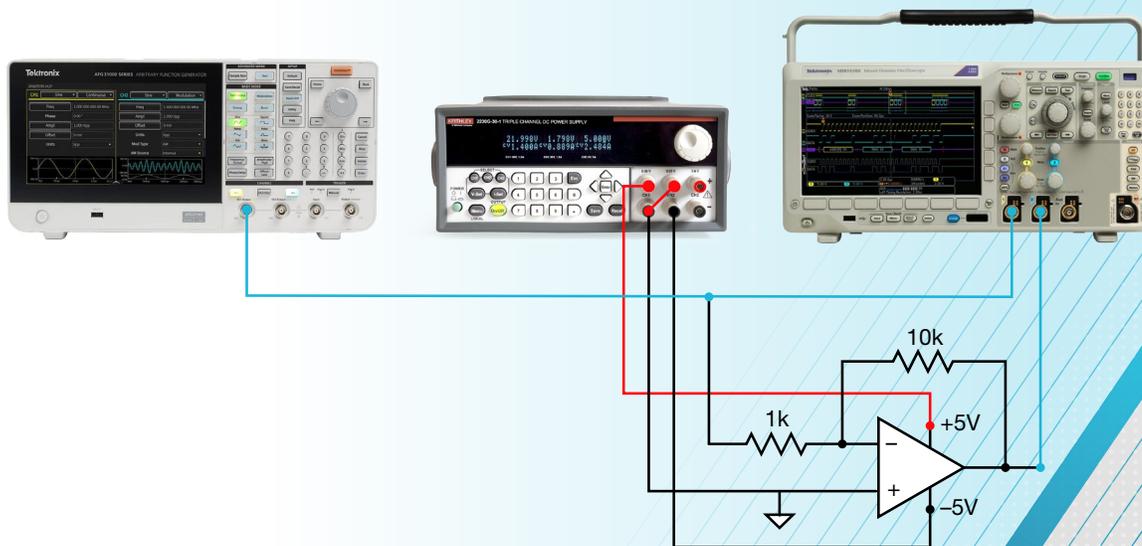


Analyzing Frequency Response Using the AFG31000, MDO3000, and Kickstart Software

APPLICATION NOTE



KEITHLEY
A Tektronix Company

Tektronix[®]

Introduction

Filter and amplifier circuits can be found in every corner of modern-day life. The speakers in our cars, the AC/DC converters on our device chargers, and the headphones we use to work remotely all utilize filters and amplifier circuits. These types of circuits are so common that studying standard configurations is required in electronics education labs. Analyzing the frequency response of these circuits is one of the most useful tools for characterizing their performance. Keithley's Kickstart Software makes using the AFG31000 Arbitrary Function Generator and MSO5 Oscilloscope to measure frequency response simple.

Measuring Frequency Response

The goal of an amplifier or a filter is to be effective at a known range of frequencies. We may want an amplifier to only amplify low frequency signals, or a filter to remove only high frequency signals. To understand the behavior of the circuit, we can measure the frequency response. The frequency response of a circuit is a characterization of how the output of the circuit behaves when varying input signals are applied. The easiest way to accomplish this is to use an arbitrary function generator (AFG) to generate the input signals and an oscilloscope to measure and compare the input and output. It is necessary to apply a wide range of input signals, so an AFG that has a built-in sweeping mode is useful. Sweep mode automatically changes the frequency of the output signal, so hundreds or thousands of measurements can be taken without manually changing the frequency.

The results of the frequency analysis usually compare the amplitude change and the phase change of the signal from input to output with respect to the frequency. A common way of displaying the results is in a Bode plot. The frequency is plotted in log scale on the x-axis to account for the wide range of frequencies and the amplitude or magnitude is plotted on the y-axis in decibels using the following formula:

$$A_{dB} = 20 \log \frac{V_{out}}{V_{in}}$$

The phase can be represented in degrees on the y-axis for the phase plot.

Frequency Response of an Amplifier in Kickstart

The frequency response of an inverting amplifier such as the one shown in **Figure 1**, can be measured using Kickstart.

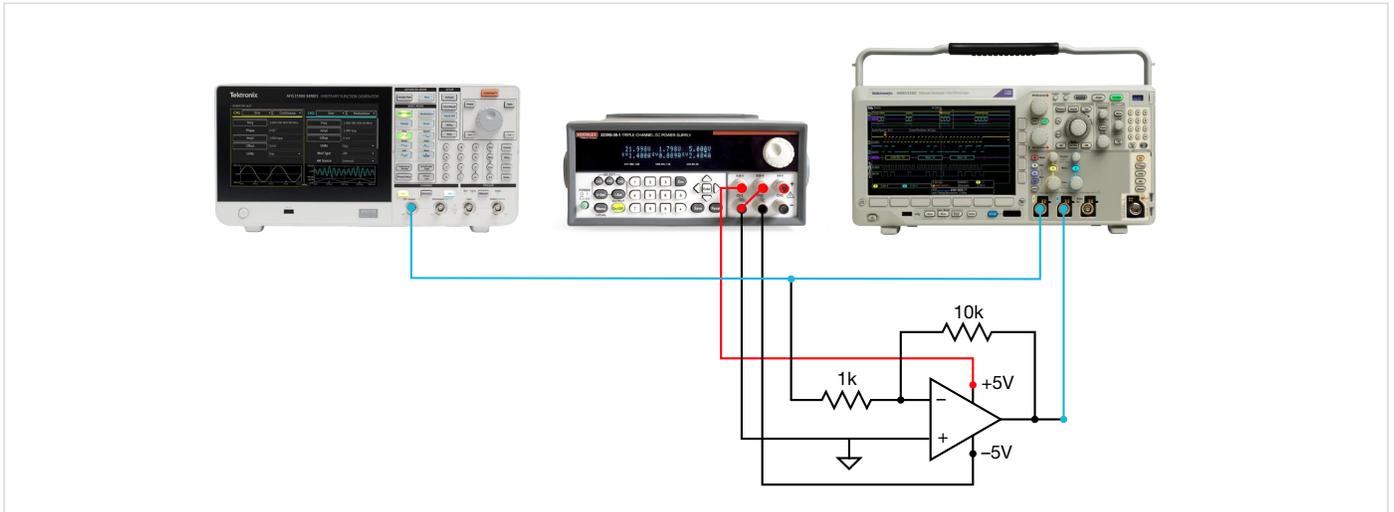


Figure 1: Inverting amplifier circuit.

Starting with Version 2.8.0, Kickstart allows you to configure the power supply and the AFG and collect measurements from the scope. For this example, a Keithley 2230G-30-1 Power Supply was used to provide ± 5 V to the op amp and a Tektronix AFG31251 was used to provide the input signal. A Tektronix MDO3104 was used to measure both the input and output signals for comparison. All three instruments were connected to the controlling PC using USB cables.

Begin by opening the Power Supply App to configure the power supply to output 5 V on channels 1 and 2 as shown in **Figure 2**. Channel 3 can be disabled.

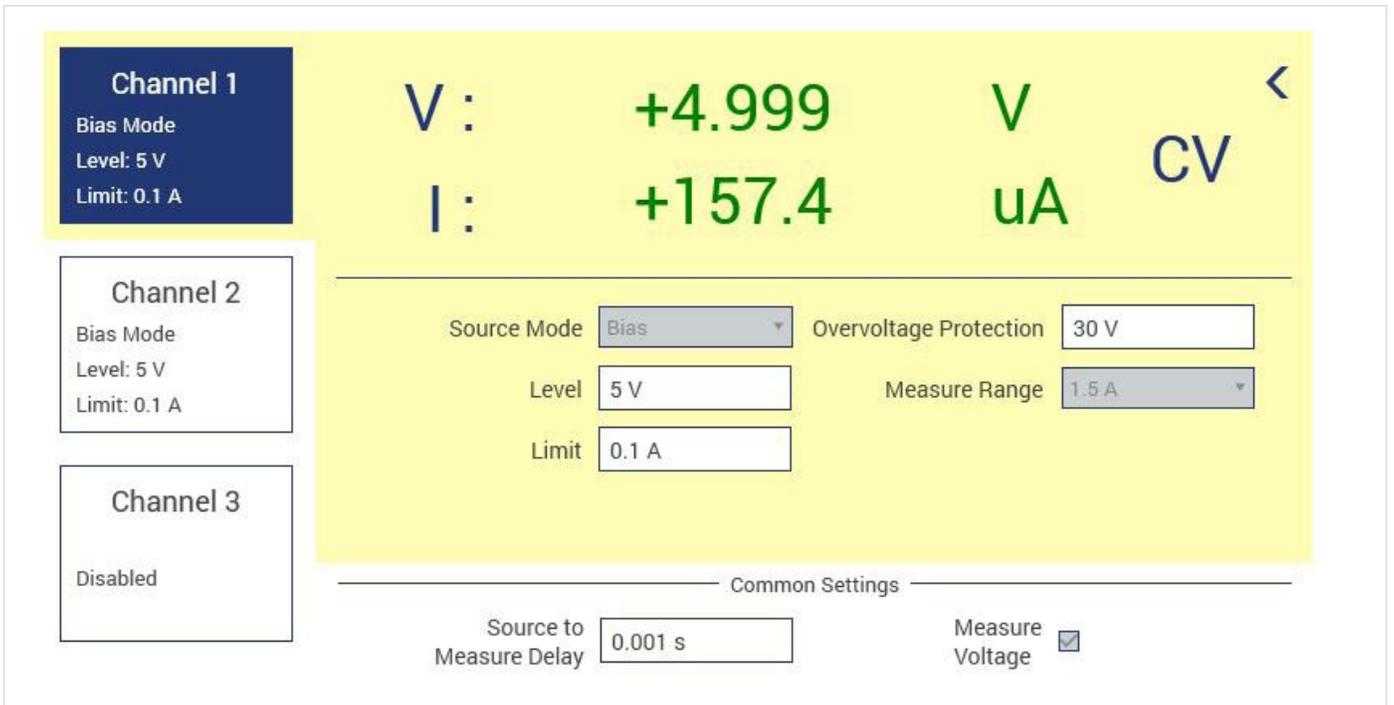


Figure 2: Power supply configuration.

Next, select the AFG App and configure channel 1 of the AFG. Since frequency response analysis requires observation over a range of frequencies, the sweep mode of the AFG will be used. For the purposes of this example, the AFG is set to sweep a 100 mV sine wave from 1 kHz to 100 kHz in a logarithmic sweep. The sweep time is extended to 200s to give the scope time to trigger the measurements. The settings in Kickstart for the AFG are shown in **Figure 3**.

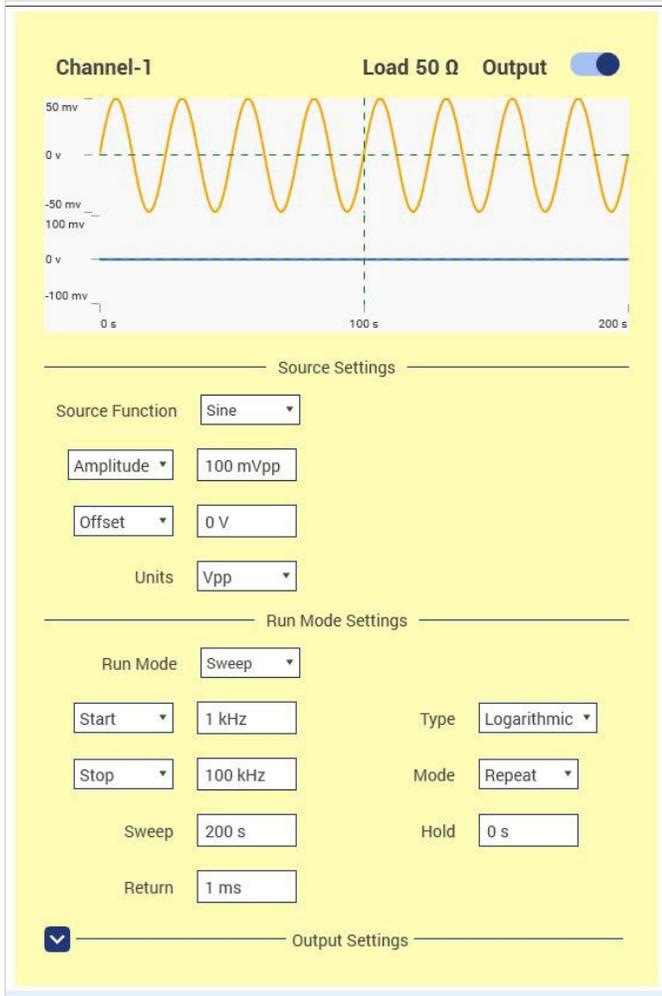


Figure 3: AFG configuration in Kickstart.

Finally, the scope can be set up to capture the waveforms from the front panel. When the Scope App is opened, the settings on the front panel are reflected in the Kickstart screen. Key measurements like the frequency and amplitude of channels 1 and 2 can be set up in the Measurements tab as shown in **Figure 4**. We will configure the scope to take 100 measurements while the AFG sweeps the frequencies.

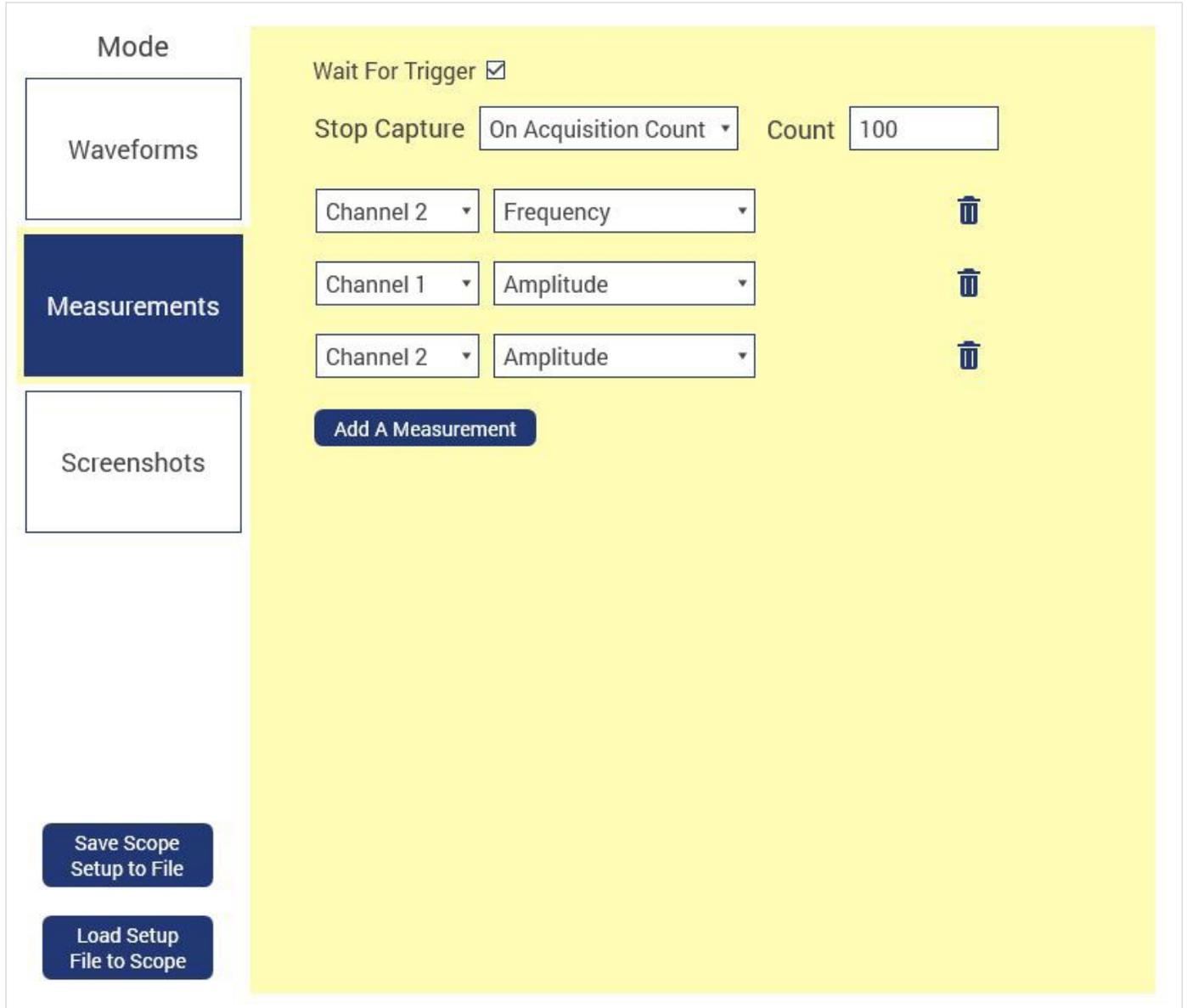


Figure 4: Configure measurements on the oscilloscope.

The AFG channel can be turned on by switching the toggle button in the AFG App. Note that this control is available even while the app is minimized, allowing you to turn the output on and off while keeping the scope app maximized for data collection. Measurements from the scope can be collected to the table by pressing the run button in the measurements tab of the Scope App. The data is populated in the table as shown in **Figure 5**.

Scope-1				
Settings Table Graph				
	Channel 2			Channel 1
	Time (s)	Frequency (Hz)	Amplitude (V)	Amplitude (V)
1	0.000000	1.471000e+3	1.860000	172.0000e-3
2	2.599803	1.552000e+3	1.860000	172.0000e-3
3	5.176722	1.657800e+3	1.860000	172.0000e-3
4	7.796496	1.758100e+3	1.860000	172.0000e-3
5	10.434952	1.865100e+3	1.860000	172.0000e-3
6	13.034024	1.983300e+3	1.840000	172.0000e-3
7	15.651684	2.105300e+3	1.840000	172.0000e-3
8	18.271700	2.238600e+3	1.840000	172.0000e-3
9	20.874643	2.374200e+3	1.840000	172.0000e-3
10	23.497854	2.526500e+3	1.840000	172.0000e-3
11	26.115130	2.679500e+3	1.820000	172.0000e-3
12	28.736185	2.850600e+3	1.820000	172.0000e-3
13	31.352715	3.039500e+3	1.800000	172.0000e-3
14	33.951297	3.211300e+3	1.800000	172.0000e-3
15	36.581931	3.403700e+3	1.800000	172.0000e-3
16	39.200625	3.606200e+3	1.800000	172.0000e-3
17	41.797082	3.852100e+3	1.800000	172.0000e-3
18	44.477658	4.088300e+3	1.800000	172.0000e-3
19	47.095868	4.344000e+3	1.760000	172.0000e-3
20	49.713745	4.629600e+3	1.760000	172.0000e-3
21	52.372146	4.899600e+3	1.760000	172.0000e-3

Figure 5: Collecting measurements from the oscilloscope to the Kickstart table.

The data can be exported automatically after each run, or manually using the built in export tool. The exported data can then be analyzed and presented in a Bode plot such as the one shown in **Figure 6**.

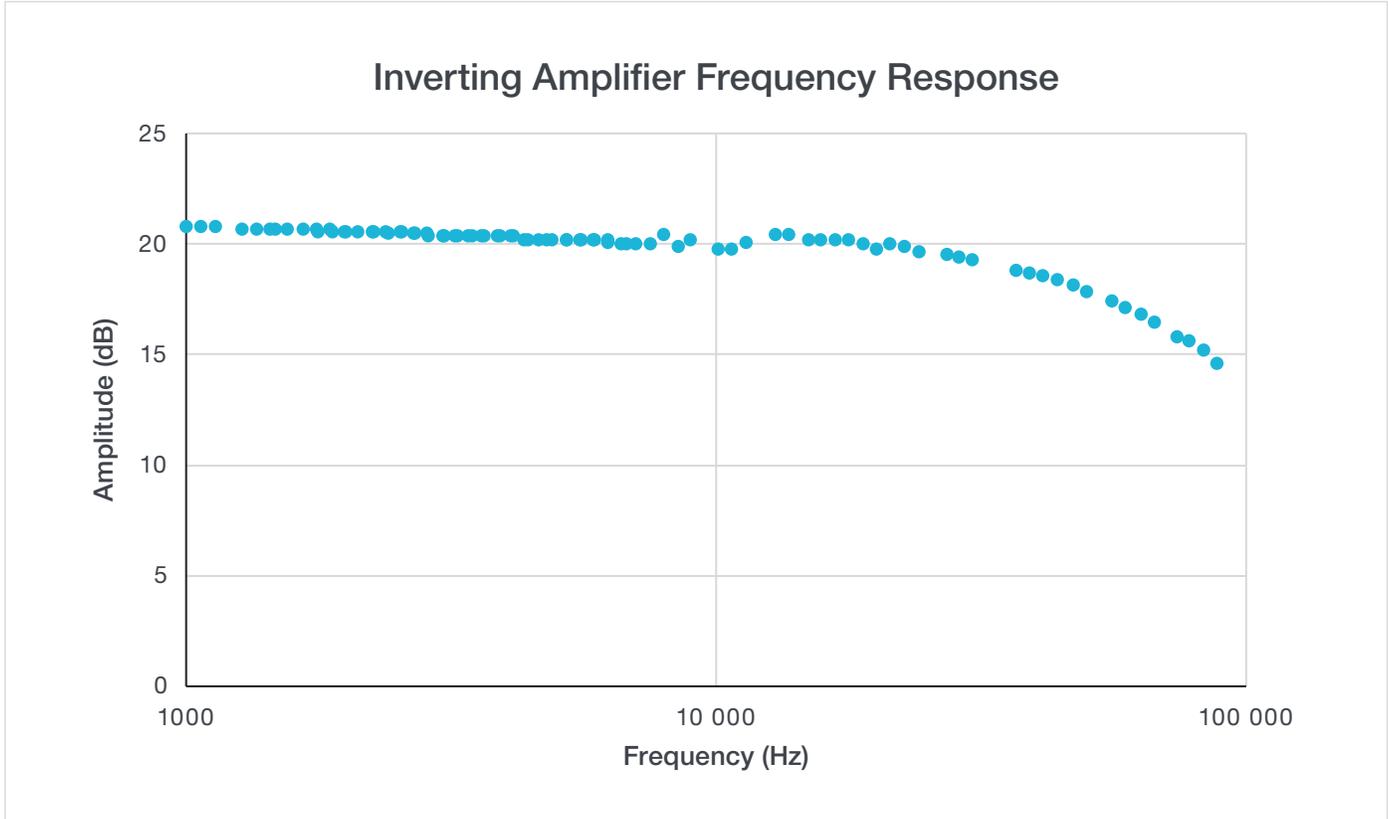


Figure 6: Bode plot of inverting amplifier circuit.

Conclusion

Frequency response of a circuit is a common method of analyzing a circuit's behavior. Keithley's Kickstart Software makes testing frequency response in a circuit simple, with apps for each instrument and the ability to control multiple instruments at once. For more information on Kickstart, visit tek.com/keithley-kickstart.

Contact Information:

Australia 1 800 709 465
Austria* 00800 2255 4835
Balkans, Israel, South Africa and other ISE Countries +41 52 675 3777
Belgium* 00800 2255 4835
Brazil +55 (11) 3530-8901
Canada 1 800 833 9200
Central East Europe / Baltics +41 52 675 3777
Central Europe / Greece +41 52 675 3777
Denmark +45 80 88 1401
Finland +41 52 675 3777
France* 00800 2255 4835
Germany* 00800 2255 4835
Hong Kong 400 820 5835
India 000 800 650 1835
Indonesia 007 803 601 5249
Italy 00800 2255 4835
Japan 81 (3) 6714 3086
Luxembourg +41 52 675 3777
Malaysia 1 800 22 55835
Mexico, Central/South America and Caribbean 52 (55) 88 69 35 25
Middle East, Asia, and North Africa +41 52 675 3777
The Netherlands* 00800 2255 4835
New Zealand 0800 800 238
Norway 800 16098
People's Republic of China 400 820 5835
Philippines 1 800 1601 0077
Poland +41 52 675 3777
Portugal 80 08 12370
Republic of Korea +82 2 565 1455
Russia / CIS +7 (495) 6647564
Singapore 800 6011 473
South Africa +41 52 675 3777
Spain* 00800 2255 4835
Sweden* 00800 2255 4835
Switzerland* 00800 2255 4835
Taiwan 886 (2) 2656 6688
Thailand 1 800 011 931
United Kingdom / Ireland* 00800 2255 4835
USA 1 800 833 9200
Vietnam 12060128

* European toll-free number. If not accessible, call: +41 52 675 3777

Rev. 02.2022



Find more valuable resources at [TEK.COM](https://www.tek.com)

Copyright © Tektronix. All rights reserved. Tektronix products are covered by U.S. and foreign patents, issued and pending. Information in this publication supersedes that in all previously published material. Specification and price change privileges reserved. TEKTRONIX and TEK are registered trademarks of Tektronix, Inc. All other trade names referenced are the service marks, trademarks or registered trademarks of their respective companies.

032422 SBG 1KW-73909-0

