOURce <source>
:FREQuency <freq_list>	:STOP
:POINts?	[:IMMediate]
	:SLOPe <edge>
	:SOURce <source>
	:SWEep
	[:IMMediate]
	:LINK <link>
	:SOURce <source>
	:TIMer <period>

Table 8-3. Non-SCPI Commands

CALibration	[SOURce:]
:COUNT?	LIST[1]
:DATA	:SSEquence
:AC[1] <block>	:ADDRes?
:AC2 <block>	:CATalog?
:DC <block>	:COMBined <combined_list>
[:DC]	:DEFine <length>
:BEGin	:DELete
:POINt?	:ALL
:SECure	[:SElected]
:CODE <code>	:DWELl
[:STATe] <mode>[,<code>]	:COUNT <repetition_list>
:STATe <state>	:POINts?
:AC <state>	:FREE?
:DC <state>	:MARKer <marker_list>
	:POINts?
	:SPOint <points>
	:SElect <name>
	:SEquence <segment_list>
	:SEGMeNts?
OUTPut[1]	
:LOAD <load>	
:AUTO <mode>	
[SOURce:]	LIST2
ARBitrary	:FORMat
:DAC	:DATA <format>[,<length>]
:FORMat <format>	MARKer
:SOURce <source>	:ECLTrg<n>
:DOWNload <source>,<dest>,<length>	:FEED <source>
COMPLete	[:STATe] <mode>
FUNction	RAMP
:USER	:POLarity <polarity>
LIST[1]	:POINts <number>
:FORMat	ROSCillator
[:DATA] <format>[,<length>]	:FREQuency
[:SEGMeNt]	:EXTernal <frequency>
:ADDRes?	
:CATalog?	STATus
:COMBined <combined_list>	:OPC
:POINts?	:INITiate <state>
:DEFine <length>	
:DELete	TRIGger
:ALL	[:START]:SEquence[1]]
[:SElected]	:GATE
:FREE?	:POLarity <polarity>
:MARKer <marker_list>	:SOURce <source>
:POINts?	:STATe <state>
:SElect <name>	
:VOLTage <voltage_list>	VINStrument
:DAC <dac_list>	[:CONFIgure]
:POINts?	:LBUS
	[:MODE] <mode>
	:AUTO <state>
	:TEST
	:CONFIgure <length>
	:DATA?
	:VME
	:RECEive
	:ADDRes
	:DATA?
	:READY?
	:IDENTity?

IEEE-488.2 Common Commands

*CLS

***CLS** clears the Standard Event Status Register, the Operation Status Register, the Questionable Signal Register, and the error queue. This clears the corresponding summary bits (3, 5, and 7) in the Status Byte Register. *CLS does not affect the enable masks of any of the Status Registers.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** STATus:PRESet
 - ***RST Condition:** None

*DMC

***DMC <name>,<data>** creates a macro with the specified name and assigns zero, one, or a sequence of commands to the name. The sequence may be composed of SCPI and/or Common Commands. The sequence may be sent in IEEE-488.2 definite or indefinite block format, or as a quoted string.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<name>	string data	1 through 12 characters	none
<data>	block data or string	any valid command sequence	none

- Comments**
- Legal macro names must start with an alphabetic character and contain only alphabetic, numeric, and underscore (" _") characters. Alphabetic character case (upper vs. lower) is ignored.

The name is allowed to be the same as a SCPI command, but may not be the same as a Common Command. When the name is the same as a SCPI command, the macro rather than the command will be executed when the name is received if macro usage is enabled. The SCPI command will be executed if macro usage is disabled.

- **Executable when Initiated:** Yes
- **Coupling Group:** None
- **Related Commands:** *EMC, *GMC, *LMC, *RMC
- ***RST Condition:** None; macro definitions are unaffected

- **Power-On Condition:** No macros are defined

Example Define Macro to Restart Waveform

***DMC "RESTART",#19ABOR;INIT** *Defines macro.*

*EMC and *EMC?

***EMC <enable>** enables and disables macro usage. When <enable> is zero, macro usage is disabled. Any non-zero value in the range of -32768 to +32767 enables macro usage.

***EMC?** returns 1 if macro usage is enabled, 0 if disabled.

Comments • Macro definitions are not affected by this command.

- **Executable when Initiated:** Yes
- **Coupling Group:** None
- ***RST Condition:** Macro usage is disabled
- **Power-On Condition:** Macro usage is enabled

*ESE and *ESE?

***ESE <mask>** enables one or more event bits of the Standard Event Status Register to be reported in bit 5 (the Standard Event Status Summary Bit) of the Status Byte Register. The <mask> is the sum of the decimal weights of the bits to be enabled.

***ESE?** returns the current enable mask.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<mask>	numeric	0 through 255	none

A 1 in a bit position enables the corresponding event; a 0 disables it.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** *ESR?, *SRE, *STB?
 - ***RST Condition:** Unaffected

- **Power-On Condition:** No events are enabled

Example Enable All Error Events

***ESE 60**

Enables error events.

***ESR?**

***ESR?** returns the value of the Standard Event Status Register. The register is then cleared (all bits 0).

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - ***RST Condition:** None
 - **Power-On Condition:** Register is cleared

***GMC?**

***GMC? <name>** returns the definition of the specified macro in IEEE-488.2 definite block format.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<name>	string data	defined macro name	none

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** *DMC
 - ***RST Condition:** None
 - **Power-On Condition:** No macros are defined

Example Query Macro Definition

***GMC? "RESTART"**

Queries macro definition.

*IDN?

***IDN?** returns identification information for the HP E1445A. The response consists of four fields:

```
HEWLETT-PACKARD , E1445A , 0 , A . 01 . 00
```

The first two fields identify this instrument as model number E1445A manufactured by Hewlett-Packard. The third field is 0 since the serial number of the HP E1445A is unknown to the firmware. The last field indicates the revision level of the firmware.

Note The firmware revision field will change whenever the firmware is revised. A.01.00 is the initial revision. The first two digits indicate the major revision number, and increment when functional changes are made. The last two digits indicate bug fix level.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - ***RST Condition:** None
 - **Power-On Condition:** Register is cleared

*LMC?

***LMC?** returns a comma-separated list of quoted strings, each containing the name of a macro. If no macros are defined, a single null string ("") is returned.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** *DMC
 - ***RST Condition:** None
 - **Power-On Condition:** No macros are defined

*LRN?

***LRN?** returns a sequence of commands that may be resent to the HP E1445A to return it to its current programming state.

Only those commands that are affected by ***RST** are included in the sequence. Notable exceptions include the DAC code format (signed vs. unsigned), the [SOURCE:]LIST commands, including waveform segment, segment sequence, and frequency list definitions, the STATUS subsystem commands, and the CALibration:SECure command state.

Note ***LRN?** should be sent singly in a program message, since the number of commands in the returned sequence is large, and may vary depending on firmware revision.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** *RCL, *RST, *SAV
 - ***RST Condition:** None

*OPC

***OPC** causes the HP E1445A to wait for all pending operations to complete. The Operation Complete bit (bit 0) in the Standard Event Status Register is then set.

If STATUS:OPC:INITiate OFF is set, the Operation Complete bit will be set when all commands received prior to the ***OPC** have been executed. If ON is set, ***OPC** waits for waveform generation to complete before setting the Operation Complete bit. No other commands will be executed until the Operation Complete bit is set.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** *OPC?, *WAI
 - ***RST Condition:** None

*OPC?

***OPC?** causes the HP E1445A to wait for all pending operations to complete. A single ASCII “1” is then placed in the output queue.

If **STATus:OPC:INITiate OFF** is set, the ASCII “1” will be placed in the output queue when all commands received prior to the ***OPC?** have been executed. If **ON** is set, ***OPC?** waits for waveform generation to complete before placing the “1” in the output queue. No other commands will be executed until the “1” is placed in the output queue.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** *OPC, *WAI
 - ***RST Condition:** None

*PMC

***PMC** purges all macro definitions.

- Comments**
- Use the ***RMC** command to purge an single macro definition.
 - **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** *DMC, *RMC
 - ***RST Condition:** None

*PUD and *PUD?

***PUD <data>** stores the specified data in the HP E1445A's non-volatile calibration memory. The data must be sent in IEEE-488.2 definite or indefinite block format. Calibration security must have been previously disabled.

***PUD?** returns the current protected user data in IEEE-488.2 definite block format. The query form may be executed regardless of the state of calibration security.

Note When shipped from the factory, the protected user data area contains information regarding when the HP E1445A was last calibrated.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<mask>	block data or string	0 through 63 characters	none

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - ***RST Condition:** Unaffected
 - **Power-On Condition:** Unaffected

Example Setting the Protected User Data

***PUD #17Unit #5** *Sets data to "Unit #5".*

*RCL

***RCL <number>** restores a previously stored programming state from one of the 10 possible stored state areas. The <number> indicates which of the stored state areas should be used.

This command affects the same command settings as does *RST. Notable exceptions include the DAC code format (signed vs. unsigned), the [SOURCE:]LIST commands, including waveform segment, segment sequence, and frequency list definitions, the STATus subsystem commands, and the CALibration:SECure command state.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<number>	numeric	0 through 9	none

- Comments**
- **Executable when Initiated:** No
 - **Coupling Group:** None
 - **Related Commands:** *LRN?, *RST, *SAV
 - ***RST Condition:** all saved states set to the same state as the *RST state

*RMC

***RMC <name>** purges only the specified macro definition.

NOTE: At printing time, *RMC is a command proposed and accepted for a revision and re-designation of IEEE-488.2.

- Comments**
- Use the *PMC command to purge all macro definitions in one command.
 - **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** *DMC, *PMC
 - ***RST Condition:** None

*RST

*RST resets the HP E1445A as follows:

- Sets all commands to their *RST state.
- Aborts all pending operations including waveform generation.

*RST does not affect:

- The state of VXIbus word serial protocol
- The output queue
- The Service Request Enable Register
- The Standard Event Status Enable Register
- The enable masks for the Operation Status and Questionable Signal Registers
- Calibration data
- Calibration security state
- Protected user data
- The DAC code format (signed vs. unsigned)
- Waveform segment, segment sequence, and frequency list definitions

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - ***RST Condition:** None

*SAV

*SAV <number> stores the current programming state into one of the 10 possible stored state areas. The <number> indicates which of the stored state areas should be used.

This command stores the states of all commands affected by *RST. Notable exceptions include the DAC code format (signed vs. unsigned), the [SOURCE:]LIST commands, including waveform segment, segment sequence, and frequency list definitions, the STATus subsystem commands, and the CALibration:SECure command state.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<number>	numeric	0 through 9	none

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None

- **Related Commands:** *LRN?, *RCL, *RST
- ***RST Condition:** unaffected
- **Power-on Condition:** all saved states set to the same state as the *RST state

*SRE and *SRE?

***SRE <mask>** specifies which bits of the Status Byte Register are enabled to generate a service request (VXIbus *reqt* signal). Event and summary bits are always set and cleared in the Status Byte Register regardless of the enable mask. The <mask> is the sum of the decimal weights of the bits to be enabled.

***SRE?** returns the current enable mask.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<mask>	numeric	0 through 255	none

A 1 in a bit position enables service request generation when the corresponding Status Byte Register bit is set; a 0 disables it.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - ***RST Condition:** Unaffected
 - **Power-On Condition:** No bits are enabled

Example Enable Service Request on Message Available Bit

***SRE 16**

Enables request on MAV.

*STB?

***STB?** returns the value of the Status Byte Register. Bit 6 (decimal weight 64) is set if a service request is pending. STB? should not be used to read the Status Byte Register if a service request is generated by a message available (MAV) condition.

- Comments**
- *STB? is a query. Thus, sending the command in response to a MAV condition will generate Error -410 "Query interrupted".
 - **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** *SRE
 - ***RST Condition:** None

*TRG

***TRG** is the command equivalent of the HP-IB Group Execute Trigger and the VXIbus Trigger word serial command and has exactly the same effect.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** ARM and TRIGger subsystem, [SOURCE:] commands
 - ***RST Condition:** None

*TST?

***TST?** causes the HP E1445A to execute its internal self-test and return a value indicating the results of the test.

A zero (0) response indicates that the self-test passed. A one (1) response indicates that the test failed. The failure also generates an error message with additional information on why the test failed.

When the test completes, all waveform segment and segment sequence definitions are deleted, and all other commands are set to their *RST values.

- Comments**
- **Executable when Initiated:** No
 - **Coupling Group:** None
 - ***RST Condition:** None

*WAI

***WAI** causes the HP E1445A to wait for all pending operations to complete before executing any further commands.

If `STATUS:OPC:INITiate OFF` is set, command execution resumes when all commands received prior to the `*WAI` have been executed. If `ON` is set, `*WAI` waits for waveform generation to complete before resuming command execution.

- Comments**
- **Executable when Initiated:** Yes
 - **Coupling Group:** None
 - **Related Commands:** `*OPC`, `*OPC?`
 - ***RST Condition:** None

Common Commands Quick Reference

This section describes the IEEE-488.2 Common Commands implemented in the HP E1445A. The table below shows the commands listed by functional group; however, commands are listed alphabetically in the reference. Examples are shown in the reference when the command has parameters or returns a non-trivial response; otherwise, the command string is as shown in the table. For additional information, refer to IEEE Standard 488.2-1987.

Table 8-4. HP E1445A Common Commands

Category	Command	Title
System Data	*IDN? *PUD <data> *PUD?	Identification Query Protected User Data Command Protected User Data Query
Internal Operations	*LRN? *RST *TST?	Learn Device Setup Query Reset Command Self Test Query
Synchronization	*OPC *OPC? *WAI	Operation Complete Command Operation Complete Command Wait-to-Continue Command
Macro	*DMC <name>,<data> *EMC <enable> *EMC? *GMC? <name> *LMC? *PMC *RMC <name>	Define Macro Command Enable Macro Command Enable Macro Query Get Macro Contents Query Learn Macro Query Purge Macros Command Remove Individual Macro Command
Status and Event	*CLS *ESE <mask> *ESE? *ESR? *SRE *SRE? *STB?	Clear Status Command Standard Event Status Enable Command Standard Event Status Enable Query Standard Event Status Register Query Service Request Enable Command Service Request Enable Query Read Status Byte Query
Trigger	*TRG	Trigger Command
Stored Settings	*RCL *SAV	Recall Command Save Command

Introduction

This chapter describes the HP E1445A Arbitrary Function Generator status system. Included is information on the status groups used by the AFG, the conditions monitored by each group, and information on how to enable a condition to interrupt the computer.

This main sections of this chapter include:

- Status System Registers Page 429
 - The Questionable Signal Status Group Page 431
 - The Operation Status Group Page 435
 - The Standard Event Status Group Page 439
 - The Status Byte Status Group Page 442

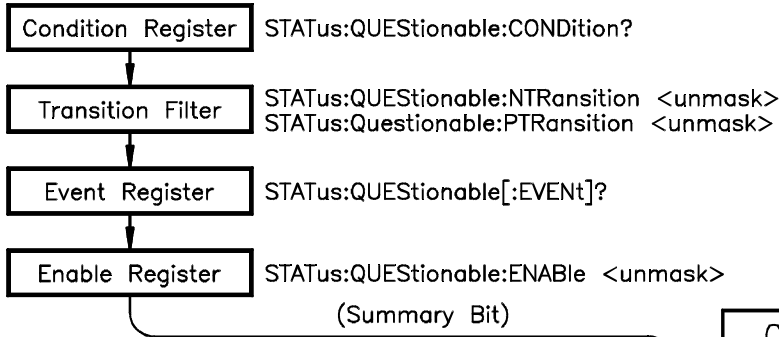
Status System Registers

Operating conditions within the AFG are monitored by registers in various status groups. The status groups implemented by the AFG are:

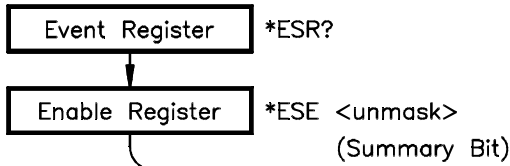
- Questionable Signal Status Group
 - Condition Register
 - Transition Filter
 - Event Register
 - Enable Register
- Operation Status Group
 - Condition Register
 - Transition Filter
 - Event Register
 - Enable Register
- Standard Event Status Group
 - Standard Event Status Register
 - Standard Event Status Enable Register
- Status Byte Status Group
 - Status Byte Register
 - Service Request Enable Register

The relationship between the registers and filters in these groups is shown in Figure 9-1.

Questionable Signal Status Group



Standard Event Status Group



Operation Status Group

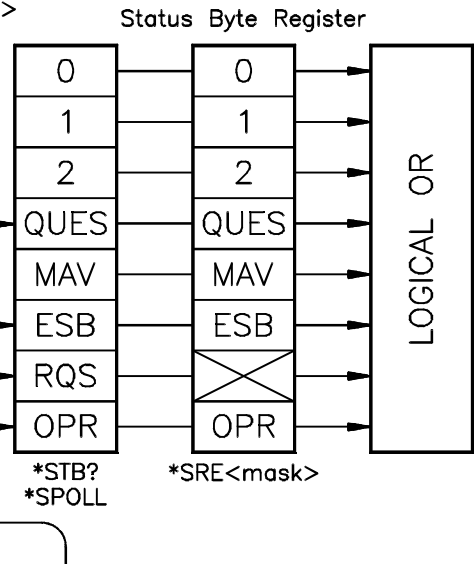
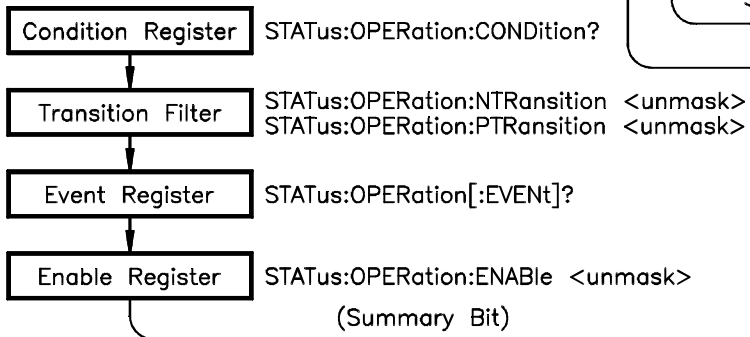


Figure 9-1. HP E1445A Status Groups and Associated Registers

The Questionable Signal Status Group

The Questionable Signal Status Group monitors the quality of various aspects of the output signal. In the AFG, the Questionable Signal Status Group monitors the frequency accuracy of the divide-by-n subsystem, and also error conditions in non-volatile calibration memory.

The Condition Register

Divide-by-n frequency accuracy and non-volatile calibration memory errors are monitored with the following bits in the Condition Register. All other bits are unused.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
unused							CAL	unused		FREQ	unused				

- **FREQuency:** Bit 5 is set (1) when the frequency generated by the divide-by-n ([SOURce:]FREQuency2) subsystem differs from the programmed frequency by greater than 1%. Otherwise, the bit remains cleared (0).
- **CALibration:** Bit 8 is set (1) when an error is detected in non-volatile calibration memory.

Reading the Condition Register

The settings of bits 5 and 8 can be determined by reading the Condition Register with the command:

```
STATus:QUESTionable:CONDition?
```

Bit 5 has a corresponding decimal value of 32 and bit 8 has a decimal value of 256. Reading the Condition Register does not affect the bit settings. The bits are cleared following a reset (*RST). Bit 8 calibration will remain set, however, if the error condition persists.

The Transition Filter

The Transition Filter specifies which type of bit transition in the Condition Register will set corresponding bits in the Event Register. Transition filter bits may be set for positive transitions (0 to 1), or negative transitions (1 to 0). The commands used to set the transitions are:

```
STATus:QUESTionable:NTRansition <unmask>
```

```
STATus:QUESTionable:PTRansition <unmask>
```

NTRansition sets the negative transition. For each bit unmasked, a 1 to 0 transition of that bit in the Condition Register sets the associated bit in the Event Register.

PTRansition sets the positive transition. For each bit unmasked, a 0 to 1 transition of that bit in the Condition Register sets the associated bit in the Event Register.

<unmask> is the decimal, hexadecimal (#H), octal (#Q), or binary (#B) value of the Condition Register bit to be unmasked. (The decimal values of bits 5 and 8 are 32 and 256.)

The Event Register The Event Register latches transition events from the Condition Register as specified by the Transition Filter. Bits in the Event Register are latched and remain set until the register is cleared by one of the following commands:

```
STATus:QUEStionable[:EVENT]?  
*CLS
```

The Enable Register The Enable Register specifies which bits in the Event Register can generate a summary bit which is subsequently used to generate a service request. The AFG logically ANDs the bits in the Event Register with bits in the Enable Register, and ORs the results to obtain a summary bit.

The bits in the Enable Register that are to be ANDed with bits in the Event Register are specified (unmasked) with the command:

```
STATus:QUEStionable:ENABle <unmask>
```

<unmask> is the decimal, hexadecimal (#H), octal (#Q), or binary (#B) value of the Enable Register bit to be unmasked. (The decimal values of bits 5 and 8 are 32 and 256.)

The Enable Register is cleared at power-on, or by specifying an *<unmask>* value of 0.

Program Example The QSSG_RQS program sets up the Questionable Signal Status Group Registers to monitor the output frequency generated by the [SOURce:]FREQuency2 subsystem. If the programmed frequency differs from the actual output frequency by greater than 1%, a service request interrupt is sent to the computer which responds with a message indicating the condition.

The steps of the program are:

1. Set the bit transition which will latch the event (frequency error) in the Event Register.

```
STATus:QUEStionable:NTRansition <unmask>  
or  
STATus:QUEStionable:PTRansition <unmask>
```

- Unmask bit 4 (FREQ) in the Enable Register so that the event latched into the Event Register will generate a Questionable Signal Status Group summary bit.

STATus:QUEStionable:ENABle <unmask>

- Unmask bit 3 (QUE) in the Service Request Enable Register so that a service request is generated when the Questionable Signal Status Group summary bit is received.

*SRE <unmask>

HP BASIC Program Example (QSSG_RQS)

```

1  !RE-STORE "QSSG_RQS"
2  !This program generates a service request when the output frequency
3  !generated by the SOURce:FREQuency2 subsystem differs from the
4  !programmed frequency by more than 1%.
5  !
10 !Assign an I/O path between the computer and the E1445A.
20 ASSIGN @Afg TO 70910
30 COM @Afg
40 !
50 !Reset the AFG
60 CALL Rst
70 !
80 !Set up the computer to respond to the service request.
90 ON INTR 7 CALL Disp_msg
100 ENABLE INTR 7;2
110 !
120 !Set up the AFG to monitor the output frequency.
130 OUTPUT @Afg;"*CLS"           !clear Status Byte and Event Registers
140 OUTPUT @Afg;"STAT:QUES:PTR 32" !pos transition of FREQ bit
150 OUTPUT @Afg;"STAT:QUES:ENAB 32" !allow FREQ bit to generate summary bit
160 OUTPUT @Afg;"*SRE 8"         !enable summary bit to generate RQS
170 !
180 !Call subprogram which outputs a signal using the SOURce:FREQ2
190 !subsystem.
200 CALL Freq2
210 WAIT .1 !allow interrupts to be serviced
220 OFF INTR 7
230 END
240 !
250 SUB Freq2
260 Freq2: !Subprogram which outputs a 10 MHz square wave using the
270 !SOURce:FREQ2 subsystem.
280 COM @Afg
290 OUTPUT @Afg;"SOUR:ROSC:SOUR INT2;"; !reference oscillator
300 OUTPUT @Afg;":TRIG:STAR:SOUR INT2;"; !frequency generator

```

Continued on Next Page

```

310     OUTPUT @Afg;":SOUR:FREQ2 10E6;";           !frequency
320     OUTPUT @Afg;":SOUR:FUNC:SHAP SQU;";       !function
330     OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL 1V"   !amplitude
340     OUTPUT @Afg;"INIT:IMM"                     !wait_for_arm state
350     LOOP          !loop continuously until frequency error occurs
360     END LOOP
370 SUBEND
380 !
390 SUB Disp_msg
400 Disp_msg: !Subprogram which is called when output frequency
410           !varies from 10 MHz by more than 1%.
420     COM @Afg
430     !Read Status Byte Register and clear service request bit (RQS)
440     B=SPOLL(@Afg)
450     LOOP
460     DISP "Output frequency error"
470     WAIT 1
480     DISP ""
490     WAIT 1
500     END LOOP
510 SUBEND
520 !
530 SUB Rst
540 Rst: !Subprogram which resets the E1445.
550     COM @Afg
560     OUTPUT @Afg;"*RST;*OPC?"                 !reset the AFG
570     ENTER @Afg;Complete
580 SUBEND

```

Comments

- This program runs continuously until a frequency change greater than 1% occurs between the programmed frequency and the output frequency. Resetting the computer stops the program.
- Clearing the Questionable Signal Event Register (line 130) allows new events to be latched into the Register. Clearing the service request bit (bit 6 (RQS)) in the Status Byte Register (line 440) when the interrupt is serviced allows the bit to be set again when the next summary bit is received.

Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, QSSG_RQS.FRM, is in directory "VBPROG" and the Visual C example program, QSSG_RQS.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

The Operation Status Group

The Operation Status Group monitors current operating conditions within the AFG. The specific conditions include: calibrating, sweeping, entering the wait-for-arm state, and execution of the INITiate:IMMediate command.

The Condition Register

Calibration, sweeping, waiting for an arm signal, and the INITiate:IMMediate command are monitored with the following bits in the Condition Register. All other bits are unused.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
unused							INIT		ARM	unused	SWE	unused	CAL		

- **CALibrating:** Bit 0 is set (1) during calibration. The bit is cleared (0) otherwise.
- **SWEeping:** Bit 3 is set (1) while a frequency sweep or list is in progress. The bit is cleared (0) when waveform generation is halted, when frequency sweeping or lists are not selected, and at the end of each sweep or list.
- **Waiting for ARM:** Bit 6 is set (1) when the AFG enters the wait-for-arm state. The bit is cleared (0) when a start arm is received or when waveform generation is aborted.
- **INITiated:** Bit 8 is set (1) when the INITiate:IMMediate command is executed. The bit is cleared (0) when waveform generation is complete and the AFG returns to the Idle state.

Reading the Condition Register

Bit settings in the Condition Register can be determined with the command:

```
STATus:OPERation:CONDition?
```

Bits 0, 3, 6, and 8 have corresponding decimal values of 1, 8, 64, and 256. Reading the Condition Register does not affect the bit settings. The bits are cleared following a reset (*RST).

The Transition Filter

The Transition Filter specifies which type of bit transition in the Condition Register will set corresponding bits in the Event Register. Transition filter bits may be set for positive transitions (0 to 1), or negative transitions (1 to 0). The commands used to set the transitions are:

```
STATus:OPERation:NTRansition <unmask>
```

```
STATus:OPERation:PTRansition <unmask>
```

NTRansition sets the negative transition. For each bit unmasked, a 1 to 0 transition of that bit in the Condition Register sets the associated bit in the Event Register.

PTRansition sets the positive transition. For each bit unmasked, a 0 to 1 transition of that bit in the Condition Register sets the associated bit in the Event Register.

<unmask> is the decimal, hexadecimal (#H), octal (#Q), or binary (#B) value of the Condition Register bit to be unmasked. (Bits 0, 3, 6, and 8 have corresponding decimal values of 1, 8, 64, and 256.)

The Event Register

The Event Register latches transition events from the Condition Register as specified by the Transition Filter. Bits in the Event Register are latched and remain set until the register is cleared by one of the following commands:

```
STATus:OPERation[:EVENT]?  
*CLS
```

The Enable Register

The Enable Register specifies which bits in the Event Register can generate a summary bit which is subsequently used to generate a service request. The AFG logically ANDs the bits in the Event Register with bits in the Enable Register, and ORs the results to obtain a summary bit.

The bits in the Enable Register that are to be ANDed with bits in the Event Register are specified (unmasked) with the command:

```
STATus:OPERation:ENABle <unmask>
```

<unmask> is the decimal, hexadecimal (#H), octal (#Q), or binary (#B) value of the Enable Register bit to be unmasked. (Bits 0, 3, 6, and 8 have corresponding decimal values of 1, 8, 64, and 256.)

The Enable Register is cleared at power-on, or by specifying an <unmask> value of 0.

Program Example

The OSG_RQS program sets up the Operation Status Group Registers to determine when the AFG enters the wait-for-arm state. When the AFG enters that state, a service request interrupt is sent to the computer which responds with a message indicating the state which exists.

The steps of the program are:

1. Set the bit transition which will latch the event (entering wait-for-arm state) in the Event Register.

```
STATus:OPERation:NTRansition <unmask>  
or  
STATus:OPERation:PTRansition <unmask>
```


2. Unmask bit 6 (ARM) in the Enable Register so that the event latched into the Event Register will generate an Operation Status Group summary bit.

STATus:OPERation:ENABLE <unmask>

3. Unmask bit 7 (OPR) in the Service Request Enable Register so that a service request is generated when the Operation Status Group summary bit is received.

*SRE <unmask>

HP BASIC Program Example (OSG_RQS)

```

1  !RE-STORE "OSG_RQS"
2  !This program generates a service request when the AFG enters the
3  !wait-for-arm state.
4  !
10 !Assign an I/O path between the computer and the E1445A.
20 ASSIGN @Afg TO 70910
30 COM @Afg
40 !
50 !Reset the AFG
60 CALL Rst
70 !
80 !Set up the computer to respond to the service request.
90 ON INTR 7 CALL Afg_ready
100 ENABLE INTR 7;2
110 !
120 !Set up the AFG to generate a service request when it enters the
130 !wait-for-arm state.
140 OUTPUT @Afg;"*CLS"           !clear Status Byte and Event Registers
150 OUTPUT @Afg;"STAT:OPER:PTR 64" !pos transition of ARM bit
160 OUTPUT @Afg;"STAT:OPER:ENAB 64" !allow ARM bit to generate summary bit
170 OUTPUT @Afg;"*SRE 128"       !enable summary bit to generate RQS
180 OUTPUT @Afg;"STAT:OPC:INIT OFF" !allow intr branching after wait-for-arm
190 !
200 !Call subprogram which sets up and initiates the AFG.
210 !subsystem.
220 CALL Afg_setup
230 WAIT .1 !allow interrupt to be serviced
240 OFF INTR 7
250 END
260 !
270 SUB Afg_setup
280 Afg_setup: !Subprogram which sets up the AFG and places it in the
290 !wait-for-arm state
300 COM @Afg
310 OUTPUT @Afg;"ABORT"           !stop current waveform

```

Continued on Next Page

```

320     OUTPUT @Afg;"SOUR:ROSC:SOUR INT1;";           !reference oscillator
330     OUTPUT @Afg;":TRIG:STAR:SOUR INT1;";         !frequency generator
340     OUTPUT @Afg;":SOUR:FREQ1:FIX 1E3;";         !frequency
350     OUTPUT @Afg;":SOUR:FUNC:SHAP SIN;";         !function
360     OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL 1V"     !amplitude
370     OUTPUT @Afg;"ARM:STAR:LAY2:SOUR HOLD"       !hold off arm signal
380     OUTPUT @Afg;"INIT:IMM;*OPC?"               !set wait-for-arm state
390     ENTER @Afg;Ready
400     OUTPUT @Afg;"ARM:STAR:LAY2:IMM"             !arm AFG (output signal)
410     SUBEND
420     !
430     SUB Afg_ready
440     Afg_ready: !Subprogram which is called when the AFG enters the
450                 !wait-for-arm state.
460     COM @Afg
470     !Read Status Byte Register and clear service request bit (RQS)
480     B=SPOLL(@Afg)
490     DISP "AFG is in the wait-for-arm state, press 'Continue' to send ARM"
500     PAUSE
510     DISP ""
520     SUBEND
530     !
540     SUB Rst
550     Rst: !Subprogram which resets the E1445.
560     COM @Afg
570     OUTPUT @Afg;"*RST;*OPC?"                   !reset the AFG
580     ENTER @Afg;Complete
590     SUBEND

```

Comments

- Clearing the Operation Status Event Register (line 140) allows new events to be latched into the register. Clearing the service request bit (bit 6 (RQS)) in the Status Byte Register (line 480) when the interrupt is serviced allows the bit to be set again when the next summary bit is received.
- STAT:OPC:INIT OFF (line 180) allows the *OPC? command (line 380) to execute following INIT:IMM, rather than waiting for the AFG to return to the Idle state (Pending Operation Flag set false). Thus, when the AFG enters the wait-for-arm state following INIT:IMM, *OPC? executes and allows time for the interrupt to be serviced (Afg_ready called) before line 400 executes.

Refer to page 382 for more information on the STATus:OPC:INITiate command.

Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, OSG_RQS.FRM, is in directory "VBPROG" and the Visual C example program, OSG_RQS.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

The Standard Event Status Group

The Standard Event Status Group monitors command execution, programming errors, and the power-on state. It is the status group used by the error checking routine in the HP BASIC example programs found throughout the manual.

The Standard Event Status Register

The conditions monitored by the Standard Event Status Register are identified below.

7	6	5	4	3	2	1	0
PON	unused	CME	EXE	DDE	QYE	unused	OPC

- **Power-on (PON):** Bit 7 is set (1) when an off-to-on transition has occurred.
- **Command Error (CME):** Bit 5 is set (1) when an incorrect command header is received, or if an unimplemented common command is received.
- **Execution Error (EXE):** Bit 4 is set (1) when a command parameter is outside its legal range.
- **Device Dependent Error (DDE):** Bit 3 is set (1) when an error other than a command error, execution error, or query error has occurred.
- **Query Error (QYE):** Bit 2 is set (1) when the AFG output queue is read and no data is present, or when data in the output queue has been lost.
- **Operation Complete (OPC):** Bit 0 is set (1) when the *OPC command is received. *OPC is used to indicate when all pending (or previous) AFG commands have completed.

Note that bits 7, 5, 4, 3, 2, and 0 have corresponding decimal values of 128, 32, 16, 8, 4, and 1.

Reading the Standard Event Status Register

The settings of the Standard Event Status Register can be read with the command:

*ESR?

The bits are cleared at power-on, or by *ESR? or *CLS.

The Standard Event Status Enable Register

The Standard Event Status Enable Register specifies which bits in the Standard Event Status Register can generate a summary bit which is subsequently used to generate a service request. The AFG logically ANDs the bits in the Event Register with bits in the Enable Register, and ORs the results to obtain a summary bit.

The bits in the Enable Register that are to be ANDed with bits in the Event Register are specified (unmasked) with the command:

```
*ESE <unmask>
```

<unmask> is the decimal, hexadecimal (#H), octal (#Q), or binary (#B) value of the Enable Register bit to be unmasked. (Bits 7, 5, 4, 3, 2, 0 have corresponding decimal values of 128, 32, 16, 8, 4, 1.)

All unmasked bits in the Enable Register can be determined with the command:

```
*ESE?
```

The Standard Event Status Enable Register is cleared at power-on, or with an <unmask> value of 0.

Program Example

The ERRORCHK program sets up the Standard Event Status Group Registers to monitor programming errors. When a command error, execution error, device dependent error, or query error occurs, a service request interrupt is sent to the computer which then reads the AFG error queue and displays the error code and message.

The steps of the program are:

1. Unmask bits 5 (CME), 4 (EXE), 3 (DDE), 2 (QYE) in the Standard Event Status Enable Register so that the error will generate a Standard Event Status Group summary bit.

```
*ESE <unmask>
```

2. Unmask bit 5 (ESB) in the Service Request Enable Register so that a service request is generated when the Standard Event Status Group summary bit is received.

```
*SRE <unmask>
```

HP BASIC Program Example (ERRORCHK)

```
1   !RE-STORE"ERRORCHK"
2   !This program represents the method used to check for programming
3   !errors in HP BASIC programs.
4   !
10  !Assign I/O path between the computer and E1445A.
20  ASSIGN @Afg TO 70910
30  COM @Afg
40  !Define branch to be taken when an E1445A error occurs.
50  !Enable HP-IB interface to generate an interrupt when an error
60  !occurs.
70  ON INTR 7 CALL Errmsg
80  ENABLE INTR 7;2
90  !Clear all bits in the Standard Event Status Register, unmask the
100 !Standard Event Status Group summary bit in the E1445A Status Byte
110 !register (decimal weight 32), unmask the query error, device
120 !dependent error, execution error, and command error bits
130 !(decimal sum 60) in the E1445A Standard Event Status Register.
140 OUTPUT @Afg;"*CLS"
150 OUTPUT @Afg;"*SRE 32"
160 OUTPUT @Afg;"*ESE 60"
170 !
180 !Subprogram calls would be here
190 !
200 WAIT .1 !allow error branch to occur before turning intr off
210 OFF INTR 7
220 END
230 !
240 SUB Errmsg
250 Errmsg: !Subprogram which displays E1445 programming errors
260     COM @Afg
270     DIM Message$[256]
280     !Read AFG status byte register and clear service request bit
290     B=SPOLL(@Afg)
300     !End of statement if error occurs among coupled commands
310     OUTPUT @Afg;"
320     OUTPUT @Afg;"ABORT"           !abort output waveform
330     REPEAT
340         OUTPUT @Afg;"SYST:ERR?"   !read AFG error queue
350         ENTER @Afg;Code,Message$
360         PRINT Code,Message$
370     UNTIL Code=0
380     STOP
390 SUBEND
```

Comments

- Clearing the service request bit (bit 6 (RQS)) in the Status Byte Register (line 290) when the interrupt is serviced allows the bit to be set again when the next summary bit is received.

Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, ERRORCHK.FRM, is in directory “VBPROG” and the Visual C example program, ERRORCHK.C, is in directory “VCPROG” on the CD that came with your HP E1445A.

The Status Byte Status Group

The registers in the Status Byte Status Group enable conditions monitored by the other status groups to generate a service request.

The Status Byte Register

The Status Byte Register contains the summary bits of the Questionable Signal Status Group (QUES), the Operation Status Group (OPER), and the Standard Event Status Group (ESB). The register also contains the message available bit (MAV) and the service request bit (RQS).

7	6	5	4	3	2	1	0
OPER	RQS	ESB	MAV	QUES	unused		

- **Questionable Signal Summary Bit (QUES):** Bit 3 is set (1) when a condition monitored by the Questionable Signal Status Group is present, when the appropriate bit is latched into the group’s Event Register, and when the bit is unmasked by the group’s Enable Register.
- **Message Available Bit (MAV):** Bit 4 is set (1) when data, such as a query response, is in the AFG’s output queue.
- **Standard Event Summary Bit (ESB):** Bit 5 is set (1) when a condition monitored by the Standard Event Status Group is present and the appropriate bit is set in the group’s Event Register, and when the bit is unmasked by the group’s Enable Register.
- **Service Request Bit (RQS):** Bit 6 is set (1) when any other bit in the Status Byte Register is set.
- **Operation Status Summary Bit (OPER):** Bit 7 is set (1) when a condition monitored by the Operation Status Group is present, when the appropriate bit is latched into the group’s Event Register, and when the bit is unmasked by the group’s Enable Register.

Reading the Status Byte Register

The Status Byte Register can be read with either of the following commands:

```
*STB?  
SPOLL
```

Both commands return the decimal weighted sum of all set bits in the register. The difference between the commands is that *STB? does not clear bit 6 (RQS service request). The serial poll (SPOLL) does clear bit 6. All bits in the Status Byte Register with the exception of MAV are cleared with the command:

```
*CLS (*CLS also aborts the current waveform)
```

MAV is cleared when data is read from the output queue.

The Service Request Enable Register

The Service Request Enable Register specifies which (status group) summary bit(s) will send a service request message to the computer over HP-IB. The bits are specified (unmasked) with the command:

```
*SRE <unmask>
```

All unmasked bits in the Enable Register can be determined with the command:

```
*SRE?
```

The Service Request Enable Register is cleared at power-on, or by specifying an <unmask> value of 0.

Presetting the Enable Register and Transition Filter

The Enable Registers and Transition Filters in the Questionable Signal and Operation Status Groups can be preset (initialized) with the command:

```
STATus:PRESet
```

All bits in the Enable Registers are masked (i.e. <unmask> is 0), and all bits in the Condition Registers set corresponding bits in the Event Registers on positive (0 to 1) transitions.

Notes

Chapter 10

Block Diagram Description

Chapter Contents

This chapter shows how the HP E1445A 13-Bit Arbitrary Function Generator (AFG) operates. The sections are as follows:

- AFG Description Page 445
- Arbitrary Waveform Description. Page 446
- Generating Non-Sinusoid Arbitrary Waveforms. Page 447
 - Output DAC. Page 447
 - Memory Page 448
 - Reference Oscillator Page 448
 - Frequency Generators Page 448
 - Trigger Circuitry Page 450
 - Output Circuitry. Page 450
 - Microprocessor Page 450
- Generating Sinusoid Waveforms. Page 450
- Output Circuitry Description Page 451
 - Attenuator Page 451
 - Filter. Page 451
 - Output Amplifier Page 451
 - Offset Circuitry Page 451
- AFG Memory Description Page 452

AFG Description

The AFG can output standard waveforms, like sinusoid, square, triangle, and ramp waveforms, and user defined arbitrary (i.e., USER function) waveforms. The AFG can also perform frequency sweeping, frequency-shift-keying, output frequency lists, and DC volts.

All waveforms that the AFG generates, except DC volts, are arbitrary waveforms. The only difference is that the AFG generates the data for the standard waveforms internally and the user supplies the data for the arbitrary waveforms.

Arbitrary Waveform Description

Refer to Figure 10-1. An arbitrary waveform is equally divided into points that are the actual voltage points of the waveform. The AFG stores these points as a waveform segment in its segment memory. The waveform segments are stored as Digital-to-Analog Converter (DAC) codes. The codes set the output DAC to the voltage values of the waveform.

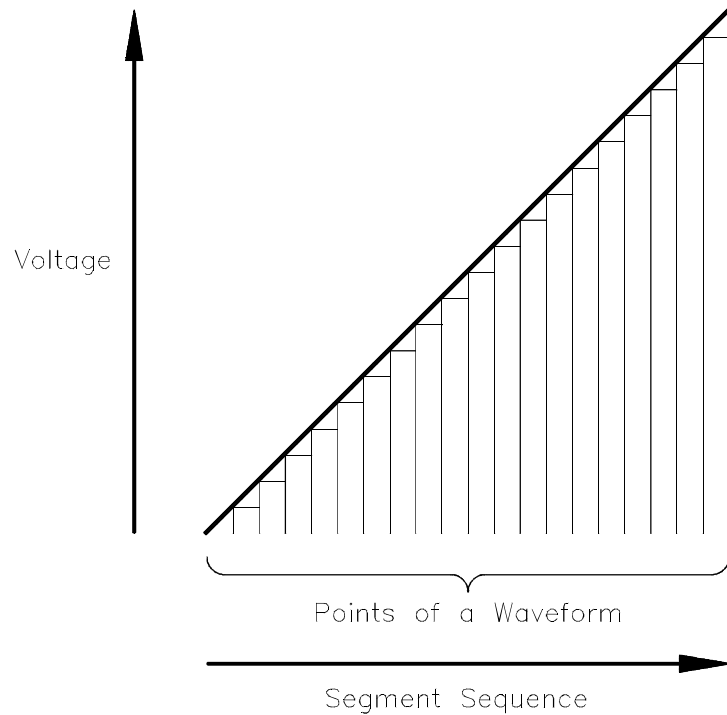


Figure 10-1. Arbitrary Waveform

The segment sequence selects the waveform segment to be output for waveform generation. The segment sequence is stored in the AFG's sequence memory.

For square, ramp, and triangle functions, the AFG calculates the waveform segments and segment sequences, and stores them in memory. For the user generated waveforms, the user transfers the waveform segments and segment sequences to the AFG which stores them into memory. (See "Generating Sinusoid Waveforms" on page 450 for sinusoid waveforms.)

Generating Non-Sinusoid Arbitrary Waveforms

Refer to Figure 10-2. The following describes the blocks that generate non-sinusoid waveforms.

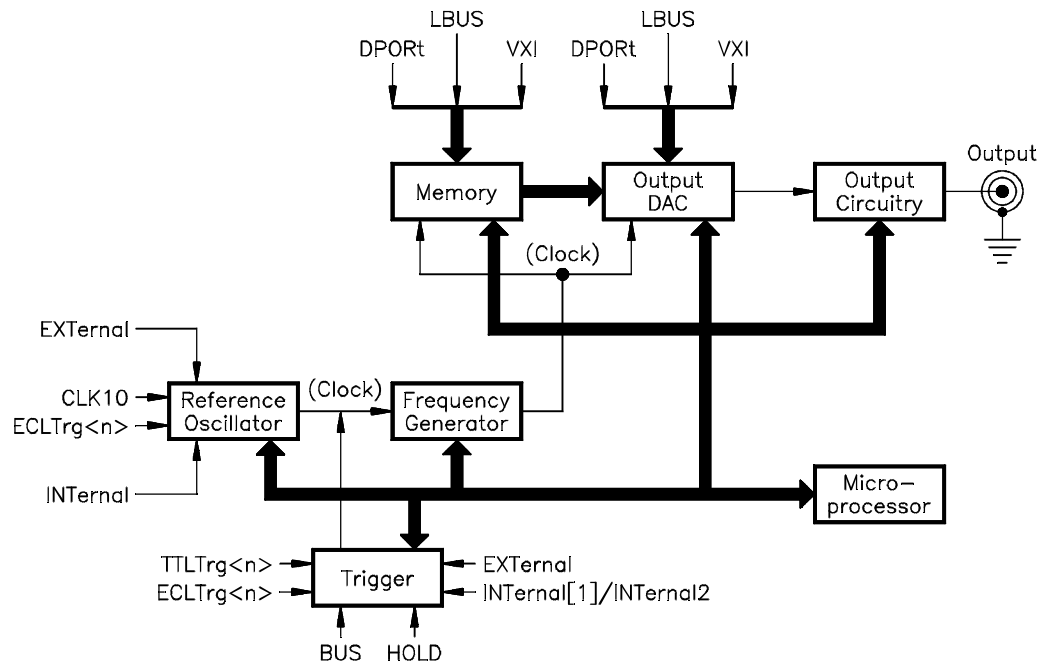


Figure 10-2. AFG Simplified Block Diagram

Output DAC

The AFG uses the 13-bit DAC to generate the waveforms. Each time the AFG's frequency generator clocks the DAC, the DAC outputs a voltage value that corresponds to the point value in the waveform segment. The bits set in the DAC determine the voltage value. For non-sinusoid functions, the DAC codes in the AFG's segment memory set the appropriate bits of the DAC. For the sinusoid function, the output of the frequency generator sets the bits to the appropriate value (see "Generating Sinusoid Waveforms" on page 450).

The DAC can also receive segment data from external sources, like the VXIbus. The external sources immediately set the DAC to an output voltage that corresponds to the DAC code value sent by the source. Each time the DAC receives a new code, the DAC's output is set to the value in the new code. Thus, the waveform frequency depends on the rate at which the DAC receives the codes.

The output DAC's voltage range is from -5.12 V to +5.11875 V.

Memory Concurrent with the DAC, the frequency generator also clocks the segment memory to output the next code to set the DAC bits to the next point on the waveform. By clocking both the memory and DAC at a certain clock rate (i.e., sample rate), the AFG outputs a waveform at a frequency determined by the length and number of waveform segments and the sample rate. (See “AFG Memory Description” on page 452 for more information on how the memory operates.)

Waveform segments and segment sequences can also be stored into memory using external sources, like the VXIbus, for user generated waveforms.

Reference Oscillator The reference oscillator provides the clock signal for the frequency generator. Thus, frequency stability depends on the stability of the reference oscillator. The oscillator also determines the frequency range of the frequency generators. The AFG allows for user supplied reference oscillator sources for custom frequency values.

Frequency Generators The frequency generator generates the clock pulses to enable both the output DAC and memory to output a segment. The frequency generator thus determines the rate (i.e., the sample rate) at which the points of a waveform segment are output.

The AFG uses two different generators. One generator (Frequency1 generator) uses a Direct-Digital-Synthesis (NCO) technique to generate the sample frequencies. The other generator (Frequency2 generator) is a Divide-by-n generator.

DDS Frequency Generator (Frequency1 Generator)

Refer to Figure 10-3. This generator has excellent resolution and allows for frequency sweeping, frequency-shift-keying, and output frequency lists. However, its maximum frequency is the Reference Oscillator frequency divided by 4.

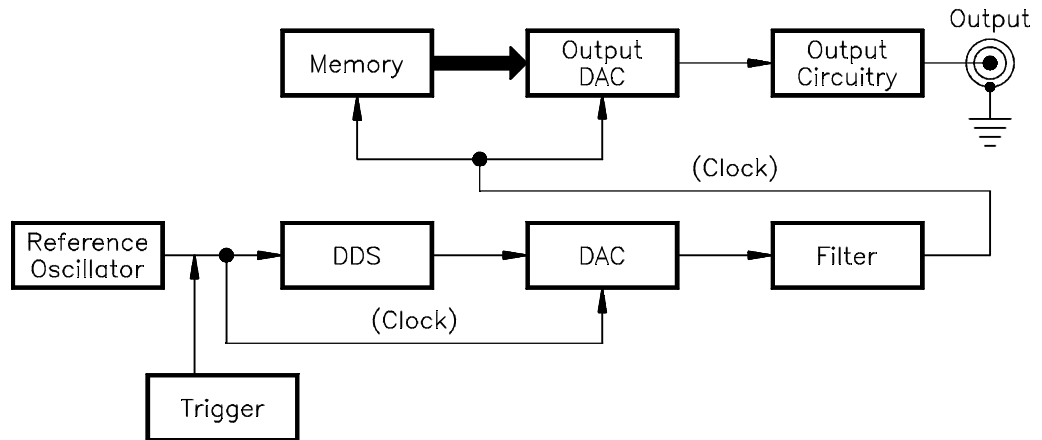


Figure 10-3. Generating Waveforms Using a Frequency1 Generator

To generate precision frequencies for the memory and output DAC clock, the output of the DDS frequency generator is applied to a DAC. The DAC output is filtered and the resultant clock signals clocks the memory and output DAC to create the waveforms.

Divide-by-N Frequency Generator (Frequency2 Generator)

Refer to Figure 10-4. This generator has better phase noise characteristics and permits higher frequency operation (up to the Reference Oscillator Frequency). The output of this filter directly clocks the memory and output DAC.

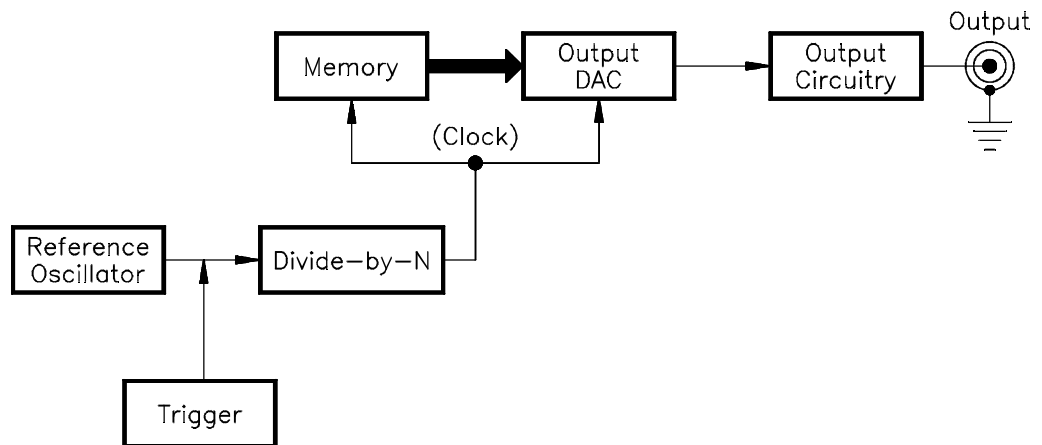


Figure 10-4. Generating Waveforms Using a Frequency2 Generator

Trigger Circuitry The trigger circuitry advances the waveform to the next segment. The external trigger sources advances the waveform directly. Thus, the sample rate and resultant waveform frequency depend on the frequency of the applied triggers.

Output Circuitry The output circuitry outputs the waveform at the front panel's "Output" connector. The circuitry sets the output amplitude, offset voltages, output impedances, and has a 250 kHz and a 10 MHz low-pass filter. (See "Output Circuitry Description" on page 451 for more information.)

Microprocessor The AFG uses a Motorola 68000 microprocessor to generate the waveform segments and segment sequences for the standard waveforms.

Generating Sinusoid Waveforms

Refer to Figure 10-5. The AFG uses the DDS (Frequency 1) frequency generator to generate Sinusoid waveforms. The generator output directly supplies the DAC data for the output DAC to generate the waveforms.

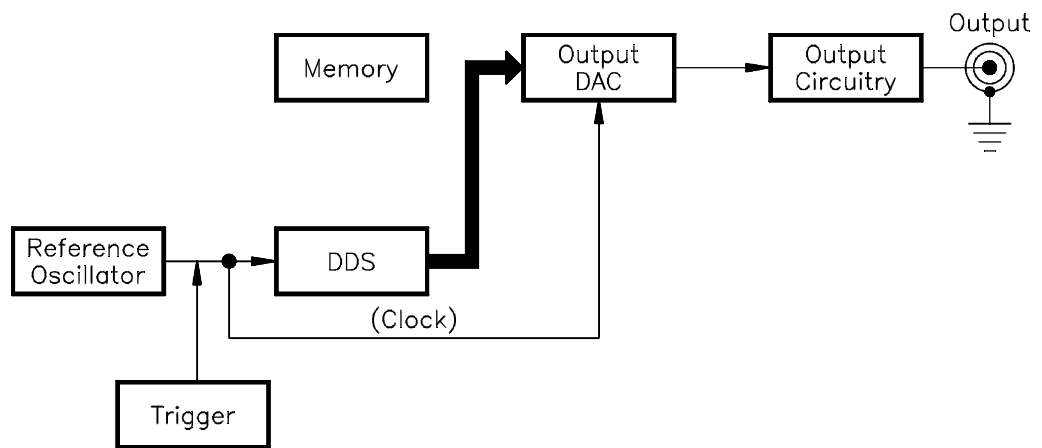


Figure 10-5. Generating Sinusoid Waveforms

Output Circuitry Description

Refer to Figure 10-6. The output circuitry consists of an output amplifier, attenuator, offset circuitry, and filter. The following describes the different parts of the circuitry.

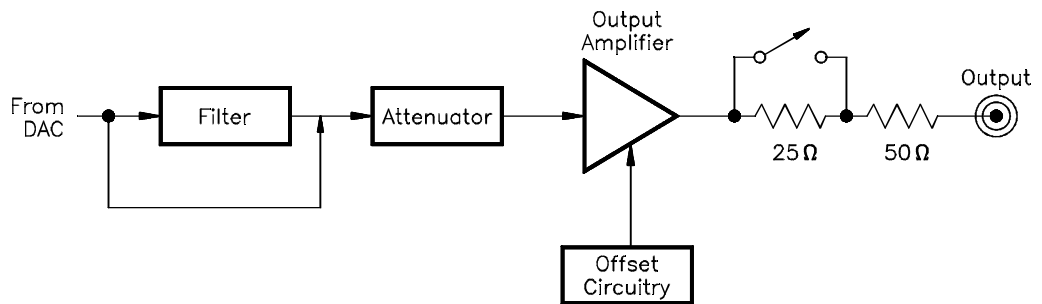


Figure 10-6. AFG Output Circuitry

Attenuator The attenuator provides 30 dB attenuation in .01 dB steps for the output voltage. The AFG automatically sets the attenuator to the appropriate value dependent on the output amplitude selected by the user. The DC volts function does not use the attenuator. For this function, the output of the output DAC is directly output, through the output amplifier, to the “Output” connector.

Filter The AFG provides a 250 kHz low-pass filter, 10 MHz low-pass filter, or no filter. The filters are used to filter the high frequency components, such as clock signals, of the output DAC’s output signal.

Output Amplifier The output amplifier provides the necessary current to drive output loads of 50Ω and 75Ω loads applied to the “Output” connector. For matched loads, the output amplitude are from -5.12 V to +5.11875 V. In addition, the amplifier can also be set for open circuit or infinite loads applied to the “Output” connector. For open circuit outputs, the amplitude range is twice the matched load values.

Offset Circuitry This circuitry offsets the output amplifier to provide an offset voltage.

AFG Memory Description

The segment memory that stores the segment list as DAC codes can store the codes either in the Signed or Unsigned number format. This memory uses 16-bit integer values for the codes. To change the number format to a different format, the memory must be completely empty before selecting the different format.

Because of hardware restrictions, the segment space in memory allocates for a multiple of 8 words for each waveform segment.

Appendix A

HP E1445A Specifications

Appendix Contents

This appendix contains the HP E1445A Arbitrary Function Generator operating specifications. Except as noted, the specifications apply under the following conditions:

- **Period:** 1 year
- **Temperature:** 0°–55° C
- **Relative Humidity:** ≤ 65% @ 0°–40° C
- **Warm up Time:** 1 hour

“Typical”, “typ”, or “nominal” values are non-warranted supplementary information provided for applications assistance.

Memory Characteristics

Segment Memory (contains DAC code and Marker Bit for each sample point):

DAC Word:	13 bits
Digital Marker:	1 bit (user-programmable)
Size:	262144 (256K, 1K = 1024)
Segment Length:	from ≥ 4 points to 262,144 points.
Number of Segments:	1 to 256
System Use:	(while one of the following waveforms is selected):
	Square: 4 points
	Triangle, Ramp : 100 points (default number, unless changed by user)

Sequence Memory (This memory concatenates segments into larger waveforms):

Size:	32768 entries
Sequence Length:	1 to 32768 entries
Number of Sequences:	1 to 128
Contents of Each Entry:	Designator of which segment to output
	Loop Count: # times to repeat the designated segment (1 to 4096, default = 1)
	“Marker Enable” Bit: a mask (default = enabled) for the marker data in the specified segment
System Use:	When square, triangle, or ramp waveform is selected, one entry is used

Frequency and Sample Rate Characteristics

Tolerances All internally-generated frequencies and rates are $\pm 0.005\%$ initial tolerance. Aging rate is 20 ppm/year.

Arbitrary Waveform Sample Rates **Maximum arbitrary waveform sample rate (internal or external rate):** 40MSa/s (Sa/s = Samples per second)

Frequency Generator #1:

Internal Reference:	42.94967296 MHz
Rate Generation Method:	Direct Digital Synthesis (DDS)
Basic Range:	
Minimum :	0.01 Sa/s
Maximum :	10.73741824 MSa/s
Resolution :	0.01 Sa/s
Jitter:	0.03% + 3 nsec (typical rms)
Extended Range:	
Minimum :	0.02 Sa/s
Maximum :	21.47483648 MSa/s
Resolution :	0.02 Sa/s
Jitter:	0.06% + 3 nsec (typical rms)
Pertinent SCPI Commands:	[SOURce:]ROSCillator:SOURce INTernal1 [SOURce:]FREQuency1 subsystem TRIGger:STARt:SOURce INTernal1
Frequency Agility: (see page 456)	Sweep (linear or log), output frequencies from a list, frequency-shift keying (FSK), phase offset
Recommendation:	Use for most applications

Frequency Generator #2:

Internal Reference:	40.000000 MHz
Rate Generation Method:	Divide-by-N, or direct use of reference
Range:	
Minimum :	305.175781 Sa/s (40/131072 MSa/s)
Maximum :	40.000000 MSa/s
Resolution :	Not Applicable. Attainable rates are 40/N MSa/s where N = 1,2,3, and all even values up to 131072.
Jitter :	80 psec (typical rms)
Pertinent SCPI commands:	[SOURce:]ROSCillator:SOURce INTernal2 [SOURce:]FREQUency2 subsystem TRIGger:STARt:SOURce INTernal2
Frequency Agility:	No
Recommendation:	Use if 40 MSa/s is required, or for lowest jitter at other sample rates.

Built-In Waveforms (using 42.94967296 MHz internal reference oscillator); in each case the frequency resolution equals the minimum frequency:

Sine Waves:	0.01 Hz to 10.73741824 MHz
Square Waves:	0.0025 Hz to 2.68435456 MHz (normal range); Average Duty cycle is 49.9 to 50.1% \pm 3 nsec. 0.005 Hz to 5.36870912 MHz (doubled range); Average Duty cycle is 44% to 56% \pm 3 nsec. Using frequency generator #1, square waves inherit the timing jitter characteristics given above for frequency generator #1. The sample period is 1/4 of the square wave period.
Triangles, Ramps:	For the default setting of 100 points per cycle: 0.0001 Hz to 107.3741824 kHz (normal range) 0.0002 Hz to 214.7483648 kHz (doubled range) Higher frequencies are possible with fewer than 100 points per cycle. Points per cycle can be 4 to 262144.

Frequency Agility:

The capabilities in this section apply to all built-in standard waveforms and to all arbitrary waveforms generated with Frequency Generator #1 (i.e., the DDS timebase).

Digital Sweep:	Linear and Log phase-continuous (0.2 to 800 points/sec typical) (Note 1)
Frequency List:	Up to 256 points phase-continuous (0.2 to 800 points/sec typical) (Note 1)
Frequency-Shift Keyed (FSK):	Up to 2M or $f(\text{ref})/5$ changes/sec phase-continuous, whichever is smaller
Digital Phase Modulation:	See "Interface Characteristics" later in this appendix

Note 1: Sine waves can be leveled at each step of a frequency sweep or list. The speeds above include leveling.

Additional Waveform Control Characteristics:

Waveform repetitions per ARM:STARt: 1 to 65536 or INFinity
Not specified for built-in sine waves. For other waveforms, the final waveform repetition stops at the last sample point.

ARM:STARt events per INITiate: 1 to 65535 or INFinity

Amplitude Characteristics

Low-Pass Filtering:	Programmable choice of three configurations: 250 kHz (nominal 3 dB point) 5th-order Bessel 10 MHz (nominal 3 dB point) 7th-order Bessel No Filter
Output Impedance (nominal):	50 Ω or 75 Ω (programmable)
Output Disconnect:	Uses a relay. Output is unterminated when relay is open.
DAC Resolution (including sign):	13 bits (12 bits, sine waves only) monotonic to 11 bits
DC Volt Function:	
Output:	into 50 Ω or 75 Ω : -5.12 to +5.11875 volts in nominal steps of 1.25 mv into open circuit: -10.24 to +10.2375 volts in nominal steps of 2.5 mv
Accuracy:	(Temperature within 5 °C of temperature at calibration (Tcal); module calibrated at 18–28 °C; output impedance 50 Ω or 75 Ω ; load 50 Ω or 75 Ω respectively, or INF): 0.3% of setting + 0.2% of full-scale (add for each ° C beyond 5° from Tcal) 0.05% of setting + 0.015% of full-scale

All Built-In Waveforms:

Output Level: into 50 Ω or 75 Ω : 0.32374 to 10.2375 Vpp
into open circuit: 0.64748 to 20.475 Vpp

Output level adjustability is equivalent to 0–30 dB of attenuation in steps of 0.01 dB.

Sine Waves:

AC Accuracy, 1 kHz, maximum output: ± 0.1 dB

add beyond Tcal $\pm 5^\circ$ C: ± 0.005 dB / ° C

Add if output is not at maximum: ± 0.05 dB

Add if frequency is not 1 kHz, flatness error relative to 1 kHz (specified for 50 Ω or 75 Ω only):

250 kHz filter:

0.1 Hz to 100 kHz: ± 0.05 dB

100 kHz to 250 kHz: ± 0.10 dB

10 MHz filter:

1 kHz to 10.73741824 MHz: ± 0.2 dB

(These flatness values are achieved by active compensation for filter frequency response in sine wave mode only, and do not imply dynamic characteristics of arbitrary waveforms.)

Sine Wave Spectral Purity

Output frequencies less than 250 kHz are characterized using the 250 kHz filter, higher output frequencies with the 10 MHz filter. Frequencies given below refer to the desired output sine wave (f_c).

Total Harmonic Distortion (through 9th harmonic):

10 Hz–250 kHz	-60 dBc
250 kHz–4 MHz:	$[-60 + 20 \log_{10}(f_c / 250k)]$ dBc
4 MHz–10 MHz:	-36 dBc

Nonharmonic Spurious and Clock Components (to 150 MHz):

10 Hz–1 MHz:	the greater of -60 dBc or -60 dBm
1 MHz–4 MHz:	50 dBc
4 MHz–10 MHz:	-45 dBc

Arbitrary Waveforms (includes square, triangle, and ramp waveforms):

DAC Full-Scale:

into 50 Ω or 75 Ω :	0.16187 to 5.11875 volts
into open circuit:	0.32374 to 10.2375 volts

The output voltage corresponding to DAC full-scale can be adjusted, over the indicated 30 dB range, with resolution equivalent to steps of 0.01 dB.

DC Accuracy: 0.9% of setting.

add for each $^{\circ}\text{C}$ beyond $T_{cal} \pm 5$:	0.05% of setting
Add DC Offset (see below)	

Step Response (no filter) (typical)

Rise/Fall Time 10–90%:	17 nsec
Precursors/Overshoot:	<1%

Slew Rate (no filter) (typical)

into 50 Ω :	750 V/ μs
into open circuit:	1470 V/ μs

DC Offset:

Resolution: 12 bits including sign

Limit (of waveform + offset):

into 50 Ω or 75 Ω :

waveform peak(*) volts ≥ 1.02486 :	± 5.5 v
waveform peak(*) volts < 1.02486 :	± 1.1 v

into high impedance load:

waveform peak(*) volts ≥ 2.04972 :	± 11 v
waveform peak(*) volts < 2.04972 :	± 2.2 v

(*): As used in this table, "waveform peak volts" means the voltage corresponding to DAC full-scale.

Accuracy: 1% of setting + 0.2% of limit

Beyond $T_{cal} \pm 5^{\circ}\text{C}$, add 0.015% of limit per $^{\circ}\text{C}$.

Interface Characteristics

BNC Connector Functions

TTL levels, except for analog output

Outputs

- | | |
|---|--|
| “Output 50/75 Ohm” | - analog output 50 Ω or 75 Ω nominal; or open |
| “Marker Out”
(This output is parallel-terminated with 50 Ω nominal) | - marker bits stored with arbitrary waveforms
- reference frequency
- waveform clock
- a pulse indicating each waveform repetition
- a level change at the start and the end of each burst of waveform repetitions
- frequency change
- phase change |

Inputs

- | | |
|-------------------------|--|
| “Ref/Sample In” | - external reference frequency (40 MHz maximum)
- trigger source (i.e., the waveform clock) |
| “Start Arm In” | - start arm (enables waveform clock for a burst of waveform repetitions) |
| “Stop Trig/FSK/Gate In” | - waveform clock stop (causes the current waveform repetition to be the last, until another Start Arm)
- FSK Input
- waveform clock gate |

NOTE: High impedance pulled up to +5 V through 4.7 K Ω resistor. External source must be able to sink 1 Ma.

VXI ECLTrg Functions

Input Functions

- reference frequency in trigger source in (i.e. the waveform clock) start arm in (enables waveform clock)

Output Functions

- marker bits stored with arbitrary waveforms
- reference frequency
- waveform clock
- a pulse indicating each waveform repetition
- a level change at the start and the end of each burst of waveform repetitions
- frequency change
- phase change

VXI TTLTrg Functions

Input Functions

- trigger source (i.e., the waveform clock)
- waveform clock gate/FSK Input
- start arm (enables waveform clock)
- waveform clock stop (causes the current waveform repetition to be the last)
- sweep arm (starts sweep or frequency list)
- sweep trigger (go to next point in sweep or frequency list)

Output Functions

- none

Front Panel “Digital Port In” Connector

Connector Type:	25-pin D-type receptacle
Signal Lines:	16 data, ext clock, int clock
Logic Compatibility:	TTL
Functions:	<ul style="list-style-type: none">- data to DAC- download to segment memory- waveform select (Note 2)- phase modulation (8 bits)
Data Rate:	1M transfers/s typical

Local Bus

Bus Type:	ECL
Functions:	<ul style="list-style-type: none">- data to DAC- download to segment memory- waveform select (Note 2)- phase modulation (8 bits)- data pass-through
Data Rate (typical):	7Msa/s; 2M/s for phase modulation

VME Register Access

All hardware registers are mapped directly into VME A24 space, permitting advanced users to bypass the on-board uP. The manual documents a functional subset. While a waveform is running, waveform memory may not be loaded, but on-the-fly re-selection (Note 2) permits a new sequence to begin immediately upon completing the present sequence.

Note 2: “Waveform Select” Up to 128 waveforms (sequences) can be stored in memory, and then selected/re-selected on-the-fly by digital words arriving on the Local Bus (typ 7 Msa/s), the Faceplate Connector (typ 1 M/s), or the VME bus (typ 2 M/s).

General VXibus Characteristics

Size:	C
Slots:	1
Connectors:	P1, P2
Weight (kg):	1.9
Device Type:	Message-Based Servant
VXibus Revision Compliance:	1.3
Register Level Documentation:	Subset
SCPI Revision:	1991.0
Manufacturer Code:	4095 Decimal
Model Code:	418 Decimal
Slave:	A16/A24 D08/D16
Master:	A16/A24 D08/D16 (The HP E1445A can control the HP E1446A Summing Amplifier/DAC.)

Currents in Amps:

+5 V		+12 V		-12 V		+24 V		-24 V		-5.2 V		-2 V	
I _{PM}	I _{DM}	I _{PM}	I _{DM}	I _{PM}	I _{DM}	I _{PM}	I _{DM}	I _{PM}	I _{DM}	I _{PM}	I _{DM}	I _{PM}	I _{DM}
3.50	0.20	0.12	0.10	0.13	0.06	0.28	0.17	0.34	0.17	2.50	0.12	1.20	0.20

Average Watts/Slot:	40-44
dPressure (mm H2O):	0.5
Air Flow (liters/s):	3.5

Notes

Appendix B Useful Tables

Appendix Contents

The tables in this appendix contain information often referred to during HP E1445A programming. The tables in this appendix include:

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Example Program Listing

Table B-1. HP E1445A Example Program Listing

Program Type	Program Name	Language	Description
Introductory (Chapter 1)	SLFTST	HP BASIC, Visual BASIC, Visual C/ C++	E1445A Self Test.
	RSTCLS	"	Resetting and clearing the AFG.
	LRN	"	Power-on/reset configuration.
	ERRORCHK	"	Error checking program.
	RSTSINE	"	Sine wave output from reset settings.
Standard Functions (Chapter 2)	DCVOLTS	HP BASIC, Visual BASIC, Visual C/ C++	+5V DC voltage.
	SINEWAVE	"	1kHz, 5Vp sine wave.
	SQUWAVE	"	4V, 5 MHz square wave - 1V DC offset.
	TRIWAVE	"	200 point, 4V, 10 kHz triangle wave.
	OUTPLOAD	"	Sets AFG's output impedance and load.
	OUTPUNIT	"	Sets amplitude units to volts peak-to-peak.
PHS_MOD	"	Shifts sine wave phase from 0 to 180 degrees.	
Arbitrary Waveforms (Chapter 3)	ARBWAVE	HP BASIC, Visual BASIC, Visual C/ C++	Procedure for generating an arbitrary waveform.
	MULSEG	"	Arbitrary waveform with two segments.
	AFGGEN1	"	Ramp arbitrary waveform using the frequency1 generator.
	AFGGEN2	"	Ramp arbitrary waveform using the frequency2 generator.
	SIN_X	"	Sin(x)/x arbitrary waveform.
	SIN_D	"	Damped sine wave arbitrary waveform.
	CHARGE	"	Exponential charge/discharge waveform.
	SPIKES	"	Sine wave with spikes.
	SIN_R	"	1/2 wave rectified sine wave.
	NOISE	"	Pseudo-random noise.

Table B-1. HP E1445A Example Program Listing (continued)

Program Type	Program Name	Language	Description
Sweeping, Frequency Lists, Frequency-Shift Keying (Chapter 4)	SMPLSWP1	HP BASIC, Visual BASIC, Visual C/ C++	0 Hz to 1 MHz sweep using start and stop frequencies.
	LIST1	"	1 kHz, 10 kHz, 100 kHz, 1 MHz frequency list.
	SMPLSWP2	"	1 kHz to 21 kHz sweep using start and span frequencies.
	LISTDEF	"	Definite length arbitrary block frequency list
	LOG_SWP	"	Seven point logarithmic frequency sweep.
	SWP_PVST	"	Setting the sweep time.
	LIST_TME	"	Setting the time through a frequency list.
	SWP_ARB	"	Sweeping an arbitrary waveform.
	SWP_LEVEL	"	Sweep with output leveling.
	FSK1	"	Frequency-shift keying with the FSK In control source.
	FSK2	"	Frequency-shift keying with the TTLTrg control source.
FSK_ARB	"	Frequency-shift keying of an arbitrary waveform.	
Arming and Triggering (Chapter 5)	EXT_ARM	HP BASIC, Visual BASIC, Visual C/ C++	Arming the AFG with a signal applied to the Start Arm In BNC.
	BURST	"	5 cycle burst for each external arm.
	DIV_N	"	10 MHz using the frequency2 generator.
	LOCKSTEP	"	Triggering Two AFGs with a common trigger signal.
	STOPTRIG	"	Aborting a cycle count using stop triggers.
	GATE	"	Gating the output on and off.
	SWP_TRIG	"	Arming and triggering a sweep using group execute trigger.
	SWP_STEP	"	Arming and triggering a sweep.
LIST_STP	"	Arming and triggering a frequency list.	
Marker Outputs (Chapter 6)	MARKSEG1	HP BASIC, Visual BASIC, Visual C/ C++	Outputting marker pulses with selected amplitude points.
	MARKSEG2	"	Outputting a single marker pulse.
	MARKTRG	"	Outputting a marker pulse with each amplitude point.
	DRIFT	"	Two AFGs using the same reference osc.

Table B-1. HP E1445A Example Program Listing (continued)

Program Type	Program Name	Language	Description
High-Speed Data Transfer (Chapter 7)	SIGN_DAT	HP BASIC, Visual BASIC, Visual C/ C++	Downloads arbitrary waveform data as signed DAC codes.
	UNS_DAT	"	Downloads arbitrary waveform data as unsigned DAC codes.
	DACBLOK1	"	Downloads arbitrary waveform data as signed DAC codes in a definite length block
	DACBLOK2	"	Downloads arbitrary waveform data as unsigned DAC codes in an indefinite length block.
	COMBSIGN	"	Downloads waveform amplitude and marker data as signed DAC codes in a definite length block.
	COMBUNS	"	Downloads waveform amplitude and marker data as unsigned DAC codes in an indefinite length block.
	COMBSEQ	"	Downloads waveform amplitude and marker data as signed DAC codes in definite length blocks. Downloads the output sequence (including repetition count, marker, and segment address) in an indefinite length block.
	VXIDOWN	"	Downloads waveform amplitude and marker data over the VXIbus backplane.
	VXISRCE	"	Writes data directly to the DAC from the VXIbus backplane. (See also Appendix C.)
WAVSELF	"	Changes output waveform sequence by writing location of a sequence's base address to the Waveform Select Register.	
AFG Status (Chapter 9)	QSSG_RQS	HP BASIC, Visual C/ C++	Monitors conditions in the Questionable Signal Status Group.
	OSG_RQS	"	Monitors conditions in the Operation Status Group.
	ERRORCHK	"	Monitors programming errors using the Standard Event Status Group.
Register-Based Applications (Appendix C)	FREQ1REG	HP BASIC, Visual BASIC, Visual C/ C++	Changes the output frequency generated by the DDS (Direct-Digital-Synthesis) chip (Frequency1 generator) by writing directly to the registers.
	FREQ2REG	"	Changes the output frequency generated by the Divide-by-N chip (Frequency2 generator) by writing directly to the registers.
	PHASCHNG	"	Changes the signal phase by writing directly to the registers.
	WAVE_SEL	"	Changes the output waveform sequence by writing directly to the registers.
	VXISRCE	"	Writes data directly to the DAC from the VXIbus backplane.

Command Coupling Groups

Table B-2. HP E1445A Command Coupling Groups

Coupling Group	Commands
None	[SOURce:]LIST2:FORMat[:DATA] [SOURce:]LIST2:FREQuency:POINts? [SOURce:]MARKer:ECLTrg<n>:FEED [SOURce:]MARKer:ECLTrg<n>[STATe] [SOURce:]MARKer:FEED [SOURce:]MARKer:POLarity [SOURce:]MARKer[:STATe] [SOURce:]PM[:DEViation] [SOURce:]PM:UNIT[:ANGLE] [SOURce:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude]:UNIT[:VOLTage] STATus:OPC:INITiate STATus:OPERation:CONDition? STATus:OPERation:ENABle STATus:OPERation:EVENT?] STATus:OPERation:NTRansition STATus:OPERation:PTRansition STATus:QUEStionable:CONDition? STATus:QUEStionable:ENABle STATus:QUEStionable[:EVENT?] STATus:QUEStionable:NTRansition STATus:QUEStionable:PTRansition STATus:PRESet TRIGger[:START][:IMMEDIATE] TRIGger[:START]:SLOPe TRIGger:STOP[:IMMEDIATE] TRIGger:SWEep[:IMMEDIATE] VINStrument[:CONFigure]:LBUS[:MODE] VINStrument[:CONFigure]:LBUS[:MODE]:AUTO VINStrument[:CONFigure]:TEST:CONFigure VINStrument[:CONFigure]:TEST:DATA? VINStrument[:CONFigure]:VME[:MODE] VINStrument[:CONFigure]:VME:RECeive:ADDRes:DATA? VINStrument[:CONFigure]:VME:RECeive:ADDRes:READY? VINStrument:IDENTity?
Frequency	ARM:SWEep:COUNT ARM:SWEep:SOURce

Table B-2. HP E1445A Command Coupling Groups (continued)

Coupling Group	Commands
Frequency <i>(continued)</i>	[SOURce:]FREQuency[1]:CENTer [SOURce:]FREQuency[1][:CW]:FIXed] [SOURce:]FREQuency[1]:FSKey [SOURce:]FREQuency[1]:FSKey:SOURce [SOURce:]FREQuency[1]:MODE [SOURce:]FREQuency[1]:RANGe [SOURce:]FREQuency[1]:SPAN [SOURce:]FREQuency[1]:STARt [SOURce:]FREQuency[1]:STOP [SOURce:]FREQuency2[:CW]:FIXed] [SOURce:]LIST2:FREQuency [SOURce:]PM:SOURce [SOURce:]PM:STATe [SOURce:]ROSCillator:FREQuency:EXTernal [SOURce:]ROSCillator:SOURce [SOURce:]SWEep:COUNT [SOURce:]SWEep:DIRection [SOURce:]SWEep:POINts [SOURce:]SWEep:SPACing [SOURce:]SWEep:TIME TRIGger[:STARt]:GATE:POLarity TRIGger[:STARt]:GATE:SOURce TRIGger[:STARt]:GATE:STATe TRIGger[:STARt]:SOURce TRIGger:STOP:SLOPe TRIGger:STOP:SOURce TRIGger:SWEep:SOURce TRIGger:SWEep:TIMer
Voltage	OUTPut[1]:IMPedance OUTPut[1]:LOAD OUTPut[1]:LOAD:AUTO [SOURce:]RAMP:POLarity [SOURce:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude] [SOURce:]VOLTage[:LEVel][:IMMEDIATE]:OFFSet
Frequency & Voltage	[SOURce:]ARBitrary:DAC:SOURce [SOURce:]FUNctioN[:SHAPe] [SOURce:]RAMP:POINts
None	ABORt ARM[:STARt][:LAYer[1]]:COUNT ARM[:STARt]:LAYer2:COUNT

Table B-2. HP E1445A Command Coupling Groups (continued)

Coupling Group	Commands
None	<p>ARM[:START]:LAYer2[:IMMEDIATE]</p> <p>ARM[:START]:LAYer2:SLOPe</p> <p>ARM[:START]:LAYer2:SOURce</p> <p>ARM:SWEep[:IMMEDIATE]</p> <p>INITiate[:IMMEDIATE]</p> <p>OUTPut[1]:FILTer[:LPASs]:FREQuency</p> <p>OUTPut[1]:FILTer[:LPASs][:STATe]</p> <p>OUTPut[1][:STATe]</p> <p>[SOURce:]ARBitrary:DAC:FORMat</p> <p>[SOURce:]ARBitrary:DOWNload</p> <p>[SOURce:]ARBitrary:DOWNload:COMPLete</p> <p>[SOURce:]FUNctIon:USER</p> <p>[SOURce:]LIST[1]:FORMat[:DATA]</p> <p>[SOURce:]LIST[1][:SEGMENT]:ADDReSS?</p> <p>[SOURce:]LIST[1][:SEGMENT]:CATalog?</p> <p>[SOURce:]LIST[1][:SEGMENT]:COMBined</p> <p>[SOURce:]LIST[1][:SEGMENT]:COMBined:POINts?</p> <p>[SOURce:]LIST[1][:SEGMENT]:DEFine</p> <p>[SOURce:]LIST[1][:SEGMENT]:DELete:ALL</p> <p>[SOURce:]LIST[1][:SEGMENT]:DELete[:SELected]</p> <p>[SOURce:]LIST[1][:SEGMENT]:FREE?</p> <p>[SOURce:]LIST[1][:SEGMENT]:MARKer</p> <p>[SOURce:]LIST[1][:SEGMENT]:MARKer:POINts?</p> <p>[SOURce:]LIST[1][:SEGMENT]:MARKer:SPOint</p> <p>[SOURce:]LIST[1][:SEGMENT]:SELect</p> <p>[SOURce:]LIST[1][:SEGMENT]:VOLTage</p> <p>[SOURce:]LIST[1][:SEGMENT]:VOLTage:DAC</p> <p>[SOURce:]LIST[1][:SEGMENT]:VOLTage:POINts?</p> <p>[SOURce:]LIST[1]:SSEQuence:ADDReSS?</p> <p>[SOURce:]LIST[1]:SSEQuence:CATalog?</p> <p>[SOURce:]LIST[1]:SSEQuence:COMBined</p> <p>[SOURce:]LIST[1]:SSEQuence:COMBined:POINts?</p> <p>[SOURce:]LIST[1]:SSEQuence:DEFine</p> <p>[SOURce:]LIST[1]:SSEQuence:DELete:ALL</p> <p>[SOURce:]LIST[1]:SSEQuence:DELete[:SELected]</p> <p>[SOURce:]LIST[1]:SSEQuence:DWELL:COUNT</p> <p>[SOURce:]LIST[1]:SSEQuence:DWELL:COUNT:POINts?</p> <p>[SOURce:]LIST[1]:SSEQuence:FREE?</p> <p>[SOURce:]LIST[1]:SSEQuence:MARKer</p> <p>[SOURce:]LIST[1]:SSEQuence:MARKer:POINts?</p> <p>[SOURce:]LIST[1]:SSEQuence:MARKer:SPOint</p> <p>[SOURce:]LIST[1]:SSEQuence:SELect</p> <p>[SOURce:]LIST[1]:SSEQuence:SEQuence</p> <p>[SOURce:]LIST[1]:SSEQuence:SEQuence:SEGMENTS?</p>

Frequency Limits

Table B-3. HP E1445A Frequency Limits

Function	Trigger Start Source	Frequency	
		Low Limit	High Limit
DC	N/A	N/A	N/A
SINusoid	INTernal[1]	0 Hz	Ref Osc freq/4
SQUare	INTernal[1]*	0 Hz	Ref Osc freq/16
	INTernal2	Ref Osc freq/4/ 131072	Ref Osc freq/4
TRIangle	INTernal[1]*	0 Hz	Ref Osc freq/ 4/ Ramp Points
	INTernal2	Ref Osc freq/ 131072/ Ramp Points	Ref Osc freq/ Ramp Points
RAMP	INTernal[1]*	0 Hz	Ref Osc freq/ 4/ Ramp Points
	INTernal2	Ref Osc freq/ 131072/ Ramp Points	Ref Osc freq/ Ramp Points
USER	INTernal[1]*	0 Hz	Ref Osc freq/4
	INTernal2	Ref Osc freq/ 131072	Ref Osc freq

* Multiply High Limit frequency values by 2 if frequency doubling is selected by the [SOURCE:]FREQUENCY[1]:RANGE command.

Amplitude Limits

Table B-4. HP E1445A Amplitude Limits

Amplitude Limits for Volts*				
Function	V (volts)	VPK (volts peak)	VPP (volts peak-to-peak)	VRMS (volts rms)
DC	-5.12 to +5.11875	N/A	N/A	N/A
SINusoid	+ .161869088 to +5.11875	+ .161869088 to +5.11875	+ .323738175 to +10.2375	+ .114458730 to +3.61950284
SQUare	+ .161869088 to +5.11875	+ .161869088 to +5.11875	+ .323738175 to +10.2375	+ .161869088 to +5.11875
TRIangle	+ .161869088 to +5.11875	+ .161869088 to +5.11875	+ .323738175 to +10.2375	+ .0934551614 to +2.9553117
RAMP	+ .161869088 to +5.11875	+ .161869088 to +5.11875	+ .323738175 to +10.2375	+ .0934551614 to +2.9553117
USER	+ .161869088 to +5.11875	+ .161869088 to +5.11875	N/A	N/A

Amplitude Limits for Watts and dB**				
Function	W (Watt @50Ω load)	W (Watt @75Ω load)	DBM DBMW (dBmW @50Ω load)	DBM DBMW (dBmW @75Ω load)
DC	N/A	N/A	N/A	N/A
SINusoid	+ .000262016016 to +.262016016	+ .000174677344 to +.174677344	-5.81672162 to +24.1832784	-7.57763421 to +22.4223658
SQUare	+ .000524032031 to +.524032031	+ .000349354678 to +.349354678	-2.80642166 to +27.1935783	-4.56733425 to +25.4326657
TRIangle	+ .000174677344 to +.174677344	+ .000116451562 to +.116451562	-7.57763421 to +22.4223658	-9.33854680 to +20.6614532
RAMP	+ .000174677344 to +.174677344	+ .000116451562 to +.116451562	-7.57763421 to +22.4223658	-9.33854680 to +20.6614532

*Double the values for Open Circuit Loads selected by OUTPUT[1]:LOAD INFINITY.
 **Not available with OUTPUT[1]:LOAD INFINITY selected

Power-On/Reset Configuration

Table B-5. HP E1445A Power-On/Reset Configuration (as returned by *LRN?)

Parameter	Command	Power-on/Reset Setting
Macro usage	*EMC	+1
Calibration state	:CAL:STAT	1 (enabled)
AC calibration	:CAL:STAT:AC	1 (enabled)
DC calibration	:CAL:STAT:DC	1 (enabled)
DAC data source	:ARB:DAC:SOUR	INTernal
Phase modulation units	:PM:UNIT:ANGL	RADians
Waveform amplitude units	:VOLT:AMPL:UNIT:VOLT	V
Sample source	TRIG:SOUR	INTernal
Sample gate polarity	TRIG:GATE:POL	INVerted
Sample gate source	TRIG:GATE:SOUR	EXTernal
Gating State	TRIG:GATE:STAT	0 (off)
Output frequency	:FREQ:FIX	+1.000000000E+004
Frequency-shift keying (FSK) frequencies	:FREQ:FSK	+1.000000000E+004, +1.000000000E+007
FSK trigger source	:FREQ:FSK:SOUR	EXTernal
Frequency mode	:FREQ:MODE	FIXed
Frequency range	:FREQ:RANG	+0.000000000E+000
Sweep start frequency	:FREQ:STAR	+0.000000000E+000
Sweep stop frequency	:FREQ:STOP	+1.073741824E+007
Output frequency (divide-by-n generator)	:FREQ2:FIX	+1.000000000E+004
Reference oscillator source	:ROSC:SOUR	INTernal1
External oscillator frequency	FREQ:EXT	+4.294967296E+007
Sweep count	:SWE:COUN	+1.000000000E+000
Sweep direction	:SWE:DIR	UP
Sweep points	:SWE:POIN	+800

Table B-5. HP E1445A Power-On/Reset Configuration (continued)

Parameter	Command	Power-on/Reset Setting
Sweep spacing (points)	:SWE:SPAC	LINear
Sweep time	:SWE:TIME	+1.000000000E+000
Stop trigger source	TRIG:STOP:SOUR	HOLD
Sweep start source	ARM:SWE:SOUR	IMMediate
Sweep advance source	TRIG:SWE:SOUR	TIMer
Function	:FUNC:SHAP	SINusoid
Ramp/triangle waveform points	:RAMP:POIN	+100
Ramp/triangle waveform polarity	:RAMP:POL	NORMAl
Output amplitude	:VOLT:AMPL	+1.61869088E-001
DC offset	:VOLT:OFFS	+0.000000000E+000
Output impedance	OUTP:IMP	+5.000000000E+001
Output load	OUTP:LOAD	+5.000000000E+001
Load-Impedance coupling	OUTP:LOAD:AUTO	1 (on)
Waveform repetitions (burst)	ARM:COUN	+9.900000000E+037
Waveform arm count	ARM:LAY2:COUN	+1.000000000E+000
External arm slope	ARM:LAY2:SLOP	POS
Arm source	ARM:LAY2:SOUR	IMMediate
Arbitrary waveform sequence	:FUNC:USER	NONE
Segment/sequence return data format and length	:LIST:FORM	ASCii,+9
Frequency list return data format and length	:LIST2:FORM	ASCii,+10
ECL trigger line 0 marker source	:MARK:ECLT0:FEED	"ARM"
Marker routing (ECLT0 line)	:MARK:ECLT0:STAT	0 (off)
ECL trigger line 1 marker source	:MARK:ECLT1:FEED	"TRIG"
Marker routing (ECLT1 line)	:MARK:ECLT1:STAT	0 (off)
"Marker Out" BNC source	:MARK:FEED	"ARM"
"Marker Out" signal polarity	:MARK:POL	NORM

Table B-5. HP E1445A Power-On/Reset Configuration (continued)

Parameter	Command	Power-on/Reset Setting
"Marker Out" BNC state	:MARK:STAT	1 (on)
Output state	OUTP:STAT	1 (on)
Output filter frequency	:FILT:FREQ	+2.50000000E+005
Output filter state	:FILT:STAT	0 (off)
Phase modulation deviation	:PM:DEV	+0.00000000E+000
Phase modulation source	:PM:SOUR	INTernal
Phase modulation state	:PM:STAT	0 (off)
External waveform advance trigger slope	TRIG:SLOP	POS
External stop trigger slope	TRIG:STOP:SLOP	POS
Local bus mode	:VINS:LBUS:REC:MODE	OFF
Local bus automatic mode	:MODE:AUTO	1 (on)

Error Messages

Table B-6. HP E1445A Error Messages

Code	Message	Description
-101	Invalid character	Unrecognized character in parameter.
-102	Syntax error	Command is missing a space or comma between parameters.
-103	Invalid separator	Parameter is separated by a character other than a comma.
-104	Data type error	The wrong data type (number, character, string, expression) was used when specifying the parameter.
-108	Parameter not allowed	Parameter specified in a command which does not require one.
-109	Missing parameter	Command requires a parameter(s).
-112	Program mnemonic too long	Command keyword > 12 characters
-113	Undefined header	Command header (keyword) was incorrectly specified.
-121	Invalid character in number	A character other than a comma or number is in the middle of a number.
-123	Numeric overflow	A parameter value is greater than what can be represented with the number format.
-124	Too many digits	More than 256 digits were used to specify a number.
-128	Numeric data not allowed	A number was specified when a letter was required.
-131	Invalid suffix	Parameter suffix incorrectly specified (e.g. VO rather than VP).
-138	Suffix not allowed	Parameter suffix is specified when one is not allowed.
-141	Invalid character data	Discrete parameter specified is not a valid choice.
-144	Character data too long	A segment or sequence name is too long, or a discrete parameter is > 12 characters. Segment and sequence names must be 12 characters or less.
-148	Character data not allowed	Discrete parameter was specified when another type (e.g. numeric, boolean) is required.
-151	Invalid string data	The string data specified (e.g. for the SOUR:MARK:FEED <source> command is not a valid choice.
-158	String data not allowed	A string was specified when another parameter type (i.e. discrete, numeric, boolean) is required.

Table B-6. HP E1445A Error Messages (continued)

Code	Message	Description
-161	Invalid block data	The number of bytes in a definite length data block does not equal the number of bytes indicated by the block header.
-168	Block data not allowed	Block data was specified when another parameter type (i.e. discrete, numeric, boolean) is required.
-178	Expression data not allowed	The parameter was specified as an expression (e.g. SOUR:FREQ1:FIX (A*B).
-183	Invalid inside macro definition	Voltage or segment list is inside a macro.
-211	Trigger ignored	Trigger was received and the AFG was not in the wait-for-trigger state. Or, a trigger was received from a source other than the specified source.
-212	Arm ignored	Arm was received and the AFG was not in the wait-for-arm state. Or, an arm was received from a source other than the specified source.
-213	Init ignored	INITiate:IMMEDIATE received while the AFG was currently initiated.
-221	Settings conflict	See "Settings Conflict Error Messages" at the end of this table.
-222	Data out of range	Parameter value is out of range for any AFG configuration (e.g. SOUR:FREQ1:FIX 1E9).
-224	Illegal parameter value	The calibration security code required to disable calibration security does not match the stored code.
-241	Hardware missing	Command was intended for the HP E1446A which was not present, or is outside the servant area of the HP E1445A AFG.
-270	Macro error	*RMC <name> was executed and name is not defined.
-272	Macro execution error	Macro program data sequence could not be executed due to a syntax error within the macro definition.
-273	Illegal macro label	The macro label defined in the *DMC command was too long, the same as a common command keyword, or contained invalid header syntax.
-276	Macro recursion error	A macro program data sequence could not be executed because the sequence leads to the execution of a macro being defined.
-277	Macro redefinition not allowed	A macro label in the *DMC command could not be executed because the macro label was already defined.

Table B-6. HP E1445A Error Messages (continued)

Code	Message	Description
-312	PUD memory lost	The protected user data saved by the *PUD command has been lost.
-313	Calibration memory lost	The nonvolatile calibration data used by the *CAL command has been lost.
-330	Self-test failed	Note the information associated with the message for a description of the failure.
-350	Too many errors	The HP E1445A error queue is full and additional errors have occurred.
-410	Query INTERRUPTED	The HP E1445A was sent a command before it was finished responding to a query command.
-420	Query UNTERMINATED	The controller (computer) attempts to read a query response from the HP E1445A without having first sent a complete query command.
-430	Query DEADLOCKED	The HP E1445A's input and output buffers are full and the AFG cannot continue.
-440	Query UNTERMINATED after indefinite response	Occurs when the *IDN? query is not the last query executed in a command string.
+1000	Out of memory	The HP E1445A segment or sequence memory is full.
+1002	Calibration security enabled	Calibration security must be disabled to calibrate the HP E1445A, to read or write calibration data, to change the security code, or to change the protected user data.
+1004	Calibration write fail	Writing calibration or protected user data (*PUD) to nonvolatile memory failed.
+1005	Calibration constant out of range	Illegal calibration constant was computed.
+1006	Calibration constant conflict	Calibration constants used during calibration set an illegal condition.
+1007	Calibration security defeated	CALibration secure state disabled and detected at power-on.
+1011	Illegal while download enabled or testing local bus	Commands such as SOUR:LIST1 ... cannot be executed under current conditions. Execute SOUR:ARB:DOWN:COMP to disable downloading, or VINS:CONF:TEST:DATA?, to complete the local bus test.
+1012	Illegal when not downloading	SOUR:ARB:DOWN:COMP disables downloading only after it has previously been enabled.
+1013	Illegal when not testing local bus	VINS:CONF:TEST:DATA? was executed and the local bus test was not performed.
+1014	Illegal while initiated	Command cannot be executed while the HP E1445A is in the initiated (instrument action) state.

Table B-6. HP E1445A Error Messages (continued)

Code	Message	Description
+1015	Illegal when SOUR:ARB:DAC not INT	SOUR:LIST1 commands cannot be executed unless the DAC data source is internal.
+1016	Illegal when VIN:LBUS:MODE not CONS	The operating mode for the local bus is "off" and SOUR:ARB:DOWN is set to LBUS.
+1017	Illegal when SOUR:FUNC:SHAP RAMP SQU TRI set	The output function must be SINusoid when testing the local bus (VINS:CONF:TEST:CONF).
+1018	Illegal while calibrating	Commands cannot be sent to the HP E1445A while the device is calibrating.
+1019	Illegal while not calibrating	The command is only valid while the HP E1445A is calibrating.
+1020	Illegal while initiated and SOUR:PM:SOUR not INT	Frequency changes during phase modulation can only occur when SOUR:PM:SOUR is INTERNAL.
+1021	Test data byte count not even number	The length parameter for the command VINS:CONF:TEST:CONF is not an even number.
+1022	VXI data transfer bus not active	VINS:CONF:VME:REC:ADDR:DATA? is executed and A24 address space is not being written to.
+1100	Illegal segment name	Attempting to download to a segment that doesn't exist, or selecting a segment name that's the same as an existing sequence name.
+1101	Too many segment names	There are >256 segment names defined. Use SOUR:LIST1:SEGM:DEL:SEL to delete the current (selected) segment, or SOUR:LIST1:SEGM:DEL:ALL to delete all segments.
+1102	Segment in use	Trying to delete a segment that is within a sequence.
+1103	Segments exist	Trying to change the data format of a segment that already exists.
+1104	Segment lists of different lengths	The length of a segment's voltage list does not equal the length of its marker list and its marker list does not equal 1.
+1105	Segment list has zero length	Querying a voltage, marker, or dac code list that has no data.
+1106	Segment name not DEFINED	Trying to load segment memory and memory has not been reserved by the SOUR:LIST1:SEGM:DEF command.
+1107	Segment name already defined	Defining a segment and a segment by that name already exists.
+1108	No segment name SElected	Trying to load a segment that has not been selected.

Table B-6. HP E1445A Error Messages (continued)

Code	Message	Description
+1109	Segment list length less than minimum	Waveform segment has less than four points.
+1110	Illegal sequence name	Attempting to download to a sequence that doesn't exist, or selecting a sequence name that's the same as an existing segment name.
+1111	Too many sequence names	There are >256 sequence names defined. Use SOUR:LIST1:SSEQ:DEL:SEL to delete the current (selected) sequence, or SOUR:LIST1:SSEQ:DEL:ALL to delete all sequences.
+1112	Sequence in use	Trying to delete a sequence currently selected by SOUR:FUNC:USER.
+1113	Sequence contains zero-length segment	Segment contains no voltage or dac code data.
+1114	Sequence lists of different lengths	The length of a sequence's segment list does not equal the length of its marker list and its marker list does not equal 1.
+1115	Sequence list has zero length	Query of a marker list, dwell count list, or sequence segment list and no data is in the list. Also occurs following INIT:IMM or SOUR:FUNC:USER when no segments are in the sequence list.
+1116	Sequence name not DEFINed	Trying to define an ordered sequence of waveform segments and sequence memory has not been reserved with the SOUR:LIST1:SSEQ:DEF command.
+1117	Sequence name already defined	Defining a sequence and a sequence by that name already exists.
+1118	No sequence name SElected	SOUR:LIST1:SSEQ subsystem command executed without a segment sequence first selected by SOUR:LIST1:SSEQ:SEL.
+1121	Frequency list has zero length	SOUR:FREQ1:MODE LIST is set and no frequency list exists.
+1122	Frequency list length less than minimum	Frequency list has less than two frequencies.

Settings Conflict Error Messages

Table B-7. HP E1445A Settings Conflict Error Messages

Settings Conflict Error Messages
SOUR:FREQ1:FIX frequency < minimum; SOUR:FREQ1:FIX MIN set
SOUR:FREQ1:FIX frequency > maximum; SOUR:FREQ1:FIX MAX set
SOUR:FREQ2:FIX frequency < minimum; SOUR:FREQ2:FIX MIN set
SOUR:FREQ2:FIX frequency > maximum; SOUR:FREQ2:FIX MAX set
SOUR:FREQ1:RANG frequency > maximum; SOUR:FREQ1:RANG MAX set
TRIG:STAR:GATE:SOUR EXT and SOUR:FREQ1:FSK:SOUR EXT; TRIG:STAR:GATE:STAT OFF set
TRIG:STAR:GATE:SOUR TTLT<n> and SOUR:FREQ1:FSK:SOUR TTLT<n>; TRIG:STAR:GATE:STAT OFF set
SOUR:FREQ1:FSK frequency < minimum; SOUR:FREQ1:FSK MIN set
SOUR:FREQ1:FSK frequency > maximum; SOUR:FREQ1:FSK MAX set
TRIG:STAR:SOUR and SOUR:ROSC:SOUR both EXT; SOUR:ROSC:SOUR INT1 set
TRIG:STAR:SOUR and TRIG:STOP:SOUR both BUS; TRIG:STOP:SOUR HOLD set
TRIG:STOP:SOUR EXT and TRIG:STAR:GATE:SOUR EXT; TRIG:STOP:SOUR HOLD set
TRIG:STOP:SOUR EXT and SOUR:FREQ1:FSK:SOUR EXT; TRIG:STOP:SOUR HOLD set
OUTP:LOAD not equal to OUTP:IMP or INF; OUTP:LOAD set to OUTP:IMP value
SOUR:FUNC:SHAP DC and INIT; INIT ignored
SOUR:ARB:DAC:SOUR not INT and INIT; INIT ignored
Frequency list value out of range; SOUR:FREQ1:MODE FIX set
SOUR:FREQ1:MODE LIST and no frequency list defined; SOUR:FREQ1:MODE FIX set
SOUR:VOLT+SOUR:VOLT:OFFS < minimum; SOUR:VOLT:OFFS MIN set
SOUR:VOLT+SOUR:VOLT:OFFS > maximum; SOUR:VOLT:OFFS MAX set
SOUR2:VOLT:OFFS < minimum; SOUR2:VOLT:OFFS MIN set

Table B-7. HP E1445A Settings Conflict Error Messages (continued)

Settings Conflict Error Messages
SOUR2:VOLT:OFFS > maximum; SOUR2:VOLT:OFFS MAX set
SOUR:FUNC:SHAP SIN and TRIG:STAR:SOUR not INT1; TRIG:STAR:SOUR INT1 set
SOUR:FREQ1:START > SOUR:FREQ1:STOP; values exchanged
SOUR:FREQ1:STAR frequency < minimum; SOUR:FREQ1:STAR MIN set
SOUR:FREQ1:STAR frequency > maximum; SOUR:FREQ1:STAR MAX set
SOUR:FREQ1:STOP frequency < minimum; SOUR:FREQ1:STOP MIN set
SOUR:FREQ1:STOP frequency > maximum; SOUR:FREQ1:STOP MAX set
ARM:SWE:SOUR TTLT<n> and TRIG:SWE:SOUR TTLT<n>; ARM:SWE:SOUR IMM set
SWE:TIME < minimum; SWE:TIME MIN set
SWE:TIME > maximum; SWE:TIME MAX set
TRIG:SWE:TIM < minimum; TRIG:SWE:TIM MIN set
TRIG:SWE:TIM > maximum; TRIG:SWE:TIM MAX set
SOUR:FUNC:SHAP not SIN and SOUR:PM:STAT ON; SOUR:PM:STAT OFF set
SOUR:FUNC:MODE LIST SWE and SOUR:PM:SOUR not INT; SOUR:PM:SOUR INT set
SOUR:VOLT voltage < minimum; SOUR:VOLT MIN set
SOUR:VOLT voltage > maximum; SOUR:VOLT MAX set
SOUR:FUNC:SHAP not DC and SOUR:VOLT voltage < 0.0V: absolute value of SOUR:VOLT set
OUTP:LOAD INF and current SOUR:VOLT unit W, DBM, OR DBMW: SOUR:VOLT:AMPL MIN (in V) set
SOUR:ARB:DAC:SOUR not INT or SOUR:FUNC:SHAP USER and current SOUR:VOLT unit not V/VPK: SOUR:VOLT:AMPL MIN (in V) set
SOUR:FUNC:SHAP DC and current SOUR:VOLT unit not V: SOUR:VOLT value converted to volts

Table B-7. HP E1445A Settings Conflict Error Messages (continued)

Settings Conflict Error Messages (when HP E1445A is used with the HP E1446A Amplifier)
OUTP2:ATT 20 and OUTP2:IMP 0; OUTP2:IMP 50 set
SOUR2:VOLT:OFFS < minimum; SOUR2:VOLT:OFFS MIN set
SOUR2:VOLT:OFFS > maximum; SOUR2:VOLT:OFFS MAX set

Appendix C

Register-Based Programming

Appendix Contents

The HP E1445A Arbitrary Function Generator (AFG) is a message-based device. As such, it supports the VXI word-serial protocol used to transfer ASCII command strings and is capable of converting the SCPI commands it receives to reads and writes of its hardware registers.

Register-based programming allows the user to access the hardware registers directly. This increases the speed at which events in the AFG occur since the parsing (converting) of SCPI commands is eliminated. In addition to describing how to access selected AFG registers, this appendix explains how to do the following functions with register reads and writes:

- Accessing the Registers Page 484
 - Determining the A24 Base Address Page 484
- Changing the Output Frequency Page 487
 - The Frequency Control Registers Page 487
 - Frequency Control Programs Page 489
- Changing the Signal Phase. Page 495
 - The Phase Control Registers Page 495
 - Phase Control Program Page 496
- Selecting the Waveform Sequence Page 498
 - The Waveform Sequence Registers Page 498
 - Waveform Sequence Selection Program Page 500
- Loading the DAC from the VXIbus Page 506

This appendix does not identify all of the AFG registers nor does it cover all of the AFG functions from the register-based programming standpoint.

System Configuration

The example programs and programming techniques shown in this appendix are based on the following system configuration:

Mainframe:	HP 75000 Series C (HP E1401)
Controller:	HP E1480A V/360 (select code 16)
Programming Language:	HP BASIC/UX (6.0)
HP E1445A AFG:	Logical address = 80

Each program uses a combination of SCPI commands and register reads/writes. In most cases, SCPI commands set up the AFG and initiate the waveform. Register reads/writes are used to change the frequency, phase, waveform, etc., instantaneously.

Accessing the Registers

Access to the AFG's operational registers is through addresses mapped into A24 address space. At power-on, the system resource manager reads the AFG's Device Type Register (in A16 address space) to determine the amount of A24 memory the AFG requires. Once known, the resource manager allocates a block of A24 memory to the AFG and writes the base (starting) address into the AFG's Offset Register.

Determining the A24 Base Address

When you are reading or writing to an AFG register, a hexadecimal or decimal register address is specified. The register address is the sum of:

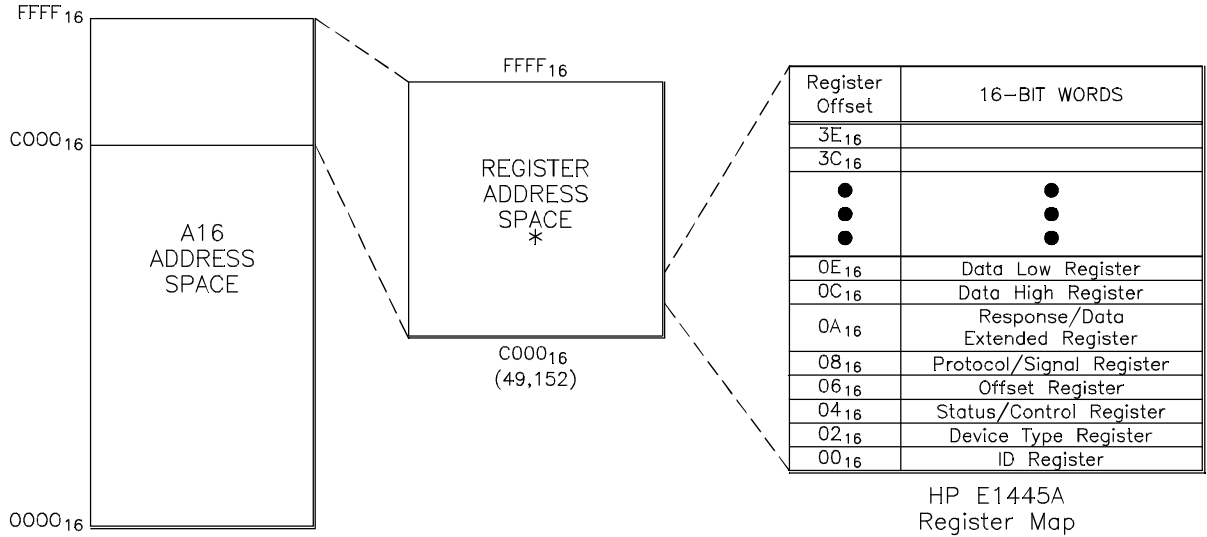
$$\text{A24 base address} + \text{register number}$$

The base address of the AFG operational registers in A24 address space is determined by reading the AFG's Offset Register and multiplying the value by 256 (100_{16}). This converts the 16-bit value of the Offset Register to a 24-bit address.

The register number is identified in the register descriptions found in the following sections.

Reading the AFG's Offset Register

As shown in Figure C-1, the AFG's configuration registers are mapped into the upper 25% of A16 address space. The Offset Register is one of the AFG's configuration registers.

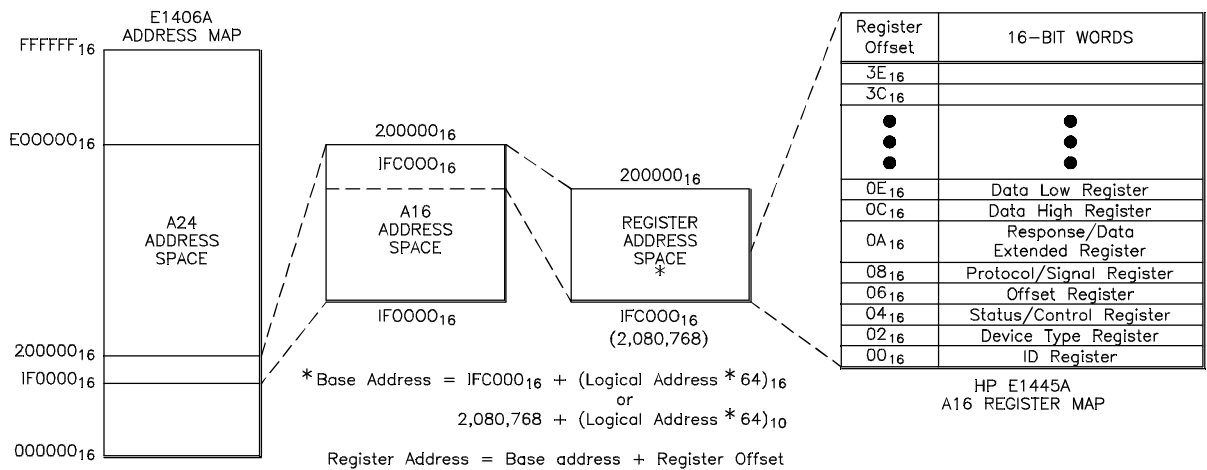


$$* \text{Base Address} = \text{C000}_{16} + (\text{Logical Address} * 64)_{16}$$

or

$$49,152 + (\text{Logical Address} * 64)_{10}$$

$$\text{Register Address} = \text{Base address} + \text{Register Offset}$$



$$* \text{Base Address} = \text{IFC000}_{16} + (\text{Logical Address} * 64)_{16}$$

or

$$2,080,768 + (\text{Logical Address} * 64)_{10}$$

$$\text{Register Address} = \text{Base address} + \text{Register Offset}$$

Figure C-1. HP E1445A AFG Registers within A16 Address Space

In a system using a V/360 (HP E1480) controller, for example, the base address of the configuration registers is computed as:

$$C000_{16} + (LADDR * 64)_{16}$$

or

$$49,152 + (LADDR * 64)$$

where $C000_{16}$ (49,152) is the starting location of the register addresses, LADDR is the AFG's logical address, and 64 is the number of address bytes in A16 per VXI device.

The AFG's factory set logical address is 80. If this address is not changed, the base address of the AFG's configuration registers in A16 is:

$$C000_{16} + (80 * 64)_{16}$$

$$C000_{16} + 1400_{16} = \mathbf{D400}_{16}$$

or (decimal)

$$49,152 + (80 * 64)$$

$$49,152 + 5120 = \mathbf{54,272}$$

Given the base address and number of the Offset Register (06 in Figure C-1), the base address of the operational registers in A24 can be determined as in the following program.

Reading the Offset Register

```
10   ASSIGN @Afg to 1680 !Path from V/360 to AFG via VXI backplane
20   COM @Afg,Base_addr
30   CALL A24_offset
40   END
50   !
60   SUB A24_offset
70 A24_offset: !Subprogram which determines the base address for
80             !the AFG registers in A24 address space.
90   COM @Afg,Base_addr
100  CONTROL 16,25;2 !access A16 space with READIO and WRITEIO
110  A16_addr=DVAL("D400",16) !convert A16 base address to decimal number
120  Offset=READIO(-16,A16_addr+6) !read AFG offset register
130  Base_addr=Offset*256 !multiply offset for 24-bit address
140  SUBEND
```

As mentioned, multiplying the value of the Offset Register by 256 (or 100_{16}) converts the 16-bit register value to a 24-bit address.

Changing the Output Frequency

This section explains how the frequency of the output signal is changed instantaneously by writing frequency codes to the appropriate registers. The section shows how to change the frequency when either the direct-digital-synthesis ([SOURCE:FREQUENCY1]) or divide-by-n ([SOURCE:FREQUENCY2]) frequency synthesis method is used.

The Frequency Control Registers

The following Frequency Control Registers are used to change the output frequency generated with the direct-digital-synthesis (DDS) and divide-by-n methods:

- Phase Increment Registers (DDS):

$\text{base_addr} + A7_{16}$ through $\text{base_addr} + A1_{16}$

- Frequency Load Strobe Register (DDS):

$\text{base_addr} + 8D_{16}$

- Sample/Hold and ROSC/N Control Register (DIV N):

$\text{base_addr} + 63_{16}$

- ROSC/N Divider Registers (DIV N):

$\text{base_addr} + 7D_{16}$ through $\text{base_addr} + 7F_{16}$

The Phase Increment Registers

Phase Increment Registers A7, A5, A3, and A1 contain the 32-bit phase increment data that is written to the DDS micro-chip. The phase increment value determines the output frequency.

Address	15–8	7	6	5	4	3	2	1	0
$\text{base} + A7_{16}$ through $\text{base} + A1_{16}$	unused	frequency value							

Register A7: Bits 31–24 of the phase increment value. These are the most significant bits (MSBs).

Register A5: Bits 23–16 of the phase increment value.

Register A3: Bits 15–8 of the phase increment value.

Register A1: Bits 7–0 of the phase increment value. These are the least significant bits (LSBs).

The Frequency Load Strobe Register

Writing any value to the Frequency Load Strobe Register loads the contents of the Phase Increment Registers into the DDS micro-chip.

Address	15–8	7	6	5	4	3	2	1	0
base + 8D ₁₆	unused	Strobe Data							

Strobe Data: Writing any value to this register loads the contents of the Phase Increment Registers into the DDS micro-chip. Once the data has been loaded, it takes 20 reference oscillator clock cycles for the new frequency to appear at the output.

The Sample/Hold and ROSC/N Control Register

The Sample/Hold and ROSC/N Control Register enables and disables signal sampling, and specifies the N value used to generate ROSC/N frequencies.

Address	15–8	7	6	5	4	3	2	1	0
base + 63 ₁₆	unused	SHOLD					SMUX2	SMUX1	SMUX0

SHOLD: Setting bit 7 to a '1' causes sample signals to be ignored. This bit is set while setting the divide-by-n counter.

SMUX2–SMUX0: bits 2–0 select N as follows:

- 0 0 0 = selects ROSC/1
- 0 0 1 = selects ROSC/2
- 0 1 0 = selects ROSC/3
- 0 1 1 = selects ROSC/2N

The ROSC/N Divider Registers

The ROSC/N Divider Registers contain the value of (N-1) when 2N is greater than or equal to 4. The reference oscillator (ROSC) will be divided by 4 through 131,072 when the registers are loaded with 1 through 65,535.

Address	15–8	7	6	5	4	3	2	1	0
base + 7D ₁₆ through base + 7F ₁₆	unused	value							

Register 7D: Contains the most significant byte of the value of (N-1).

Register 7F: Contains the least significant byte of the value of (N-1).

Frequency Control Programs

The following programs demonstrate how to change the signal frequency while the waveform is currently at the AFG output.

DDS Frequency Control

The `FREQ_REG` program changes the signal frequency that is generated using the DDS (`[SOURCE:FREQ[1]]`) subsystem and the reference oscillator from any of the available sources. The program accesses the Phase Increment and Frequency Load Strobe Registers.

HP BASIC Program Example (`FREQ1_REG`)

```
1  !RE-STORE "FREQ1_REG"
2  !This program changes the output frequency generated by the direct-
3  !digital-synthesis (DDS) method by writing frequency-value data to
4  !the AFG's Phase Increment registers.
5  !
10  ASSIGN @Afg TO 1680
20  COM @Afg,Base_addr
30  !
40  !Call the subprograms which reset the AFG, which determine the base
50  !address of the AFG registers in A24 address space, and which set the
60  !output function.
70  CALL Rst
80  CALL A24_offset
90  CALL Output_function
100 !
110 DISP "Press 'Continue' to change frequency (register writes)"
120 PAUSE
130 DISP ""
140 !Call the subprogram which changes the output frequency, and pass the
150 !frequency, the number of waveform points, the reference oscillator
160 !frequency, and the frequency range (SOURCE:FREQ1:RANGE command).
170 !(Note: sine waves and arb waves: npts=1, square waves: npts=4,
180 !ramp/triangle waves: npts=RAMP:POINTS value.)
190 !
200 CALL Freq_change(2000.,1,4.294967296E+7,0)
210 END
220 !
230 SUB A24_offset
240 A24_offset: !Subprogram which determines the base address for
250             !the AFG registers in A24 address space.
260             COM @Afg,Base_addr
270             CONTROL 16,25;2!access A16 space with READIO and WRITEIO
280             A16_addr=DVAL("D400",16)             !AFG A16 base address
290             Offset=READIO(-16,A16_addr+6)         !read AFG offset register
300             Base_addr=Offset*256 !shift offset for 24-bit address
310 SUBEND
320 !
330 SUB Output_function
```

Continued on Next Page

```

340 Output_function:    !Subprogram which uses SCPI commands to set the
350                    !42.94967296 MHz reference oscillator, to set DDS
360                    !frequency synthesis, to set the output frequency/
370                    !function/amplitude, and to start the waveform.
380    COM @Afg,Base_addr
390    OUTPUT @Afg;"SOUR:ROSC:SOUR INT1;"; !reference oscillator (42 MHz)
400    OUTPUT @Afg;".TRIG:STAR:SOUR INT1;"; !frequency1 generator
410    OUTPUT @Afg;".SOUR:FREQ1:FIX 1E3;"; !frequency
420    OUTPUT @Afg;".SOUR:FUNC:SHAP SIN;"; !function
430    OUTPUT @Afg;".SOUR:VOLT:LEV:IMM:AMPL 5V" !amplitude
440    OUTPUT @Afg;"INIT:IMM" !wait_for_arm state
450    OUTPUT @Afg;"STAT:OPC:INIT OFF;*OPC?" !wait for INIT to complete
460    ENTER @Afg;Complete
470    SUBEND
480    !
490    SUB Freq_change(Freq,Npts,Reference_osc,Range)
500 Freq_change: !Subprogram which changes the output frequency by writing
510             !the frequency to registers on the AFG.
520    COM @Afg,Base_addr
530    CONTROL 16,25;3!access A24 space with READIO and WRITEIO
540    !
550    !Calculate frequency value written to registers
560    IF Range>0 THEN
570    Phase$=DVAL$((Freq*Npts/Reference_osc/2)*4.294967296E+9,16)
580    ELSE
590    Phase$=DVAL$((Freq*Npts/Reference_osc)*4.294967296E+9,16)
600    END IF
610    !
620    !Write the first byte of the frequency value to register A7, the
630    !second byte to register A5, the third byte to register A3, and the
640    !fourth byte to register A1.
650    WRITEIO -16,Base_addr+IVAL("A7",16);IVAL(Phase$[1;2],16)
660    WRITEIO -16,Base_addr+IVAL("A5",16);IVAL(Phase$[3;2],16)
670    WRITEIO -16,Base_addr+IVAL("A3",16);IVAL(Phase$[5;2],16)
680    WRITEIO -16,Base_addr+IVAL("A1",16);IVAL(Phase$[7;2],16)
690    !
700    !Generate the pulse which loads the new frequency. Once the pulse is
710    !received, it takes 20 reference oscillator clock cycles before the
720    !new frequency appears at the output.
730    WRITEIO -16,Base_addr+IVAL("8D",16);0
740    SUBEND
750    !
760    SUB Rst
770 Rst: !Subprogram which resets the E1445.
780    COM @Afg,Base_addr
790    OUTPUT @Afg;"*RST;*OPC?" !reset the AFG
800    ENTER @Afg;Complete
810    SUBEND

```

Comments

- To simplify the program, SCPI commands are included to select the reference oscillator, the DDS subsystem, and to start the waveform. This requires that the only registers written to be the Phase Increment and Frequency Load Strobe Registers. This program executes as intended when the SCPI commands in subprogram Output_function are executed before the registers are written to.
- The subprogram Output_function sets the initial reference oscillator frequency to 42.94967296 MHz. If a different reference oscillator frequency is used (that is, 40 MHz or an externally supplied oscillator), specify that frequency when the Freq_change subprogram is called (line 200).
- If frequency doubling is in effect (SOUR:FREQ1:RANG command in subprogram Output_function), the doubled frequency can be changed to another doubled frequency by passing a number other than 0 as the fourth parameter to the Freq_change subprogram (line 200).
- Note the following when specifying the number of waveform points (Npts value passed to the Freq_change subprogram): sine waves and arbitrary waveforms, Npts = 1; square waves, Npts = 4; ramp and triangle waves, Npts = RAMP:POINTs value.

Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, FREQ1REG.FRM, is in directory “VBPROG” and the Visual C example program, FREQ1REG.C, is in directory “VCPROG” on the CD that came with your HP E1445A.

Divide-by-N Frequency Control

The `FREQ2_REG` program changes the signal frequency that is generated using the Divide-by-N ([SOURCE:]FREQUENCY2) subsystem and the reference oscillator from any of the available sources. The program accesses the Sample/Hold and ROSC/N Control Register, and the ROSC/N Divider Registers.

HP BASIC Program Example (FREQ2_REG)

```
1  !RE-STORE "FREQ2_REG"
2  !This program changes the output frequency generated with the
3  !divide-by-n frequency synthesis method by writing frequency
4  !data to the Sample/Hold and ROSC/N Control register, and to the
5  !ROSC/N Divider registers.
6  !
10  ASSIGN @Afg TO 1680
20  COM @Afg,Base_addr
30  !
40  !Call the subprograms which reset the AFG, which determine the base
50  !address of the AFG registers in A24 address space, and which set
60  !the output function.
70  CALL Rst
80  CALL A24_offset
90  CALL Output_function
100 !
110 DISP "Press 'Continue' to change frequency (register writes)"
120 PAUSE
130 DISP ""
140 !Call the subprogram which changes the output frequency. Pass the
150 !reference oscillator frequency, the new output frequency, and
160 !the number of waveform points. (Note arbitrary waveforms: npts=1
170 !square waves: npts=4, ramp/triangle waves:
180 !npts=RAMP:POINTS value.)
190 !
200 CALL Divide_by_n(4.E+7,2.5E+6,4)
210 END
220 !
230 SUB A24_offset
240 A24_offset: !Subprogram which determines the base address for
250             !the AFG registers in A24 address space.
260             COM @Afg,Base_addr
270             CONTROL 16,25;2             !access A16 space with READIO and WRITEIO
280             A16_addr=DVAL("D400",16)   !AFG A16 base address
290             Offset=READIO(-16,A16_addr+6) !read AFG offset register
300             Base_addr=Offset*256       !shift offset for 24-bit address
310 SUBEND
320 !
330 SUB Output_function
```

Continued on Next Page


```

340 Output_function:      !Subprogram which uses SCPI commands to set the
350                      !40 MHz reference oscillator, to set divide-by-n
360                      !frequency synthesis, to set the output frequency/
370                      !function/amplitude, and to start the waveform.
380      COM @Afg,Base_addr
390      OUTPUT @Afg;"SOUR:ROSC:SOUR INT2;";          !reference oscillator (40 MHz)
400      OUTPUT @Afg;".TRIG:STAR:SOUR INT2;";        !frequency generator
410      OUTPUT @Afg;".SOUR:FREQ2:FIX 1E6;";         !frequency
420      OUTPUT @Afg;".SOUR:FUNC:SHAP SQU;";         !function
430      OUTPUT @Afg;".SOUR:VOLT:LEV:IMM:AMPL 5V"    !amplitude
440      OUTPUT @Afg;"INIT:IMM"                      !wait-for-arm state
450      OUTPUT @Afg;"STAT:OPC:INIT OFF;*OPC?"      !wait for INIT to complete
460      ENTER @Afg;Complete
470      SUBEND
480      !
490      SUB Divide_by_n(Reference_osc,Frequency,Points)
500 Divide_by_n:      !Subprogram which changes the output frequency by writing
510                      !to the register which controls divide-by-n frequency
520                      !synthesis.
530      COM @Afg,Base_addr
540      INTEGER Divider
550      CONTROL 16,25;3                               !access A24 space with READIO and WRITEIO
560      !
570      !Read register 63. Write to register 63 setting the SHOLD bit (bit 7)
580      !so sample signals are ignored.
590      Sample_hold=READIO(-16,Base_addr+IVAL("63",16))
600      Sample_hold=BINIOR(Sample_hold,128)          !set bit 7
610      WRITEIO -16,Base_addr+IVAL("63",16);Sample_hold
620      !
630      !Set the reference oscillator divider based on the new frequency.
640      !Also load the new divider value if n is greater than 3.
650      Divider=Reference_osc/Frequency/Points
660      SELECT Divider
670      CASE 1
680          Sample_hold=BINAND(Sample_hold,248)+0
690      CASE 2
700          Sample_hold=BINAND(Sample_hold,248)+1
710      CASE 3
720          Sample_hold=BINAND(Sample_hold,248)+2
730      CASE ELSE
740          Sample_hold=BINAND(Sample_hold,248)+3
750          Divider=Divider/2-1
760          WRITEIO -16,Base_addr+IVAL("7D",16);SHIFT(Divider,8)
770          WRITEIO -16,Base_addr+IVAL("7F",16);BINAND(Divider,255)
780      END SELECT
790      !
800      WRITEIO -16,Base_addr+IVAL("63",16);Sample_hold
810      !
820      !Clear sample/hold bit which activates new frequency

```

Continued on Next Page

```

830     WRITEIO -16,Base_addr+IVAL("63",16);BINAND(Sample_hold,127)
840     SUBEND
850     !
860     SUB Rst
870 Rst: !Subprogram which resets the E1445.
880     COM @Afg,Base_addr
890     OUTPUT @Afg;"*RST;*OPC?"      !reset the AFG
900     ENTER @Afg;Complete
910     SUBEND

```

Comments

- To simplify the program, SCPI commands are included to select the reference oscillator, the divide-by-n subsystem and to start the waveform. This requires that the only registers written to be the Sample/Hold and ROOSC/N Control Register, and the ROOSC/N Divider Registers. This program executes as intended when the SCPI commands in subprogram Output_function are executed before the registers are written to.
- The subprogram Output_function sets the initial reference oscillator frequency to 40 MHz. If a different reference oscillator frequency is used (that is, 42.94967296 MHz or an externally supplied oscillator), specify that frequency when the Divide_by_n subprogram is called (line 200).
- Standard function sine waves are not available with the divide-by-n subsystem ([SOURce:]FREQuency2). Frequency doubling should not be used with the divide-by-n subsystem.

Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, `FREQ2REG.FRM`, is in directory “VBPROG” and the Visual C example program, `FREQ2REG.C`, is in directory “VCPROG” on the CD that came with your HP E1445A.

Changing the Signal Phase

This section explains how the phase of a sine wave generated by the DDS ([SOURCE:|FREQUENCY[1]) subsystem is changed by writing phase data to the Phase Modulation Registers.

The Phase Control Registers

The following phase control registers are used to change the phase of the sine wave generated by the DDS subsystem:

- Phase Modulation Registers:

$\text{base_addr} + B3_{16}$ through $\text{base_addr} + B1_{16}$

- Phase Load Strobe Register:

$\text{base_addr} + 8B_{16}$

The Phase Modulation Registers

Phase Modulation Registers B3 and B1 contain the 12-bit phase modulation data that is added to the output of the phase accumulator.

Address	15–8	7	6	5	4	3	2	1	0
$\text{base} + B3_{16}$ through $\text{base} + B1_{16}$	unused	Phase modulation value							

Register B3: This register contains the eight most significant bits of the 12-bit phase modulation value (bits 11–4).

Register B1: Bits 7–4 of this register are the four least significant bits of the 12-bit phase modulation value (bits 3–0). Bits 3–0 of register B1 are ignored.

The Phase Load Strobe Register

Writing any value to the Phase Load Strobe Register adds the data in the Phase Modulation Registers to the output of the phase accumulator.

Address	15–8	7	6	5	4	3	2	1	0
$\text{base} + 8B_{16}$	unused	Strobe Data							

Strobe Data: Writing any value to this register adds the data in the Phase Modulation Registers to the output of the phase accumulator. Once the phase has been added, it takes 14 reference oscillator clock cycles for the new phase to appear at the output.

Phase Control Program The PHAS_CHNG program demonstrates how to change the sine wave signal phase while the waveform is currently at the AFG output.

HP BASIC Program Example (PHAS_CHNG)

```

1   !RE-STORE "PHAS_CHNG"
2   !This program changes the phase of the output signal by writing
3   !phase offset data to the phase modulation registers.
4   !
10  ASSIGN @Afg TO 1680
20  COM @Afg,Base_addr
30  !
40  !Call the subprograms which reset the AFG, which determine the base
50  !address of the AFG registers in A24 address space, and which set the
60  !output function.
70  CALL Rst
80  CALL A24_offset
90  CALL Output_function
100 !
110 DISP "Press 'Continue' to change the signal phase (register writes)"
120 PAUSE
130 DISP ""
140 !Call the subprogram which changes the signal phase, and pass the new
150 !phase value.
160 !
170 CALL Phase_change(180)
180 END
190 !
200 SUB A24_offset
210 A24_offset: !Subprogram which determines the base address for
220             !the AFG registers in A24 address space.
230     COM @Afg,Base_addr
240     CONTROL 16,25;2             !access A16 space with READIO and WRITEIO
250     A16_addr=DVAL("D400",16)   !AFG A16 base address
260     Offset=READIO(-16,A16_addr+6) !read AFG offset register
270     Base_addr=Offset*256        !shift offset for 24-bit address
280 SUBEND
290 !
300 SUB Output_function
310 Output_function: !Subprogram which uses SCPI commands to set DDS
320                 !frequency synthesis, to set the output frequency/
330                 !function/amplitude, to set up phase modulation, and
340                 !to start the waveform.
350     COM @Afg,Base_addr
360     OUTPUT @Afg;"TRIG:STAR:SOUR INT1;";             !frequency generator
370     OUTPUT @Afg;":SOUR:FREQ1:FIX 60;";             !frequency
380     OUTPUT @Afg;":SOUR:PM:SOUR INT;";             !phase modulation source
390     OUTPUT @Afg;":SOUR:PM:STAT ON;";             !enable phase modulation
400     OUTPUT @Afg;":SOUR:FUNC:SHAP SIN;";           !function

```

Continued on Next Page

```

410     OUTPUT @Afg;"SOUR:VOLT:LEV:IMM:AMPL 5V" !amplitude
420     OUTPUT @Afg;"SOUR:PM:DEV 0DEG"           !phase modulation angle
430     OUTPUT @Afg;"INIT:IMM"                   !wait_for_arm state
440     OUTPUT @Afg;"STAT:OPC:INIT OFF;*OPC?"    !wait for INIT to complete
450     ENTER @Afg;Complete
460 SUBEND
470 !
480 SUB Phase_change(Phase)
490 Phase_change: !Subprogram which changes the phase of the output signal
500               !by writing phase data to the registers on the AFG.
510     COM @Afg,Base_addr
520     CONTROL 16,25;3!access A24 space with READIO and WRITEIO
530     !
540     !Calculate phase increment
550     Phase1=Phase MOD 360
560     IF Phase1<0 THEN Phase1=Phase1+360
570     Phase_data$=IVAL$(4096.*(16.*Phase1/360.))-65536.*(Phase1>=180.),16)
580     !
590     !Write the first byte of the phase increment to register B3.
600     !Write the second byte to register B1.
610     WRITEIO -16,Base_addr+IVAL("B3",16);IVAL(Phase_data$[1;2],16)
620     WRITEIO -16,Base_addr+IVAL("B1",16);IVAL(Phase_data$[3;2],16)
630     !
640     !Generate pulse which loads the new phase. Once the pulse is
650     !received, it takes 14 reference oscillator clock cycles before
660     !the new phase appears at the output.
670     WRITEIO -16,Base_addr+IVAL("8B",16);0
680 SUBEND
690 !
700 SUB Rst
710 Rst: !Subprogram which resets the E1445.
720     COM @Afg,Base_addr
730     OUTPUT @Afg;"*RST;*OPC?"                 !reset the AFG
740     ENTER @Afg;Complete
750 SUBEND

```

Comments

- To simplify the program, SCPI commands are included to configure the AFG, enable phase modulation, and start the waveform. Thus, the only registers written to are the Phase Modulation and Phase Load Strobe Registers. This program executes as intended when the SCPI commands in subprogram Output_function are executed before the registers are written to.
- Phase modulation is only available with standard function sine waves. Standard function sine waves are only available with the DDS ([SOURce:]FREQUENCY[1]) subsystem.

Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, PHASCHNG.FRM, is in directory "VBPROG" and the Visual C example program, PHASCHNG.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Selecting the Waveform Sequence

This section shows how to select and output an arbitrary waveform without aborting the current waveform and re-initializing the AFG.

The Waveform Sequence Registers

The following Waveform Sequence Registers are used to change the output waveform sequence:

- Traffic Register:

$\text{base_addr} + 8_{16}$

- Waveform Select Register:

$\text{base_addr} + A_{16}$

- Sequence Base Register:

$\text{base_addr} + 20_{16}$

- Status Register:

$\text{base_addr} + 2_{16}$

The Traffic Register

The Traffic Register specifies the source which selects the waveform sequence.

Address	15	14	13	12	11	10	9	8	7–0
$\text{base} + 8_{16}$	Sequencer data source		High-speed clock source			High-speed data source			other control bits

Sequencer Data Source: The Sequencer data source field specifies the source which selects addresses in sequence base memory that, in turn, select the waveform sequences. The available sources are:

0 0 = sequencer data source is Local Bus

0 1 = sequencer data source is Front Panel

1 0 = sequencer data source is Waveform Select Register

The source specified in the Sequence Selection program is the Waveform Select Register. Note that when the **sequencer data source** is specified, the contents of the other register fields **must** remain unchanged.

The Waveform Select Register The Waveform Select Register contains the location of the output sequence's base address in sequence base memory.

Address	15	14	13	12	11	10	9	8	7–0
base + A ₁₆	Waveform Index								other control bits

Waveform Index: The Waveform Index is the location in sequence base memory where the base address of the sequence in sequence memory is located.

When specifying a waveform index it is recommended that you begin with an index of 1, then 2, and so on. Index 0 is reserved for SCPI usage.

The Sequence Base Register The Sequence Base Register contains the base address of the selected sequence in sequence memory.

Address	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
base + 20 ₁₆	Sequence Base Address															

Sequence Base Address: The Sequence Base Address is the location of the sequence in sequence memory.

The Status Register The Status Register is used to determine when a new waveform can be selected from sequence base memory.

Address	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
base + 2 ₁₆	other status bits					WF USED	other status bits									

WFUSED: A '0' to '1' transition of this bit indicates that a new waveform can be selected from sequence base memory. This bit is cleared by reading, and then writing to the Waveform Select Register.

Sequence Selection Program The WAVE_SEL program shows how to change the output waveform (sequence) without aborting the current waveform and re-initializing the AFG.

HP BASIC Program Example (WAVE_SEL)

```
1   !RE-STORE "WAVE_SEL"
2   !This program changes the output waveform sequence once the AFG has been
3   !INITiated by writing the location of a sequence's base address to the
4   !Waveform Select register. All register reads and writes are 16 bit.
5   !
10  !Assign an I/O path between the computer and the AFG
20  ASSIGN @Afg TO 1680
30  ASSIGN @Afg1 TO 1680;FORMAT OFF           !path for binary data
40  COM @Afg,@Afg1,Base_addr,Seq1_addr,Seq2_addr,Seq3_addr
50  !
60  !Subprograms which reset the AFG and erase all existing waveforms.
70  CALL Rst
80  CALL Wf_del
90  !
100 !SCPI commands which configure the AFG
110 OUTPUT @Afg;"SOUR:FREQ1:FIX 4.096E6;";           !Sample rate
120 OUTPUT @Afg;":SOUR:FUNC:SHAP USER;";           !function
130 OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL 2.1V"      !amplitude
140 OUTPUT @Afg;"SOUR:ARB:DAC:SOUR INT"           !dac data source
150 OUTPUT @Afg;"SOUR:ARB:DAC:FORM SIGN"          !dac data format
160 !
170 !Subprograms which define waveforms and load them into segment
180 !and sequence memory, which determine the AFG's register locations
190 !in A24, and which configure the AFG's sequence base memory.
200 CALL Waveform_def
210 CALL A24_offset
220 CALL Build_ram
230 !
240 !Select an output sequence, and initiate (start) waveform output.
250 OUTPUT @Afg;"SOUR:FUNC:USER SEQ1"             !waveform sequence
260 OUTPUT @Afg;"INIT:IMM"                        !wait-for-arm state
270 !
280 !Subprogram which changes the output sequence with register writes.
290 CALL Wave_change
300 END
310 !
320 SUB Waveform_def
330   COM @Afg,@Afg1,Base_addr,Seq1_addr,Seq2_addr,Seq3_addr
340   CALL Sinx_def
350   CALL Sind_def
360   CALL Spike_def
370 SUBEND
380 !
390 SUB A24_offset
```

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```

400 A24_offset: !Subprogram which determines the base address for
410             !the AFG registers in A24 address space.
420     COM @Afg,@Afg1,Base_addr,Seq1_addr,Seq2_addr,Seq3_addr
430     CONTROL 16,25;2!access A16 space with READIO and WRITEIO
440     A16_addr=DVAL("D400",16)           !AFG A16 base address
450     Offset=READIO(-16,A16_addr+6)      !read AFG offset register
460     Base_addr=Offset*256                !shift offset for 24-bit address
470     SUBEND
480     !
490     SUB Build_ram
500 Build_ram: !This subprogram configures the AFG's sequence base memory
510             !such that there are valid sequence base addresses in memory
520             !before the AFG is INITiated and waveforms are selected.
530     COM @Afg,@Afg1,Base_addr,Seq1_addr,Seq2_addr,Seq3_addr
540     CONTROL 16,25;3!access A24 space with READIO and WRITEIO
550     !
560     !Preserve Traffic register contents. Set bits 15-14 to 1 0 to set
570     !the Waveform Select register as the source which selects the output
580     !waveform sequence.
590     Traffic=BINAND(READIO(-16,Base_addr+IVAL("8",16)),IVAL("3FFF",16))
600     WRITEIO -16,Base_addr+IVAL("8",16);BINIOR(Traffic,IVAL("8000",16))
610     !
620     !Write the location of the sequence base address (waveform index)
630     !to the Waveform Select register. Write the base address of
640     !of the sequence in sequence memory to the Sequence Base register.
650     !
660     Wav_sel=BINAND(READIO(-16,Base_addr+IVAL("A",16)),IVAL("00FF",16))
670     WRITEIO -16,Base_addr+IVAL("A",16);BINIOR(Wav_sel,IVAL("0100",16))
680     WRITEIO -16,Base_addr+IVAL("20",16);Seq1_addr !sequence mem base addr
690     !
700     Wav_sel=BINAND(READIO(-16,Base_addr+IVAL("A",16)),IVAL("00FF",16))
710     WRITEIO -16,Base_addr+IVAL("A",16);BINIOR(Wav_sel,IVAL("0200",16))
720     WRITEIO -16,Base_addr+IVAL("20",16);Seq2_addr !sequence mem base addr
730     !
740     Wav_sel=BINAND(READIO(-16,Base_addr+IVAL("A",16)),IVAL("00FF",16))
750     WRITEIO -16,Base_addr+IVAL("A",16);BINIOR(Wav_sel,IVAL("0300",16))
760     WRITEIO -16,Base_addr+IVAL("20",16);Seq3_addr !sequence mem base addr
770     SUBEND
780     !
790     SUB Wave_change
800 Wave_change: !Once the AFG has been INITiated, this subprogram changes
810             !the output waveform sequence by writing the location of the
820             !sequence's base address in sequence base memory to the
830             !Waveform Select register.
840     COM @Afg,@Afg1,Base_addr,Seq1_addr,Seq2_addr,Seq3_addr
850     INTEGER I
860     CONTROL 16,25;3 !access A24 space with READIO and WRITEIO
870     !
880     !Read the waveform select register and write back the value read, in
890     !order to clear the WFUSED bit in the Status register.

```

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```

900     Wav_sel=READIO(-16,Base_addr+IVAL("A",16))
910     WRITEIO -16,Base_addr+IVAL("A",16);Wav_sel
920     !
930     !Select a waveform by writing to the Waveform Select register
940     !following a 0-to-1 transition of the WFUSED bit in the Status
950     !register. The transition indicates a new waveform can be selected.
960     !256 selects sequence 1, 512 selects sequence 2, and 768 selects
970     !sequence 3.
980     Wav_sel=BINAND(READIO(-16,Base_addr+IVAL("A",16)),IVAL("00FF",16))
990     LOOP
1000    FOR I=256 TO 768 STEP 256
1010        WRITEIO -16,Base_addr+IVAL("A",16);BINIOR(Wav_sel,I)
1020        REPEAT
1030            UNTIL BIT(READIO(-16,Base_addr+2),10)
1040        NEXT I
1050    END LOOP
1060    SUBEND
1070    !
1080    SUB Sinx_def
1090 Sinx_def: !Define the waveform Sin(x)/x. Download the waveform data
1100            !as a combined list (voltage and marker) of signed numbers
1110            !in an indefinite length block. Download the sequence as a
1120            !combined list (repetition count, marker, and segment address)
1130            !in an indefinite length arbitrary block.
1140    COM @Afg,@Afg1,Base_addr,Seq1_addr,Seq2_addr,Seq3_addr
1150    INTEGER Waveform(1:4096)
1160    INTEGER Sequence(1:2)
1170    REAL Addr_seg1
1180    FOR I=-2047 TO 2048
1190        IF I=0 THEN I=1.E-38
1200        Waveform(I+2048)=((SIN(2*PI*.53125*I/256)))/(.53125*I/256)*.159154943092)/.00125
1210        !shift bits to dac code positions
1220        Waveform(I+2048)=SHIFT(Waveform(I+2048),-3)
1230    NEXT I
1240    !
1250    OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL SIN_X"           !segment name
1260    OUTPUT @Afg;"SOUR:LIST1:SEGM:DEF 4096"           !segment size
1270    OUTPUT @Afg USING "#,K";"SOUR:LIST1:SEGM:COMB #0" !waveform points
1280    OUTPUT @Afg1;Waveform(*)                         !indefinite length block
1290    OUTPUT @Afg;CHR$(10);END                         !terminate with line feed (LF) and EOI
1300    !
1310    OUTPUT @Afg;"SOUR:LIST1:SEGM:ADDR?"
1320    ENTER @Afg;Addr_seg1
1330    Addr_seg1=Addr_seg1/8                            !/8 to set starting address (boundary) of segment
1340    !
1350    !Sequence (1) is the repetition count and marker enable for
1360    !segment SIN_X. Sequence (2) is the starting address of segment SIN_X.
1370    Sequence(1)=SHIFT(4096-1,-4)+Addr_seg1 DIV 65536.
1380    Sequence(2)=Addr_seg1 MOD 65536.-65536.*(Addr_seg1 MOD 65536.>32767)

```

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```

1390      !
1400      OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL SEQ1"           !sequence name
1410      OUTPUT @Afg;"SOUR:LIST1:SSEQ:DEF 1"             !sequence size
1420      OUTPUT @Afg USING "#,K";"SOUR:LIST1:SSEQ:COMB #0" !segm execution order
1430      OUTPUT @Afg1;Sequence(*)                       !sequence list in indefinite length block
1440      OUTPUT @Afg;CHR$(10);END                       !terminate with Line Feed (LF) and EOI
1450      !
1460      OUTPUT @Afg;"SOUR:LIST1:SSEQ:ADDR?"           !sequence location
1470      ENTER @Afg;Seq1_addr
1480      SUBEND
1490      !
1500      SUB Sind_def
1510      Sind_def: !Compute the damped sine waveform. Download the data
1520      !as a combined list (voltage and marker) of signed numbers
1530      !in an indefinite length block. Download the sequence as a
1540      !combined list (repetition count, marker, and segment address)
1550      !in an indefinite length arbitrary block.
1560      COM @Afg,@Afg1,Base_addr,Seq1_addr,Seq2_addr,Seq3_addr
1570      INTEGER Waveform(1:4096)
1580      INTEGER Sequence(1:2)
1590      REAL Addr_seg2
1600      A=4/4096
1610      W=(2*PI)/50
1620      FOR T=1 TO 4096
1630          Waveform(T)=EXP(-A*T)*SIN(W*T)/.00125
1640          !shift bits to dac code positions
1650          Waveform(T)=SHIFT(Waveform(T),-3)
1660      NEXT T
1670      !
1680      OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL SIN_D"         !segment name
1690      OUTPUT @Afg;"SOUR:LIST1:SEGM:DEF 4096"         !segment size
1700      OUTPUT @Afg USING "#,K";"SOUR:LIST1:SEGM:COMB #0" !waveform points
1710      OUTPUT @Afg1;Waveform(*)                       !indefinite length block
1720      OUTPUT @Afg;CHR$(10);END                       !terminate with line feed (LF) and EOI
1730      !
1740      OUTPUT @Afg;"SOUR:LIST1:SEGM:ADDR?"
1750      ENTER @Afg;Addr_seg2
1760      Addr_seg2=Addr_seg2/8                          !/8 to set starting address (boundary) of segment
1770      !
1780      !Sequence (1) is the repetition count and marker enable for
1790      !segment SIN_D. Sequence (2) is the starting address of segment SIN_D.
1800      Sequence(1)=SHIFT(4096-1,-4)+Addr_seg1 DIV 65536.
1810      Sequence(2)=Addr_seg2 MOD 65536.-65536.*(Addr_seg2 MOD 65536.>32767)
1820      !
1830      OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL SEQ2"         !sequence name
1840      OUTPUT @Afg;"SOUR:LIST1:SSEQ:DEF 1"             !sequence size
1850      OUTPUT @Afg USING "#,K";"SOUR:LIST1:SSEQ:COMB #0" !segm execution order
1860      OUTPUT @Afg1;Sequence(*)                       !sequence list in indefinite length block
1870      OUTPUT @Afg;CHR$(10);END                       !terminate with Line Feed (LF) and EOI

```

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```

1880      !
1890      OUTPUT @Afg;"SOUR:LIST1:SSEQ:ADDR?"           !sequence location
1900      ENTER @Afg;Seq2_addr
1910      SUBEND
1920      !
1930      SUB Spike_def
1940      Spike_def: !Compute the waveform (sine wave with spike). Download the
1950                  !data as a combined list (voltage and marker) of signed
1960                  !numbers in an indefinite length block. Download the sequence as
1970                  !a combined list (repetition count, marker, and segment address)
1980                  !in an indefinite length arbitrary block.
1990      COM @Afg,@Afg1,Base_addr,Seq1_addr,Seq2_addr,Seq3_addr
2000      INTEGER Waveform(1:4096)
2010      INTEGER Sequence(1:2)
2020      REAL Addr_seg3
2030      FOR I=1 TO 4096
2040          Waveform(I)=SIN(2*PI*(I/4096))/0.00125
2050      NEXT I
2060      Width=50
2070      FOR J=1 TO Width
2080          I=1024-Width+J
2090          Waveform(I)=Waveform(I)+.9*J/Width/0.00125
2100      NEXT J
2110      FOR J=1 TO Width-1
2120          I=1024+Width-J
2130          Waveform(I)=Waveform(I)+.9*J/Width/0.00125
2140      NEXT J
2150      !
2160      !shift bits to dac code positions
2170      FOR I=1 TO 4096
2180          Waveform(I)=SHIFT(Waveform(I),-3)
2190      NEXT I
2200      !
2210      OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL SPIKE"         !segment name
2220      OUTPUT @Afg;"SOUR:LIST1:SEGM:DEF 4096"         !segment size
2230      OUTPUT @Afg USING "#,K";"SOUR:LIST1:SEGM:COMB #0" !waveform points
2240      OUTPUT @Afg1;Waveform(*)                       !indefinite length block
2250      OUTPUT @Afg;CHR$(10);END                       !terminate with line feed (LF) and EOI
2260      !
2270      OUTPUT @Afg;"SOUR:LIST1:SEGM:ADDR?"
2280      ENTER @Afg;Addr_seg3
2290      Addr_seg3=Addr_seg3/8                          !/8 to set starting address (boundary) of segment
2300      !
2310      !Sequence (1) is the repetition count and marker enable for
2320      !segment SPIKE. Sequence (2) is the starting address of segment SPIKE.
2330      Sequence(1)=SHIFT(4096-1,-4)+Addr_seg3 DIV 65536.
2340      Sequence(2)=Addr_seg3 MOD 65536.-65536.*(Addr_seg3 MOD 65536.>32767)
2350      !
2360      OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL SEQ3"         !sequence name

```

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```

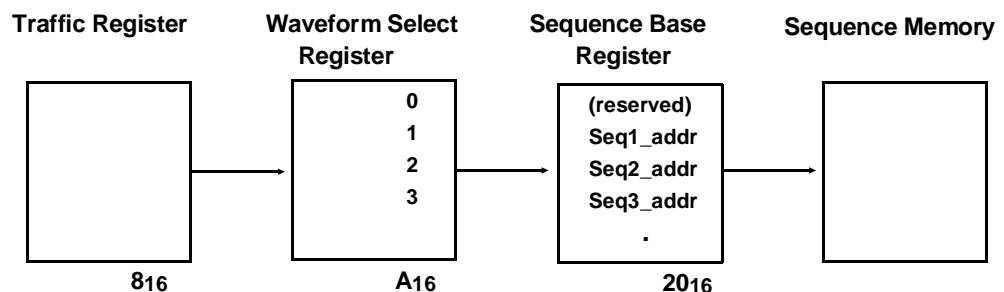
2370     OUTPUT @Afg;"SOUR:LIST1:SSEQ:DEF 1"           !sequence size
2380     OUTPUT @Afg USING "#,K";"SOUR:LIST1:SSEQ:COMB #0" !segm execution order
2390     OUTPUT @Afg1;Sequence(*)           !sequence list in indefinite length block
2400     OUTPUT @Afg;CHR$(10);END           !terminate with Line Feed (LF) and EOI
2410     !
2420     OUTPUT @Afg;"SOUR:LIST1:SSEQ:ADDR?"           !sequence location
2430     ENTER @Afg;Seq3_addr
2440 SUBEND
2450     !
2460 SUB Rst
2470 Rst: !Subprogram which resets the E1445.
2480     COM @Afg,@Afg1,Base_addr,Seq1_addr,Seq2_addr,Seq3_addr
2490     OUTPUT @Afg;"*RST;*CLS;*OPC?"           !reset the AFG
2500     ENTER @Afg;Complete
2510 SUBEND
2520     !
2530 SUB Wf_del
2540 Wf_del: !Subprogram which deletes all sequences and segments.
2550     COM @Afg,@Afg1,Base_addr,Seq1_addr,Seq2_addr,Seq3_addr
2560     OUTPUT @Afg;"FUNC:USER NONE"           !select no sequences
2570     OUTPUT @Afg;"LIST:SSEQ:DEL:ALL"           !Clear sequence memory
2580     OUTPUT @Afg;"LIST:SEGM:DEL:ALL"           !Clear segment memory
2590 SUBEND

```

Comments

- SCPI commands are included in this program to load segment and sequence memory, and initialize the AFG. This program executes as intended when the SCPI commands are executed prior to writing to the registers.
- The sequence in which the Waveform Selection Registers are written to and the register contents are summarized below.

The Traffic Register selects the source which specifies addresses in sequence base memory that, in turn, select the waveform sequences. The Waveform Select Register (selected by the Traffic Register) contains the waveform index which is the location in sequence base memory where the base address of the sequence in sequence memory is located.



Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, WAVE_SEL.FRM, is in directory "VBPROG" and the Visual C example program, WAVE_SEL.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

Loading the DAC from the VXIbus

This section shows how to load waveform data into the AFG's DAC directly from the VXIbus backplane. For additional information on loading the DAC directly, refer to Chapter 7.

The High Speed Data Register Waveform data from the VXIbus is loaded into the DAC via the following register.

- High-Speed Data Register:

base_addr + 26₁₆

Address	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
base + 26 ₁₆	DAC code													unused		

DAC Code: The DAC code is a 13-bit signed (2's complement) or unsigned number. With [SOURce:]VOLTage[:LEVel][:IMMEDIATE][:AMPLitude] set to 5.12 V and a matched output load, the least significant bit (LSB) is 1.25 mV.

HP BASIC Program Example (VXISRCE)

The program uses the V360 Controller to download the data using the VXIbus instead of transferring it directly to the AFG using HP-IB.

```

1  IRE-STORE"VXISRCE"
2  !This program uses the V/360 embedded controller to send waveform
3  !data directly to the AFG dac over the VXIbus backplane.
4  !
10 !Assign I/O path between the computer and E1445A.
20 ASSIGN @Afg TO 1680
30 COM @Afg,Addr
40 !
50 !Call the subprograms which reset the AFG and determine the base
60 !address of the registers in A24 address space.
70 CALL Rst
80 CALL A24_offset
90 !
100 !Scale the amplitude, set the dac data format and dac data source.
110 OUTPUT @Afg;"SOUR:VOLT:LEV:IMM:AMPL 5.11875V"      !amplitude
120 OUTPUT @Afg;"SOUR:ARB:DAC:FORM SIGN"              !dac data format (signed)
130 OUTPUT @Afg;"SOUR:ARB:DAC:SOUR VXI"              !dac data source
140 OUTPUT @Afg;"*OPC?"                               !Wait for the SCPI commands to complete
150 ENTER @Afg;Complete
160 !
170 !Call the subprogram which sends data directly to the dac.

```

Continued on Next Page

```

180 CALL Dac_drive
190 END
200 !
210 SUB A24_offset
220 A24_offset: !Subprogram which determines the base address for
230             !the AFG registers in A24 address space, then adds the
240             !offset and register number to the base to get the
250             !complete address.
260 COM @Afg,Addr
270 !CONTROL 16,25;2             !access A16 space with READIO and WRITEIO
280 A16_addr=DVAL("D400",16)    !AFG A16 base address
290 Offset=READIO(-16,A16_addr+6) !read AFG offset register
300 Base_addr=Offset*256        !shift offset for 24-bit address
310 !Add the register number of the high speed data register
320 !to the A24 base address.
330 Addr=Base_addr+IVAL("26",16)
340 SUBEND
350 !
360 SUB Dac_drive
370 Dac_drive: !Subprogram which computes a 128 point, 5 Vpp triangle wave and
380            !writes the corresponding codes directly to the DAC via
390            !the VXIbus and High Speed Data register.
400 COM @Afg,Addr
410 !CONTROL 16,25;3             !access A24 space with WRITEIO
420 !
430 INTEGER I,Waveform(1:128)    !Calculate triangle wave (dac codes)
440 FOR I=1 TO 64
450     Waveform(I)=I*.0755/.00125
460     Waveform(I)=SHIFT(Waveform(I),-3)    !shift bits to dac code positions
470 NEXT I
480 FOR I=65 TO 128
490     Waveform(I)=(128-I)*.0755/.00125
500     Waveform(I)=SHIFT(Waveform(I),-3)    !shift bits to dac code positions
510 NEXT I
520 !
530 !Continuously write data (in 16-bit words) to the dac via the
540 !VXIbus and High Speed Data register.
550 LOOP
560     FOR I=1 TO 128
570         WRITEIO -16,Addr;Waveform(I)
580     NEXT I
590 END LOOP
600 SUBEND
610 !
620 SUB Rst
630 Rst: !Subprogram which resets the E1445.
640 COM @Afg,Addr
650 OUTPUT @Afg;"*RST;*OPC?"        !reset the AFG
660 ENTER @Afg;Complete
670 SUBEND

```

Comments

- To simplify the program, SCPI commands are included so that the only register written to is the High-Speed Data Register. This program executes as intended when those SCPI commands which configure the AFG are executed before the register is written to.
- This program was written using the system configuration described on page 484. Data is written to the DAC at a rate of 115 μ s per amplitude point, which is limited by the execution speed of HP BASIC.

Visual BASIC and Visual C/C++ Program Versions

The Visual BASIC example program, VXISRCE.FRM, is in directory “VBPROG” and the Visual C example program, VXISRCE.C, is in directory “VCPROG” on the CD that came with your HP E1445A.

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