[Trigger and synchronize digitizers to acquire the right data]

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Triggering is an essential function for any instrument that acquires and digitizes signals. Without the ability to trigger on a specific waveform characteristic, you may never see the point of interest within a digitized waveform. Digitizers can acquire data in several modes. The ring buffer or normal mode behaves just like a digital oscilloscope. Acquired data is loaded into a ring buffer. When the trigger occurs, the data, allowing for post trigger delay, is locked for display and processing. Digitizers also support a streaming acquisition mode where the digitizer captures, digitizes, and continuously stores waveforms. Triggers, therefore don't indicate the start of a waveform, but rather a point in time where a specific characteristic occurs. In either mode, you can see what happened both before and after the event of interest.

The most common trigger method uses the signal input from one of the digitizer's channels. The basic principle is that a defined point on the waveform is detected and this "trigger event" is marked as a known position on the acquired data. **Figure 1** provides an example of a basic edge trigger. The signal source is the input channel with the trigger event occurring when the waveform crosses the trigger level at 500 mV with a positive slope. When this occurs, that position on the acquired signal is marked as the zero time point on the time axis as shown by the cursor position in the figure. If the signal is repetitive, the digitizer will be triggered at the same point each time a new acquisition is made, resulting in a stable display.

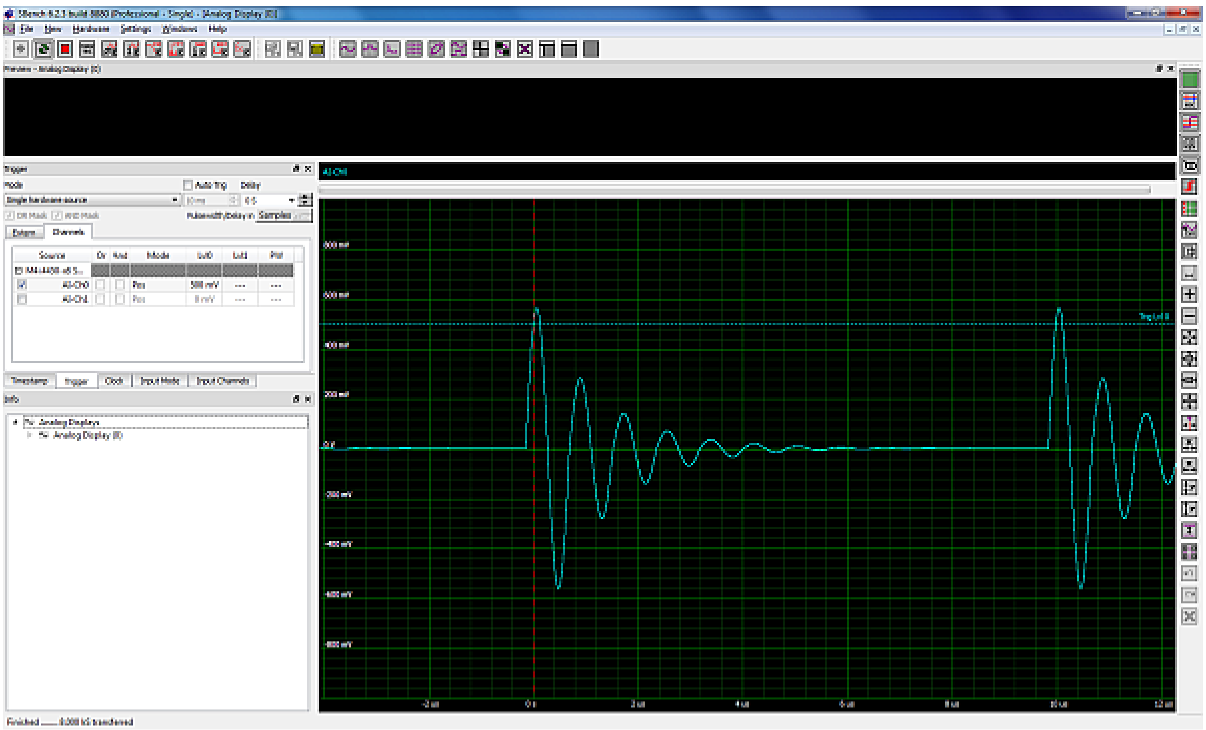

Figure 1. A basic edge trigger defines the zero time value on the time axis (marked by the vertical dashed line), which occurs when the waveform crosses the trigger level (horizontal dashed line) with a positive slope.

The wide variation in possible signal waveforms, levels, and timing requires that a digitizer's trigger circuit be extremely flexible. **Figure 2** shows a block diagram of the trigger ‘engine’ of a Spectrum M4i series digitizer. This provides an example of the wide range of trigger conditions that are supported in modern digitizers.

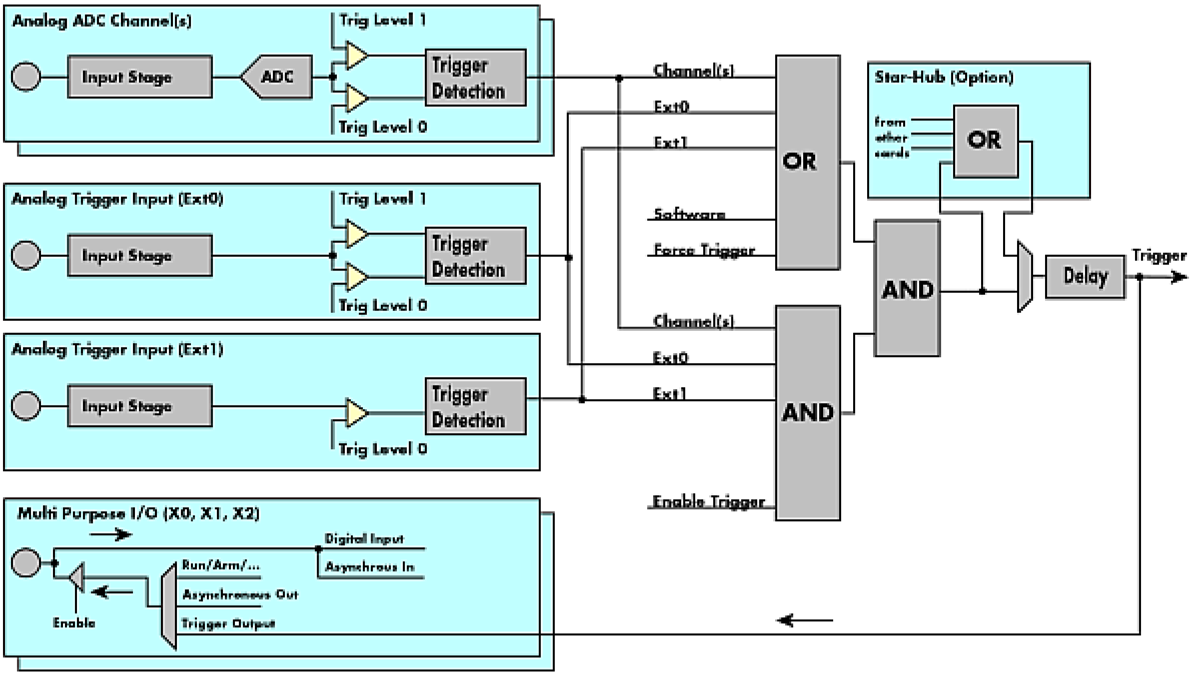

Figure 2. The block diagram of a Spectrum M4i digitizer shows the "Trigger Engine" the trigger sources and trigger logic for these general-purpose digitizers.

The hardware trigger sources of a digitizer are shown on the left side of the block diagram. They include any of the input channels and either of the two external trigger inputs (Ext0 or Ext1). Each of these sources is capable of supporting multiple trigger types. Because many digitizer modules have multipurpose I/O lines, you can use them to report the digitizer's run/arm state and they can provide a trigger output signal, plus other functions. In addition to the hardware trigger sources, you can use software triggers that operate under program control. That's useful for developing automated tests.

Digitizers may include powerful trigger AND/OR logic elements that let you combine inputs from multiple sources into a complex multi-element trigger. Such triggers can ensure that the digitizer will only trigger when specifically defined patterns occur. Yet another feature is the ability to cross trigger with other digitizer cards.

Trigger modes

Trigger modes
The principal trigger sources contain dual trigger-level comparators that support multiple trigger modes. These include single-slope and dual-slope edge triggers, re-arm (hysteresis) triggers, window triggers, and for the multiple source trigger, there are related trigger gate generators.

Edge triggers are the most basic trigger type. You simply set a trigger level and selects the desired trigger slope. The digitizer then marks the point in time where trigger source crosses the trigger threshold with the selected slope. The slope selection can be positive, negative, or both.

Re-arm or Hysteresis triggers set two levels, the first is the arm level the second is the trigger level. As with the edge trigger, the user also selects a slope. The signal must cross the arm level with the selected slope first, which arms the trigger. The digitizer will then only trigger when the signal subsequently crosses the trigger level with the same slope. The re-arm trigger modes can be used to prevent the digitizer from triggering on the wrong edges of noisy signals.

Window triggers use two trigger thresholds per trigger source to define an amplitude window. There are two operational modes for the window trigger: trigger upon entering the window and trigger upon exiting the window. Trigger on entering will trigger whenever the source signal crosses one of the threshold levels and enters the window. The trigger on exiting triggers when the source signal has been between the two trigger thresholds and then leaves the window. Window triggers are used when the source signal can change states in either direction.

When using a multi-source trigger mode with a digitizer's built-in trigger logic, you often need to use one channel to create a gate waveform to enable a trigger from another channel. You can accomplish this using the high level, low level, inside window, or outside window selections. These trigger modes generate an internal gate signal that can be used together with a second trigger source and AND logic to gate the trigger.

Figure 3 shows an example of using the high level trigger to gate a trigger source on another channel. Whenever the sine wave on channel CH0 exceeds the trigger level, a positive gate is generated for the entire time that the signal is above the threshold. This gate signal is ANDed with the signal on channel CH1; since the gate signal is positive only while the low amplitude pulse is present on CH1 the digitizer triggers when the pulse waveform crosses the trigger level shown as a horizontal, red dashed line in the figure.

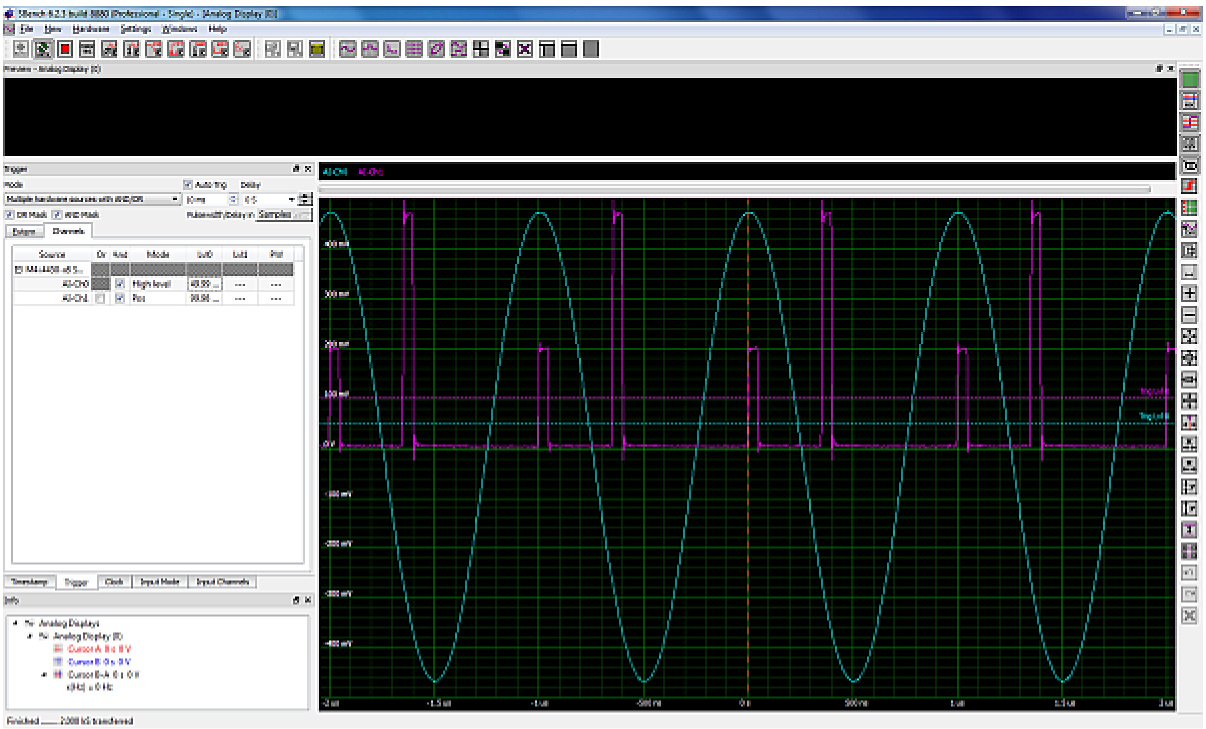

Figure 3. Use of the High Level trigger on CH0 to create a gate signal to select the lower of the two pulses on channel CH1. The Hi Level trigger creates a gate that is in a positive state as long as the trigger source is above the trigger level (Trig Lvl 0.). This gate is

ANDed with the CH1 pulse waveform which allows the digitizer to trigger on the lower amplitude pulse.

Trigger Logic
The example in Figure 3 shows one use for the available trigger logic when dealing with multiple trigger sources. Both AND and OR logic elements are supported. Inputs to the OR function include any of the channels, the external trigger inputs, the software trigger, and the force trigger function. The logical OR function permits any of these trigger sources to trigger the digitizer. Inputs to the AND logic function include all the channels, the external trigger inputs and the enable trigger function. The AND function requires that all selected trigger inputs be asserted at the same time, which initiates a trigger. Remember that the gating trigger modes—high level and low level—provide the ability to logically invert an inputs input's logic so that you can create NAND and NOR conditions.

Figure 4 shows an example of a radio location application that uses the OR trigger logic. Each of the input channels is connected to a sensor. Direction to the source is determined by the arrival time of the emitted pulse at each sensor.

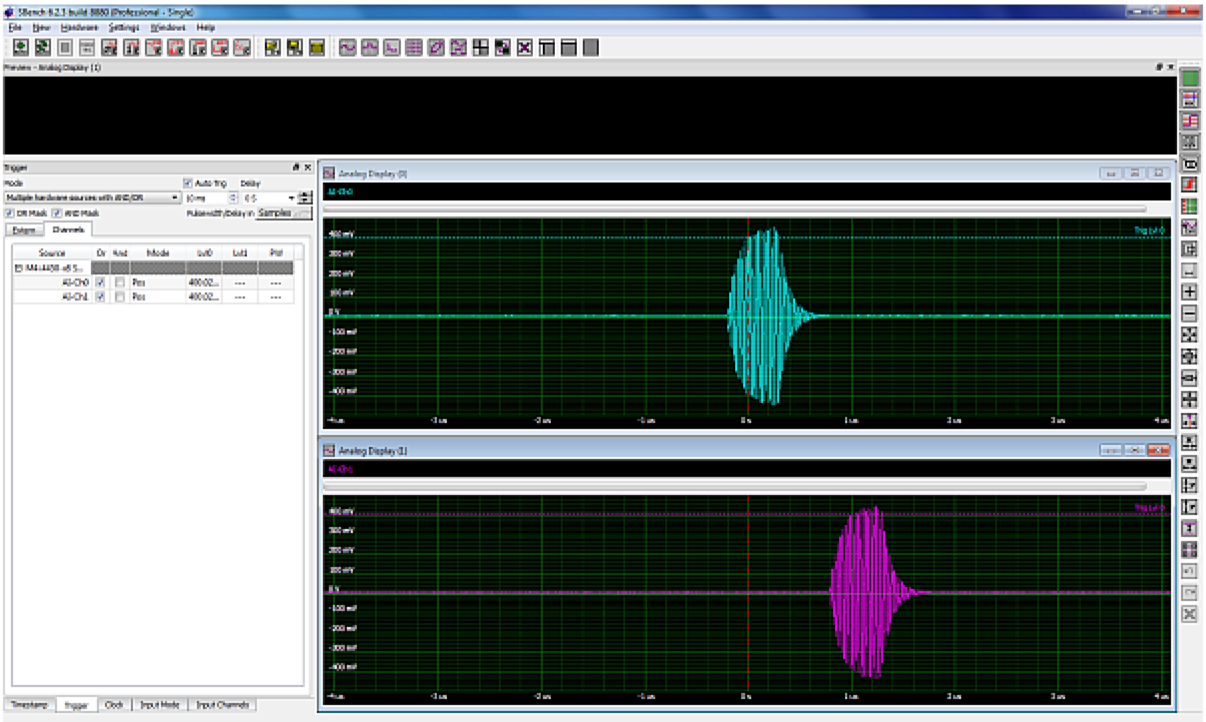

Figure 4. You can use an OR trigger logic to trigger on the channel where the earliest RF burst occurs.

The location of the source determines which channel sees it first. The OR trigger logic allows the channel with the earliest burst to trigger the digitizer, guaranteeing that both sensor outputs will be captured.

Other trigger-related features

Other trigger-related features
There are two additional trigger functions worth mentioning. The first is trigger delay, which is the last element in the trigger block diagram in Figure 2. This function uses a counter and lets you delay the trigger event a specified number of samples later. If the delay is changed from the default (zero) setting, then the trigger point on the horizontal axis is changed from zero to the delay valued

entered.

The second feature is the external trigger output and trigger status lines. These features are useful in synchronizing multiple instruments. Trigger output, ARM and RUN status are available via the multi-purpose I/O channels as shown in Figure 2.

Synchronization
Theoretically, there are two issues that occur when synchronizing instruments. The first is to arrange for a common trigger. The second is to have both instruments operate from a synchronized clock. As simple as this seems, there are issues that arise when attempting to synchronize multiple digitizers.

The clock can be synchronized by using an external clock at the desired clock rate. A second method is to supply an external reference such as 10 MHz, this is then applied to a PLL (phase locked loop) used to multiply the frequency of the reference clock to the desired clock rate. Many digitizers such as the Spectrum M4i series digitizers used in this article handle both types of external clock through a common external clock input. The external clock input is connected to an internal PLL and you can set this to either multiply a reference clock or to phase lock the digitizer to the external clock and pass it through without changing the frequency. This guarantees the correct frequency for the clock but won't guarantee that the clock in each digitizer has the identical phase.

On the trigger side of the synchronization process, you must consider that each digitizer's external trigger input uses a separate comparator to detect the trigger-level crossing. Small differences in reference level and differences in setup and hold times can result in discrete changes in the trigger point location in time, a form of trigger jitter. The only way to guarantee exact synchronization of multiple digitizers is to distribute the clock to each module and to synchronize the trigger event to the system clock.

Synchronizing multiple digitizers
The Spectrum M4i series digitizer used in these examples has an optional synchronization accessory called Star Hub. The star hub module allows the synchronization of up to 8 cards of the same family.

The module acts as a star connected hub for clock and trigger signals. The digitizer with the module acts as the clock master and that card or any other card can be the trigger master. All the trigger modes that are available on the master card are also available if the star-hub module is used. It also expands the AND/OR trigger logic to accommodate inputs from any of the attached digitizers. The star-hub also synchronizes different pre-trigger, memory segment size, and post trigger settings among digitizers by synchronizing the ARM signals from the digitizers.

Conclusion
Digitizers require a trigger to relate the acquisition to a known point in time. Multiple trigger sources and modes make it easy to select the desired trigger point. Additionally, the ability to precisely synchronize the time base via the Star-Hub allows multiple instruments to be coupled together offering a large number of acquisition channels. Digitizers with smart trigger engines let you trigger on and capture a wide variety of complex signals.

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