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Documentation History

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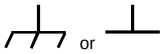
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Indicates the field wiring terminal that must be connected to earth ground before operating the equipment—protects against electrical shock in case of fault.



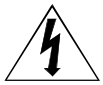
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Direct current (DC).



Indicates hazardous voltages.

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Manufacturer's Address: 815 14th Street S.W.
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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

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Tested in a typical HP C-Size VXI Mainframe.



July 29, 1996 **Jim White, QA Manager**

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

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Edition 3

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Chapter 1
Getting Started

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
  - SCPI Programming . . . . . Page 26
  - Command Coupling . . . . . Page 27

- Program Languages . . . . . Page 29
  - HP BASIC Language Programs . . . . . Page 29
  - Visual BASIC Language Programs . . . . . Page 32
  - Visual C/C++ Language Programs . . . . . Page 40

- Introductory Programs . . . . . Page 46
  - AFG Self-Test . . . . . Page 46
  - Resetting and Clearing the AFG . . . . . Page 47
  - Querying the Power-On/Reset Configuration. . . . . Page 48
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  - Generating Sine Waves . . . . . Page 51

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*.

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VXIbus Factory Settings

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

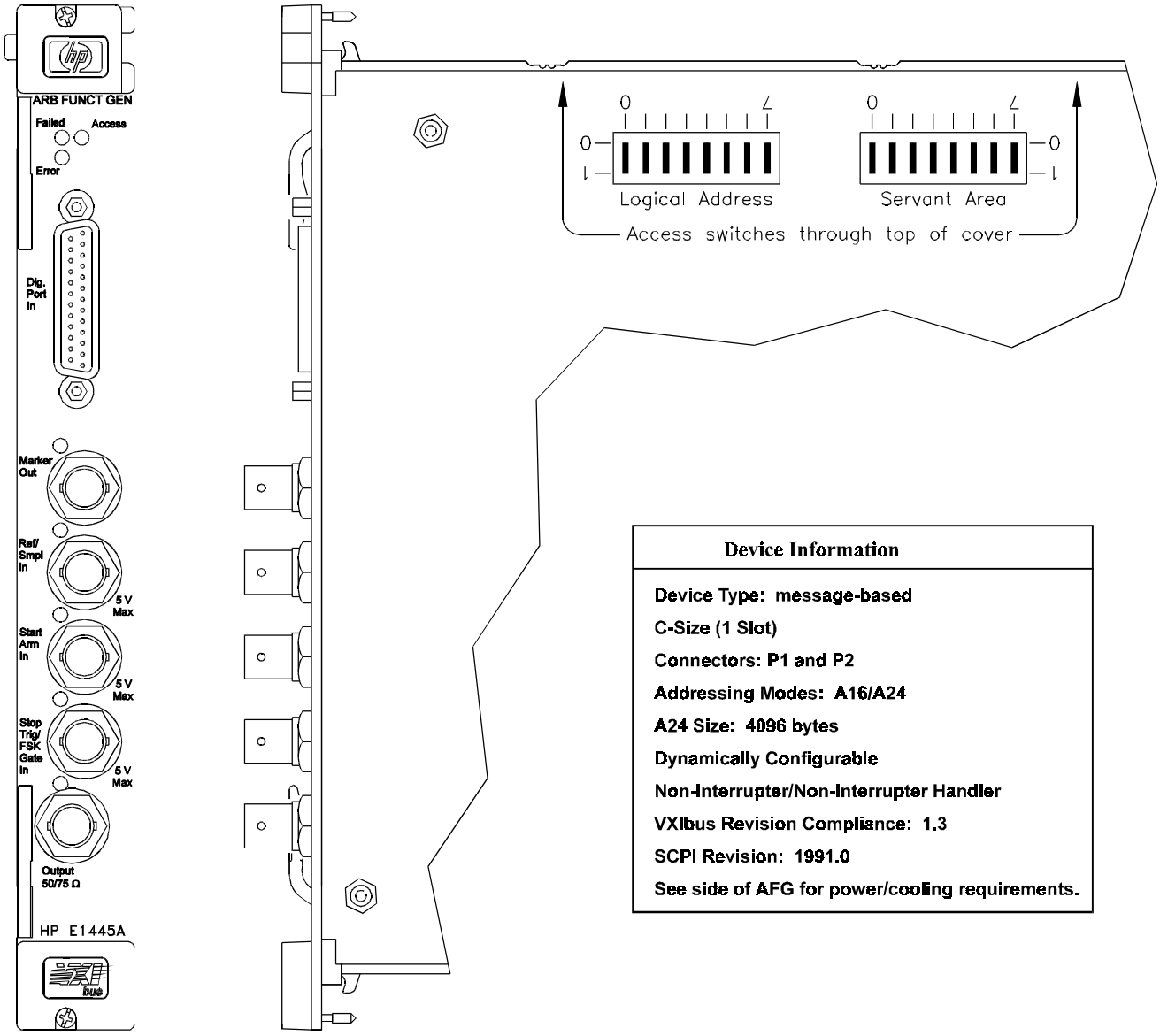


Figure 1-1. The HP E1445A Arbitrary Function Generator

Table 1-1. HP E1445A VXIbus System Factory Settings

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

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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

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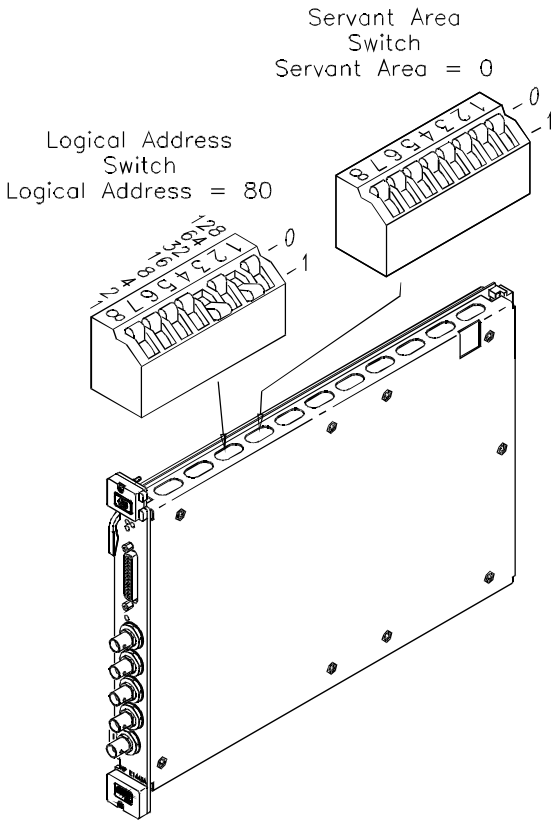


Figure 1-2. HP E1445A Logical Address and Servant Area Switch Location

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.

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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.

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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*.)

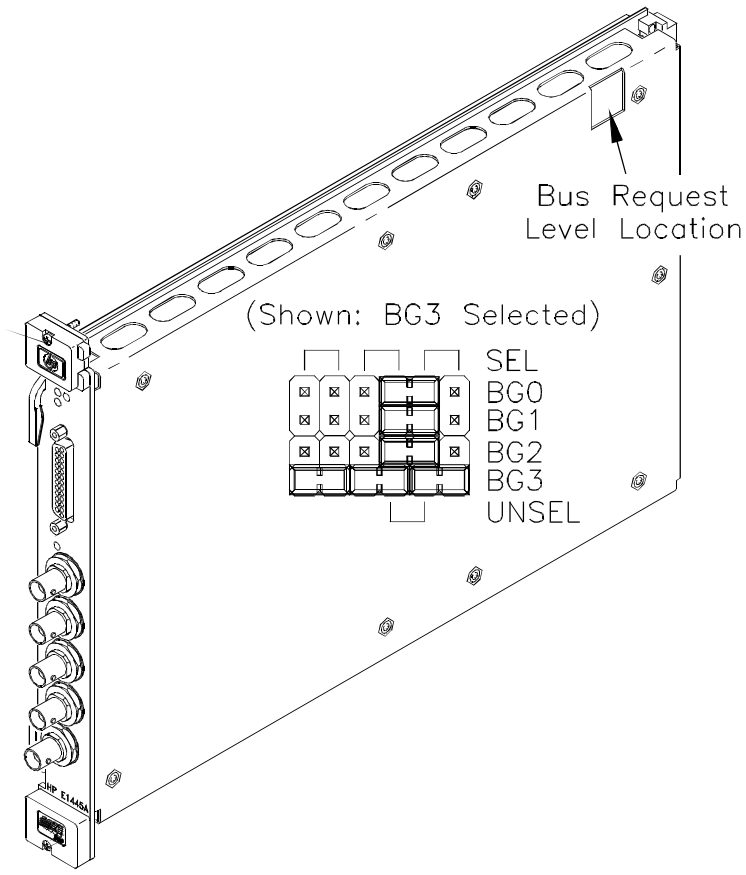


Figure 1-3. Setting the AFG Bus Request Level

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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.

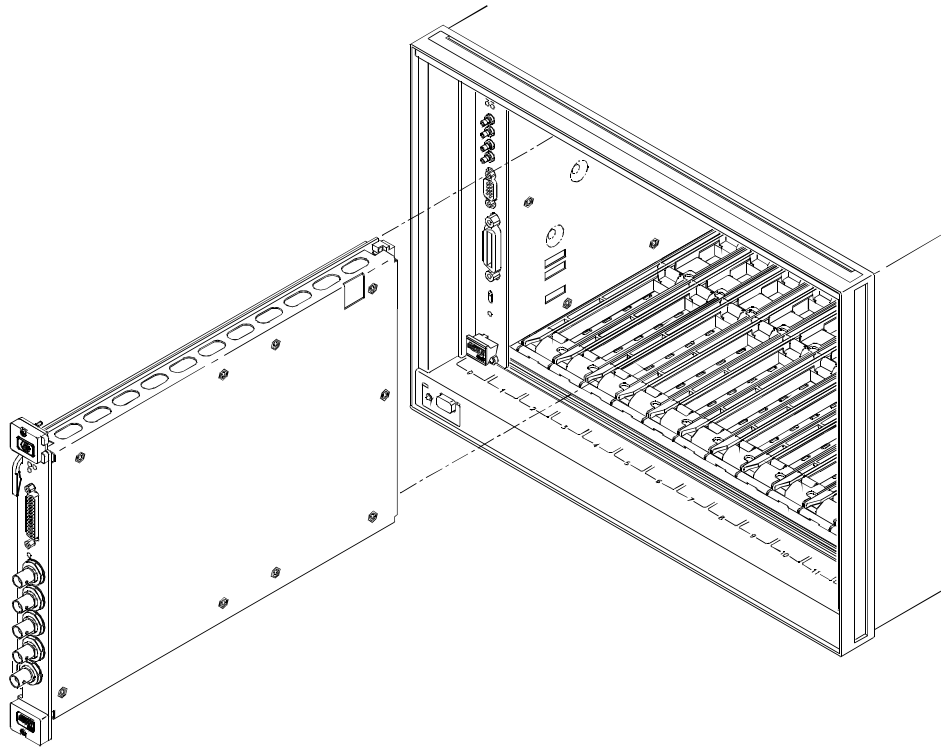


Figure 1-4. Installing the AFG Module in a VXIbus Mainframe

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.

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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

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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:]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 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.

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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.

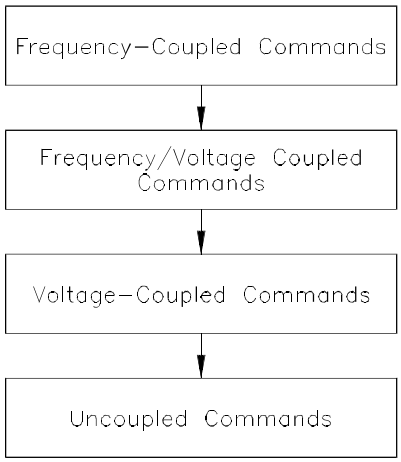


Figure 1-5. High-Level HP E1445A Programming Sequence

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.

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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

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Typical HP BASIC Example Program

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

```
!RE-STORE"SWP_LEVL"
!This program enables output leveling over the 0 Hz to 10 MHz sweep.
!
!Assign I/O path between the computer and E1445A.
ASSIGN @Afg TO 70910
COM @Afg
!
!Set up error checking
ON INTR 7 CALL Errmsg
ENABLE INTR 7;2
OUTPUT @Afg;"*CLS"
OUTPUT @Afg;"*SRE 32"
OUTPUT @Afg;"*ESE 60"
!
!Call the subprograms
CALL Rst
CALL Swp_levl
!
WAIT .1  !allow interrupt to be serviced
OFF INTR 7
END
!
SUB Swp_levl
Swp_levl:  !Subprogram which sets output leveling for sweeping from
             !0 TO 10 MHz
        COM @Afg
        OUTPUT @Afg;"SOUR:FREQ1:MODE SWE;";              !sweep mode
        OUTPUT @Afg;"  :SOUR:FREQ1:STAR 0;";             !start frequency
        OUTPUT @Afg;"  :SOUR:FREQ1:STOP 10E6;";          !stop frequency
        OUTPUT @Afg;"  :SOUR:SWE:COUN INF;"              !sweep count
        OUTPUT @Afg;":SOUR:FUNC:SHAP SIN;";              !function
        OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL 5 V"        !amplitude
        OUTPUT @Afg;"OUTP1:FILT:LPAS:FREQ 10 MHZ"        !filter cutoff frequency
        OUTPUT @Afg;"OUTP1:FILT:LPAS:STAT ON"            !enable output filter
        OUTPUT @Afg;"INIT:IMM"                           !wait-for-arm state
        SUBEND
        !
        SUB Rst
Rst:  !Subprogram which resets the E1445.
        COM @Afg
        OUTPUT @Afg;"*RST;*OPC?"                         !reset the AFG
        ENTER @Afg;Complete
    SUBEND
    !
    SUB Errmsg
Errmsg:   !Subprogram which displays E1445 programming errors
        COM @Afg
```

Continued on Next Page

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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
```

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.

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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®.

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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

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```
    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 siclcleanup

        ' 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

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```
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

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```
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

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```
    ' 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 siclcleanup

Exit Sub

  ' In case of timeout
AfgErr:
```

Continued on Next Page

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```
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
```

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```
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 siclcleanup

   ' End program
End

End Sub
```


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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

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- 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);
```

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```
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
        _siclcleanup();

        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
```

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```
":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)");
```

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```
        // 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(!iprintf(addr, "%s\n", commands[loop]))
            time_out(func_tion);

}
//*************************************************************************
void run_query(void)
{
    char    mem_size[21];

        // Query segment memory
    if(!ipromptf(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(!ipromptf(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(!ipromptf(addr, "*RST;*OPC?\n", "%i", &into))
        time_out("rst_clr - send *RST command");

    if(!ipromptf(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

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```
        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
            _siclcleanup();

            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
        _siclcleanup();

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

        exit(1);
}
```


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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.

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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.

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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.

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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

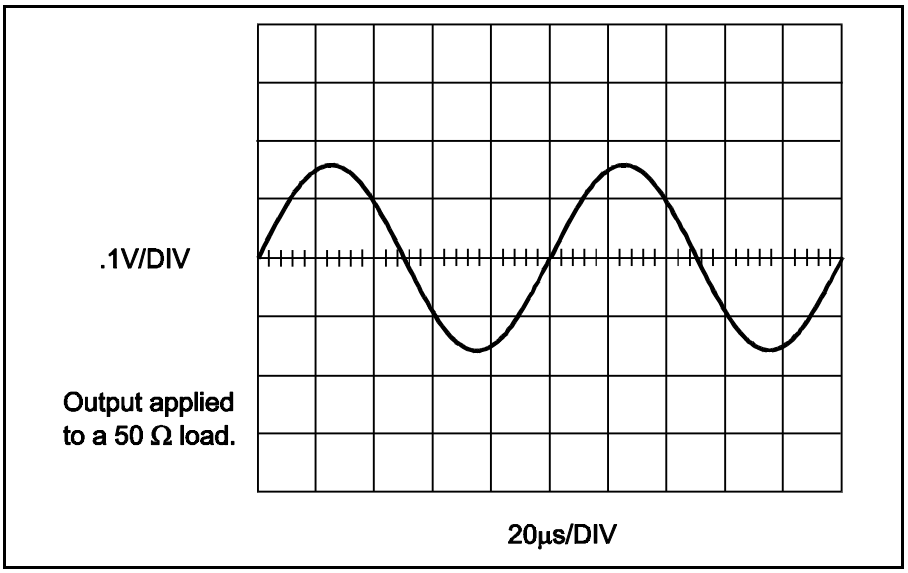
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```
230     !
240     SUB Errmsg
250 Errmsg:   !Subprogram which displays E1445 programming errors
260     COM @Afg
270     DIM Message$[256]
280     !Read AFG status byte register and clear service request bit
290     B=SPOLL(@Afg)
300     !End of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


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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.

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Notes

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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, Vpeak, 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.

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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.

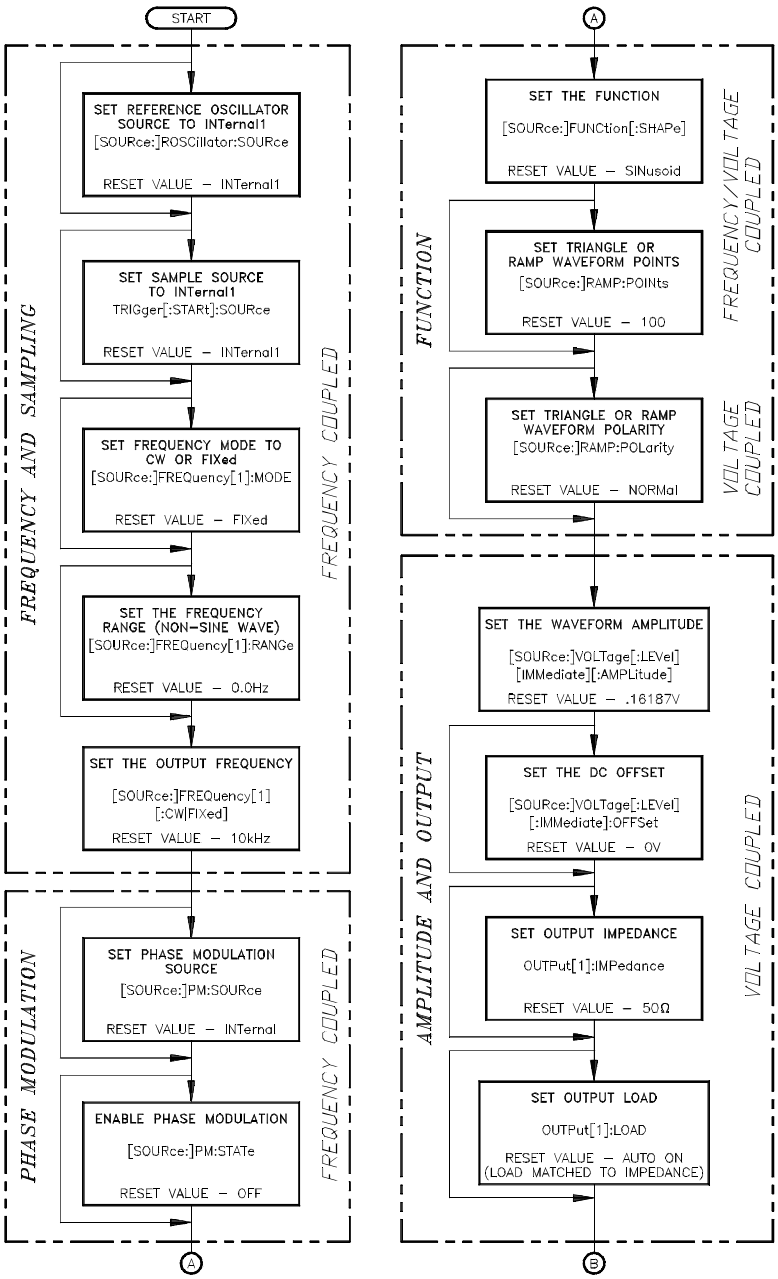


Figure 2-1. Commands for Generating Standard Waveforms
(*continued on next page*)

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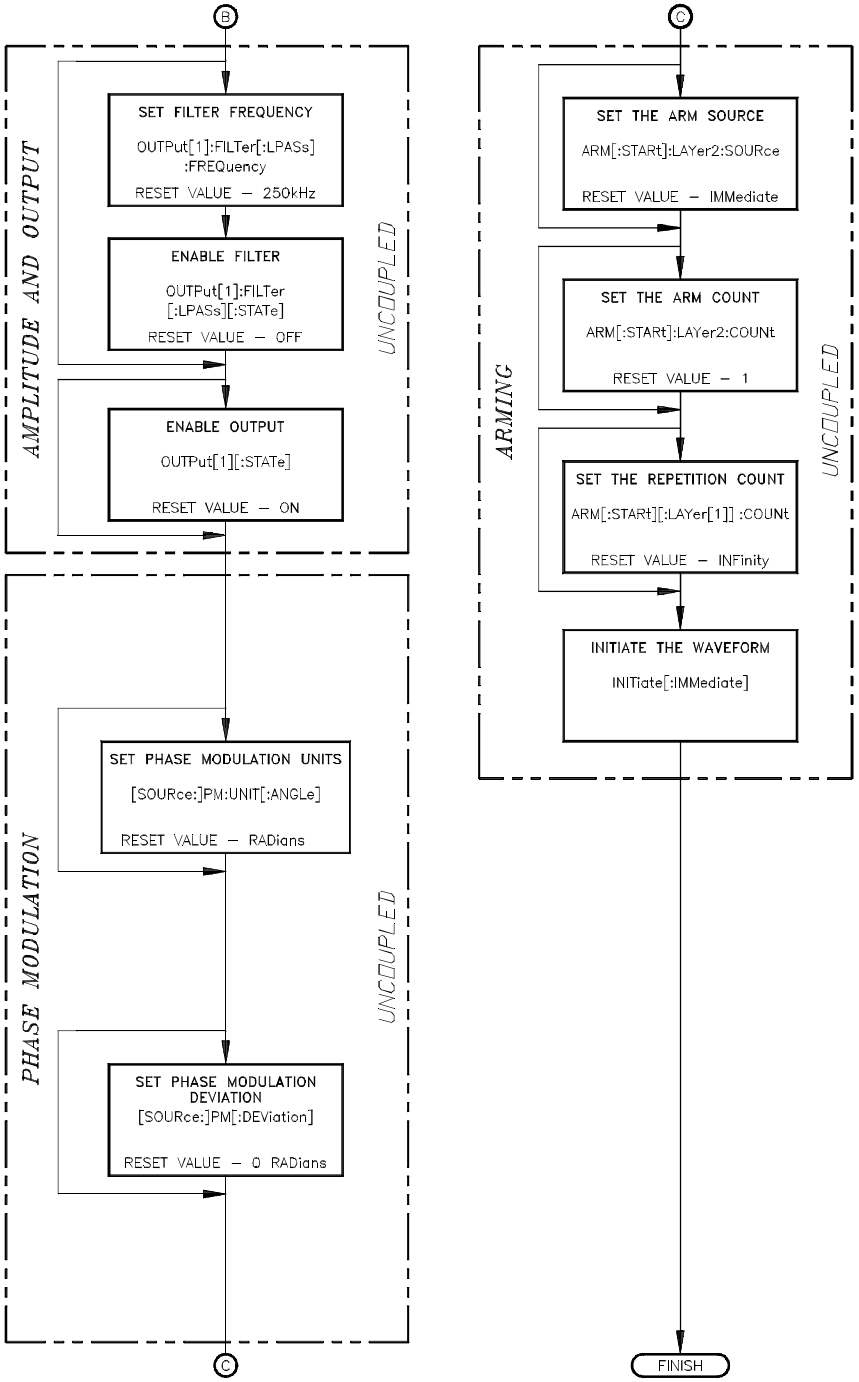


Figure 2-1. Commands for Generating Standard Waveforms
(*continued from previous page*)

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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
```

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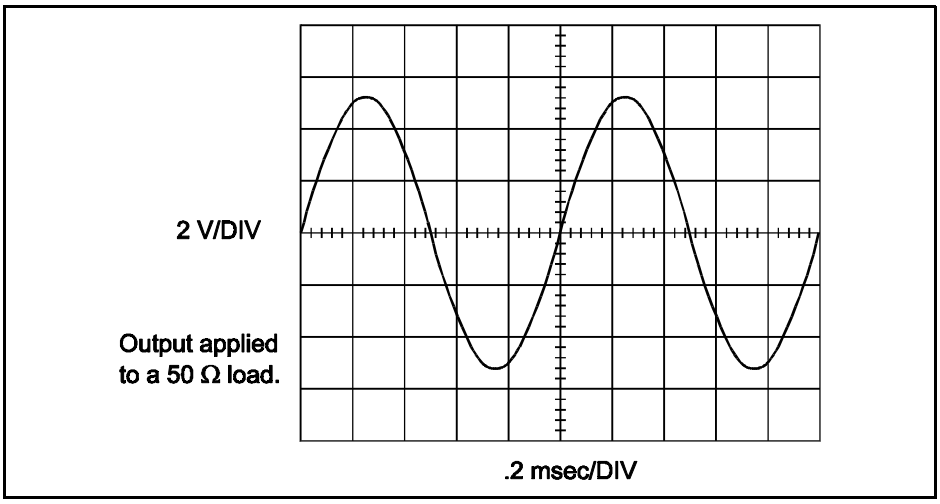
```
250     SUBEND
260     !
270     SUB Rst
280 Rst:    !Subprogram which resets the E1445.
290         COM @Afg
300         OUTPUT @Afg;"*RST;*OPC?"            !reset the AFG
310         ENTER @Afg;Complete
320     SUBEND
330     !
340     SUB Errmsg
350 Errmsg:  !Subprogram which displays E1445 programming 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.

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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.

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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
```

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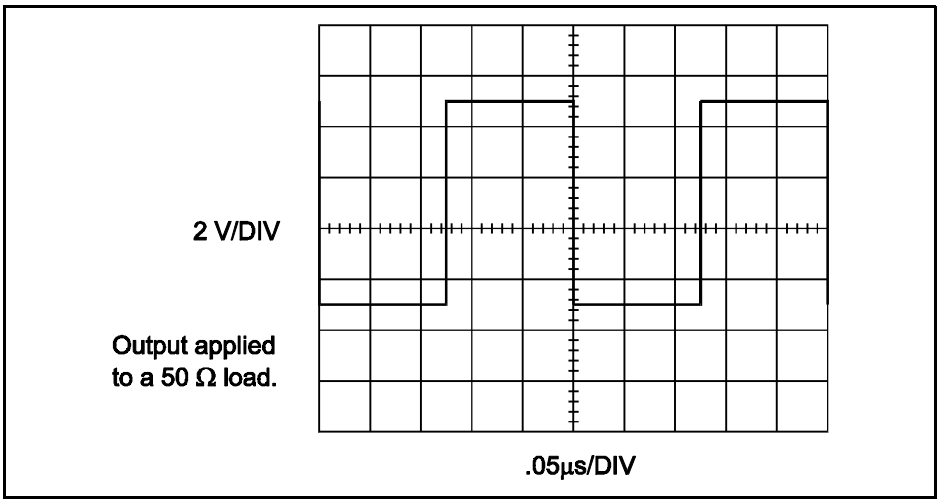
```
460           OUTPUT @Afg;"SYST:ERR?"                    !read AFG error queue
470           ENTER @Afg;Code,Message$
480           PRINT   Code,Message$
490         UNTIL Code=0
500         STOP
510       SUBEND
```

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.

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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.)

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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.

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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
```

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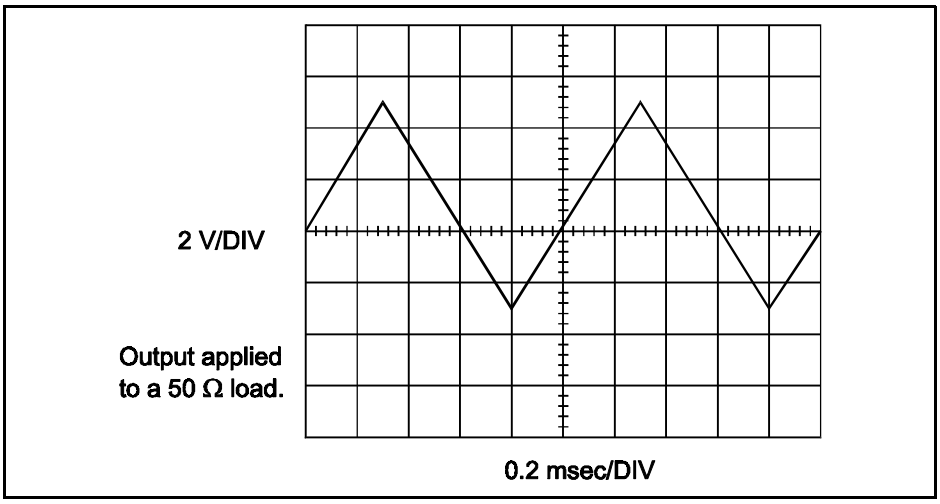
```
460         B=SPOLL(@Afg)
470         !End of statement if error occurs among coupled commands
480         OUTPUT @Afg;""
490         OUTPUT @Afg;"ABORT"                 !abort output waveform
500         REPEAT
510            OUTPUT @Afg;"SYST:ERR?"          !read AFG error queue
520            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.

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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.)

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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.

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HP BASIC Program Example (TRIWAVE)

```
    !RE-STORE“TRIWAVE”
    !This program outputs a 200 point, 10 kHz, 4V triangle wave
    !with a 1V DC offset.
    !
    !Assign I/O path between the computer and E1445A.
    ASSIGN @Afg TO 70910
    COM @Afg
    !
    !Set up error checking
    ON INTR 7 CALL Errmsg
    ENABLE INTR 7;2
    OUTPUT @Afg;“*CLS”
    OUTPUT @Afg;“*SRE 32”
    OUTPUT @Afg;“*ESE 60”
    !
    !Call the subprograms
    CALL Rst
    CALL Tri_wave
    !
    WAIT .1  !allow interrupt to be serviced
    OFF INTR
    END
    !
    SUB Tri_wave
Tri_wave:    !Subprogram which outputs a triangle wave
        COM @Afg
        OUTPUT @Afg;“SOUR:ROSC:SOUR  INT1;”;          !reference oscillator
        OUTPUT @Afg;“:TRIG:STAR:SOUR  INT1;”;         !trigger source
        OUTPUT @Afg;“:SOUR:FREQ1:RANG  0;”;           !frequency range
        OUTPUT @Afg;“:SOUR:FREQ1:FIX  10E3;”;         !frequency
        OUTPUT @Afg;“:SOUR:FUNC:SHAP  TRI;”;          !function
        OUTPUT @Afg;“:SOUR:RAMP:POIN  200;”;          !waveform points
        OUTPUT @Afg;“:SOUR:VOLT:LEV:IMM:AMPL  4V;”;   !amplitude
        OUTPUT @Afg;“:SOUR:VOLT:LEV:IMM:OFFS  1V”     !dc offset
        OUTPUT @Afg;“INIT:IMM”                        !wait-for-arm state
    SUBEND
    !
    SUB Rst
Rst:    !Subprogram which resets the E1445.
        COM @Afg
        OUTPUT @Afg;"*RST;*OPC?"                      !reset the AFG
        ENTER @Afg;Complete
    SUBEND
    !
    SUB Errmsg
Errmsg:  !Subprogram which displays E1445 programming errors
        COM @Afg
        DIM Message$[256]
```

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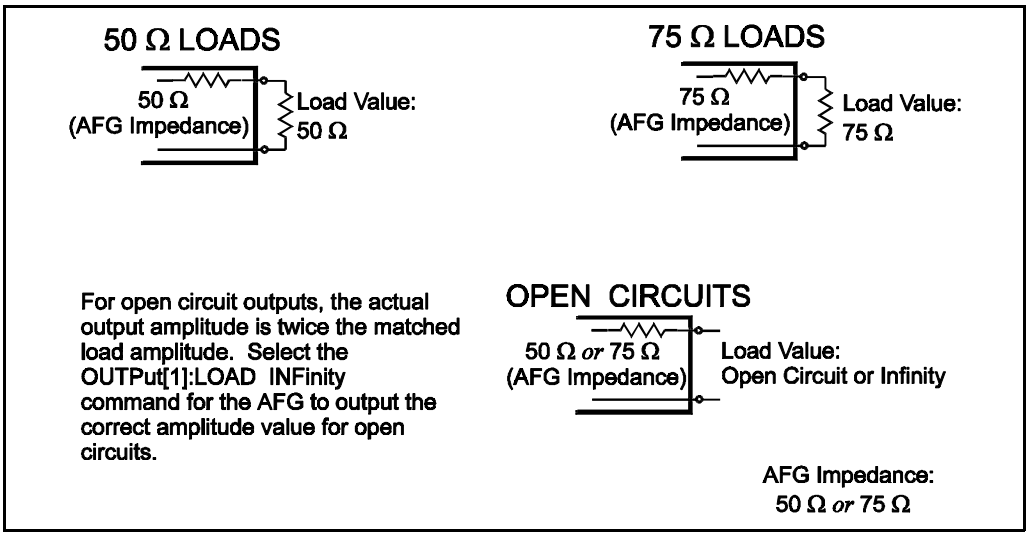
```
450       !Read AFG status byte register and clear service request bit
460       B=SPOLL(@Afg)
470       !End of statement if error occurs among coupled commands
480       OUTPUT @Afg;""
490       OUTPUT @Afg;"ABORT"                !abort output waveform
500       REPEAT
510          OUTPUT @Afg;"SYST:ERR?"         !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.

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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.

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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

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```
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.

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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.

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HP BASIC Program Example (OUTPUNIT)

```
!RE-STORE“OUTPUNIT”
!This programs sets the output amplitude units to volts peak-to-peak
!
!Assign I/O path between the computer and E1445A.
ASSIGN @Afg TO 70910
COM @Afg
!
!Set up error checking
ON INTR 7 CALL Errmsg
ENABLE INTR 7;2
OUTPUT @Afg;“*CLS”
OUTPUT @Afg;“*SRE 32”
OUTPUT @Afg;“*ESE 60”
!
!Call the subprograms
CALL Rst
CALL Out_unit
!
WAIT .1  !allow interrupt to be serviced
OFF INTR 7
END
!
SUB Out_unit
Out_unit:!Subprogram which sets the amplitude units
    COM @Afg
    OUTPUT @Afg;“SOUR:VOLT:LEV:IMM:AMPL:UNIT:VOLT  VPP”    !amplitude units
    OUTPUT @Afg;“SOUR:VOLT:LEV:IMM:AMPL  8;”;                !amplitude
    OUTPUT @Afg;“:SOUR:VOLT:LEV:IMM:OFFS  1”                 !offset
    OUTPUT @Afg;“INIT:IMM”                                   !wait-for-arm state
SUBEND
!
SUB Rst
Rst:   !Subprogram which resets the E1445.
    COM @Afg
    OUTPUT @Afg;"*RST;*OPC?"                                 !reset the AFG
    ENTER @Afg;Complete
SUBEND
!
SUB Errmsg
Errmsg:  !Subprogram which displays E1445 programming errors
    COM @Afg
    DIM Message$[256]
    !Read AFG status byte register and clear service request bit
    B=SPOLL(@Afg)
    !End of statement if error occurs among coupled commands
    OUTPUT @Afg;""
    OUTPUT @Afg;"ABORT"                                      !abort output waveform
    REPEAT
```

Continued on Next Page

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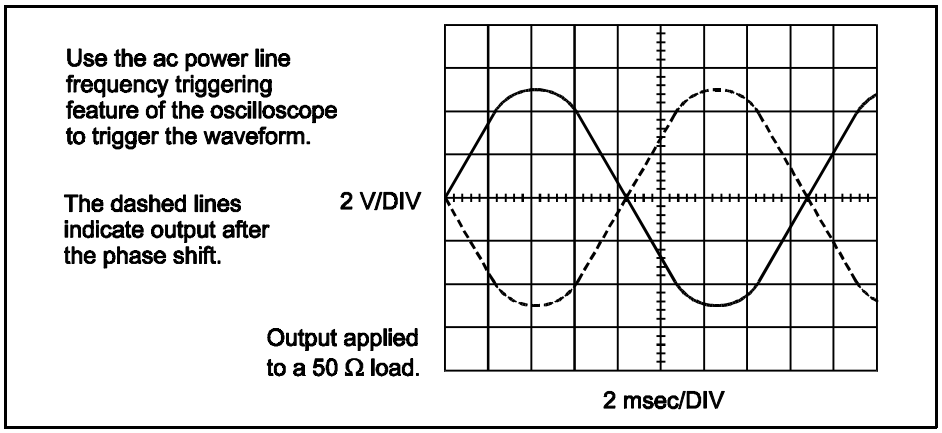
```
460             OUTPUT @Afg;"SYST:ERR?"          !read AFG error queue
470             ENTER @Afg;Code,Message$
480             PRINT   Code,Message$
490         UNTIL Code=0
500         STOP
510     SUBEND
```

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.

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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.

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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 (– Π to + Π) or –180° to +180°. (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
```

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```
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.

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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 the 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)

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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.

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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

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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.

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Notes

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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

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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.

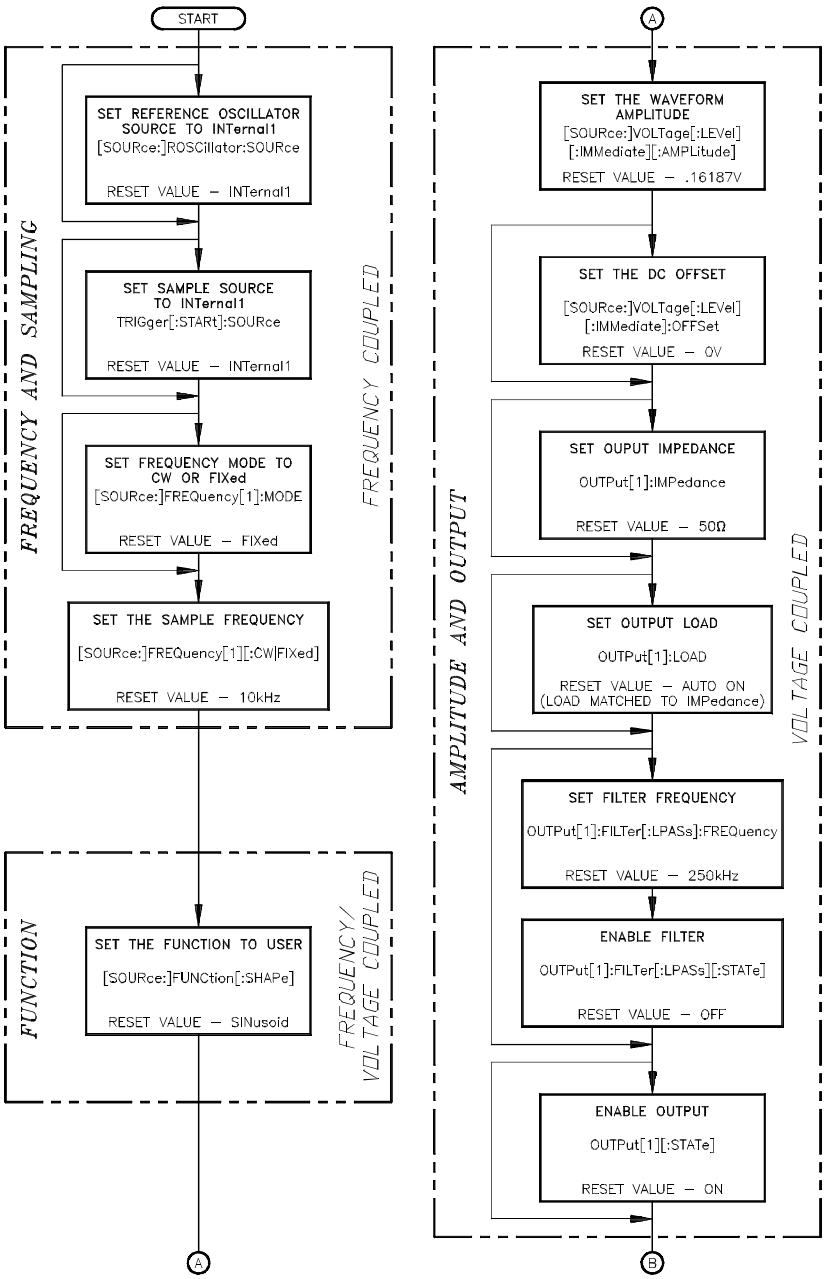


Figure 3-1. Commands for Generating Arbitrary Waveforms
(*continued on next page*)

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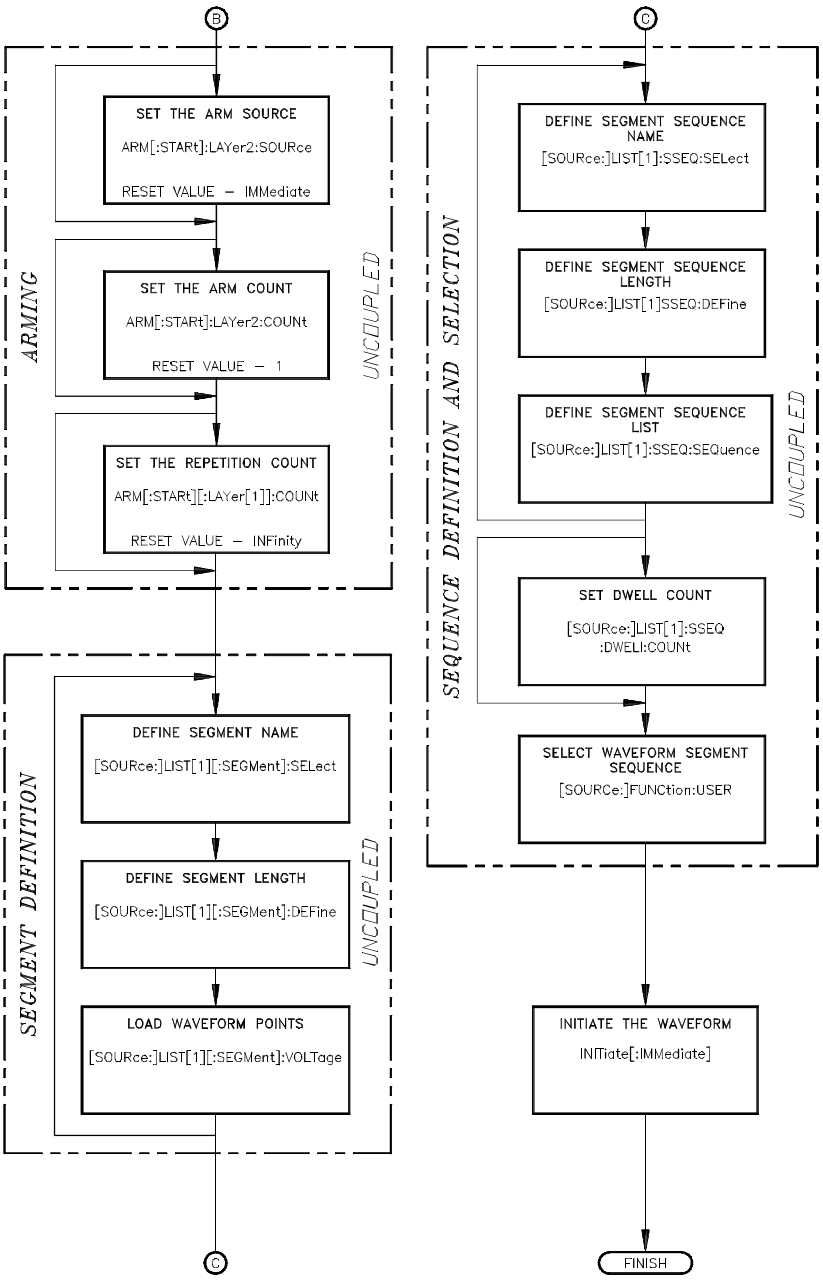


Figure 3-1. Commands for Generating Arbitrary Waveforms
(*continued from previous page*)

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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.

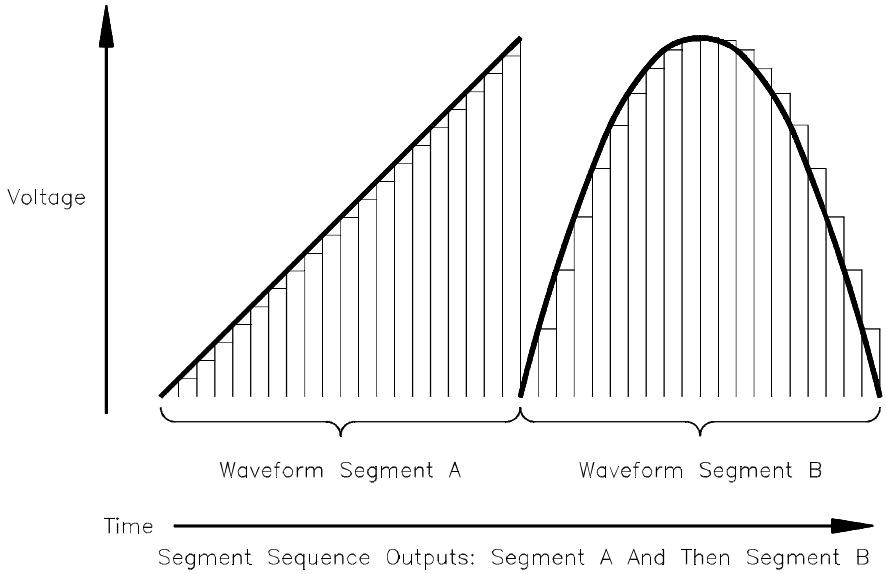


Figure 3-2. Generating Arbitrary Waveforms

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.

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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.

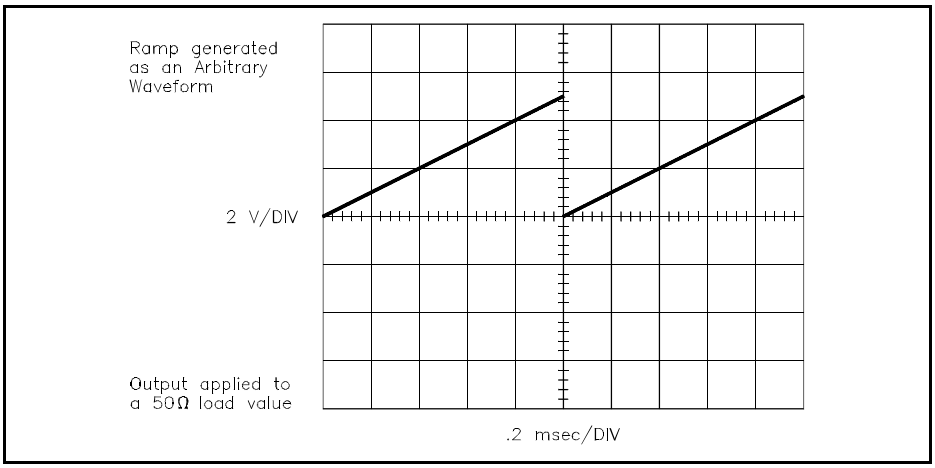
The waveform segment names in a segment sequence can either be sent as names or as an address value (see Chapter 7 for more information).

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.

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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).

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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:

   (sample frequency) / (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.

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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).

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HP BASIC Program Example (ARBWAVE)

```
!RE-STORE"ARBWAVE"
!This program demonstrates the procedure for developing and
!outputting an arbitrary waveform.
!
!Assign I/O path between the computer and E1445A.
ASSIGN @Afg TO 70910
COM @Afg,Seg_mem$[256],Seq_mem$[256]
!
!Set up error checking
ON INTR 7 CALL Errmsg
ENABLE INTR 7;2
OUTPUT @Afg;"*CLS"
OUTPUT @Afg;"*SRE 32"
OUTPUT @Afg;"*ESE 60"
!
!Call the subprograms
CALL Rst
CALL Wf_del
!
OUTPUT @Afg;"SOUR:FREQ1:FIX  100E3;";                    !frequency
OUTPUT @Afg;":SOUR:FUNC:SHAP  USER;";                    !function
OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL  5.1V"              !amplitude
!
CALL Ramp_wave
!
OUTPUT @Afg;"SOUR:FUNC:USER  RAMP_OUT"                   !waveform sequence
OUTPUT @Afg;"INIT:IMM"                                   !wait-for-arm state
!
PRINT “Segment memory points available, used: ”;Seg_mem$
PRINT
PRINT “Sequence memory points available, used: ”;Seq_mem$
!
WAIT .1  !allow interrupt to be serviced
OFF INTR 7
END
!
SUB Ramp_wave
Ramp_wave:   !Subprogram which defines a ramp waveform and output
             !sequence.
    COM @Afg,Seg_mem$,Seq_mem$
    DIM Waveform(1:100)                                  !Calculate waveform points
    FOR I=1 TO 100
        Waveform(I)=I*.0505
    NEXT I
    !
    OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL  RAMP"              !segment name
    OUTPUT @Afg;"  SOUR:LIST1:SEGM:DEF  100"             !segment size
    OUTPUT @Afg;"  SOUR:LIST1:SEGM:VOLT ";Waveform(*)  !waveform points
```

Continued on Next Page

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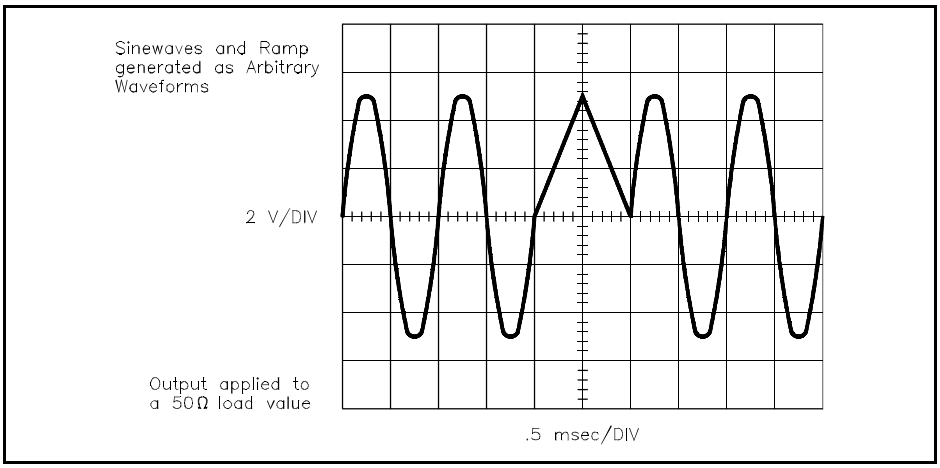
```
450         OUTPUT @Afg;"  SOUR:LIST1:SEGM:FREE?"
460         ENTER @Afg;Seg_mem$
470         !
480         OUTPUT @Afg;"SOUR:LIST1:SSEQ:SEL  RAMP_OUT"    !sequence name
490         OUTPUT @Afg;"  SOUR:LIST1:SSEQ:DEF  1"          !sequence size
500         OUTPUT @Afg;"  SOUR:LIST1:SSEQ:SEQ  RAMP"       !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,Seg_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,Seg_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,Seg_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.

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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:

   (sample frequency) / (number of points)

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

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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.

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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.

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HP BASIC Program Example (MULSEG)

```
!RE-STORE"MULSEG"
!This program outputs an arbitrary waveform that is comprised of
!two waveform segments.
!
!Assign I/O path between the computer and E1445A.
ASSIGN @Afg TO 70910
COM @Afg
!
!Set up error checking
ON INTR 7 CALL Errmsg
ENABLE INTR 7;2
OUTPUT @Afg;"*CLS"
OUTPUT @Afg;"*SRE 32"
OUTPUT @Afg;"*ESE 60"
!
!Call the subprograms which reset the AFG and clear segment
!and sequence memory.
CALL Rst
CALL Wf_del
!Set the signal frequency, the function, and the amplitude.
OUTPUT @Afg;"SOUR:FREQ1:FIX  2.048E6;";
OUTPUT @Afg;":SOUR:FUNC:SHAP  USER;";
OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL  5.1V"
!Call the subprograms which define the triangle wave, sine wave,
!and output waveform sequence.
CALL Tri_wave
CALL Sine_wave
CALL Seq_def
!Select the output sequence and start the waveform.
OUTPUT @Afg;"SOUR:FUNC:USER  WAVE_OUT"
OUTPUT @Afg;"INIT:IMM"
!
WAIT .1  !allow interrupt to be serviced
OFF INTR 7
END
!
SUB Tri_wave
Tri_wave:    !Subprogram which defines a triangle waveform and stores
             !it in a segment
    COM @Afg
    DIM Waveform(1:2048)                          !Calculate waveform points
    FOR I=1 TO 2048
        IF I<1024 THEN
            Waveform(I)=I*.0048828
        ELSE
            Waveform(I)=(2048-I)*.0048828
        END IF
    NEXT I
```

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```
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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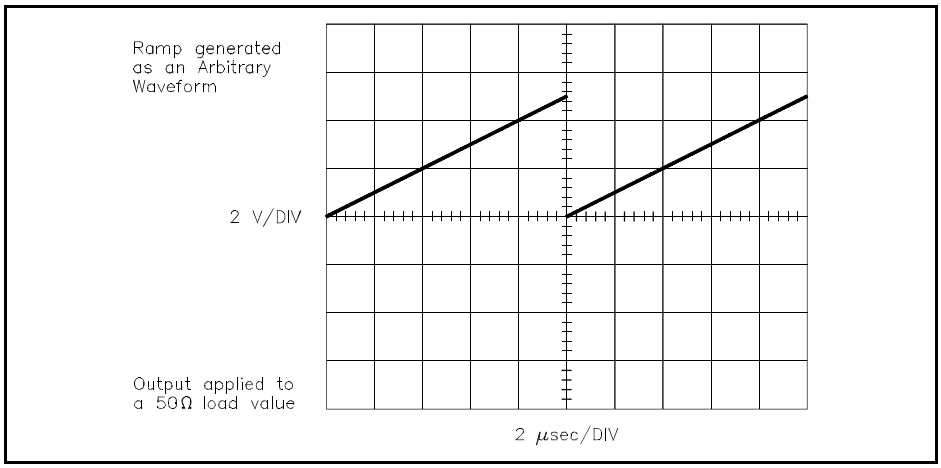
```
950         !End of statement if error occurs among coupled commands
960         OUTPUT @Afg;""
970         OUTPUT @Afg;"ABORT"                 !abort output waveform
980         REPEAT
990            OUTPUT @Afg;"SYST:ERR?"          !read AFG error queue
1000           ENTER @Afg;Code,Message$
1010           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.

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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.

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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.

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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.

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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        !
```

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```
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.

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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

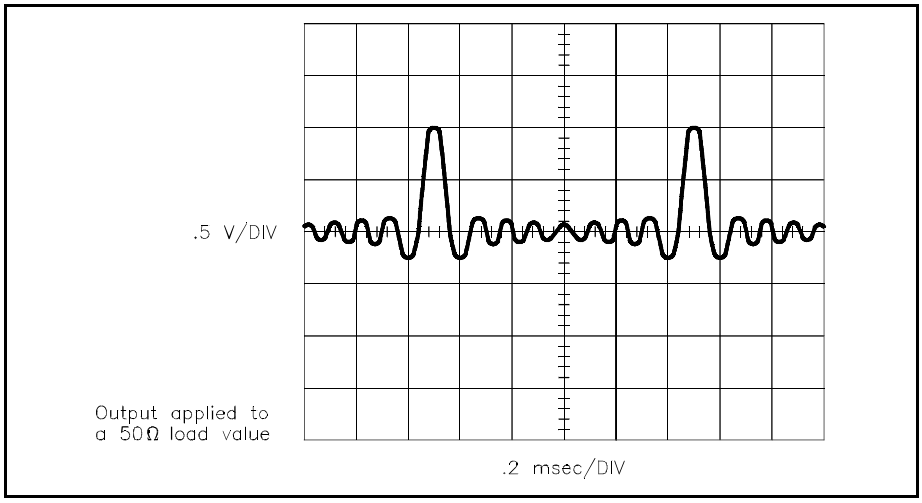
The programs in this section generate various arbitrary waveforms. All programs output waveforms at a 1 kHz repetition frequency and 5 V amplitude. These programs do not delete any waveform segments and segment sequences stored in memory. Thus, once a program is executed, it generates Error +1100,"Illegal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

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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

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```
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
```

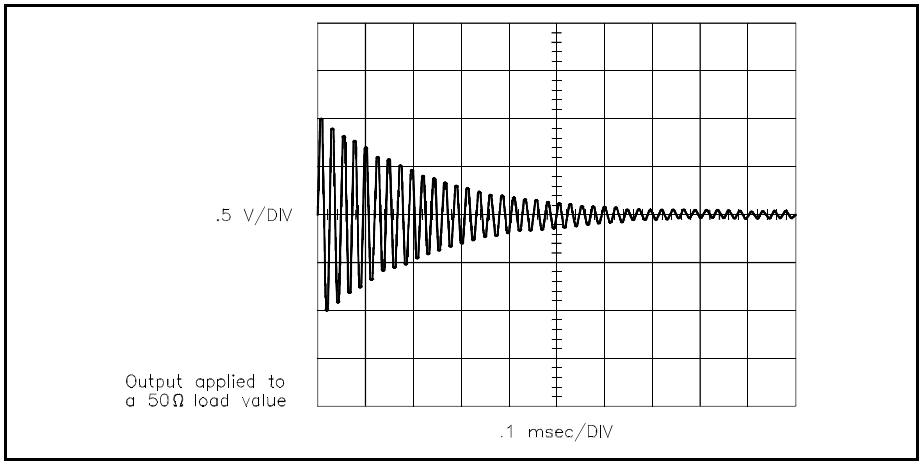
Visual BASIC and Visual C/C++ Program Versions

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.

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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     !RE-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
```

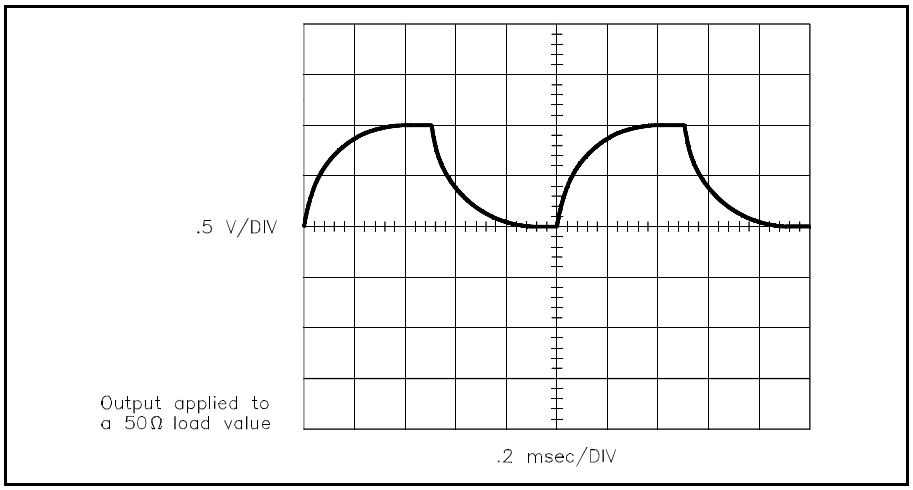

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Visual BASIC and Visual C/C++ Program Versions

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
```

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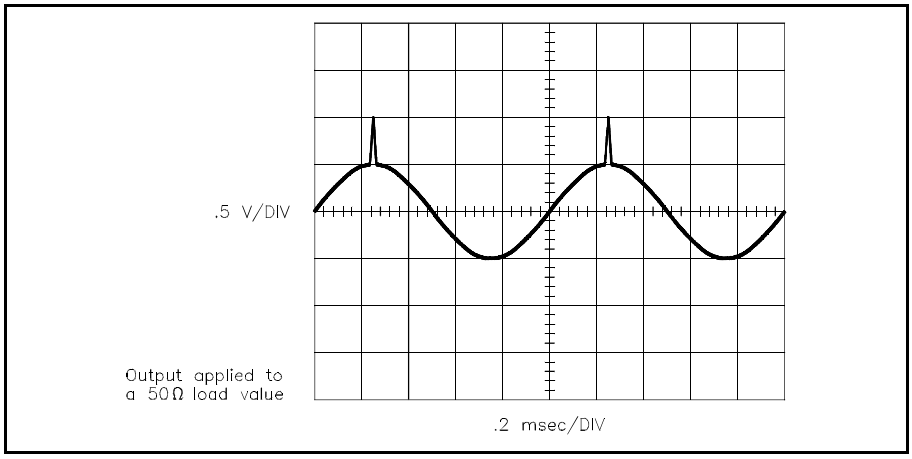
```
380           IF T>=2047 THEN
390              Waveform(T)=1*(1-EXP(-2048/Rc))-1*(1-EXP(-(T-2047)/Rc))
400           END IF
410        NEXT T
420        OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL  CHARGE"  !select segment to be defined
430        OUTPUT @Afg;"SOUR:LIST1:SEGM:DEF  4096"       !reserve memory 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     !RE-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

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```
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
```

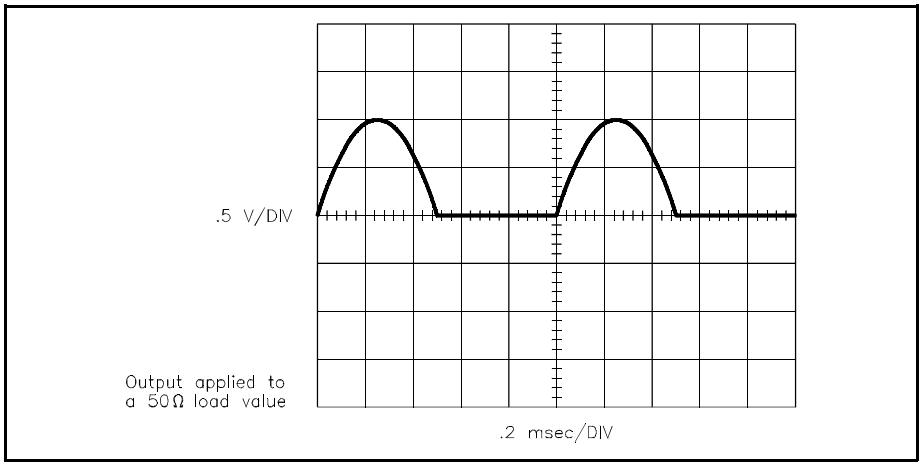
Visual BASIC and Visual C/C++ Program Versions

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.

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Generating a ½ 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     !RE-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
```


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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.

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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.

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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 illustrates 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).

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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)

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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.

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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:

- FSK Programming Flowchart . . . . . Page 118
  - 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
  - FSK Using an Arbitrary Waveform . . . . . Page 152

- 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
  - Frequency Points . . . . . Page 157
  - Sweep Spacing. . . . . Page 157
  - Sweep Direction . . . . . Page 157
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  - Output Frequency and Sample Rate . . . . . Page 160
  - AC Leveling . . . . . Page 160
  - FSK Control Sources. . . . . Page 161
  - Frequency-Shift Delay . . . . . Page 162
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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.

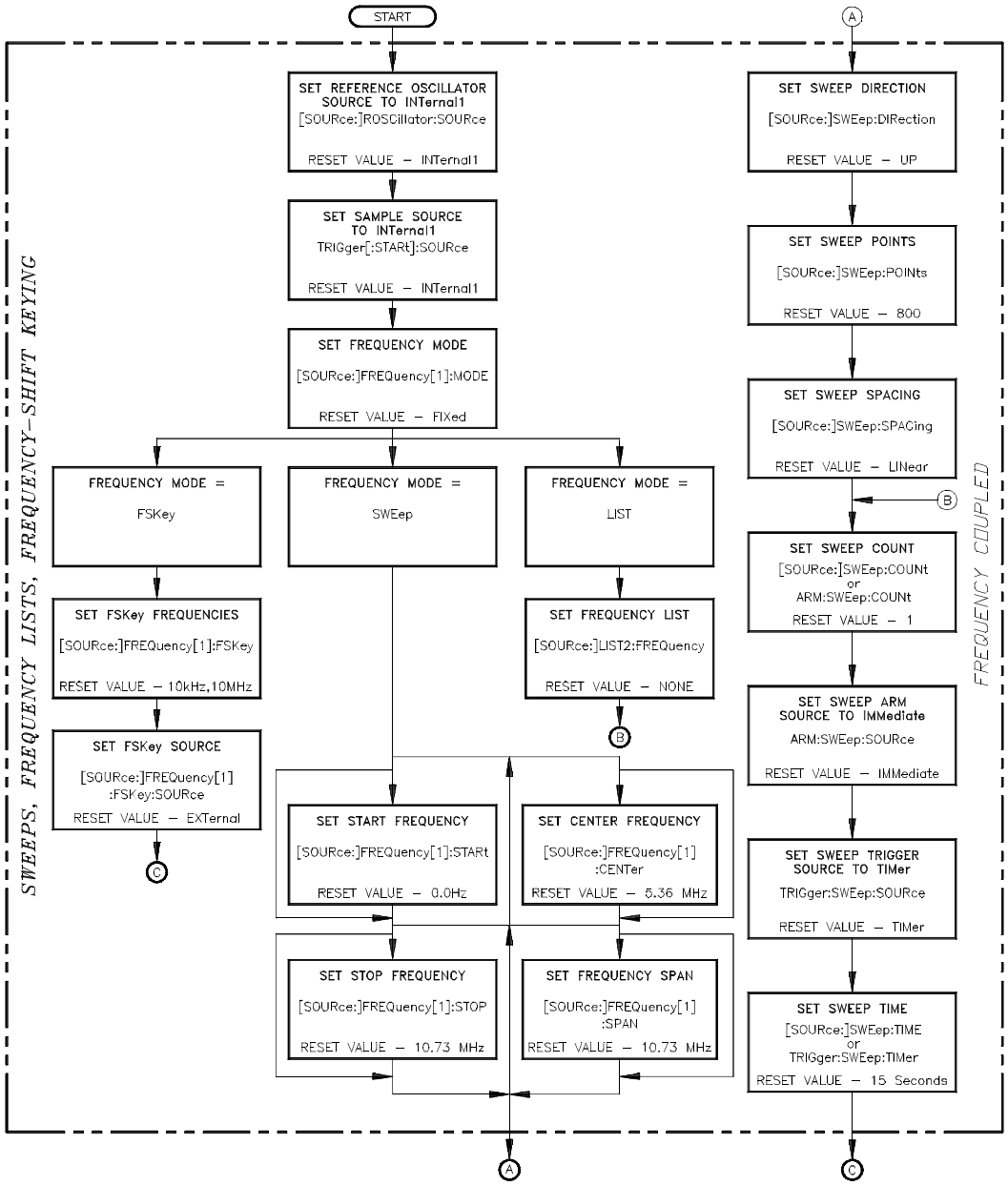


Figure 4-1. Commands for Frequency Sweeps, Frequency Lists, and FSK Keying
(*continued on next page*)

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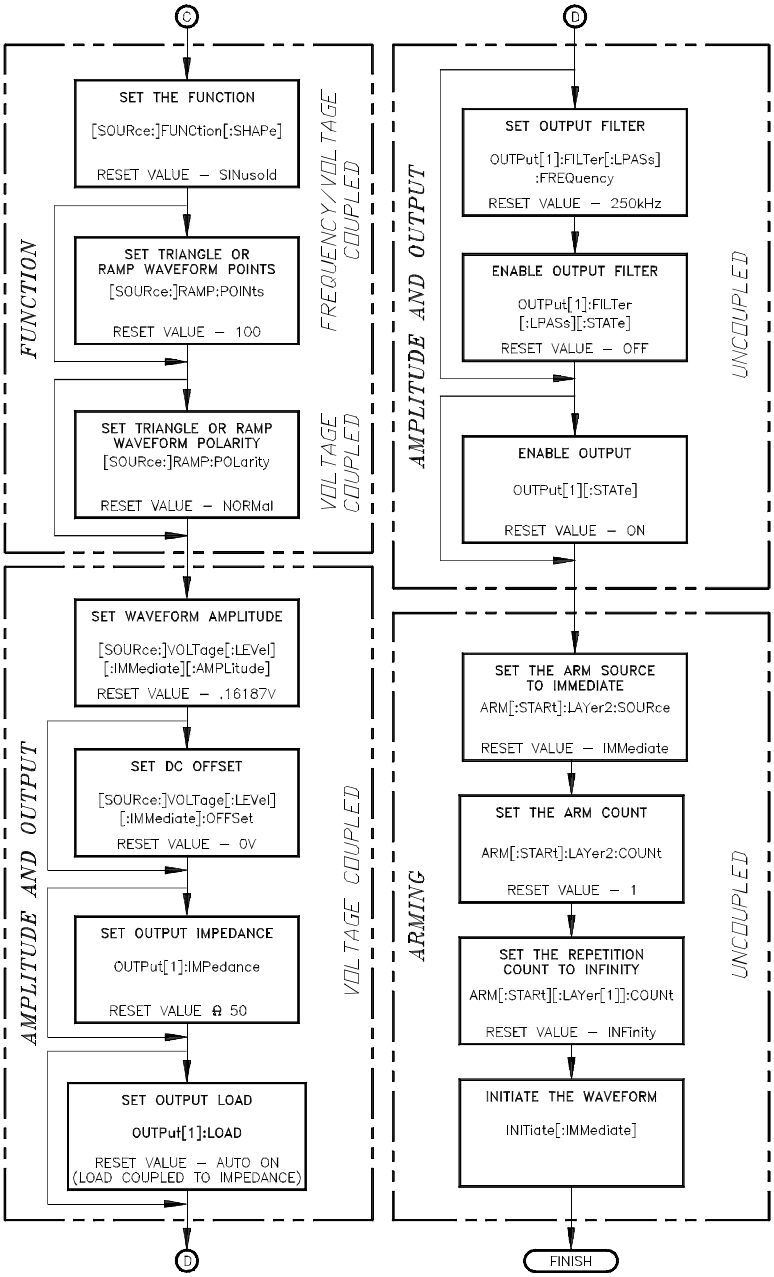


Figure 4-1. Commands for Frequency Sweeps, Frequency Lists, and FSK Keying
(*continued from previous page*)

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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.

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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]

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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

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```
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$
790         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.

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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]

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HP BASIC Program Example (LIST1)

```
    !RE-STORE “LIST1”
    !The following program outputs the frequencies 1 kHz, 10 kHz,
    !100 kHz, and 1 MHz in a (default) period of 1 second.
    !
    !Assign I/O path between the computer and E1445A.
    ASSIGN @Afg TO 70910
    COM @Afg
    !
    !Set up error checking
    ON INTR 7 CALL Errmsg
    ENABLE INTR 7;2
    OUTPUT @Afg;"*CLS"
    OUTPUT @Afg;"*SRE 32"
    OUTPUT @Afg;"*ESE 60"
    !
    !Call the subprograms
    CALL Rst
    CALL List1
    CALL List_length
    !
    WAIT .1  !allow interrupt to be serviced
    OFF INTR 7
    END
    !
    SUB List1
List1:  !Subprogram which outputs a frequency list
        COM @Afg
        OUTPUT @Afg;"SOUR:ROSC:SOUR  INT1;";              !reference oscillator
        OUTPUT @Afg;":TRIG:STAR:SOUR  INT1;";             !frequency1 generator
        OUTPUT @Afg;":SOUR:FREQ1:MODE  LIST;";            !list mode
        OUTPUT @Afg;"  :SOUR:LIST2:FREQ 1E3,10E3,100E3,1E6;";   !freq list
        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
    !
    SUB Rst
Rst:    !Subprogram which resets the E1445.
        COM @Afg
        OUTPUT @Afg;"*RST;*OPC?"                          !reset the AFG
        ENTER @Afg;Complete
    SUBEND
    !
    SUB List_length
List_length:  !Subprogram which queries frequency list length
        COM @Afg
        OUTPUT @Afg;"SOUR:LIST2:FREQ:POIN?"
```

Continued on Next Page

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```
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.

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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]

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HP BASIC Program Example (SMPLSWP2)

```
    !RE-STORE"SMPLSWP2"
    !This program continuously sweeps from 1 kHz to 21 kHz and specifies
    !a start frequency and a frequency span.
    !
    !Assign I/O path between the computer and E1445A.
    ASSIGN @Afg TO 70910
    COM @Afg
    !
    !Set up error checking
    ON INTR 7 CALL Errmsg
    ENABLE INTR 7;2
    OUTPUT @Afg;"*CLS"
    OUTPUT @Afg;"*SRE 32"
    OUTPUT @Afg;"*ESE 60"
    !
    !Call the subprograms
    CALL Rst
    CALL Sweep2
    CALL Query
    !
    WAIT .1  !allow interrupt to be serviced
    OFF INTR 7
    END
    !
    SUB Sweep2
Sweep2: !Subprogram which outputs a swept sine wave from 1 kHz to
            !21 kHz.
        COM @Afg
        OUTPUT @Afg;"SOUR:FREQ1:MODE  SWE;";              !sweep mode
        OUTPUT @Afg;" :SOUR:FREQ1:STAR  1E3;";            !start frequency
        OUTPUT @Afg;" :SOUR:FREQ1:SPAN  20E3;";           !frequency span
        OUTPUT @Afg;":SOUR:SWE:COUN  INF;";               !sweep count
        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
    !
    SUB Rst
Rst:    !Subprogram which resets the E1445.
        COM @Afg
        OUTPUT @Afg;"*RST;*OPC?"                          !reset the AFG
        ENTER @Afg;Complete
    SUBEND
    !
    SUB Query
Query:    !Subprogram which queries sweep parameters
        COM @Afg
        OUTPUT @Afg;"SOUR:FREQ1:CENT?"
```

Continued on Next Page

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```
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.

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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]

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HP BASIC Program Example (LISTDEF)

```
!RE-STORE"LISTDEF"
!This program sends a definite length arbitrary block of frequencies
!to the AFG. Once the AFG receives the frequencies, it steps through
!the list at a rate of one frequency per second.
!
!Assign I/O paths between the computer and E1445A. One path sends
!data in ASCII format to the AFG, the other path sends frequency
!list data to the AFG in binary format.
COM @Afg,@Afg1
ASSIGN @Afg TO 70910 !path for ASCII data
ASSIGN @Afg1 TO 70910;FORMAT OFF                    !path for binary data
!
!Set up error checking
ON INTR 7 CALL Errmsg
ENABLE INTR 7;2
OUTPUT @Afg;"*CLS"
OUTPUT @Afg;"*SRE 32"
OUTPUT @Afg;"*ESE 60"
!
!Call the subprograms
CALL Rst
CALL List1
!
WAIT .1  !allow interrupt to be serviced
OFF INTR 7
END
!
SUB List1
List1:  !Subprogram which downloads a list of 100 frequencies
        !(1 kHz to 100 kHz) in a definite length arbitrary block.
        COM @Afg,@Afg1
        DIM Freqlist(1:100)
        FOR I=1 TO 100
            Freqlist(I)=1000.*I
        NEXT I
        !
        OUTPUT @Afg;"SOUR:ROSC:SOUR  INT1;";          !reference oscillator
        OUTPUT @Afg;":TRIG:STAR:SOUR  INT1;";         !frequency1 generator
        OUTPUT @Afg;":SOUR:FREQ1:MODE  LIST;";        !frequency list mode
        OUTPUT @Afg USING "#,K";":SOUR:LIST2:FREQ  #3800"!download freqs
        OUTPUT @Afg1;Freqlist(*)                      !^ 800 bytes - 3 digits
        OUTPUT @Afg                                   !CR LF
        OUTPUT @Afg;"SOUR:SWE:TIME 100;";             !time (seconds) through list
        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
    !
```

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```
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
630     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.

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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

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```
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.

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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]

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HP BASIC Program Example (SWP_PVST)

```
!RE-STORE"SWP_PVST"
!This program sweeps from 5 kHz to 15 kHz in 0.1 seconds to
!demonstrate how to set the sweep time. The program also sets
!the direction of the sweep.
!
!Assign I/O path between the computer and E1445A.
ASSIGN @Afg TO 70910
COM @Afg
!
!Set up error checking
ON INTR 7 CALL Errmsg
ENABLE INTR 7;2
OUTPUT @Afg;"*CLS"
OUTPUT @Afg;"*SRE 32"
OUTPUT @Afg;"*ESE 60"
!
!Call the subprograms
CALL Rst
CALL Swp_pvst
!
WAIT .1  !allow interrupt to be serviced
OFF INTR 7
END
!
SUB Swp_pvst
Swp_pvst:   !Subprogram which sets sweep direction, points, and time
    COM @Afg
    OUTPUT @Afg;"SOUR:FREQ1:MODE SWE;";              !sweep mode
    OUTPUT @Afg;"  :SOUR:FREQ1:STAR  5E3;";          !start frequency
    OUTPUT @Afg;"  :SOUR:FREQ1:STOP  15E3;";         !stop frequency
    OUTPUT @Afg;"  :SOUR:SWEEP:DIR DOWN;";           !sweep direction
    OUTPUT @Afg;"  :SOUR:SWEEP:POIN 100;";           !sweep points
    OUTPUT @Afg;"  :SOUR:SWE:COUN  INF;";            !sweep count
    OUTPUT @Afg;"  :TRIG:SWE:SOUR  TIM;";            !sweep advance source
    OUTPUT @Afg;"  :SOUR:SWE:TIME  .12375;";         !sweep time
    OUTPUT @Afg;":SOUR:FUNC:SHAP  SIN;";             !function
    OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL  5 V"       !amplitude
    OUTPUT @Afg;"INIT:IMM"                           !wait-for-trigger state
SUBEND
!
SUB Rst
Rst:   !Subprogram which resets the E1445.
    COM @Afg
    OUTPUT @Afg;"*RST;*OPC?"                         !reset the AFG
    ENTER @Afg;Complete
SUBEND
!
SUB Errmsg
```

Continued on Next Page

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```
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.

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Frequency Lists Versus Time

To demonstrates 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:]FUNCtion[: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]

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HP BASIC Program Example (LIST_TME)

```
    !RE-STORE"LIST_TME"
    !The following program steps through a frequency list at a rate
    !such that a new frequency is output every 1 second.
    !
    !Assign I/O path between the computer and E1445A.
    ASSIGN @Afg TO 70910
    COM @Afg
    !
    !Set up error checking
    ON INTR 7 CALL Errmsg
    ENABLE INTR 7;2
    OUTPUT @Afg;"*CLS"
    OUTPUT @Afg;"*SRE 32"
    OUTPUT @Afg;"*ESE 60"
    !
    !Call the subprograms
    CALL Rst
    CALL List_time
    !
    WAIT .1  !allow interrupt to be serviced
    OFF INTR 7
    END
    !
    SUB List_time
List_count:  !Subprogram which continuously outputs a frequency list
             !in which the frequencies are 1s apart
        COM @Afg
        OUTPUT @Afg;"SOUR:FREQ1:MODE  LIST;";              !list mode
        OUTPUT @Afg;"  :SOUR:LIST2:FREQ  2.5E3,5E3,7.5E3,10E3;";!freq list
        OUTPUT @Afg;"  :SOUR:SWE:COUN  INF;";          !hop through list continuously
        OUTPUT @Afg;":TRIG:SWE:SOUR  TIM;";               !list advance source
        OUTPUT @Afg;"  :SOUR:SWE:TIME  3;";               !time through list
        OUTPUT @Afg;":SOUR:FUNC:SHAP  TRI;";              !function
        OUTPUT @Afg;":SOUR:RAMP:POIN  1E3;";              !1000 point waveform
        OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL  5 V"        !amplitude
        OUTPUT @Afg;"INIT:IMM"                            !wait-for-arm state
    SUBEND
    !
    SUB Rst
Rst:   !Subprogram which resets the E1445.
        COM @Afg
        OUTPUT @Afg;"*RST;*OPC?"                          !reset the AFG
        ENTER @Afg;Complete
    SUBEND
    !
    SUB Errmsg
Errmsg:  !Subprogram which displays E1445 programming errors
        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, 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.

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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)

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

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```
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
```


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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]

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HP BASIC Program Example (SWP_LEVL)

```
    !RE-STORE"SWP_LEVL"
    !This program enables output leveling over the 0 Hz to 10 MHz
    !sweep.
    !
    !Assign I/O path between the computer and E1445A.
    ASSIGN @Afg TO 70910
    COM @Afg
    !
    !Set up error checking
    ON INTR 7 CALL Errmsg
    ENABLE INTR 7;2
    OUTPUT @Afg;"*CLS"
    OUTPUT @Afg;"*SRE 32"
    OUTPUT @Afg;"*ESE 60"
    !
    !Call the subprograms
    CALL Rst
    CALL Swp_levl
    !
    WAIT .1  !allow interrupt to be serviced
    OFF INTR 7
    END
    !
    SUB Swp_levl
Swp_levl:   !Subprogram which sets output leveling for sweeping from
            !0 TO 10 MHz
        COM @Afg
        OUTPUT @Afg;"SOUR:FREQ1:MODE  SWE;";          !sweep mode
        OUTPUT @Afg;"  :SOUR:FREQ1:STAR  0;";         !start frequency
        OUTPUT @Afg;"  :SOUR:FREQ1:STOP  10E6;";      !stop frequency
        OUTPUT @Afg;"  :SOUR:SWE:COUN  INF;";         !sweep count
        OUTPUT @Afg;":SOUR:FUNC:SHAP  SIN;";          !function
        OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL  5 V"    !amplitude
        OUTPUT @Afg;"OUTP1:FILT:LPAS:FREQ  10 MHZ"    !filter cutoff frequency
        OUTPUT @Afg;"OUTP1:FILT:LPAS:STAT  ON"        !enable output filter
        OUTPUT @Afg;"INIT:IMM"                        !wait-for-arm state
    SUBEND
    !
    SUB Rst
Rst:    !Subprogram which resets the E1445.
        COM @Afg
        OUTPUT @Afg;"*RST;*OPC?"                      !reset the AFG
        ENTER @Afg;Complete
    SUBEND
    !
    SUB Errmsg
Errmsg:  !Subprogram which displays E1445 programming errors
        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_LEVL.FRM, is in directory "VBPROG" and the Visual C example program, SWP_LEVL.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

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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*>

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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.

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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

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```
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
```

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```
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

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```
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
```

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```
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.

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- **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 (Rosc/(4*npts)).

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.

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- **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:

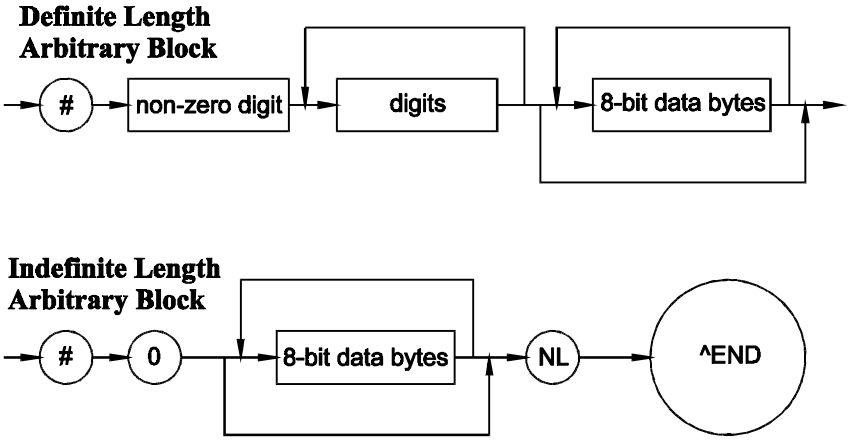


Figure 4-2. Arbitrary Block Data Diagram

- "#" 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'.

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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.

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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:

TIME = TIMer * (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

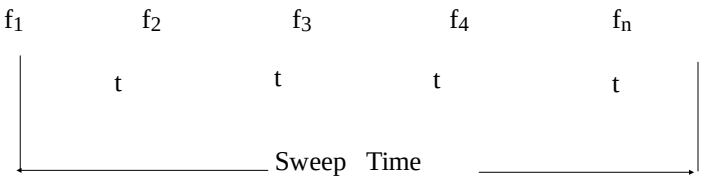
The source which advances the sweep or list to the next frequency is set with the TRIGger:SWEep:SOURce command. The available sources are:

- **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:

specified sweep time/(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:

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

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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:

MINimum = 1.25 mS * (points - 1)
MAXimum = 4.19430375 S * (points - 1)

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

(points -1)/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:

Rosc/(4*npts) = 42.94967296E6 / (4 * 1000) = 10.7374 kHz

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Output Frequency and Sample Rate

The output frequency of an arbitrary waveform is defined as:

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

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 (freq$_1$ to freq$_2$) of 10% and 1% from the filter's cutoff frequency.

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Table 4-1. Amplitude Errors Versus Settling Times

Error in Volts	Settling Time (ms)	% Error	dB Error
Amplitude = 5 Vpk, 10 MHz filter, frequency change =10 %, $Freq_1$ = 10.7 MHz, $Freq_2$ = 0.9 * $Freq_1$			
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 * $Freq_1$			
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 * $Freq_1$			
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 * $Freq_1$			
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***.

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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.

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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:

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- Initiating Waveforms . . . . . Page 165
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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.

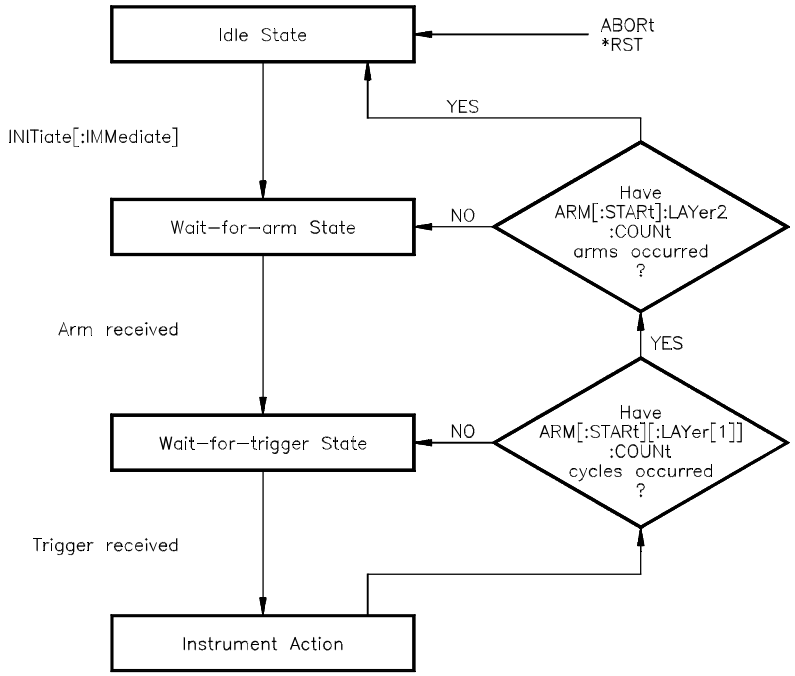


Figure 5-1. The ARM-TRIG Triggering Model

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.

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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>
```


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

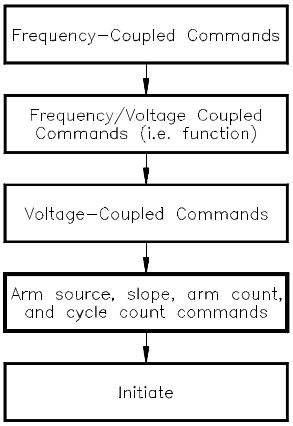


Figure 5-2. AFG Arming Command Sequence

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:]FUNCtion[:SHAPe] <*shape*>
4. **Set the signal amplitude**
   [SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude] <*amplitude*>

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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

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```
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

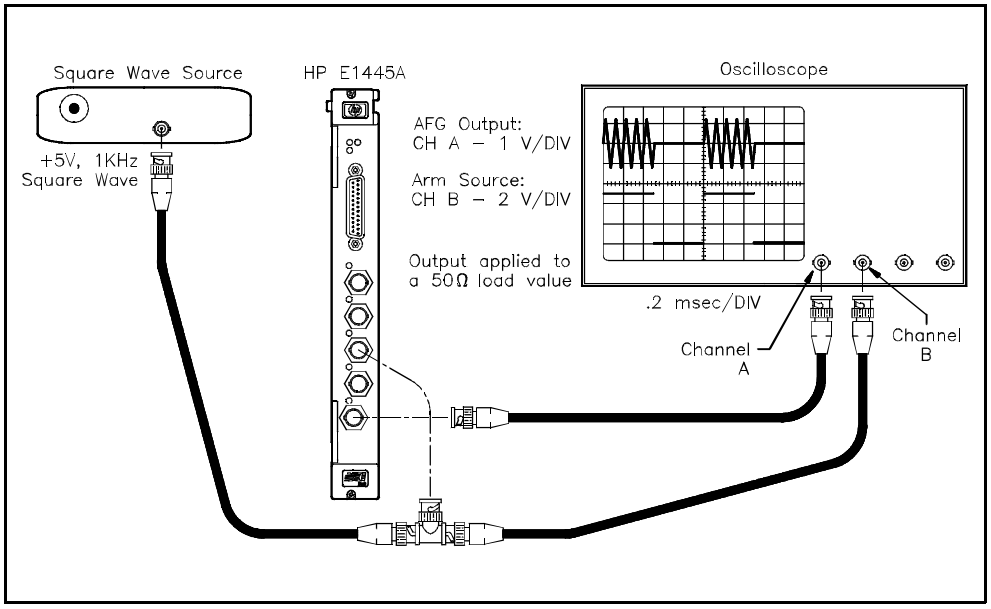
The Visual BASIC example program, EXT_ARM.FRM, is in directory "VBPROG" and the Visual C example program, EXT_ARM.C, is in directory "VCPROG" on the CD that came with your HP E1445A.

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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]

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HP BASIC Program Example (BURST)

```
    !RE-STORE"BURST"
    !This program sets the arm count to infinity, and the cycle count
    !count to 5. The arm source is set to external and a 1 kHz square
    !wave is applied to the AFG's "Start Arm In" BNC connector. The
    !AFG outputs a 5 cycle burst on each positive edge of the external
    !arm signal.
    !
    !Assign I/O path between the computer and E1445A.
    ASSIGN @Afg TO 70910
    COM @Afg
    !
    !Set up error checking
    ON INTR 7 CALL Errmsg
    ENABLE INTR 7;2
    OUTPUT @Afg;"*CLS"
    OUTPUT @Afg;"*SRE 32"
    OUTPUT @Afg;"*ESE 60"
    !
    !Call the subprograms
    CALL Rst
    CALL Burst_arm
    !
    WAIT .1  !allow interrupt to be serviced
    OFF INTR 7
    END
    !
    SUB Burst_arm
Burst_arm:  !Subprogram which outputs a 5 cycle burst on each
            !positive edge of an external arm signal.
        COM @Afg
        OUTPUT @Afg;"SOUR:FREQ1:FIX  10E3;";                !burst frequency
        OUTPUT @Afg;":SOUR:FUNC:SHAP  SIN;";                !function
        OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL  2.5VPP"       !amplitude
        OUTPUT @Afg;"ARM:STAR:LAY2:SOUR  EXT"               !arm source
        OUTPUT @Afg;"ARM:STAR:LAY2:SLOP  POS"               !arm slope
        OUTPUT @Afg;"  ARM:STAR:LAY2:COUN  INF"             !arm count
        OUTPUT @Afg;"  ARM:STAR:LAY1:COUN  5"               !cycle count
        OUTPUT @Afg;"INIT:IMM"                              !wait-for-arm state
    SUBEND
    !
    SUB Rst
Rst:    !Subprogram which resets the E1445.
        COM @Afg
        OUTPUT @Afg;" *RST;*OPC?                            !reset the AFG
        ENTER @Afg;Complete
    SUBEND
    !
    SUB Errmsg
```

Continued on Next Page

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```
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.

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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.

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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.

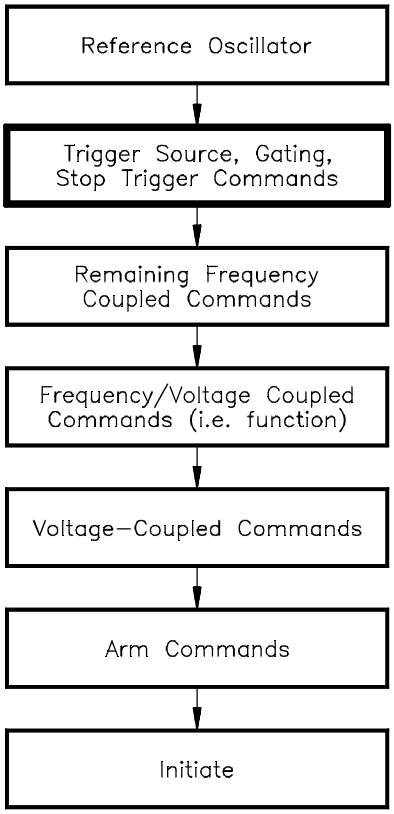


Figure 5-3. AFG Triggering Command Sequence

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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

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```
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
```

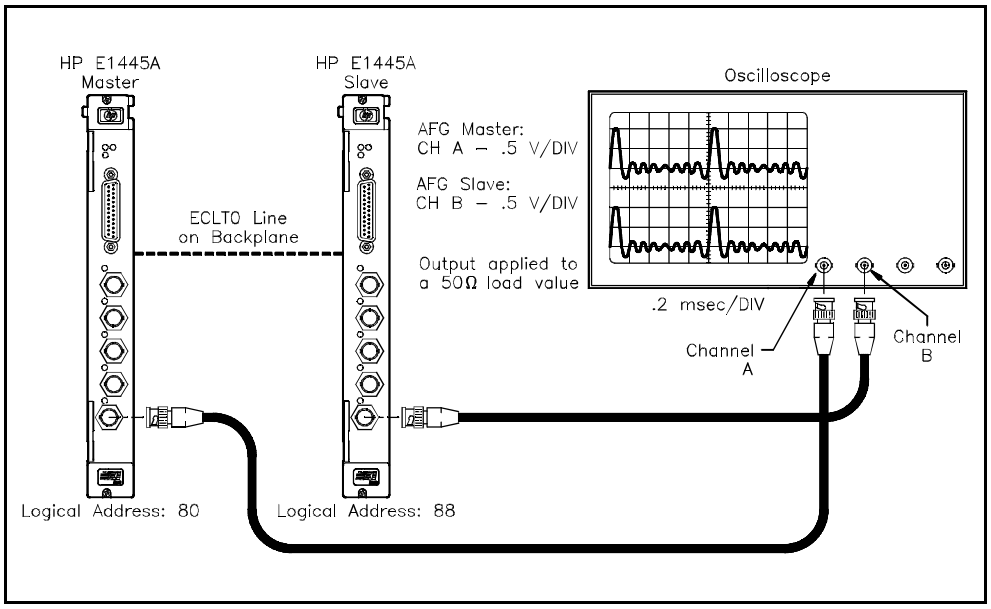
Visual BASIC and Visual C/C++ Program Versions

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.

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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*>

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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
```

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```
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.
```

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```
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
```

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```
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*>

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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
```

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```
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.

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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]

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HP BASIC Program Example (GATE)

```
    !RE-STORE"GATE"
    !The following program gates the output of a 40 point triangle
    !wave whose frequency is 1 MHz. When the signal on the “Gate In” BNC
    !is high, the gate is active and the output is suspended at the last
    !amplitude point triggered. When the signal is low, the gate is inactive
    !and the waveform resumes.
    !
    !Assign I/O path between the computer and E1445A.
    ASSIGN @Afg TO 70910
    COM @Afg
    !
    !Set up error checking
    ON INTR 7 CALL Errmsg
    ENABLE INTR 7;2
    OUTPUT @Afg;"*CLS"
    OUTPUT @Afg;"*SRE 32"
    OUTPUT @Afg;"*ESE 60"
    !
    !Call the subprograms
    CALL Rst
    CALL Tri_wave
    !
    WAIT .1  !allow interrupt to be serviced
    OFF INTR 7
    END
    !
    SUB Tri_wave
Tri_wave:    !Subprogram which outputs a triangle wave
        COM @Afg
        OUTPUT @Afg;"SOUR:ROSC:SOUR  INT2;";          !reference oscillator
        OUTPUT @Afg;":TRIG:STAR:SOUR  INT2;";         !frequency2 generator
        OUTPUT @Afg;" :TRIG:STAR:GATE:SOUR  EXT;";    !gate source
        OUTPUT @Afg;" :TRIG:STAR:GATE:POL  NORM;";    !gate polarity
        OUTPUT @Afg;" :TRIG:STAR:GATE:STAT  ON;";     !enable gate
        OUTPUT @Afg;":SOUR:FREQ2:FIX  1E6;";          !frequency
        OUTPUT @Afg;":SOUR:FUNC:SHAP  TRI;";          !function
        OUTPUT @Afg;":SOUR:RAMP:POIN  40;";           !waveform points
        OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL  5V"     !amplitude
        OUTPUT @Afg;"INIT:IMM"                        !wait-for-arm state
    SUBEND
    !
    SUB Rst
Rst:    !Subprogram which resets the E1445.
        COM @Afg
        OUTPUT @Afg;" *RST;*OPC?                      !reset the AFG
        ENTER @Afg;Complete
    SUBEND
    !
```

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```
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.

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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

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 points

The SWP_TRIG program shows how to output a sweep using a user selected trigger mode.

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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:]FUNCtion[: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

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HP BASIC Program Example (SWP_TRIG)

```
    !RE-STORE"SWP_TRIG"
    !This program triggers a sweep using the Group Execute
    !Trigger command. The sweep is from 1 kHz to 1 MHz.
    !
    !Assign I/O path between the computer and E1445A.
    ASSIGN @Afg TO 80910.
    COM @Afg
    !
    !Set up error checking
    ON INTR 8 CALL Errmsg
    ENABLE INTR 8;2
    OUTPUT @Afg;"*CLS"
    OUTPUT @Afg;"*SRE 32"
    OUTPUT @Afg;"*ESE 60"
    !
    !Call the subprograms
    CALL Rst
    CALL Swp_trig
    !
    WAIT .1  !allow interrupt to be serviced
    OFF INTR 8
    END
    !
    SUB Swp_trig
Swp_trig:    !Subprogram that triggers a sweep
        COM @Afg
        OUTPUT @Afg;"SOUR:FREQ1:MODE  SWE;";          !Sweep mode
        OUTPUT @Afg;"  :SOUR:FREQ1:STAR  1E3;";       !start frequency
        OUTPUT @Afg;"  :SOUR:FREQ1:STOP  1E6;";       !stop frequency
        OUTPUT @Afg;"  :SOUR:SWE:COUN  INF;";         !repetition count
        OUTPUT @Afg;"  :SOUR:SWE:POIN  100;";         !frequency points
        OUTPUT @Afg;"  :SOUR:SWE:TIME  .13"           !sweep time
        OUTPUT @Afg;"ARM:SWE:SOUR  LINK"              !trigger mode
        OUTPUT @Afg;"ARM:STAR:LAY1:COUN  65536"       !waveform repetitions
        OUTPUT @Afg;"ARM:STAR:LAY2:COUN  INF"         !waveform starts
        OUTPUT @Afg;"ARM:STAR:LAY2:SOUR  BUS"         !trigger source
        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
        CALL Step
    SUBEND
    !
    SUB Step
Step:  !Subprogram which starts sweep
        COM @Afg
        DISP “Press ’Continue’ when ready to start a sweep”
        PAUSE
        TRIGGER @Afg                                  !trigger AFG
```

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```
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.

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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]

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HP BASIC Program Example (SWP_STEP)

```
    !RE-STORE"SWP_STEP"
    !This program sets the AFG arm source and trigger source to
    !HOLD. The AFG is armed and advanced through the sweep points
    !using “arm immediate” and “trigger immediate” commands.
    !
    !Assign I/O path between the computer and E1445A.
    ASSIGN @Afg TO 70910
    COM @Afg,Pts
    !
    !Set up error checking
    ON INTR 7 CALL Errmsg
    ENABLE INTR 7;2
    OUTPUT @Afg;"*CLS"
    OUTPUT @Afg;"*SRE 32"
    OUTPUT @Afg;"*ESE 60"
    !
    !Call the subprograms
    CALL Rst
    CALL Swp_step
    !
    WAIT .1  !allow interrupt to be serviced
    OFF INTR 7
    END
    !
    SUB Swp_step
Swp_step:   !Subprogram which sets up a sweep from 1 kHz to 10 kHz
            !which is armed and advanced on “IMMediate” command.
        COM @Afg,Pts
        OUTPUT @Afg;"TRIG:STAR:SOUR  INT1;";          !DDS time base
        OUTPUT @Afg;":SOUR:FREQ1:MODE  SWE;";         !sweep mode
        OUTPUT @Afg;"  :SOUR:FREQ1:STAR  1E3;";       !start frequency
        OUTPUT @Afg;"  :SOUR:FREQ1:STOP  10E3;";      !stop frequency
        OUTPUT @Afg;"  :SOUR:SWE:POIN  10;";          !frequency points
        OUTPUT @Afg;"  :ARM:SWE:SOUR  HOLD;";         !suspend sweep arm
        OUTPUT @Afg;"  :TRIG:SWE:SOUR  HOLD;";        !suspend sweep trigger
        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
        CALL Step
    SUBEND
    !
    SUB Step
Step:  !Subprogram which starts and advances sweep
        COM @Afg,Pts
            DISP “Press ’Continue’ to arm trigger system”
            PAUSE
        OUTPUT @Afg;"ARM:SWE:IMM"          !start sweep (sweep does not advance)
        OUTPUT @Afg;"SOUR:SWE:POIN?"       !query number of waveform points
```

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```
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.

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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:SWEep:SOURce <*source*>
5. **Set the source which advances the list to the next frequency**
   TRIGger:SWEep: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]

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HP BASIC Program Example (LIST_STP)

```
    !RE-STORE"LIST_STP"
    !The following program configures the AFG to step through a
    !frequency list when an HP-IB group execute trigger is received.
    !
    !Assign I/O path between the computer and E1445A.
    ASSIGN @Afg TO 70910
    COM @Afg,Pts
    !
    !Set up error checking
    ON INTR 7 CALL Errmsg
    ENABLE INTR 7;2
    OUTPUT @Afg;"*CLS"
    OUTPUT @Afg;"*SRE 32"
    OUTPUT @Afg;"*ESE 60"
    !
    !Call the subprograms
    CALL Rst
    CALL List_stp
    !
    WAIT .1  !allow interrupt to be serviced
    OFF INTR 7
    END
    !
    SUB List_stp
List_stp: !Subprogram which sets up a frequency list which is armed
          !and advanced with HP-IB group execute triggers (TRIGGER 7).
      COM @Afg,Pts
      OUTPUT @Afg;"TRIG:STAR:SOUR  INT1;";                !DDS time base
      OUTPUT @Afg;":SOUR:FREQ1:MODE  LIST;";              !frequency list mode
      OUTPUT @Afg;"  :SOUR:LIST2:FREQ 10E3,20E3,30E3,40E3,50E3;"; !freq list
      OUTPUT @Afg;"  :ARM:SWE:SOUR  BUS;";                !arm on HP-IB trigger
      OUTPUT @Afg;"  :TRIG:SWE:SOUR  BUS;";               !advance on HP-IB trigger
      OUTPUT @Afg;":SOUR:FUNC:SHAP  SQU;";                !function
      OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL  1 V"          !amplitude
      OUTPUT @Afg;"INIT:IMM"                              !wait-for-arm state (10 kHz is output)
      WAIT .1 !wait in case of error
      CALL Step
    SUBEND
    !
    SUB Step
Step:  !Subprogram which starts and advances frequency list
      COM @Afg,Pts
      DISP “Press ’Continue’ to arm trigger system”
      PAUSE
      TRIGGER 7                                           !start frequency list (10 kHz is still output)
    FOR I=1 TO 4                                          !Triggers for the four remaining frequencies
        DISP “Press ’Continue’ to advance to next frequency”
        PAUSE
```

Continued on Next Page

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```
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.

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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.

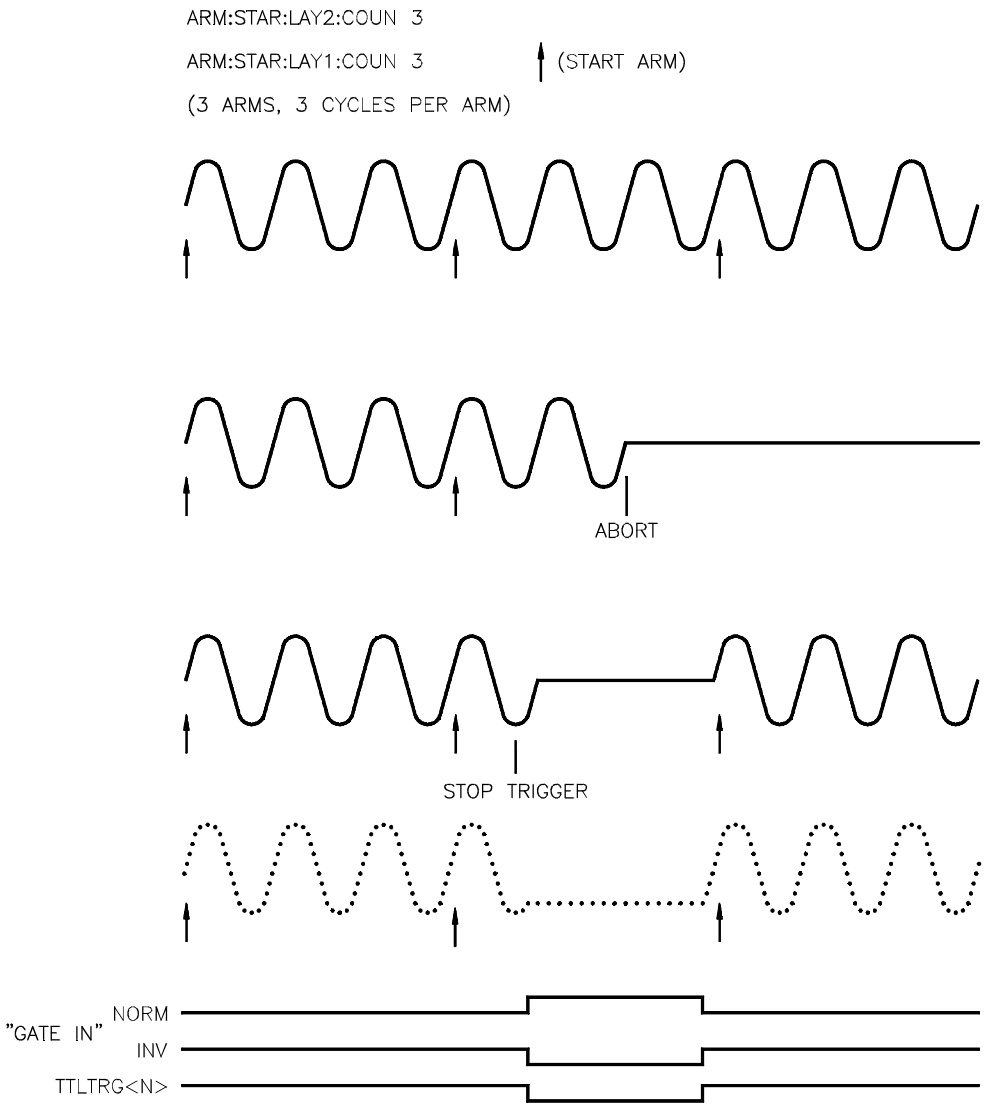


Figure 5-4. Effects of ABORt, Stop Triggers, and Gating

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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.

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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.

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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.

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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.

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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.

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Notes

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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

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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.

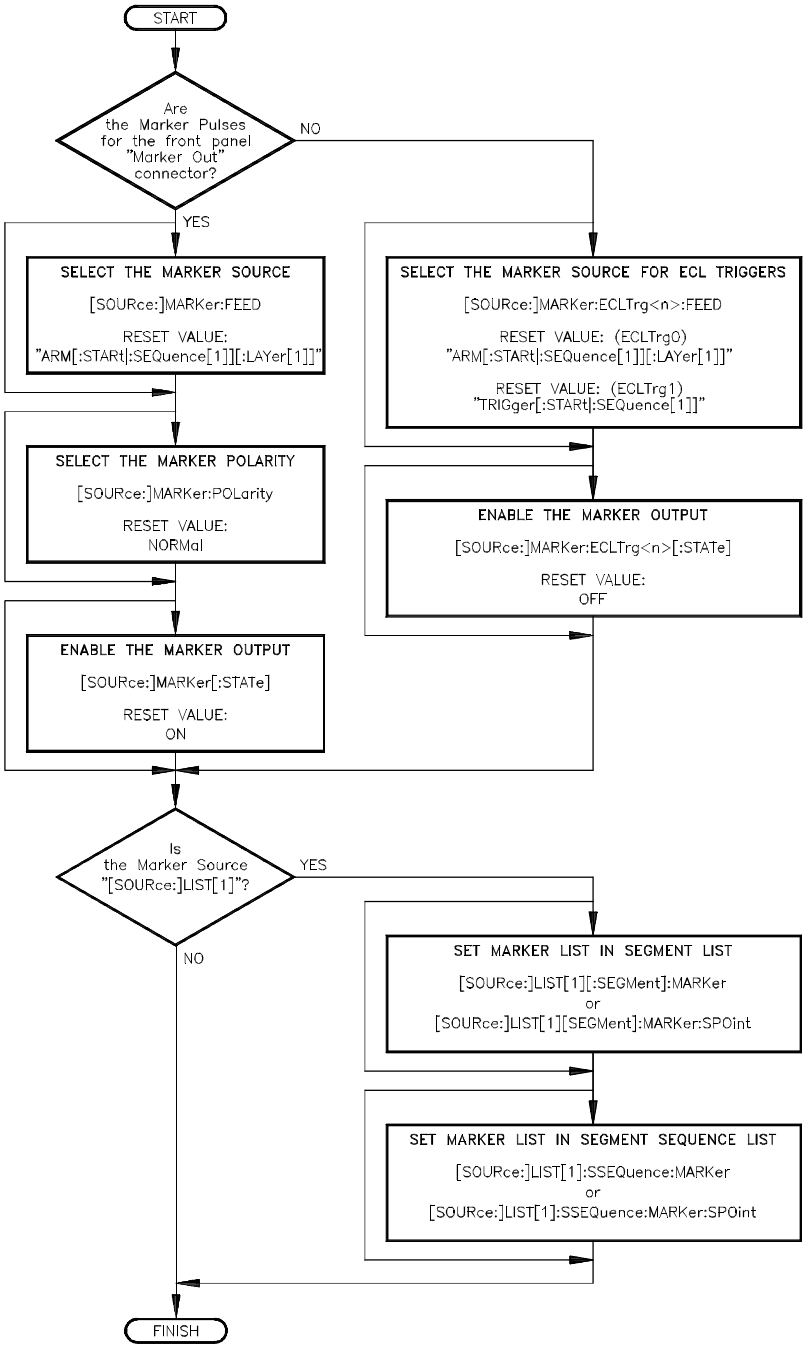


Figure 6-1. Commands for Marker Pulses

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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.

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[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

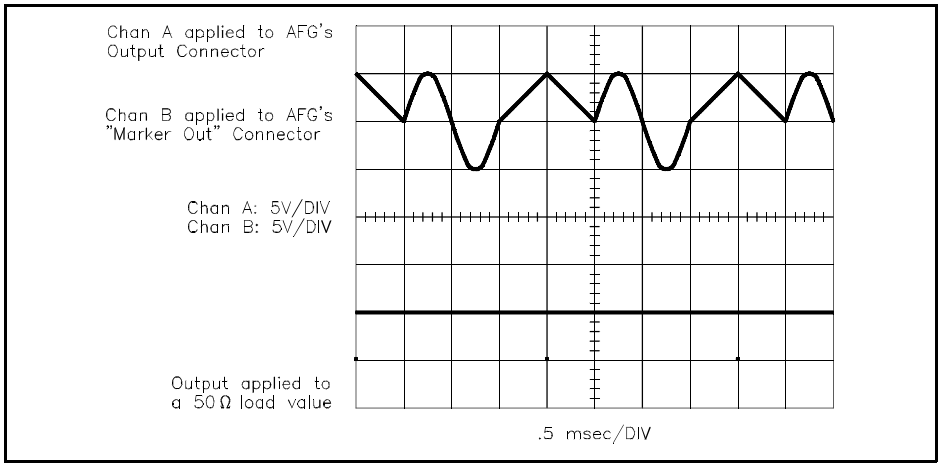
The following programs show how to generate the marker pulses using two different methods. The two methods are:

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.

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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]:SSEQuence: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]: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 "[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.

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6. **Enable Marker Outputs**
   [SOURce:]MARKer[:STATe] ON
   This commands 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]

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HP BASIC Program Example (MARKSEG1)

```
    !RE-STORE“MARKSEG1”
    !This program computes a sine wave and a triangle wave as arbitrary
    !waveforms. A corresponding marker list is defined for the triangle
    !wave. The program sets the output sequence to consist of both
    !waveforms, and enables marker pulses to be output with selected
    !triangle waveform amplitude points.
!
    !Assign I/O path between the computer and E1445A.
    ASSIGN @Afg TO 70910
    COM @Afg
    !
    !Set up error checking
    ON INTR 7 CALL Errmsg
    ENABLE INTR 7;2
    OUTPUT @Afg;"*CLS"
    OUTPUT @Afg;"*SRE 32"
    OUTPUT @Afg;"*ESE 60"
    !
    !Call the subprograms which reset the AFG and delete all existing
    !waveform segments and sequences.
    CALL Rst
    CALL Wf_del
    !
    !Set up the AFG
    OUTPUT @Afg;"SOUR:FREQ1:FIX  512E3;";                !frequency
    OUTPUT @Afg;":SOUR:FUNC:SHAP  USER;";                !function
    OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL  5.1V"          !amplitude
    OUTPUT @Afg;"SOUR:MARK:FEED  ""SOUR:LIST1"""""       !marker source
    OUTPUT @Afg;"SOUR:MARK:POL  INV"                     !marker polarity
    OUTPUT @Afg;"SOUR:MARK:STAT  ON"                     !enable marker
    !
    CALL Sine_wave
    CALL Tri_wave
    CALL Seq_list
    !
    OUTPUT @Afg;"SOUR:FUNC:USER  WAVE_OUT"               !waveform sequence
    OUTPUT @Afg;"INIT:IMM"                               !wait-for-arm state
    !
    WAIT .1  !allow interrupt to be serviced
    OFF INTR 7
    END
    !
    SUB Sine_wave
Sine_wave: !Subprogram which computes a sine wave.
        COM @Afg
        DIM Waveform(1:512)                              !Calculate sine wave
        FOR I=1 TO 512
            Waveform(I)=5.*(SIN(2.*PI*(I/512.)))
```

Continued on Next Page

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```
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)=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

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```
 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
```

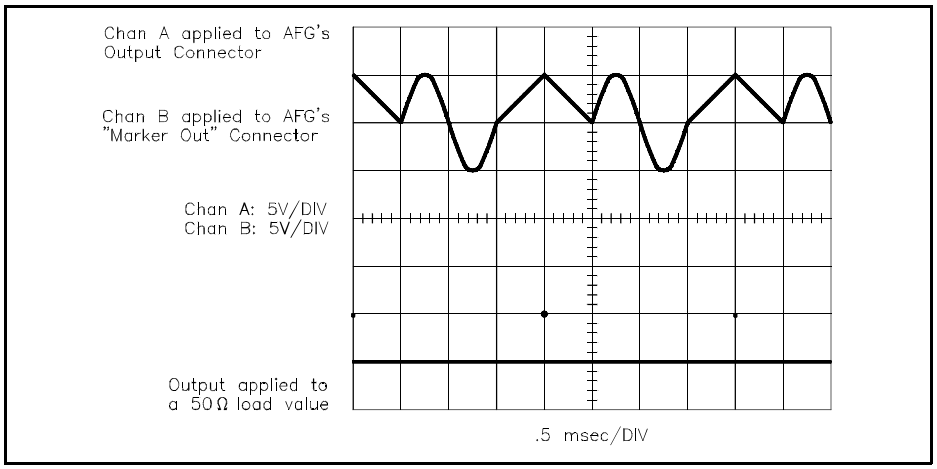
Visual BASIC and Visual C/C++ Program Versions

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.

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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.

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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)=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
```

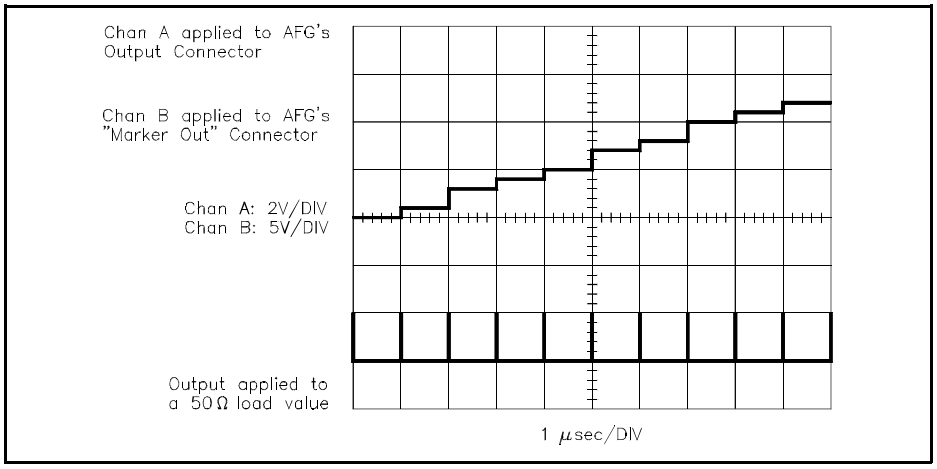
Visual BASIC and Visual C/C++ Program Versions

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.

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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.)

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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[:IMMediate]

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
```

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```
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
```

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```
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
```

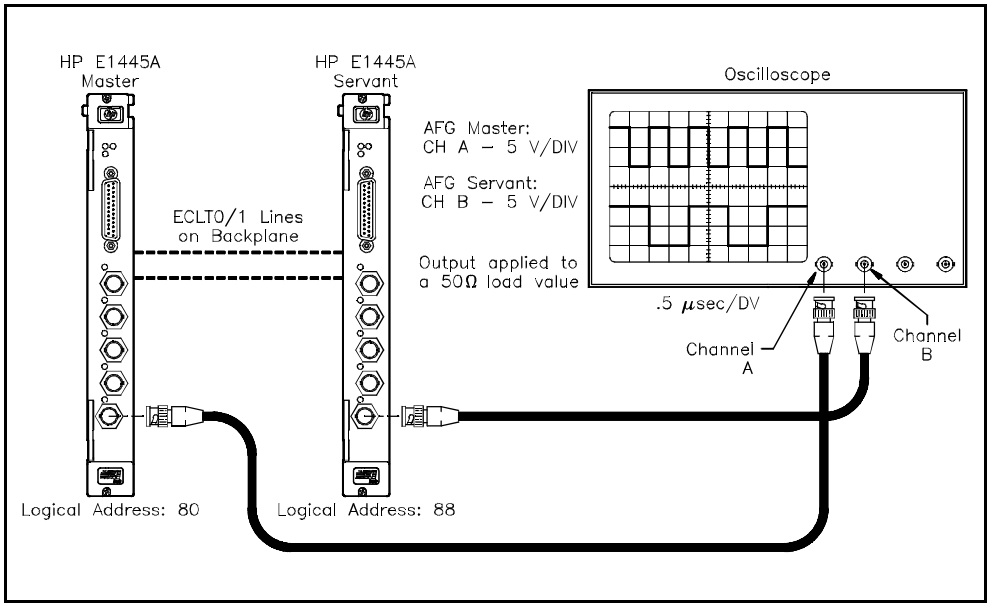
Visual BASIC and Visual C/C++ Program Versions

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.

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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.

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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]

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HP BASIC Program Example (DRIFT)

```
!RE-STORE"DRIFT"
!This program sets up two AFG's to output 1 MHz square waves.
!To prevent these signals from drifting and creating a phase
!difference, the reference oscillator of a "master" AFG is shared
!by a "servant" AFG. The master's reference oscillator signal is
!output on VXI backplane trigger line ECLT0.
!Assign I/O paths between the computer and the AFGs.
ASSIN @Afg_m TO 70910                   !master AFG
ASSIGN @Afg_s TO 70911                  !servant AFG
COM @Afg_m,@Afg_s
!
!Set up error checking
CALL Rst
OUTPUT @Afg_m;"*CLS"                    !master
OUTPUT @Afg_m;"*SRE 32"
OUTPUT @Afg_m;"*ESE 60"
OUTPUT @Afg_m;"*OPC?"
ENTER @Afg_m;Complete
!
OUTPUT @Afg_s;"*CLS"                    !servant
OUTPUT @Afg_s;"*SRE 32"
OUTPUT @Afg_s;"*ESE 60"
OUTPUT @Afg_s;"*OPC?"
ENTER @Afg_s;Complete
ON INTR 7 CALL Errmsg
ENABLE INTR 7;2
!
!Call the subprograms which reset the AFGs output sine waves 180
!degrees out of phase.
CALL Square_wave_m
CALL Square_wave_s
!
!Set master AFG to wait-for-arm state
OUTPUT @Afg_m;"INIT:IMM"                                !start waveform
!
WAIT .1  !allow interrupt to be serviced
OFF INTR 7
END
!
SUB Square_wave_m
Square_wave_m:      !Subprogram which sets up master AFG
    COM @Afg_m,@Afg_s
    OUTPUT @Afg_m;"SOUR:ROSC:SOUR  INT2;";          !reference osc. source
    OUTPUT @Afg_m;":TRIG:STAR:SOUR  INT2;";             !trigger source
    OUTPUT @Afg_m;":SOUR:FREQ2:FIX  1E6;";              !frequency
    OUTPUT @Afg_m;":SOUR:FUNC:SHAP  SQU;";              !function
    OUTPUT @Afg_m;":SOUR:VOLT:LEV:IMM:AMPL  5V"         !amplitude
```

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```
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$[256]
800         !Read AFG status byte register and clear service request bit
810         B=SPOLL(@Afg_m)
820         IF B THEN                                       !master error
830         !End of statement if error occurs among coupled commands
840             OUTPUT @Afg_m;""
850             OUTPUT @Afg_m;"ABORT"                       !abort output waveform
860             PRINT "Master AFG"
870             PRINT
880             REPEAT
890                 OUTPUT @Afg_m;"SYST:ERR?"               !read AFG error queue
900                 ENTER @Afg_m;Code,Message$
```

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```
 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.

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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 Arbitr`ary 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
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  - Using the Combined List with the Unsigned Number Format . . . . . Page 245
- Using Combined Waveform Segments and Segment Sequences . . . . . Page 250
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  - 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

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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:

DAC Code = voltage value / .00125

For example, to output -2V:

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.

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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]

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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    !RE-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

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```
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.

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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:

DAC Code = (voltage value / .00125) + 4096

For example, to output -2V:

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:

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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.

These 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.

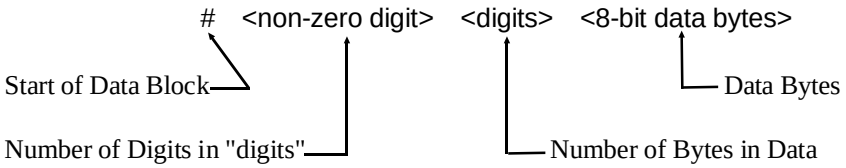
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Using Definite Length Arbitrary Blocks to Transfer Data

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

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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

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```
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

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```
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.

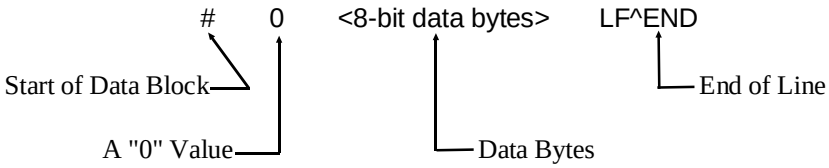
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Using Indefinite Length Arbitrary Blocks to Transfer Data

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:

$$1000 * 2 = 2000$$

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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

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```
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;""
```

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```
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.

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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.

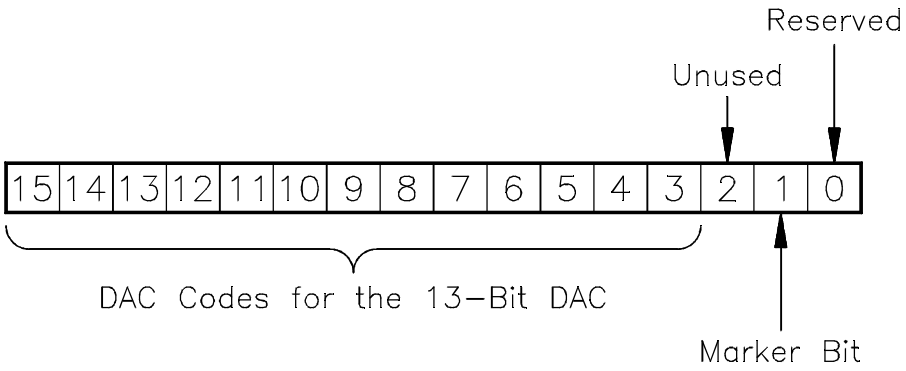


Figure 7-1. Combined List Format

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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:

Code = (voltage value / .00125) shift left by 3

For example, to output -2V:

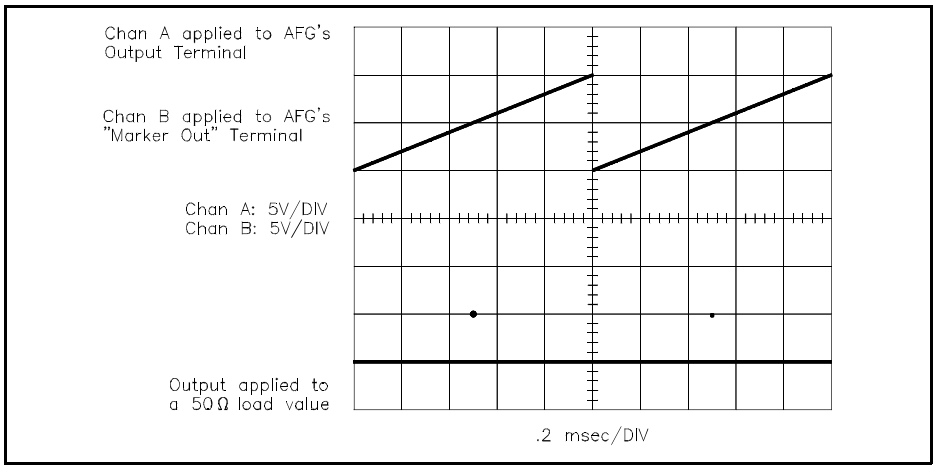
DAC Code = (-2 / .00125) shift left by 3 = -12800

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:

Code = ((5 / .00125) shift left by 3) + 2 = 32000 + 2 = 32002

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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.

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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   !RE-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
```

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```
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
```

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```
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.

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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

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To calculate combined list codes from NEGATIVE voltage values, use the formula:

DAC Code = ((voltage value / .00125) shift left by 3) + 32768

For example, to output -2V:

DAC Code = ((-2 / .00125) shift left by 3) + 32768 = -12800 + 32768 = 19968

To calculate combined list codes from POSITIVE voltage values, use the formula:

DAC Code = ((voltage value / .00125) shift left by 3) - 32768

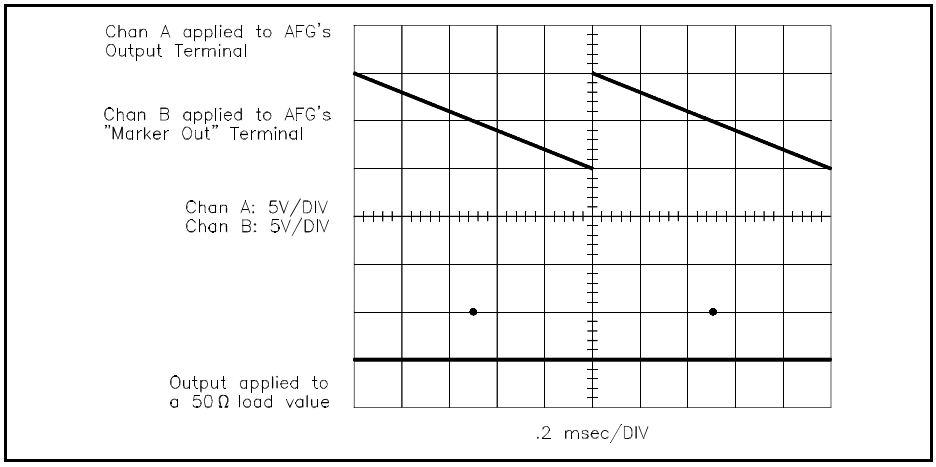
For example, to output +5V:

DAC Code = ((5 / .00125) 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:

Code = ((5 / .00125) 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.



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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   !RE-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   !
```

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```
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.
```

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```
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.

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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.

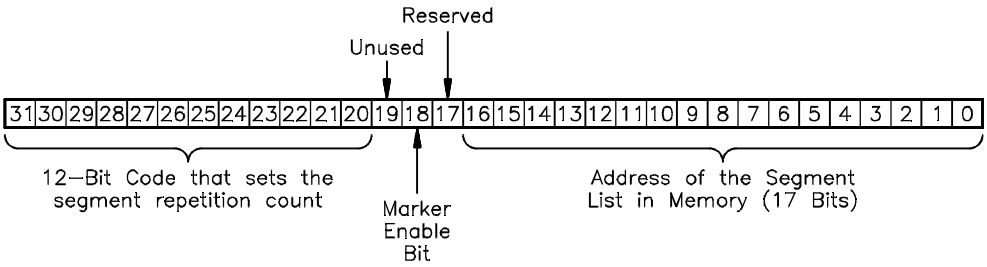


Figure 7-2. Combined Sequence List Format

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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 - desired repetition count.
   For example, 2 repetition counts = 4096 - 2 = 4094.

2. **Shift the Repetition Count Value left by 20**

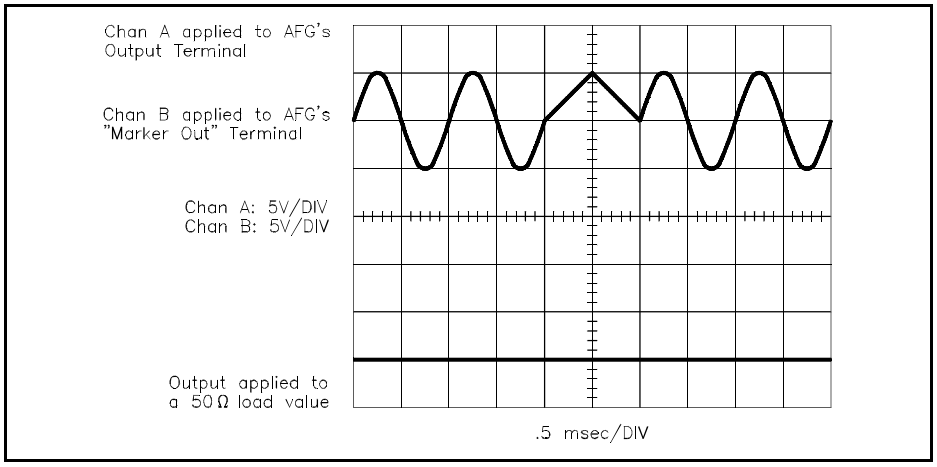
3. **Add the Shifted Repetition Count Value to the Data Byte in the Combined Segment Sequence List**

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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.

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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.

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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]

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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.

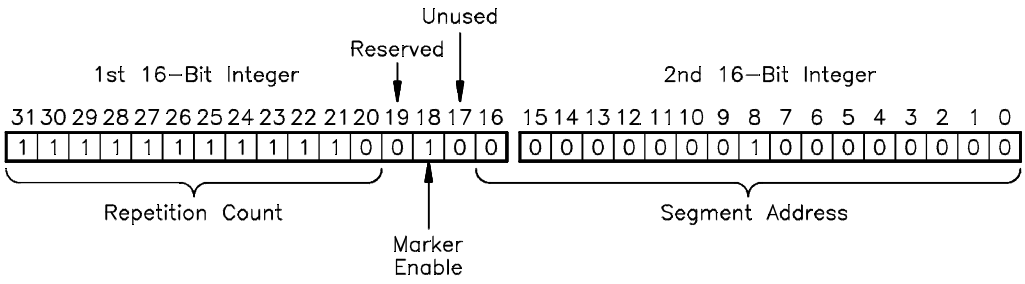


Figure 7-3. Sending 32-Bit Integers in HP BASIC

HP BASIC determines the value for the first integer as follows:

Repetition Count/Marker = (SHIFT(4096 - <repetition count>, -4) + <segment address> DIV 65536) +4

HP BASIC determines the value for the second integer as follows:

Segment Address = <segment address> MOD 65536 - 65536 * (<segment address> 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
```

Continued on Next Page

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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)=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)=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 Addrm1,Addrm2
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;Addrm1
930       Addrm1=Addrm1/4                  ! /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)+Addrm1 DIV 65536
980       Sequence(1,2)=Addrm1 MOD 65536-65536*(Addrm1 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;Addrm2
1030      Addrm2=Addrm2/4                  ! /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.

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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.

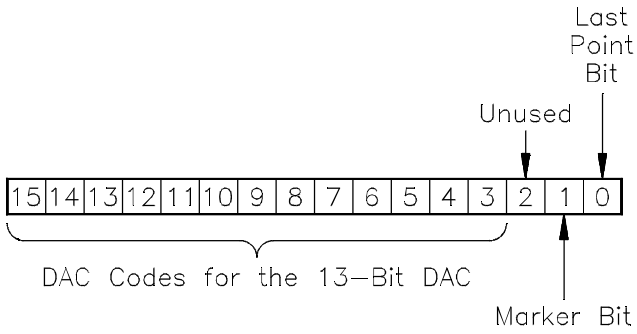


Figure 7-4. Combined List Format for Downloading

- 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.

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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.

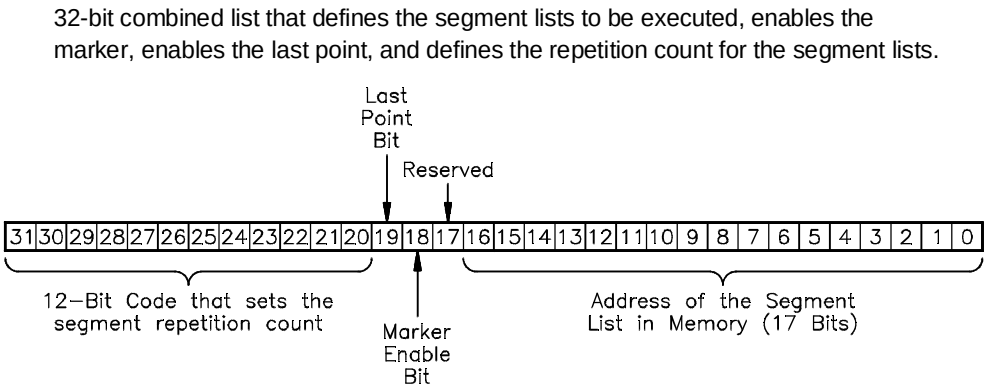


Figure 7-5. Combined Sequence List Format

- 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 – 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).

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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*>).

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8. **Place the AFG into Hold Until All Commands are Executed**
   *OPC?
   This commands 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 commands 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

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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

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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 commands 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    !RE-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

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```
 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

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```
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)=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

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```
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 Addrm1,Addrm2
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;Addrm1
1200        Addrm1=Addrm1/8                  ! /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)+Addrm1 DIV 65536)
1250        Sequence(1,2)=(Addrm1 MOD 65536-65536*(Addrm1 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;Addrm2
1300        Addrm2=Addrm2/8                  ! /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)+Addrm2 DIV 65536)+12
1360        Sequence(2,2)=Addrm2 MOD 65536-65536*(Addrm2 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
```

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```
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.

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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 disables 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 commands 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

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[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.

```
!RE-STORE"VXISRCE"
!This program uses the V/360 embedded controller to send waveform
!data directly to the AFG dac over the VXIbus backplane.
!
!Assign I/O path between the computer and E1445A.
ASSIGN @Afg TO 1680
COM @Afg,Addr
!
!Call the subprograms which reset the AFG and determine the base
!address of the registers in A24 address space.
CALL Rst
CALL A24_offset
!
!Scale the amplitude, set the dac data format and dac data source.
OUTPUT @Afg;"SOUR:VOLT:LEV:IMM:AMPL  5.11875V"      !amplitude
OUTPUT @Afg;"SOUR:ARB:DAC:FORM  SIGN"               !dac data format (signed)
OUTPUT @Afg;"SOUR:ARB:DAC:SOUR  VXI"                !dac data source
OUTPUT @Afg;"*OPC?"                    !Wait for the SCPI commands to complete
ENTER @Afg;Complete
!
!Call the subprogram which sends data directly to the dac.
CALL Dac_drive
END
!
SUB A24_offset
A24_offset:  !Subprogram which determines the base address for
             !the AFG registers in A24 address space, then adds the
             !offset and register number to the base to get the
             !complete address.
    COM @Afg,Addr
    !CONTROL 16,25;2                !access A16 space with READIO and WRITEIO
    A16_addr=DVAL("D400",16)        !AFG A16 base address
    Offset=READIO(-16,A16_addr+6)   !read AFG offset register
    Base_addr=Offset*256            !shift offset for 24-bit address
    !Add the register number of the high speed data register
    !to the A24 base address.
    Addr=Base_addr+IVAL("26",16)
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)=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.

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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)

```
!RE-STORE "WAVSELFP"
!This program changes the output waveform sequence once the AFG has been
!INITiated by writing the location of a sequence's base address to the
!Waveform Select register. All register reads and writes are 16 bit.
!The program uses the front panel 'Digital Port In' connector to
!change 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
!
!Assign an I/O path between the computer and the AFG
ASSIGN @Cmd TO 80900
ASSIGN @Afg TO 80910
ASSIGN @Afg1 TO 80910;FORMAT OFF                    !path for binary data
Laddr=80            !logical address for AFG
COM @Cmd,@Afg,@Afg1,Base_addr,Seq1_addr,Seq2_addr,Seq3_addr
!
!Subprograms which reset the AFG and erase all existing waveforms.
CALL Rst
CALL Wf_del
!
!SCPI commands which configure the AFG
OUTPUT @Afg;"SOUR:FREQ1:FIX  4.096E6;";             !Sample rate
OUTPUT @Afg;":SOUR:FUNC:SHAP  USER;";               !function
OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL  2.1V"         !amplitude
OUTPUT @Afg;"SOUR:ARB:DAC:SOUR  INT"                !dac data source
OUTPUT @Afg;"SOUR:ARB:DAC:FORM  SIGN"               !dac data format
!
```

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```
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))
```

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```
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.
```

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```
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
```

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```
1700        OUTPUT @Afg;CHR$(10);END              !terminate with Line Feed (LF) and EOI
1710        !
1720        OUTPUT @Afg;"SOUR:LIST1:SSEQ:ADDR?"          !sequence location
1730        ENTER @Afg;Seq2_addr
1740      SUBEND
1750      !
1760      SUB Spike_def
1770    Spike_def: !Compute the waveform (sine wave with spike). Download the
1780             !data as a combined list (voltage and marker) of signed
1790             !numbers in an indefinite length block. Download the sequence as
1800             !a combined list (repetition count, marker, and segment address)
1810             !in an indefinite length arbitrary block.
1820        COM @Cmd,@Afg,@Afg1,Base_addr,Seq1_addr,Seq2_addr,Seq3_addr
1830        INTEGER Waveform(1:4096)
1840        INTEGER Sequence(1:2)
1850        REAL Addr_seg3
1860        FOR I=1 TO 4096
1870           Waveform(I)=SIN(2*PI*(I/4096))/.00125
1880        NEXT I
1890        Width=50
1900        FOR J=1 TO Width
1910        I=1024-Width+J
1920        Waveform(I)=Waveform(I)+.9*J/Width/.00125
1930        NEXT J
1940        FOR J=1 TO Width-1
1950        I=1024+Width-J
1960        Waveform(I)=Waveform(I)+.9*J/Width/.00125
1970        NEXT J
1980        !
1990        !shift bits to dac code positions
2000        FOR I=1 TO 4096
2010        Waveform(I)=SHIFT(Waveform(I),-3)
2020        NEXT I
2030        !
2040        OUTPUT @Afg;"SOUR:LIST1:SEGM:SEL  SPIKE"          !segment name
2050        OUTPUT @Afg;"SOUR:LIST1:SEGM:DEF  4096"           !segment size
2060        OUTPUT @Afg USING "#,K";"SOUR:LIST1:SEGM:COMB  #0"!waveform points
2070        OUTPUT @Afg1;Waveform(*)              !indefinite length block
2080        OUTPUT @Afg;CHR$(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
```

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```
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
```

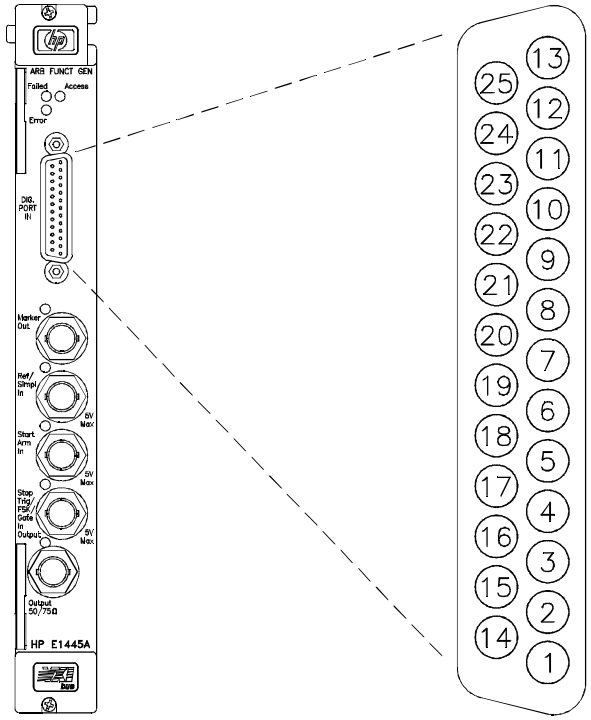
Visual BASIC and Visual C/C++ Program Versions

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.

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"Digital Port In" Connector Pinout

Figure 7-6 shows a pinout of the "Digital Port In" connector.



PIN	SIGNAL
1	FPD00
2	FPD01
3	FPD03
4	FPD04
5	FPD06
6	FPD07
7	GND
8	FPD10
9	FPD11
10	FPD13
11	FPD14
12	FPCLK*
13	FPPACE*
14	GND
15	FPD02
16	GND
17	FPD05
18	GND
19	FPD08
20	FPD09
21	GND
22	FPD12
23	GND
24	FPD15
25	GND

Figure 7-6. HP E1445A "Digital Port In" Connector

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Using the "Digital Port In" Connector to Select a Sequence

Figure 7-7 shows the timing relationship to select a segment sequence.

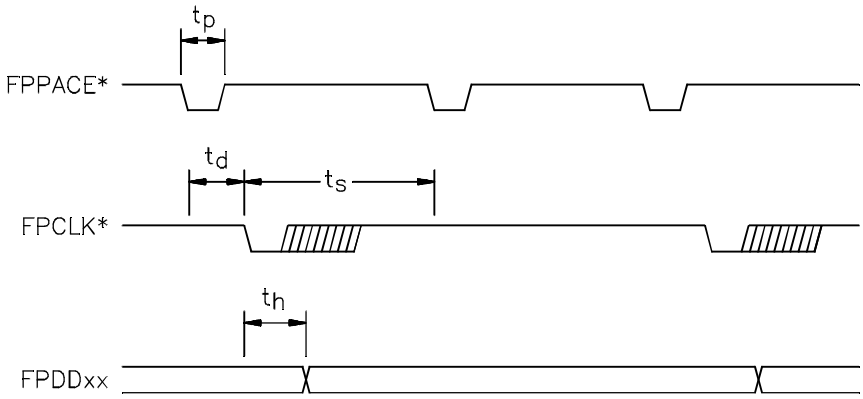


Figure 7-7. "Digital Port In" Data Timing

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 de 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.

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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 affect 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 ≥ 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]:SSEQuence: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.

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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
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- SCPI Command Quick Reference . . . . . Page 409
- SCPI Conformance Information . . . . . Page 414
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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.

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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.

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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).

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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.

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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.

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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.

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ABORt

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.
```


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ARM

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.

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- **Executable when Initiated:** Query form only
- **Coupling Group:** None
- **Related Commands:** ABORt, TRIGger:STOP[:IMMediate]
- ***RST Condition:** ARM:STARt:LAYer1:COUNt INFinity

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 | INFinity	none
MINimum selects 1 arms; MAXimum selects 65535 arms. 9.9E+37 is equivalent to INFinity.			

Comments

- Use the ABORt command to return the trigger system to the idle state when ARM[:STARt]:LAYer2:COUNt set to INFinity 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.*

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[: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.
```


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[: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
<*source*>	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.

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: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
<*number*>	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:COUN 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

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Example Starting a Frequency Sweep

```
SWE:START  1E3;STOP  10E3      Sets sweep frequency limits.
SWE:POIN  10                   Sets 1 kHz steps.
ARM:SOUR  IMM                  Sets output to start immediately.
ARM:SWE:SOUR  HOLD             Sets manual sweep arm.
INIT                           Initiates trigger system.
ARM:SWE                        Starts sweep.
```

: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 | :SEQuence1]: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             Links sweep arm to start arm.
ARM:SWE:LINK "ARM"
```


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: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.*

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CALibration

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

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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:COUNt? 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:COUNt? query).
- **Executable when Initiated:** Yes
- **Coupling Group:** None
- **Related Commands:** CALibration:COUNt?, CALibration:SECure[:STATe]
- ***RST Condition:** Unaffected

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: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

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[: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

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: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
<*code*>	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.
```


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: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.

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: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
<*state*>	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
<*state*>	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.*

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: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
<*state*>	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.
```


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INITiate

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).

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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.
```


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OUTPut[1]

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.
```


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: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
<*mode*>	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
<*impedance*>	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.
```


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: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
<*load*>	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.
```


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: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
<*mode*>	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
<*mode*>	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.
```


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[SOURce:]

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

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[SOURce:]ARBitrary

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.

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- 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.
```


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: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.

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: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.

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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                  Creates segment name.
LIST:DEF  512                  Reserves 512 points of segment memory.
ARB:DOWN  VXI,ABC,512          Sets up for download.
download data
ARB:DOWN:COMP                  Indicates download complete.
```


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: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	*Creates segment name.*
LIST:DEF 512	*Reserves 512 points of segment memory.*
ARB:DOWN VXI,ABC,512	*Sets up for download.*
download data	
ARB:DOWN:COMP	*Indicates download complete.*

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[SOURce:]FREQuency[1]

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:

  CENTer = (STARt + STOP)/2
  SPAN = STOP - STARt

- 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:

  STARt = CENTer - (SPAN/2)
  STOP = CENTer + (SPAN/2)

- 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

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([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>
```


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: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
<*center_freq*>	numeric	see below | MINimum | MAXimum	Hz
The legal range for <*center_freq*>, 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.*

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[: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
<*frequency*>	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 <*frequency*>.

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.

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: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 o f Values	Default Units
<*frequency1*> <*frequency2*>	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 <*frequency1*> and <*frequency2*>.

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.*

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: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
<*source*>	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.*

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: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
<*mode*>	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.
```


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: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

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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
<*freq_span*>	numeric	see below | MINimum | MAXimum	Hz
The legal range for <*freq_span*>, 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.
```


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: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
<*start_freq*>	numeric	see below | MINimum | MAXimum	Hz
The legal range for <*start_freq*>, 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.*

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: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
<*stop_freq*>	numeric	see below | MINimum | MAXimum	Hz
The legal range for <*stop_freq*>, 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.*

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[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>
```


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[: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
<*frequency*>	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 <*frequency*>. The <*frequency*> 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:]FUNCtion[: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.
```


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[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.

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- 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.
```


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[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]
            :DWELl
                :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]
```


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: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:DWELl: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
<*format*>	discrete	ASCii | PACKed	none
<*length*>	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.
```


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[: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.
```


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[: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

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Example **Defining a Waveform Segment Combined List**

```
LIST:SEL  ABC                                   Selects waveform segment ABC.
LIST:DEF  8                                     ABC is 8 points long.
LIST:COMB  16000,32000,16000,0,-16000,-32000,-16000,0
                                                Defines waveform segment.
```

[: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                                   Selects waveform segment ABC.
LIST:COMB:POIN?                                 Queries combined point list length.
```


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[: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
<*length*>	numeric	see below | MINimum | MAXimum	none
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. 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).			

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.
```


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[: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

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- **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.*

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[: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

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Example **Defining a Waveform Segment Marker Pulse List**

LIST:SEL ABC	*Selects waveform segment ABC.*
LIST:DEF 8	*ABC is 8 points long.*
LIST:VOLT -1,.5,.5.,5.,.5,0,-.5,-1	*Defines waveform voltages.*
LIST:MARK 1,0,0,0,1,0,0,0	*Outputs a marker pulse on first and fifth voltage points.*

[: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	*Selects waveform segment ABC.*
LIST:MARK:POIN?	*Queries the marker pulse list length.*

[: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
<*point*>	numeric	see below | MINimum | MAXimum	none
The valid range for <*point*> 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

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- ***RST Condition:** Unaffected
- **Power-On Condition:** No waveform segments are defined

Example Creating a Single Point Marker List

LIST:SEL ABC	*Selects waveform segment ABC.*
LIST:DEF 8	*ABC is 8 points long.*
LIST:VOLT -1,.5,.5.,5.,.5,0,-.5,-1	*Defines waveform voltages.*
LIST:MARK:SPO 5	*Outputs a marker pulse on the fifth voltage point.*

[: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	*Selects waveform segment ABC.*

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[: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

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Example **Defining a Waveform Segment Voltage Point List**

LIST:SEL ABC	*Selects waveform segment ABC.*
LIST:DEF 8	*ABC is 8 points long.*
LIST:VOLT .5,1,.5,0,-.5,-1,-.5,0	*Defines waveform voltages.*

[: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

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- **Power-On Condition:** No waveform segments are defined

Example **Defining a Waveform Segment Voltage Point List**

```
ARB:DAC:FORM  SIGN                    Selects signed DAC code format.
LIST:SEL  ABC                         Selects waveform segment ABC.
LIST:DEF  8                           ABC is 8 points long.
LIST:VOLT:DAC  400,800,400,0,-400,-800,-400,0
                                      Defines waveform voltages.
```

[: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                         Selects waveform segment ABC.
LIST:VOLT:POIN?                       Queries voltage point list length.
```

: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?                       Queries sequence address.
```


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: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.

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- 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:DWELl:COUNt, [SOURce:]LIST[1]:SSEQuence:MARKer, [SOURce:]LIST[1]:SSEQuence:SEQuence
- ***RST Condition:** Unaffected
- **Power-On Condition:** No segment sequences are defined

Example **Defining a Segment Sequence Combined List**

LIST:SSEQ:SEL ABC	*Selects sequence ABC.*
LIST:SSEQ:DEF 1	*ABC is 1 point long.*
LIST:SSEQ:COMB -786432	*Outputs segment at address 0 one time with markers enabled.*

: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	*Selects sequence ABC.*
LIST:SSEQ:COMB:POIN?	*Queries combined point list length.*

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: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
<*length*>	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:DWELl: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.
```


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: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.*

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:SSEQuence:DWELl:COUNt

[SOURce:]LIST[1]:SSEQuence:DWELl: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 6,1,1,1,1,1,1,1	*Outputs segment A six times, others once.*

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:SSEQuence:DWELl:COUNt:POINts?

[SOURce:]LIST[1]:SSEQuence:DWELl: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	*Selects segment sequence ABC.*
LIST:SSEQ:DWEL:COUN:POIN?	*Queries repetition count list length.*

: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?	*Queries segment memory usage.*

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: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	*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:MARK 1,0,0,0,1,0,0,0	*Enables marker output on segments A and E.*

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: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
<*point*>	numeric	see below | MINimum | MAXimum	none
The valid range for <*point*> 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.*

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: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
```


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: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.*

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[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.
```


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: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:]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 frequency list length.
- **Executable when Initiated:** Query form only
- **Coupling Group:** Frequency
- **Related Commands:** TRIGger[:STARt]:SOURce, [SOURce:]FREQuency[1]:MODE, [SOURce:]SWEep
- ***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.*

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: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.*

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[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.

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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*.*

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: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]]"

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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.*

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[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 -π; 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°.*

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: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.

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: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
<*mode*>	boolean	OFF | 0 | ON | 1	none

Comments

- **Executable when Initiated:** Yes
- **Coupling Group:** Frequency
- **Related Commands:** [SOURce:]FUNCtion[: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 π/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
<*units*>	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.
```


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[SOURce:]RAMP

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.
```


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: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
<polarity>	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          Selects ramp output.
RAMP:POL  INV            Selects negative-going ramp.
```


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[SOURce:]ROSCillator

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 ECLTrg*n*.

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.
```


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: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.
```


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[SOURce:]SWEep

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 INTernal1 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

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- ***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
<*direction*>	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.*

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: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
<*number*>	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.

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:SPACing

[SOURce:]SWEep:SPACing ***<mode>*** selects either linear or logarithmic frequency sweep mode.

Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<*mode*>	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.
```


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: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:

TIME = TIMer * (*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:

  SWEep:TIME = time * (points - 1) / 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.
```


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[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.

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Parameters

Parameter Name	Parameter Type	Range of Values	Default Units
<*amplitude*>	numeric	see below | MINimum | MAXimum	see below

DC Output: When a matched load has been specified, MINimum selects -5.12 V; MAXimum selects 5.11875 V.

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.

For all waveform shapes, when an open circuit load has been specified, double the all the above voltages.

These values bound the legal range of values for <*amplitude*>.

Default units are specified by the [SOURce:]VOLTage[:LEVel][:IMMediate][:AMPLitude]:UNIT[:VOLTage] command.

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.*

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[: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
<*units*>	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.*

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[: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
<*offset*>	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 <*offset*>.

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.
```


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STATus

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.

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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.
```


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: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.*

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: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.*

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: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.*

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: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.*

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: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.*

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: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.

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SYSTem

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.
```


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: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.
```


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TRIGger

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>
```


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[:STARt]:COUNt

TRIGger[:STARt]: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
<*number*>	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
```


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[: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
<*polarity*>	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
<*source*>	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

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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.*

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[: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          Sets immediate arming.
TRIG:SOUR  HOLD             Sets manual sample generation.
INIT                        Initiates trigger system.
TRIG                        Advances waveform.
```

[: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
<edge>	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              Sets negative trigger slope.
```


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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
<source>	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.

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: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	*Allows 5 arms.*
ARM:LAY2:SOUR HOLD	*Sets manual start arm.*
ARM:COUN 100	*Sets 100 repetitions per arm.*
INIT	*Initiates trigger system.*
ARM:LAY2	*Starts arm waveform.*
TRIG:STOP	*Terminates arm cycle at end of waveform repetition.*
ARM:LAY2	*Starts arm waveform again.*

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: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
<*edge*>	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
<*source*>	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.

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- 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

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- ***RST Condition:** None

Example Advancing a Frequency Sweep

SWE:STAR 1E3;STOP 10E3	*Sets sweep frequency limits.*
SWE:POIN 10	*Sets 1 kHz steps.*
ARM:LAY2:SOUR IMM	*Sets output to start immediately.*
ARM:SWE:SOUR IMM	*Sets sweep to start immediately.*
TRIG:SWE:SOUR HOLD	*Sets sweep to advance sweep manually.*
INIT	*Initiates trigger system.*
TRIG:SWE	*Advances to next frequency.*

: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
<*link*>	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	*Links sweep advance trigger to start arm.*
TRIG:SWE:LINK "ARM:LAY2"	

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: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.*

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: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:

TIME = TIMer * (*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
<*period*>	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 <period>			

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.*

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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.

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- 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
<*mode*>	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]

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- ***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
<*length*>	numeric	see below	none
The valid range for <*length*> is 2 through the size of largest available contiguous piece of waveform segment memory in bytes (2 bytes per point). <*length*> 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.
```


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[: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.
```


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[: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	*Creates waveform segment.*
ARB:DOWN VXI,ABC,100	*Starts download to segment.*
VINS:VME:REC:ADDR:DATA?	*Queries A24 offset for data writes.*

[: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

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- ***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.*

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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*>

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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?

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Table 8-1. HP E1445A SCPI Commands (*continued*)

Subsystem	Commands
[SOURce:]LIST[1]	[SOURce:]LIST[1][:SEGMent]:MARKer <*marker_list*>
(Cont'd)	[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]:SSEQuence:ADDRess?
	[SOURce:]LIST[1]:SSEQuence:CATalog?
	[SOURce:]LIST[1]:SSEQuence:COMBined <*combined_list*>
	[SOURce:]LIST[1]:SSEQuence:COMBined:POINts?
	[SOURce:]LIST[1]:SSEQuence:DEFine <*length*>
	[SOURce:]LIST[1]:SSEQuence:DELete:ALL
	[SOURce:]LIST[1]:SSEQuence:DELete[:SELected]
	[SOURce:]LIST[1]:SSEQuence:DWELl:COUNt <*repetition list*>
	[SOURce:]LIST[1]:SSEQuence:DWELl:COUNt:POINts?
	[SOURce:]LIST[1]:SSEQuence:FREE?
	[SOURce:]LIST[1]:SSEQuence:MARKer <*marker_list*>
	[SOURce:]LIST[1]:SSEQuence:MARKer:POINts?
	[SOURce:]LIST[1]:SSEQuence:MARKer:SPOint <*point*>
	[SOURce:]LIST[1]:SSEQuence:SELect <*name*>
	[SOURce:]LIST[1]:SSEQuence:SEQuence <*segment_list*>
	[SOURce:]LIST[1]:SSEQuence:SEQuence:SEGMents?
[SOURce:]LIST2	[SOURce:]LIST2:FORMat[:DATA] <*format*> [,<*length*>]
	[SOURce:]LIST2:FREQuency <*freq_list*>
	[SOURce:]LIST2:FREQuency:POINts?

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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

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Table 8-1. HP E1445A SCPI Commands (*continued*)

Subsystem	Commands
SYSTem	SYSTem:ERRor?
	SYSTem:VERsion?
TRIGger	TRIGger[:STARt]:GATE:POLarity <*polarity*>
	TRIGger[:STARt]:GATE:SOURce <*source*>
	TRIGger[:STARt]:GATE:STATe <*mode*>
	TRIGger[:STARt][:IMMediate]
	TRIGger[:STARt]:SLOPe <*edge*>
	TRIGger[:STARt]:SOURce <*source*>
	TRIGger:STOP[:IMMediate]
	TRIGger:STOP:SLOPe <*edge*>
	TRIGger:STOP:SOURce <*source*>
	TRIGger:SWEep[:IMMediate]
	TRIGger:SWEep:LINK <*link*>
	TRIGger:SWEep:SOURce <*source*>
	TRIGger:SWEep:TIMer <*period*>
VINStrument	VINStrument[:CONFigure]:LBUS[:MODE] <*mode*>
	VINStrument[:CONFigure]:LBUS[:MODE]:AUTO <*mode*>
	VINStrument[:CONFigure]:TEST:CONFigure <*length*>
	VINStrument[:CONFigure]:TEST:DATA?
	VINStrument[:CONFigure]:VME[:MODE] <*mode*>
	VINStrument[:CONFigure]:VME:RECeive:ADDRess:DATA?
	VINStrument[:CONFigure]:VME:RECeive:ADDRess:READy?
	VINStrument:IDENtity?

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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

ARM
    [:START|:SEQuence[1]]
        [:LAYer[1]]
            :COUNt <number>
        :LAYer2
            :COUNt <number>
            [:IMMediate]
            :SLOPe <edge>
            :SOURce<source>
     :SWEep|:SEQuence3]
        :COUNt <number>
        [:IMMediate]
        :LINK <link>
        :SOURce <source>

INITiate
    [:IMMediate]

OUTPut[1]
     :FILTer
        [:LPASs]
            :FREQuency <frequency>
            [:STATe] <mode>
        :IMPedance <impedance>
    [:STATe] <mode>

[SOURce:]
    FREQuency[1]
        :CENTer <center_freq>
        [:CW|:FIXed] <frequency>
        :MODE <mode>
        :SPAN <freq_span>
        :STARt <start_freq>
        :STOP <stop_freq>
    FREQuency2
        [:CW|:FIXed] <frequency>
    FUNCtion
        [:SHAPe] <shape>
    LIST2
        :FREQuency <freq_list>
            :POINts?

[SOURce:]
    MARKer
        [:STATe] <mode>
    PM
        [:DEViation] <phase>
        :SOURce <source>
        :STATe <mode>
        :UNIT
            [:ANGLe] <units>
    ROSCillator
        :SOURce <source>
    SWEep
        :COUNt <number>
        :DIRection <direction>
        :POINts <number>
        :SPACing <mode>
        :TIME <time>

STATus
    :OPERation
        :CONDition?
        :ENABle <mask>
        :NTRansition <mask>
        :PTRansition <mask>
    :PRESet
    :QUEStionable
        :CONDition?
        :ENABle <mask>
        :NTRansition <mask>
        :PTRansition <mask>

SYSTem
    :ERRor?
    :VERSion?

TRIGger
    [:STARt|:SEQuence[1]]
        :COUNt <number>
        [:IMMediate]
        :SLOPe <edge>
        :SOURce <source>
    :STOP
        [:IMMediate]
        :SLOPe <edge>
        :SOURce <source>
    :SWEep
        [:IMMediate]
        :LINK <link>
        :SOURce <source>
        :TIMer <period>
```


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Table 8-3. Non-SCPI Commands

```
CALibration
    :COUNt?
    :DATA
        :AC[1] <block>
        :AC2 <block>
        :[DC] <block>
    [:DC]
        :BEGin
        :POINt?
    :SECure
        :CODE <code>
        [:STATe] <mode>[,<code>]
    :STATe <state>
        :AC <state>
        :DC <state>

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

[SOURce:]
    ARBitrary
        :DAC
            :FORMat <format>
            :SOURce <source>
        :DOWNload <source>,<dest>,<length>
            COMPlete
    FUNCtion
        :USER
    LIST[1]
        :FORMat
            [:DATA] <format>[,<length>]
        [:SEGMent]
            :ADDRess?
            :CATalog?
            :COMBined <combined_list>
                :POINts?
            :DEFine <length>
            :DELete
                :ALL
                [:SELected]
            :FREE?
            :MARKer <marker_list>
                :POINts?
            :SELect <name>
            :VOLTage <voltage_list>
                :DAC <dac_list>
                :POINts?

[SOURce:]
    LIST[1]
        :SSEQuence
            :ADDRess?
            :CATalog?
            :COMBined <combined_list>
            :DEFine <length>
            :DELete
                :ALL
                [:SELected]
            :DWELl
                :COUNt <repetition_list>
                :POINts?
            :FREE?
            :MARKer <marker_list>
                :POINts?
                :SPOint <points>
            :SELect <name>
            :SEQuence <segment_list>
                :SEGMents?
    LIST2
        :FORMat
            [:DATA] <format>[,<length>]
    MARKer
        :ECLTrg<n>
            :FEED <source>
            [:STATe] <mode>
    RAMP
        :POLarity <polarity>
        :POINts <number>
    ROSCillator
        :FREQuency
            :EXTernal <frequency>

STATus
    :OPC
        :INITiate <state>

TRIGger
    [:STARt|:SEQuence[1]]
        :GATE
            :POLarity <polarity>
            :SOURce <source>
            :STATe <state>

VINStrument
    [:CONFigure]
        :LBUS
            [:MODE} <mode>
                :AUTO <state>
        :TEST
            :CONFigure <length>
            :DATA?
        :VME
            :RECeive
                :ADDRess
                    :DATA?
                    :READY?
    :IDENtity?
```


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*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 be 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

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- **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

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- **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.*

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*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

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*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

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*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

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*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".*

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*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

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*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

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- **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.*

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*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

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***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

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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

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Chapter 9
AFG Status

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.

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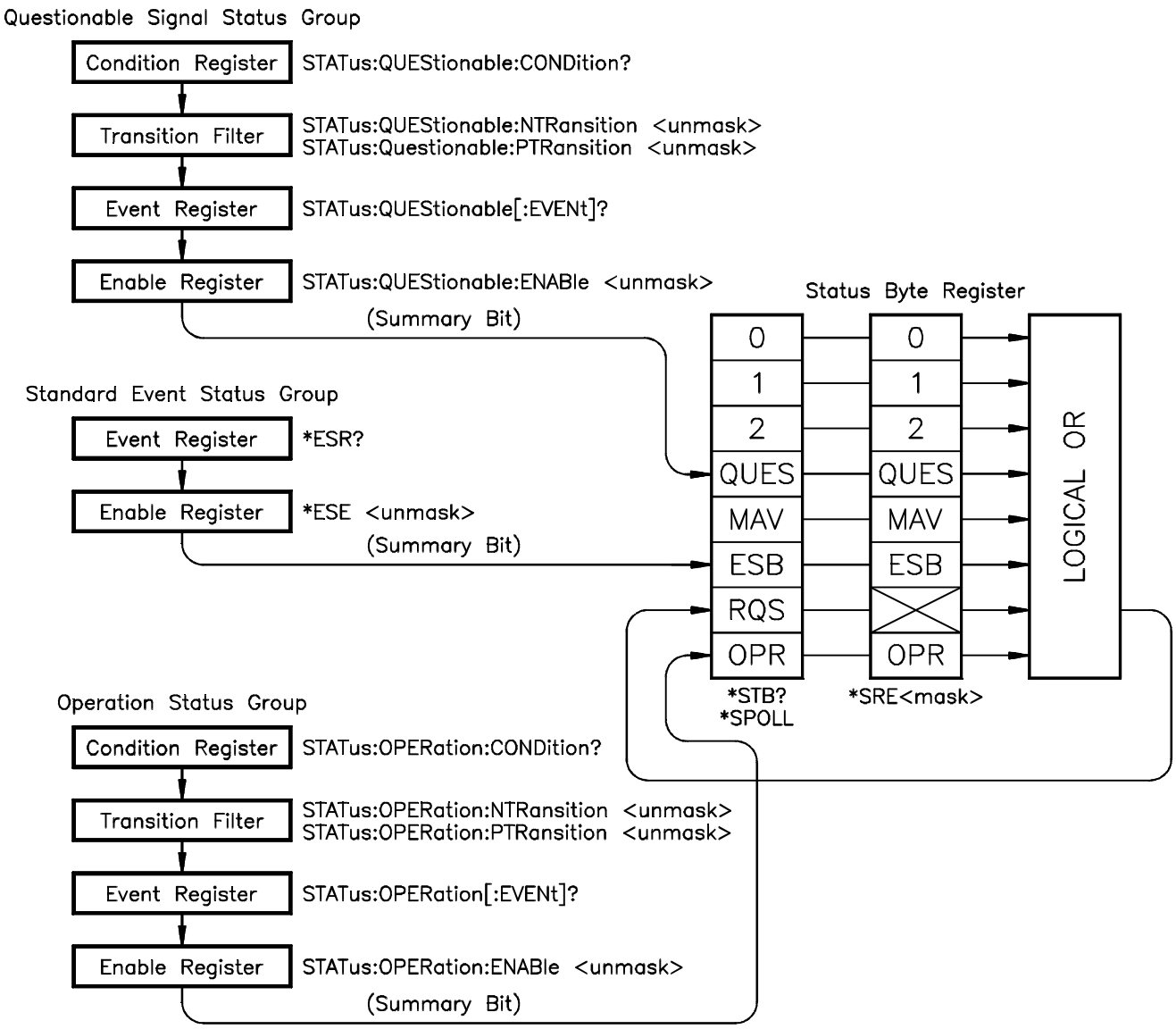


Figure 9-1. HP E1445A Status Groups and Associated Registers

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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.

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<*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>
```


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2. 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*>

3. 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

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```
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.

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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.

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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>
```


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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
```

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```
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.

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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.

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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>
   ```


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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.

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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.

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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.

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Notes

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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.

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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.

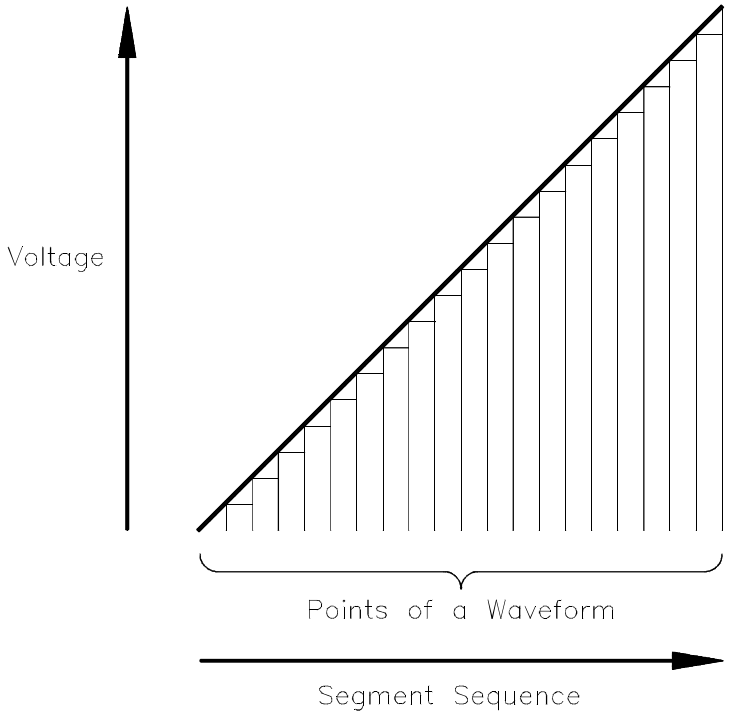


Figure 10-1. Arbitrary Waveform

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.)

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Generating Non-Sinusoid Arbitrary Waveforms

Refer to Figure 10-2. The following describes the blocks that generate non-sinusoid waveforms.

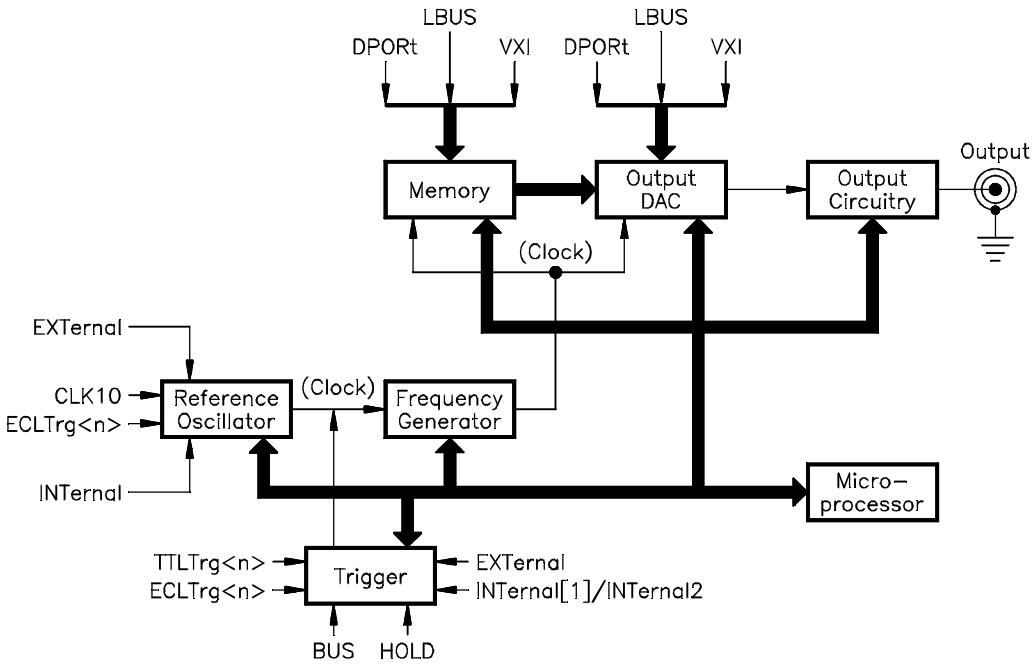


Figure 10-2. AFG Simplified Block Diagram

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.

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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.

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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.

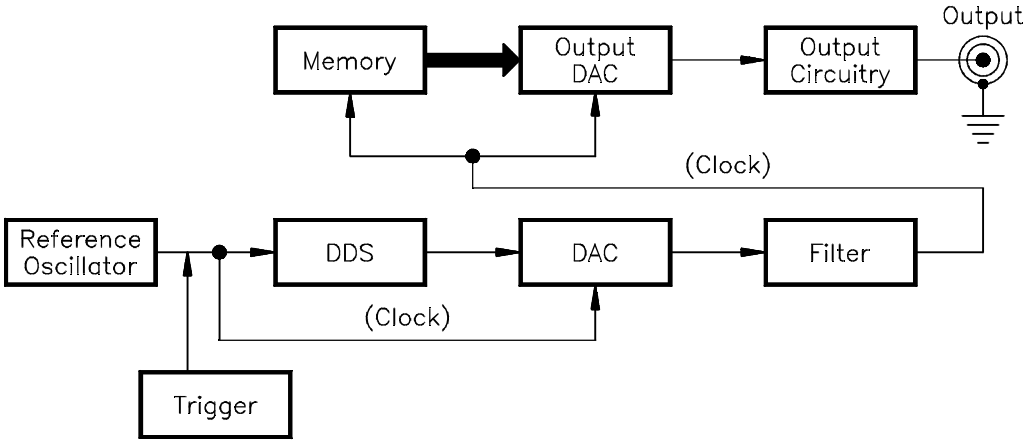


Figure 10-3. Generating Waveforms Using a Frequency1 Generator

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.

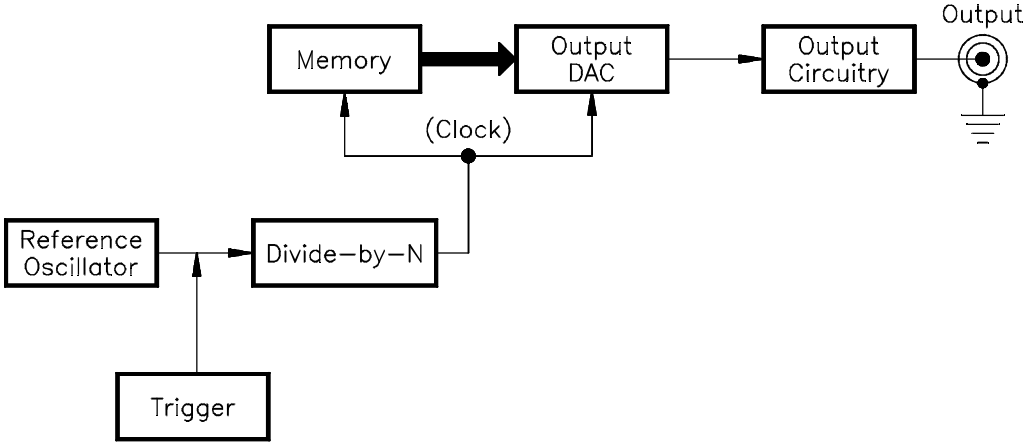


Figure 10-4. Generating Waveforms Using a Frequency2 Generator

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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 generates the waveform segments and segment sequences for the standard waveforms.

Generating Sinusoid Waveforms

Refer to Figure 10-5. The AFG uses the DDS (Frequency1) frequency generator to generate Sinusoid waveforms. The generator output directly supplies the DAC data for the output DAC to generate the waveforms.

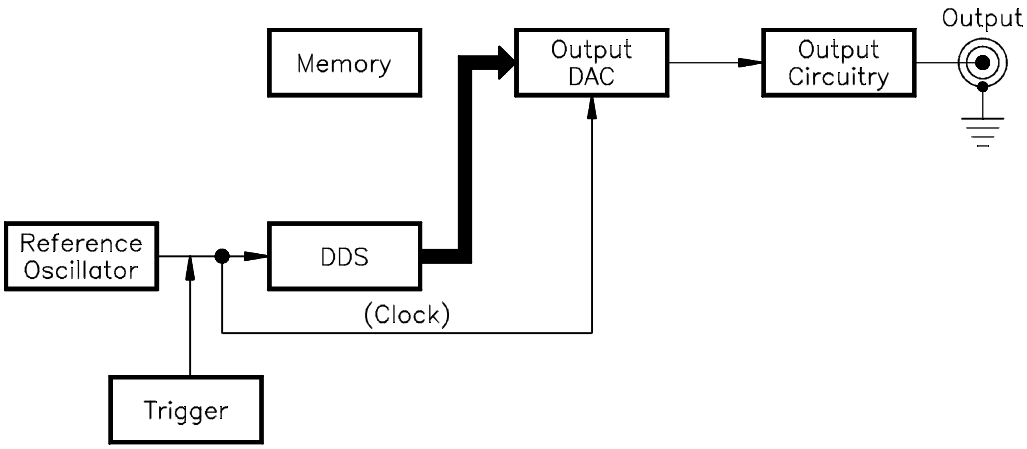


Figure 10-5. Generating Sinusoid Waveforms

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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.

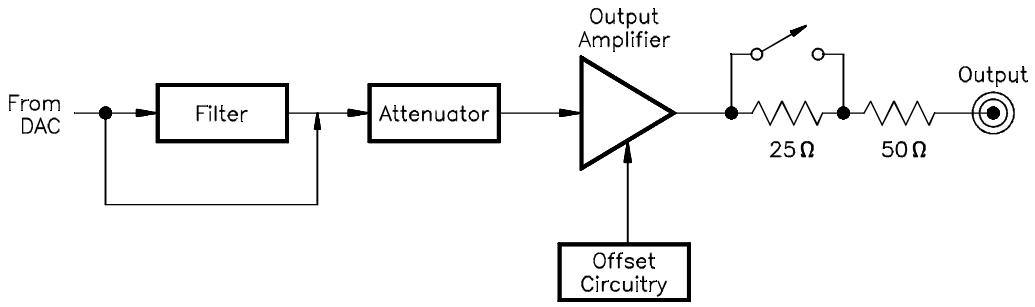


Figure 10-6. AFG Output Circuitry

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.

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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.

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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)

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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 ± 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

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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% ± 3 nsec. 0.005 Hz to 5.36870912 MHz (doubled range); Average Duty cycle is 44% to 56% ± 3 nsec. Using frequency generator #1, square waves inherit the timing jitter characteristics given above for frequency generator #1. The sample period is ¼ 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.

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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(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

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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 ± 5° 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.)

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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 (fc).

Total Harmonic Distortion (through 9th harmonic):

10 Hz–250 kHz	-60 dBc
250 kHz–4 MHz:	[-60 + 20 $\log_{10}$ (fc / 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 °C beyond Tcal ± 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 Tcal ± 5° C, add 0.015% of limit per °C.

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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 KΩ resistor. External source must be able to sink 1 Ma.

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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:	- 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:	- 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

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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}	IDM	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

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Notes

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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:

- Table B-1. HP E1445A Example Program Listing . . . . . Page 464
- Table B-2. HP E1445A Command Coupling Groups . . . . . Page 467
- Table B-3. HP E1445A Frequency Limits . . . . . Page 470
- Table B-4. HP E1445A Amplitude Limits . . . . . Page 471
- Table B-5. HP E1445A Power-on/Reset Conditions . . . . . Page 472
- Table B-6. HP E1445A Error Messages . . . . . Page 475
- Table B-7. HP E1445A Settings Conflict Error Messages . . . . . Page 480

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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.

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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_LEVL	"	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.

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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.)
	WAVSELFP	"	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.

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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:ADDRess:DATA? VINStrument[:CONFigure]:VME:RECeive:ADDRess:READy? VINStrument:IDENtity?
Frequency	ARM:SWEep:COUNt ARM:SWEep:SOURce

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Table B-2. HP E1445A Command Coupling Groups (*continued*)

Coupling Group	Commands
Frequency (*continued*)	[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

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Table B-2. HP E1445A Command Coupling Groups (*continued*)

Coupling Group	Commands
None	ARM[:STARt]:LAYer2[:IMMediate] ARM[:STARt]:LAYer2:SLOPe ARM[:STARt]:LAYer2:SOURce ARM:SWEep[:IMMediate] INITiate[:IMMediate] OUTPut[1]:FILTer[:LPASs]:FREQuency OUTPut[1]:FILTer[:LPASs][:STATe] OUTPut[1][:STATe] [SOURce:]ARBitrary:DAC:FORMat [SOURce:]ARBitrary:DOWNload [SOURce:]ARBitrary:DOWNload:COMPlete [SOURce:]FUNCtion:USER [SOURce:]LIST[1]:FORMat[:DATA] [SOURce:]LIST[1][:SEGMent]:ADDRess? [SOURce:]LIST[1][:SEGMent]:CATalog? [SOURce:]LIST[1][:SEGMent]:COMBined [SOURce:]LIST[1][:SEGMent]:COMBined:POINts? [SOURce:]LIST[1][:SEGMent]:DEFine [SOURce:]LIST[1][:SEGMent]:DELete:ALL [SOURce:]LIST[1][:SEGMent]:DELete[:SELected] [SOURce:]LIST[1][:SEGMent]:FREE? [SOURce:]LIST[1][:SEGMent]:MARKer [SOURce:]LIST[1][:SEGMent]:MARKer:POINts? [SOURce:]LIST[1][:SEGMent]:MARKer:SPOint [SOURce:]LIST[1][:SEGMent]:SELect [SOURce:]LIST[1][:SEGMent]:VOLTage [SOURce:]LIST[1][:SEGMent]:VOLTage:DAC [SOURce:]LIST[1][:SEGMent]:VOLTage:POINts? [SOURce:]LIST[1]:SSEQuence:ADDRess? [SOURce:]LIST[1]:SSEQuence:CATalog? [SOURce:]LIST[1]:SSEQuence:COMBined [SOURce:]LIST[1]:SSEQuence:COMBined:POINts? [SOURce:]LIST[1]:SSEQuence:DEFine [SOURce:]LIST[1]:SSEQuence:DELete:ALL [SOURce:]LIST[1]:SSEQuence:DELete[:SELected] [SOURce:]LIST[1]:SSEQuence:DWELl:COUNt [SOURce:]LIST[1]:SSEQuence:DWELl:COUNt:POINts? [SOURce:]LIST[1]:SSEQuence:FREE? [SOURce:]LIST[1]:SSEQuence:MARKer [SOURce:]LIST[1]:SSEQuence:MARKer:POINts? [SOURce:]LIST[1]:SSEQuence:MARKer:SPOint [SOURce:]LIST[1]:SSEQuence:SELect [SOURce:]LIST[1]:SSEQuence:SEQuence [SOURce:]LIST[1]:SSEQuence:SEQuence:SEGMents?

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Frequency Limits

Table B-3. HP E1445A Frequency Limits

Function	Trigger Start Source	Frequency Low Limit	Frequency 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.

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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

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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

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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	+0.00000000E+000
Output impedance	OUTP:IMP	+5.00000000E+001
Output load	OUTP:LOAD	+5.00000000E+001
Load-Impedance coupling	OUTP:LOAD:AUTO	1 (on)
Waveform repetitions (burst)	ARM:COUN	+9.90000000E+037
Waveform arm count	ARM:LAY2:COUN	+1.00000000E+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

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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)

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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.

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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.

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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.

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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.

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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.

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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

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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

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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

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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.

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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:

A24 base address + register number

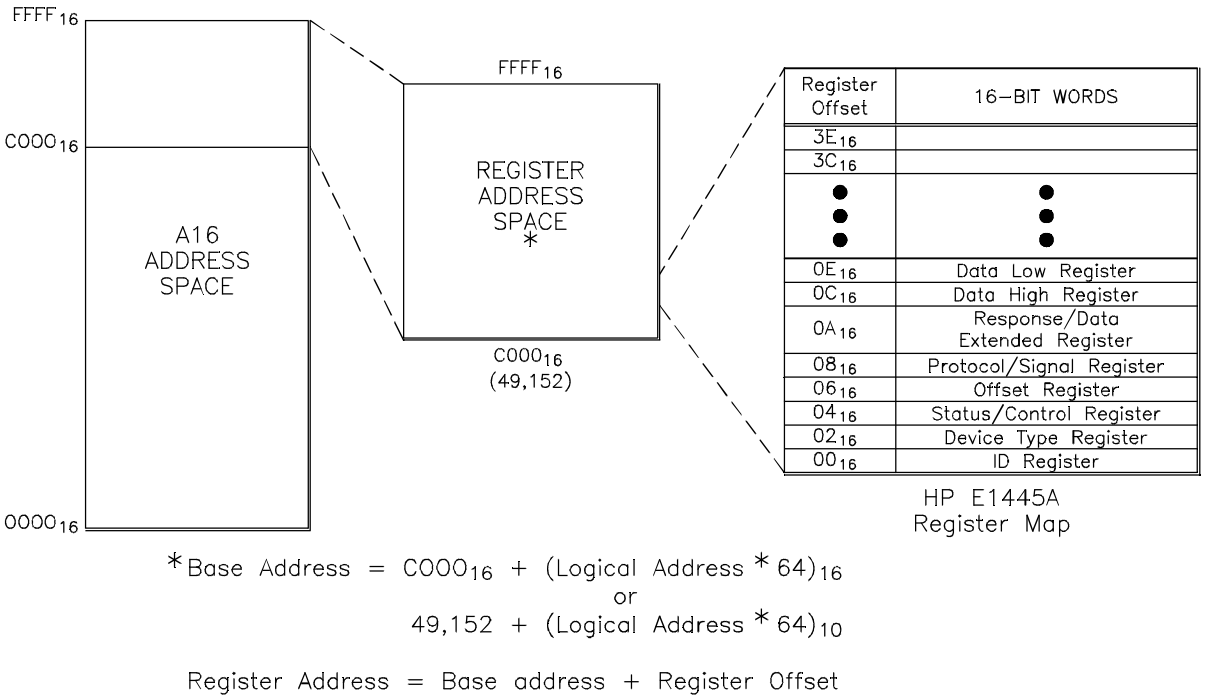
The base address of the AFG operational registers in A24 address space is determined by reading the AFG's Offset Register and multiplying the value by 256 (100_{16}). This converts the 16-bit value of the Offset Register to a 24-bit address.

The register number is identified in the register descriptions found in the following sections.

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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.



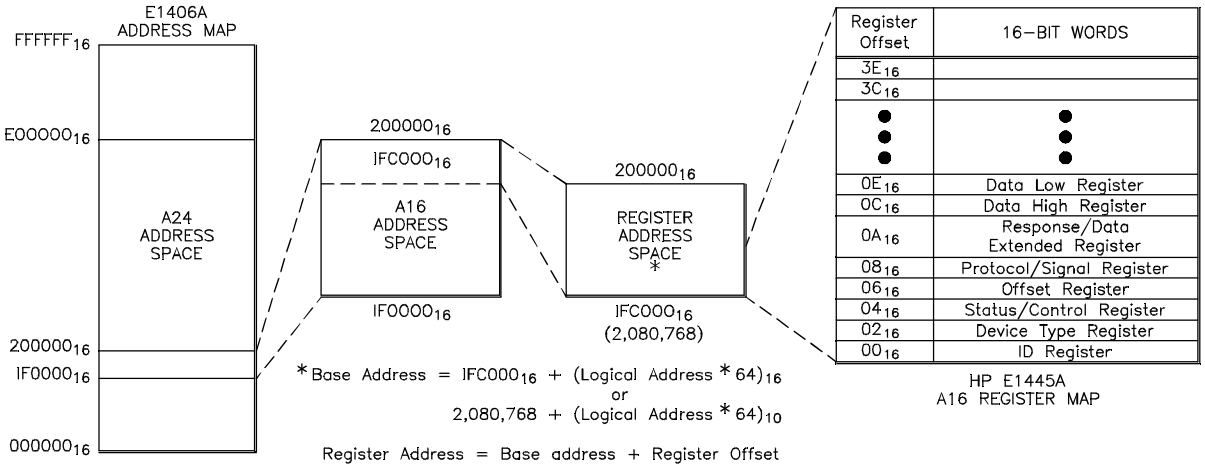


Figure C-1. HP E1445A AFG Registers within A16 Address Space

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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 = **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.

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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:]FREQuency[1]) 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):

  base_addr + $A7_{16}$ through base_addr + $A1_{16}$

- Frequency Load Strobe Register (DDS):

  base_addr + $8D_{16}$

- Sample/Hold and ROSC/N Control Register (DIV N):

  base_addr + 63_{16}

- ROSC/N Divider Registers (DIV N):

  base_addr + $7D_{16}$ through 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
base + $A7_{16}$ through 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).

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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							

Stobe 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).

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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)

```
!RE-STORE "FREQ1_REG"
!This program changes the output frequency generated by the direct-
!digital-synthesis (DDS) method by writing frequency-value data to
!the AFG's Phase Increment registers.
!
ASSIGN @Afg TO 1680
COM @Afg,Base_addr
!
!Call the subprograms which reset the AFG, which determine the base
!address of the AFG registers in A24 address space, and which set the
!output function.
CALL Rst
CALL A24_offset
CALL Output_function
!
DISP "Press 'Continue' to change frequency (register writes)"
PAUSE
DISP ""
!Call the subprogram which changes the output frequency, and pass the
!frequency, the number of waveform points, the reference oscillator
!frequency, and the frequency range (SOUR:FREQ1:RANGe command).
!(Note: sine waves and arb waves: npts=1, square waves: npts=4,
!ramp/triangle waves: npts=RAMP:POINts value.)
!
CALL Freq_change(2000.,1,4.294967296E+7,0)
END
!
SUB A24_offset
A24_offset:  !Subprogram which determines the base address for
             !the AFG registers in A24 address space.
    COM @Afg,Base_addr
    CONTROL 16,25;2!access A16 space with READIO and WRITEIO
    A16_addr=DVAL("D400",16)          !AFG A16 base address
    Offset=READIO(-16,A16_addr+6)     !read AFG offset register
    Base_addr=Offset*256 !shift offset for 24-bit address
SUBEND
!
SUB Output_function
```

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```
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
```


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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.

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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)

```
!RE-STORE "FREQ2_REG"
!This program changes the output frequency generated with the
!divide-by-n frequency synthesis method by writing frequency
!data to the Sample/Hold and ROSC/N Control register, and to the
!ROSC/N Divider registers.
!
ASSIGN @Afg TO 1680
COM @Afg,Base_addr
!
!Call the subprograms which reset the AFG, which determine the base
!address of the AFG registers in A24 address space, and which set
!the output function.
CALL Rst
CALL A24_offset
CALL Output_function
!
DISP "Press 'Continue' to change frequency (register writes)"
PAUSE
DISP ""
!Call the subprogram which changes the output frequency. Pass the
!reference oscillator frequency, the new output frequency, and
!the number of waveform points. (Note arbitrary waveforms: npts=1
!square waves: npts=4, ramp/triangle waves:
!npts=RAMP:POINts value.)
!
CALL Divide_by_n(4.E+7,2.5E+6,4)
END
!
SUB A24_offset
A24_offset:  !Subprogram which determines the base address for
             !the AFG registers in A24 address space.
    COM @Afg,Base_addr
    CONTROL 16,25;2                 !access A16 space with READIO and WRITEIO
    A16_addr=DVAL("D400",16)            !AFG A16 base address
    Offset=READIO(-16,A16_addr+6)       !read AFG offset register
    Base_addr=Offset*256                !shift offset for 24-bit address
SUBEND
!
SUB Output_function
```

Continued on Next Page

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```
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
```

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```
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 ROSC/N Control Register, and the ROSC/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.

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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:

  base_addr + $B3_{16}$ through base_addr + $B1_{16}$

- Phase Load Strobe Register:

  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
base + $B3_{16}$ through 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
base + $8B_{16}$	unused	Strobe Data							

Stobe 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.

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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)

```
!RE-STORE "PHAS_CHNG"
!This program changes the phase of the output signal by writing
!phase offset data to the phase modulation registers.
!
ASSIGN @Afg TO 1680
COM @Afg,Base_addr
!
!Call the subprograms which reset the AFG, which determine the base
!address of the AFG registers in A24 address space, and which set the
!output function.
CALL Rst
CALL A24_offset
CALL Output_function
!
DISP "Press 'Continue' to change the signal phase (register writes)"
PAUSE
DISP ""
!Call the subprogram which changes the signal phase, and pass the new
!phase value.
!
CALL Phase_change(180)
END
!
SUB A24_offset
A24_offset:  !Subprogram which determines the base address for
             !the AFG registers in A24 address space.
    COM @Afg,Base_addr
    CONTROL 16,25;2                 !access A16 space with READIO and WRITEIO
    A16_addr=DVAL("D400",16)        !AFG A16 base address
    Offset=READIO(-16,A16_addr+6)   !read AFG offset register
    Base_addr=Offset*256            !shift offset for 24-bit address
SUBEND
!
SUB Output_function
Output_function:    !Subprogram which uses SCPI commands to set DDS
                    !frequency synthesis, to set the output frequency/
                    !function/amplitude, to set up phase modulation, and
                    !to start the waveform.
    COM @Afg,Base_addr
    OUTPUT @Afg;"TRIG:STAR:SOUR  INT1;";        !frequency generator
    OUTPUT @Afg;":SOUR:FREQ1:FIX  60;";         !frequency
    OUTPUT @Afg;":SOUR:PM:SOUR  INT;";          !phase modulation source
    OUTPUT @Afg;":SOUR:PM:STAT  ON;";           !enable phase modulation
    OUTPUT @Afg;":SOUR:FUNC:SHAP  SIN;";        !function
```

Continued on Next Page

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```
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.

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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:

  base_addr + 8_{16}

- Waveform Select Register:

  base_addr + A_{16}

- Sequence Base Register:

  base_addr + 20_{16}

- Status Register:

  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
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.

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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.

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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)

```
!RE-STORE "WAVE_SEL"
!This program changes the output waveform sequence once the AFG has been
!INITiated by writing the location of a sequence's base address to the
!Waveform Select register. All register reads and writes are 16 bit.
!
!Assign an I/O path between the computer and the AFG
ASSIGN @Afg TO 1680
ASSIGN @Afg1 TO 1680;FORMAT OFF                    !path for binary data
COM @Afg,@Afg1,Base_addr,Seq1_addr,Seq2_addr,Seq3_addr
!
!Subprograms which reset the AFG and erase all existing waveforms.
CALL Rst
CALL Wf_del
!
!SCPI commands which configure the AFG
OUTPUT @Afg;"SOUR:FREQ1:FIX  4.096E6;";          !Sample rate
OUTPUT @Afg;":SOUR:FUNC:SHAP  USER;";            !function
OUTPUT @Afg;":SOUR:VOLT:LEV:IMM:AMPL  2.1V"      !amplitude
OUTPUT @Afg;"SOUR:ARB:DAC:SOUR  INT"             !dac data source
OUTPUT @Afg;"SOUR:ARB:DAC:FORM  SIGN"            !dac data format
!
!Subprograms which define waveforms and load them into segment
!and sequence memory, which determine the AFG's register locations
!in A24, and which configure the AFG's sequence base memory.
CALL Waveform_def
CALL A24_offset
CALL Build_ram
!
!Select an output sequence, and initiate (start) waveform output.
OUTPUT @Afg;"SOUR:FUNC:USER  SEQ1"               !waveform sequence
OUTPUT @Afg;"INIT:IMM"                           !wait-for-arm state
!
!Subprogram which changes the output sequence with register writes.
CALL Wave_change
END
!
SUB Waveform_def
    COM @Afg,@Afg1,Base_addr,Seq1_addr,Seq2_addr,Seq3_addr
    CALL Sinx_def
    CALL Sind_def
    CALL Spike_def
SUBEND
!
SUB A24_offset
```

Continued on Next Page

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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.
```

Continued on Next Page

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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)
```

Continued on Next Page

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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
```

Continued on Next Page

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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))/.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/.00125
2100        NEXT J
2110        FOR J=1 TO Width-1
2120        I=1024+Width-J
2130           Waveform(I)=Waveform(I)+.9*J/Width/.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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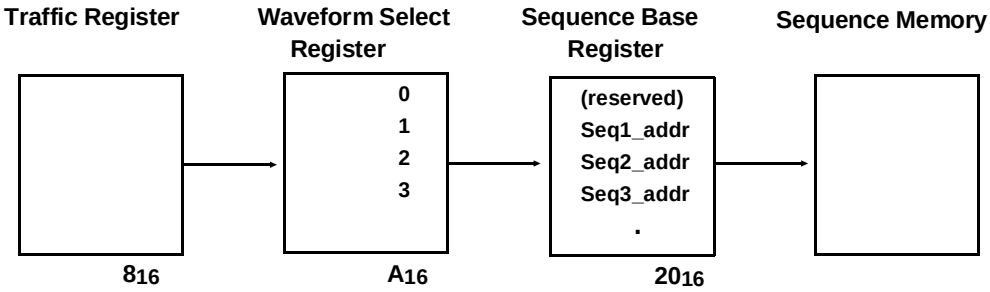
```
2370        OUTPUT @Afg;"SOUR:LIST1:SSEQ:DEF  1"                    !sequence size
2380        OUTPUT @Afg USING "#,K";"SOUR:LIST1:SSEQ:COMB  #0"      !segm execution order
2390        OUTPUT @Afg1;Sequence(*)            !sequence list in indefinite length block
2400        OUTPUT @Afg;CHR$(10);END            !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.

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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 + 26_{16}

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    !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.
```

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```
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
```


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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 µs 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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