5 Tips for Getting the Most Out of Your Function Generator

eBook

KEYSIGHT

INTRODUCTION

Modern function/waveform generators are extremely versatile, going well beyond the basic sine, square, and ramp waveforms. Function generator technology has evolved from simple analog wave shaping instruments to modern direct digital synthesis (DDS) generators.

Today's digital function/waveform generators can do much more than their predecessors, but many engineers are not aware of these advanced capabilities. This eBook will introduce you to five advanced waveform capabilities that can help improve testing and save you time in the lab.

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TIP 1

Combining Two Waveforms

Combining Two Waveforms

In product design validation and characterization, you often need to quickly generate many complex signals. For example, a medical device design engineer may need to create a human cardiograph signal. Or an automotive engineer may need to simulate an engine crank signal or test a CAN bus's resilience to engine noise. To simulate these complex real-world signals, it is helpful to be able to combine two waveforms. Combining waveforms is the act of taking two individual inputs and combining them into one output. Let's look more closely at a medical device example: a heart rate meter or a cardiac monitor. Pacemakers are used to regulate a person's heart beat rate and they introduce pulses into the patient's own ECG (electrocardiogram) signal. To test how a heart rate meter or a cardiac monitor interacts with a pacemaker's pulses, you need a function generator to simulate the combined pacemaker's pulse signal and a simulated ECG signal.

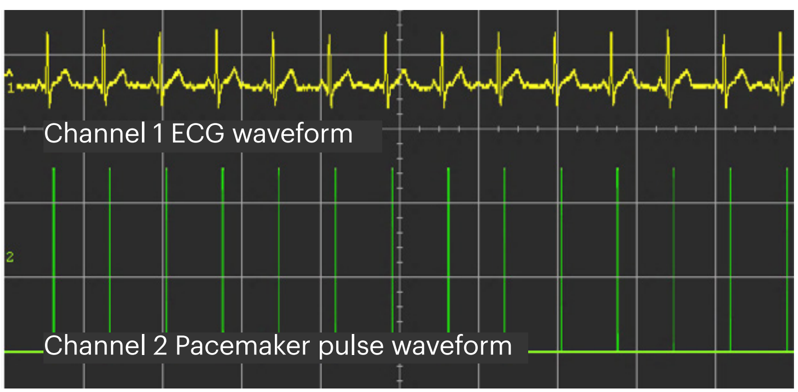


Figure 1. Two waveforms combined into one

Figure 1 shows an ECG signal on channel 1 and a pulse train generated by a pacemaker on channel 2. In order to test the cardiac monitor, you want to have both signals phase locked and combined into one signal output. To do this, your function generator needs to be able to do a few things. First, it needs at least two outputs—one for the ECG and one for the pacemaker pulse. Second, it has to be able to phase synchronize the two outputs (see Tip #2). Third, it needs to combine the two outputs into one output (Figure 2). Once you have the combined output, you can alter the inputs individually and test the cardiac monitor under varying situations.

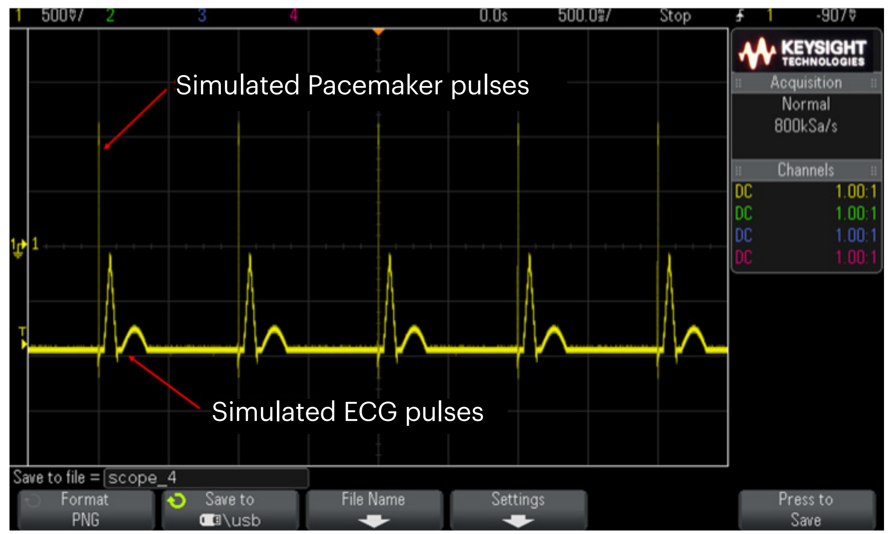


Figure 2. Resultant waveform by combining the above two waveforms

Example of adding noise into a test signal

Another application where you may need to combine two waveforms is testing for the robustness or immunity of your device under test (DUT) to noise. To show an example of this, let's use sum modulation and add noise to a real-world ECG signal. Figure 4 shows this as well as the resultant noisy ECG signal. Here is how you would configurate this setup using a Keysight 33622A function generator:

- Select "Sum Modulation" as the modulation type
- Select "Internal" source to combine with your clean signal
- Select "Noise" as your internal source
- Define the amplitude and bandwidth of the noise signal
- Turn Modulate "On"

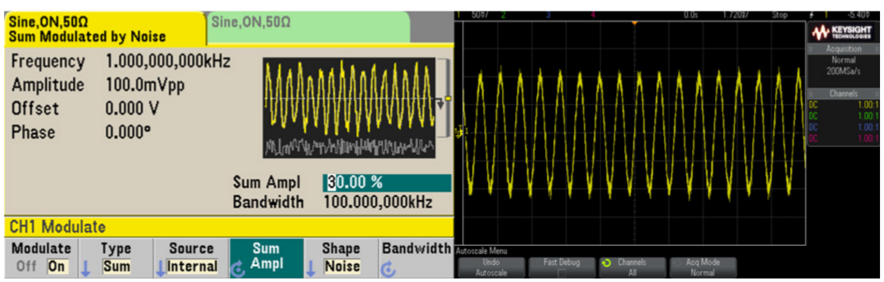


Figure 3. Resultant waveform by combining the above two waveforms

Combining waveforms is the act of taking two individual inputs and combining them into one output

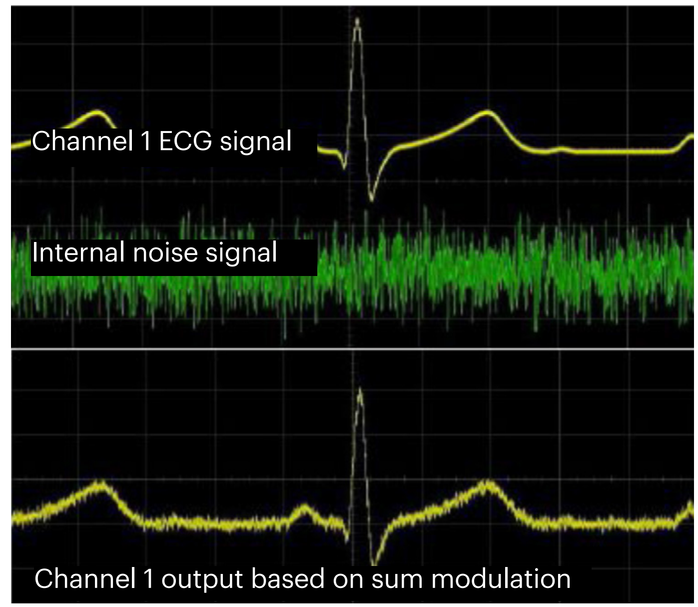
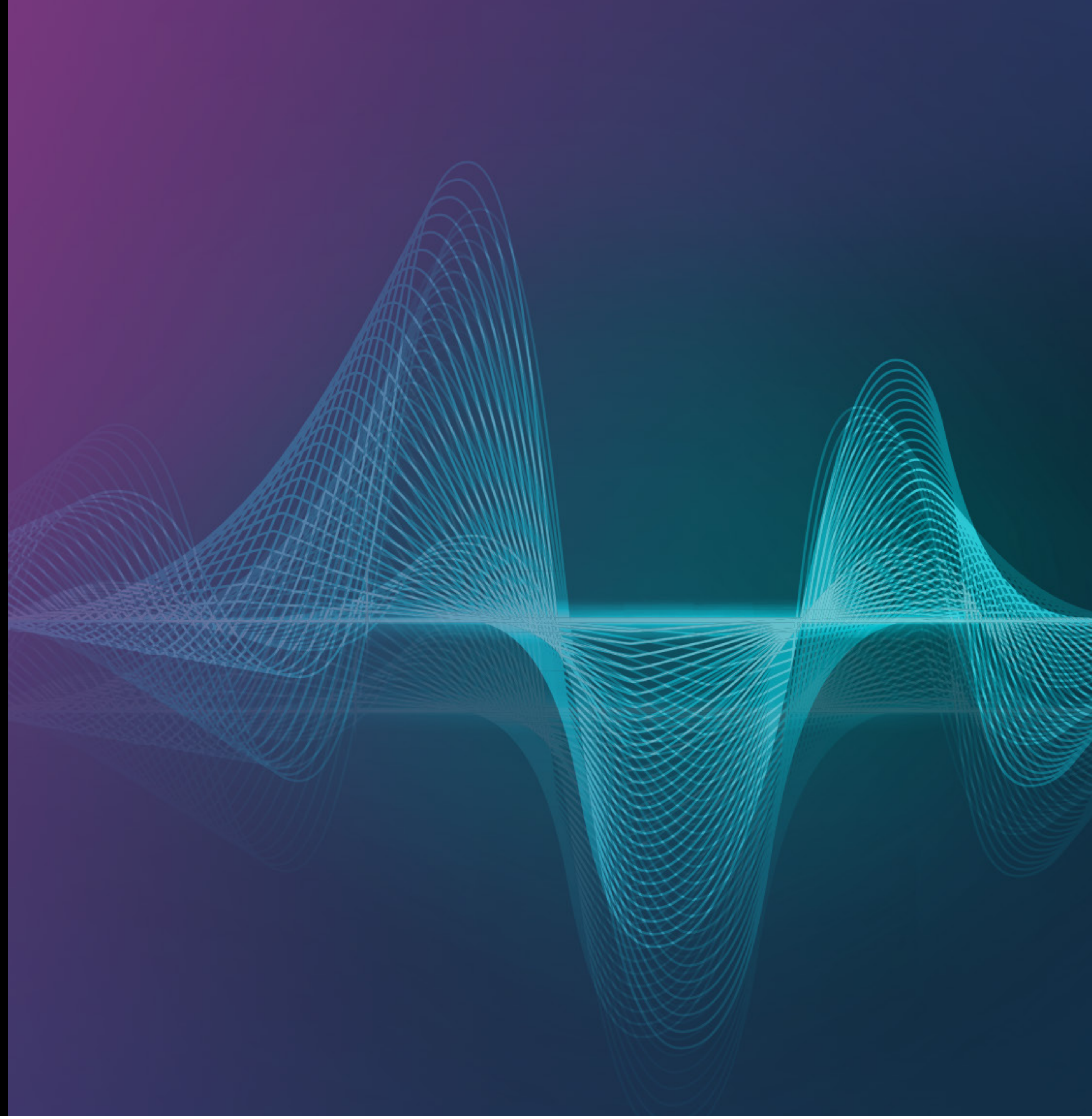


Figure 4. Combination of an ECG signal and a noise signal using the sum modulation capability of Keysight's 33622A function generator

TIP 2

Synchronizing Two Waveforms



Synchronizing Two Waveforms

Synchronized waveforms are waveforms with a specified amplitude, frequency, or phase relationship. In electronic design and testing, you sometimes want to have two synchronized clock signals related by a frequency ratio. This can be handy when you simulate a frequency doubler or for testing devices that require multiple reference clocks (Figure 5). To do this, one clock signal needs to maintain a certain frequency ratio with the other clock.

Or perhaps you may need to amplitude-couple two signals to simulate an amplifier with an offset. The simulated amplifier output needs to maintain a defined offset from the input amplitude. (Figure 6). You may also need to phase synchronize two waveforms together. Figure 6 is also a good example of two different signals that are phase synchronized.

These requirements may sound basic, but building your own clock reference device or frequency/amplitude coupling circuit takes time and resources. It’s much easier to use a dual-channel function generator that has built-in signal coupling.

Synchronized waveforms are waveforms with a specified amplitude, frequency, or phase relationship

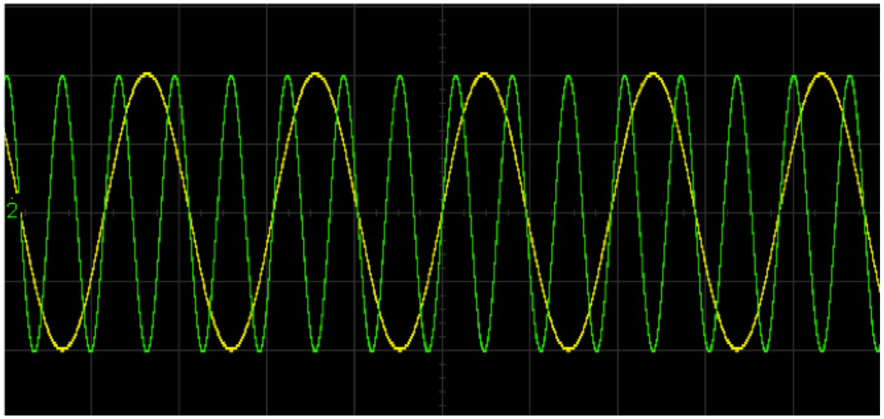


Figure 5. Two signals that are frequency coupled together

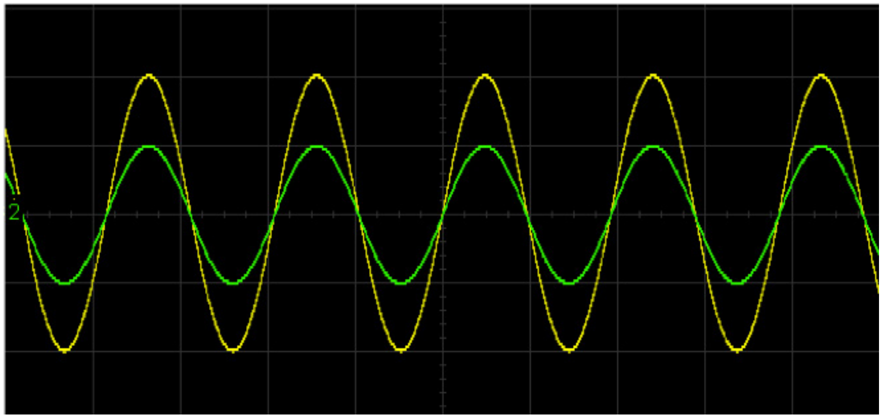


Figure 6. Two signals that are amplitude and phase coupled together

Example of testing a differential amplifier

Now, let's look at a concrete example involving synchronized signals: testing a differential amplifier.

Testing the differential gain of an amplifier requires synchronized input signals. A function generator and oscilloscope are the ideal test setup for this (Figure 7). If you have perfectly identical input signals for the amplifier, you should see a zero-difference output (straight line). Figure 8 shows an amplifier's non-zero resultant output.

- Use a power supply to provide DC bias for the amplifier
- Use a function generator to provide differential input source for the amplifier
- Use an oscilloscope to capture the differential inputs and the resultant amplifier output

Here are the steps used to configure the function generator:

1. Setup square wave for both Channel 1 and 2
2. Set the frequency of Channel 1 to be double of Channel 2
3. Set amplitude and phase coupling for Channels 1 and 2

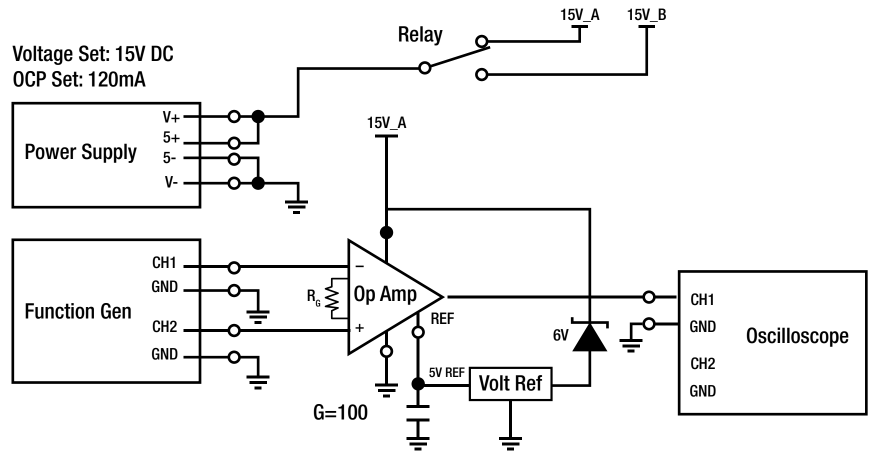


Figure 7. A diagram for setting up instruments to test a differential amplifier

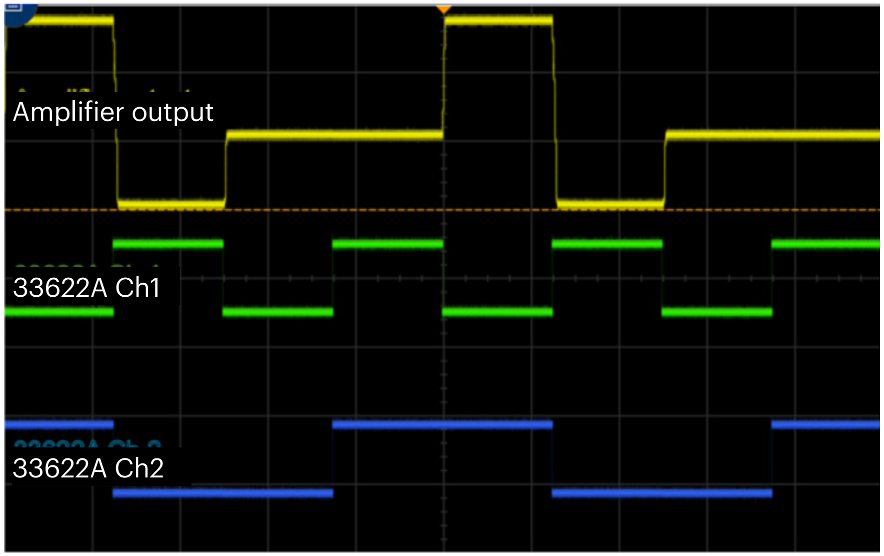


Figure 8. Two phased synchronized signals from the function generator and the resultant output signal from the differential amplifier

TIP 3

Creating Frequency Sweep Waveforms

Combining Two Waveforms

Synchronizing Two Waveforms

Sweep Waveforms

Modulating Your Waveforms

Time-Synchronized Waveforms

TIP 3

Creating Frequency Sweep Waveforms

A frequency sweep is a waveform that begins at a specified start frequency and sweeps to a specified stop frequency at a certain sweep rate. There are many applications that use frequency sweeping including microphone testing, mechanical resonant testing, electronic amplifier testing, passive filter response testing, automotive component durability testing, and more.

Typically, function generators can sweep up or down in frequency with either linear or logarithmic spacing. Figure 9 shows the frequency sweeps over time for both types of spacings. Figure 10 shows what an oscilloscope's captured sinusoidal output looks like for a linear frequency sweep.

A frequency sweep is a waveform that begins at a specified start frequency and sweeps to a specified stop frequency at a specified sweep rate.

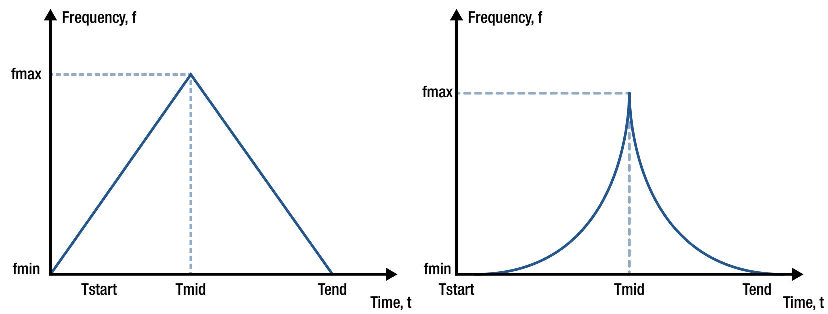


Figure 9. Frequency sweeps over time for linear and logarithmic spacings.

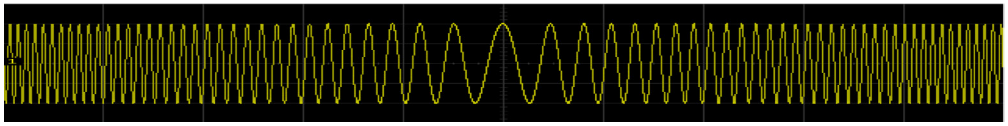


Figure 10. Linear frequency sweep output

Example of creating a radio frequency hopping signal

In addition to the frequency sweep capability, modern function generators can also use a “sweep frequency list.” As an example, this is useful if you need to simulate radio frequency hopping to test radio communication devices. Figure 11 shows you a Keysight 33622A function generator’s menu, where you can:

- enter your desired frequencies in the order you want
- set the dwell time for each frequency

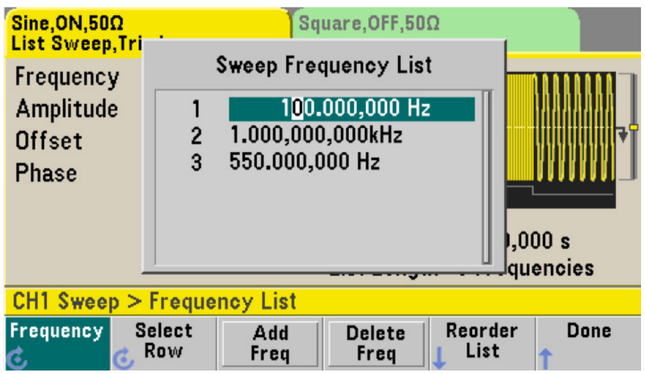


Figure 11. Sweep frequency list can simulate radio frequency hopping

Frequency hopping techniques are commonly used in radio and television broadcasting to minimize signal interference.

Military radio communication uses frequency hopping to avoid unauthorized tracking and interception of radio signals.

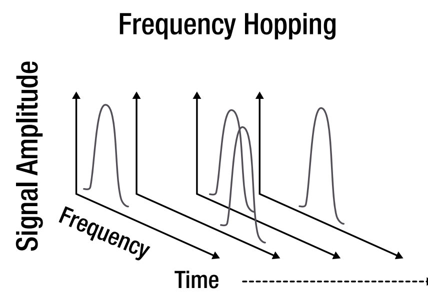
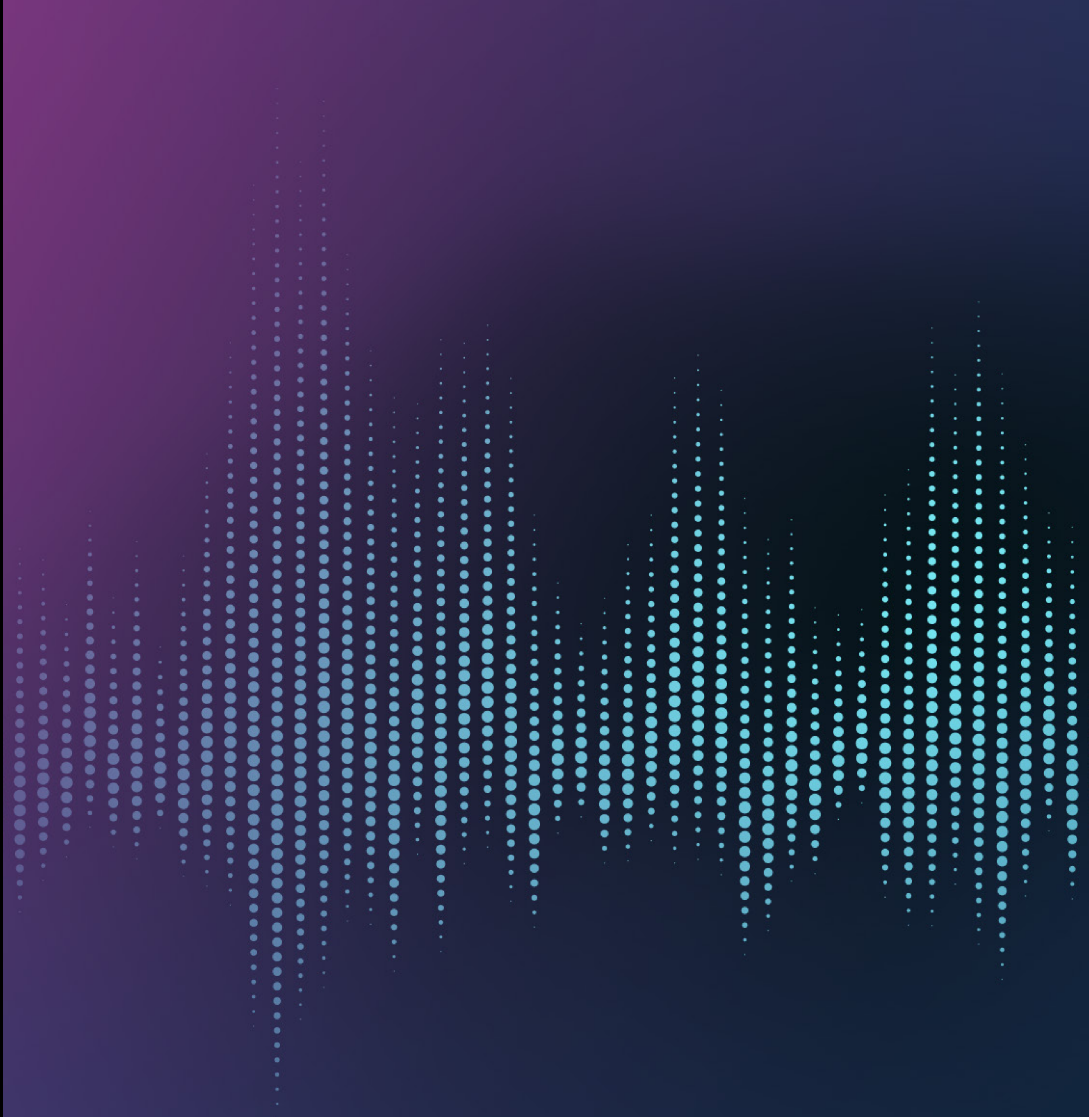


Figure 12. Graph shows user-defined radio frequency hopping over time

TIP 4

Modulating Your Waveforms



TIP 4

Modulating Your Waveforms

Most modern function generators can produce amplitude modulated waveforms and frequency modulated waveforms. Modulated waveforms are made up of a periodic waveform, called the carrier, and a modulating signal that modifies an attribute of the carrier. These attributes are typically frequency, amplitude, or phase.

Modulated waveforms are used for testing things such as RF signal generators, radio receivers and transceivers, filters, and amplifiers. Virtually all modern communication systems use modulation. What is modulation? Modulation is a way of encoding information into a carrier signal. If we have a carrier signal: **f(t) = A sin (wt + ø)**

Where:
A = Amplitude/magnitude
w = Frequency
ø = Phase angle

Some common types of modulations would be:

AM (amplitude modulation)
A modulating signal is used to change the amplitude of the carrier

FM (frequency modulation)
A modulating signal is used to change the frequency of the carrier

PM (phase modulation)
The phase of the carrier is changed

Modulated waveforms are made up of a periodic waveform, called the carrier and a modulating signal that modifies an attribute of the carrier.

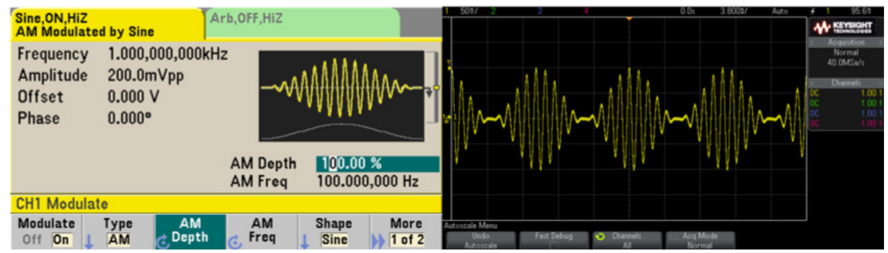


Figure 13. Simple amplitude modulation setup and output shown on oscilloscope

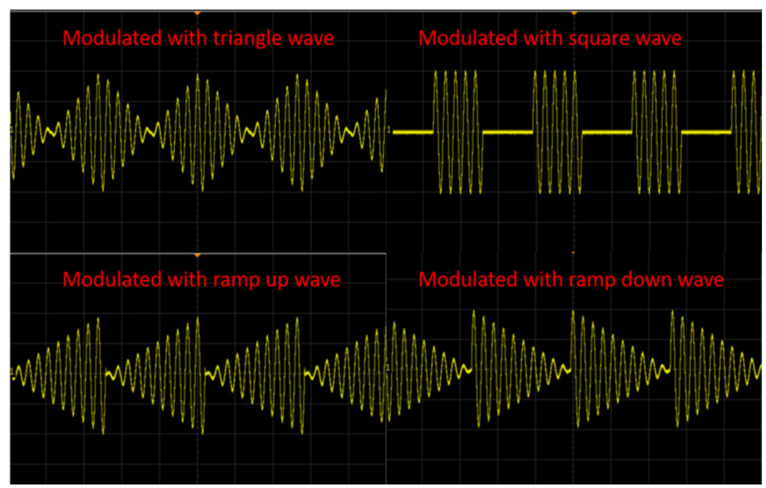


Figure 14. Various carrier signals used for waveform modulations (other than sine wave)

Setting up more advanced modulation

In addition to these types of modulations, there are more advanced modulation schemes. Some examples include:

FSK (Frequency-Shift Keying) – This is a form of frequency modulation in which information is transmitted using a pair of discrete frequencies to transmit binary (0s and 1s) information. This is commonly used in many communication systems. Figure 15 shows an example.

- *Button presses: Select menu button, Modulate > Type > FSK*
- *Button presses: Select menu button, Modulate > Hop Freq > 100 Hz*
- *Button presses: Select menu button, Modulate > FSK rate > 10 Hz*

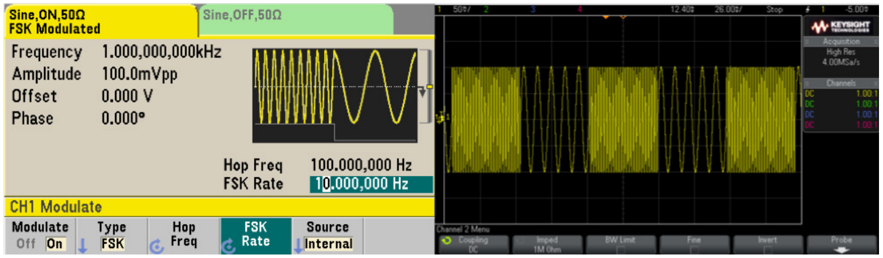


Figure 15. Simple FSK modulation setup and output shown on oscilloscope

BPSK (Binary Phase Shift Keying) – This is a form of phase modulation also referred to as phase reversal shift keying. Information is encoded by shifting the phase of the carrier to represent binary bits (1s or 0s). Figure 16 shows an example setup.

- *Button presses: Select menu button, Modulate > Type > BPSK*
- *Button presses: Select menu button, Modulate > BPSK phase > 180°*
- *Button presses: Select menu button, Modulate > BPSK rate > 10 Hz*

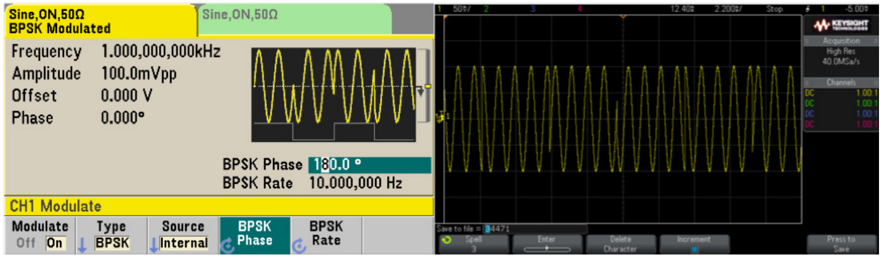
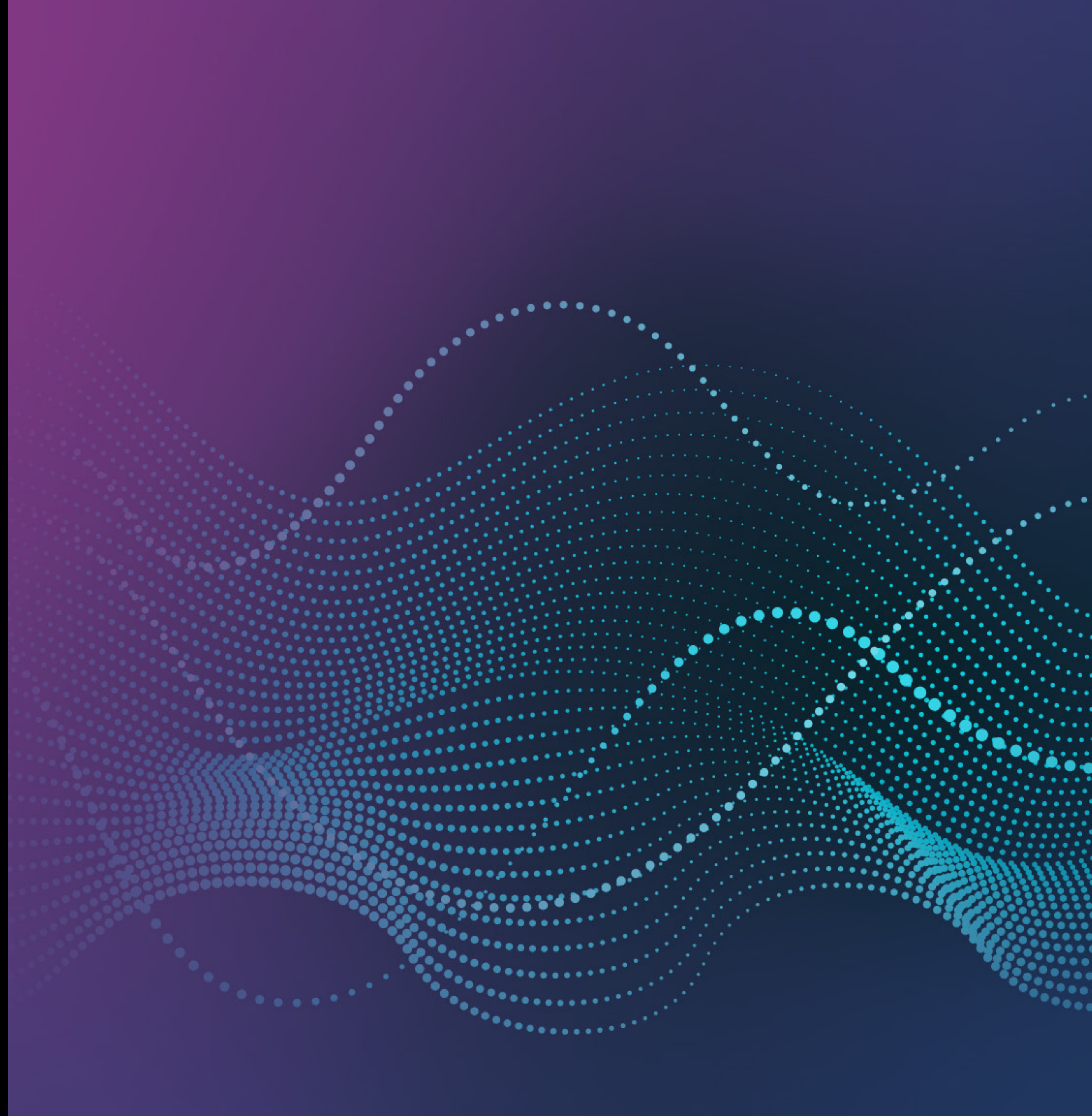


Figure 16. Simple BPSK modulation setup and output shown on oscilloscope

PWM (Pulse Width Modulation) – The duty cycle or width of the carrier wave is altered, usually square waves change according to the modulating signal. PWM is used widely in driving and controlling the speed of electric motors.

TIP 5

Creating More Than Two Time-Synchronizing Pulses



TIP 5

Creating More Than Two Time-Synchronizing Pulses

There are many applications that require multi-channel, time-synchronized waveforms. For example, some devices calibrate with synchronized pulses of varying pulse widths, or you might be simulating optocoupler decoder signals and multi-channel PWM motor controllers. You can easily simulate these signals using multiple basic function generators. Figure 17 shows four time-synchronized pulse trains with varying pulse widths. Keysight's 33500B and 33600A Series function generators can time synchronize up to four instruments together so you can actually have up to eight time-synchronized channels.

Figure 17. Time-synchronized, multi-channel outputs

Most instruments can be synchronized together using a 10 MHz reference clock signal. To do this, **set one of the function generators as the reference**, and set the other function generators to use the supplied reference instead of the internal reference. Then wire the instruments as shown in Figure 18, with the reference function generator shown on the left.

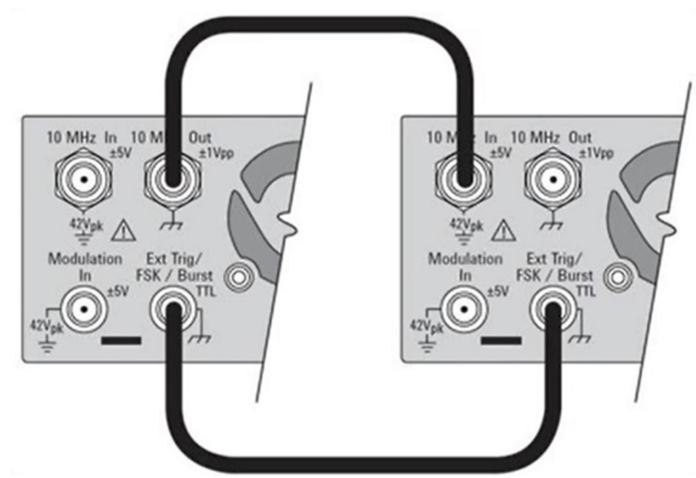


Figure 18. Example of a Keysight 33600A function generator's rear wire configurations on time-base and external trigger synchronization between two function generators

Time-synchronized waveforms are waveforms that share the same reference clock.

How to time-synchronize multiple generators

Here are the general steps to follow to time-synchronize multiple generators:

Step 1: Configure the reference oscillator source to an external source. Connect your second function generator to your reference function generator, and configure your second function generator's reference oscillator to "external." In the case of 33600A, press "menu," then ***System > Instrument Setup > 10 MHz Ref Osc > Source > External.*** Once this is done, you will see a green "Ext Lock" sign on the top right-hand side of your function generator, as shown in Figure 19.

Step 2: Use the reference function generator's trigger output. Set up your trigger for both channels on your second function generator. This tells the second function generator to start at the same time as the reference function generator. ***Button presses: Select Channel 1 output button and then press the Trigger button. Select Trigger Setup > Source > Ext (External). On the same screen menu level, select zero seconds delay and trigger slope on the rising edge. See Figure 15 on the external trigger menu.*** On the first reference function generator, set up the trigger for both channels to "manual" and "zero delays."

Step 3: Setup burst mode to trigger all channels together. Burst mode is available in most modern function generators. Use the burst mode to trigger all the channels to start simultaneously. Set up burst mode to run an infinite number of cycles and arm the trigger (Figure 20). ***Button presses: Go to all 4 channels, Select Burst > N Cycle > # Cycle > Infinite.*** Once the reference function generator is triggered, the output of all the function generators will be time-synchronized.

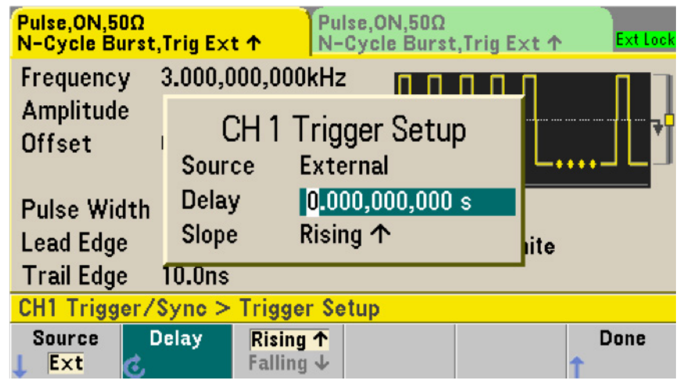


Figure 19. Time-synchronized, multi-channel outputs

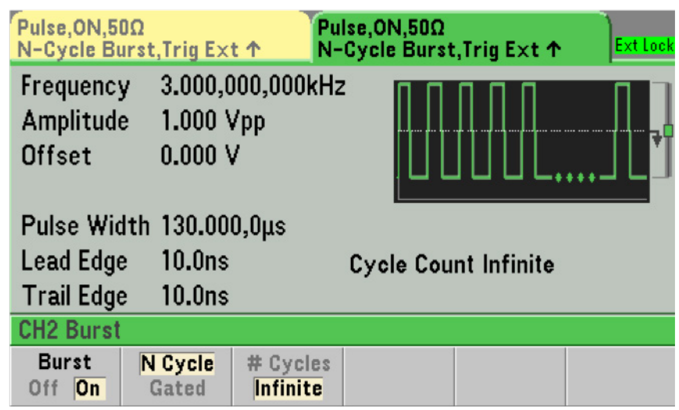
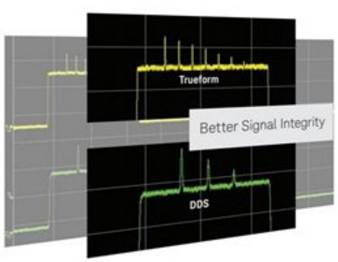


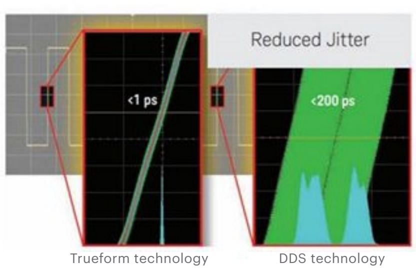
Figure 20. Burst mode setup menu on function generator

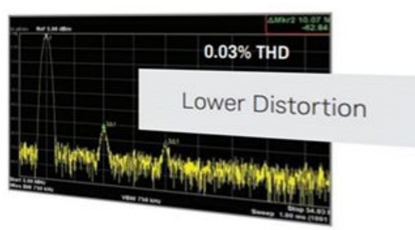
Modern function generators are very versatile and can do far more than create simple waveforms. These 5 tips should help you get the most out of your function generator.

- Combine two waveforms together to build more complex signals. You can also frequency couple the two combined waveforms.
- Synchronize two waveforms together in terms of frequency, amplitude, or phase. Synchronizing outputs allows you to create parallel complex signals to test or control your DUT (device under test).
- Sweep frequencies to perform frequency hop tests and characterize devices.
- Modulation allows you to modulate a waveform in terms of amplitude, frequency, or phase angle.
- Synchronize multiple function generators together. This allows you to create multi-channel signals that are phase synchronized.

Learn more about Keysight's latest Trueform function generators.







Keysight's True*form* Function Generators

The 33500B and 33600A Series function/arbitrary waveform generators offer the standard signals and features you'd expect, such as modulation, sweep, and burst, while also giving you additional capabilities and flexibility to help you get your job done faster. And the intuitive front-panel user interface makes them easy to learn how to use.

What else do you get?

- Large, color, graphical display that offers simultaneous parameter setup, signal viewing, and editing for easy operation
- Two independent channels that can be coupled in amplitude and frequency
- Front-panel USB thumb drive port for file management
- Built-in help system
- LAN (LXI Core), USB, and optional GPIB for quick and easy connectivity to a PC or network
- External triggering

Learn more about Keysight's latest Trueform function generators.

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