Simulate this!

Arbitrary waveform generator applications

Application Note

Generating complex real-world, mixed-signal waveforms may not be trivial. But it should be feasible, practical, and routine.

Simulation, in the best of cases, is an exacting science.

In other cases, such as when complex natural events or physical systems are involved, the outcome may be downright unpredictable.

Some events cannot be simulated with any degree of precision—for example, natural phenomena with many complex variables, such as the risk of extinction of a species. Still others, such as weather patterns, can be simulated accurately, but only for hours or days ahead. Conversely, events with fewer variables to consider can be simulated both easily and accurately. Traffic flow is one of those.

Man-made systems present their own challenges. As with natural events, successful simulation of man-made systems is a factor of the complexity of system inputs that drive various subsystems. But when electrical or electronic systems are involved, the required inputs to a subsystem may not be available until various input circuits are designed and debugged. And that situation forces the designer or test engineer to wait until late in the development process to use those real-life inputs in testing. Often, too, the input signals to be simulated may be much more complex than textbook waveforms such as sine, square, ramping, or sawtooth waves.

And, therefore, we have the arbitrary waveform generator.

Simulating complex waveforms

An arbitrary waveform generator, or AWG, can best be described by reference to a well known instrument, the function generator. On command, a function generator creates a range of standard waveforms such as sine waves, square waves, and ramps. In reality, most waveforms don't follow precisely defined functions such as sine waves. While many waveforms display a predictable sequence, they also tend to exhibit arbitrary behavior that, at best, can be described only in very complex terms. Strangely, this behavior can describe an intentional waveform such as a television broadcast signal, or it may be the unintended result when glitches, drift, or noise wreak havoc on a signal.

An AWG is best used to create nonstandard waveforms for simulating complex system inputs if input circuitry is not available—for example, from an external source, or from another subsystem that is still under development.

Assume you have debugged your product design in software, and your prototype boards are nearing completion. To debug your boards, you need to couple simulation with rigorous prototype testing. That also means stress-testing the prototype to ensure its operation under such conditions as jitter, code violations, and noise.

If your system is complex, debugging of individual modules will require generating a number of complex waveforms. It is this ability that sets an AWG apart from the everyday function generator and other types of test instrumentation. It lets designers precisely create real-world signals, making it an indispensable tool during the design, test, and manufacture of electronic components and systems. It excels in creating mixed-signal waveforms that are eerily similar to the waveshapes of "arbitrary" real-world conditions. Think of it as skillful, artistic, and legal forgery.

Effectively, an AWG combines the capability of a function generator with that of a pulse or pulse-train generator, a modulation source, a noise generator, a sweep generator, and a trigger generator. As such, it's a good tool for everyday use in the design lab, allowing you to create a custom solution for a wide range of test applications.

AWG applications

The applications for an AWG are many, and they span virtually all industries. Any application requiring a stimulus that cannot be supplied by another available standard signal source is a good candidate for an AWG.

Designers and test engineers frequently use an AWG in order to simulate worst-case conditions during design verification. An AWG is the ideal tool for degrading or stressing signals as a means of establishing and verifying performance limits. It also serves to identify unacceptable levels of noise, timing problems, signal-level abnormalities, bandwidth loss, harmonic distortion, or a host of related maladies.

DTMF simulation

Touch-tone signals on a push-button telephone are each created by combining a low-frequency and a high-frequency signal. Simulating the superimposed frequencies creates a special challenge if the frequencies are not harmonically related. Generating these signals with controlled levels of noise and harmonic content is not trivial, but the task is straightforward with an AWG. See Figure 1.

Pacemaker® testing

In the past, a simple square-wave or sine-wave pulse was used to test a pacemaker. Today, with an AWG, actual heartbeat waveforms that are detected by the Pacemaker can be used to test the device. Using this approach allows the Pacemaker to be customized and tested for a particular patient. (See Figure 2a and 2b.)

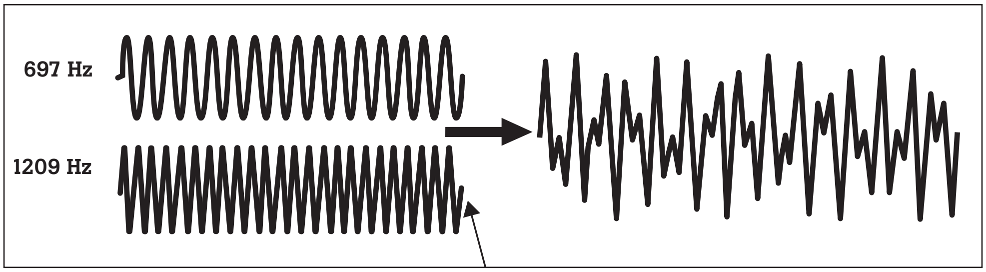

Figure 1. A DTMF signal combines two tones of different frequencies. Recreating the composite signal is not a trivial matter unless the tones are harmonically related. However, an AWG makes the operation a routine matter.

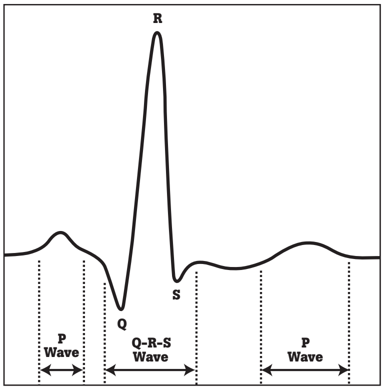

Figure 2a. A waveform of a typical heartbeat.

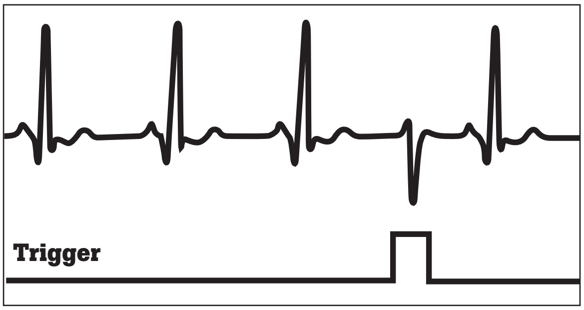

Figure 2b. The flexibility of an AWG enables the user to simulate any aspect of a heartbeat signal, such as a signal dropout or similar condition. This capability allows the Pacemaker to be customized and tested for individual patients.

Automobile suspension testing

An automobile's suspension can be simulated with a four-channel AWG, enabling simulation of each wheel independently as the automobile hits a bump. The suspension's response and reliability can be tested under virtually any road conditions, and the size of the "bumps" can be precisely controlled. See Figure 3.

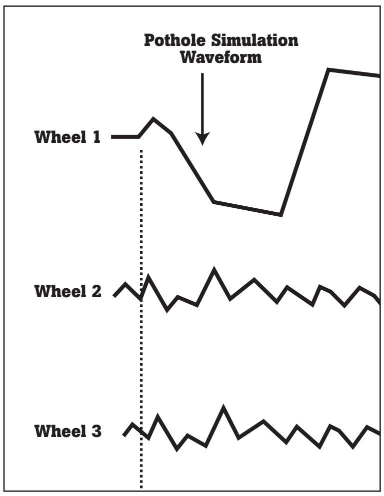

Figure 3. A four-channel AWG is used here to simulate a complex pothole waveform. Through appropriate triggering, the car's suspension response and reliability can be tested under virtually any road condition.

Power line testing

A multichannel AWG is an ideal tool for simulating three-phase power. One channel can be used for each phase. Transients or glitches can then be simulated by linking in problem waveforms in response to a trigger. See Figure 4.

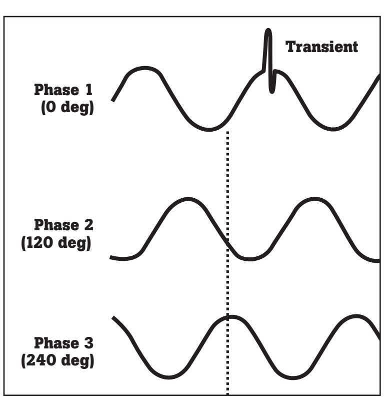

Figure 4. By synchronizing three channels of an AWG, you can simulate multiple power-line problems by linking in problem waveforms in response to triggers. Here the AWG can be set up to simulate a transient on one phase and signal dropout on another.

Performance parameters

When evaluating your requirements and examining the field of arbitrary waveform generators, you need to take heed of a few key specifications.

Sample rate

Sample rate defines the highest-frequency signal that can be accurately generated. The higher the sample rate, the higher the frequency of the signal. Today, AWGs with sampling rates of 100 megasamples per second (ms/s) are common.

Waveform memory

Waveform memory refers to the total number of waveform points that can be stored in memory. The higher the number of points, the longer the waveform that can be stored, or the higher the resolution that can be obtained for a shorter waveform.

Waveform repetition frequency

The waveform repetition frequency equals the sampling frequency divided by the waveform size, or:

$F_w = f_s \div w_{size}$

Where sampling frequency (ms/s) equals the number of waveform points generated per second, and the waveform size equals the number of points that define the waveform.

If the maximum sampling frequency of your AWG is 50 ms/s, and you have defined a 1,000-point waveform, the maximum available waveform repetition frequency is 50,000,000 ÷ 1,000 = 50 KHz.

Vertical (A to D) resolution

Vertical resolution defines the number of discrete voltage values that can be reproduced by the AWG. For a 12-bit AWG, each point on the waveform can have one of 4,096 (2^{12}) voltage values. The higher the number of bits, the greater the resolution that each waveform point can be given. The benefit is lower distortion and noise.

Number of channels

The more channels your AWG has, the more versatile you can be in creating complex waveforms.

Here is a practical application. With a two-channel (or higher-channel) AWG you can sum the outputs of those channels to create a composite signal. A single-channel AWG allows you to re-create a noisy signal. However, viewing both the clean and noisy signals at the same time requires an AWG with two channels.

New expectations

With the tremendous complexity of today's electronic systems, it's no wonder that the AWG is becoming the de facto standard for simulation of complex waveforms. Driving this trend are the relentless expectations for reduced time-to-market of new products—with no room to sacrifice initial quality or product performance. Where complex, mixed-signal electronic systems are concerned, serial development of input modules or circuits was once the norm. But the arbitrary waveform generator has changed the landscape, providing a practical solution to the challenges of concurrent engineering.

Today's AWGs offer the speed, flexibility, and performance that give credit to the benefits of simulation. At least one AWG belongs in every design lab and on every test bench.

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