Creating and Downloading Waveform Files

Agilent Technologies
E4438C/E8267D Signal Generators

This guide applies to the following signal generator models:

E4438C ESG Vector Signal Generator

E8267D PSG Vector Signal Generator

Due to our continuing efforts to improve our products through firmware and hardware revisions, signal generator design and operation may vary from descriptions in this guide. We recommend that you use the latest revision of this guide to ensure you have up-to-date product information. Compare the print date of this guide (see bottom of page) with the latest revision, which can be downloaded from the following websites:

http://www.agilent.com/find/intuilink

http://www.agilent.com/find/downloadassistant

http://www.agilent.com/find/signalstudio

http://www.agilent.com/find/esg

http://www.agilent.com/find/psg

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Creating and Downloading Waveform Files

This manual explains how to create Arb-based waveform data and download it into the signal generator: This information is also available in the signal generator's *Programming Guide*.

Overview

The signal generator lets you download and extract waveform files. You can create these files either external to the signal generator or by using one of the internal modulation formats. The signal generator also accepts waveforms files created for the earlier E443xB ESG signal generator models. For file extractions, the signal generator encrypts the waveform file information. The exception to encrypted file extraction is user-created I/Q data. The signal generator lets you extract this type of file unencrypted. After extracting a waveform file, you can download it into another Agilent signal generator that has the same option or software license required to play it. Waveform files consist of three items:

- I/Q data
- Marker data
- File header

The signal generator automatically creates the marker file and the file header if the two items are *not* part of the download. In this situation, the signal generator sets the file header information to unspecified (no settings saved) and sets all markers to zero (off).

There are two ways to download waveform files: programmatically or using one of three available free download utilities created by Agilent Technologies:

- Intuilink for PSG/ESG Signal Generators
  www.agilent.com/find/intuilink
- PSG/ESG Download Assistant for use only with MATLAB®
  www.agilent.com/find/downloadassistant
- N7622A Signal Studio Toolkit
  www.agilent.com/find/signalstudio

Waveform Data Requirements

To be successful in downloading files, you must first create the data in the required format.

- Signed 2’s complement
- 2-byte integer values
- Input data range of –32768 to 32767
- Minimum of 60 samples per waveform (60 I and 60 Q data points)
- Interleaved I and Q data

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- Big endian byte order
- The same name for the marker and I/Q file

  This is only a requirement if you create and download a marker file, otherwise the signal generator automatically creates the marker file using the I/Q data file name. For more information, see "Waveform Structure" on page 11.

For more information on waveform data, see "Understanding Waveform Data" on page 4.

Understanding Waveform Data

The signal generator accepts binary data formatted into a binary I/Q file. This section explains the necessary components of the binary data, which uses ones and zeros to represent a value.

Bits and Bytes

Binary data uses the base-two number system. The location of each bit within the data represents a value that uses base two raised to a power (2^{n-1}). The exponent is n – 1 because the first position is zero. The first bit position, zero, is located at the far right. To find the decimal value of the binary data, sum the value of each location:

$$1101 = (1 \times 2^3) + (1 \times 2^2) + (0 \times 2^1) + (1 \times 2^0)$$
$$= (1 \times 8) + (1 \times 4) + (0 \times 2) + (1 \times 1)$$
$$= 13 \text{ (decimal value)}$$

Notice that the exponent identifies the bit position within the data, and we read the data from right to left.

The signal generator accepts data in the form of bytes. Bytes are groups of eight bits:

$$01101110 = (0 \times 2^7) + (1 \times 2^6) + (1 \times 2^5) + (0 \times 2^4) + (1 \times 2^3) + (1 \times 2^2) + (1 \times 2^1) + (0 \times 2^0)$$
$$= 110 \text{ (decimal value)}$$

The maximum value for a single unsigned byte is 255 (11111111 or 2^8–1), but you can use multiple bytes to represent larger values. The following shows two bytes and the resulting integer value:

01101110 10110011= 28339 (decimal value)

The maximum value for two unsigned bytes is 65535. Since binary strings lengthen as the value increases, it is common to show binary values using hexadecimal (hex) values (base 16), which are shorter. The value 65535 in hex is FFFF. Hexadecimal consists of the values 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, and F. In decimal, hex values range from 0 to 15 (F). It takes 4 bits to represent a single hex value.

1 = 0001	2 = 0010	3 = 0011	4 = 0100	5 = 0101
6 = 0110	7 = 0111	8 = 1000	9 = 1001	A = 1010
B = 1011	C = 1100	D = 1101	E = 1110	F = 1111

For I and Q data, the signal generator uses two bytes to represent an integer value.

LSB and MSB (Bit Order)

Within groups (strings) of bits, we designate the order of the bits by identifying which bit has the highest value and which has the lowest value by its location in the bit string. The following is an example of this order.

Most Significant Bit (MSB)	This bit has the highest value (greatest weight) and is located at the far left of the bit string.
Least Significant Bit (LSB)	This bit has the lowest value (bit position zero) and is located at the far right of the bit string.

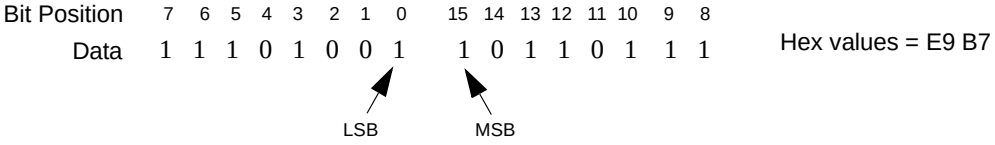
Because we are using 2 bytes of data, the MSB appears in the second byte.

Little Endian and Big Endian (Byte Order)

When you use multiple bytes (as required for the waveform data), you must identify their order. This is similar to identifying the order of bits by LSB and MSB. To identify byte order, use the terms little endian and big endian. These terms are used by designers of computer processors.

Little Endian Order

The lowest order byte that contains bits 0–7 comes first.



Big Endian Order

The highest order byte that contains bits 8–15 comes first.

Notice in the previous figure that the LSB and MSB positioning changes with the byte order. In little endian order, the LSB and MSB are next to each other in the bit sequence.

NOTE For I/Q data downloads, the signal generator requires big endian order. For each I/Q data point, the signal generator uses four bytes (two integer values), two bytes for the I point and two bytes for the Q point.

The byte order, little endian or big endian, depends on the type of processor used with your development platform. Intel© processors and its clones use little endian. Sun™ and Motorola processors use big endian. The Apple PowerPC processor, while big endian oriented, also supports the little endian order. Always refer to the processor's manufacturer to determine the order they use for bytes and, if they support both, to understand how to ensure that you are using the correct byte order.

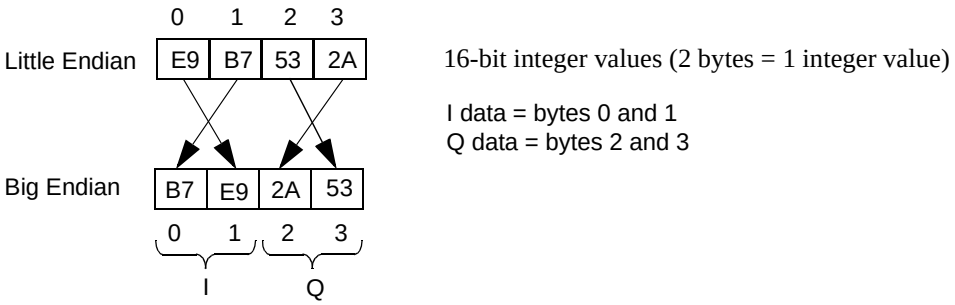
Development platforms include any product that creates and saves waveform data to a file. This includes Agilent Technologies Advanced Design System EDA software, C++, MATLAB, and so forth.

The byte order describes how the system processor stores integer values as binary data in memory. If you output data from a little endian system to a text file (ASCII text), the values are the same as viewed from a big endian system. The order only becomes important when you use the data in binary format, as is done when downloading data to the signal generator.

Byte Swapping

While the processor for the development platform determines the byte order, the recipient of the data may require the bytes in the reverse order. In this situation, you must reverse the byte order before downloading the data. This is commonly referred to as byte swapping. You can swap bytes either programmatically or by using the Agilent Technologies IntuiLink for PSG/ESG Signal Generators software. For the signal generator, byte swapping is the method to change the byte order of little endian to big endian. For more information on little endian and big endian order, see "Little Endian and Big Endian (Byte Order)" on page 5.

The following figure shows the concept of byte swapping for the signal generator. Remember that we can represent data in hex format (4 bits per hex value), so each byte (8 bits) in the figure shows two example hex values.



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To correctly swap bytes, you must group the data to maintain the I and Q values. One common method is to break the two-byte integer into one-byte character values (0–255). Character values use 8 bits (1 byte) to identify a character. Remember that the maximum unsigned 8-bit value is 255 ($2^8 - 1$). Changing the data into character codes groups the data into bytes. The next step is then to swap the bytes to align with big endian order.

NOTE The signal generator always assumes that downloaded data is in big endian order, so there is no data order check. Downloading data in little endian order will produce an undesired output signal.

DAC Input Values

The signal generator uses a 16-bit DAC (digital-to-analog convertor) to process each of the 2-byte integer values for the I and Q data points. The DAC determines the range of input values required from the I/Q data. Remember that with 16 bits we have a range of 0–65535, but the signal generator divides this range between positive and negative values:

- 32767 = positive full scale output
- 0 = 0 volts
- –32768 = negative full scale output

Because the DAC's range uses both positive and negative values, the signal generator requires signed input values. The following list illustrates the DAC's input value range.

Voltage	DAC Range	Input Range	Binary Data	Hex Data
Vmax	65535	32767	01111111 11111111	7FFF
	32768	1	00000000 00000001	0001
0 Volts	32767	0	00000000 00000000	0000
	32766	-1	11111111 11111111	FFFF
Vmin	0	-32768	10000000 00000000	8000

Notice that it takes only 15 bits (2^{15}) to reach the Vmax (positive) or Vmin (negative) values. The MSB determines the sign of the value. This is covered in "2's Complement Data Format" on page 9.

Using E443xB ESG DAC Input Values

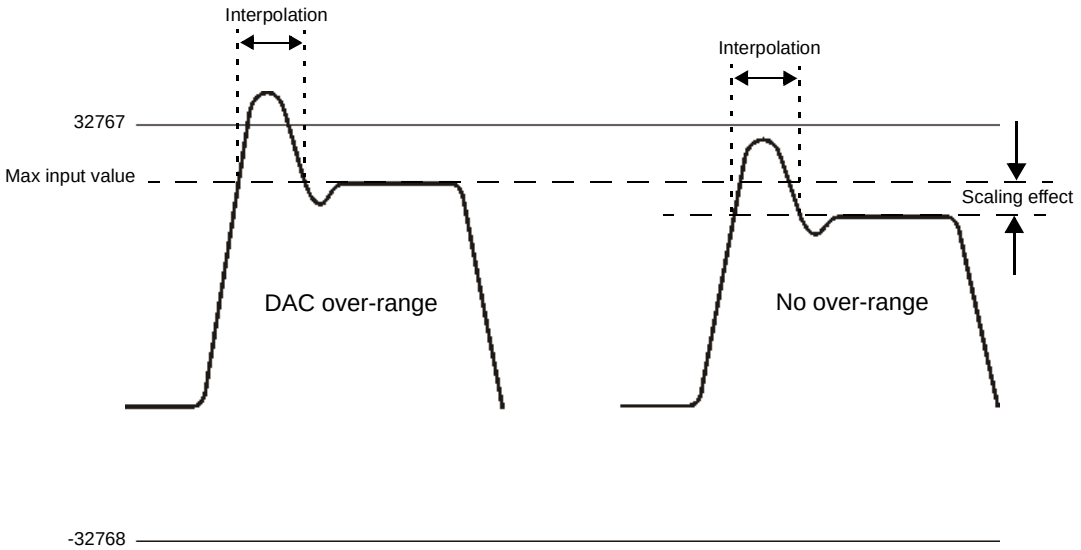
In this section, the words *signal generator* without a model number refer to an E4438C ESG or an E8257D PSG signal generator. The signal generator input values differ from those of the earlier E443xB ESG models. For the E443xB models, the input values are all positive (unsigned) and the data is contained within 14 bits plus 2 bits for markers. This means that the E443xB DAC has a smaller range:

- 0 = negative full scale output
- 8192 = 0 volts
- 16383 = positive full scale output

Although the signal generator uses signed input values, it accepts unsigned data created for the E443xB and converts it to the proper DAC values. To download an E443xB files to the signal generator, use the same command syntax as for the E443xB models. For more information on downloading E443xB files, see "Downloading E443xB Signal Generator Files" on page 44.

Scaling DAC Values

The signal generator uses an interpolation algorithm (sampling between the I/Q data points) when reconstructing the waveform. For common waveforms, this interpolation can cause overshoot, which may create a DAC over-range error condition. Because of the interpolation, the error condition can occur even when all the I and Q values are within the DAC input range. To avoid the DAC over-range problem, you must scale (reduce) the I and Q input values, so that any overshoot remains within the DAC range.



There is no single scaling value that is optimal for all waveforms. To achieve the maximum dynamic range, select the largest scaling value that does not result in a DAC over-range error. There are two ways to scale the I/Q data:

- Reduce the input values for the DAC.
- Use the SCPI command `:RADio:ARB:RSCaling <val>` or the front-panel keys, **Mode** > **Dual ARB** > **ARB Setup** > **More (1 of 2)** > **Waveform Runtime Scaling**, to set the waveform amplitude as a percentage of full scale.

NOTE The signal generator comes from the factory with scaling set to 70%. If you reduce the DAC input values, ensure that you set the signal generator scaling (`:RADio:ARB:RSCaling`) to an appropriate setting that accounts for the reduced values.

To further minimize overshoot problems, use the correct FIR filter for your signal type and adjust your sample rate to accommodate the filter response.

2's Complement Data Format

The signal generator requires signed values for the input data. For binary data, two's complement is a way to represent positive and negative values. The most significant bit (MSB) determines the sign.

- 0 equals a positive value (01011011 = 91 decimal)
- 1 equals a negative value (10100101 = –91 decimal)

Like decimal values, if you sum the binary positive and negative values, you get zero. The one difference with binary values is that you have a carry, which is ignored. The following shows how to calculate the two's complement using 16-bits. The process is the same for both positive and negative values.

Convert the decimal value to binary.

```
23710 = 01011100 10011110
```

Notice that 15 bits (0-14) determine the value and bit 16 (MSB) indicates a positive value.
Invert the bits (1 becomes 0 and 0 becomes 1).

```
10100011 01100001
```

Add one to the inverted bits. Adding one makes it a two's complement of the original binary value.

```
  10100011 01100001
+ 00000000 00000001
  10100011 01100010
```

The MSB of the resultant is one, indicating a negative value (–23710).
Test the results by summing the binary positive and negative values; when correct, they produce zero.

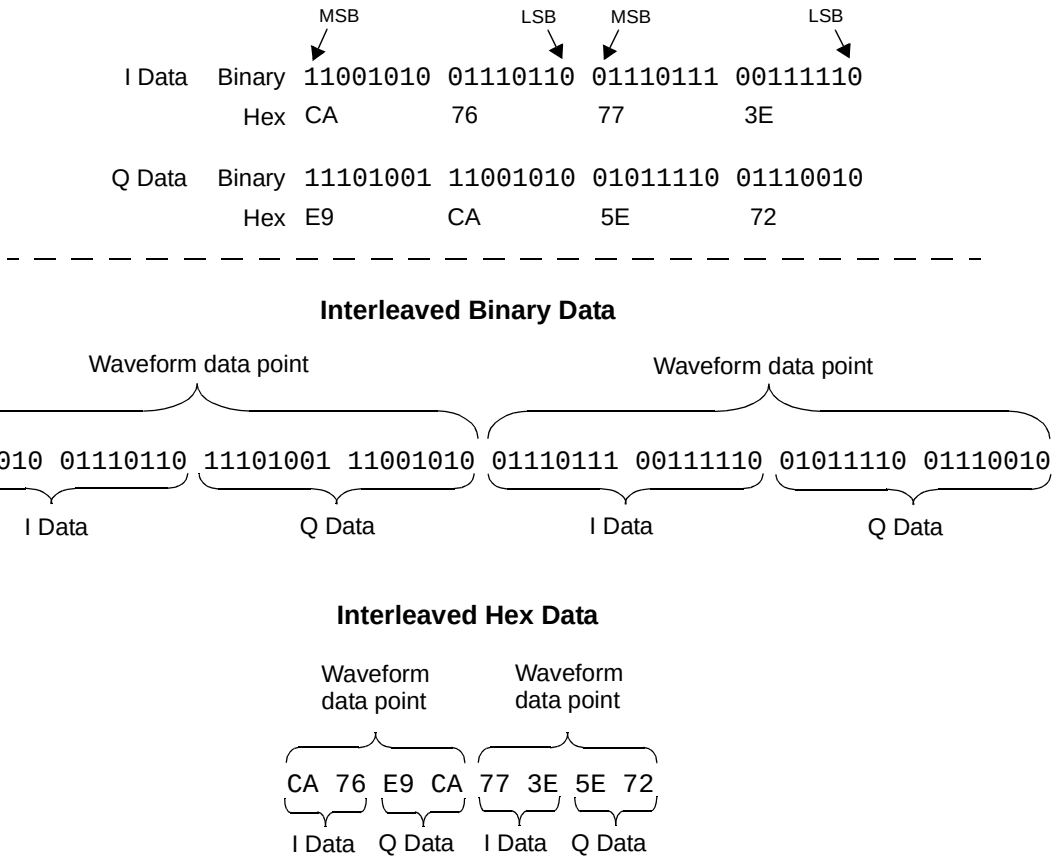
```
  01011100 10011110
+ 10100011 01100001
  00000000 00000000
```

I and Q Interleaving

When you create the waveform data, the I and Q data points typically reside in separate arrays or files. The signal generator requires a single I/Q file for waveform data playback. The process of interleaving creates a single array with alternating I and Q data points, with the Q data following the I data. This array is then downloaded to the signal generator as a binary file. The interleaved file comprises the waveform data points where each set of data points, one I data point and one Q data point, represents one I/Q waveform point.

NOTE The signal generator can accept separate I and Q files created for the earlier E443xB ESG models. For more information on downloading E443xB files, see "Downloading E443xB Signal Generator Files" on page 44.

The following figure illustrates interleaving I and Q data. Remember that it takes two bytes (16 bits) to represent one I or Q data point.



Waveform Structure

To play back waveforms, the signal generator uses data from the following three files:

- File header
- Marker file
- I/Q file

All three files have the same name, the name of the I/Q data file, but the signal generator stores each file in its respective directory (headers, markers, and waveform). When you extract the waveform file (I/Q data file), it includes the other two files, so there is no need to extract each one individually. For more information on file extractions, see "Commands for Downloading and Extracting Waveform Data" on page 19.

File Header

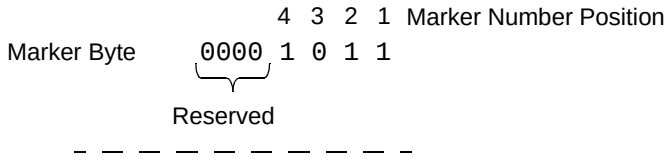
The file header contains settings for the ARB modulation format such as sample rate, marker polarity, I/Q modulation attenuator setting and so forth. When you create and download I/Q data, the signal generator automatically creates a file header with all saved parameters set to unspecified. With unspecified header settings, the waveform either uses the signal generator default settings, or if a waveform was previously played, the settings from that waveform. Ensure that you configure and save the file header settings for each waveform. Refer to the *User's Guide* for more information on file headers

NOTE If you have no RF output when you play back a waveform, ensure that the marker RF blanking function has not been set for any of the markers. The marker RF blanking function is a header parameter that can be inadvertently set active for a marker by a previous waveform.

Marker File

The marker file uses one byte per I/Q waveform point to set the state of the four markers either on (1) or off (0) for each I/Q point. When a marker is active (on), it provides an output trigger signal to the rear panel EVENT connector that corresponds to the active marker number. Because markers are set at each waveform point, the marker file contains the same number of bytes as there are waveform points. For example, for 200 waveform points, the marker file contains 200 bytes.

Although a marker point is one byte, the signal generator uses only bits 0–3 to configure the markers; bits 4–7 are reserved and set to zero. The following example shows a marker byte.



Example of Setting a Marker Byte

Binary 0000 0101

Hex 05

Sets markers 1 and 3 on for a waveform point

The following example shows a marker binary file (all values in hex) for a waveform with 200 points. Notice the first marker point, `0f`, shows all four markers on for only the first waveform point.

```
00000000: 0f 01 01 01 01 01 01 01 01 01 01 01 01 01 01 01
00000010: 01 01 01 01 01 01 01 01 01 01 01 01 01 01 01 01
00000020: 01 01 01 01 01 01 01 01 01 01 01 01 01 01 01 01
00000030: 01 05 05 05 05 05 05 05 05 05 05 05 05 05 05 05
00000040: 05 05 05 05 05 05 05 05 05 05 05 05 05 05 05 05
00000050: 05 05 05 05 05 05 05 05 05 05 05 05 05 05 05 05
00000060: 05 05 05 05 04 04 04 04 04 04 04 04 04 04 04 04
00000070: 04 04 04 04 04 04 04 04 04 04 04 04 04 04 04 04
00000080: 04 04 04 04 04 04 04 04 04 04 04 04 04 04 04 04
00000090: 04 04 04 04 04 04 00 00 00 00 00 00 00 00 00 00
000000a0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
000000b0: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
000000c0: 00 00 00 00 00 00 00 00
```

`0f` = All markers on

`01` = Marker 1 on

`05` = Markers 1 and 3 on

`04` = Marker 3 on

`00` = No active markers

If you create your own marker file, its name must be the same as the waveform file. If you download I/Q data without a marker file, the signal generator automatically creates a marker file with all points set to zero. For more information on markers, see the *User's Guide*.

NOTE Downloading marker data using a file name that currently resides on the signal generator overwrites the existing marker file without affecting the I/Q (waveform) file. However downloading just the I/Q data with the same file name as an existing I/Q file also overwrites the existing marker file setting all bits to zero.

I/Q File

The I/Q file contains the interleaved I and Q data points (signed 16-bit integers for each I and Q data point). Each I/Q point equals one waveform point. The signal generator stores the I/Q data in the waveform directory.

NOTE If you download I/Q data using a file name that currently resides on the signal generator, it also overwrites the existing marker file setting all bits to zero and the file header setting all parameters to unspecified.

Waveform

A waveform consists of samples. When you select a waveform for playback, the signal generator loads settings from the file header and creates the waveform samples from the data in the marker and I/Q (waveform) files. The file header, while required, does not affect the number of bytes that compose a waveform sample. One sample contains five bytes:

I/Q Data		+	Marker Data	=	1 Waveform Sample
2 bytes I (16 bits)	2 bytes Q (16 bits)		1byte (8 bits) Bits 4–7 reserved—Bits 0–3 set		5 bytes

To create a waveform, the signal generator requires a minimum of 60 samples. To help minimize signal imperfections, use an even number of samples (for information on waveform continuity, see "Waveform Phase Continuity" on page 14). When you store waveforms, the signal generator saves changes to the waveform file, marker file, and file header.

Waveform Phase Continuity

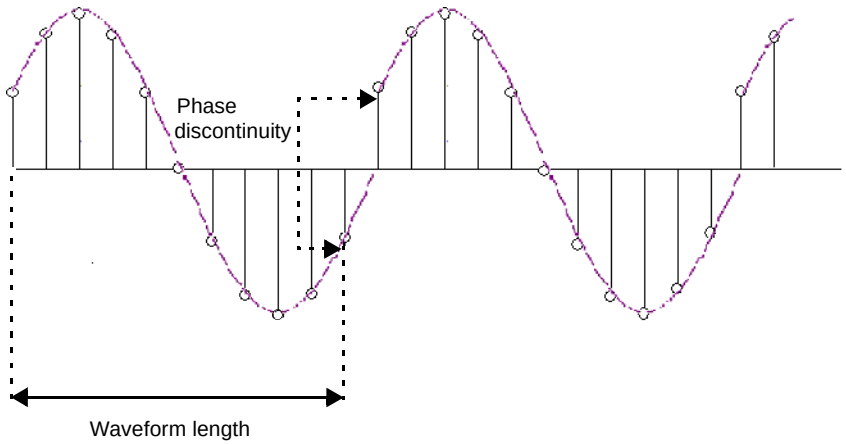
Phase Discontinuity, Distortion, and Spectral Regrowth

The most common arbitrary waveform generation use case is to play back a waveform that is finite in length and repeat it continuously. Although often overlooked, a phase discontinuity between the end of a waveform and the beginning of the next repetition can lead to periodic spectral regrowth and distortion.

For example, the sampled sinewave segment in the following figure may have been simulated in software or captured off the air and sampled. It is an accurate sinewave for the time period it occupies, however the waveform does not occupy an entire period of the sinewave or some multiple thereof. Therefore, when repeatedly playing back the waveform by an arbitrary waveform generator, a phase discontinuity is introduced at the transition point between the beginning and the end of the waveform.

Repetitions with abrupt phase changes result in high frequency spectral regrowth. In the case of playing back the sinewave samples, the phase discontinuity produces a noticeable increase in distortion components in addition to the line spectra normally representative of a single sinewave.

Sampled Sinewave with Phase Discontinuity



Avoiding Phase Discontinuities

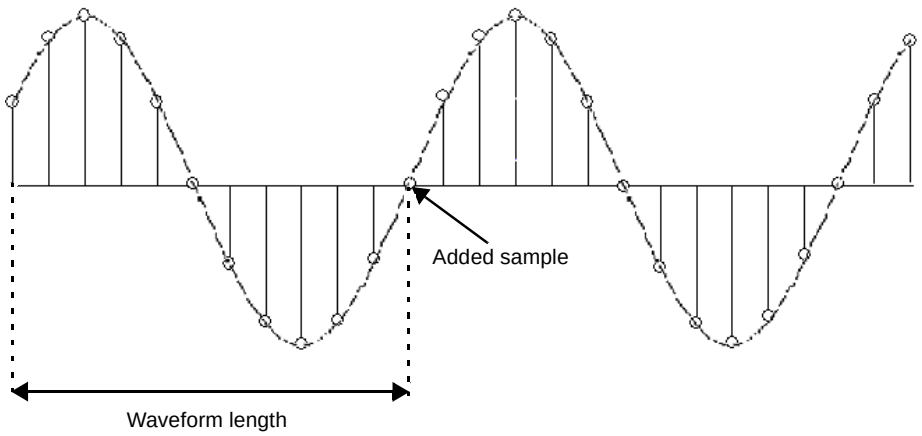
You can easily avoid phase discontinuities for periodic waveforms by simulating an integer number of cycles when you create your waveform segment.

NOTE If there are N samples in a complete cycle, only the first N-1 samples are stored in the waveform segment. Therefore, when continuously playing back the segment, the first and Nth waveform samples are always the same, preserving the periodicity of the waveform.

By adding off time at the beginning of the waveform and subtracting an equivalent amount of off time from the end of the waveform, you can address phase discontinuity for TDMA or pulsed periodic waveforms. Consequently, when the waveform repeats, the lack of signal present avoids the issue of phase discontinuity.

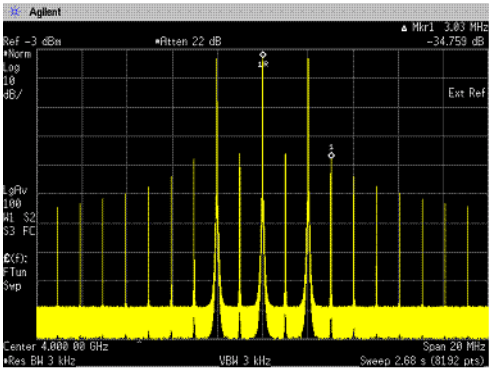
However, if the period of the waveform exceeds the waveform playback memory available in the arbitrary waveform generator, a periodic phase discontinuity could be unavoidable. N5110B Baseband Studio for Waveform Capture and Playback alleviates this concern because it does not rely on the signal generator waveform memory. It streams data either from the PC hard drive or the installed PCI card for N5110B enabling very large data streams. This eliminates any restrictions associated with waveform memory to correct for repetitive phase discontinuities. Only the memory capacity of the hard drive or the PCI card limits the waveform size.

Sampled Sinewave with No Discontinuity



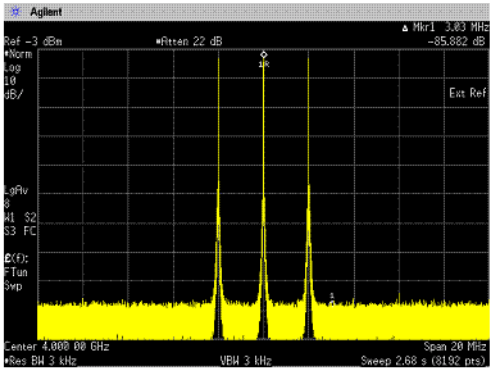
The following figures illustrate the influence a single sample can have. The generated 3-tone test signal requires 100 samples in the waveform to maintain periodicity for all three tones. The measurement on the left shows the effect of using the first 99 samples rather than all 100 samples. Notice all the distortion products (at levels up to −35 dBc) introduced in addition to the wanted 3-tone signal. The measurement on the right shows the same waveform using all 100 samples to maintain periodicity and avoid a phase discontinuity. Maintaining periodicity removes the distortion products.

Phase Discontinuity



3-tone - 20 MHz Bandwidth
Measured distortion = 35 dBc

Phase Continuity



3-tone - 20 MHz Bandwidth
Measured distortion = 86 dBc

Waveform Memory

The signal generator provides two types of memory, volatile and non-volatile. You can download files to either memory type.

Volatile

Random access memory that does not survive cycling of the signal generator power. This memory is commonly referred to as waveform memory (WFM1) or waveform playback memory. To play back waveforms, they must reside in volatile memory. The following file types share this memory:

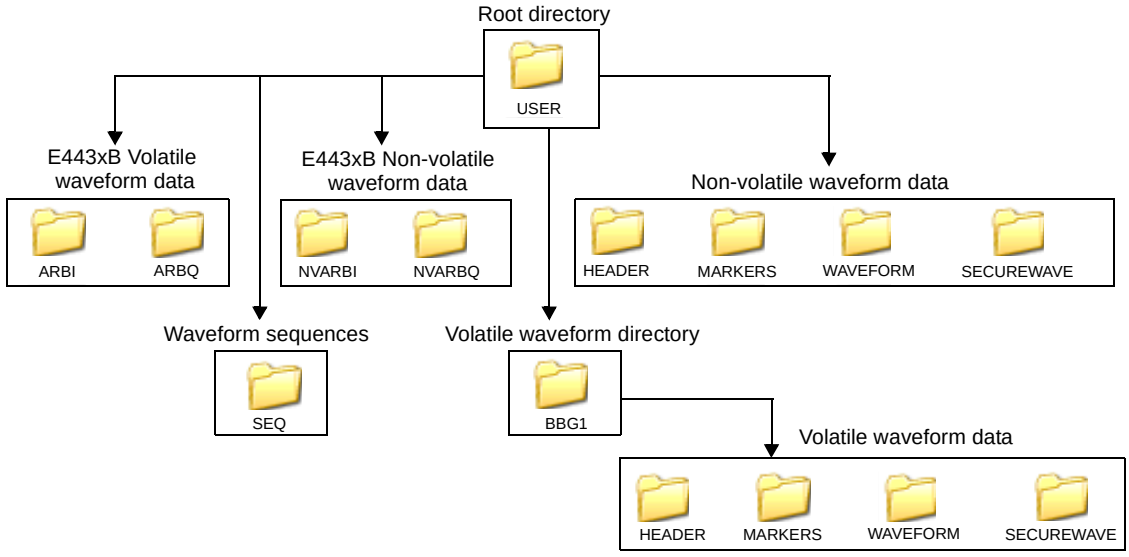
- I/Q
- marker
- file header
- user PRAM
- waveform sequences (multiple I/Q files played together)

Non-volatile

Storage memory where files survive cycling the signal generator power. Files remain until overwritten or deleted. To play back waveforms after cycling the signal generator power, you must load waveforms from non-volatile waveform memory (NVWFM) to volatile waveform memory (WFM1). The following file types share this memory:

- I/Q
- marker
- file header
- instrument state
- user data
- user PRAM
- sweep list
- waveform sequences (multiple I/Q files played together)

The following figure shows the locations within the signal generator for volatile and non-volatile waveform data.



Memory Allocation

Volatile Memory

The signal generator allocates volatile memory in blocks of 1024 bytes. For example, a waveform file with 60 samples (the minimum number of samples) has 300 bytes (5 bytes per sample × 60 samples), but the signal generator allocates 1024 bytes of memory. If a waveform is too large to fit into 1024 bytes, the signal generator allocates additional memory in multiples of 1024 bytes. For example, the signal generator allocates 3072 bytes of memory for a waveform with 500 samples (2500 bytes).

3 x 1024 bytes = 3072 bytes of memory

As shown in the examples, waveforms can cause the signal generator to allocate more memory than what is actually used, which decreases the amount of available memory.

Non-Volatile Memory

The signal generator allocates non-volatile memory in blocks of 512 bytes. For files less than or equal to 512 bytes, the file uses only one block of memory. For files larger than 512 bytes, the signal generator allocates additional memory in multiples of 512 byte blocks. For example, a file that has 21,538 bytes consumes 43 memory blocks (22,016 bytes).

Memory Size

The amount of available memory, volatile and non-volatile, varies by option and the size of the other files that share the memory. When we refer to waveform files, we state the memory size in samples (one sample equals five bytes). The baseband generator (BBG) options (001/601 and 002/602) contain the waveform playback memory. The following tables show the maximum available memory.

Volatile (WFM1) Memory	
Option	**Size**
001/601 (BBG)[1]	8 MSa (40 MB)
002 (BBG)[1]	32 MSa (160 MB)
602 (BBG)	64 MSa (320 MB)

Non-Volatile (NVWFM) Memory	
Option	**Size**
Standard	3 MSa (15 MB)
005 (Hard disk)	1 GSa (5 GB)

1. Options 001 and 002 apply only to the E4438C ESG.

Commands for Downloading and Extracting Waveform Data

You can download I/Q data and the associated file header and marker file information (collectively called waveform data) into volatile or non-volatile memory. For information on waveform structure, see "Waveform Structure" on page 11.

NOTE Before downloading files into volatile memory (`WFM1`), turn off the ARB.
Press: **Mode > Dual Arb > ARB Off On** until Off highlights
Or send: `[:SOURce]:RADio:ARB[:STATe] OFF`

The signal generator provides the option of downloading waveform data either for extraction or not for extraction. When you extract waveform data, the signal generator encrypts the data. The SCPI download commands determine whether the waveform data is extractable.

If you use SCPI commands to download waveform data to be extracted later, you must use the `MEM:DATA:UNPRotected` command. If you use FTP commands, no special command syntax is necessary.

You can download or extract waveform data created in any of the following ways:

- with signal simulation software, such as MATLAB or Agilent Advanced Design System (ADS)
- with advanced programming languages, such as C++, VB or VEE
- with Agilent Signal Studio software
- with the signal generator

NOTE You can *not* extract files created with ESG firmware revisions prior to C.03.10.

Waveform Data Encryption

You can download encrypted waveform data extracted from one signal generator into another signal generator with the same option or software license for the modulation format. You can also extract encrypted waveform data created with software such as MATLAB or ADS, providing the data was downloaded to the signal generator using the proper command.

When you generate a waveform from the signal generator's internal ARB modulation format or download a waveform from an Agilent Signal Studio software product, the resulting waveform data is automatically stored in volatile memory and is available for extraction as an encrypted file.

The exception to encrypted file extraction is user-created I/Q data. You can extract this I/Q data unencrypted.

Encrypted I/Q Files and the Securewave Directory

The signal generator uses the `securewave` directory to perform file encryption (extraction) and decryption (downloads). The `securewave` directory is not an actual storage directory, but rather a portal for the encryption and decryption process. While the `securewave` directory contains file names, these are actually pointers to the true files located in signal generator memory (volatile or non-volatile). When you download an encrypted file, the `securewave` directory decrypts the file and unpackages the contents into its file header, I/Q data, and marker data. When you extract a file, the `securewave` directory packages the file header, I/Q data, and marker data and encrypts the waveform data file.

The signal generator uses the following `securewave` directory paths for file extractions and encrypted file downloads:

Volatile	*/user/securewave/file_name* or *swfm:file_name*
Non-volatile	*/user/bbg1/securewave/file_name* or *snvwfm1:file_name*

NOTE To extract files (other than user-created I/Q files) and to download encrypted files, you *must* use the `securewave` directory. If you attempt to extract previously downloaded encrypted files (including Signal Studio downloaded files or internally created signal generator files) *without* using the securewave directory, the signal generator generates an error and displays `ERROR: 221, Access Denied`.

File Transfer Methods

- SCPI using VXI-11 (VMEbus Extensions for Instrumentation as defined in VXI-11)
- SCPI over the GPIB or RS 232
- SCPI with sockets LAN (using port 5025)
- File Transfer Protocol (FTP)

SCPI Command Line Structure

The signal generator expects to see waveform data as block data (binary files). The IEEE standard 488.2-1992 section 7.7.6 defines block data. The following example shows how to structure a SCPI command for downloading waveform data (#ABC represents the block data):

```
:MMEM:DATA "<file_name>",#ABC
```

`"<file_name>"`	the I/Q file name and file path within the signal generator
#	indicates the start of the data block
A	the number of decimal digits present in B
B	a decimal number specifying the number of data bytes to follow in C
C	the actual binary waveform data

The following example demonstrates this structure:

```
MMEM:DATA "WFM1:my_file",#3240 12%S!4&07#8g*Y9@7...
```

`WFM1:`	the file path
`my_file`	the I/Q file name as it will appear in the signal generator's memory catalog
`#`	indicates the start of the data block
`3`	B has three decimal digits
`240`	240 bytes of data to follow in C
`12%S!4&07#8g*Y9@7...`	the ASCII representation of some of the binary data downloaded to the signal generator, however not all ASCII values are printable

NOTE If you use SCPI with sockets to send data to the signal generator, you must provide an end-of-file indicator, as shown in the following command:
`MMEM:DATA "WFM1:<file_name>",<blockdata>NL^END`

Commands and File Paths for Downloading and Extracting Waveform Data

You can download or extract waveform data using the commands and file paths in the following tables:

- Table 1, "Downloading Unencrypted Files for No Extraction," on page 21
- Table 2, "Downloading Encrypted Files for No Extraction," on page 22
- Table 3, "Downloading Unencrypted Files for Extraction," on page 22
- Table 4, "Downloading Encrypted Files for Extraction," on page 23
- Table 5, "Extracting Encrypted Waveform Data," on page 24

Table 1 Downloading Unencrypted Files for No Extraction

Download Method / Memory Type	Command Syntax Options

SCPI/volatile memory	`MMEM:DATA "WFM1:<file_name>",<blockdata>`
	`MMEM:DATA "MKR1:<file_name>",<blockdata>`
	`MMEM:DATA "HDR1:<file_name>",<blockdata>`

SCPI/volatile memory with full directory path	`MMEM:DATA "user/bbg1/waveform/<file_name>",<blockdata>`
	`MMEM:DATA "user/bbg1/markers/<file_name>",<blockdata>`
	`MMEM:DATA "user/bbg1/header/<file_name>",<blockdata>`

Table 1 Downloading Unencrypted Files for No Extraction

Download Method / Memory Type	Command Syntax Options

SCPI/non-volatile memory	`MMEM:DATA "NVWFM:<file_name>",<blockdata>`
	`MMEM:DATA "NVMKR:<file_name>",<blockdata>`
	`MMEM:DATA "NVHDR:<file_name>",<blockdata>`

SCPI/non-volatile memory with full directory path	`MMEM:DATA /user/waveform/<file_name>",<blockdata>`
	`MMEM:DATA /user/markers/<file_name>",<blockdata>`
	`MMEM:DATA /user/header/<file_name>",<blockdata>`

Table 2 Downloading Encrypted Files for No Extraction

Download Method / Memory Type	Command Syntax Options

SCPI/volatile memory	`MMEM:DATA "user/bbg1/securewave/<file_name>",<blockdata>`
	`MMEM:DATA "SWFM1:<file_name>",<blockdata>`
	`MMEM:DATA "file_name@SWFM1",<blockdata>`

SCPI/non-volatile memory	`MMEM:DATA "user/securewave/<file_name>",<blockdata>`
	`MMEM:DATA "SNVWFM:<file_name>",<blockdata>`
	`MMEM:DATA "file_name@SNVWFM",<blockdata>`

Table 3 Downloading Unencrypted Files for Extraction

Download Method / Memory Type	Command Syntax Options

SCPI/volatile memory	`MEM:DATA:UNPRotected "/user/bbg1/waveform/file_name",<blockdata>`
	`MEM:DATA:UNPRotected "/user/bbg1/markers/file_name",<blockdata>`
	`MEM:DATA:UNPRotected "/user/bbg1/header/file_name",<blockdata>`
	`MEM:DATA:UNPRotected "WFM1:file_name",<blockdata>`
	`MEM:DATA:UNPRotected "MKR1:file_name",<blockdata>`
	`MEM:DATA:UNPRotected "HDR1:file_name",<blockdata>`
	`MEM:DATA:UNPRotected "file_name@WFM1",<blockdata>`
	`MEM:DATA:UNPRotected "file_name@MKR1",<blockdata>`
	`MEM:DATA:UNPRotected "file_name@HDR1",<blockdata>`

Table 3 Downloading Unencrypted Files for Extraction

Download Method / Memory Type	Command Syntax Options

SCPI/non-volatile memory	`MEM:DATA:UNPRotected "/user/waveform/file_name",<blockdata>`
	`MEM:DATA:UNPRotected "/user/markers/file_name",<blockdata>`
	`MEM:DATA:UNPRotected "/user/header/file_name",<blockdata>`
	`MEM:DATA:UNPRotected "NVWFM:file_name",<blockdata>`
	`MEM:DATA:UNPRotected "NVMKR:file_name",<blockdata>`
	`MEM:DATA:UNPRotected "NVHDR:file_name",<blockdata>`
	`MEM:DATA:UNPRotected "file_name@NVWFM",<blockdata>`
	`MEM:DATA:UNPRotected "file_name@NVMKR",<blockdata>`
	`MEM:DATA:UNPRotected "file_name@NVHDR",<blockdata>`

FTP/volatile memory[1]	`put <file_name> /user/bbg1/waveform/<file_name>` `put <file_name> /user/bbg1/markers/<file_name>`
FTP/non-volatile memory[1]	`put <file_name> /user/waveform/<file_name>` `put <file_name> /user/markers/<file_name>`

1. See "FTP Procedures" on page 24.

Table 4 Downloading Encrypted Files for Extraction

Download Method / Memory Type	Command Syntax Options

SCPI/volatile memory	`MEM:DATA:UNPRotected "/user/bbg1/securewave/file_name",<blockdata>`
	`MEM:DATA:UNPRotected "SWFM1:file_name",<blockdata>`
	`MEM:DATA:UNPRotected "file_name@SWFM1",<blockdata>`

SCPI/non-volatile memory	`MEM:DATA:UNPRotected "/user/securewave/file_name",<blockdata>`
	`MEM:DATA:UNPRotected "SNVWFM:file_name",<blockdata>`
	`MEM:DATA:UNPRotected "file_name@SNVWFM",<blockdata>`

FTP/volatile memory[1]	`put <file_name> /user/bbg1/securewave/<file_name>`
FTP/non-volatile memory[1]	`put <file_name> /user/securewave/<file_name>`

1. See "FTP Procedures" on page 24.

Table 5 Extracting Encrypted Waveform Data

Download Method / Memory Type	Command Syntax Options

SCPI/volatile memory	`MMEM:DATA? "/user/bbg1/securewave/file_name"`
	`MMEM:DATA? "SWFM1:file_name"`
	`MMEM:DATA? "file_name@SWFM1"`

SCPI/non-volatile memory	`MMEM:DATA? "/user/securewave/file_name"`
	`MMEM:DATA? "SNVWFM:file_name"`
	`MMEM:DATA? "file_name@SNVWFM"`

FTP/volatile memory[1]	`get /user/bbg1/securewave/<file_name>`
FTP/non-volatile memory[1]	`get /user/securewave/<file_name>`

1. See "FTP Procedures" on page 24.

FTP Procedures

There are three ways to FTP files:

- use Microsoft's ® Internet Explorer FTP feature
- use the signal generator's internal web server (ESG firmware ≥ C.03.76)
- use the PC's or UNIX command window

Using Microsoft's Internet Explorer

1. Enter the signal generator's hostname or IP address as part of the FTP URL.

   ftp://<host name> or <IP address>

2. Press **Enter** on the keyboard or **Go** from the Internet Explorer window.

   The signal generator files appear in the Internet Explorer window.

3. Drag and drop files between the PC and the Internet Explorer window

Microsoft is a U.S registered trademark of Microsoft Corporation.

Using the Signal Generator's Internal Web Server

1. Enter the signal generator's hostname or IP address in the URL.

   http://<host name> or <IP address>

2. Click the **Signal Generator FTP Access** button located on the left side of the window.

   The signal generator files appear in the web browser's window.

3. Drag and drop files between the PC and the browser's window

For more information on the web server feature, see the *Programming Guide* for the signal generator.

Using the Command Window (PC or UNIX)

This procedure downloads to non-volatile memory. To download to volatile memory, change the file path.

1. From the PC command prompt or UNIX command line, change to the destination directory for the file you intend to download.
2. From the PC command prompt or UNIX command line, type `ftp <instrument name>`. Where `instrument name` is the signal generator's hostname or IP address.
3. At the `User:` prompt in the ftp window, press **Enter** (no entry is required).
4. At the `Password:` prompt in the ftp window, press **Enter** (no entry is required).
5. At the `ftp` prompt, type:
   `put <file_name> /user/waveform/<file_name1>`

   where `<file_name>` is the name of the file to download and `<file_name1>` is the name designator for the signal generator's `/user/waveform/` directory.

   - If a marker file is associated with the data file, use the following command to download it to the signal generator:
     `put <marker file_name> /user/markers/<file_name1>`

     where `<marker file_name>` is the name of the file to download and `<file_name1>` is the name designator for the file in the signal generator's `/user/markers/` directory. Marker files and the associated I/Q waveform data have the same name.

NOTE If no marker file is provided, the signal generator automatically creates a default marker file consisting of all zeros.

---

6. At the `ftp` prompt, type: `bye`
7. At the command prompt, type: `exit`

Creating Waveform Data

This section examines the C++ code algorithm for creating I/Q waveform data by breaking the programming example into functional parts and explaining the code in generic terms. This is done to help you understand the code algorithm in creating the I and Q data, so you can leverage the concept into your programming environment. If you do not need this level of detail, you can find the complete programming example in "Programming Examples" on page 47.

You can use various programming environments to create ARB waveform data. Generally there are two types:

- **Simulation software**— this includes MATLAB, Agilent Technologies EESof Advanced Design System (ADS), Signal Processing WorkSystem (SPW), and so forth.
- **Advanced programming languages**—this includes, C++, VB, VEE, MS Visual Studio.Net, Labview, and so forth.

No matter which programming environment you use to create the waveform data, make sure that the data conforms to the data requirements shown on page 2. To learn about I/Q data for the signal generator, see "Understanding Waveform Data" on page 4.

Code Algorithm

This section uses code from the C++ programming example "Importing, Byte Swapping, Interleaving, and Downloading I and Q Data—Big and Little Endian Order" on page 68 to demonstrate how to create and scale waveform data.

There are three steps in the process of creating an I/Q waveform:

1. Create the I and Q data.
2. Save the I and Q data to a text file for review.
3. Interleave the I and Q data to make an I/Q file, and swap the byte order for little-endian platforms.

For information on downloading I/Q waveform data to a signal generator, refer to "Commands and File Paths for Downloading and Extracting Waveform Data" on page 21 and "Downloading Waveform Data" on page 33.

1. Create I and Q data.

The following lines of code create scaled I and Q data for a sine wave. The I data consists of one period of a sine wave and the Q data consists of one period of a cosine wave.

Line	Code—Create I and Q data
1	`const int NUMSAMPLES=500;`
2	`main(int argc, char* argv[]);`
3	`{`
4	`short idata[NUMSAMPLES];`
5	`short qdata[NUMSAMPLES];`
6	`int numsamples = NUMSAMPLES;`
7	`for(int index=0; index<numsamples; index++);`
8	`{`
9	`idata[index]=23000 * sin((2*3.14*index)/numsamples);`
10	`qdata[index]=23000 * cos((2*3.14*index)/numsamples);`
11	`}`

Line	Code Description—Create I and Q data
1	Define the number of waveform points. Note that the maximum number of waveform points that you can set is based on the amount of available memory in the signal generator. For more information on signal generator memory, refer to "Waveform Memory" on page 17.
2	Define the main function in C++.
4	Create an array to hold the generated I values. The array length equals the number of the waveform points. Note that we define the array as type *short*, which represents a 16-bit signed integer in most C++ compilers.
5	Create an array to hold the generated Q values (signed 16-bit integers).
6	Define and set a temporary variable, which is used to calculate the I and Q values.

Line	Code Description—Create I and Q data
7–11	Create a loop to do the following: • Generate and scale the I data (DAC values). This example uses a simple sine equation, where 2*3.14 equals one waveform cycle. Change the equation to fit your application. — The array pointer, *index*, increments from 0–499, creating 500 I data points over one period of the sine waveform. — Set the scale of the DAC values in the range of –32767 to 32768, where the values –32767 and 32768 equal full scale negative and positive respectively. This example uses 23000 as the multiplier, resulting in approximately 70% scaling. For more information on scaling, see "Scaling DAC Values" on page 8. **NOTE** The signal generator comes from the factory with I/Q scaling set to 70%. If you reduce the DAC input values, ensure that you set the signal generator scaling (`:RADio:ARB:RSCaling`) to an appropriate setting that accounts for the reduced values. • Generate and scale the Q data (DAC value). This example uses a simple cosine equation, where 2*3.14 equals one waveform cycle. Change the equation to fit your application. — The array pointer, *index*, increments from 0–499, creating 500 Q data points over one period of the cosine waveform. — Set the scale of the DAC values in the range of –32767 to 32768, where the values –32767 and 32768 equal full scale negative and positive respectively. This example uses 23000 as the multiplier, resulting in approximately 70% scaling. For more information on scaling, see "Scaling DAC Values" on page 8.

2. Save the I/Q data to a text file to review.

The following lines of code export the I and Q data to a text file for validation. After exporting the data, open the file using Microsoft Excel or a similar spreadsheet program, and verify that the I and Q data are correct.

Line **Code Description—Saving the I/Q Data to a Text File**

```
12  char *ofile = "c:\\temp\\iq.txt";
13  FILE *outfile = fopen(ofile, "w");
14  if (outfile==NULL) perror ("Error opening file to write");
15  for(index=0; index<numsamples; index++)
16  {
17  fprintf(outfile, "%d, %d\n", idata[index], qdata[index]);
18  }
19  fclose(outfile);
```

Line	Code Description—Saving the I/Q Data to a Text File
12	Set the absolute path of a text file to a character variable. In this example, *iq.txt* is the file name and **ofile* is the variable name. For the file path, some operating systems may not use the drive prefix (‘c:’ in this example), or may require only a single forward slash (/), or both (`"/temp/iq.txt"`)
13	Open the text file in *write* format.
14	If the text file does not open, print an error message.
15–18	Create a loop that prints the array of generated I and Q data samples to the text file.
19	Close the text file.

3. Interleave the I and Q data, and byte swap if using little endian order.

This step has two sets of code:

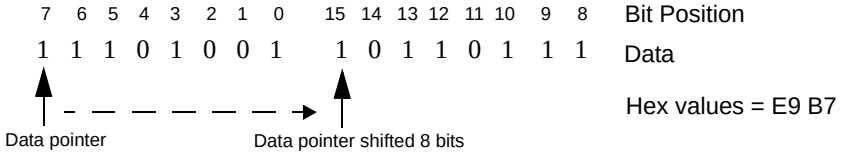
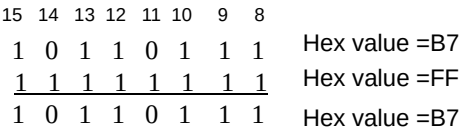
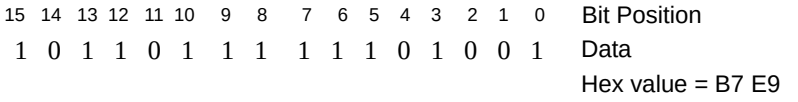
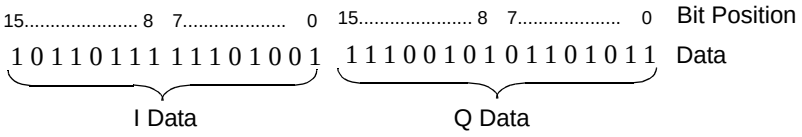
- Interleaving and byte swapping I and Q data for little endian order
- Interleaving I and Q data for big endian order

For more information on byte order, see "Little Endian and Big Endian (Byte Order)" on page 5.

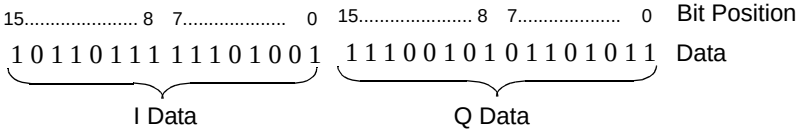
Line **Code—Interleaving and Byte Swapping for Little Endian Order**

```
20  char iqbuffer[NUMSAMPLES*4];
21  for(index=0; index<numsamples; index++)
22  {
23  short ivalue = idata[index];
24  short qvalue = qdata[index];
25  iqbuffer[index*4]   = (ivalue >> 8) & 0xFF;
26  iqbuffer[index*4+1] = ivalue & 0xFF;
27  iqbuffer[index*4+2] = (qvalue >> 8) & 0xFF;
28  iqbuffer[index*4+3] = qvalue & 0xFF;
29  }
30  return 0;
```

Line	Code Description—Interleaving and Byte Swapping for Little Endian Order
20	Define a character array to store the interleaved I and Q data. The character array makes byte swapping easier, since each array location accepts only 8 bits (1 byte). The array size increases by four times to accommodate two bytes of I data and two bytes of Q data.
21–29	Create a loop to do the following: • Save the current I data array value to a variable. **NOTE** In rare instances, a compiler may define *short* as larger than 16 bits. If this condition exists, replace *short* with the appropriate object or label that defines a 16-bit integer. • Save the current Q data array value to a variable. • Swap the low bytes (bits 0–7) of the data with the high bytes of the data (done for both

Line	Code Description—Interleaving and Byte Swapping for Little Endian Order
21–29	the I and Q data), and interleave the I and Q data. — shift the data pointer right 8 bits to the beginning of the high byte (*ivalue >> 8*) **Little Endian Order**  — *AND* (boolean) the high I byte with 0xFF to make the high I byte the value to store in the IQ array—(*ivalue >> 8*) *& 0xFF*  — *AND* (boolean) the low I byte with 0xFF (*ivalue & 0xFF*) to make the low I byte the value to store in the I/Q array location just after the high byte [*index* * 4 + 1] **I Data in I/Q Array after Byte Swap (Big Endian Order)**  — Swap the Q byte order within the same loop. Notice that the I and Q data interleave with each loop cycle. This is due to the I/Q array shifting by one location for each I and Q operation [*index* * 4 + n]. **Interleaved I/Q Array in Big Endian Order** 

Line	Code—Interleaving I and Q data for Big Endian Order
20	`short iqbuffer[NUMSAMPLES*2];`
21	`for(index=0; index<numsamples; index++)`
22	`{`
23	`iqbuffer[index*2]   = idata[index];`
24	`iqbuffer[index*2+1] = qdata[index];`
25	`}`
26	`return 0;`

Line	Code Description—Interleaving I and Q data for Big Endian Order
20	Define a 16-bit integer (short) array to store the interleaved I and Q data. The array size increases by two times to accommodate two bytes of I data and two bytes of Q data. **NOTE** In rare instances, a compiler may define *short* as larger than 16 bits. If this condition exists, replace *short* with the appropriate object or label that defines a 16-bit integer.
21–25	Create a loop to do the following: • Store the I data values to the I/Q array location [*index**2]. • Store the Q data values to the I/Q array location [*index**2+1]. **Interleaved I/Q Array in Big Endian Order** 

To download the data created in the above example, see "Using Advanced Programming Languages" on page 36.

Downloading Waveform Data

This section examines methods of downloading I/Q waveform data created in MATLAB (a simulation software) and C++ (an advanced programming language). For more information on simulation and advanced programming environments, see "Creating Waveform Data" on page 26.

To download data from simulation software environments, it is typically easier to use one of the free download utilities (described on page 43), because simulation software usually saves the data to a file. In MATLAB however, you can either save data to a .mat file or create a complex array. To facilitate downloading a MATLAB complex data array, Agilent created the PSG/ESG Download Assistant (one of the free download utilities), which downloads the complex data array from within the MATLAB environment. This section shows how to use the download assistant.

For advanced programming languages, this section closely examines the code algorithm for downloading I/Q waveform data by breaking the programming examples into functional parts and explaining the code in generic terms. This is done to help you understand the code algorithm in downloading the interleaved I/Q data, so you can leverage the concept into your programming environment. While not discussed in this section, you may also save the data to a binary file and use one of the download utilities to download the waveform data (see "Using the Download Utilities" on page 43).

If you do not need the level of detail this section provides, you can find complete programming examples in "Programming Examples" on page 47. Prior to downloading the I/Q data, ensure that it conforms to the data requirements shown on page 2. To learn about I/Q data for the signal generator, see "Understanding Waveform Data" on page 4. For creating waveform data, see "Creating Waveform Data" on page 26.

NOTE Before downloading files into volatile memory (`WFM1`), turn off the ARB.
Press: **Mode > Dual Arb > ARB Off On** until Off highlights
Or send: `[:SOURce]:RADio:ARB[:STATe] OFF`

Using Simulation Software

This procedure uses a complex data array created in MATLAB and uses the PSG/ESG Download Assistant to download the data. To obtain the PSG/ESG Download Assistant, see "Using the Download Utilities" on page 43.

There are two steps in the process of downloading an I/Q waveform:

1. Open a connection session.
2. Download the I/Q data.

1. Open a connection session with the signal generator.

The following code establishes a LAN connection with the signal generator, sends the IEEE SCPI command `*idn?`, and if the connection fails, displays an error message.

Line **Code—Open a Connection Session**

```
1   io = agt_newconnection('tcpip','IP address');
    %io = agt_newconnection('gpib',<primary address>,<secondary
2   address>);
3   [status,status_description,query_result] = agt_query(io,'*idn?');
4   if status == -1
5   display ‘fail to connect to the signal generator’;
    end;
```

Line	Code Description—Open a Connection Session with the Signal Generator
1	Sets up a structure (indicated above by *io*) used by subsequent function calls to establish a LAN connection to the signal generator. • *agt_newconnection()* is the function of Agilent Download Assistant used in MATLAB to build a connection to the signal generator. • If you are using GPIB to connect to the signal generator, provide the board, primary address, and secondary address: *io = agt_newconnection('gpib',0,19);* Change the GPIB address based on your instrument setting.
2	Send a query to the signal generator to verify the connection. • *agt_query()* is an Agilent Download Assistant function that sends a query to the signal generator. • If signal generator receives the query `*idn?`, *status* returns a zero and *query_result* returns the signal generator’s model number, serial number, and firmware version.
3–5	If the query fails, display a message.

2. Download the I/Q data

The following code downloads the generated waveform data to the signal generator, and if the download fails, displays a message.

Line **Code—Download the I/Q data**

```
6    [status, status_description] = agt_waveformload(io, IQwave,
     'waveformfile1', 2000, 'no_play','norm_scale');
7    if status == -1
8    display ‘fail to download to the signal generator’;
9    end;
```

Line	Code Description—Download the I/Q data
6	Download the I/Q waveform data to the signal generator by using the function call (*agt_waveformload*) from the Agilent Download Assistant. Some of the arguments are optional as indicated below, but if one is used, you must use all arguments previous to the one you require. Notice that with this function, you can perform the following actions: • download complex I/Q data • name the file (optional argument) • set the sample rate (optional argument) If you do not set a value, the signal generator uses its preset value of 100 MHz, or if a waveform was previously play, the value from that waveform. • start or not start waveform playback after downloading the data (optional argument) Use either the argument *play* or the argument *no_play*. • whether to normalize and scale the I/Q data (optional argument) If you normalize and scale the data within the body of the code, then use *no_normscale*, but if you need to normalize and scale the data, use *norm_scale*. This normalizes the waveform data to the DAC values and then scales the data to 70% of the DAC values. • download marker data (optional argument) If there is no marker data, the signal generator creates a default marker file, all marker set to zero. To verify the waveform data download, see “Loading, Playing, and Verifying a Downloaded Waveform” on page 40.
7–9	If the download fails, display an error message.

Using Advanced Programming Languages

This procedure uses code from the C++ programming example "Importing, Byte Swapping, Interleaving, and Downloading I and Q Data—Big and Little Endian Order" on page 68.

For information on creating I/Q waveform data, refer to "Creating Waveform Data" on page 26.

There are two steps in the process of downloading an I/Q waveform:

1. Open a connection session.
2. Download the I/Q data.

1. Open a connection session with the signal generator.

The following code establishes a LAN connection with the signal generator or prints an error message if the session is not opened successfully.

Line	Code Description—Open a Connection Session
1	`char* instOpenString ="lan[hostname or IP address]";`
	`//char* instOpenString ="gpib<primary addr>,<secondary addr>";`
2	`INST id=iopen(instOpenString);`
3	`if (!id)`
4	`{`
5	`fprintf(stderr, "iopen failed (%s)\n", instOpenString);`
6	`return -1;`
7	`}`

Line	Code Description—Open a Connection Session
1	Assign the signal generator's LAN hostname, IP address, or GPIB address to a character string. • This example uses the Agilent IO library's *iopen()* SICL function to establish a LAN connection with the signal generator. The input argument, *lan[hostname or IP address]* contains the device, interface, or commander address. Change it to your signal generator host name or just set it to the IP address used by your signal generator. For example: "*lan[999.137.240.9]*" • If you are using GPIB to connect to the signal generator, use the commented line in place of the first line. Insert the GPIB address based on your instrument setting, for example "*gpib0,19*". • For the detailed information about the parameters of the SICL function *iopen()*, refer to the online "*Agilent SICL User's Guide for Windows*."

Line	Code Description—Open a Connection Session
2	Open a connection session with the signal generator to download the generated I/Q data. The SICL function *iopen()* is from the Agilent IO library and creates a session that returns an identifier to *id*. • If *iopen()* succeeds in establishing a connection, the function returns a valid session *id*. The valid session *id* is not viewable, and can only be used by other SICL functions. • If *iopen()* generates an error before making the connection, the session identifier is set to zero. This occurs if the connection fails. • To use this function in C++, you must include the standard header #include <sicl.h> before the main() function.
3–7	If *id* = 0, the program prints out the error message and exits the program.

2. Download the I/Q data.

The following code sends the SCPI command and downloads the generated waveform data to the signal generator.

Line **CodeDescription—Download the I/Q Data**

```
8   int bytesToSend;
9   bytesToSend = numsamples*4;
10  char s[20];
11  char cmd[200];
12  sprintf(s, "%d", bytesToSend);
13  sprintf(cmd, ":MEM:DATA \"WFM1:FILE1\", #%d%d", strlen(s),
    bytesToSend);
14  iwrite(id, cmd, strlen(cmd), 0, 0);
15  iwrite(id, iqbuffer, bytesToSend, 0, 0);
16  iwrite(id, "\n", 1, 1, 0);
```

Line	Code Description—Download the I/Q data
8	Define an integer variable (*bytesToSend*) to store the number of bytes to send to the signal generator.

Line	Code Description—Download the I/Q data
9	Calculate the total number of bytes, and store the value in the integer variable defined in line 8. In this code, *numsamples* contains the number of waveform points, not the number of bytes. Because it takes four bytes of data, two I bytes and two Q bytes, to create one waveform point, we have to multiply *numsamples* by four. This is shown in the following example: numsamples = 500 waveform points numsamples × 4 = 2000 (four bytes per point) bytesToSend = 2000 (numsamples × 4) For information on setting the number of waveform points, see "1. Create I and Q data." on page 27.
10	Create a string large enough to hold the *bytesToSend* value as characters. In this code, string *s* is set to 20 bytes (20 characters—one character equals one byte)
11	Create a string and set its length (*cmd*[200]) to hold the SCPI command syntax and parameters. In this code, we define the string length as 200 bytes (200 characters).
12	Store the value of *bytesToSend* in string *s*. For example, if bytesToSend = 2000; *s* = "2000"
13	Store the SCPI command syntax and parameters in the string *cmd*. The SCPI command prepares the signal generator to accept the data. • *sprintf()* is a standard function in C++, which writes string data to a string variable. • *strlen()* is a standard function in C++, which returns length of a string. • If *bytesToSend* = 2000, then *s* = "2000", *strlen(s)* = 4, so *cmd* = :MEM:DATA "WFM1:FILE1\" #42000.
14	Send the SCPI command stored in the string *cmd* to the signal generator, which is represented by the session *id*. • *iwrite()* is a SICL function in Agilent IO library, which writes the data (block data) specified in the string *cmd* to the signal generator (*id*). • The third argument of *iwrite()*, *strlen(cmd)*, informs the signal generator of the number of bytes in the command string. The signal generator parses the string to determine the number of I/Q data bytes it expects to receive. • The fourth argument of iwrite(), zero, means there is no END indicator for the string. This lets the session remain open, so the program can download the I/Q data.

Line	Code Description—Download the I/Q data
15	Send the generated waveform data stored in the I/Q array *(iqbuffer)* to the signal generator. • *iwrite()* sends the data specified in *iqbuffer* to the signal generator (session identifier specified in *id*). • The third argument of *iwrite()*, *bytesToSend*, contains the length of the *iqbuffer* in bytes. In this example, it is 2000. • The fourth argument of *iwrite()*, 0, means there is no END indicator in the data. In many programming languages, there are two methods to send SCPI commands and data: — Method 1 where the program stops the data download when it encounters the first zero (END indicator) in the data. — Method 2 where the program sends a fixed number of bytes and ignores any zeros in the data. This is the method used in our program. For your programming language, you must find and use the equivalent of method two. Otherwise you may only achieve a partial download of the I and Q data.
16	Send the terminating carriage (\n) as the last byte of the waveform data. • *iwrite()* writes the data "\n" to the signal generator (session identifier specified in *id)*. • The third argument of *iwrite()*, 1, sends one byte to the signal generator. • The fourth argument of *iwrite()*, 1, is the END indicator, which the program uses to terminate the data download. To verify the waveform data download, see "Loading, Playing, and Verifying a Downloaded Waveform" on page 40.

Loading, Playing, and Verifying a Downloaded Waveform

The following procedures show how to perform the steps using either front-panel key presses or SCPI commands.

Loading a File from Non-Volatile Memory

Select the downloaded I/Q file in non-volatile waveform memory (NVWFM) and load it into volatile waveform memory (WFM1). The file comprises three items: I/Q data, marker file, and file header information. Loading the I/Q file also loads the marker file and file header.

- From the front panel:
  1. Press **Mode** > **Dual ARB** > **Select Waveform** > **Waveform Segments** > **Load Store** until Load highlights.
  2. Highlight the I/Q file in the NVWFM catalog.
  3. Press **Load Segment From NVWFM Memory**.
  4. Press **Return**.
- Remotely send one of the following SCPI command to copy the I/Q file, marker file and file header information:

```
:MEMory:COPY[NAME]"<NVWFM:file_name>","<WFM1:file_name>"
:MEMory:COPY[NAME]"<NVMKR:file_name>","<MKR1:file_name>"
```

NOTE When you copy a waveform file or marker file information from volatile or non-volatile memory, the waveform and associated marker and header files are all copied. Conversely, when you delete an I/Q file, the associated marker and header files are deleted. It is not necessary to send separate commands to copy or delete the marker and header files.

Playing the Waveform

Play the waveform and use it to modulate the RF carrier.

1. Select the waveform from the volatile memory waveform list:
   - From the front panel:
     a. Press **Mode** > **Dual ARB** > **Select Waveform.**
     b. Highlight the desired waveform.

c. Press **Select Waveform.**

- Remotely send the following SCPI command:

```
[:SOURce}:RADio:ARB:WAVeform "WFM1:<file_name>"
```

2. Play the waveform:

- From the front panel:

a. Press **ARB Off On** until On is highlighted.

b. Press **Mod On/Off** until the `MOD ON` annunciator appears on the display.

c. Press **RF On/Off** until the `RF ON` annunciator appears on the display.

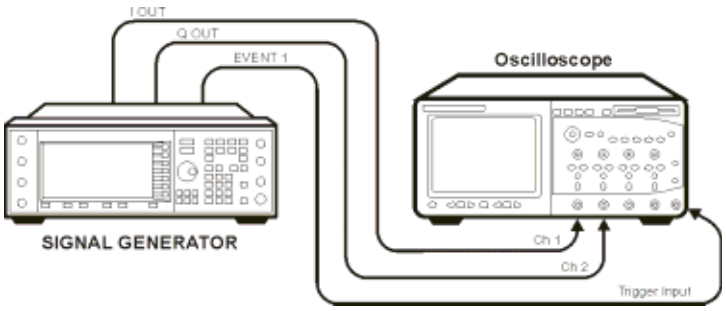
Remotely send the following SCPI commands:

```
[:SOURce]:RADio:ARB[:STATe] ON
:OUTPut:MODulation[:STATe] ON
:OUTPut[:STATe] ON
```

Verifying the Waveform

Perform this procedure after completing the steps in the previous procedure, Playing the Waveform.

1. Connect the signal generator to an oscilloscope as shown in the figure.



2. Set an active marker point on the first waveform point for marker one.

- From the front panel:

a. Press **ARB Setup** > **Marker Utilities** > **Set Markers**.

b. Highlight the same waveform selected in "Playing the Waveform" on page 40.

c. Press **Set Markers** > **Marker 1 2 3 4** to 1.

d. Press **Set Markers Off All Points > Set Marker on First Point**.

- Remotely send the following SCPI commands:

  a. `[:SOURce]:RADio:ARB:MARKer:CLEar:ALL "WFM1:<file_name>",1`

  b. `[:SOURce]:RADio:ARB:MARKer:[SET]"WFM1:<file_name>",1,1,1,0`.

3. Compare the oscilloscope display to the plot of the I and Q data from the text file you created when you generated the data.

   If the oscilloscope display, and the I and Q data plots differ, recheck your code. For detailed information on programmatically creating and downloading waveform data, see "Creating Waveform Data" on page 26 and "Downloading Waveform Data" on page 33. For information on the waveform data requirements, see "Waveform Data Requirements" on page 2.

Using the Download Utilities

Agilent provides free download utilities to download waveform data into the signal generator. The table in this section describes the capabilities of three such utilities.

For more information and to install the utilities, refer to the following URLs:

- Agilent Signal Studio Toolkit: *www.agilent.com/find/signalstudio*

  This software provides a graphical interface for downloading files.

- Agilent IntuiLink for PSG/ESG Signal Generators: *www.agilent.com/find/intuilink*

  This software places icons in the Microsoft Excel and Word toolbar. Use the icons to connect to the signal generator and open a window for downloading files.

- PSG/ESG Download Assistant: *www.agilent.com/find/downloadassistant*

  This software provides functions for the MATLAB environment to download waveform data.

Features	Agilent Signal Studio Toolkit	Agilent IntuiLink	PSG/ESG Download Assistant
Downloads encrypted waveform files	X		
Downloads Signal Studio waveform files	X[1]		
Downloads complex MATLAB waveform data			X
Downloads MATLAB files (.mat)	X		
Downloads unencrypted interleaved 16-bit I/Q files [2]	X	X	
Interleaves and downloads earlier 14-bit E443xB I and Q files [2]	X	X	
Swaps bytes for little endian order		X	
Downloads user-created marker files	X	X	X
Performs scaling	X	X	X
Starts waveform play back	X		X
Sends SCPI Commands and Queries	X		X
Builds a waveform sequence	X		X

1. Some Signal Studio products let you create and export waveform files to a PC. Signal Studio Toolkit downloads the exported files.
2. ASCII or binary format.

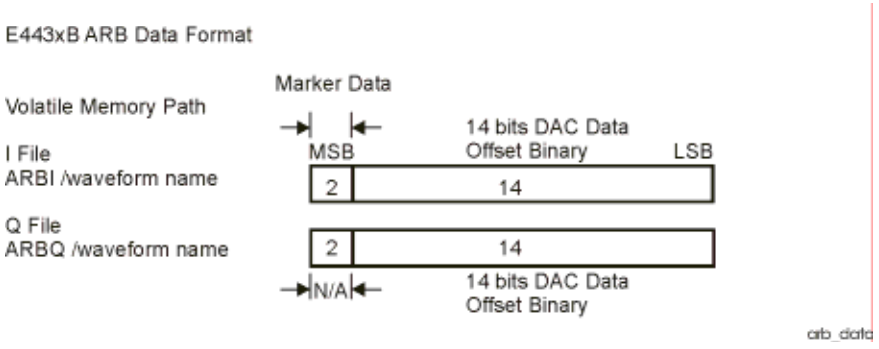
Downloading E443xB Signal Generator Files

In this section, the words *signal generator* without a model number refer to an E4438C ESG or an E8257D PSG signal generator. To download earlier E443xB model I and Q files to a signal generator, use the same SCPI commands as if downloading files to an E443xB signal generator. The signal generator automatically converts the E443xB files to the proper file format as described in "Waveform Structure" on page 11 and stores them in the signal generator's memory. This conversion process causes the signal generator to take more time to download the earlier file format. To minimize the time to convert earlier E443xB files to the proper file format, store E443xB file downloads to volatile memory, and then transfer them over to non-volatile (NVWFM) memory.

NOTE You cannot extract waveform data downloaded as E443xB files.

E443xB Data Format

The following diagram describes the data format for the E443xB waveform files. This file structure can be compared with the new style file format shown in "Waveform Structure" on page 11. If you create new waveform files for the signal generator, use the format shown in "Waveform Data Requirements" on page 2.



Storage Locations for E443xB ARB files

Place waveforms in either volatile memory or non-volatile memory. The signal generator supports the E443xB directory structure for waveform file downloads.

Volatile Memory Storage Locations

- `/user/arbi/`
- `/user/arbq/`

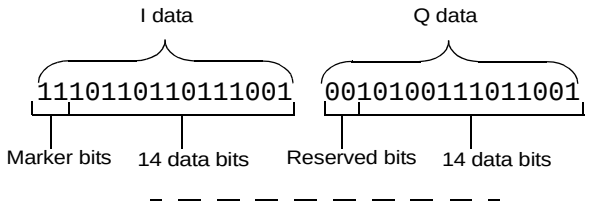
Non-Volatile Memory Storage Locations

- `/user/nvarbi/`
- `/user/nvarbq/`

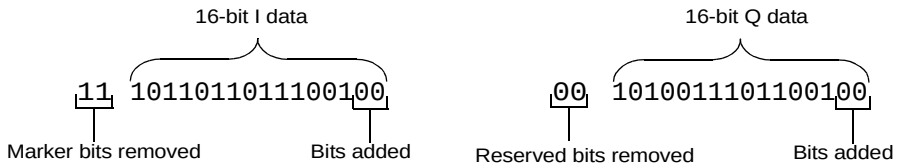
Loading files into the above directories (volatile or non-volatile memory) does not actually store them in those directories. Instead, these directories function as “pipes” to the format translator. The signal generator performs the following functions on the E443xB data:

- Converts the 14-bit I and Q data into 16-bit data.
  Left shifts the data and appends two bits (zeros) before the least significant bit.

E443xB 14-Bit Data

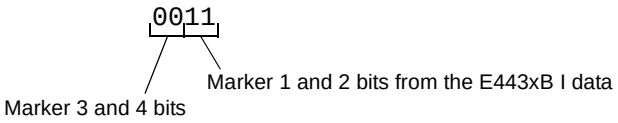


Left Shifts and Adds Zeros—Removes Marker and Reserved Bits (16-Bit Data Format)



- Creates a maker file and places the marker information, bits 14 and 15 of the E443xB I data, into the marker file for markers one and two. Markers three and four, within the new marker file, are set to zero (off).

Places the I Marker Bits into the Signal Generator’s Marker File



- Interleaves the 16-bit I and Q data creating one I/Q file.
- Creates a file header with all parameters set to unspecified (factory default file header setting).

SCPI Commands

Use the following commands to download E443xB waveform files into the signal generator.

NOTE Before downloading waveform data into volatile memory, turn off the Dual ARB player by pressing **Mode** > **Dual ARB** > **ARB Off On** until Off is highlighted or send the SCPI command `[:SOURce]:RADio:ARB[:STATe] OFF`.

Extraction Method / Memory Type	Command Syntax Options
SCPI/ volatile memory	`:MMEM:DATA "ARBI:<file_name>", <I waveform block data>` `:MMEM:DATA "ARBQ:<file_name>", <Q waveform data>`
SCPI/ non-volatile memory	`:MMEM:DATA "NVARBI:<file_name>", <I waveform block data>` `:MMEM:DATA "NVARBQ:<file_name>", <Q waveform block data>`

The variables <`I waveform block data`> and <`Q waveform block data`> represents data in the E443xB file format. The string variable `<file_name>` is the name of the I and Q data file. After downloading the data, the signal generator associates a file header and marker file with the I/Q data file.

Programming Examples

The programming examples use GPIB or LAN interfaces and are written in the following languages:

- C++
- MATLAB
- Visual Basic
- HP Basic

See signal generator's *Programming Guide* for information on interfaces and I/O libraries.

The example programs are also available on the signal generator's documentation CD-ROM, which allows you to cut and paste the examples into an editor.

C++ Programming Examples

This section contains the following programming examples:

Creating and Storing Offset I/Q Data—Big and Little Endian Order

On the signal generator's documentation CD, this programming example's name is "*offset_iq_c++.txt*."

This C++ programming example (compiled using Microsoft Visual C++ 6.0) follows the same coding algorithm as the MATLAB programming example "Creating and Storing I/Q Waveform" on page 76 and performs the following functions:

- error checking
- data creation
- data normalization
- data scaling
- I/Q signal offset from the carrier (single sideband suppressed carrier signal)
- byte swapping and interleaving for little endian order data
- I and Q interleaving for big endian order data
- binary data file storing to a PC or workstation
- reversal of the data formatting process (byte swapping, interleaving, and normalizing the data)

After creating the binary file, you can use FTP, one of the download utilities, or one of the C++ download programming examples to download the file to the signal generator.

```
// This C++ example shows how to
// 1.) Create a simple IQ waveform
// 2.) Save the waveform into the ESG/PSG Internal Arb format
//       This format is the for the E4438C, E8267C, E8267D
//       This format will not work with the ESG E443xB
// 3.) Load the internal Arb format file into an array

#include <stdio.h>
#include <string.h>
#include <math.h>

const int POINTS = 1000;  // Size of waveform
const char *computer = "PCWIN";

int main(int argc, char* argv[])
{
```

```
// 1.) Create Simple IQ Signal ****************************************
 // This signal is a single tone on the upper
 // side of the carrier and is usually refered to as
 // a Single Side Band Suppressed Carrier (SSBSC) signal.
 // It is nothing more than a cosine wavefomm in I
 // and a sine waveform in Q.

 int points = POINTS; // Number of points in the waveform
 int cycles = 101; // Determines the frequency offset from the carrier
 double Iwave[POINTS]; // I waveform
 double Qwave[POINTS]; // Q waveform
 short int waveform[2*POINTS]; // Holds interleaved I/Q data
 double maxAmp = 0; // Used to Normalize waveform data
 double minAmp = 0; // Used to Normalize waveform data
 double scale = 1;
 char buf; // Used for byte swapping
 char *pChar; // Used for byte swapping
 bool PC = true; // Set flag as appropriate

 double phaseInc = 2.0 * 3.141592654 * cycles / points;
 double phase = 0;
 int i = 0;
 for( i=0; i<points; i++ )
 {
   phase = i * phaseInc;
   Iwave[i] = cos(phase);
   Qwave[i] = sin(phase);
 }

 // 2.) Save waveform in internal format ********************************
 // Convert the I and Q data into the internal arb format
 // The internal arb format is a single waveform containing interleaved IQ
```

```
// data. The I/Q data is signed short integers (16 bits).
// The data has values scaled between +-32767 where
//   DAC Value   Description
//    32767      Maximum positive value of the DAC
//        0      Zero out of the DAC
//   -32767      Maximum negative value of the DAC
// The internal arb expects the data bytes to be in Big Endian format.
// This is opposite of how short integers are saved on a PC (Little Endian).
// For this reason the data bytes are swapped before being saved.

// Find the Maximum amplitude in I and Q to normalize the data between +-1
maxAmp = Iwave[0];
minAmp = Iwave[0];
for( i=0; i<points; i++)
{
  if( maxAmp < Iwave[i] )
      maxAmp = Iwave[i];
   else if( minAmp > Iwave[i] )
      minAmp = Iwave[i];

  if( maxAmp < Qwave[i] )
      maxAmp = Qwave[i];
  else if( minAmp > Qwave[i] )
    minAmp = Qwave[i];
}
maxAmp = fabs(maxAmp);
minAmp = fabs(minAmp);
if( minAmp > maxAmp )
  maxAmp = minAmp;

// Convert to short integers and interleave I/Q data
scale = 32767 / maxAmp;     // Watch out for divide by zero.
```

```
for( i=0; i<points; i++)
{
  waveform[2*i] = (short)floor(Iwave[i]*scale + 0.5);
  waveform[2*i+1] = (short)floor(Qwave[i]*scale + 0.5);
}
// If on a PC swap the bytes to Big Endian
if( strcmp(computer,"PCWIN") == 0 )
//if( PC )
{
  pChar = (char *)&waveform[0];   // Character pointer to short int data
  for( i=0; i<2*points; i++ )
  {
     buf = *pChar;
     *pChar = *(pChar+1);
     *(pChar+1) = buf;
     pChar+= 2;
   }
}
// Save the data to a file
// Use FTP or one of the download assistants to download the file to the
// signal generator
char *filename = "C:\\Temp\\EsgTestFile";
FILE *stream = NULL;
stream = fopen(filename, "w+b");// Open the file
if (stream==NULL) perror ("Cannot Open File");
int numwritten = fwrite( (void *)waveform, sizeof( short ), points*2, stream );
fclose(stream);// Close the file

// 3.) Load the internal Arb format file ********************************
// This process is just the reverse of saving the waveform
// Read in waveform as unsigned short integers.
// Swap the bytes as necessary
// Normalize between +-1
```

```
  // De-interleave the I/Q Data
  // Open the file and load the internal format data
  stream = fopen(filename, “r+b”);// Open the file
  if (stream==NULL) perror (“Cannot Open File”);
  int numread = fread( (void *)waveform, sizeof( short ),  points*2, stream );
  fclose(stream);// Close the file
  // If on a PC swap the bytes back to Little Endian
  if( strcmp(computer,”PCWIN”) == 0 )
  {
     pChar = (char *)&waveform[0];   // Character pointer to short int data
     for( i=0; i<2*points; i++ )
     {
        buf = *pChar;
        *pChar = *(pChar+1);
        *(pChar+1) = buf;
        pChar+= 2;
     }
  }
  // Normalize De-Interleave the IQ data
  double IwaveIn[POINTS];
  double QwaveIn[POINTS];
  for( i=0; i<points; i++)
  {
    IwaveIn[i] = waveform[2*i] / 32767.0;
    QwaveIn[i] = waveform[2*i+1] / 32767.0;
  }
  return 0;
}
```

Creating and Storing I/Q Data—Little Endian Order

On the signal generator's documentation CD, this programming example's name is "*CreateStore_Data_c++.txt*."

This C++ programming example (compiled using Metrowerks CodeWarrior 3.0) performs the following functions:

- error checking
- data creation
- byte swapping and interleaving for little endian order data
- binary data file storing to a PC or workstation

After creating the binary file, you can use FTP, one of the download utilities, or one of the C++ download programming examples to download the file to the signal generator.

```
#include <iostream>
#include <fstream>
#include <math.h>
#include <stdlib.h>
using namespace std;

int main ( void )
{
    ofstream out_stream;       // write the I/Q data to a file
    const unsigned int SAMPLES =200;    // number of sample pairs in the waveform
    const short AMPLITUDE = 32000;      // amplitude between 0 and full scale dac value
    const double two_pi = 6.2831853;

    //allocate buffer for waveform
    short* iqData = new short[2*SAMPLES];// need two bytes for each integer
    if (!iqData)
    {
       cout << "Could not allocate data buffer." << endl;
       return 1;
    }
```

```
    out_stream.open("IQ_data");// create a data file
    if (out_stream.fail())
    {
      cout << "Input file opening failed" << endl;
      exit(1);
    }
    //generate the sample data for I and Q. The I channel will have a sine
    //wave and the Q channel will a cosine wave.

    for (int i=0; i<SAMPLES; ++i)
    {
        iqData[2*i] = AMPLITUDE * sin(two_pi*i/(float)SAMPLES);
        iqData[2*i+1] = AMPLITUDE * cos(two_pi*i/(float)SAMPLES);
    }
   // make sure bytes are in the order MSB(most significant byte) first. (PC only).

    char* cptr = (char*)iqData;// cast the integer values to characters

    for (int i=0; i<(4*SAMPLES); i+=2)// 4*SAMPLES
    {
        char temp = cptr[i];// swap LSB and MSB bytes
        cptr[i]=cptr[i+1];
        cptr[i+1]=temp;
    }

    // now write the buffer to a file

        out_stream.write((char*)iqData, 4*SAMPLES);
 return 0;
}
```

Creating and Downloading I/Q Data—Big and Little Endian Order

On the signal generator's documentation CD, this programming example's name is "*CreateDwnLd_Data_c++.txt*."

This C++ programming example (compiled using Microsoft Visual C++ 6.0) performs the following functions:

- error checking
- data creation
- data scaling
- text file creation for viewing and debugging data
- byte swapping and interleaving for little endian order data
- interleaving for big endian order data
- data saving to an array (data block)
- data block download to the signal generator

```
// This C++ program is an example of creating and scaling
// I and Q data, and then downloading the data into the
// signal generator as an interleaved I/Q file.
// This example uses a sine and cosine wave as the I/Q
// data.
//
// Include the standard headers for SICL programming
#include <sicl.h>
#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include <math.h>

// Choose a GPIB, LAN, or RS-232 connection
char* instOpenString =”lan[galqaDhcp1]”;
//char* instOpenString =”gpib0,19”;

// Pick some maximum number of samples, based on the
// amount of memory in your computer and the signal generator.
```

```
const int NUMSAMPLES=500;

int main(int argc, char* argv[])
{
     // Create a text file to view the waveform
     // prior to downloading it to the signal generator.
     // This verifies that the data looks correct.

    char *ofile = “c:\\temp\\iq.txt”;

    // Create arrays to hold the I and Q data

    int idata[NUMSAMPLES];
    int qdata[NUMSAMPLES];

    // save the number of sampes into numsamples
    int numsamples = NUMSAMPLES;

    // Fill the I and Q buffers with the sample data
    for(int index=0; index<numsamples; index++)
    {
         // Create the I and Q data for the number of waveform
        // points and Scale the data (20000 * ...) as a precentage
        // of the DAC full scale (-32768 to 32767). This example
        // scales to approximately 70% of full scale.
        idata[index]=23000 * sin((4*3.14*index)/numsamples);
        qdata[index]=23000 * cos((4*3.14*index)/numsamples);
    }

    // Print the I and Q values to a text file. View the data
    // to see if its correct and if needed, plot the data in a
    // spreadsheet to help spot any problems.
```

```
FILE *outfile = fopen(ofile, “w”);

if (outfile==NULL) perror (“Error opening file to write”);
for(index=0; index<numsamples; index++)
{
    fprintf(outfile, “%d, %d\n”, idata[index], qdata[index]);
}
fclose(outfile);

// Little endian order data, use the character array and for loop.
// If big endian order, comment out this character array and for loop,
// and use the next loop (Big Endian order data).

// We need a buffer to interleave the I and Q data.
// 4 bytes to account for 2 I bytes and 2 Q bytes.

char iqbuffer[NUMSAMPLES*4];

// Interleave I and Q, and swap bytes from little
// endian order to big endian order.
for(index=0; index<numsamples; index++)
{
    int ivalue = idata[index];
    int qvalue = qdata[index];
    iqbuffer[index*4]   = (ivalue >> 8) & 0xFF; // high byte of i
    iqbuffer[index*4+1] = ivalue & 0xFF;        // low byte of i
    iqbuffer[index*4+2] = (qvalue >> 8) & 0xFF; // high byte of q
    iqbuffer[index*4+3] = qvalue & 0xFF;        // low byte of q
}

// Big Endian order data, uncomment the following lines of code.
// Interleave the I and Q data.
```

```
// short iqbuffer[NUMSAMPLES*2];            // Big endian order, uncomment this line
// for(index=0; index<numsamples; index++)  // Big endian order, uncomment this line
// {                                        // Big endian order, uncomment this line
//     iqbuffer[index*2]   = idata[index];  // Big endian order, uncomment this line
//     iqbuffer[index*2+1] = qdata[index];  // Big endian order, uncomment this line
// }                                        // Big endian order, uncomment this line

// Open a connection to write to the instrument
INST id=iopen(instOpenString);
if (!id)
{
    fprintf(stderr, “iopen failed (%s)\n”, instOpenString);
    return -1;
}

// Declare variables to hold portions of the SCPI command
int bytesToSend;
char s[20];
char cmd[200];

bytesToSend = numsamples*4;       // calculate the number of bytes
sprintf(s, “%d”, bytesToSend); // create a string s with that number of bytes

// The SCPI command has four parts.
//   Part 1 = :MEM:DATA “filename”,#
//   Part 2 = length of Part 3 when written to a string
//   Part 3 = length of the data in bytes.  This is in s from above.
//   Part 4 = the buffer of data

// Build parts 1, 2, and 3 for the I and Q data.
sprintf(cmd, “:MEM:DATA \”WFM1:FILE1\”, #%d%d”, strlen(s), bytesToSend);
// Send parts 1, 2, and 3
```

```
    iwrite(id, cmd, strlen(cmd), 0, 0);
    // Send part 4.  Be careful to use the correct command here.  In many
    // programming languages, there are two methods to send SCPI commands:
    //   Method 1 = stop at the first '0' in the data
    //   Method 2 = send a fixed number of bytes, ignoring '0' in the data.
    // You must find and use the correct command for Method 2.
    iwrite(id, iqbuffer, bytesToSend, 0, 0);
    // Send a terminating carriage return
    iwrite(id, "\n", 1, 1, 0);

    printf("Loaded file using the E4438C, E8267C and E8267D format\n");
    return 0;
}
```

Importing and Downloading I/Q Data—Big Endian Order

On the signal generator's documentation CD, this programming example's name is "*impDwnLd_c++.txt*."

This C++ programming example (compiled using Metrowerks CodeWarrier 3.0) assumes that the data is in big endian order and performs the following functions:

- error checking
- binary file importing from the PC or workstation
- binary file download to the signal generator

```
// Description: Send a file in blocks of data to a signal generator
//
#include <sicl.h>
#include <stdlib.h>
#include <stdio.h>
#include <string.h>

// ATTENTION:
// - Configure these three lines appropriately for your instrument
//   and use before compiling and running
//
char* instOpenString = "gpib7,19"; //for LAN replace with "lan[<hostname or IP address>]"
const char* localSrcFile = "D:\\home\\TEST_WAVE"; //enter file location on PC/workstation
const char* instDestFile = "/USER/BBG1/WAVEFORM/TEST_WAVE"; //for non-volatile memory
                                                            //remove BBG1 from file path
// Size of the copy buffer
const int BUFFER_SIZE = 100*1024;

int
main()
{
    INST id=iopen(instOpenString);
    if (!id)
    {
        fprintf(stderr, "iopen failed (%s)\n", instOpenString);
```

```
    return -1;
}

FILE* file = fopen(localSrcFile, "rb");
if (!file)
{
    fprintf(stderr, "Could not open file: %s\n", localSrcFile);
    return 0;
}

if( fseek( file, 0, SEEK_END ) < 0 )
{
    fprintf(stderr,"Cannot seek to the end of file.\n" );
    return 0;
}

long lenToSend = ftell(file);
printf("File size = %d\n", lenToSend);

if (fseek(file, 0, SEEK_SET) < 0)
{
    fprintf(stderr,"Cannot seek to the start of file.\n");
    return 0;
}

char* buf = new char[BUFFER_SIZE];
if (buf && lenToSend)
{
    // Prepare and send the SCPI command header
    char s[20];
    sprintf(s, "%d", lenToSend);
    int lenLen = strlen(s);
```

```
        char s2[256];
        sprintf(s2, "mmem:data \"%s\", #%d%d", instDestFile, lenLen, lenToSend);
        iwrite(id, s2, strlen(s2), 0, 0);

        // Send file in BUFFER_SIZE chunks
        long numRead;
        do
        {
            numRead = fread(buf, sizeof(char), BUFFER_SIZE, file);
            iwrite(id, buf, numRead, 0, 0);
        } while (numRead == BUFFER_SIZE);

        // Send the terminating newline and EOM
        iwrite(id, "\n", 1, 1, 0);

        delete [] buf;
    }
    else
    {
        fprintf(stderr, "Could not allocate memory for copy buffer\n");
    }

    fclose(file);
    iclose(id);
    return 0;
}
```

Importing and Downloading Using VISA—Big Endian Order

On the signal generator's documentation CD, this programming example's name is "*DownLoad_Visa_c++.txt*."

This C++ programming example (compiled using Microsoft Visual C++ 6.0) assumes that the data is in big endian order and performs the following functions:

- error checking
- binary file importing from the PC or workstation
- binary file download to the signal generator's non-volatile memory

To load the waveform data to volatile (WFM1) memory, change the `instDestfile` declaration to: "`USER/BBG1/WAVEFORM/`".

```
//**************************************************************************
// PROGRAM NAME:Download_Visa_c++.cpp
//
// PROGRAM DESCRIPTION:Sample test program to download ARB waveform data. Send a
// file in chunks of ascii data to the signal generator.
//
// NOTE: You must have the Agilent IO Libraries installed to run this program.
//
// This example uses the LAN/TCPIP to download a file to the baseband generator's
// non-volatile memory. The program allocates a memory buffer on the PC or
// workstation of 102400 bytes (100*1024 bytes). The actual size of the buffer is
// limited by the memory on your PC or workstation, so the buffer size can be
// increased or decreased to meet your system limitations.
//
// While this program uses the LAN/TCPIP to download a waveform file into
// non-volatile memory, it can be modified to store files in volatile memory
// WFM1 using GPIB by setting the instrOpenString = "TCPIP0::xxx.xxx.xxx.xxx::INSTR"
// declaration with "GPIB::19::INSTR"
//
// The program also includes some error checking to alert you when problems arise
// while trying to download files. This includes checking to see if the file exists.
//**************************************************************************
```

```
// IMPORTANT: Replace the xxx.xxx.xxx.xxx IP address in the instOpenString declaration
// in the code below with the IP address of your signal generator. (or you can use the
// instrument's hostname). Replace the localSrcFile and instDestFile directory paths
// as needed.
//*************************************************************************



#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include  "visa.h"
//
// IMPORTANT:
//   Configure the following three lines correctly before compiling and running

char* instOpenString ="TCPIP0::xxx.xxx.xxx.xxx::INSTR"; // your instrument's IP address

const char* localSrcFile = "\\Files\\IQ_DataC";

const char* instDestFile = "/USER/WAVEFORM/IQ_DataC";

const int BUFFER_SIZE = 100*1024;// Size of the copy buffer

int main(int argc, char* argv[])
{
    ViSession defaultRM, vi;
    ViStatus status = 0;

    status = viOpenDefaultRM(&defaultRM);// Open the default resource manager

    // TO DO: Error handling here
```

```
    status = viOpen(defaultRM, instOpenString, VI_NULL, VI_NULL, &vi);

    if (status)// If any errors then display the error and exit the program
    {
        fprintf(stderr, "viOpen failed (%s)\n", instOpenString);
return -1;
    }

    FILE* file = fopen(localSrcFile, "rb");// Open local source file for binary reading

    if (!file) // If any errors display the error and exit the program
    {
        fprintf(stderr, "Could not open file: %s\n", localSrcFile);
return 0;
    }

    if( fseek( file, 0, SEEK_END ) < 0 )
    {
        fprintf(stderr,"Cannot lseek to the end of file.\n" );
        return 0;
    }

    long lenToSend = ftell(file);// Number of bytes in the file

    printf("File size = %d\n", lenToSend);

    if (fseek(file, 0, SEEK_SET) < 0)
    {
        fprintf(stderr,"Cannot lseek to the start of file.\n");
        return 0;
    }
```

```
    unsigned char* buf = new unsigned char[BUFFER_SIZE]; // Allocate char buffer memory

    if (buf && lenToSend)
    {
        // Do not send the EOI (end of instruction) terminator on any write except the
        // last one

        viSetAttribute( vi, VI_ATTR_SEND_END_EN, 0 );

        // Prepare and send the SCPI command header

        char s[20];
        sprintf(s, "%d", lenToSend);

        int lenLen = strlen(s);
        unsigned char s2[256];

// Write the command mmem:data and the header.The number lenLen represents the
// number of bytes and the actual number of bytes is the variable lenToSend

        sprintf((char*)s2, "mmem:data \"%s\", #%d%d", instDestFile, lenLen, lenToSend);

// Send the command and header to the signal generator

        viWrite(vi, s2, strlen((char*)s2), 0);

        long numRead;

// Send file in BUFFER_SIZE chunks to the signal generator

        do
        {
```

```
            numRead = fread(buf, sizeof(char), BUFFER_SIZE, file);

            viWrite(vi, buf, numRead, 0);

        } while (numRead == BUFFER_SIZE);

        // Send the terminating newline and EOI

        viSetAttribute( vi, VI_ATTR_SEND_END_EN, 1 );

        char* newLine = "\n";

        viWrite(vi, (unsigned char*)newLine, 1, 0);

        delete [] buf;
    }
    else
    {
        fprintf(stderr, "Could not allocate memory for copy buffer\n");
    }

    fclose(file);
    viClose(vi);
    viClose(defaultRM);

    return 0;
}
```

Importing, Byte Swapping, Interleaving, and Downloading I and Q Data—Big and Little Endian Order

On the signal generator's documentation CD, this programming example's name is "*impDwnLd2_c++.txt*."

This C++ programming example (compiled using Microsoft Visual C++ 6.0) performs the following functions:

- error checking
- binary file importing (earlier E443xB or current model signal generators)
- byte swapping and interleaving for little endian order data
- data interleaving for big endian order data
- data scaling
- binary file download for earlier E443xB data or current signal generator formatted data

```
// This C++ program is an example of loading I and Q
// data into an E443xB, E4438C, E8267C, or E8267D signal
// generator.
//
// It reads the I and Q data from a binary data file
// and then writes the data to the instrument.

// Include the standard headers for SICL programming
#include <sicl.h>
#include <stdlib.h>
#include <stdio.h>
#include <string.h>

// Choose a GPIB, LAN, or RS-232 connection
char* instOpenString =”gpib0,19”;

// Pick some maximum number of samples, based on the
// amount of memory in your computer and your waveforms.
const int MAXSAMPLES=50000;

int main(int argc, char* argv[])
```

```
{
    // These are the I and Q input files.
    // Some compilers will allow '/' in the directory
    // names.  Older compilers might need '\\' in the
    // directory names.  It depends on your operating system
    // and compiler.
    char *ifile = "c:\\SignalGenerator\\data\\BurstA1I.bin";
    char *qfile = "c:\\SignalGenerator\\data\\BurstA1Q.bin";

    // This is a text file to which we will write the
    // I and Q data just for debugging purposes.  It is
    // a good programming practice to check your data
    // in this way before attempting to write it to
    // the instrument.
    char *ofile = "c:\\SignalGenerator\\data\\iq.txt";

    // Create arrays to hold the I and Q data
    int idata[MAXSAMPLES];
    int qdata[MAXSAMPLES];

    // Often we must modify, scale, or offset the data
    // before loading it into the instrument.  These
    // buffers are used for that purpose.  Since each
    // sample is 16 bits, and a character only holds
    // 8 bits, we must make these arrays twice as long
    // as the I and Q data arrays.
    char ibuffer[MAXSAMPLES*2];
    char qbuffer[MAXSAMPLES*2];

    // For the E4438C, we might also need to interleave
    // the I and Q data.  This buffer is used for that
    // purpose.  In this case, this buffer must hold
```

```
// both I and Q data so it needs to be four times
// as big as the data arrays.
char iqbuffer[MAXSAMPLES*4];

// Declare variables which will be used later
bool done;
FILE *infile;
int index, numsamples, i1, i2, ivalue;

// In this example, we'll assume the data files have
// the I and Q data in binary form as unsigned 16 bit integers.
// This next block reads those binary files.  If your
// data is in some other format, then replace this block
// with appropriate code for reading your format.
// First read I values
done = false;
index = 0;
infile = fopen(ifile, "rb");
if (infile==NULL) perror ("Error opening file to read");
while(!done)
{
    i1 = fgetc(infile);  // read the first byte
    if(i1==EOF) break;
    i2 = fgetc(infile);  // read the next byte
    if(i2==EOF) break;
    ivalue=i1+i2*256;    // put the two bytes together
    // note that the above format is for a little endian
    // processor such as Intel.  Reverse the order for
    // a big endian processor such as Motorola, HP, or Sun
    idata[index++]=ivalue;
    if(index==MAXSAMPLES) break;
}
```

```
fclose(infile);

// Then read Q values
index = 0;
infile = fopen(qfile, “rb”);
if (infile==NULL) perror (“Error opening file to read”);
while(!done)
{
    i1 = fgetc(infile);  // read the first byte
    if(i1==EOF) break;
    i2 = fgetc(infile);  // read the next byte
    if(i2==EOF) break;
    ivalue=i1+i2*256;    // put the two bytes together
    // note that the above format is for a little endian
    // processor such as Intel.  Reverse the order for
    // a big endian processor such as Motorola, HP, or Sun
    qdata[index++]=ivalue;
    if(index==MAXSAMPLES) break;
}
fclose(infile);

// Remember the number of samples which were read from the file.
numsamples = index;

// Print the I and Q values to a text file.  If you are
// having trouble, look in the file and see if your I and
// Q data looks correct.  Plot the data from this file if
// that helps you to diagnose the problem.
FILE *outfile = fopen(ofile, “w”);
if (outfile==NULL) perror (“Error opening file to write”);
for(index=0; index<numsamples; index++)
{
```

```
    fprintf(outfile, “%d, %d\n”, idata[index], qdata[index]);
}
fclose(outfile);

// The E443xB, E4438C, E8267C or E8267D all use big-endian
// processors.  If your software is running on a little-endian
// processor such as Intel, then you will need to swap the
// bytes in the data before sending it to the signal generator.

// The arrays ibuffer and qbuffer are used to hold the data
// after any byte swapping, shifting or scaling.

// In this example, we’ll assume that the data is in the format
// of the E443xB without markers.  In other words, the data
// is in the range 0-16383.
//  0 gives negative full-scale output
//  8192 gives 0 V output
//  16383 gives positive full-scale output
// If this is not the scaling of your data, then you will need
// to scale your data appropriately in the next two blocks.

// ibuffer and qbuffer will hold the data in the E443xB format.
// No scaling is needed, however we need to swap the byte order
// on a little endian computer.  Remove the byte swapping
// if you are using a big endian computer.
for(index=0; index<numsamples; index++)
{
    int ivalue = idata[index];
    int qvalue = qdata[index];
    ibuffer[index*2]   = (ivalue >> 8) & 0xFF; // high byte of i
    ibuffer[index*2+1] = ivalue & 0xFF;        // low byte of i
    qbuffer[index*2]   = (qvalue >> 8) & 0xFF; // high byte of q
```

```
    qbuffer[index*2+1] = qvalue & 0xFF;        // low byte of q
}

// iqbuffer will hold the data in the E4438C, E8267C, E8267D
// format.  In this format, the I and Q data is interleaved.
// The data is in the range -32768 to 32767.
//   -32768 gives negative full-scale output
//        0 gives 0 V output
//    32767 gives positive full-scale output
// From these ranges, it appears you should offset the
// data by 8192 and scale it by 4.  However, due to the
// interpolators in these products, it is better to scale
// the data by a number less than four.  Commonly a good
// choice is 70% of 4 which is 2.8.
// By default, the signal generator scales data to 70%
// If you scale the data here, you may want to change the
// signal generator scaling to 100%
// Also we need to swap the byte order on a little endian
// computer.  This code also works for big endian order data
// since it swaps bytes based on the order.
for(index=0; index<numsamples; index++)
{
    int iscaled = 2.8*(idata[index]-8192); // shift and scale
    int qscaled = 2.8*(qdata[index]-8192); // shift and scale
    iqbuffer[index*4]   = (iscaled >> 8) & 0xFF; // high byte of i
    iqbuffer[index*4+1] = iscaled & 0xFF;        // low byte of i
    iqbuffer[index*4+2] = (qscaled >> 8) & 0xFF; // high byte of q
    iqbuffer[index*4+3] = qscaled & 0xFF;  // low byte of q
}

// Open a connection to write to the instrument
INST id=iopen(instOpenString);
```

```
if (!id)
{
    fprintf(stderr, “iopen failed (%s)\n”, instOpenString);
    return -1;
}

// Declare variables which will be used later
int bytesToSend;
char s[20];
char cmd[200];

// The E4438C, E8267C and E8267D accept the E443xB format.
// so we can use this next section on any of these signal generators.
// However the E443xB format only uses 14 bits.

bytesToSend = numsamples*2;       // calculate the number of bytes
sprintf(s, “%d”, bytesToSend); // create a string s with that number of bytes

// The SCPI command has four parts.
//   Part 1 = :MEM:DATA “filename”,
//   Part 2 = length of Part 3 when written to a string
//   Part 3 = length of the data in bytes.  This is in s from above.
//   Part 4 = the buffer of data

// Build parts 1, 2, and 3 for the I data.
sprintf(cmd, “:MEM:DATA \”ARBI:FILE1\”, #%d%d”, strlen(s), bytesToSend);
// Send parts 1, 2, and 3
iwrite(id, cmd, strlen(cmd), 0, 0);
// Send part 4.  Be careful to use the correct command here.  In many
// programming languages, there are two methods to send SCPI commands:
//   Method 1 = stop at the first ‘0’ in the data
//   Method 2 = send a fixed number of bytes, ignoring ‘0’ in the data.
```

```
    // You must find and use the correct command for Method 2.
    iwrite(id, ibuffer, bytesToSend, 0, 0);
    // Send a terminating carriage return
    iwrite(id, "\n", 1, 1, 0);

    // Identical to the section above, except for the Q data.
    sprintf(cmd, ":MEM:DATA \"ARBQ:FILE1\", #%d%d", strlen(s),bytesToSend);
    iwrite(id, cmd, strlen(cmd), 0, 0);
    iwrite(id, qbuffer, bytesToSend, 0, 0);
    iwrite(id, "\n", 1, 1, 0);

    printf("Loaded FILE1 using the E443xB format\n");

    // The E4438C, E8267C and E8267D have a newer faster format which
    // allows 16 bits to be used.  However this format is not accepted in
    // the E443xB.  Therefore do not use this next section for the E443xB.

    printf("Note: Loading FILE2 on a E443xB will cause \"ERROR: 208, I/O error\"\n");

    // Identical to the I and Q sections above except
    //   a) The I and Q data are interleaved
    //   b) The buffer of I+Q is twice as long as the I buffer was.
    //   c) The SCPI command uses WFM1 instead of ARBI and ARBQ.
    bytesToSend = numsamples*4;
    sprintf(s, "%d", bytesToSend);
    sprintf(cmd, ":mem:data \"WFM1:FILE2\", #%d%d", strlen(s),bytesToSend);
    iwrite(id, cmd, strlen(cmd), 0, 0);
    iwrite(id, iqbuffer, bytesToSend, 0, 0);
    iwrite(id, "\n", 1, 1, 0);
    printf("Loaded FILE2 using the E4438C, E8267C and E8267D format\n");
    return 0;
}
```

MATLAB Programming Example

Creating and Storing I/Q Waveform

On the signal generator's documentation CD, this programming example's name is "*offset_iq_ml.m*."

This MATLAB programming example follows the same coding algorithm as the C++ programming example "Creating and Storing Offset I/Q Data—Big and Little Endian Order" on page 48 and performs the following functions:

- error checking
- data creation
- data normalization
- data scaling
- I/Q signal offset from the carrier (single sideband suppressed carrier signal)
- byte swapping and interleaving for little endian order data
- I and Q interleaving for big endian order data
- binary data file storing to a PC or workstation
- reversal of the data formatting process (byte swapping, interleaving, and normalizing the data)

```
function main
% Using MatLab this example shows how to
% 1.) Create a simple IQ waveform
% 2.) Save the waveform into the ESG/PSG Internal Arb format
%     This format is for the E4438C, E8267C, and E8267D
%     This format will not work with the earlier E443xB ESG
% 3.) Load the internal Arb format file into a MatLab array

% 1.) Create Simple IQ Signal ***************************************
% This signal is a single tone on the upper
% side of the carrier and is usually refered to as
% a Single Side Band Suppressed Carrier (SSBSC) signal.
% It is nothing more than a cosine wavefomm in I
% and a sine waveform in Q.
%
points = 1000;      % Number of points in the waveform
cycles = 101;       % Determines the frequency offset from the carrier
```

```
phaseInc = 2*pi*cycles/points;
phase = phaseInc * [0:points-1];

Iwave = cos(phase);
Qwave = sin(phase);

% 2.) Save waveform in internal format ********************************
% Convert the I and Q data into the internal arb format
% The internal arb format is a single waveform containing interleaved IQ
% data. The I/Q data is signed short integers (16 bits).
% The data has values scaled between +-32767 where
%   DAC Value   Description
%    32767      Maximum positive value of the DAC
%        0      Zero out of the DAC
%   -32767      Maximum negative value of the DAC
% The internal arb expects the data bytes to be in Big Endian format.
% This is opposite of how short integers are saved on a PC (Little Endian).
% For this reason the data bytes are swapped before being saved.

% Interleave the IQ data
waveform(1:2:2*points) = Iwave;
waveform(2:2:2*points) = Qwave;
%[Iwave;Qwave];
%waveform = waveform(:)';

% Normalize the data between +-1
waveform = waveform / max(abs(waveform));   % Watch out for divide by zero.

% Scale to use full range of the DAC
waveform = round(waveform * 32767);     % Data is now effectively signed short integer
values
```

```
% waveform = round(waveform * (32767 / max(abs(waveform))));    % More efficient than
previous two steps!


% PRESERVE THE BIT PATTERN but convert the waveform to
% unsigned short integers so the bytes can be swapped.
% Note: Can't swap the bytes of signed short integers in MatLab.
waveform = uint16(mod(65536 + waveform,65536)); %


% If on a PC swap the bytes to Big Endian
if strcmp( computer, 'PCWIN' )
    waveform = bitor(bitshift(waveform,-8),bitshift(waveform,8));
end


% Save the data to a file
% Note: The waveform is saved as unsigned short integers. However,
%       the acual bit pattern is that of signed short integers and
%       that is how the ESG/PSG interprets them.
filename = 'C:\Temp\EsgTestFile';
[FID, message] = fopen(filename,'w');% Open a file to write data
if FID == -1 error('Cannot Open File'); end
fwrite(FID,waveform,'unsigned short');% write to the file
fclose(FID);                        % close the file


% 3.) Load the internal Arb format file *********************************
% This process is just the reverse of saving the waveform
% Read in waveform as unsigned short integers.
% Swap the bytes as necessary
% Convert to signed integers then normalize between +-1
% De-interleave the I/Q Data


% Open the file and load the internal format data
[FID, message] = fopen(filename,'r');% Open file to read data
```

```
if FID == -1 error('Cannot Open File'); end
[internalWave,n] = fread(FID, 'uint16');% read the IQ file
fclose(FID);% close the file

internalWave = internalWave';   % Conver from column array to row array

% If on a PC swap the bytes back to Little Endian
if strcmp( computer, 'PCWIN' )  % Put the bytes into the correct order
    internalWave= bitor(bitshift(internalWave,-8),bitshift(bitand(internalWave,255),8));
end

% convert unsigned to signed representation
internalWave = double(internalWave);
tmp = (internalWave > 32767.0) * 65536;
iqWave = (internalWave - tmp) ./ 32767;  % and normalize the data

% De-Interleave the IQ data
IwaveIn = iqWave(1:2:n);
QwaveIn = iqWave(2:2:n);
```

Visual Basic Programming Examples

Creating I/Q Data—Little Endian Order

On the signal generator's documentation CD, this programming example's name is "*Create_IQData_vb.txt*."

This Visual Basic programming example, using Microsoft Visual Basic 6.0, uses little endian order data, and performs the following functions:

- error checking
- I an Q integer array creation
- I an Q data interleaving
- byte swapping to convert to big endian order
- binary data file storing to a PC or workstation

Once the file is created, you can download the file to the signal generator using FTP (see "FTP Procedures" on page 24).

```
'*************************************************************************************
' Program Name: Create_IQData
' Program Description: This program creates a sine and cosine wave using 200 I/Q data
' samples. Each I and Q value is represented by a 2 byte integer. The sample points are
' calculated, scaled using the AMPLITUDE constant of 32767, and then stored in an array
' named iq_data. The AMPLITUDE scaling allows for full range I/Q modulator DAC values.
' Data must be in 2's complemant, MSB/LSB big-endian format. If your PC uses LSB/MSB
' format, then the integer bytes must be swapped. This program converts the integer
' array values to hex data types and then swaps the byte positions before saving the
' data to the IQ_DataVB file.
'*************************************************************************************

Private Sub Create_IQData()
Dim index As Integer
Dim AMPLITUDE As Integer
Dim pi As Double
Dim loByte As Byte
Dim hiByte As Byte
Dim loHex As String
Dim hiHex As String
Dim strSrc As String
```

```
Dim numPoints As Integer
Dim FileHandle As Integer
Dim data As Byte
Dim iq_data() As Byte
Dim strFilename As String

strFilename = "C:\IQ_DataVB"

Const SAMPLES = 200     ' Number of sample PAIRS of I and Q integers for the waveform
AMPLITUDE = 32767       ' Scale the amplitude for full range of the signal generators
                        ' I/Q modulator DAC
pi = 3.141592

Dim intIQ_Data(0 To 2 * SAMPLES - 1)  'Array for I and Q integers: 400
ReDim iq_data(0 To (4 * SAMPLES - 1)) 'Need MSB and LSB bytes for each integer value: 800

'Create an integer array of I/Q pairs

    For index = 0 To (SAMPLES - 1)
        intIQ_Data(2 * index) = CInt(AMPLITUDE * Sin(2 * pi * index / SAMPLES))
        intIQ_Data(2 * index + 1) = CInt(AMPLITUDE * Cos(2 * pi * index / SAMPLES))
    Next index

 'Convert each integer value to a hex string and then write into the iq_data byte array
 'MSB, LSB ordered
 For index = 0 To (2 * SAMPLES - 1)
    strSrc = Hex(intIQ_Data(index)) 'convert the integer to a hex value

    If Len(strSrc) <> 4 Then
        strSrc = String(4 - Len(strSrc), "0") & strSrc  'Convert to hex format i.e "800F
    End If                                              'Pad with 0's if needed to get 4
                                                        'characters i.e '0' to "0000"
```

```
        hiHex = Mid$(strSrc, 1, 2)   'Get the first two hex values (MSB)
        loHex = Mid$(strSrc, 3, 2)   'Get the next two hex values (LSB)
        loByte = CByte("&H" & loHex) 'Convert to byte data type LSB
        hiByte = CByte("&H" & hiHex) 'Convert to byte data type MSB

        iq_data(2 * index) = hiByte      'MSB into first byte
        iq_data(2 * index + 1) = loByte  'LSB into second byte

  Next index

  'Now write the data to the file

FileHandle = FreeFile()     'Get a file number

numPoints = UBound(iq_data) 'Get the number of bytes in the file

Open strFilename For Binary Access Write As #FileHandle Len = numPoints + 1

On Error GoTo file_error

    For index = 0 To (numPoints)
        data = iq_data(index)
        Put #FileHandle, index + 1, data 'Write the I/Q data to the file
    Next index

Close #FileHandle

Call MsgBox("Data written to file " & strFilename, vbOKOnly, "Download")

Exit Sub
```

```
file_error:
    MsgBox Err.Description
    Close #FileHandle

End Sub
```

Downloading I/Q Data

On the signal generator's documentation CD, this programming example's name is "*Download_File_vb.txt*."

This Visual Basic programming example, using Microsoft Visual Basic 6.0, downloads the file created in "Creating I/Q Data—Little Endian Order" on page 80 into non-volatile memory using a LAN connection. To use GPIB, replace the `instOpenString` object declaration with "`GPIB::19::INSTR`". To download the data into volatile memory, change the `instDestfile` declaration to "`USER/BBG1/WAVEFORM/`".

NOTE The example program listed here uses the VISA COM I/O API, which includes the `WriteIEEEBlock` method. This method eliminates the need to format the download command with arbitrary block information such as defining number of bytes and byte numbers. Refer to "SCPI Command Line Structure" on page 20 for more information.

This program also includes some error checking to alert you when problems arise while trying to download files. This includes checking to see if the file exists.

```
'************************************************************************
' Program Name: Download_File
' Program Description: This program uses Microsoft Visual Basic 6.0 and the Agilent
' VISA COM I/O Library to download a waveform file to the signal generator.
'
' The program downloads a file (the previously created 'IQ_DataVB' file) to the signal
' generator. Refer to the Programming Guide for information on binary
' data requirements for file downloads. The waveform data 'IQ_DataVB' is
' downloaded to the signal generator's non-volatile memory(NVWFM)
' " /USER/WAVEFORM/IQ_DataVB". For volatile memory(WFM1) download to the
' " /USER/BBG1/WAVEFORM/IQ_DataVB" directory.
'
' You must reference the Agilent VISA COM Resource Manager and VISA COM 1.0 Type
' Library in your Visual Basic project in the Project/References menu.
' The VISA COM 1.0 Type Library, corresponds to VISACOM.tlb and the Agilent
' VISA COM Resource Manager, corresponds to AgtRM.DLL.
' The VISA COM 488.2 Formatted I/O 1.0, corresponds to the BasicFormattedIO.dll
' Use a statement such as "Dim Instr As VisaComLib.FormattedIO488" to
```

```
' create the formatted I/O reference and use
' "Set Instr = New VisaComLib.FormattedIO488" to create the actual object.
'*************************************************************************
' IMPORTANT: Use the TCPIP address of your signal generator in the rm.Open
' declaraion. If you are using the GPIB interface in your project use "GPIB::19::INSTR"
' in the rm.Open declaration.
'*************************************************************************

Private Sub Download_File()
' The following four lines declare IO objects and instantiate them.
Dim rm As VisaComLib.ResourceManager
Set rm = New AgilentRMLib.SRMCls
Dim SigGen As VisaComLib.FormattedIO488
Set SigGen = New VisaComLib.FormattedIO488

' NOTE: Use the IP address of your signal generator in the rm.Open declaration
Set SigGen.IO = rm.Open("TCPIP0::000.000.000.000")

Dim data As Byte
Dim iq_data() As Byte
Dim FileHandle As Integer
Dim numPoints As Integer
Dim index As Integer
Dim Header As String
Dim response As String
Dim hiByte As String
Dim loByte As String
Dim strFilename As String

strFilename = "C:\IQ_DataVB" ‘File Name and location on PC
                            'Data will be saved to the signal generator’s NVWFM
                        ‘/USER/WAVEFORM/IQ_DataVB directory.
```

```
FileHandle = FreeFile()

On Error GoTo errorhandler

With SigGen                 'Set up the signal generator to accept a download
    .IO.Timeout = 5000      'Timeout 50 seconds
    .WriteString "*RST"     'Reset the signal generator.
End With

numPoints = (FileLen(strFilename))  'Get number of bytes in the file: 800 bytes

ReDim iq_data(0 To numPoints - 1)      'Dimension the iq_data array to the
                                       'size of the IQ_DataVB file: 800 bytes

Open strFilename For Binary Access Read As #FileHandle  'Open the file for binary read
On Error GoTo file_error

For index = 0 To (numPoints - 1)    'Write the IQ_DataVB data to the iq_data array
        Get #FileHandle, index + 1, data    '(index+1) is the record number
        iq_data(index) = data
Next index

    Close #FileHandle                   'Close the file

'Write the command to the Header string. NOTE: syntax
 Header = "MEM:DATA ""/USER/WAVEFORM/IQ_DataVB"","

   'Now write the data to the signal generator's non-volatile memory (NVWFM)

    SigGen.WriteIEEEBlock Header, iq_data
```

```
    SigGen.WriteString "*OPC?"          'Wait for the operation to complete
    response = SigGen.ReadString        'Signal generator reponse to the OPC? query
    Call MsgBox("Data downloaded to the signal generator", vbOKOnly, "Download")
    Exit Sub
errorhandler:
    MsgBox Err.Description, vbExclamation, "Error Occurred", Err.HelpFile, Err.HelpContext
Exit Sub
file_error:
    Call MsgBox(Err.Description, vbOKOnly)  'Display any error message
    Close #FileHandle
End Sub
```

HP Basic Programming Examples

This section contains the following programming examples:

Downloading Waveform Data Using HP BASIC for Windows®

On the signal generator's documentation CD, this programming example's name is "*hpbasicWin.txt*."

The following program will download a waveform using HP Basic for Windows into volatile ARB memory. The waveform generated by this program is the same as the default `SINE_TEST_WFM` waveform file available in the signal generator's waveform memory. This code is similar to the code shown for BASIC for UNIX but there is a formatting difference in line 130 and line 140.

To download into non-volatile memory, replace line 190 with:

190 OUTPUT @ESG USING "#,K";":MMEM:DATA ""NVWFM:testfile"", #"

As discussed at the beginning of this section, I and Q waveform data is interleaved into one file in 2's compliment form and a marker file is associated with this I/Q waveform file.

In the `Output` commands, `USING "#,K"` formats the data. The pound symbol (#) suppresses the automatic EOL (End of Line) output. This allows multiple output commands to be concatenated as if they were a single output. The `"K"` instructs HP Basic to output the following numbers or strings in the default format.

```
10 !  RE-SAVE "BASIC_Win_file"
20    Num_points=200
30    ALLOCATE INTEGER Int_array(1:Num_points*2)
40    DEG
50    FOR I=1 TO Num_points*2 STEP 2
60      Int_array(I)=INT(32767*(SIN(I*360/Num_points)))
70    NEXT I
80    FOR I=2 TO Num_points*2 STEP 2
90      Int_array(I)=INT(32767*(COS(I*360/Num_points)))
100   NEXT I
```

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```
110   PRINT "Data Generated"
120   Nbytes=4*Num_points
130   ASSIGN @Esg TO 719
140   ASSIGN @Esgb TO 719;FORMAT MSB FIRST
150   Nbytes$=VAL$(Nbytes)
160   Ndigits=LEN(Nbytes$)
170   Ndigits$=VAL$(Ndigits)
180   WAIT 1
190   OUTPUT @Esg USING "#,K";":MMEM:DATA ""WFM1:data_file"",#"
200   OUTPUT @Esg USING "#,K";Ndigits$
210   OUTPUT @Esg USING "#,K";Nbytes$
220   WAIT 1
230   OUTPUT @Esgb;Int_array(*)
240   OUTPUT @Esg;END
250   ASSIGN @Esg TO *
260   ASSIGN @Esgb TO *
270   PRINT
280   PRINT "*END*"
290   END
```

Program Comments

10:	Program file name
20:	Sets the number of points in the waveform.
30:	Allocates integer data array for I and Q waveform points.
40:	Sets HP BASIC to use degrees for cosine and sine functions.
50:	Sets up first loop for I waveform points.
60:	Calculate and interleave I waveform points.
70:	End of loop
80	Sets up second loop for Q waveform points.
90:	Calculate and interleave Q waveform points.

Program Comments (Continued)

100:	End of loop.
120:	Calculates number of bytes in I/Q waveform.
130:	Opens an I/O path to the signal generator using GPIB. 7 is the address of the GPIB card in the computer, and 19 is the address of the signal generator. This I/O path is used to send ASCII data to the signal generator.
140:	Opens an I/O path for sending binary data to the signal generator.
150:	Creates an ASCII string representation of the number of bytes in the waveform.
160 to 170:	Finds the number of digits in Nbytes.
190:	Sends the first part of the SCPI command, MEM:DATA along with the name of the file, `data_file`, that will receive the waveform data. The name, `data_file,` will appear in the signal generator's memory catalog.
200 to 210:	Sends the rest of the ASCII header.
230:	Sends the binary data. Note that `ESGb` is the binary I/O path.
240:	Sends an End-of-Line to terminate the transmission.
250 to 260:	Closes the connections to the signal generator.
290:	End the program.

Downloading Waveform Data Using HP BASIC for UNIX

On the signal generator's documentation CD, this programming example's name is "*hpbasicUx.txt*."

The following program shows you how to download waveforms using HP Basic for UNIX. The code is similar to that shown for HP BASIC for Windows, but there is a formatting difference in line 130 and line 140.

To download into non-volatile memory, replace line 190 with:

190 OUTPUT @ESG USING "#,K";":MMEM:DATA ""NVWFM:testfile"", #"

As discussed at the beginning of this section, I and Q waveform data is interleaved into one file in 2's compliment form and a marker file is associated with this I/Q waveform file.

In the `Output` commands, `USING "#,K"` formats the data. The pound symbol (#) suppresses the automatic EOL (End of Line) output. This allows multiple output commands to be concatenated as if they were a single output. The "K" instructs HP BASIC to output the following numbers or strings in the default format.

```
10 !  RE-SAVE "UNIX_file"
20    Num_points=200
30    ALLOCATE INTEGER Int_array(1:Num_points*2)
40    DEG
50    FOR I=1 TO Num_points*2 STEP 2
60      Int_array(I)=INT(32767*(SIN(I*360/Num_points)))
70    NEXT I
80    FOR I=2 TO Num_points*2 STEP 2
90      Int_array(I)=INT(32767*(COS(I*360/Num_points)))
100   NEXT I
110   PRINT "Data generated "
120   Nbytes=4*Num_points
130   ASSIGN @Esg TO 719;FORMAT ON
140   ASSIGN @Esgb TO 719;FORMAT OFF
150   Nbytes$=VAL$(Nbytes)
160   Ndigits=LEN(Nbytes$)
170   Ndigits$=VAL$(Ndigits)
180   WAIT 1
190   OUTPUT @Esg USING "#,K";":MMEM:DATA ""WFM1:data_file"",#"
200   OUTPUT @Esg USING "#,K";Ndigits$
```

```
210   OUTPUT @Esg USING "#,K";Nbytes$
220   WAIT 1
230   OUTPUT @Esgb;Int_array(*)
240   WAIT 2
241   OUTPUT @Esg;END
250   ASSIGN @Esg TO *
260   ASSIGN @Esgb TO *
270   PRINT
280   PRINT "*END*"
290   END
```

Program Comments

10:	Program file name
20:	Sets the number of points in the waveform.
30:	Allocates integer data array for I and Q waveform points.
40:	Sets HP BASIC to use degrees for cosine and sine functions.
50:	Sets up first loop for I waveform points.
60:	Calculate and interleave I waveform points.
70:	End of loop
80	Sets up second loop for Q waveform points.
90:	Calculate and interleave Q waveform points.
100:	End of loop.
120:	Calculates number of bytes in I/Q waveform.
130:	Opens an I/O path to the signal generator using GPIB. 7 is the address of the GPIB card in the computer, and 19 is the address of the signal generator. This I/O path is used to send ASCII data to the signal generator.
140:	Opens an I/O path for sending binary data to the signal generator.
150:	Creates an ASCII string representation of the number of bytes in the waveform.
160 to 170:	Finds the number of digits in Nbytes.

Program Comments (Continued)

190:	Sends the first part of the SCPI command, MEM:DATA along with the name of the file, `data_file`, that will receive the waveform data. The name, `data_file,` will appear in the signal generator's memory catalog.
200 to 210:	Sends the rest of the ASCII header.
230:	Sends the binary data. Note that `ESGb` is the binary I/O path.
240:	Sends an End-of-Line to terminate the transmission.
250 to 260:	Closes the connections to the signal generator.
290:	End the program.

Downloading E443xB Waveform Data Using HP BASIC for Windows

On the signal generator's documentation CD, this programming example's name is "*hpbasicWin2.txt*."

The following program shows you how to download waveforms using HP Basic for Windows into volatile ARB memory. This program is similar to the following program example as well as the previous examples. The difference between BASIC for UNIX and BASIC for Windows is the way the formatting, for the most significant bit (MSB) on lines 110 and 120, is handled.

To download into non-volatile ARB memory, replace line 80 with:

160 OUTPUT @ESG USING "#,K";":MMEM:DATA ""NVARBI:testfile"", #"

and replace line 130 with:

210 OUTPUT @ESG USING "#,K";":MMEM:DATA ""NVARBQ:testfile"", #"

First, the I waveform data is put into an array of integers called `Iwfm_data` and the Q waveform data is put into an array of integers called Qwfm_data. The variable `Nbytes` is set to equal the number of bytes in the I waveform data. This should be twice the number of integers in `Iwfm_data`, since an integer is 2 bytes. Input integers must be between 0 and 16383.

In the `Output` commands, `USING "#,K"` formats the data. The pound symbol (#) suppresses the automatic EOL (End of Line) output. This allows multiple output commands to be concatenated as if they were a single output. The `"K"` instructs HP Basic to output the following numbers or strings in the default format.

```
10    ! RE-SAVE "ARB_IQ_Win_file"
20    Num_points=200
30    ALLOCATE INTEGER Iwfm_data(1:Num_points),Qwfm_data(1:Num_points)
40    DEG
50    FOR I=1 TO Num_points
60      Iwfm_data(I)=INT(8191*(SIN(I*360/Num_points))+8192)
70      Qwfm_data(I)=INT(8191*(COS(I*360/Num_points))+8192)
80    NEXT I
90    PRINT "Data Generated"
100   Nbytes=2*Num_points
110   ASSIGN @Esg TO 719
120   !ASSIGN @Esgb TO 719;FORMAT MSB FIRST
130   Nbytes$=VAL$(Nbytes)
140   Ndigits=LEN(Nbytes$)
150   Ndigits$=VAL$(Ndigits)
160   OUTPUT @Esg USING "#,K";":MMEM:DATA ""ARBI:file_name_1"",#"
```

```
170   OUTPUT @Esg USING "#,K";Ndigits$
180   OUTPUT @Esg USING "#,K";Nbytes$
190   OUTPUT @Esgb;Iwfm_data(*)
200   OUTPUT @Esg;END
210   OUTPUT @Esg USING "#,K";":MMEM:DATA ""ARBQ:file_name_1"",#"
220   OUTPUT @Esg USING "#,K";Ndigits$
230   OUTPUT @Esg USING "#,K";Nbytes$
240   OUTPUT @Esgb;Qwfm_data(*)
250   OUTPUT @Esg;END
260   ASSIGN @Esg TO *
270   ASSIGN @Esgb TO *
280   PRINT
290   PRINT "*END*"
300   END
```

Program Comments

10:	Program file name.
20	Sets the number of points in the waveform.
30:	Defines arrays for I and Q waveform points. Sets them to be integer arrays.
40:	Sets HP BASIC to use degrees for cosine and sine functions.
50:	Sets up loop to calculate waveform points.
60:	Calculates I waveform points.
70:	Calculates Q waveform points.
80:	End of loop.
160 and 210:	The I and Q waveform files have the same name
90 to 300:	See the table on page 89 for program comments.

Downloading E443xB Waveform Data Using HP Basic for UNIX

On the signal generator's documentation CD, this programming example's name is "*hpbasicUx2.txt*."

The following program shows you how to download waveforms using HP BASIC for UNIX. It is similar to the previous program example. The difference is the way the formatting for the most significant bit (MSB) on lines is handled.

First, the I waveform data is put into an array of integers called `Iwfm_data` and the Q waveform data is put into an array of integers called `Qwfm_data`. The variable `Nbytes` is set to equal the number of bytes in the I waveform data. This should be twice the number of integers in `Iwfm_data`, since an integer is represented 2 bytes. Input integers must be between 0 and 16383.

In the `Output` commands, `USING "#,K"` formats the data. The pound symbol (#) suppresses the automatic EOL (End of Line) output. This allows multiple output commands to be concatenated as if they were a single output. The "K" instructs HP BASIC to output the following numbers or strings in the default format.

```
10    ! RE-SAVE "ARB_IQ_file"
20    Num_points=200
30    ALLOCATE INTEGER Iwfm_data(1:Num_points),Qwfm_data(1:Num_points)
40    DEG
50    FOR I=1 TO Num_points
60      Iwfm_data(I)=INT(8191*(SIN(I*360/Num_points))+8192)
70      Qwfm_data(I)=INT(8191*(COS(I*360/Num_points))+8192)
80    NEXT I
90    PRINT "Data Generated"
100   Nbytes=2*Num_points
110   ASSIGN @Esg TO 719;FORMAT ON
120   ASSIGN @Esgb TO 719;FORMAT OFF
130   Nbytes$=VAL$(Nbytes)
140   Ndigits=LEN(Nbytes$)
150   Ndigits$=VAL$(Ndigits)
160   OUTPUT @Esg USING "#,K";":MMEM:DATA ""ARBI:file_name_1"",#"
170   OUTPUT @Esg USING "#,K";Ndigits$
180   OUTPUT @Esg USING "#,K";Nbytes$
190   OUTPUT @Esgb;Iwfm_data(*)
200   OUTPUT @Esg;END
210   OUTPUT @Esg USING "#,K";":MMEM:DATA ""ARBQ:file_name_1"",#"
```

```
220   OUTPUT @Esg USING "#,K";Ndigits$
230   OUTPUT @Esg USING "#,K";Nbytes$
240   OUTPUT @Esgb;Qwfm_data(*)
250   OUTPUT @Esg;END
260   ASSIGN @Esg TO *
270   ASSIGN @Esgb TO *
280   PRINT
290   PRINT "*END*"
300   END
```

Program Comments

10:	Program file name.
20	Sets the number of points in the waveform.
30:	Defines arrays for I and Q waveform points. Sets them to be integer arrays.
40:	Sets HP BASIC to use degrees for cosine and sine functions.
50:	Sets up loop to calculate waveform points.
60:	Calculates I waveform points.
70:	Calculates Q waveform points.
80:	End of loop.
160 and 210:	The I and Q waveform files have the same name
90 to 300	See the table on page 92 for program comments.

Troubleshooting Waveform Files

Symptom	Possible Cause
ERROR 224, Text file busy	Attempting to download a waveform that has the same name as the waveform currently being played by the signal generator. To solve the problem, either change the name of the waveform being downloaded or turn off the ARB.
ERROR 628, DAC over range	The amplitude of the signal exceeds the DAC input range. The typical causes are unforeseen overshoot (DAC values within range) or the input values exceed the DAC range. To solve the problem, scale or reduce the DAC input values. For more information, see "DAC Input Values" on page 7.
ERROR 629, File format invalid	The signal generator requires a minimum of 60 samples to build a waveform and the same number of I and Q data points.
ERROR -321, Out of memory	There is not enough space in the ARB memory for the waveform file being downloaded. To solve the problem, either reduce the file size of the waveform file or delete unnecessary files from ARB memory.
No RF Output	The marker RF blanking function may be active. To check for and turn RF blanking off, press **Mode** > **Dual ARB** > **ARB Setup** > **Marker Utilities** > **Marker Routing** > **Pulse / RF Blank** > **None**. This problem occurs when the file header contains unspecified settings and a previously played waveform used the marker RF blanking function. For more information on the marker functions, see the *User's Guide*.
Undesired output signal	Check for the following: • The data was downloaded in little endian order. See "Little Endian and Big Endian (Byte Order)" on page 5 for more information. • The waveform contains an odd number of samples. An odd number of samples can cause waveform discontinuity. See "Waveform Phase Continuity" on page 14 for more information.

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