Application Note

December 9, 2009 | MS-21-09.12.09-A

Defining and Generating Arbitrary Waveforms Using Fluke 294 Arbitrary Waveform Generator

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Scope

This application note describes how to use software installed on a Personal Computer (PC) to define arbitrary waveforms and then download the wave data to an arbitrary waveform generator (AWG) to generate the desired waveforms. The application is developed using NI Labview. The instrument used in this application is a Fluke 294 Four Channel Signal Generator.

The target audiences are students and researchers who are interested in generation of arbitrary wave forms.

Background

A complete measurement solution requires two components: a signal generator and an acquisition instrument, such as an oscilloscope, or a Spectrum analyzer. For many applications, standard waveforms such as sine and square waveforms may not be sufficient to provide a stimulus that can test a device under test (DUT) across a full range of operating conditions. A variety of stimuli may be required.

However, generating an arbitrary waveform can be a time-consuming and tedious process if using the front panel of an instrument, which also gives opportunity for mistakes. To resolve this problem, a more advanced method, which consists of the following three steps, can be used:

1. Define parameters of a wave using a software package installed on a PC
2. Verify the wave shape to ensure it meets the test requirements.
3. Download the wave shape to an AWG via available interface such as USB, RS232 or GPIB, to generate the required waveform.

Defining a Waveform

A software defined waveform can be realized in many ways:

- Formula based waveforms
- Drawing line segments
- Loading signal from an oscilloscope
- Combining existing waveforms [2]

A variety of software packages are available to perform the above tasks: NI Labview, Matlab, Mathcad, and Excel. It is important that the data is properly formatted so that it can be correctly interpreted by a generator firmware. The formatting task usually involves scaling of point values of a wave so they take full advantage of the resolution of an instrument. For example, Fluke 294 has a resolution of 12-bit in amplitude definition. Therefore, wave point values must be scaled to between -2048 and +2047 [3]. The scaled values need to be sent to the memory of an instrument. It requires the instrument to be connected to the host PC via one of the available interfaces: USB, RS232, or GPIB. The libraries to handle these interfaces are available for NI Labview, Matlab, and Microsoft Visual Studio.

This application note demonstrates two methods to define arbitrary wave shapes: using the NI Labview built-in functions **Arbitrary Waveform.vi**, and Excel spread sheet. The examples are developed using NI Labview and the host PC is connected to Fluke 294 via USB. The provided software can be used as is or can be a starting point to develop custom applications. The latter requires some knowledge of NI Labview programming.

Arbitrary Waveform Generator

An AWG can provide standard wave shapes such as sine, square, and triangle. You can also use an AWG to add, subtract, and multiply two or more waveforms, superimpose noise, generate formula based waveforms, and replicate real world signals by means of synthesizing signals previously captured on an oscilloscope [1].

In this application, the Fluke 294 AWG is used. Relevant specifications of this equipment are:

- Four signal channels
- The amplitude is between -2048 and +2047 (12 bits), which corresponds to a maximum swing of programmed values
- Maximum clock rate for arbitrary waves is 100 MHz
- Horizontal size of a wave is 8 to 1,048,576 samples per channel
- To perform arbitrary function generation, a supplied flash card has to be plugged in the signal generator [3].

For more details, refer to the Fluke 294 User Manual [3].

Application Description

System Hardware

The system to generate the wave shapes consist of a host PC (Lenovo Think Station), a Fluke 294 AWG, and a Tektronix DPO4054 oscilloscope. The setup is as shown in Figure 1.

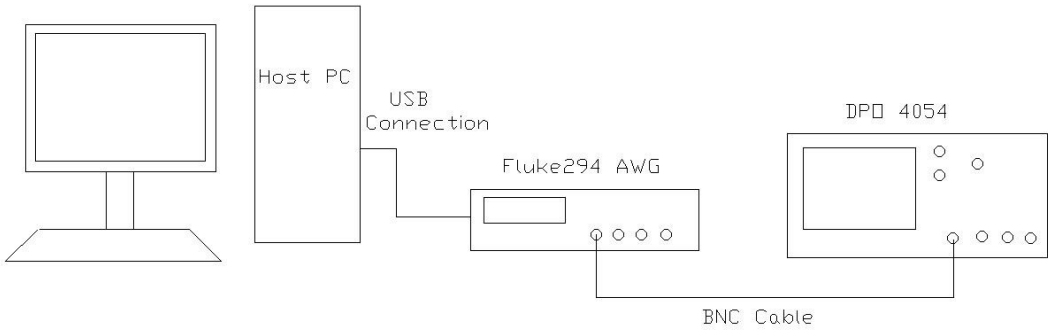

Figure 1: Experimental Setup for Waveforms Verification

Labview Program

In this application, two examples using different wave definition methods are shown. Both use the same basic programming architecture: the execution is controlled by a *While* loop, and the tasks are controlled by *Event* structure, as shown in Figure 2. The Events correspond to the front panel buttons on the GUI (see Figure 3). Clicking a given button constitutes an event and the event triggers a programmed action.

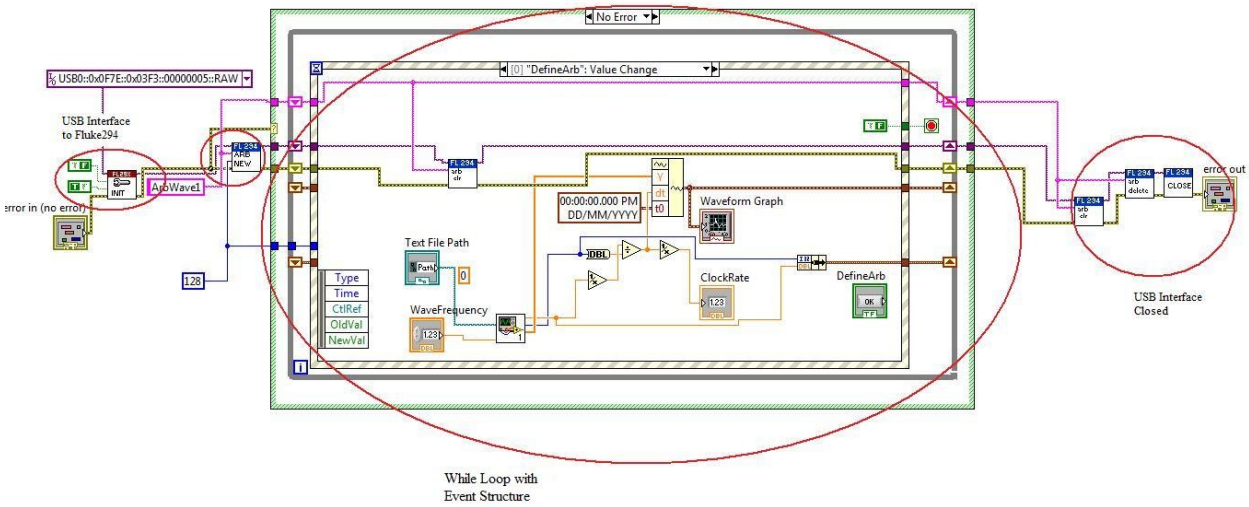

Figure 2: Architecture of Labview Code

The front panel of the GUI is shown in Figure 3. The buttons have the following functions:

- Define Arbitrary Waveform—loads a wave shape defining vi.
- Download to Fluke294—sends wave data—number of samples and clock rate to Fluke 294 via USB. In this application, number of samples is set to 128.
- Output ON—turns on the output of an active channel of Fluke 294. In this application, Channel 1 is used.
- Waveform Graph—shows the prototype of a synthesized wave.
- Stop—stops the application.

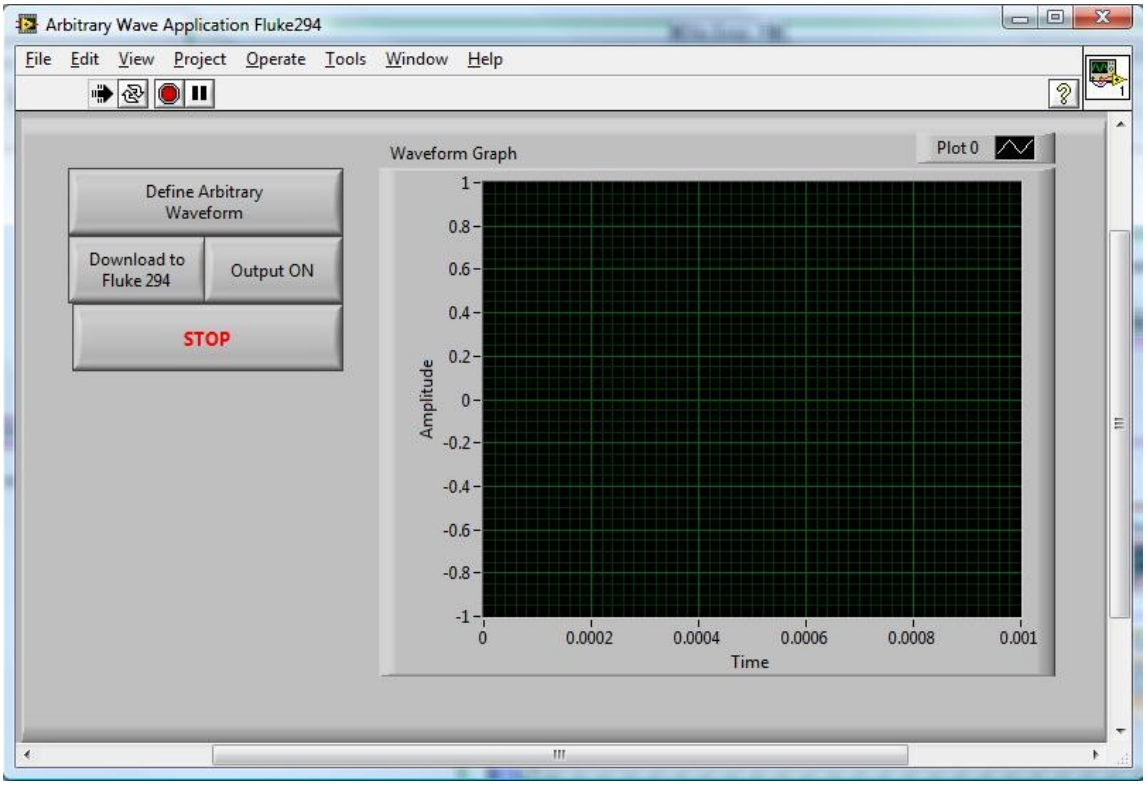

Figure 3: Front Panel When the Application Starts

The program starts with initialization of USB connection with the Fluke 294. The instrument is reset to a known state. Next, an empty arbitrary wave is created. At this point, the program is ready to perform tasks placed in the event structure: obtaining data, scaling and sending it to the Fluke 294. Lastly, the wave definition is erased from Fluke 294 memory and the USB interface is closed.

Wave Data Scaling

To ensure that the wave data is correctly interpreted by Fluke 294 firmware, the wave data must be scaled before sending to the signal generator. The software sub-component that performs this action is *ArbWaveWrite.vi*, as shown in Figure 4.

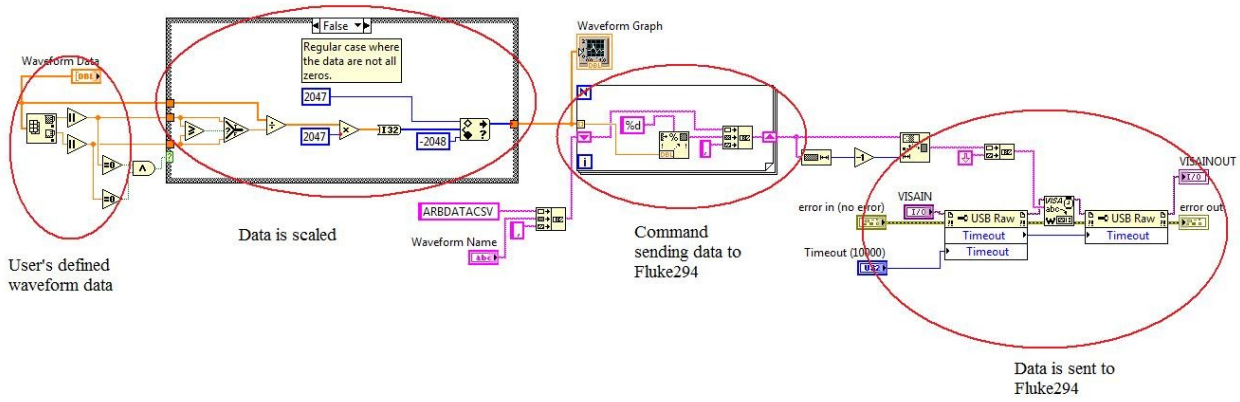

Figure 4: Sequence of Waveform Data Scaling and Sending to Fluke 294

User defined waveform data is an array of data points that comes either from *newwave.vi* or a *text file*. The data is then scaled so that its values are distributed between +2047 and -2048. Next, a command is built to include the scaled data, and then executed to sent the waveform data to the Fluke 294.

Required Equipment

Hardware:

- PC with USB port
- Fluke 294 AWG with 1 GB flash memory card, the generator can be obtained from CMC through Short Term Loan program. For more information, go to https://www1.cmc.ca/clients/test/test_loan.php. You can also contact CMC at test@cmc.ca.
- Tektronix DPO4054 oscilloscope
- USB cable
- BNC cable

Software:

- NI Labview code and the compiled executable, the software can be downloaded from https://www1.cmc.ca/clients/search/product-details.html?id=13109369.
- To further develop source code provided, NI Labview2009 is required.

Installing USB Driver for Fluke 294

Before running the application, the USB driver for Fluke 294 has to be installed on the host PC:

1. Unzip the downloaded file **Fluke294ArbWaveApp_zp.zip** to your working directory.
2. From the provided folder **Fluke294ArbWaveApps\USB_driver**, copy the file **USB_generic_vista.inf** to the folder **\inf** on the host PC. For example, in Windows, this path is usually the hidden directory **C:\Windows\inf.**
3. Right-click on the file **USB_generic_vista.inf** and click on **Install**.
   This step creates a *.pnf file for Fluke 294.

4. To install the Fluke 294 control application on the host PC, from the directory **Fluke294ArbWaveApps/ExcellApplication/My Installer/Volume**, double-click on the setup file **setup.exe**.
5. Plug in the Fluke 294 to the host PC.
   The **Add New Hardware Wizard** appears. Follow the on-screen instructions to install the instrument.

Installing Compiled Applications and NI Labview Source Code for Further Development (MEJ)

If you are running NI Labview 2009, copy the downloaded source code files from directory **Fluke294ArbWaveApps/LVSourceCode** to a designated directory, and then modify path of the dynamically loaded virtual instruments (vi). The top level programs are **main.vi** where wave table is used to define a waveform and **mainexcel.vi** where Excell file is used. Compiled executables should be installed using provided installers (setup.exe). These are located at /Fluke294ArbWaveApps/ExcellApplication/My Installer/Volume/ and /Fluke294ArbWaveApps/WaveTableApplication/My Installer/Volume/

Example 1: Defining Wave Using Wave Table

1. Follow Figure 1, connects the Fluke 294 to the oscilloscope.
2. To start the application, double-click either NI Labview **main.vi** or **main.exe**.
   The window **Arbitrary Wave Application Fluke294** appears, as shown in Figure 5.

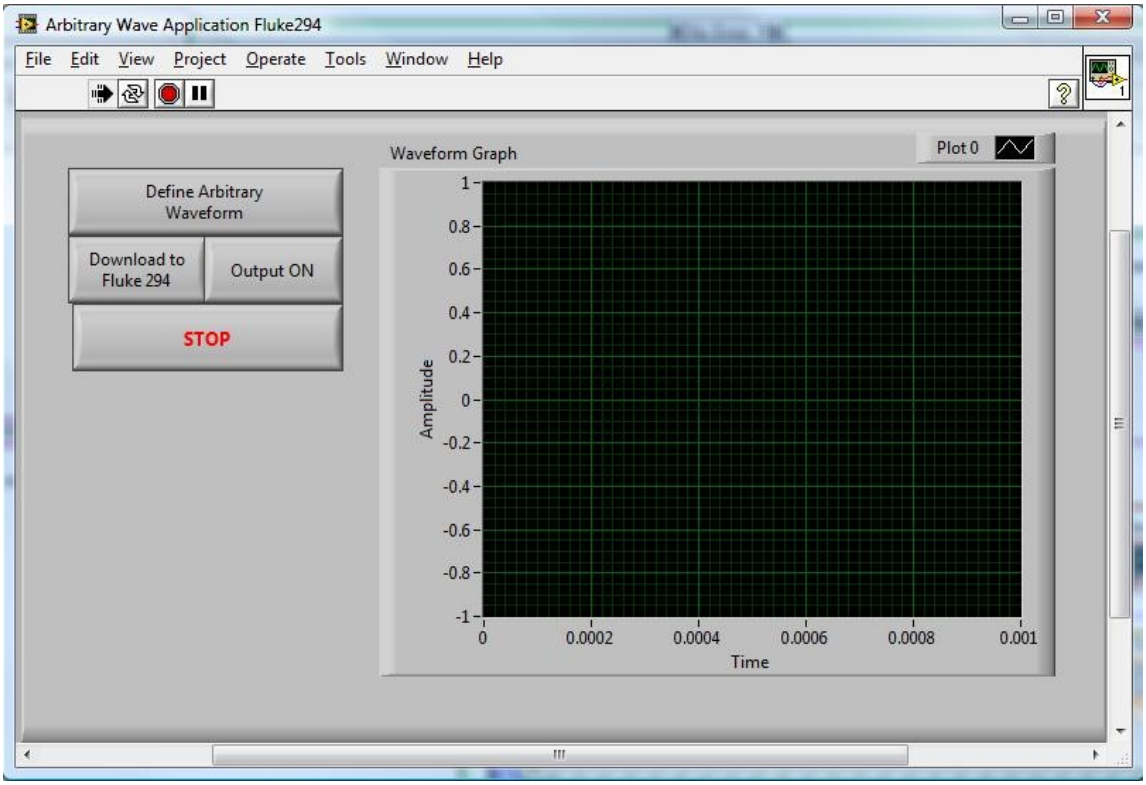

Figure 5: Front Panel When the Application Starts

3. Click **Define Arbitrary Waveform**.

The **Arb Waveform Definition Tool** appears, as shown in Figure 6.

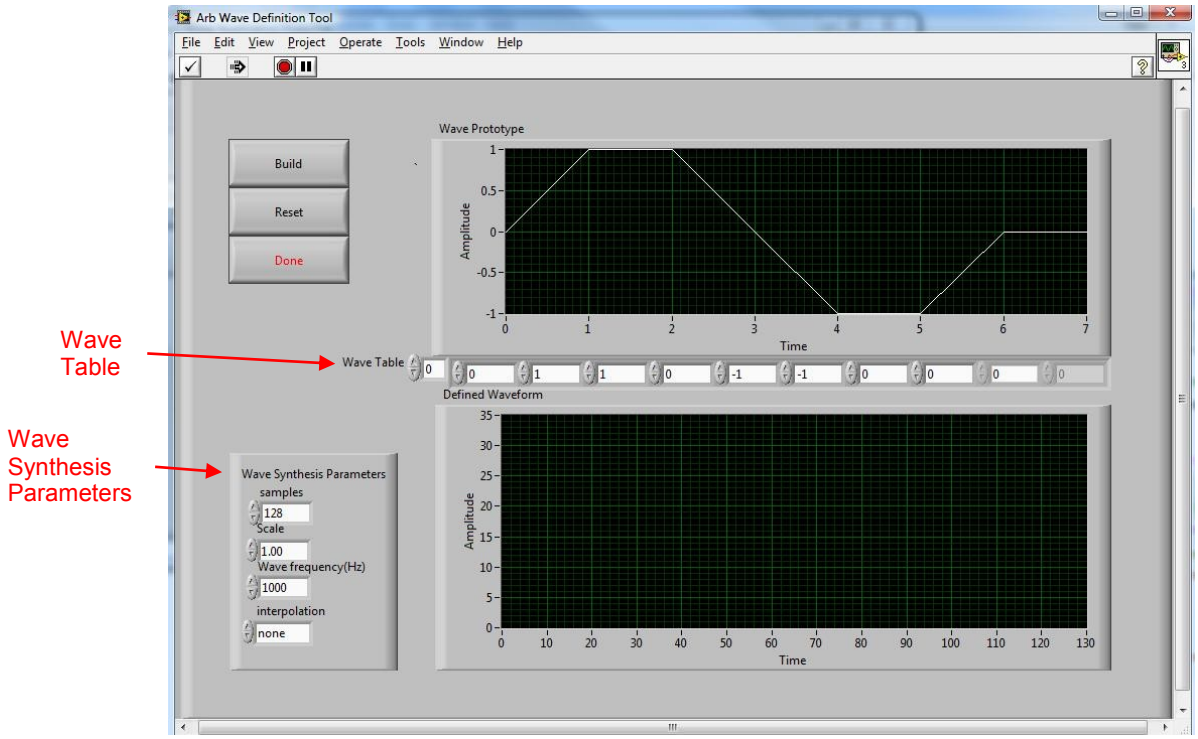

Figure 6: Defining Wave Shape Using Wave Table

4. Using **Wave Table** control, enter points that define wave shape.
   As the example shown in Figure 6, eight points were entered to define a single cycle.
5. In the lower left corner, enter **Wave Synthesis Parameters**: number of **samples**, **Scale**, **Wave frequency**, and **interpolation** (can be either **linear** or **none**).
6. To synthesize the wave, click **Build**.
   Figure 4 shows the synthesized waveform with no interpolation, and Figure 5 with linear interpolation.

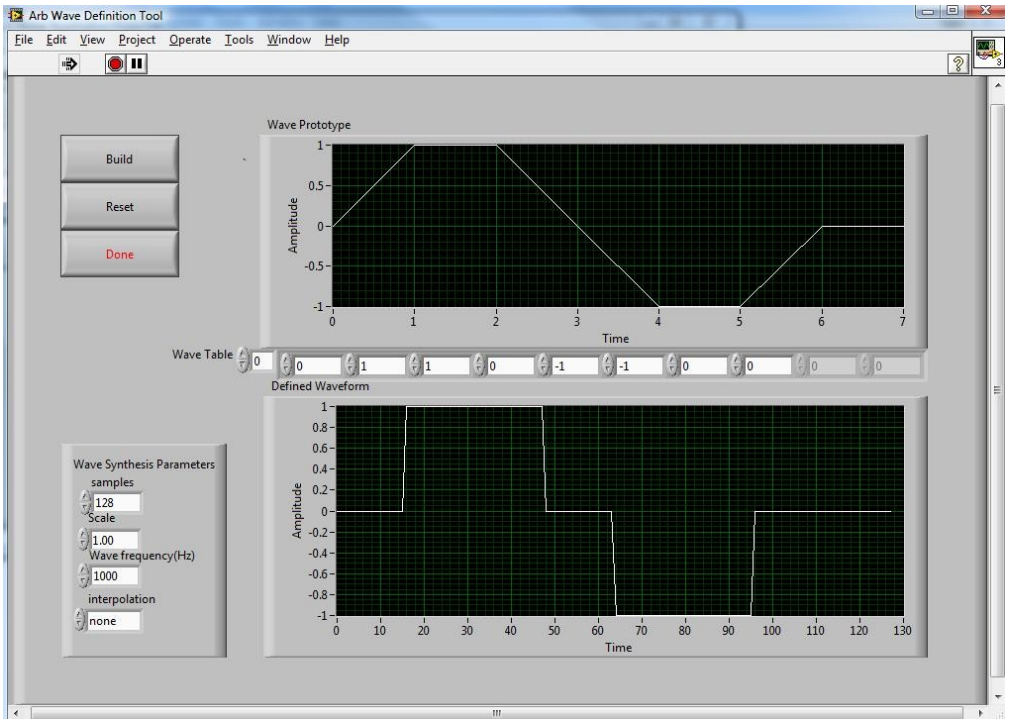

Figure 7: Synthesized Wave with No Interpolation

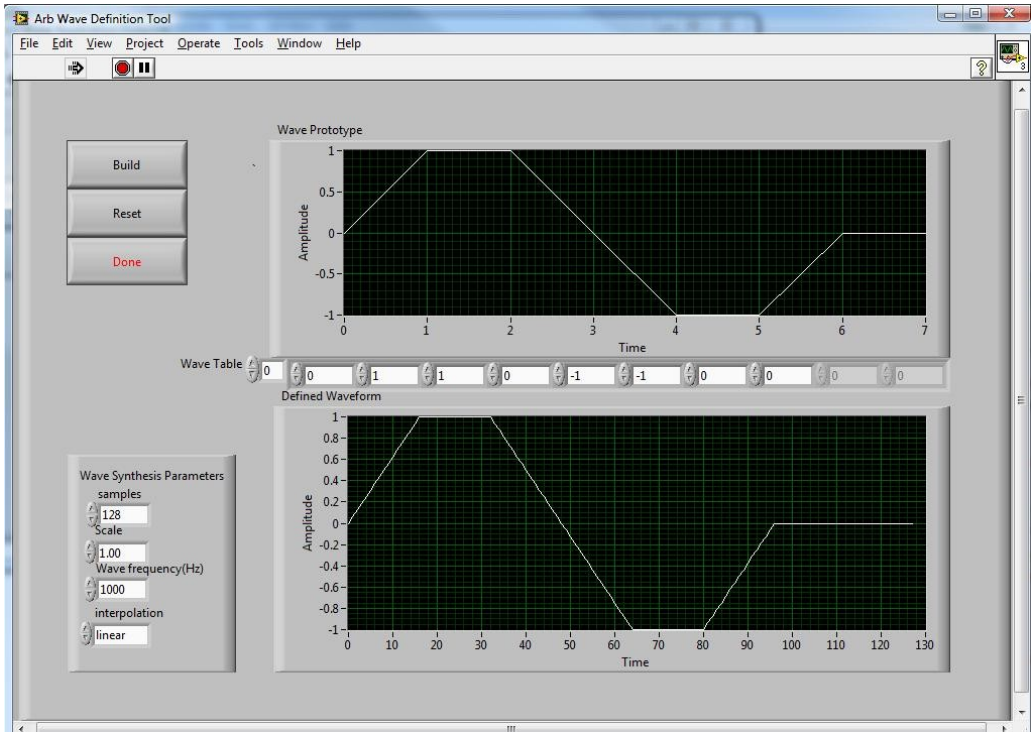

Figure 8: Synthesized Wave with Linear Interpolation

7. If you are satisfied with the wave shape, close the definition tool by clicking **Done**, and proceed to step 8. If you are not satisfied, click **Reset** and then repeat steps 4 to 6 until a satisfactory waveform is obtained.

   Note: Once you click **Done**, the wave data is passed to **main.vi**.

8. To send the data to the signal generator, from the window **Arbitrary Wave Application Fluke294**, click **Download to Fluke 294**.
   A prototype of the wave is displayed in the **Waveform Graph** area, as shown in Figure 9.

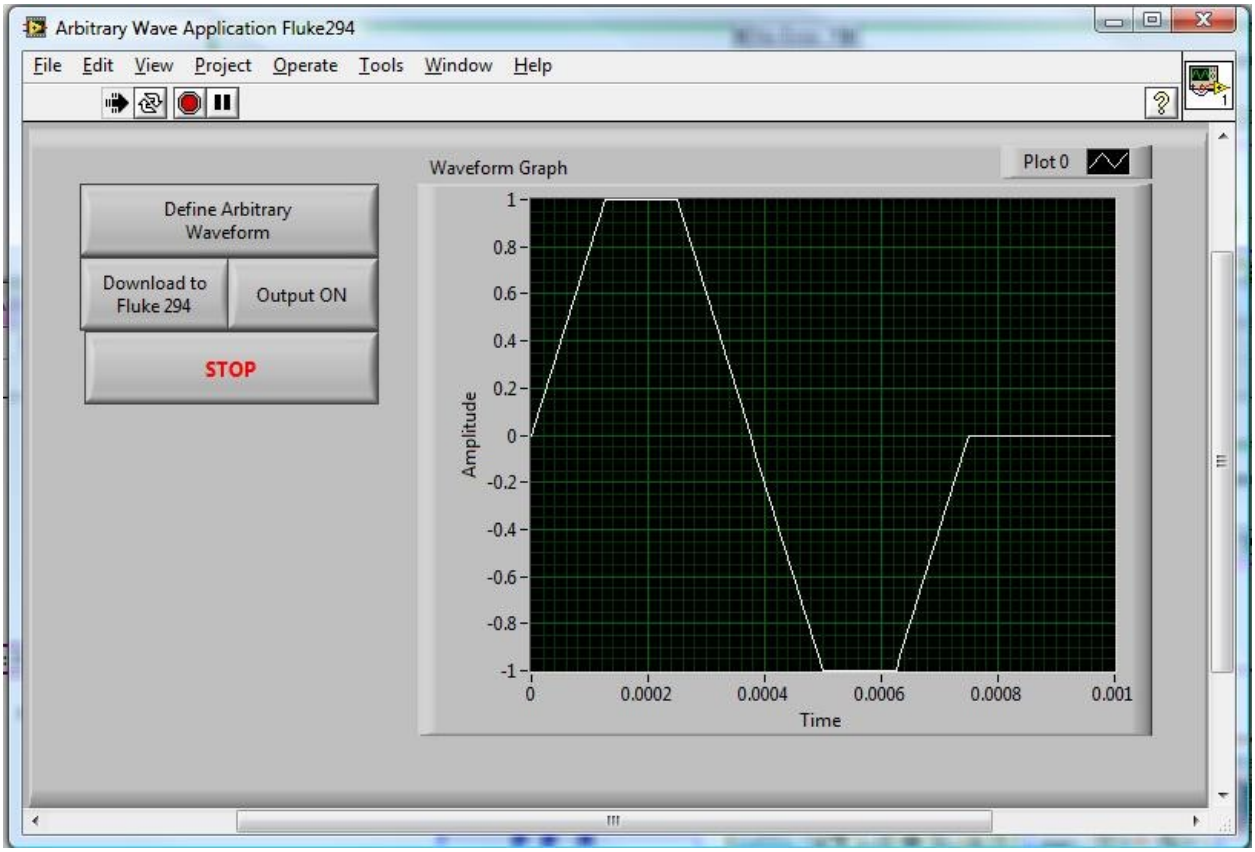

Figure 9: Prototype of the Downloaded Waveform

9. To turn on and off the output of the wave generator, toggle the button **Output ON**.
   The generated wave form can be captured using the oscilloscope, as shown Figure 10.

Figure 10: Wave Generated by Fluke 294 and Captured on DPO4054 Oscilloscope

10. To close the application, click **Stop**.

Example 2: Defining Wave Using Excel

In this example, the following formula is used in Excel to define the waveform:

$$y_{i=(\sin\theta_i)^2 \times n_i} \quad (1)$$

Where i is a sample index (number of samples = i + 1), and n_i values scale squared sine function. The result wave is shown in Figure 11.

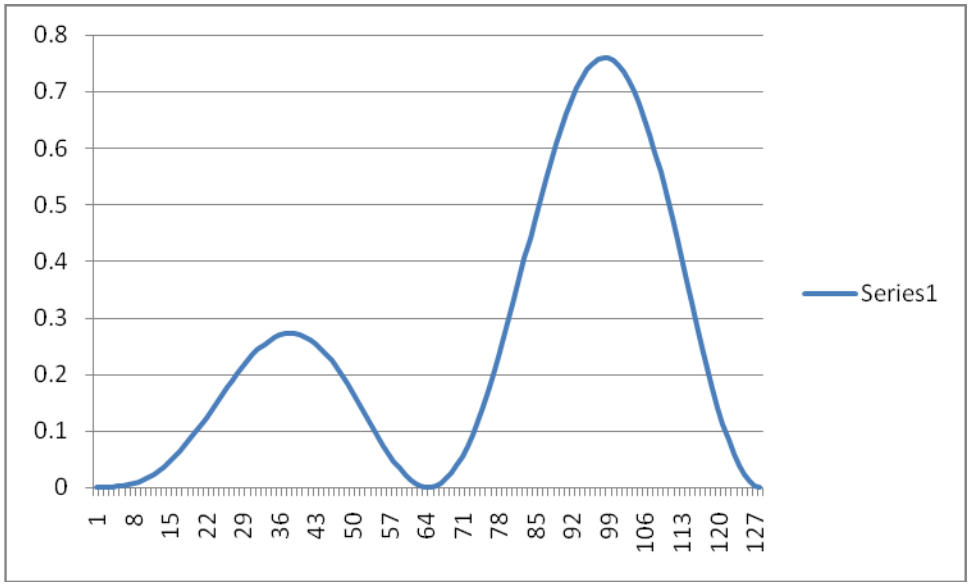

Figure 11: Formula Based Arbitrary Wave Shape

Follow these steps to generate the waveform:

1. From Excel, create a wave data file using formula (1), and save this file as a text file *.txt.

Note: tab delimiters are allowed in the text file.

2. To start the application, double-click **Excelmain.vi** or **Excelmain.exe**.
   The **Arb Wave Excel Tool** appears, as shown in Figure 12.

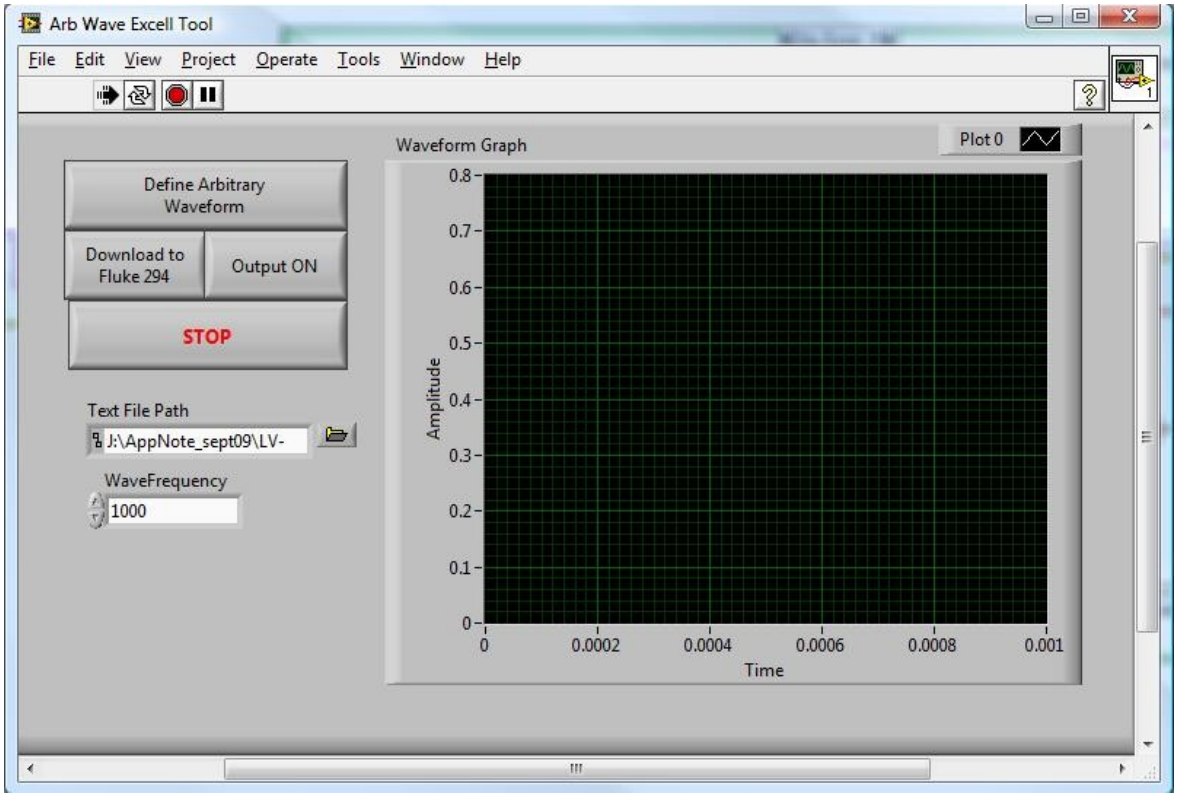

Figure 12: Front Panel of the Application

3. Under **Text File Path**, enter the path of the wave data file, or use the browse button to locate the data file.
4. Under **WaveFrequency**, enter that the frequency of the wave you wish to generate.
5. Click **Define Arbitrary Waveform**.
   A prototype wave appears in the **Waveform Graph** area, as shown in Figure 13.

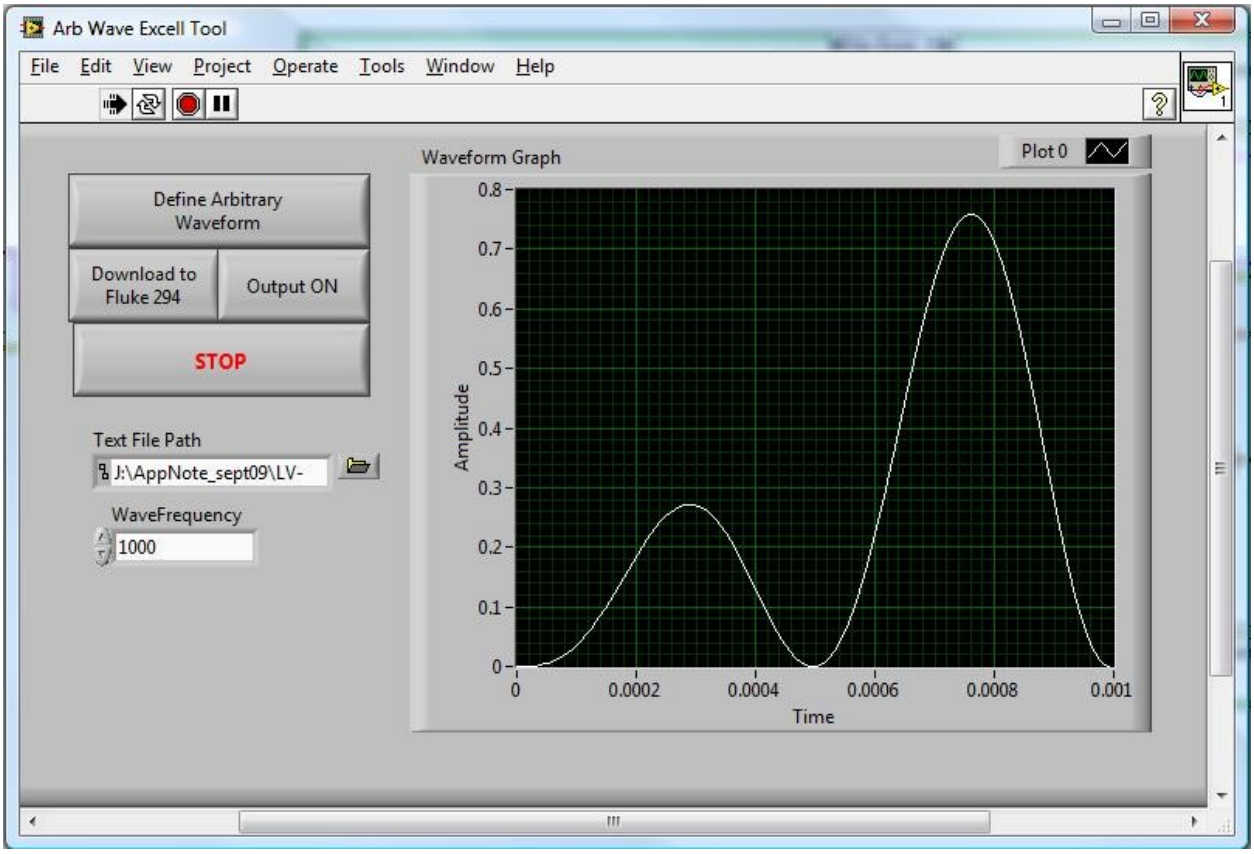

Figure 13: Prototype of the Waveform Defined by the Excel Data File

6. To send the data to the signal generator, click **Download to Fluke 294**.
7. To turn on and off the output of the wave generator, toggle the button **Output ON**. The wave form captured on the oscilloscope is shown in Figure 14.

Figure 14: Wave Generated by Fluke 294, and Captured on DPO4054 Oscilloscope

8. To close the application, click **Stop**.

Conclusions

This application note has presented a method of synthesizing arbitrary waveform signals that are suitable for a variety of testing applications. Two methods of defining wave shapes are demonstrated: using the NI Labview built-in functions **Arbitrary Waveform.vi**, and Excel spread sheet. The wave data is then scaled and sent to the Fluke 294 Arbitrary Wave Generator to produce the wave signals. The provided software can be used as is or can be a starting point to develop custom applications.

References

[1] "25 Common Things You Can Do With an Arbitrary/Function Generator," Available: http://www.tektronix.com/AFG3000. [Accessed: November 20, 2009].

[2] "Arbitrary Waveform Designer AWD-K1," Rhode&Schwartz. [PDF Quick View]. Available: http://docs.google.com/viewer?a=v&q=cache:rHuKHLlJNjkJ:www2.rohde-schwarz.com/file/AWD-K1_23.pdf+Arbitrary+Waveform+Designer+AWD-K1&hl=en&gl=ca&pid=bl&srcid=ADGEESjfXVmJETKAy-CmAK7U5O_oNn1Mrnl9xA29jYjBkDjZQ_D_5TwPu0Ttr7R6MyGLwNP0OWFpiuZE867B1FQaQIQXLvm6DbBH-6XySUdtQXIpekH3LG8vYGJA1bXm4sovelFa5Otc&sig=AHIEtbR-qiiiqrTzWjvF8tD-6ixAwP0Kjg. [Accessed: November 20, 2009].

[3] Fluke 291, 292, 294 User's Manual, Fluke Corporation, March 2006.