4 Ways to Efficiently Generate Complex Waveforms

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Generating the signals to characterize, test or troubleshoot electrical designs or systems can be tedious and time-consuming. So, our experts came up with four ideas to help you more efficiently generate simple or complex waveforms.

TIP ① Get Started with Pure Sinewaves

Check clarity of waveform generator output

There is no substitute for pure water when making beverages like soft drinks or beer, as it is virtually impossible to remove impurities from the final product. Likewise, when creating circuits that amplify, mix or modulate signals, it makes sense to test them using pure sinewaves with low harmonic distortion. Using a waveform generator with the cleanest output can help when troubleshooting a design to determine the sources of error, particularly when working on transmitters, receivers and phase-lock-loops.

Check the noise level of your waveform generator by using a spectrum analyzer, starting with the generator's bandwidth. See if the bandwidth is specified as a 3 db point, or if the generator can output sinewaves or even square waves up to the specified bandwidth. Noise is often specified as total harmonic distortion, the ratio of the energy in the fundamental frequency compared to the sum of all the energy in the harmonic or related frequencies. Figure 1 shows an example of noise (0.04 THD) generated by a Keysight True*form* Waveform Generator. The screen capture, taken from a spectrum analyzer, shows the fundamental 10 MHz (tallest peak) and the harmonics (smaller peaks), which occur at even multiplies of the fundamental frequency.

Cabling also has a significant effect on noise. Be sure to use high quality cables with good connectors that deliver only the desired signal to the circuit. A double shielded coax cable does a good job of keeping unwanted signals from being coupled into source signal. Impedance matching the source, cable and circuit eliminates reflections and maximizes the power transferred.
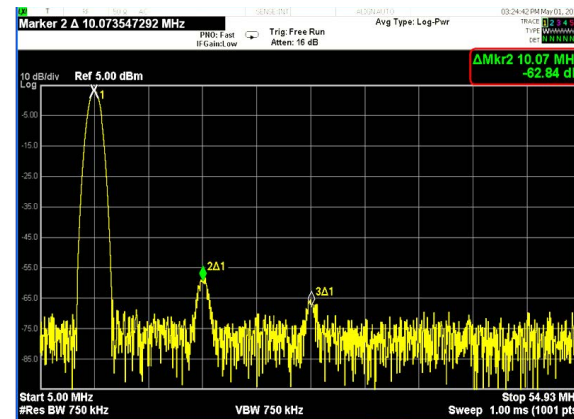

Figure 1. The spectral purity of a True*form* Waveform Generator which has less than 0.04 THD

TIP 2 Generate Basic or Variable Edge Pulses

How to create pulses with an inexpensive waveform generator

Instead of using a dedicated pulse generator, a relatively inexpensive waveform generator can be used to generate trigger signals, clock signals and logic control. When designing a control circuit, you can use a waveform generator as an external source to trigger delays and to easily change the delays between triggers. Here are three techniques that you can use to generate pulses with a waveform generator.

Square wave: You can create pulses by varying the duty cycle of a square wave, typically between 20 and 80%. If you want higher or lower duty cycles, use burst mode, which lets you output a single cycle (pulse) of a square wave and specify a waiting period before sending the next pulse.

Arbitrary waveform: If you need a wide variety of custom pulses and patterns, you can define different shapes and parameters with a waveform generator that has flexible, arbitrary waveform capabilities. For the best time resolution, use as many points as you can to describe the pulse. Keysight's BenchVue Function Generator Control and Automation PC software simplifies the creation of custom arbitrary waveforms.

Pulse mode: Many newer waveform generators, such as Keysight's True*form* Waveform Generators, have built-in pulse capability, which gives you an easy, flexible way to generate pulses. Simply specify the main parameters of a pulse: period, pulse width rise and fall time. In all three cases, you can use burst mode to output multiple cycles (N-cycle burst) to create longer, more complex pulse trains. If an external gating signal is available, it can also be used with trigger delay and burst mode to create precise trigger signals. Keysight's 33600 True*form* Waveform Generators can create pulses with a rise/fall time as fast as 3 ns and jitter lower than 1 ps.

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Using a Function/Arbitrary Waveform
Generator to Generate Pulses

Application Note

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> ### Download application note
> *Using a Function/Arbitrary Waveform Generator to Generate Pulses*
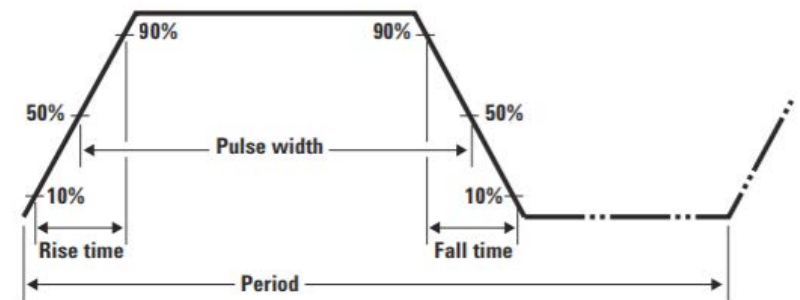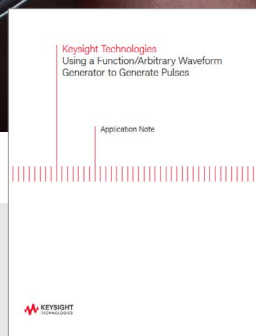
TIP 3 Create Multitone Signals

Use additive noise to test a device's immunity to noise under real operation

The upper trace is the clean signal. The middle, green trace is the noise to be added, which can be a fraction of the amplitude of the clean signal. The lower trace shows the sum of both signals.
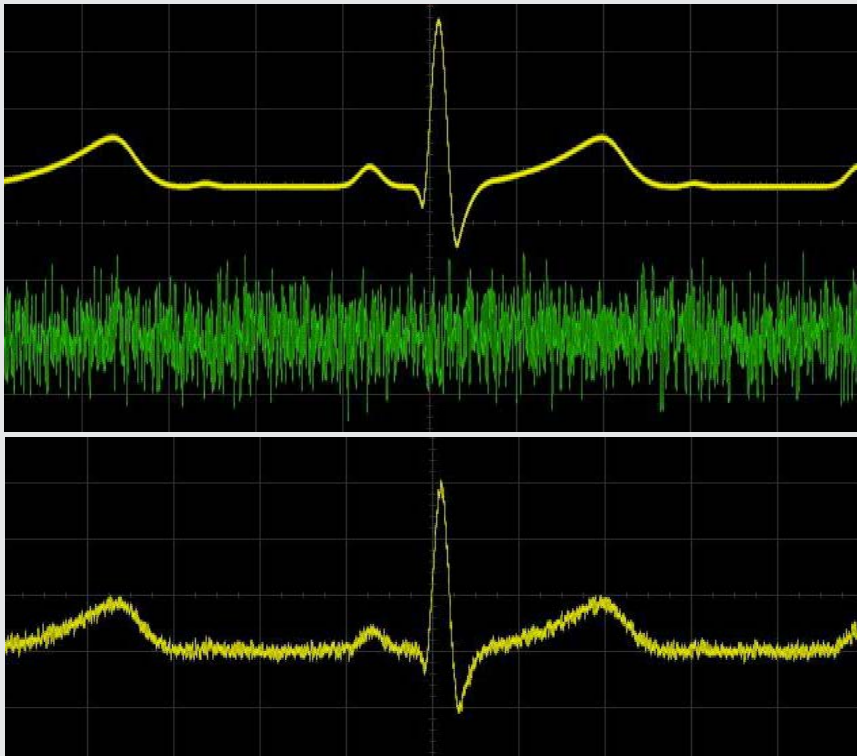
Make one signal from two

A multitone signal is the superposition of several sine waves or tones, each with a distinct amplitude, phase, and frequency. They are used in many test specifications as they can quickly and efficiently stimulate a circuit or system over its entire bandwidth. They can also determine the frequency response of a device for a given selection of frequencies, or make measurements such as intermodulation distortion. The dial tone in the US is a multitone signal made of 350 Hz and 440 Hz tones.

Here are two ways to create multitones:

Method 1: Connect two or more sinewave generators in series and add their amplitudes to generate a single waveform. The generators need to have the same clock source and phase control to sync the waveforms.

Method 2: Create the waveforms mathematically and download them to an arbitrary waveform generator. A single arbitrary waveform can be created to last the length of the test or care needs to be taken to create a waveform segment that can be repeated without any anomalies.

Use a 2-channel waveform generator capable of adding two channels together, as described in method 1. Keysight's True*form* Waveform Generators can produce a dual tone signal while synchronizing the signals and the phase. They have unique ability to add signals together on a single channel without needing to use a second channel or to create an arbitrary waveform. With True*form*, complex multitone signals can be created directly from the front panel.

> **Watch video**

TIP ④ Create Custom Arbitrary Waveforms
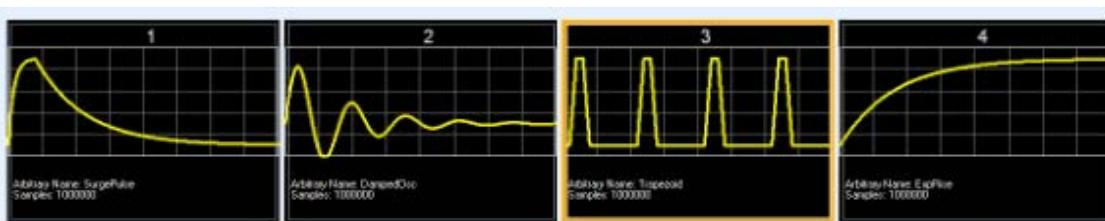
Create custom "mixes" using sequences

Arbitrary or custom waveforms are typically created by a waveform generator with a list of amplitudes. Once the generator reaches the end of the list, it plays the list again from the beginning. The most common waveform generators use a DDS technique that skips points based on the desired frequency. The complexity of the signal is limited by sample rate and memory depth.

Complex communication signals, such as those used for robotics or automotive applications, typically don't repeat for several seconds. You can generate a single, long waveform using a generator with extremely deep memory or divide it up into smaller segments. In the case of robotics, a motion could be driven by the same signal repeated 1000 times but with a different beginning (for ramp up) and a different ending (for ramp down). Using the segmentation approach provides multiple advantages: it's simpler to setup, uses less memory, and is much easier to modify. For example, you might be satisfied with the ramp up and the drive segment but would like to only modify the ramp down segment.

Arbitrary waveforms are also commonly used to introduce transients, or drop outs to test a circuit's reaction to infrequent events. A poorly designed circuit could latch up or reset when a drop out occurs. Segmentation simplifies the process of introducing unique cycles or varying the ratio of good to bad cycles.

Waveform sequencing can greatly improve test efficiency. Starting with just a few arbitrary waveforms, sequencing can be used to create a really large number of combinations by changing the order and number of cycles of each segment. You can easily create arbitrary waveforms with True*form* Waveform Generators. With True*form*, a sequence can have up to 512 steps. A total of 32 sequences with up to 1,024 segments can be pre-loaded into the generators' volatile memory to improve throughput.

> ## Download app brief
> *Be More Efficient Designing Your Arbitrary Waveforms*
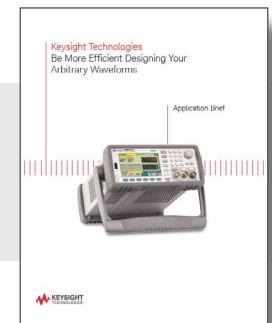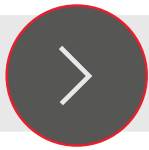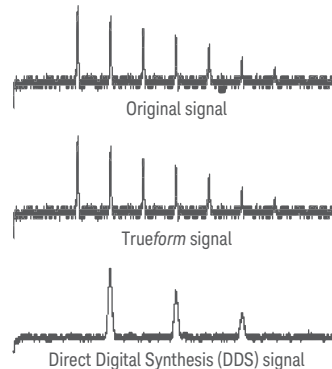
Want to Learn More About Complex Waveform Generation?

Get the True*form* advantage

Many waveform generators are built with direct digital synthesis (DDS) technology that uses a fixed clock to simulate signals. The fixed clock approach adds or reduces points in signals to meet a fixed clock rate and may generate signals that are different than you expect. In contrast, True*form* Waveform Generators are built with a proprietary technology that plays every point in your signal exactly as you designed it.

Visit Website

Original signal

True*form* signal

Direct Digital Synthesis (DDS) signal

Compare Keysight Waveform Generator Prices, Product Features and More

Visit Comparison Webpage

Keysight True*form* Waveform Generators

	33600A Series, 80 and 120 MHz	33500B Series, 20 and 30 MHz
Jitter	<1 ps	<40 ps
Pulse edge time	2.9 ns independent rise & fall	8.4 ns independent rise & fall
Arbitrary waveforms	64 MSa memory w/sequencing	16 MSa memory w/sequencing
PRBS patterns	200 Mbits/s, N from 3 to 32	50 Mbits/s, N from 7 to 28
2-channel coupling	*Equal, differential, ratio and combined*	

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