

Adding DC Offsets to a Function Generator's Output

Introduction

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 voltages, currents, 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.

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 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 can 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. The latest Keysight function generators do not have this limitation. For example, the Keysight 33500B and 33600A function / arbitrary waveform generator can 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 33220A to produce a small 10-mVpp waveform combined 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, 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.

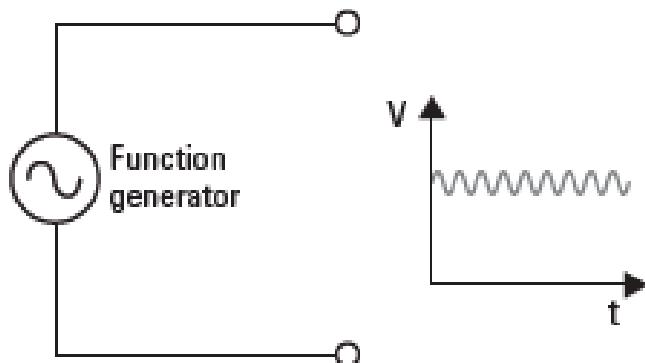
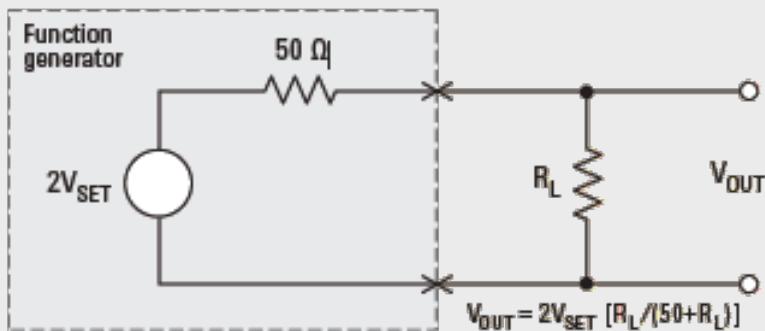


Figure 1. Producing DC + AC using only a function generator



Measurement Tip

Most function generators are designed with a 50-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 that is produced is twice your set value, V_{SET} , to produce an output voltage on the 50-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 ohms, the actual output voltage, V_{OUT} , will be: $V_{OUT} = 2V_{SET} [R_L / (50 + R_L)]$. 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 2. Effect of the function generator 50 Ω output impedance on the output voltage

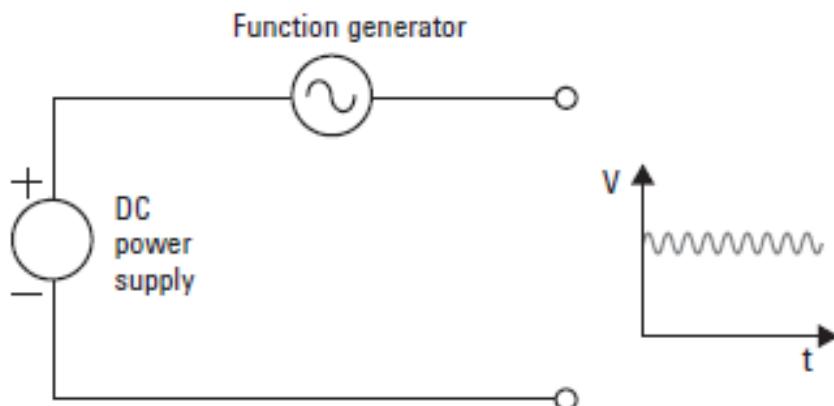


Figure 3. Producing DC + AC using a function generator in series with a DC power supply

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 significant 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 33500B and 33600A series output is isolated from earth ground. You can float the output off the ground up to ± 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 ± 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). The vast majority of Keysight power supplies have outputs that are isolated from earth ground, and they can typically float ± 240 V from ground.

Measurement Tip

Keysight 33500B and 33600A series function/arbitrary waveform generators allow you to enter a value for the expected load resistance, RL , in the range of 1-ohm to 10k-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.

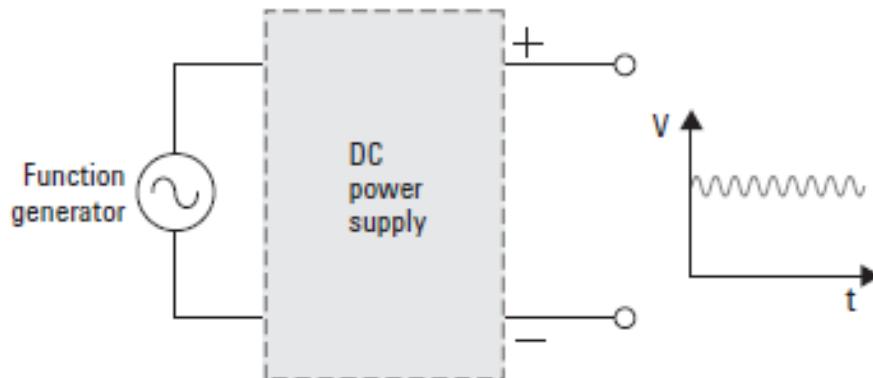


Figure 4. Producing DC + AC using a function generator to drive the analog programming input of a DC power supply

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.

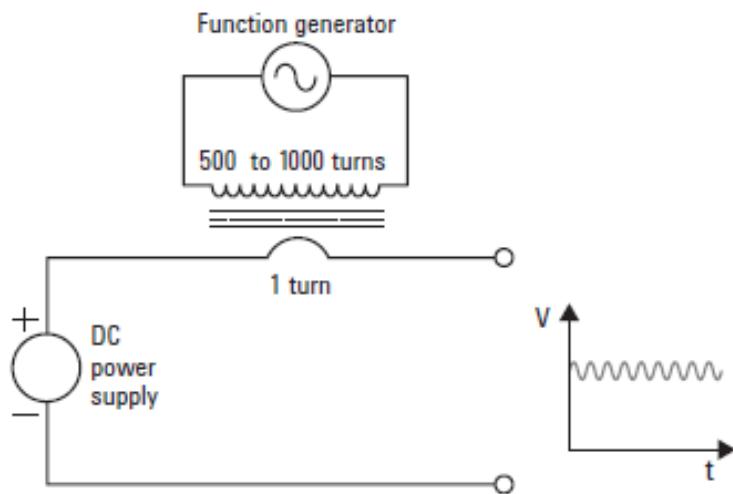


Figure 5. Producing DC + AC using a DC power supply in series with a current transformer driven by a function generator

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 N6705C DC power analyzer can 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 to accomplish this task; each method has its 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

To learn more about the Keysight's function generators, go to
www.keysight.com/us/en/products/waveform-and-function-generators.html

Keysight enables innovators to push the boundaries of engineering by quickly solving design, emulation, and test challenges to create the best product experiences. Start your innovation journey at www.keysight.com.