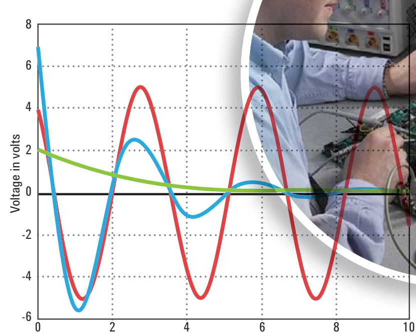
MEASUREMENT TIPS
Volume 6, Number 3

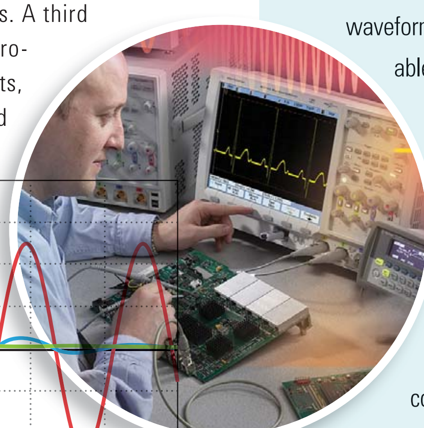
Using MATLAB® in Conjunction with an Arbitrary Waveform Generator to Create Complex Repetitive Waveforms

Engineers often need to generate complex test signals that go far beyond a simple sine, square or triangle waveform. They typically use an arbitrary waveform generator or "arb" to generate these signals.

You can use a variety of methods to create these complex waveforms. If the signal already exists as the output of a circuit or a physical transducer, for example, you can capture the signal with a scope and download it to an arb generator for later playback. Another option is to use the software provided with most arb generators to help you develop somewhat more complex waveforms. A third alternative is to use MATLAB, a software environment and programming language used to configure and control instruments, generate waveforms, make measurements, analyze data, and build test systems. MATLAB software is used by more than 1 million engineers and scientists worldwide.

This Measurement Tip will focus on using MATLAB to generate and download complex waveforms into an arb generator for playback.





Snapshot: Using MATLAB to Generate a Damped Sine Wave

In order to test the susceptibility of a high-speed pulse circuit to ringing, an engineer required a damped sine wave to simulate the ringing. The waveform needed to be generated in such a way that the shape of the waveform could be easily and quickly modified to validate the design under a variety of conditions. By generating the desired waveform in MATLAB, the engineer was able to control the basic shape of the output signal. The waveform coordinates were then downloaded to a function/ARB generator, where the amplitude and frequency of the output waveform could be adjusted. The effect of these variations on the circuit could then be directly observed.

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An arbitrary waveform can be thought of as a series of x and y coordinates that define the shape of the desired waveform. These x and y coordinates are limited by the number of vertical bits available in the particular function/arb generator used, as well as the size of the memory, or memory depth. As an example, the Agilent 33220A can store waveforms of up to 64K points in length, with 14 bits of vertical resolution. Stored waveforms can be sampled at a rate of up to 50 MSa/s. By essentially "connecting the dots," the waveform is then generated. This is a bit like a modern-day digital sampling scope, but in reverse. Rather than sampling a waveform and reconstructing it on a screen for observation and analysis, the function/arb generator is sampling a set of x,y data in memory and generating a waveform. The waveform's frequency and amplitude can then be controlled via the function/arb generator. In addition, some generators allow an arbitrary waveform to be swept and/or modulated, just as an internally generated sine or square wave might be.

Generating a complex waveform with MATLAB software

MATLAB is an extremely powerful math tool that can be used in a multitude of ways. One application of this potent software package is to use it to generate complex waveforms that can be defined mathematically. The following sample program demonstrates this capability using an Agilent 33220A function/arb generator.

In the sample program, three sine waves are created (wave1, wave2, and wave3). For flexibility and ease of modification, the basic characteristics of amplitude and frequency are controlled by variables. The amplitude of each sine wave is defined by variables (Amp1, Amp2, and Amp3). Similarly, the frequency of each sine wave is defined by variables (frequency1, frequency2, and frequency3). These three sine waves are then combined to generate a single composite waveform. Additionally, a random noise component is added to the waveform, with another variable determining the amplitude of the superimposed noise. The resultant waveform is plotted along with the three basic waveforms.

```
%% Example application to generate an arbitrary waveform and download it to an Agilent
Arbitrary Waveform Generator.

% Generate the arbitrary waveform in MATLAB

time = 0:0.001:1;                              % Define time vector to contain whole
                                                        number of cycles of waveform
Amp1 = 0.2;                                    % Amplitude for each component of waveform
Amp2 = 0.8;
Amp3 = 0.6;
frequency1 = 10;                               % Frequency for each component of waveform
frequency2 = 14;
frequency3 = 18;
wave1 = Amp1*sin(2*pi*frequency1*time);        % Waveform component 1
wave2 = Amp2*sin(2*pi*frequency2*time);        % Waveform component 2
wave3 = Amp3*sin(2*pi*frequency3*time);        % Waveform component 3
wave = wave1 + wave2 + wave3;                  % Some combination of individual waveforms
wave = wave + 0.3*rand(1,size(wave,2));        % Now add random noise into the signal
wave = (wave./max(wave))';                     % Normalize so values are between -1 to + 1

% Visualize the signals

plot(time,wave1,'m',time,wave2,'k',time,wave3,'r');
hold on; hw = plot(time,wave,'b'); set(hw,'Linewidth',2.5)
xlabel('Time (s)'); ylabel('Voltage (V)'); axis tight;
legend('Component 1','Component 2','Component 3', 'Combination of components \newline with
random noise')
```

The resultant plot is shown in **Figure 1,** below. The dark blue plot is the resultant waveform, a combination of the three sine waves and some random noise.

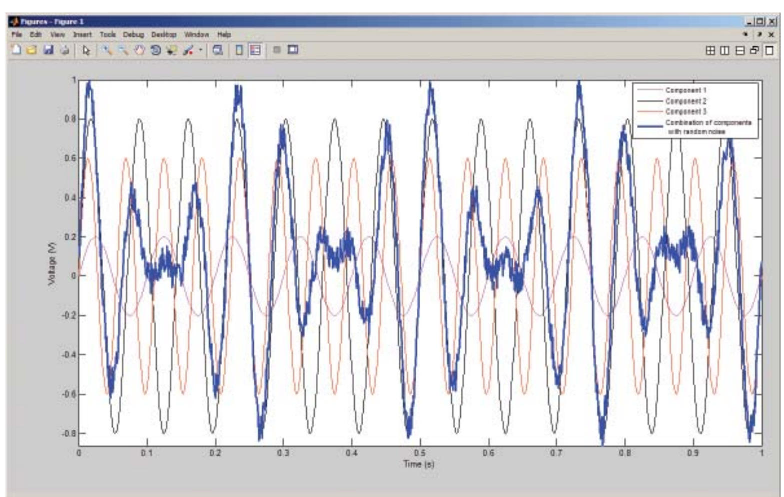

FIGURE 1. ***A complex waveform generated with MATLAB software***

Downloading the MATLAB waveform to a function/arb generator

The next step is to download the waveform into a function/arb generator. In this example program we take advantage of the IVI-COM drivers that are available for the Agilent 33220A function/arb generator in the MATLAB Instrument Control Toolbox. We give the generated waveform the name "MATLABWFM1." The code at right downloads MATLABWFM1 into the memory of the Agilent 33220A.

The resultant waveform is stored as a user-defined waveform and can be selected in the 33220A menu. The resultant output is then displayed on an oscilloscope. **Figure 2.**

Once the waveform is downloaded into the 33220A function/arbitrary waveform generator, you can further adjust parameters such as frequency and amplitude. In this first case, **Figure 3**, the frequency was set to 2 kHz and the amplitude was adjusted to 200 mVRMS.

In this second case, **Figure 4**, the frequency was increased to 5 kHz and the amplitude was increased to 3.5 VRMS. Notice that in both cases the shape originally created in MATLAB is maintained, even though the frequency and amplitude are being modified by the 33220A function/arb generator.

```
% Connect to the Agilent 33220. Using the IVI driver, load the arbitrary waveform and enable it.

device = icdevice('Agilent33220.mdd','GPIB0::10::INSTR');
connect(device);
invoke(device.Arbitrarywaveform,'SetData',wave);
invoke(device.Arbitrarywaveform,'CopyData','MATLABWFM1');
set(device.Arbitrarywaveform,'User','MATLABWFM1');
set(device.Output, 'Function', 'Agilent33220OutputFunctionUser');
set(device.Output, 'Frequency', 1);
set(device.OutputVoltage, 'Amplitude', 10);
set(device.Output,'State','on')
```

FIGURE 2

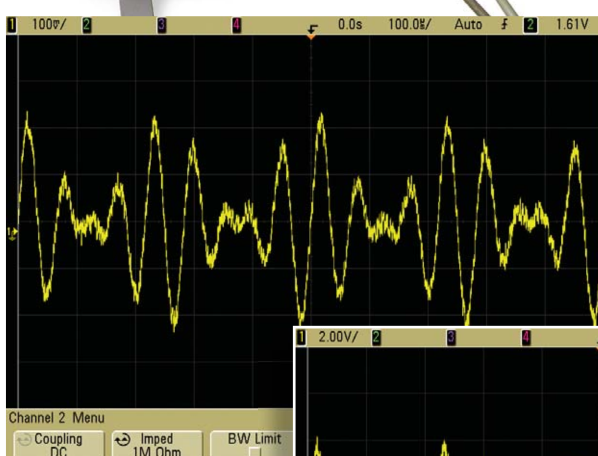

FIGURE 3.
Frequency set to 2 kHz and amplitude set to 200 mVRMS

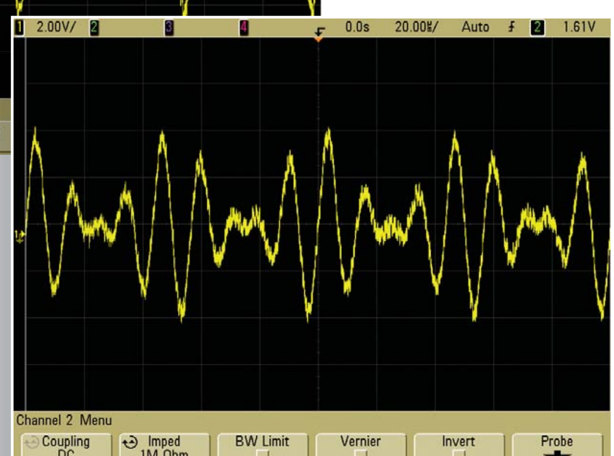

FIGURE 4.
Frequency changed to 5 kHz and amplitude changed to 3.5 VRMS

Summary

We have shown that MATLAB software can be a powerful tool for generating complex waveforms based on mathematical models. Many engineers and scientists are already using this industry-standard software environment and programming language to configure and control instruments, make measurements, analyze data, and build test systems. Now those same engineers can put it to use to generate and download complex waveforms into a function/arbitrary waveform generator as well.

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