

# Keysight Technologies

## Adding DC Offsets to a Function Generator's Output

Application Note



A variety of electronic test applications require a DC offset to be added to the output of a function generator. 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 can appear 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, can be 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 can produce a waveform with a DC offset. If the DC offset cannot be set high enough, adding a DC power supply in series with the function generator can help. When you need larger currents, you can use a DC power supply that has external analog programming terminals 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. Finally, some power supplies can produce AC waveforms right on top of their own DC outputs.

### Snapshot: 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 Keysight Technologies 33220A function/arbitrary waveform generator, they were able to create the required waveforms with a DC offset on a signal for which they could vary the frequency, pulse width, and rise time using simple controls built into the function generator.

## Using a function generator by itself

Most function generators have the ability to 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 allow you to 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 33220A function/arbitrary waveform generator can produce an output signal with a combined DC offset plus waveform signal voltage in the range of  $-5\text{ V}$  to  $+5\text{ V}$  into a  $50\text{-ohm}$  load ( $-10\text{ V}$  to  $+10\text{ V}$  into an open circuit). Therefore, you can set the 33220A to produce a small  $10\text{-mVpp}$  waveform combined with a DC offset as large as  $4.995\text{ V}$  into  $50\text{ ohms}$ . While this is the most convenient way to produce a signal riding on top of a DC offset, your application may require more. If you need to produce a signal with a larger DC offset than is available from your function generator, you will have to use a different technique.

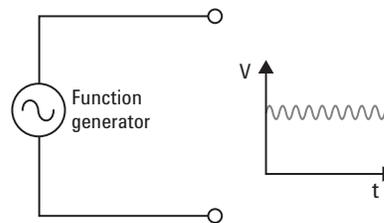
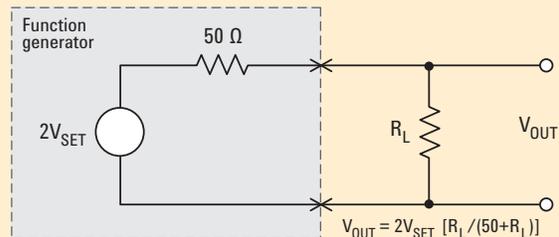


Figure 1.  
Producing DC + AC using  
only a function generator

### MEASUREMENT TIP

Most function generators are designed with a  $50\text{-ohm}$  output impedance – there is a  $50\text{-ohm}$  resistor inside the function generator that is in series with the output. This design helps to minimize signal reflections when the output is connected to a coax cable that has a characteristic impedance of  $50\text{ ohms}$  and is terminated with a  $50\text{-ohm}$  load. The  $50\text{-ohm}$  output impedance and  $50\text{-ohm}$  load form a 2-to-1 voltage divider. Therefore, the actual internal function generator voltage that is produced is twice your set value,  $V_{\text{SET}}$ , to produce an output voltage on the  $50\text{-ohm}$  load equal to your setting. Note that if the load resistance is infinite (an open circuit), the resulting output voltage will be twice your setting. And if the load resistance,  $R_L$ , is any value other than  $50\text{ ohms}$ , the actual output voltage,  $V_{\text{OUT}}$ , will be:  $V_{\text{OUT}} = 2V_{\text{SET}} [R_L / (50 + R_L)]$ . See Figure 2.



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

Figure 2. Effect of function generator  $50\ \Omega$  output impedance on output voltage

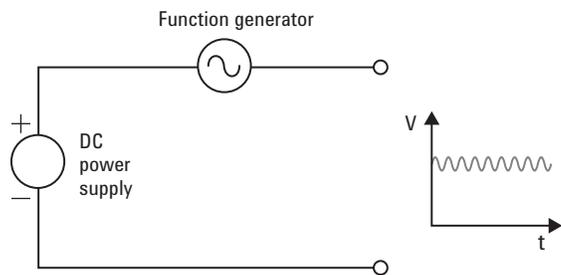


Figure 3. Producing DC + AC using a function generator in series with a DC power supply

## 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 you require a DC offset larger than your function generator can deliver, you can put a DC power supply in series with the function generator output, as shown in Figure 3 above. Using this technique, you will have the full bandwidth capabilities of the function generator available to you in addition to having flexibility in the DC level provided by the power supply. However, this technique has a few important limitations. The output of the function generator 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 off of earth ground that you can float the output. For example, the Keysight 33220A's output is isolated from earth ground and you can float the output off of 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, then the power supply output voltage must be isolated from earth ground (unless you plan to connect the earth grounded nodes together). The vast majority of Keysight power supplies have outputs that are isolated from earth ground, and they can typically float  $\pm 240$  V from ground.

### MEASUREMENT TIP

Keysight 33210A, 33220A, and 33250A function/arbitrary waveform generators allow you to enter a value for the expected load resistance,  $R_L$ , 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 will automatically adjust 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  $V_{OUT}$  is equal to your voltage setting. This adjustment applies to both the DC offset and the AC portion of the function generator output signal.

Another limitation of using this method is that 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 the function generator. Also, most function generators have a 50-ohm output impedance, meaning any load current will flow through this resistance. This resistance will form 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 to use a power supply that has an external analog programming input. A voltage applied to this input gets 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 can 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 output of the power supply consisting of the DC offset plus a waveform will have a bandwidth of only a few kHz.

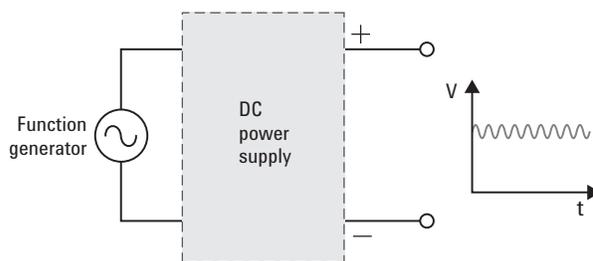


Figure 4. Producing DC + AC using a function generator to drive the analog programming input of a DC power supply

## 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. Be sure to select a current transformer that can support the bandwidth you need. Also be sure that the current transformer can support the maximum DC current you expect to flow through it to your load. This configuration is shown in Figure 5.

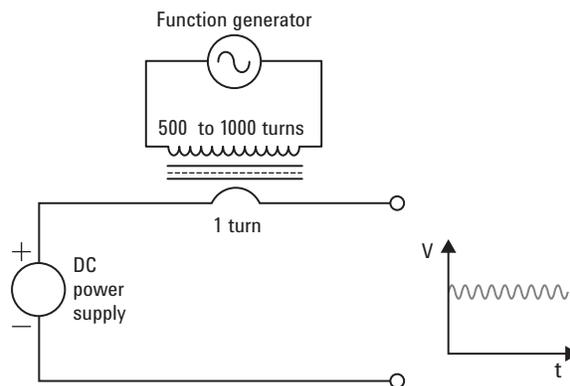


Figure 5. Producing DC + AC using a DC power supply in series with a current transformer driven by a function generator

## Using a power supply with a built-in waveform generator

If you require voltages or currents that are larger than those available from a function generator and your frequency requirements are low (up to several kHz), consider using a power supply with a built-in waveform generator. The Keysight N6705A DC power analyzer has the ability to produce arbitrary waveforms on top of its DC output voltages without the need for any external equipment (such as a function generator or current transformer). Since this capability is fully integrated into the product, it is the most convenient method available for producing signals of this type. However, since the outputs are really DC power supplies, the bandwidth is again limited to several kHz.

## Summary

Adding a DC offset to a function generator's output is required in a variety of applications. There are several different ways of accomplishing this task; each method has advantages and disadvantages affecting output voltage, output current, output bandwidth, and ease of implementation. Keysight function generators have the benefit of being able to produce DC offsets across their entire output voltage range, even with small amplitude waveforms. Ultimately, the method you choose to use will depend on your specific requirements, the equipment you have at your disposal, and the time you can commit to creating a solution for yourself.



For more information on Keysight Technologies' products, applications or services, please contact your local Keysight office. The complete list is available at: [www.keysight.com/find/contactus](http://www.keysight.com/find/contactus)

### Americas

Canada	(877) 894 4414
Brazil	55 11 3351 7010
Mexico	001 800 254 2440
United States	(800) 829 4444

### Asia Pacific

Australia	1 800 629 485
China	800 810 0189
Hong Kong	800 938 693
India	1 800 112 929
Japan	0120 (421) 345
Korea	080 769 0800
Malaysia	1 800 888 848
Singapore	1 800 375 8100
Taiwan	0800 047 866
Other AP Countries	(65) 6375 8100

### Europe & Middle East

Austria	0800 001122
Belgium	0800 58580
Finland	0800 523252
France	0805 980333
Germany	0800 6270999
Ireland	1800 832700
Israel	1 809 343051
Italy	800 599100
Luxembourg	+32 800 58580
Netherlands	0800 0233200
Russia	8800 5009286
Spain	0800 000154
Sweden	0200 882255
Switzerland	0800 805353
	Opt. 1 (DE)
	Opt. 2 (FR)
	Opt. 3 (IT)
United Kingdom	0800 0260637

For other unlisted countries:  
[www.keysight.com/find/contactus](http://www.keysight.com/find/contactus)  
 (BP-07-10-14)

[www.keysight.com/find/functiongenerators](http://www.keysight.com/find/functiongenerators)