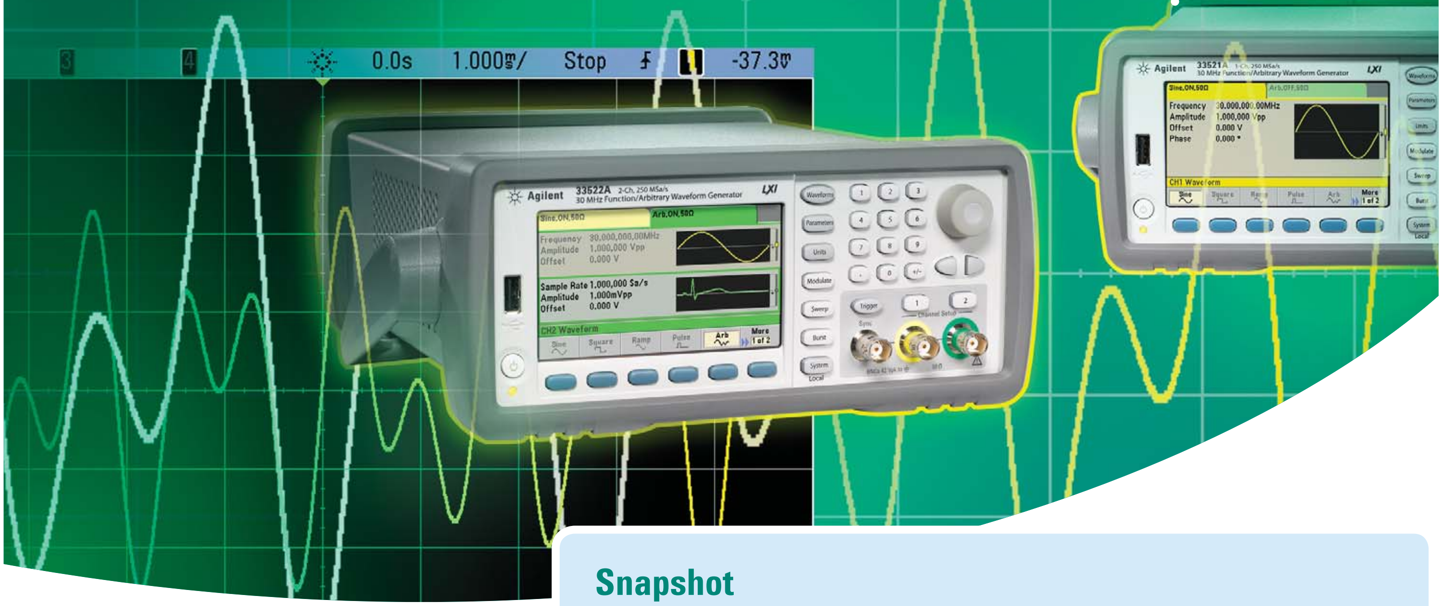
MEASUREMENT TIPS
Volume 10, Number 2

Simplify Testing with Waveform Summing Capability



Snapshot

A major supplier of telephony support equipment was getting complaints that its system too easily mistook some people's laughter as tone input to the system, causing it to temporarily branch out of the call. The company's design engineers changed their tone decoding algorithm to make it more immune to voice and musical sounds on the phone, but they still had to confirm that it processed the real tones properly. They used an Agilent 33522A function/arbitrary waveform generator to test their new algorithm to confirm that it did properly process all variations in range of the dual-tone multi-frequency tones.

Introduction

In a variety of applications, if you want to properly test a device, product, or system, you need a signal that consists of the sum of two waveforms. For example:

- Telephones produce dual-tone sine wave signals that are deciphered by receiving electronics and appropriately acted upon. You can test the receivers in these telephony systems by subjecting them to various dual-tone input signals.
- Audio amplifiers cause small amounts of distortion of their input waveforms. You can evaluate the distortion introduced by the amplifier using an input signal consisting of the sum of a square wave and a sine wave.
- Clock signals with noise on them can cause timing errors. You can test immunity to noise on a clock signal by creating a signal that adds noise to a square wave.

The testing required in each of these examples makes use of a signal consisting of the sum of two waveforms. This measurement brief discusses these three examples and provides a simple method for creating summed waveforms using a single channel on an Agilent Technologies 33521A/22A function/arbitrary waveform generator.

Agilent Technologies

Testing telephony DTMF decoders

We are all familiar with the typical tones used in telephone systems—each time we press a key on our phone, we hear a tone through the earpiece. In the most common case, these tones are used by the system to simply route a call from one location to another. However, these tones are also used in various other telephony applications, such as entering passwords and commands into a personal answering machine, interacting with an automated banking system, or traversing through the branches of a typical business phone tree. If you listen carefully, you will notice that each tone is actually two tones—two different frequencies, each a pure sine wave, being playing simultaneously. These tones are called dual-tone multi-frequency (DTMF) tones. The tone you hear is a combination of one low-frequency tone and one high-frequency tone determined by the intersection of the row and column selected by depressing a phone key. See **Figure 1**. The "A," "B," "C," and "D" keys depicted in the figure are not on a standard phone, but are included here because they are part of the DTMF push-button phone definition.

In the telephony world, standards exist for these tones so that all of the various systems that use them will work gracefully together. To ensure that the DTMF decoding electronics used in these various systems works properly, it is necessary to test the DTMF decoders by subjecting them to all forms of DTMF generation tones. For example, one standard mentions that each frequency must be within +/- 1.8% of the nominal frequency and covers the relative magnitudes of the sine waves. Therefore, engineers need a way to generate and control the DTMF tones within the extremes of the frequencies and amplitudes mentioned in the standard.

The Agilent 33521A/22A function/arbitrary waveform generator has a sum function that allows you to add an internally (or externally) generated signal to the primary signal on a single channel. Clearly, if the primary signal is a sine wave and the added sum signal is also a sine wave, the combined waveform is exactly what you need to generate and control a DTMF tone for testing DTMF decoders. You can easily adjust the amplitude, frequency, and duration of each of the dual tones to the limits specified in the regulatory standard. **Figure 2** shows an example of a waveform generated using a single-channel 33521A.

		High frequencies			
		1209 Hz	1336 Hz	1477 Hz	1633 Hz
Low frequencies	697 Hz	1	ABC 2	DEF 3	A
	770 Hz	GHI 4	JKL 5	MNO 6	B
	852 Hz	PQRS 7	TUV 8	WXYZ 9	C
	941 Hz	*	OPER 0	#	D

FIGURE 1. ***DTMF keypad frequencies—the sum of one low-frequency and one high-frequency sine wave is used to represent each of the 16 keys (4 rows by 4 columns)***

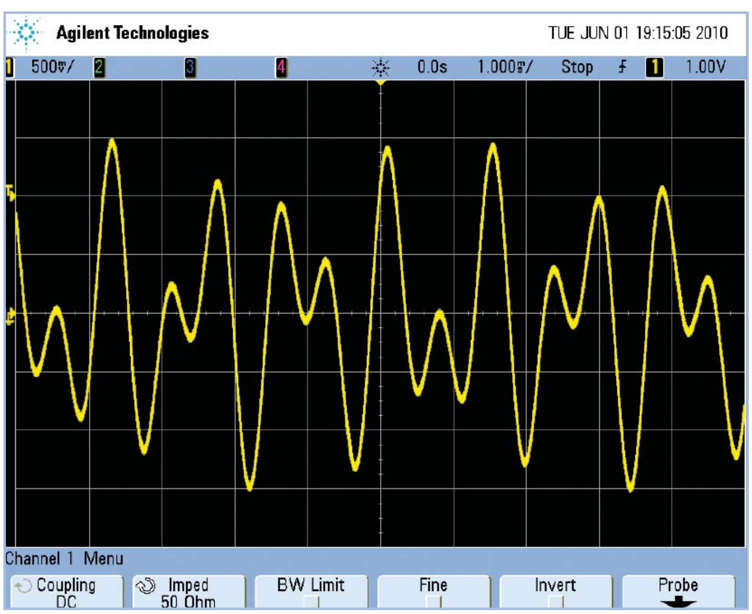


FIGURE 2. ***DTMF waveform showing a 1336-Hz sine wave summed with a 770-Hz sine wave corresponding to a "5" on the phone keypad***

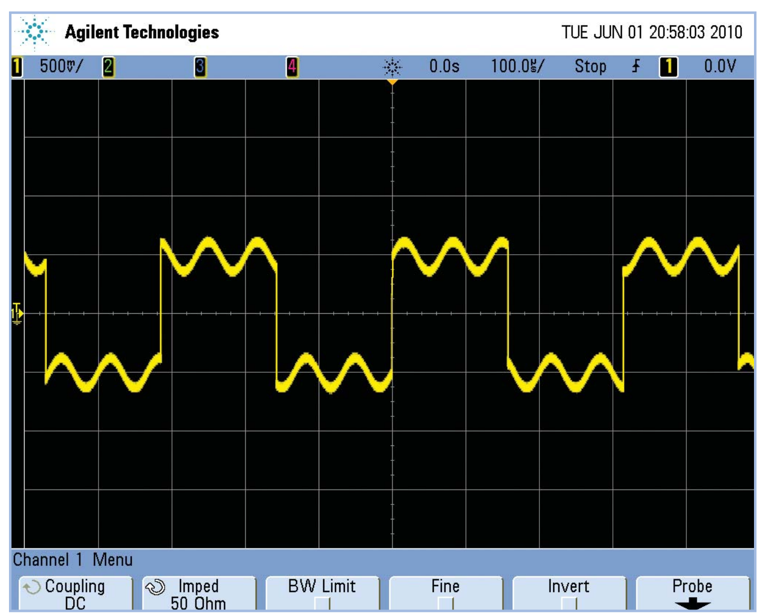


FIGURE 3. ***Square-sine waveform showing a 3.18-kHz square wave summed with a 15-kHz sine wave. The summed waveform is used as the input signal to test audio amplifier transient intermodulation distortion.***

Testing audio amplifier intermodulation distortion

When a single sine wave signal is applied to a nonlinear system, the output of the system contains harmonics that are related to the frequency of the input signal. The output therefore has harmonic distortion. When multiple sine wave signals are applied to a nonlinear system, the output of the system contains harmonics of the input signals and intermodulation products that are related to the sums and differences of the input frequencies. The output therefore has intermodulation distortion. This intermodulation distortion can create problems on the output. For example, if the nonlinear system is an audio amplifier, and if the intermodulation distortion is high, the sound coming from the speakers that are driven by the audio amplifier will sound harsh. Dynamic intermodulation distortion is particularly disruptive and should be evaluated on systems such as audio amplifiers.

One method for evaluating dynamic intermodulation distortion is to provide a square-sine wave input to the nonlinear system and examine the response of the system on the output using a spectrum analyzer. The square-sine wave input is the sum of an appropriately chosen square wave and sine wave. This method is described in ***Reference 1***, which also includes the values for the amplitudes and frequencies of the waveforms. Using the sum function in the Agilent 33521A function/arbitrary waveform generator, you can create the required square-sine wave signal. **Figure 3** shows an example. With the summed signal applied to the input of the amplifier, the spectrum analyzer shows the amplitudes of the intermodulation products of the output waveform, which you can use to calculate the total intermodulation distortion.

Testing clock signal noise immunity

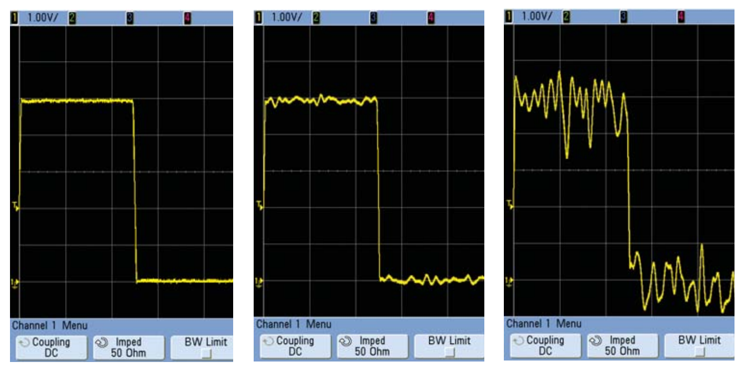
A large percentage of electronics today include some type of digital circuitry or microprocessor. These circuits are invariably controlled by a clock signal that is responsible for pacing and coordinating the actions of the circuits. Any noise that appears on the clock signal can cause problems with the circuits it is controlling, such as performance degradation, loss of transmitted data, undesired sounds in audio, or unwanted image effects in video. The sources of noise are many and include noise types such as thermal, shot, and flicker as well as interference types such as crosstalk, electro-magnetic interference, and switching devices. Ensuring that the circuits connected to your clock signal are immune to possible noise sources is imperative to guarantee the proper operation of your circuit. Therefore, it is important to test your circuits with noise purposefully added to your clock.

__Reference 1:__ "A Method for Measuring Transient Intermodulation Distortion (TIM)", Eero Leinonen, Matti Otala, and John Curl, presented October 30, 1976, at the 55th Convention of the Audio Engineering Society, New York

MEASUREMENT TIP

One or both of the summed waveforms in the 33521A/22A can be an arbitrary waveform you create yourself. For the audio amplifier intermodulation distortion test, it is helpful to use a self-generated arbitrary waveform because the input square wave described in reference 1 should be passed through a single-pole low-pass filter with a cutoff frequency of either 30 kHz or 100 kHz, depending on the type of amplifier you are testing. You can easily produce the data for these filtered square waves using a standard math package, then load them into the 33521A/22A as an arbitrary waveform and sum them with the sine waves to produce the desired amplifier input signals.

As an example, consider a square-wave clock that is subjected to a source of white noise (additive white Gaussian noise, or AWGN) corrupting the otherwise clean signal. The circuits driven by this clock could be adversely affected depending on the magnitude of the noise relative to the clock signal magnitude. Once again, using the sum function in the 33521A, you can easily produce this noisy clock signal. **Figure 4a** shows the clean square-wave clock produced by the 33521A. **Figure 4b** shows the same clock signal with a small amount of white noise added using the sum function, while **Figure 4c** shows the same clock with a large amount of white noise added.



4a **4b** **4c**

FIGURE 4. ***Clock signal showing no added noise (4a), a small amount of added noise (4b), and a large amount of added noise (4c)***

Conclusion

Many different applications include tests that require a signal consisting of two waveforms added together. Two sine waves summed together are needed in DTMF applications. The sum of a sine wave and a square wave is used to evaluate audio amplifier intermodulation distortion. Immunity to noisy clock signals can be evaluated by summing noise with a square wave. In each of these applications, the use of the sum function in an Agilent 33521A/22A function/arbitrary waveform generator greatly simplifies the test by providing a simple method for creating a signal consisting of the sum of two waveforms. Making adjustments to the frequency and amplitude of each of the waveforms is easy, and it enables you to test your device to all of the extremes of these variable parameters.

www.agilent.com

For more information on Agilent Technologies' products, applications or services, please contact your local Agilent office. The complete list is available at:

www.agilent.com/find/contactus

Learn more about Agilent's function/arbitrary waveform generator solutions at
www.agilent.com/find/FunctionGeneratorSpotlight

Product specifications and descriptions in this document subject to change without notice.

Printed in USA, July 1, 2010
5990-5898EN

Agilent Technologies