

Keysight Technologies

Transferring Arbitrary Waveform Data to the 33200A Family of Function/Arbitrary Waveform Generators

Application Note



Introduction

Function Waveform Generators are used to simulate the signals on the input of a device. A speaker test might require a sweep through an audio band over several seconds, or a controller may need different pulse waveforms to simulate varying frequencies of a clock. However, real-world signals are not always perfect sine waves or pulses. It can be more useful to create a custom waveform or capture a real waveform, modify it and recreate the waveform with a function/arbitrary waveform generator. You may even have a complex waveform or a waveform file that was provided for you.

We will review three methods of transferring arbitrary waveform data to 33200A Function/Arbitrary Waveform Generators: front panel, Keysight Technologies, Inc. IntuiLink Waveform Editor, and programming.

Front Panel

The graphical interface on the 33210A, 33220A, and 33250A function/arbitrary waveform generators provides a simple method to create basic arbitrary waveforms. The front panel method works best on waveforms that are comprised of a few linear segments. Complex waveforms, waveforms having many segments, or waveforms with curves are better suited for download using the free IntuiLink Waveform Editor software or another application.

For this example, we will use the front panel interface to create and store a modified ramp waveform comprised of four linear segments (Figure 1).

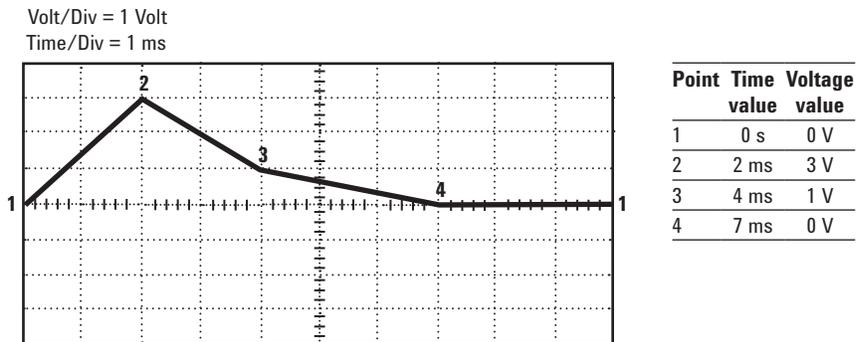


Figure 1

1. Select the arbitrary waveform function.



When you press to select the arbitrary function, a temporary message is displayed indicating which waveform is currently selected.

2. Start the arbitrary waveform editor. Press the **Edit Wform** softkey, then press the **Create New** softkey to edit the waveform. While in the waveform editor, you define the waveform by specifying time and voltage values for each point in the waveform. When creating a new waveform, the previous waveform in volatile memory is overwritten.

3. Set the waveform period. Press the **Cycle Period** softkey to set the time boundaries for the waveform. The time value of the last point that can be defined in the waveform must be less than the specified cycle period. *For this example, set the period of the waveform to 10 ms.*

4. Set the waveform voltage limits. Press the **High V Limit** and **Low V Limit** softkeys to set the upper and lower voltage levels that can be reached while editing the waveform. The upper limit must be greater than the lower limit. By default, Point #1 is set equal to the upper limit and Point #2 is set equal to the lower limit. *For this example, set the upper limit to 3.0 V and the lower limit to 0 V.*

5. Select whether or not to use linear interpolation.

Press the **Interp** softkey to enable or disable linear interpolation between waveform points (this feature is available from the front panel only). With interpolation enabled (default), the waveform editor makes a straight-line connection between points. With interpolation disabled, the waveform editor maintains a constant voltage level between points and creates a "step-like" waveform. *For this example, turn on linear interpolation.*

6. Set the initial number of waveform points. The waveform editor initially builds a waveform with two points and automatically connects the last point of the waveform to the voltage level of the first point to create a continuous waveform. Press the **Init # Points** softkey to specify the initial number of waveform points (you can add or remove points later if necessary). For this example, set the initial number of points to "4."

7. Start the point-by-point editing process. Press the **Edit Points** softkey to accept the initial waveform settings and begin point-by-point editing. The status line at the top of the display window shows the point number at the left, the time value of the current point in the center, and the voltage value of the current point to the right.

8. Define the first waveform point. Press the **Voltage** softkey to set the voltage level for **Point #1** (this point is fixed at a time of 0 seconds). By default, Point #1 is set equal to the upper limit. *For this example, set the voltage level of Point #1 to 0 V. The waveform editor performs all amplitude calculations using V_{pp} , rather than V_{rms} or dBm.*

9. Define the next waveform point. Press the **Point #** softkey and then turn the knob to move to Point #2. Press the **Time** softkey to set the time for the current point (this softkey is not available for Point #1). Press the **Voltage** softkey to set the voltage level for the current point. *For this example, set the time to 2 ms and the voltage level to 3.0 V.*

10. Define the remaining waveform points. Using the **Time** and **Voltage** softkeys, define the remaining waveform points using the values shown in the table. Some helpful tips:

- The time value of the last point that can be defined in the waveform must be less than the specified cycle period.
- The time value of a point must be between the neighboring points. Points are kept in sequential order when adjusted.
- The waveform editor automatically connects the last waveform point to the voltage level of first point to create a continuous waveform.
- To insert additional points after the current waveform point, press the **Insert Point** softkey. The new point is inserted midway between the current point and the next defined point.
- To remove the current waveform point, press the **Remove Point** softkey. The remaining points are joined using the interpolation method currently selected. You cannot remove Point #1 since the waveform must have a defined initial value.

Keysight IntuiLink Waveform Editor

11. Store the arbitrary waveform in memory. Press the **End/Store** softkey to store the new waveform in memory. Then press the **DONE** softkey to store the waveform in volatile memory or press the **Store in Non-Vol** softkey to store the waveform in one of four non-volatile memory locations. You can assign a custom name to the four non-volatile memory locations:

- The custom name can contain up to 12 characters. The first character must be a letter but the remaining characters can be letters, numbers, or the underscore character (“_”).
- To add additional characters, press the right-cursor key until the cursor is to the right of the existing name and then turn the knob.
- To delete all characters to the right of the cursor, press the key.

*For this example, assign the name “RAMP_NEW” to memory location 1 and then press the **STORE ARB** softkey to store the waveform.*

The waveform is now stored in non-volatile memory and is currently being output from the function generator. The name that you used to store the waveform should now appear in the list of stored waveforms (under the **Stored Wform** softkey).

For simple arbitrary waveforms comprised of a few linear segments, the graphical user interface may be used. For more complex arbitrary waveforms, a software application is recommended.

The Keysight IntuiLink Waveform Editor is a powerful stand-alone application for creating and editing arbitrary waveforms. Waveform data can be imported from a file or captured using an oscilloscope then edited to optimize your waveform. The IntuiLink Waveform Editor is free, and can be downloaded from Keysight’s website at www.keysight.com/find/IntuiLink.

Create waveforms graphically

To create an arbitrary waveform from scratch with IntuiLink, open a new file using the menu or the icon on the standard toolbar. The file menu will also allow you to modify the defaults for new waveforms, including the default number of points and whether to use a fixed number of points or automatically readjust to number of points needed for the waveform (Figure 2).

To insert a standard waveform segment, click one of the icons on the waveform toolbar to insert a

2000-point segment with the default parameters. Double-clicking the segment will open up the parameters window where you can change the parameters. You can also use the Segment Parameters dialog box in the edit menu to insert new waveform segments.

You can also draw freehand waveforms using the mouse. When you select **Freehand** in the edit menu or the freehand icon in the waveform toolbar, the cursor changes to a pencil when inside the waveform edit window. Click and drag with the mouse to draw the desired shape, then release the mouse button when finished. Freehand segments are automatically connected to any pre-existing waveform segments. To exit the freehand mode, deselect the freehand icon on the waveform toolbar or the freehand option in the edit menu.

Opening waveform files

IntuiLink Waveform Editor makes it easy to select and open supported data file types. You can save and open IntuiLink Waveform Editor files (.wvf). You can also open file formats such as Comma Separated Values (.csv) or Text (.txt) which may be helpful when importing data from applications such as Microsoft Excel.

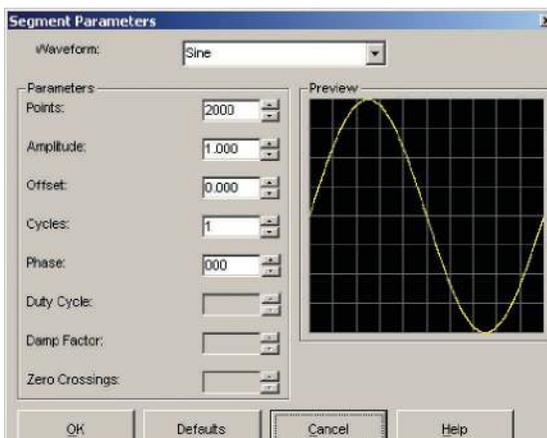


Figure 2

Resizing waveform data

You can resize the waveform data to compress or expand the selected waveform or segment both horizontally and vertically. To resize the waveform data, the waveform or segment must be selected. To select the entire waveform, right click and choose "Select All." From the math menu, select Resize to display the resize dialog box.

- To expand or compress a segment horizontally, specify a value for Number of Points under X Points. Number of Points can take any value from 8 points to the width of the waveform edit window. The window width can be set from the Properties dialog box up to 65,536 points.
- To expand or compress a segment vertically, specify a value for Percent of Original Data under Y Amplitude. You can specify any percentage value. However, if you expand the waveform or segment beyond the vertical window size, the waveform data will be clipped.

Math menu

- You can use the Waveform Math dialog box to perform addition, subtraction, and multiplication operations on the selected waveform or segment. The math menu also provides additional features:
 - **Clip:** Clips the selected waveform data to the vertical (Y) values as specified by the markers.
 - **Absolute:** Creates a waveform with only positive-value points by inverting any points with negative values.
 - **Filter:** Applies a Low Pass or Smoothing filter to the selected waveform data. The Low Pass filter is a FIR digital filter with a pass-band and stop-band ripple of less than 1% and attenuates components above the cutoff point.

The Smoothing filter is a moving average of the points in the waveform.

- **Windowing:** Multiplies waveform data point-by-point by a corresponding point in the window. Three window functions are provided: Extended Cosine, Raised Cosine, and Hamming.
- **Invert:** Flips the selected waveform or segment vertically.
- **Mirror:** Rotates the selected waveform or segment horizontally.

The Waveform Math dialog box allows you to perform a math operation on two waveforms. The first waveform is the selected waveform or segment selected in the active window. The second waveform is either a standard waveform or a waveform that has been copied to the clipboard.

For example, use the Segment Parameters dialog box to create 10 cycles of a sine wave and then select the entire waveform. From the Math menu, select "multiplication" to open the Waveform Math dialog box. (If you wish to perform addition or subtraction instead, you can either select these options in the Math menu or use the drop-down list in the Waveform Math dialog box.) (Figure 3).

Under "Select Segment," you can choose clipboard (if a waveform has been stored to the clipboard) or use the drop-down list to select a standard waveform. The Waveform Math dialog box will show a preview of the waveform. Select "Scale to Fit" to resize the waveform so that all points are resized to fit within the window, or deselect the option to clip any points of the waveform that exceed the window (Figure 4).

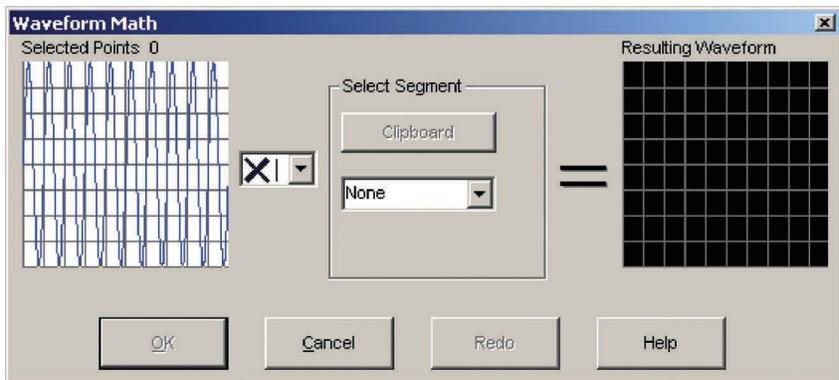


Figure 3

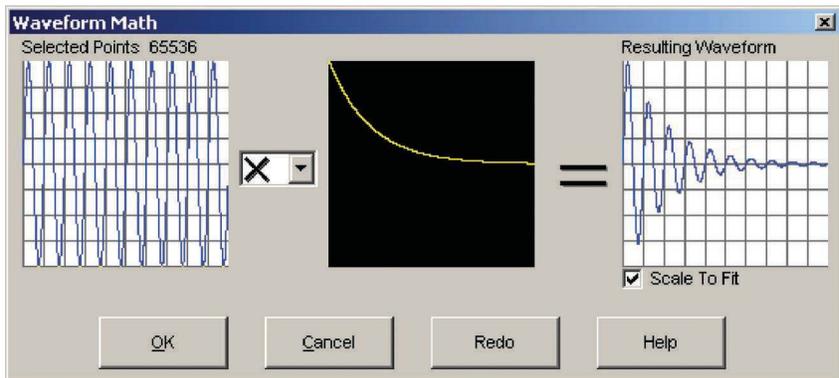


Figure 4

Transfer waveform data to the function generator

Once you have prepared the waveform that you want to send, establish a connection to the function generator in the Communications menu. Once a connection has been established, select “Send Waveform” from the Communications menu to launch the Send Arbitrary Waveform dialog box (Figure 5).

Select the desired waveform parameters and select “Send” to download the arbitrary waveform into volatile memory. To use the existing parameters from the instrument, select “Current from Instrument” and press “Reset” before sending the waveform.

The Manage Waveforms tab is used if you wish to store the waveform into non-volatile memory. A total of four user-defined arbitrary waveforms may be stored. To store the arbitrary waveform in non-volatile memory, check the Manage Waveforms tab to be sure there is space (you can delete a waveform if needed). From the Send Waveform tab, select “Memory Name” and select a custom name (up to 12 characters). When the

waveform is sent to the instrument, it will be stored in non-volatile memory and the name will appear on the Manage Waveforms tab.

Add-ins

The capabilities of the IntuiLink Waveform Editor may be expanded by including additional modules, or add-ins. Add-ins for pulse creation, filtering and using equations may be found on the IntuiLink home page at www.keysight.com/find/IntuiLink. You can also create your own tools by creating an ActiveX DLL and copying it into the Tools folder. IntuiLink contains help and examples for creating your own tools.

Capturing waveforms

IntuiLink Waveform Editor can create arbitrary waveforms from waveform data captured using an oscilloscope. Many oscilloscopes will save waveform data in a .csv or .txt file, which can then be opened using IntuiLink Waveform Editor. You can also import data directly from an oscilloscope using IntuiLink from the Tools menu. If your oscilloscope is not listed, you may need to install or create an add-

in. Add-ins for Keysight oscilloscopes can also be found on the IntuiLink home page.

When importing waveform data from an oscilloscope, IntuiLink Waveform Editor can help you edit the waveform before sending it to the waveform generator for the best results:

- Remove unnecessary data using the cut feature from the edit menu and trim the captured waveform to an integral number of cycles
- Edit points at the beginning and end of the waveform to minimize discontinuities
- Resize the waveform data to take advantage of the full vertical resolution and memory depth available in the function/arbitrary waveform generator
- Use math functions to add noise, spurs, ringing, or other impurities to your waveform
- Filter the waveform data to smooth out unwanted noise or remove high frequency components

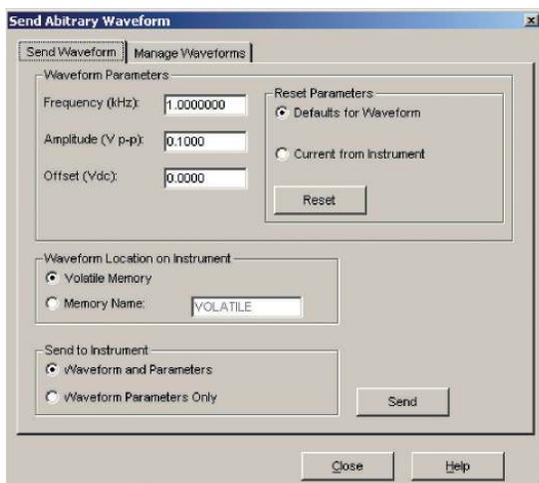


Figure 5

Programming

If you are using an external application to control your instruments, you may wish to transfer arbitrary waveform data and control the generator using Standard Commands for Programmable Instruments (SCPI).

Waveform data can be transferred to the generator as either floating-point values or as binary or decimal integer values.

Floating-point values

Downloading floating-point values between -1 and +1 is slower than using binary values, but is a more convenient method for most programmers. The values -1 and +1 correspond to the peak values of the waveform. For example, if you set the amplitude to 10 Vpp (0 V offset) the value "+1" will correspond to +5 V and "-1" corresponds to -5 V.

The SCPI command is

```
DATA VOLATILE, <value>,
<value>, ...
```

To download 7 points into volatile memory:

```
DATA VOLATILE, 1, .67, .33, 0,
-.33, -.67, -1
```

Binary block format

Using the IEEE-488.2 binary block format allows for the fastest transfer speeds. The values values -8191 and +8191 correspond to the peak values of the waveform for the 33210A and 33220A, and -2047 and +2047 for the 33250A. For example, if you set the amplitude to 10 Vpp (0 V offset) the value "+8191" (or +2047) will correspond to +5 V and "-8191" (or -2047) corresponds to -5 V.

The SCPI command is

```
DATA:DAC VOLATILE, <binary
block>
```

In the IEEE-488.2 binary block format, a block header precedes the waveform data. See the User's Guide for more information.

Storing waveforms in non-volatile memory

Whether using floating-point values or the binary block format, the waveform is initially loaded into volatile memory and will be lost when power is cycled to the instrument. Up to four user-defined waveforms may be stored in non-volatile memory. To copy the waveform from volatile memory into non-volatile memory, use the command:

```
DATA:COPY <arb name>
```

The arb name may contain up to 12 characters.

Programming examples

Programming examples may be found in the User's Guide and on the product web pages on Keysight's web site www.keysight.com. If you have installed Keysight's IntuiLink Waveform Editor, examples can also be found in the "Examples" folder.

Example

Waveform data can come from a variety of sources: pre-defined waveform files, data from software applications, or data captured using an oscilloscope, data logger or digitizer. We have mentioned using IntuiLink Waveform Editor to open files using .csv or .txt file formats, and how to download data using programming. Now we will walk through an example of taking waveform data from Microsoft Excel and transfer it to the waveform generator using IntuiLink Waveform Editor and Visual Basic for Applications (VBA).

Example: Formatting data in Excel

Whether your data has come from a file, a software application, or measurement data, it can typically be saved or converted into a common file format. Two common formats for data files are comma-separated values (.csv) and text (.txt).

The comma-separated values file format uses the comma as the delimiter between columns, and a carriage-return/line-feed to terminate each row. Because .csv files use a comma as a delimiter, it only supports the US English number format where periods are used as decimal points.

The text file format places all data in a single column, with a carriage-return/line-feed after each value. If you read a .txt file in Microsoft Excel, the data points will be in column A.

This format can be used in cases where a comma is used as a decimal point.

Whether you use the .csv or .txt file format, the data points for each waveform should appear in a single column with the carriage-return/line-feed after each value (Figure 6).

When transferring floating-point values into the function generator, the values -1 and +1 correspond to the peak values of the waveform. To verify in Excel that all data points fit between these limits, you can use the functions “=max(A:A)” and “=min(A:A)” to find the maximum and minimum values, respectively.

Example: Excel & IntuiLink

Once you have your data formatted into a single column, you can use Microsoft Excel to save the data in either the .csv or .txt formats. Select “Save As” in the file menu and use the “Save as type” list to select either CSV (Comma delimited) or Text (MS-DOS). In either of these formats, Excel will only save the active sheet. If you have additional data on other tabs, be sure to also save a copy of the file as an Excel workbook to preserve your data and formatting.

To open the data file using Keysight’s IntuiLink Waveform Editor, select “Open...” in the file menu. IntuiLink will default to all file types, or you can filter your search to only look for .csv or .txt files using the “Files of type:” list. IntuiLink will open the data file and graphically display the waveform.

You can now use IntuiLink to resize the waveform data to take full advantage of the vertical and horizontal resolution of the function generator. You can also use all the math functions IntuiLink provides.

Now that your waveform is ready for download, you can establish a connection to the function generator and send your waveform. Refer to the earlier section “Transfer waveform data to the function generator.”

Example: Excel & VBA

Visual Basic for Applications (VBA) is built into most Microsoft Office applications, including Excel. You can use VBA and the instrument’s SCPI commands to transfer the waveform data (Figure 7).

To begin programming, select the “Visual Basic” toolbar from the View > Toolbars menu. Select the “Design Mode” icon to create the button that will be used to begin your program.

Click the “Control Toolbox” icon to open a window of control choices and select the command button. Your mouse will change to a crosshairs and you can click where you would like to place the button.

Right-click on the button to modify the properties. The “Caption” property is the text that appears on the button. You can change this to something more meaningful, such as “Start” or “Download Waveform.”

To begin editing your program, double-click on the button. This will open the window for Microsoft Visual Basic where you can begin programming the commands you wish to execute when the button is clicked.

	A	B	C	D
1	2.65E-04			
2	3.49E-04			
3	4.33E-04			
4	5.18E-04			
5	6.02E-04			
6	6.86E-04			
7	7.70E-04			
8	8.54E-04			

Figure 6

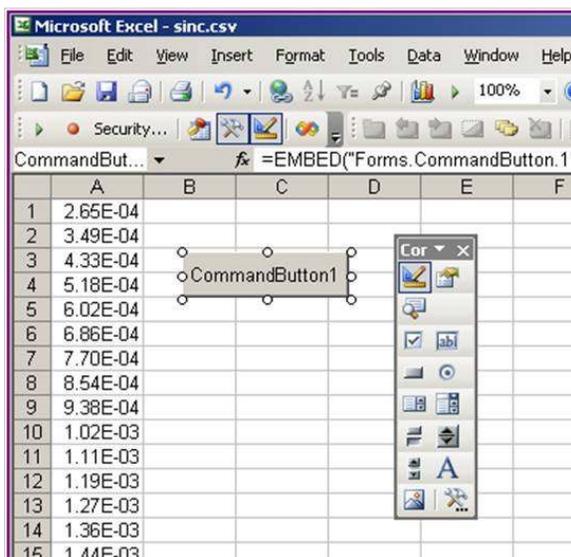


Figure 7

We will use the DATA VOLATILE, <value>, <value>, ... command to download the waveform data as a long string of values. You can use the following commands to convert the waveform values into a long variable strData, use this routine:

```

Dim rng As Range
Dim dblTemp As Double
Dim strTemp As String
Dim strData as String
Dim rowCount As Long
Dim i As Long
Set rng = Range("A1:A8192")           ' Location of waveform data
rowCount = rng.Rows.Count           ' The number of rows (points)

For i = 1 To rowCount - 1           ' For each row...
    dblTemp = rng.Cells(i, 1)       ' Save data in column 1 as dblTemp
    strTemp = Format$(dblTemp, "0.000E+0") ' Convert number to a string
                                        ' Very long string of waveform values
                                        ' separated by commas
    strData = strData & strTemp & "," ' Create string
Next i

dblTemp = rng.Cells(i, 1)           ' For the last row...
strTemp = Format$(dblTemp, "0.000E+0")
strData = strData & strTemp         ' No comma after the last value

```

The actual commands you will use to establish a connection and transfer the data to the function generator will depend on the IO interface, libraries, and drivers you wish to use. Programming examples using VBA with Excel can be found on the product pages at Keysight's web site www.keysight.com. If you have installed Keysight's IntuiLink Waveform Editor, examples can also be found in the "Examples" folder.

If using Keysight VISA COM to download the waveform, your commands may look something like this:

```

' Establish IO connection to the generator
' Set the reference to include the libraries in the Tools/References menu
' VISA COM requires a COM reference to the VISA COM x.x Type library
' and to VISA COM 488.2 Formatted I/O
Dim io_mgr As VisaComLib.ResourceManager
Dim Fgen As VisaComLib.FormattedIO488
Dim session As VisaComLib.IMessage

Set io_mgr = New KeysightRMLib.SRMCLs
Set Fgen = New VisaComLib.FormattedIO488
Set Fgen.IO = io_mgr.Open("GPIB::10") ' Instrument address

With Fgen
    ' set timeout large enough to send all data in the long download string
    .IO.Timeout = 40000                ' Set timeout to 40 seconds

    .WriteString "**RST"                ' Reset the function generator
    .WriteString "Data Volatile, " & strData ' Download data points to volatile
    .WriteString "Data:Copy Sinx, Volatile" ' Copy arb to non-volatile memory

    .WriteString "Function:User Sinx"    ' Select the active arb waveform
    .WriteString "Function:Shape User"   ' Output selected arb waveform
    .WriteString "Output:Load 50"        ' Output termination is 50 ohms
    .WriteString "Frequency 5000; Voltage 5" ' Output frequency is 5 kHz @ 5 Vpp
    .WriteString "OUTPut ON"            ' Enable output
End With

```

Summary

Creating, editing, and downloading arbitrary waveforms allows you to generate a wider variety of waveforms than can be done with a basic function generator. We have reviewed three methods of creating arbitrary waveforms, and how Keysight's IntuiLink Waveform Editor software provides the editing and data transfer tools to simplify the process.

- **Front Panel** used for basic arbitrary waveforms comprised of a few linear segments
- **Keysight IntuiLink Waveform Editor** a standalone application that provides an easy way to create waveforms or import and edit existing waveform data before transferring the data to the generator
- **Programming** uses an external application to send SCPI commands to the generator



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