SPECTRUM

Application Note

Source-Response-Testing with AWGs and Digitizers combined in one instrument

In the world of electronic testing there are two classes of testing. Self-excited electronic devices such as power supplies, oscillators, transmitters, and signal generators are tested using data acquisition type instruments like digitizers, oscilloscope, or spectrum analyzers. The second class of testing involves testing devices like amplifiers, filters, receivers, and digital interfaces that must be externally excited by a signal source before the signal acquisition instruments can be used. This class of test is called source-response testing.

Spectrum Instrumentation's hybridNETBOX combines multichannel digitizers and arbitrary waveform generators (AWG) in a universal LXI compliant instrument capable of stimulus and response measurements. It is truly a test system in a box. Figure 1 shows a typical hybridNETBOX.

Figure 1: A model DN2.806-08 which includes eight channels each of 16-bit AWG's and digitizers in an LXI compliant instrument case.

Six different hybridNETBOX configurations are available with sampling and output clock rates for 40, 80, and 125 Megasamples per second (MS/s) on two, four or eight channels for both signal generation and acquisition. Each channel has 16-bit resolution with bandwidths of up to 60 MHz, proportional to sampling rate, providing the technology to ensure that the digitizer and AWG channels deliver exceptional accuracy and precision.

The AWG can have two to eight channels that are fully synchronized using a common clock and trigger either internally or externally generated. AWG output levels can be up to ±6 Volts into 50 Ohms or ±12 Volts into high impedance for the two and four channel versions or up to ±3 Volts into 50 Ohms or ±6 Volts into high impedance for the eight-channel version. The AWG capabilities are augmented by the availability of four digital input/output (I/O) lines for user programmable marker pulses as well as external clock and trigger inputs.

Two to eight digitizer channels handle a broad range of input signals from ± 200 mVolts to ±10 Volts with adjustable DC offset and a user selectable 50 Ohm or 1 MOhm input impedance. Both single ended and differential inputs are available in the digitizers. The digitizer also has external clock and trigger input as well as two general purpose digital I/O lines which are user defined.

The hybridNETBOX is a fully LXI compliant. Simply connect the unit, or units, to your computer, or network, via the rear panel Gbit Ethernet port, and you are ready to go! The hybridNETBOX is also fully programmable and is supplied with drivers for the Windows and Linux operating systems.

Spectrum Instrumentation supplies its SBench 6 software tool for control, display, measurement, and signal processing for its entire product line. The software even has built-in report generation. Additionally, so the units can be programmed for custom applications, examples are provided for C++, LabVIEW, MATLAB, Visual Basic .NET, Python, and other popular programming languages.

Source Response Testing

By having up to eight channels of signal generation and acquisition available, the hybridNETBOX is ideally configured for stimulus-response type measurement systems. Since a single hybridNETBOX can produce multiple transmit and receive signals it is perfect for testing and evaluating array-based MIMO or bus-based systems. The hybridNETBOX fits in ATE applications for testing components and subassemblies in an automated way ascertaining the functionality and calibration of the devices being tested.

Consider a simple example of a source-response measurement where the AC open loop gain of an operational amplifier is being measured using an AWG and a digitizer. The test circuit is shown in Figure 2.

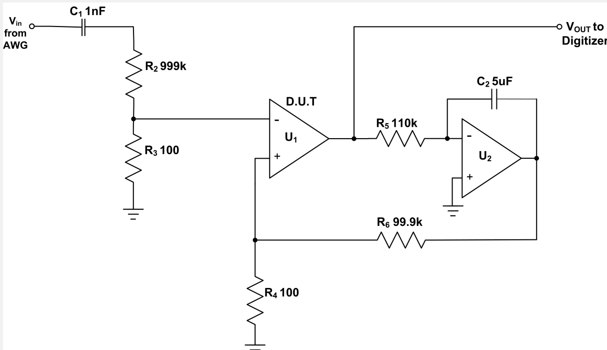

Figure 2: The test circuit for measuring the AC open loop gain of an operational amplifier using an AWG as the source and a digitizer for the response measurement.

This test applies a small AC waveform, from an AWG, to the input of the operational amplifier under test. Since the gain of the amplifier is quite high the input signal has to be attenuated. A 10,000 to 1 resistive attenuator (R1 and R2) decreases the input by 80 dB. The amplifier U1 is the device under test (DUT). U2 is an auxiliary amplifier which stabilizes the average DC level at the output of the DUT.

The AC open loop gain is specified as a function of frequency. The input waveform has to have a flat frequency response over the desired range of test frequencies. Waveforms that satisfy that requirement could be one's with a linearly swept frequency or, as an alternative, an impulse function. The AWG can easily be programmed to produce either of these signals using Spectrum's SBench6 control and signal processing software. SBench 6 allows waveforms to be created using standard functions, mathematical equations, or to be imported from a digitizer or oscilloscope. In this case, a sine sweep extending from 100 Hz to 100 kHz is created with a sweep time of one second using equations. The swept sine is chosen because it provides greater dynamic range than an impulse function. The sweep signal is applied to the test circuit and a digitizer measures the circuit output over the duration of the sweep. The results are summarized in Figure 3.

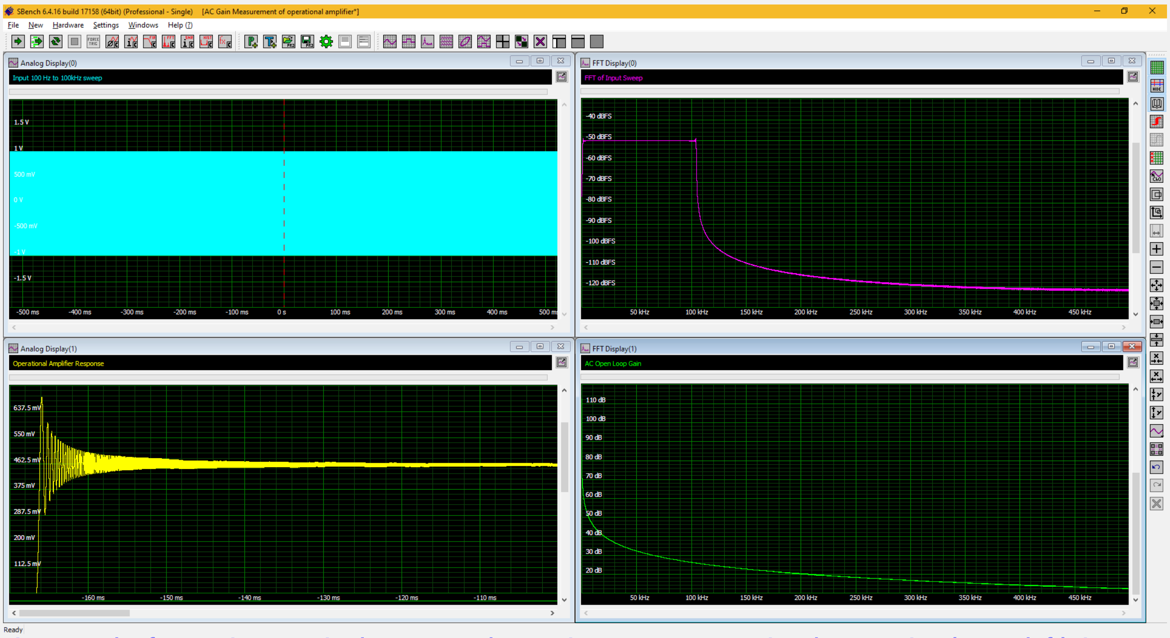

Figure 3: The four major steps in the AC open loop gain measurement. Signal generation (upper left), input signal frequency range verification (upper right), output signal acquisition (lower left) and frequency response extraction from the output signal (Lower right) which is the AC open loop gain.

The upper left grid shows the swept sine input signal over its full 1 second duration to verify its amplitude flatness over time. The signal processing capability of SBench 6 includes the calculation of the Fast Fourier Transform or FFT. The FFT displays the signals power versus frequency like a spectrum analyzer. The upper right grid contains the FFT of the input signal verifying a flat frequency response from 100 Hz to 100 kHz. The operational amplifier response to the attenuated input signal is shown in the lower left grid. The spectrum display of the output signal is shown in the lower right-hand grid including amplitude correction for the 80 dB attenuator. This spectral view is the AC open loop gain. This shows the AC gain from 100 Hz to 100 kHz with the maximum AC gain of 112 dB. The amplitude rolls off with frequency at -6 dB per octave or -20 dB per decade which is expected for the operational amplifier.

The hybridNETBOX, containing both the signal source and the signal acquisition hardware, makes this test simple. Keep in mind that with up to eight channels of signal sources and digitizers available up to eight parallel tests can be run simultaneously.

Record and Replay application

Another useful capability of the hybridNETBOX is the ability to acquire one or more signals and then replay them on demand for simulation or when it is required to replace a missing subassembly. As an example, consider acquiring and replaying the electrocardiogram signals from a three wire Holter recorder. This would permit circuit development without having a patient wearing the device. A library of pre-recorded signals expands this simulation capability. Figure 4 provides an example.

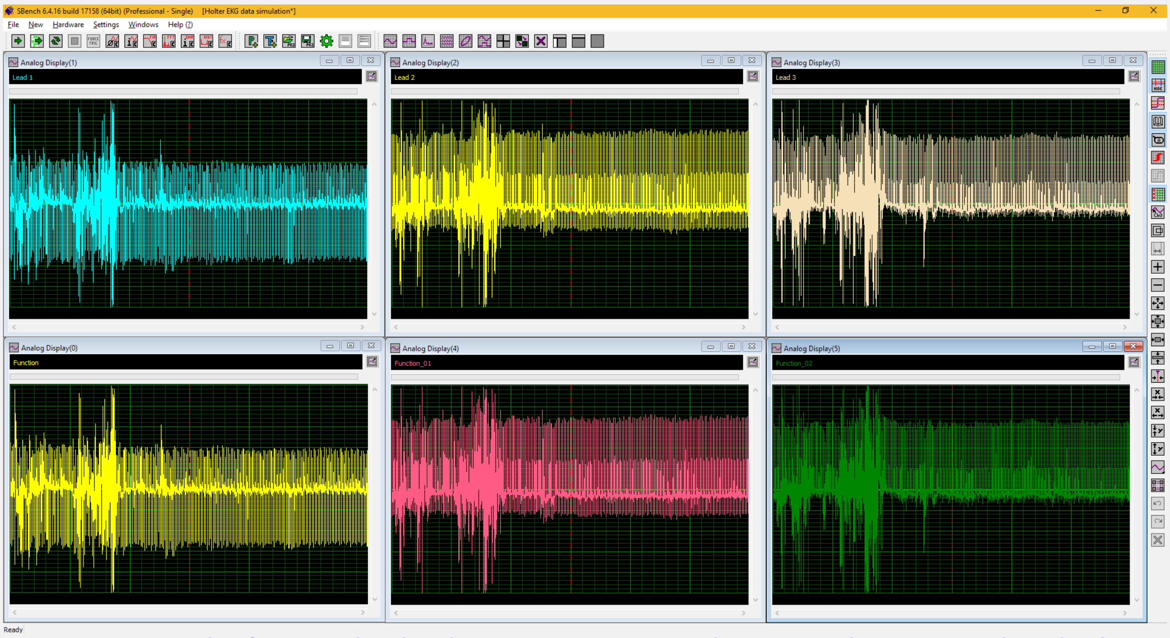

Figure 4: An example of an record and replay test strategy using a three wire Holter ECG recorder. The three upper traces are acquired from leads 1 through 3. The signals are copied and replayed three AWGs channels.

The top three traces show the signal acquired from leads 1 through 3 of the recorder. These traces are copied into the AWG channels designated as Function, Function_01, and Function_02. The acquired channels could also be improved using the filtering and signal processing capabilities of SBench6 before being output via the AWG's.

Similarly, anomalies can be introduced into these signals which can then be transferred to the AWG channels to be output on demand. Figure 5 illustrates the addition of a 50 Hz anomaly to the lead 1 signal.

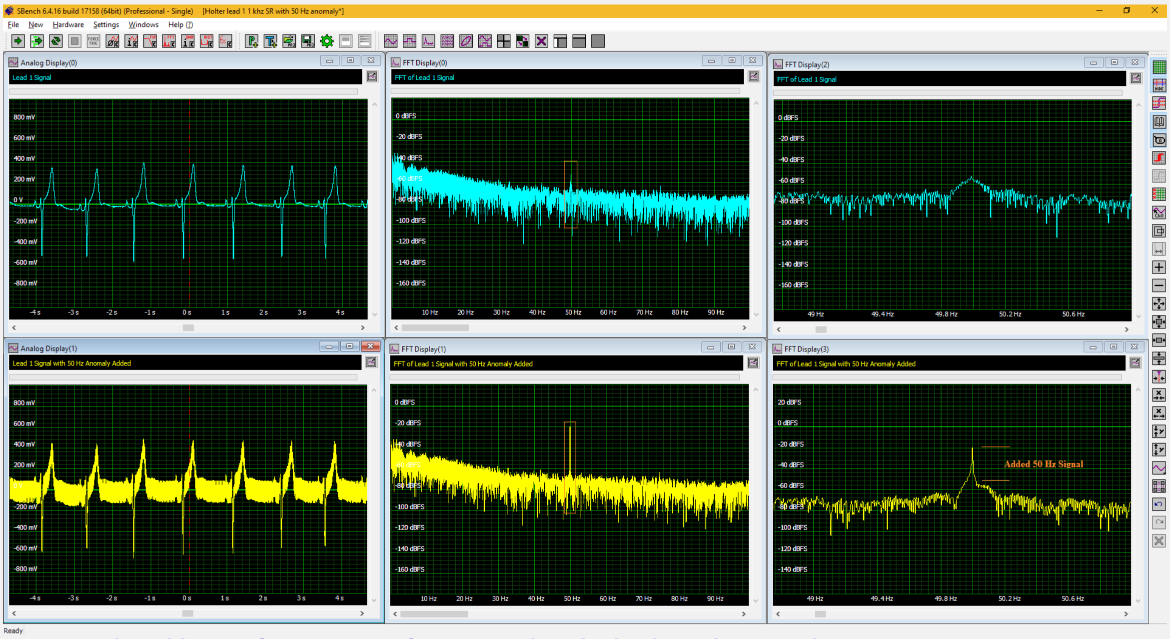

Figure 5: The addition of a 50 Hz interfering signal to the lead 1 Holter signal

The original lead 1 signal appears in the upper left grid expanded horizontally to see individual heart cycles. The FFT of the entire signal appears in the top-center grid. The top-right grid shows a horizontally expanded view of that FFT about 50 Hz. Note that the original signal has a small 50 Hz component. The lower-left grid shows the same lead 1 signal with a 0.1 Volt, 50 Hz anomaly added. The FFT of the signal with the 50 Hz anomaly appears in the center-right grid. An orange box marks 50 Hz, which now shows increased amplitude due to the added anomaly. The lower-right grid expands the FFT horizontally about 50 Hz. The increased amplitude of the 50 Hz interference is marked and noted. The ability to modify the acquired signal before playback allows users to evaluate the effectiveness of filtering and error correction circuits on demand.

Echo ranging and location

Applications that utilize "echo" signals for location and ranging such as those found in Radar, Sonar, Lidar, or Ultrasound are well matched to the hybridNETBOX capabilities. The AWG source can generate these complex signals and the 16-bit digitizers provide the dynamic range needed to see echo signals as shown in Figure 6.

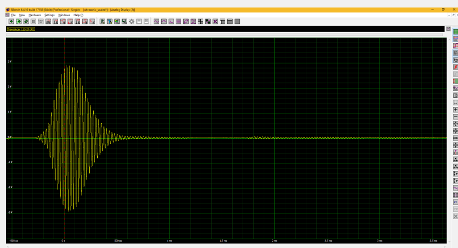

Figure 6: A transmitted ultrasonic pulse and multiple reflected echoes.

This is an acquired 40 kHz ultrasonic pulse from a range finder along with subsequent echoes. The amplitude of the echo pulses is about 36 dB below the transmitted pulse so they can be discerned visually in the figure. In practice they are generally much lower! The 16-bit amplitude resolution of the hybridNETBOX is important in applications like this where the echo signals are much lower than the transmitted signal and the dynamic range is needed to generate or detect the low amplitude echoes.

The multiple echoes are due to the poor directionality of the ultrasonic transducer. All the echo location and ranging applications experience this problem and seek to improve the directionality and gain by using phased arrays of transducers or antennae. Since the hybridNETBOX can produce multiple transmit signals and receive multiple channels it is ideal for testing and evaluating these array-based systems.

Consider an ultrasonic imaging system where multiple signals are generated and fed to an array of transducers. Adjusting the delay and attenuation of the individual signals can be used to control the output of the transducer array. Phased Array systems, be they antennas for RF signals or ultrasonic transducers, are a common form of multiple input multiple output (MIMO) system. Multichannel AWGs can provide the signals needed for driving these systems enabling steering of the emitted signals. Likewise, a multichannel digitizer supports receiving the transmitted signals. The basic signal components of an eight-element ultrasonic phased array transmission system are illustrated in Figure 7.

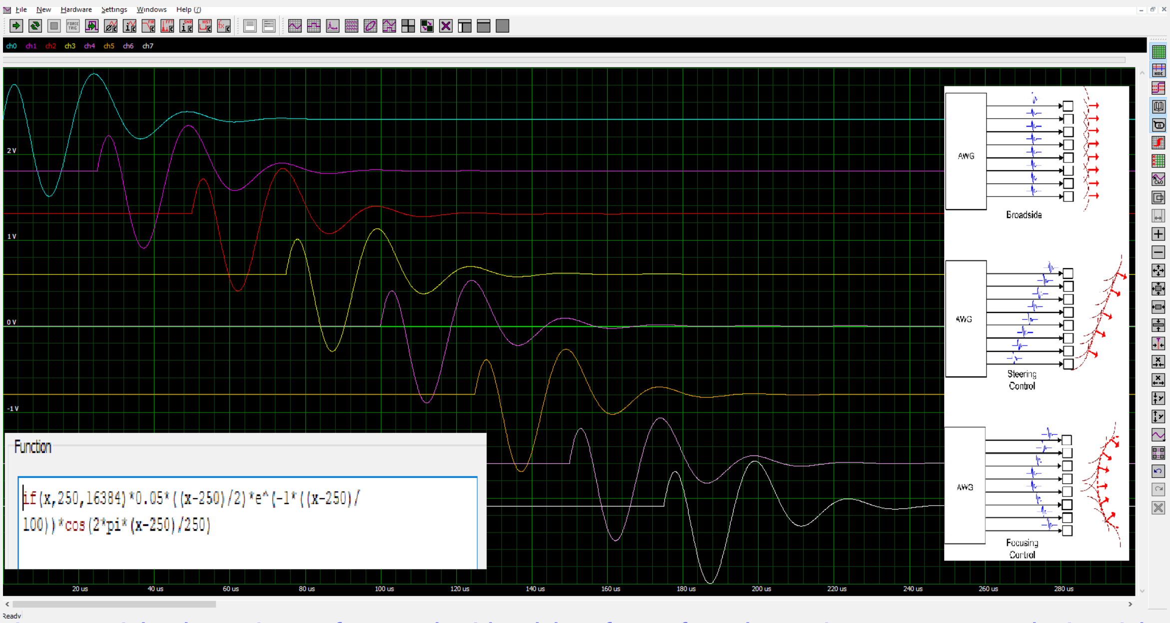

Figure 7: Eight ultrasonic waveforms each with a delay of 25 µs from the previous one are created using eight equations, one of which is shown in the insert on the lower left of the figure. The other insert shows possible steering or focusing opportunities based on the programmed delay of each waveform.

Creation of a large number of signal waveforms is easily done using the SBench6 program's equation editor as shown in the insert in the lower left of Figure 7. The individual waveforms are amplitude modulated 40 kHz cosine waves. Each of the eight waveforms is delayed from the previous one by 25 µs. The modulation envelope is composed of summed ramp, which controls the attack time, and an exponential element, which determines the decay time. They are all clocked at a 10 MHz rate and each waveform uses 16 kilo samples (kS) of the AWG's 512 MS memory. Long waveform memory is important as for a given sample rate it determines the time duration of the output analog waveform.

If the eight signals are phased to reach the transducers at the same time, then a uniform or broadside wavefront is propagated as shown in the insert on the right side of Figure 7. The transmitted signal from an ultrasonic acoustic transducer array can be steered by arranging the individual drive signals to be delayed sequentially. The spherical wave fronts emitted by the transducers are spatially delayed causing the composite signal to be directed downward in the example. Similarly, if the drive signals are delayed from the outside of the array to the inside, as shown in the arrangement in the lower drawing in the insert, the beam can be focused toward the center. These phased arrays permit steering and moving radiated beams by non-mechanical means. The waveforms in the example implement the steering function. Adjustments to the drive signals amplitude in addition to the delay can achieve other effects. AWG users have complete control over the waveform's characteristics and timing offering complete flexibility in controlling the emitted wave front.

Conclusion

These examples provide a view of the power of the hybridNETBOX to provide both the signal source and the measuring instrument in a single instrument that can be used stand-alone or as a programmed instrument within a fully integrated test system.

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