Testing Medical Electronics

TECHNICAL BRIEF

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Summary

The world market for medical electronics is very large and growing. Devices range from very complex medical imaging systems such as MRI (magnetic resonance imaging) machines to much simpler devices such as blood pressure monitors used for home health care.

Of course everyone wants the products used for health care to be as accurate as possible, but making measurements of the condition of a human body can be challenging.

When testing electronics in a lab, an engineer can inject a known test signal that is always the same shape and then look at the output of the device under test. This can also be done when testing medical electronics but when it comes to actual use in the marketplace, making measurements of the signals from a human can be much trickier. There is no repetitive signal source: Each heart beat is a bit different and each firing of an electrical synapse differs from the previous ones. Often the signal-to-noise ratio (SNR) is not nearly as good as when testing other types of signals. And yet, a high degree of accuracy is needed. From an engineering point of view, the test equipment needs to make good measurements of "single-shot" signals (no averaging because the signal is not repetitive) in conditions where the noise level is significant.

Generating Test Signals

Of course, when a medical product is under development it undergoes a plethora of testing before it ever interacts with a human. During the product design stage, a signal source is needed to emulate the signals which will eventually be tested. The same is true of production testing of medical products once they are in production. Test signals are used before the item is shipped to the end user. The upper trace in Figure 1 shows an example of a test signal. The signal shape is captured using a digital storage oscilloscope (DSO), also commonly referred to as a digital scope. There are regular pulses, such as the one near the middle of the screen. Each large pulse has smaller pulses just before and just after it. The whole waveform resembles the output of an EKG machine. The large pulses are called "R waves" and the smaller pulses just before the R waves are called "P waves." The whole set of pulses is riding on top of a slow modulation. This signal is being produced by an ArbStudio arbitrary waveform generator (made by Teledyne LeCroy). An instrument such as this can produce any arbitrary signal shape or standard functions (like sine waves, triangles, ramps, etc.). It can even import real-world signals that have been captured by a digital oscilloscope, and then reproduce those signal shapes.

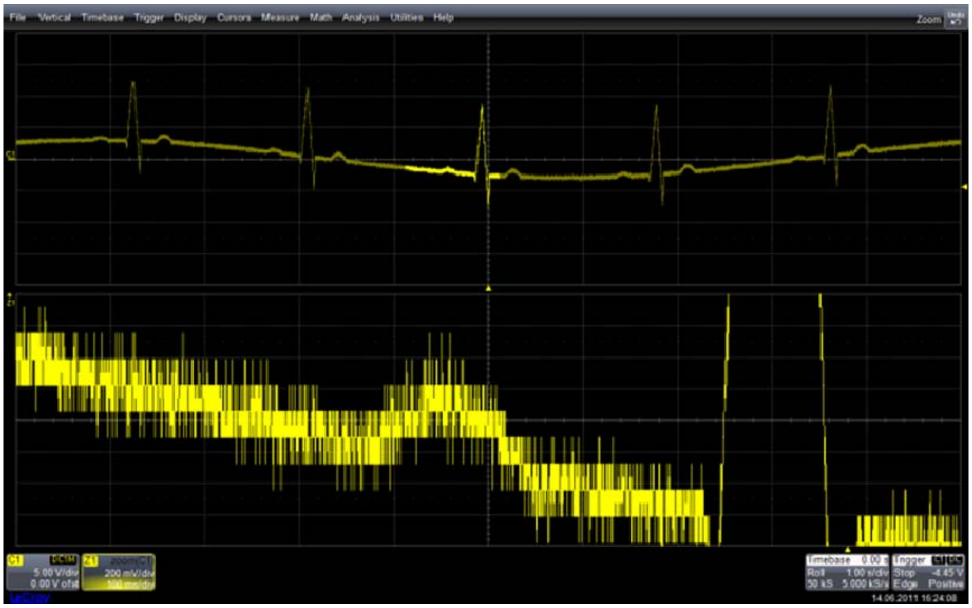

Figure 1: The upper trace is a signal produced by an ArbStudio arbitrary waveform generator and captured by an 8-bit oscilloscope. The lower trace is a zoomed detail of the highlighted portion of the upper trace.

Signals can be produced once (single shot), several times, or as a continuous loop. An engineer can also modify a real-world signal by adding/reducing noise, adding glitches or other types of signal modifications. Arbitrary waveform generators are a very useful tool when a complex signal stimulus is needed to test a product. Teledyne LeCroy offers two types – the ArbStudio (with longer memory to produce longer, more complex signals) and the WaveStation (with shorter memory for generating shorter, simpler test signals).

Making Measurements

Let's suppose the small "beat" (the P wave) before the larger pulse (the R wave) is the interesting part of the signal to be measured. The lower trace in Figure 1 is a zoomed detail of a portion of the full signal. It is the brighter, highlighted portion of the upper trace. If you want to measure the amount of noise compared to the height of the small bump, this is a good signal to work on. The oscilloscope offers parameters that will measure the peak-to-peak height and the RMS noise. But what if the important characteristic to study is the shape of the underlying signal and, further, what if it is being substantially obscured by the noise? Because the underlying signal is not repetitive, signal averaging cannot be used. Another technique to reduce noise components in a signal is the application of filters. In this example, the noise is of a higher frequency than the signal of interest, so a low-pass filter is needed. Many oscilloscopes offer low-pass filters. Teledyne LeCroy offers a Digital Filter Package (DFP) which allows a scope user to select from a wide range of low-pass, high-pass, notch and other types of filters. The roll-off rates of the filters can also be selected. If only a simple filter is acceptable, a standard feature of many Teledyne LeCroy oscilloscopes is a math function called Enhanced Resolution. This function has user-selectable low-pass filters which will remove high frequency noise. Other oscilloscope manufacturers also offer built-in low-pass filters, often called High Resolution mode. But they tend to give the engineer less control over the filter. Figure 2 shows the same signal as in Figure 1, but with high-resolution mode invoked. The noise is greatly reduced. Unfortunately, the shape of the underlying signal is also substantially modified. The "quick and dirty" method of getting rid of noise is not very useful in this case.

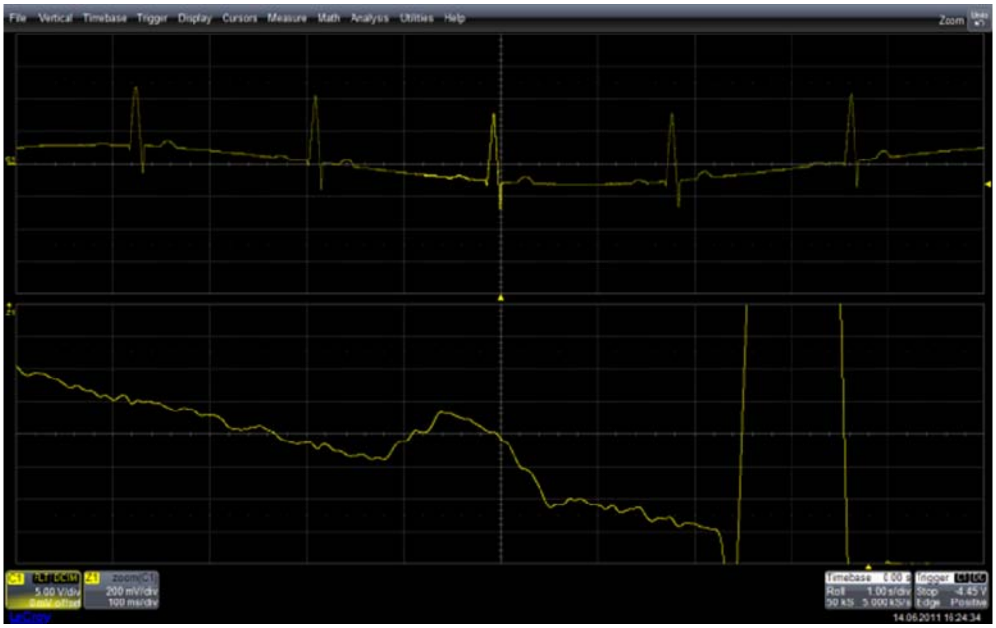

Figure 2: The same signal and same 8-bit oscilloscope as in Figure 1, but this time the signal was acquired using high-resolution mode. This reduces the noise but also distorts the signal.

In Figure 3 the same signal is captured using a more precise digital oscilloscope, an HRO (high resolution oscilloscope). These types of instruments have lower noise front end amplifiers which add much less noise to the signal in the process of capturing it. They also capture the signal using 12 bit ADCs (analog to digital converters)

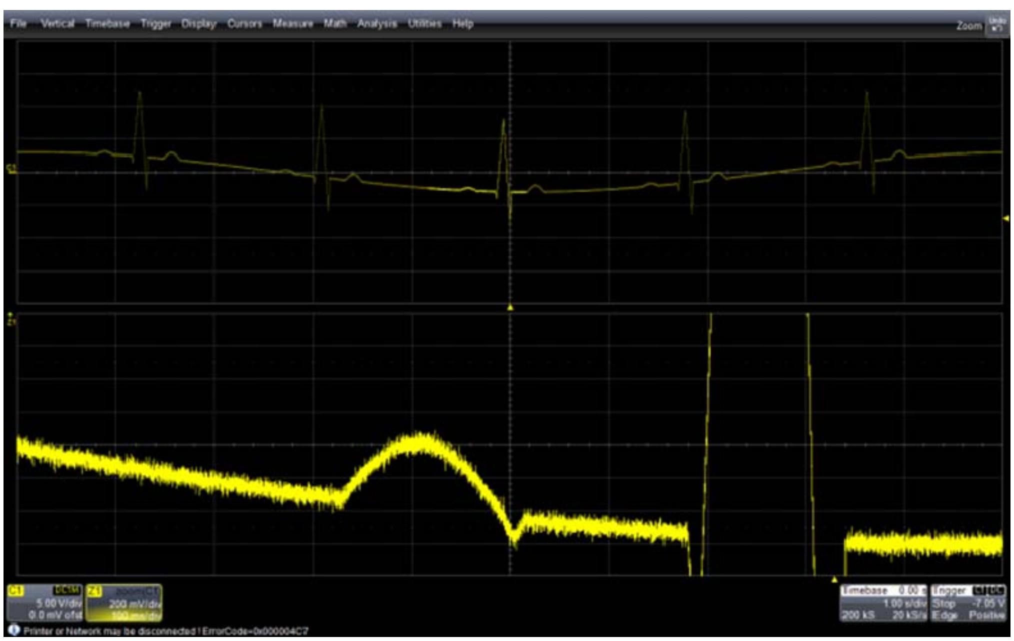

Figure 3: The same signal as in Figures 1 and 2 but this time captured using a low noise, High Resolution Oscilloscope (HRO). The true signal shape is not as noisy as Figure 1.

rather than the more common 8 bit ADCs of most oscilloscopes. Though the signal in Figure 3 is still noisy, it is not nearly as noisy as in Figure 1. The difference is that the signal shown in Figure 3 is much closer to the true shape of the signal. In Figure 1, the extra noise has been added by the process of capturing the signal using a lower-resolution instrument. In Figure 4, filtering has been used to reduce the signal's noise. The engineer now gets a clean look at the underlying signal shape. There is a very interesting small overshoot at the trailing end of the small pulse (the P wave). This might be very useful to the medical diagnosis.

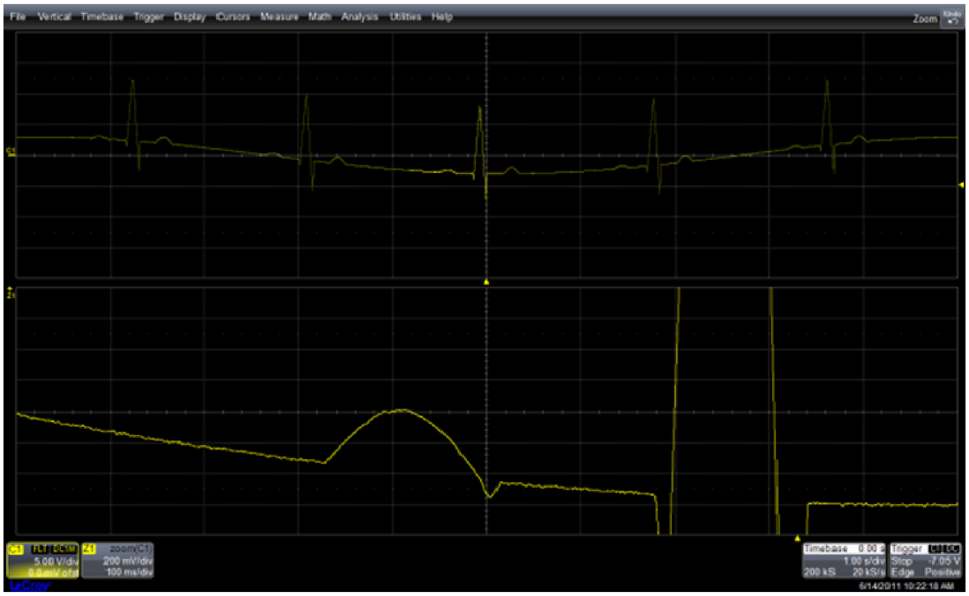

Figure 4: Using high resolution mode on the HRO the real shape of the underlying signal can now be seen.

Summary

Testing medical devices often involves the capture and measurement of single shot signals that contain substantial amounts of noise. When characterizing these devices, it can be important to know how much of the noise is a real part of the signal that is being tested and how much of the noise was added by the process of capturing the signal. An HRO from Teledyne LeCroy is highly recommended for this application. Arbitrary waveform generators can be an excellent tool for producing stimulus waveforms that mimic the human body. An engineer can even capture a real signal from a human body and then reproduce it using the AWG.