When to Choose a Dedicated Arbitrary Function Generator (AFG)

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TECHNICAL BRIEF

Tektronix®

Abstract

This paper aims to help you select a method of arbitrary function generation best suited to your needs by addressing the key specifications of various Tektronix and Keithley dedicated Arbitrary Function Generators (AFGs) and the AFG functionality optionally included in Tektronix Oscilloscopes. Furthermore, this paper uses these specifications and examples of real-world applications to help you determine the optimum method of arbitrary function generation for your application.

Introduction

An Arbitrary Function Generator is an instrument with the ability to create arbitrary waveforms, replicate generate standard waveforms (e.g., sine waves, square waves, etc.) and custom or arbitrary waveforms. AFGs are commonly used in bench top applications where a waveform is generated and output to a Device Under Test (DUT), whose performance can be analyzed by a Tektronix Oscilloscope. Tektronix offers AFGs as both dedicated instruments and as upgradeable functionality on Oscilloscopes, allowing you to choose the instrument that most efficiently and economically meets your needs. You may find that the built-in AFG on select oscilloscope models, with their ability to generate signals and take measurements on just one instrument, meets your needs sufficiently and offers variety and density that cannot be matched by a multi-instrument setup. Or you may require more functionality than the on-scope AFG provides. This is where the AFG1k and AFG31k series are best suited.

Key AFG Specs

The following are crucial factors to help you determine which Tektronix AFG is right for you: output frequency, number of channels, amplitude, sample rate, and record length. The output frequency determines the maximum frequency of the signal being output. When choosing an AFG solution, customers should ensure their selection can output at their desired frequency. Next, the number of channels determines how many signals can be generated and output at any given time. The amplitude of an AFG, measured in peak-to-peak voltage at 50 Ω input, determines the "size" of the waveform. When choosing an AFG solution, ensure that your AFG can output a waveform with your desired amplitude. The record length is the number of samples that can be used to define a waveform. A higher record length allows for greater resolution and more accurate reproduction of a waveform. Lastly, the sample rate is how many of these samples can be taken in one second. A higher sampling rate leads to more precise, high-fidelity signals.

On–Scope AFG Features

Most Tektronix oscilloscopes have optional, built-in AFG functionality, including the 2 series, 4 series, 5 series B, and 6 Series B Mixed Signal Oscilloscopes (MSOs), 3000, 4000C, and 3 series Mixed Domain Oscilloscopes (MDOs), and the low-profile version of the 5 Series MSO. Except for the 5 series B MSOs, all Oscilloscope AFG applications have a maximum bandwidth of 50 MHz, maximum amplitude of 5 Vp-p, sampling rate of 250 MS/s, 128K sample record length, and 1 channel. The 5 series MSOs increase the maximum bandwidth to 100 MHz. Additionally, the 4 series, 5 series B, and 6 series B MSOs have an optional Double Pulse test package for power applications.

Model	2/4/5-LP/6B/6-LP Series MSO, 3000C/4000C/3 Series MDO	5 Series B MSO
Bandwidth	0.1 Hz to 50 MHz (sine) 25 MHz (Square/Pulse) 500 kHz (Ramp/Triangle)	0.1 Hz to 100 MHz (sine) 50 MHz (Square/Pulse) 1 MHz (Ramp/Triangle)
Sampling Rate	250 MS/s	250 MS/s
Waveform Length	128K points	128K points
Amplitude	10 mVp-p to 2.5 Vp-p (Most waveforms) (Double both into Hi-Z)	10 mVp-p to 2.5 Vp-p (Most waveforms) (Double both into Hi-Z)

Table 1: On-Scope AFG Comparisons

Dedicated AFG Features

Tektronix also offers a variety of hardware dedicated to signal generation. These offerings include the entry AFG1k models and the mainstream AFG31k. While the AFG1k models are roughly equivalent to the on-scope AFGs in terms of functionality, the advantages of the AFG31000 Series over the on-scope AFGs include more channels, higher bandwidths, better resolution, and one hundred times greater arb memory, allowing for the creation of more complex waveform creation. Other unique features of the AFG31ks include InstaView™, on-instrument apps like ArbBuilder and Double Pulse Test, and sequencing.

InstaView™ is a technology patented by Tektronix which allows users to see the signal generated by the AFG exactly as it is seen by the DUT, without any additional equipment. While most function generators assume a 50 Ω load impedance, and Tektronix AFG31K models can manually set a load impedance from 1 Ω to 100 Ω, an impedance mismatch at the source and load can cause a signal to appear differently at the DUT. This is where InstaView™ technology adds value: it can calculate the waveform appearing at the DUT and display that waveform in real-time on the AFG31K display, by allowing the AFG31K to measure the propagation delay in a BNC and determine any existing impedance mismatch between the AFG31K and the DUT.

ArbBuilder is an app included with AFG31K models that expands on the functionality of the AFG by giving you the ability to create and edit arbitrary waveforms directly on the AFG. With ArbBuilder, users can create a waveform by either selecting one from a list of standard functions, entering an equation, or manually drawing one. After you create a waveform, you can then edit the waveform with various in-app tools while the waveform is displayed in the preview window. The same functionality is also offered in the ArbExpress software, which is available for use on Windows-based operating systems.

Also included with the AFG31K is the ability to perform Double Pulse tests with the on-instrument Double Pulse app. While most function generators are unable to easily and independently adjust pulse width and amplitude, Tektronix AFG31K models with the Double Pulse test app are able. With the app you can easily and quickly measure the turn-on, turn-off, and reverse recovery parameters of a MOSFET or IGBT.

The AFG31K models also have a sequencing option in advanced mode. This sequencing option further expands the functionality of AFG31Ks and allows you to use the AFG31k as an arbitrary waveform generator. With the sequence option in advanced mode, you can stitch together various waveforms, in various combinations, to create a new arbitrary waveform. More specifically, sequence mode allows you to:

- Populate a list with waveforms and choose when to run each individual waveform;

- Set number of repetitions of each individual waveform;

- Set what step to go to after a waveform is outputted;

- what step to jump to if a certain condition has been met, when to wait if a certain condition has been met, and how many times to run the overall sequence.

Model	2/4/5-LP/6B/6-LP Series MSO, 3000C/4000C/3 Series MDO	5 Series B MSO	AFG1022	AFG1062
Bandwidth	0.1 Hz to 50 MHz (Sine) 25 MHz (Square/Pulse) 500 kHz (Ramp/Triangle)	0.1 Hz to 100 MHz (Sine) 50 MHz (Square/Pulse) 1 MHz (Ramp/Triangle)	1 µHz to 25 MHz (Sine) 12.5 MHz (Square/Pulse/Arbitrary) 1 MHz (Ramp/Triangle)	1 µHz to 60 MHz (Sine) 30 MHz (Square/Pulse/Arbitrary) 2 MHz (Ramp/Triangle)
Sampling Rate	250 MS/s	250 MS/s	125 MS/s	300 MS/s
Waveform Length	128K points	128K points	8K points	8k points
Amplitude	10 mVp-p to 2.5 Vp-p (Most waveforms) (Double both into Hi-Z)	10 mVp-p to 2.5 Vp-p (Most waveforms) (Double both into Hi-Z)	1 mVp-p to 10 Vp-p (Most Waveforms) (Double both into Hi-Z)	≤ 25 MHz: 1 mVp-p to 10 Vp-p > 25 MHz: 1 mVp-p to 5 Vp-p (Double both into Hi-Z)
ArbBuilder	No	No	No	No
InstaView™	No	No	No	No
Sequence	No	No	No	No
Double Pulse Test	Yes (4/5/6B series)	Yes	No	No
Channels	1	1	1 or 2	1 or 2

Table 2: AFG1K vs On-Scope AFG

Model	2/4/5-LP/6B/6-LP Series MSO, 3000C/4000C/3 Series MDO	5 Series B MSO	AFG3102X	AFG3105X
Bandwidth	0.1 Hz to 50 MHz (Sine) 25 MHz (Square/Pulse) 500 kHz (Ramp/Triangle)	0.1 Hz to 100 MHz (Sine) 50 MHz (Square/Pulse) 1 MHz (Ramp/Triangle)	1 µHz to 25 MHz (Sine) 20 MHz (Square/Pulse) 12.5 MHz (Arbitrary) 500 kHz (Others)	1 µHz to 50 MHz (Sine) 40 MHz (Square/Pulse) 25 MHz (Arbitrary) 800 kHz (Others)
Sampling Rate	250 MS/s	250 MS/s	250 MS/s	1 GS/s
Waveform Length	128K points	128K points	131,072 points	131,072 points
Waveform Memory Size	N/A	N/A	16 MS/CH (128 MS/CH Optional)	16 MS/CH (128 MS/CH Optional)
Amplitude	10 mV to 2.5V (Most waveforms) (Double both into Hi-Z)	10 mV to 2.5V (Most waveforms) (Double both into Hi-Z)	1 mVpp to 10 Vpp (Double both into Hi-Z)	1 mVpp to 10 Vpp (Double both into Hi-Z)
ArbBuilder	No	No	Yes	Yes
InstaView™	No	No	Yes	Yes
Sequence	No	No	Yes	Yes
Double Pulse Test	Yes (4/5/6B series)	Yes	Yes	Yes
Channels	1	1	1 or 2	1 or 2

Model	AFG3110X	AFG3115X	AFG3125X
Bandwidth	1 µHz to 100 MHz (Sine) 80 MHz (Square/Pulse) 50 MHz (Arbitrary) 1 MHz (Others)	1 µHz to 150 MHz (Sine) 120 MHz (Square/Pulse) 75 MHz (Arbitrary) 1.5 MHz (Others)	1 µHz to 250 MHz (Sine) 160 MHz (Square/Pulse) 125 MHz (Arbitrary) 2.5 MHz (Others)
Sampling Rate	1 GS/s	2 GS/s	2 GS/s
Waveform Length	131,072 points	131,072 points	131,072 points
Waveform Memory Size	16 MS/CH (128 MS/CH Optional)	16 MS/CH (128 MS/CH Optional)	16 MS/CH (128 MS/CH Optional)
Amplitude	1 mVp-p to 10 Vp-p, 1 mVp-p to 8 Vp-p (Sine wave at >60 MHz to 80 MHz), 1 mVp-p to 6 Vp-p (Sine wave at >80 MHz to 100 MHz), 1 mVp-p to 5 Vp-p (Square/pulse at >40 MHz to 80 MHz) (Double into Hi-Z)	1 mVpp to 5 Vpp (Double Both into Hi-Z)	1 mVpp to 5 Vpp (Double Both into Hi-Z)
ArbBuilder	Yes	Yes	Yes
InstaView™	Yes	Yes	Yes
Sequence	Yes	Yes	Yes
Double Pulse Test	Yes	Yes	Yes
Channels	1 or 2	1 or 2	1 or 2

Table 3: AFG31K vs On-Scope AFG

Applications

The AFG1022, AFG1062, and On-Scope AFGs offer plenty of bandwidth, resolution, and memory to store and reproduce high-fidelity signals perfect for filling your education lab's bench. This means that if you are looking for both a basic arbitrary signal generation device and a measurement device receive a tremendous value when purchasing one of the select oscilloscope models. One device can take care of both of your needs while freeing up test bench space. If you are looking for basic signal generation and either already own a Tektronix Oscilloscope or do not need an oscilloscope, you can choose between the AFG1022 and AFG1062 for a valuable two channel solution.

Because the On-Scope AFGs have similar specifications as the AFG1K series, but only have one channel, they are ideal for tasks that do not require the additional channels of a dedicated AFG or the more advanced specifications of the AFG31K series. For instance, the On-Scope AFG can be used as a clock source for embedded and semiconductor tests. In doing so, the clock frequency operating range of digital circuits can be tested. Additionally, the one-channel On-Scope AFG can be used to test detector circuits for medical ultrasound equipment. This can be done by using the arbitrary waveform setting to simulate an ultrasound detector signal, which is then used to characterize the input circuit of an ultrasound system.

In addition to being able to perform the same tasks discussed previously, the AFG1K series has an optional second channel which can expand functionality. For instance, the second channel allows AFG1Ks to test audio Digital to Analog Converters (DACs) and Analog to Digital Converters (ADCs), with the first channel driving the DAC clock, and the second channel controlling a digital audio generator. This allows for the evaluation of clock frequency operating range of audio

ADCs and DACs. Next, the AFG1K's list sweep function allows the user to measure the frequency response of a bandpass filter.

For applications that require higher bandwidth, more memory, or a higher sampling rate, the AFG31000 series (maximum 250 MHz bandwidth) is ideal. The AFG31000 series offer higher bandwidths, larger memory, and faster sampling rates than their respective counterparts in the other oscilloscope series and AFG1022, AFG1062, and lineups.

One such application that the AFG31K is suited for is driving and modulating laser diodes. The two channels of the AFG31K can drive both a laser diode and electro-optical modulator, while the high bandwidth allows for arbitrary waveforms up to 125 MHz. Additionally, the AFG31K's ability to synchronize channels, and set channel 2 as the complement of channel 1, allows for applications such as the testing of implantable medical devices. In this application an arbitrary waveform is set up as a differential signal and simulates a biomedical signal sigh as a heartbeat.

Conclusion

Whether choosing a dedicated AFG or an oscilloscope with built-in AFG application, Tektronix and Keithley offers a variety of solutions. From basic AFGs for cost-effective or education purposes, to the value-packed oscilloscope and On-Scope AFG app combos, and to the advanced high frequency and bandwidth offerings of Tektronix's AFG31K lineup, Tektronix and Keithley offer products to meet every need.

For more information about possible applications for AFGs, or to learn more about a particular instrument or software, be sure to visit Tek.com. Here you can find the "25 Common Things You Can Do with an Arbitrary Function Generator" app note as well as various user manuals.

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