▶ **Application Note**

Using Spectrum Digitizers in Ultrasonic Applications

The use of Ultrasonic products is increasing as new techniques and improvements in instrument performance constantly expand the range of applications. Spectrum digitizers are ideal tools for making ultrasonic measurements and can play a key role required in the development, testing and operation of these products. Spectrum digitizers and arbitrary waveform generators offer a wide range of bandwidths, sampling rates, and dynamic range to match the broad spectrum of ultrasonic measurement needs.

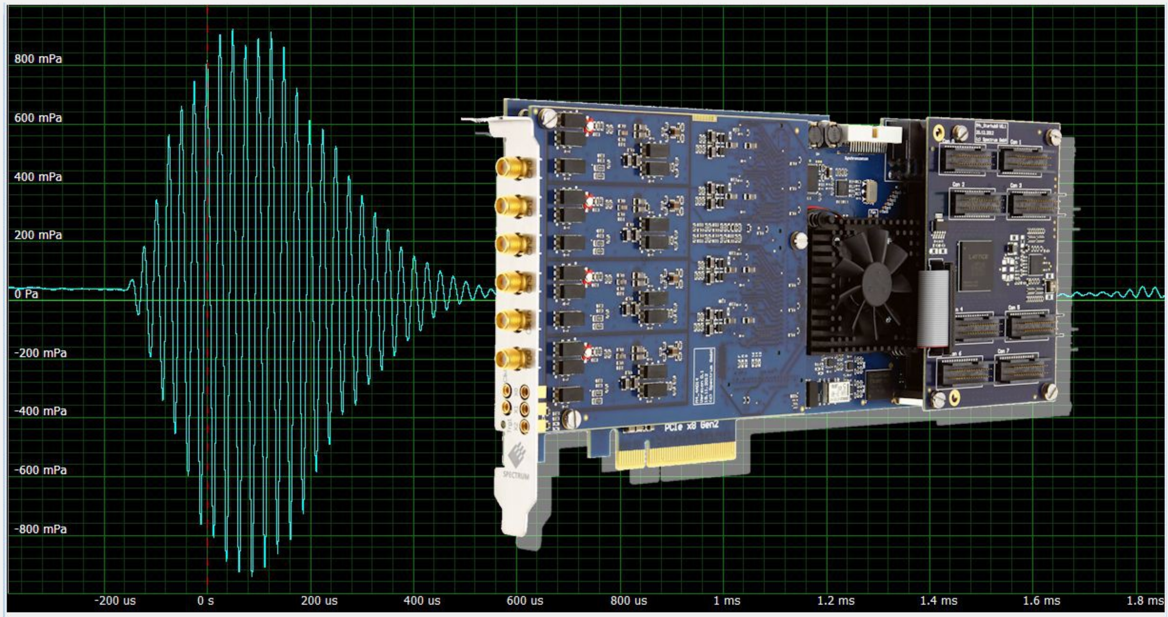

Figure 1: Spectrums M4i.4451-x8 – a PCIe 4 channel 14 bit 500 MS/s digitizer in acquisition of ultrasonic signals

Ultrasonic Applications

Ultrasound is an acoustic sound pressure (acoustic) wave with a frequency greater than the upper limit of the human hearing range. Ultrasound devices operate with frequencies from 20 kHz up to several gigahertz.

Table 1 summarizes the characteristics of a range of some the more common ultrasonic applications.

Application	Typical Frequency Range	Simplex or Duplex	Dynamic Range	Recommended Spectrum Digitizers
Nondestructive Testing (NDT)	0.1-100 MHz	Duplex (Transmit/Receive)	Moderate	M2i.20xx, M2i.49xx, M4i.22xx
Medical Imaging	1-18 MHz (High-Res up to several GHz)	Duplex	High	M2i.49xx, M4i.44xx, M4i.22xx
Ultrasonic cleaning	40 kHz	Simplex (Transmit)	Low	M2i.20xx, M2i.47xx
Ultrasonic Welding	20-100kHz	Simplex	Low	M2i.20xx, M2.47xx
Range Finding	40 kHz	Duplex	Moderate	M2i.47xx
Parking Assistance	40 kHz	Duplex	Moderate	M2i.30xx, M2i.47xx
Scanning Acoustic Microscopy (SAM)	2 MHz – 1 GHz 2- 230 MHz typical	Duplex	High	M4i.22xx, M4i.44xx
Flowmeters	640 kHz – 1 MHz	Duplex	Moderate	M2i.49xx, M4i.22xx, M4i.44xx
Time of Flight Diffraction	1 – 15 MHz	Duplex	Moderate	M2i.49xx, M4i.22xx, M4i.44xx

Table 1: Characteristics of common ultrasonic applications along with the recommended Spectrum digitizers

The range of frequencies used in each application reflect an engineering trade-off. Increasing the operating frequency allows detection of smaller artifacts by increasing resolution but the higher frequency signals don't penetrate as far. The common problem with ultrasound applications is signal attenuation, which is inversely proportional to the signal frequency. As a result, very high frequencies tend to be used in surface study applications while lower frequencies are more dominant whenever greater penetration and power is needed. Of course, increasing the dynamic range of your digitizer also allows you to detect smaller signals.

Sample Rate

The basis for the products selection is related primarily to the frequencies used in the application. The sampling rate of the digitizer, in general, needs to be 5 to 10 times the application's frequency. Except when the application uses Doppler shifts, even though the frequencies may not be that high, the timing resolution needs to be higher as frequency shifts, which are often fractions of a signal period need to be measured. In Doppler applications the sample rate of the digitizer may need to be much more than 10 times the used frequency.

Bandwidth

The digitizer bandwidth should exceed the highest frequency used in the application by at least a factor of two. Working with a lower bandwidth will lead to attenuation of higher frequency signals and may limit measurement resolution and accuracy.

Dynamic Range

Increasing the digitizer's dynamic range (number of bits) allows the detection of smaller signals. Higher resolution ADC's generally deliver better signal-to-noise ratio making it possible to detect large and small signals in the same acquisition. This is why leading edge systems often use higher resolution ADC's or signal processing (like averaging and filtering) to improve their overall measurement sensitivity.

Other Considerations

The digitizer’s input circuits must be a good match to the ultrasonic sensor’s output impedance and coupling requirements. Many of the Spectrum digitizers offer a choice of input paths, configurations and termination impedances allowing for the best possible match.

Depending on the nature of the ultrasonic signal the digitizer’s acquisition modes may also be important. Applications using multiple signal bursts, or pulsed ultrasound, benefit from the digitizer’s ability to accept and process multiple acquisitions with minimal dead-time between the burst events. Multiple (segmented), gated and streaming acquisition modes can all play a part in making sure each event can be accurately captured and analyzed.

Additionally, Spectrum digitizers offer signal processing such as averaging, peak detection, filtering and Fast Fourier transform (FFT). Of these, averaging and peak detection are available as FPGA based internal processing functions. The other signal processing features are available in Spectrum’s SBench 6 or third party software.

A Typical Ultrasonic Application

The following measurement of an ultrasonic range finder illustrates some of the features available in Spectrum digitizers. The device transmits a burst of five, 40 kHz, acoustic pulses. The measurement sensor for this test was a 100 kHz bandwidth instrumentation microphone. The microphone required a one megaohm input termination, DC coupled. Figure 2 shows the Spectrum SBench 6 software’s display of this measurement.

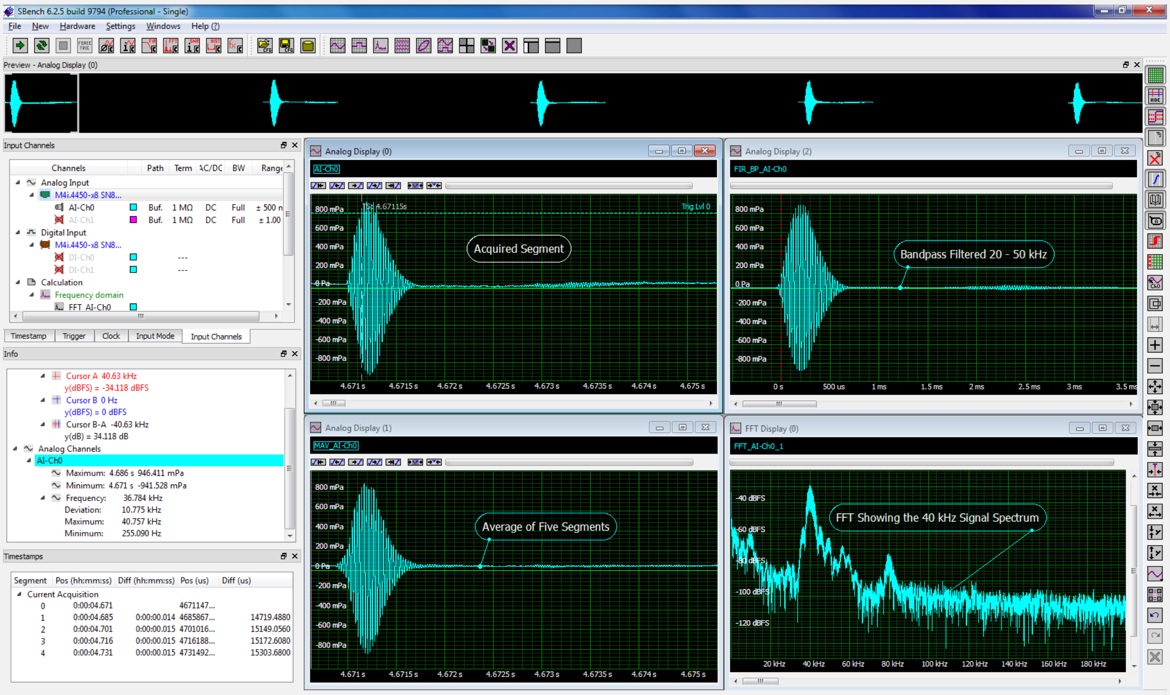

Figure 2: The use of Spectrum’s SBench 6 software to acquire and process a 40 kHz ultrasonic signal. The five segments of a multiple acquisition are processed using a band pass filter, averaging, and FFT

The digitizer was setup using multiple acquisition mode. It acquired the five ultrasonic pulses as a single measurement. The preview pane at the top of the display shows these burst pulses. Each of these events was time stamped and the timestamp table in the lower left corner of the screen shows the event time both absolutely and relative to the other events. Time stamping provides a simple way to measure the pulse repetition period while the multiple acquisition mode makes it easy to compare individual events and make other measurements such as pulse duration, duty factor, spatial pulse length, peak amplitude and time.

A zoom display of the first of the acquired bursts, including the attenuated reflection from the target, is shown in the upper left displayed trace. Note that the trailing edge is not flat. A view of the FFT shows the spectrum of the acquired signal in the lower right quadrant. In addition to the 40 kHz primary frequency there is a second harmonic at 80 kHz and significant low frequency spurious components. The baseline rise in the acquired signal is due to the low frequency spurious pickup. Based on this spectral view a band pass filter with cutoff frequencies of 20 and 50 kHz is applied to the signal (upper right grid). Filtering resulted in a flattening of the trailing edge of the signal. The average of the five acquired bursts is displayed in the lower left grid. The vertical axis of each of these views is scaled by the microphone’s sensitivity and reads in units of sound pressure (Pascal). These views provide significant quantified information about the acquired signal.

In addition, measurements of the signal frequency and maximum and minimum signal amplitude are shown in the box marked ‘Info’. This is a small sample of the measurements available.

The digitizer and its accompanying software provide a multitude of measurement and analysis tools to aid in the development of ultrasonic applications.