

# Adding DC Offsets to a Function Generator's Output

A variety of electronic test applications require you to add a DC offset to a function generator's output. The result is a signal that is a waveform superimposed on top of a DC voltage. For example, you can use a sine wave added on top of a DC bias voltage for testing a circuit's immunity to noise that appears on its real bias voltages. For amplifier testing, you can bias a transistor with DC that has an AC component riding on top of it. Even a repetitive series of unipolar pulses (used for driving a FET gate signal for DC/DC converters) are thought of as a pulse train with a DC offset. All of these applications need a DC plus AC signal, all with different voltage, current, and waveform bandwidth requirements.

You can use various methods to generate a waveform on top of a DC voltage. A function generator by itself produces a waveform with a DC offset. If you cannot set the DC offset high enough, adding a DC power supply in series with the function generator helps. When you need larger currents, you can use a DC power supply with external analog programming terminals that you can drive with a function generator. Or you can use a current transformer driven by a function generator to couple an AC waveform onto the output of a DC power supply.

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#### DC-to-DC Converter Design

Engineers working on a new DC-to-DC converter design needed to experiment with the switching frequencies and drive levels of the main FET switching elements. To experiment with the control signals for the FET gate drive circuitry, they needed to create various drive signals consisting of voltage pulses offset by a DC voltage.



### Using a Function Generator by Itself

Most function generators produce a DC offset in conjunction with their output waveforms, as shown in Figure 1. However, because of the placement of internal attenuators, some function generators do not let you produce the full range of DC output voltages when small amplitude waveforms are set. Recent Keysight Technologies, Inc. function generators do not have this limitation. For example, the Keysight 33210A, 33500B and 33600A function/ arbitrary waveform generators produce an output signal with a combined DC offset plus waveform signal voltage in the range of –5 V to +5 V into a 50-ohm load (–10 V to +10 V into an open circuit). Therefore, you can set the function/arbitrary waveform generators to produce a small 10-mVpp waveform with a DC offset as large as 4.995 V into 50 ohms. While this is the most convenient way to produce a signal riding on top of a DC offset than is available from your function generator, you need to use a different technique.



Figure 1: Producing DC+AC using only a function generator

### Measurement Tip

Most function generators have a 50-ohm output impedance. There is a 50-ohm resistor inside the function generator that is in series with the output. This design helps minimize signal reflections when the output is connected to a coax cable with a characteristic impedance of 50 ohms and is terminated with a 50-ohm load. The 50-ohm output impedance and 50-ohm load form a 2-to-1 voltage divider. Therefore, the actual internal function generator voltage is twice your set value,  $V_{ser}$ , to produce an output voltage on the 50-ohm load equal to your setting. Note: if the load resistance is infinite (an open circuit), the resulting output voltage is twice your set value other than 50 ohms, the actual output voltage,  $V_{our}$  is:  $V_{our} = 2V_{ser}$  [RL / (50 + RL)]. See Figure 2.



If you set a voltage  $V_{set}$  with  $R_L = 50\Omega$ :  $V_{out}=2V_{set} [50/(50+50)] = V_{set}$ If you set a voltage  $V_{set}$  with  $R_L = \infty \Omega$ :  $V_{out}=2V_{set} [\infty/(50+\infty)] = 2V_{set}$ 





Figure 3: Producing DC+AC using a function generator in series with a DC power supply

### Using a Function Generator in Series with a Power Supply

If you want to produce a signal riding on top of a DC offset, but require a DC offset larger than your function generator delivers, place a DC power supply in series with the function generator output, as shown in Figure 3 above. This technique offers you the function generator's full bandwidth capabilities in addition to having flexibility in the DC level provided by the power supply. However, this technique has a few important limitations. The function generator output may or may not be internally isolated (floating) from earth ground. When it is isolated, there is a specification indicating the maximum amount of voltage from earth ground that you can float the output. For example, the Keysight function/arbitrary waveform generator's output is isolated from earth ground, and you can float the output from ground up to  $\pm 42$  V. This means that if you put a DC power supply in series with the function generator output, the DC offset must be less than  $\pm 42$  V. If the function generator output is internally connected to earth ground, the power supply output voltage must be isolated from earth ground (unless you plan to connect the earth grounded nodes together). The majority of Keysight power supplies have outputs isolated from earth ground, and they can typically float  $\pm$  240 V from ground.

# Measurement Tip

Keysight's function/arbitrary waveform generators let you enter a value for the expected load resistance, RL, in the range of 1 ohm to 10 k ohms, or infinite. The default value is 50 ohms. If you change the value for this parameter, the function generator automatically adjusts the internal voltage it produces to take into consideration the voltage divider formed by the internal 50-ohm resistor and your load resistance such that VOUT is equal to your voltage setting. This adjustment applies to both the DC offset and AC portion of the function generator output signal.

Another limitation of using this method is the current available to your load is limited to the output current of the function generator you choose, since the load current must flow through both the power supply and function generator. Also, most function generators have a 50-ohm output impedance, meaning any load current flows through this resistance. This resistance forms a voltage divider with your load impedance, so be sure to adjust the DC power supply output voltage accordingly.



### Using a Power Supply Driven by a Function Generator

Another way to produce a signal with a large DC offset is using a power supply that has an external analog programming input. A voltage applied to this input is amplified by the power supply and produces a proportional voltage on the power supply output terminals. Therefore, you can connect a function generator output to the analog programming input and modulate the power supply output voltage with the function generator signal. See Figure 4. This technique provides a lot of flexibility in the DC offset voltage and in the amount of current available to your load (both of which are determined by the power supply ratings). However, the performance of most DC power supplies imposes significant bandwidth limitations. While most function generators produce waveforms in the MHz range, the output voltage of most DC power supplies has a bandwidth of only a few kHz. So, when you use this technique, the signal on the power supply's output (consisting of the DC offset plus a waveform) has a bandwidth of only a few kHz.



Figure 4: Producing DC + AC using a function generator to drive the analog programming input of a DC power supply

#### Using a Current Transformer Driven by a Function Generator

To get the full output voltage and current benefits of a power supply combined with the higher signal bandwidth available from a function generator, you can put a current transformer, driven by a function generator, in series with the output of a power supply. Select a current transformer that can support the bandwidth you need. Also, ensure the current transformer can support the maximum DC current you expect to flow through it to your load. See this configuration in Figure 5.

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Figure 5: Producing DC + AC using a DC power supply in series with a current transformer driven by a function generator

## Summary

A variety of applications require adding a DC offset to a function generator's output. There are several different ways to accomplish this task. Each method has advantages and disadvantages affecting output voltage, output current, output bandwidth, and the ease of implementation. Keysight function generators produce DC offsets across their entire output voltage range, even with small amplitude waveforms. Ultimately, the method you choose depends on your specific requirements, the equipment at your disposal, and the time you can commit to creating a solution.

To learn more about Keysight's function generators, please visit our website at: www.keysight.com/find/function-generators.

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