▶ **Product Note**

Using Modular Digitizer Acquisition Modes

Introduction

Modular digitizers like the Spectrum Instrumentation M4i models shown in Figure 1, offer many acquisition features matched to the primary application of acquiring multiple channels of input data and transferring that data at high rates to analysis computers. They also offer multiple acquisition modes that are intended to use on-board memory efficiently and decrease the dead time between acquisitions. This is especially true with signals that occur at low duty cycles in such applications as echo ranging (including radar, sonar, lidar, and ultrasound), and transient data collection applications (such as time of flight spectrometry and other stimulus-response based analysis).

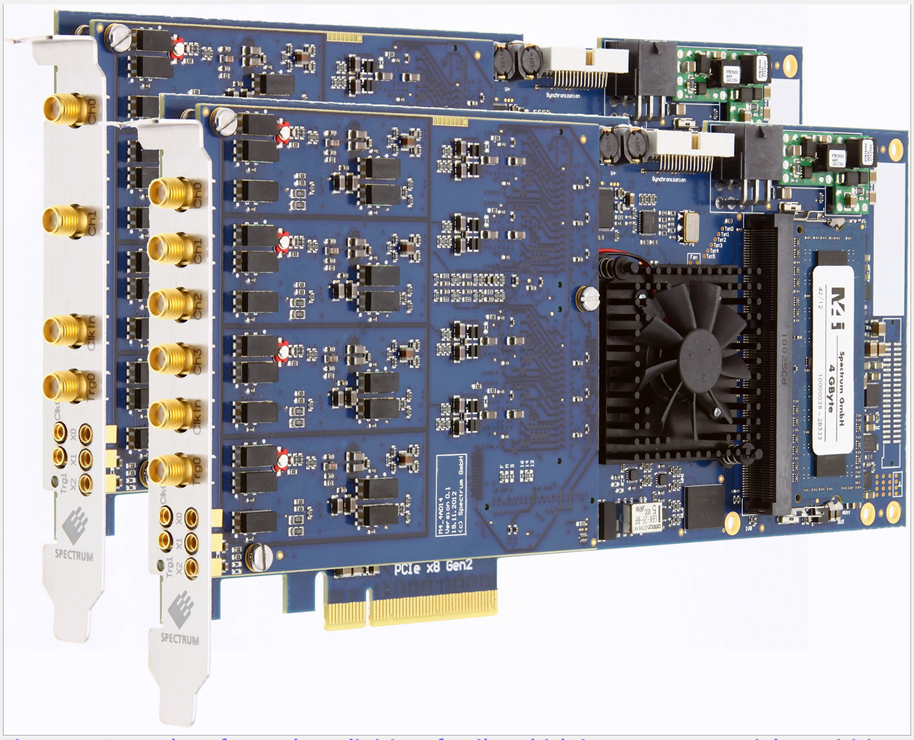

Figure 1: Examples of a modern digitizer family, which incorporate special acquisition modes, the Spectrum M4i series digitizer platform including both the 2 and 4 channel versions with resolutions of 14 or 16 bits built on a PCI Express x8 Gen2 interface which supports transfer rates of up to 3.4 Gbytes/s

Basic Acquisition Configurations

Typical modular digitizers will generally offer two operating modes. The standard mode uses the acquisition memory as a ring buffer just like an oscilloscope. Data is written in the ring memory of the digitizer until a trigger event occurs. After the trigger, post-trigger values are recorded. This results in both pre and post-trigger values being included in the recorded data. This mode is used primarily with the digitizer's associated data acquisition software which is used for viewing, logging and post processing of captured signals and is used to verify the digitizer's setup and to do preliminary processing on the data.

The other mode is FIFO (first in-first out) mode, this is a streaming mode which is designed for continuous data transfer between the digitizer and an external host computer. The digitizer used for this article, a Spectrum M4i.4451-x8, uses a PCI Express x8 Gen 2 interface with streaming speeds up to 3.4 GByte/s. The control of the data stream is handled automatically, by the driver, based on an interrupt request.

The main difference between all standard and all FIFO modes is that the standard modes are limited to on-board memory. The FIFO modes are designed to transfer data continuously over the bus to PC memory or to hard disk and can therefore run much longer. The complete, installed acquisition memory is used as a buffer, providing reliable, data streaming.

Multiple Recording Modes

The standard and FIFO modes each offer three multiple recording methods which provide more efficient use of the acquisition memory in low duty cycle measurement applications. Low duty cycle applications include those which have short duration events of interest followed by long quiescent intervals. The acquisition methods optimized for the capture of this type of signal are Multiple Recording (segment) mode, Gated mode, and ABA (dual time base) acquisition. All of these modes segment the memory and make multiple acquisitions within it. The dual time base ABA mode reduces the sampling rate between triggers saving memory space but providing a view of what is happening in the dead-time between triggers.

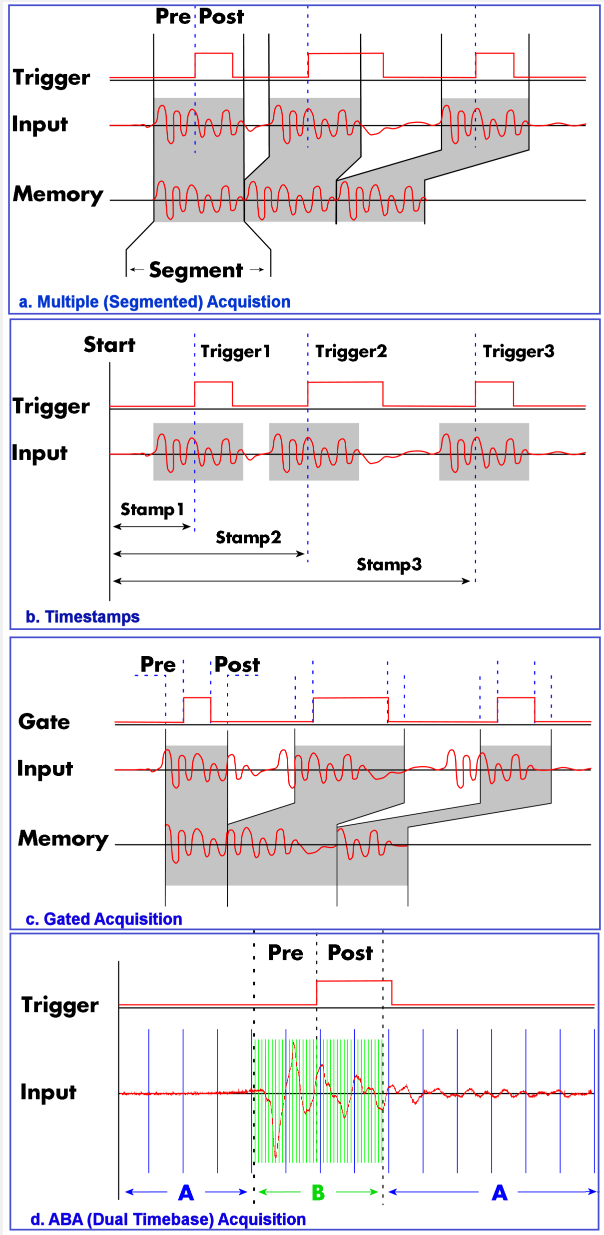

Figure 2: A summary view if Multiple, Gated, and ABA acquisition modes and associated timestamps.

Let’s take a look at how these unique acquisition modes work. Figure 2 summarizes the operation of the digitizer in these modes.

The Multiple Recording (segmented) mode, Figure 2a, allows the recording of multiple trigger events with an extremely short re-arm time. The acquisition memory is divided into several segments of equal size. One segment is filled for each trigger event. The acquisition stops between segments. The user can program pre- and post-trigger intervals within the segment. The number of acquired segments is only limited by the memory used and is unlimited when using FIFO mode. Significant data associated with multiple triggers is stored in the acquisition memory in the contiguous segments. Data associated with the dead-time between events is not recorded. Each trigger event is time stamped so the precise location of each trigger is known. Figure 2b shows a graphical view of the time stamp operation for the Multiple Recording mode. The timestamps are stored in an extra FIFO memory that is located in hardware on the card. It can be read out if needed much as the data is.

Gated acquisition, shown in Figure 2c, uses the state of a gating (enabling) signal, which can be either another channel or an external trigger input, to start and stop the sampling process. Data is only written to memory while the gate is active. As in the Multiple Recording mode, the user can program pre- and post-trigger intervals about the gate. In Gated mode the timestamps mark the opening and closing of the gate not including the pre and post gate acquisition interval. The number of acquired gate segments is limited by the acquisition memory and is only limited by the host memory when using FIFO mode.

ABA mode, Figure 2d, is a dual time base acquisition combining a fast acquisition on trigger events (B time base) with a slow sampling rate (A time base) between triggers. The ABA mode works like a slow data logger combined with a fast digitizer. The exact position of the trigger events is marked with timestamps as in the Multiple Recording mode.

Multiple Recording and Gated acquisition modes offer the following general advantages:

1. The re-arm or trigger 'dead-time' is reduced in multiple and gated modes. Re-arm time of the Spectrum M4i digitizer used in the examples is 40 samples + programmed pre-trigger. At the highest sampling rate the re-arm time is as low as 80 ns. Spectrum digitizers with slower sampling speed like the M2i series have an even smaller re-arm time of only 4 samples. A low trigger re-arm time means you reduce the chance of missing an event even in high event rate applications. The table below summarizes the minimum re-arm time for selected Spectrum digitizers.

Summary of Spectrum Digitizers Re-arm Times

Card	Sampling Rate	Channels	Resolution	Dead-Time (Samples)	Minimum Dead-Time
M4i.4451-x8	500 MS/s	4	14 Bit	40 samples	80 ns
M4i.4411-x8	130 MS/s	4	16 Bit	40 samples	300 ns
M2i.4932-exp	30 MS/s	8	16 Bit	4 samples	132 ns
M2i.4642-exp	1 MS/s	8	16 Bit	4 samples	4 us
M2i.4711-exp	100 kS/s	16	16 Bit	4 samples	40 us

2. Segmentation of the acquisition memory allows more efficient use of memory by recording data at full sample rate only when the signal is active.
3. The storage of only significant measurement events without the intervening 'dead' time results in less data to be transferred and allows continuous data acquisition and processing of segmented signals.
4. The Timestamp of each trigger event allows you to read the time difference between events. When the events represent abnormalities in the signal, timestamps provide information on the rate of occurrence of the anomalies.
5. Timestamps can by synchronized to an external reference signals such as a radio clock or IRIG-B timing generator to get UTC synchronized timestamp information on every event.
6. All segments can be viewed simultaneously and individual segments can be zoomed to reveal fine details within each acquisition.

The ABA mode uses a low sampling rate to provide a view of the signal between triggers while a faster sampling rate is used to show signal components at the trigger with greater time resolution. This method doesn't use memory as efficiently as the Multiple Recording or Gated modes but it does offer a continuous view of what happens between triggers. Using the time stamp the slow and fast data are synchronized with a resolution of one sample.

Application Examples

The first example, shown in Figure 3, shows a Multiple Recording mode acquisition of the acoustic output of an ultrasonic range finder. This device outputs 40 kHz bursts and determines range by detecting the time it takes until an echo is received. The bursts occur in groups of five at a spacing of 15 µs with processing taking place in the 450 ms 'dead-time' between these multiple bursts. The acoustic signal was picked up using an instrumentation microphone with a bandwidth of 100 kHz. The settings on the left side of the figure show the setup of the acquisition. Each segment consists of 32kS with 1kS of pre-trigger and 31kS of post-trigger recording. The sample rate, not shown, is 7.8 MS/s. The upper trace is a preview of the entire acquisition showing the multiple bursts and the processing intervals. The center trace is a zoom view showing five segments. The beginning of each segment is marked with a time stamp. The bottom trace is a zoom view of the first burst in the acquisition. Here you can see the details of the individual burst. The software displaying this data can show the segments contiguously as they are actually stored in memory but the view incorporating the measured spacing is generally more useful. By storing only the segments associated with each trigger the digitizer eliminates over 3.5 MSamples (MS) of data that would have been consumed in recording each instance of the dead time.

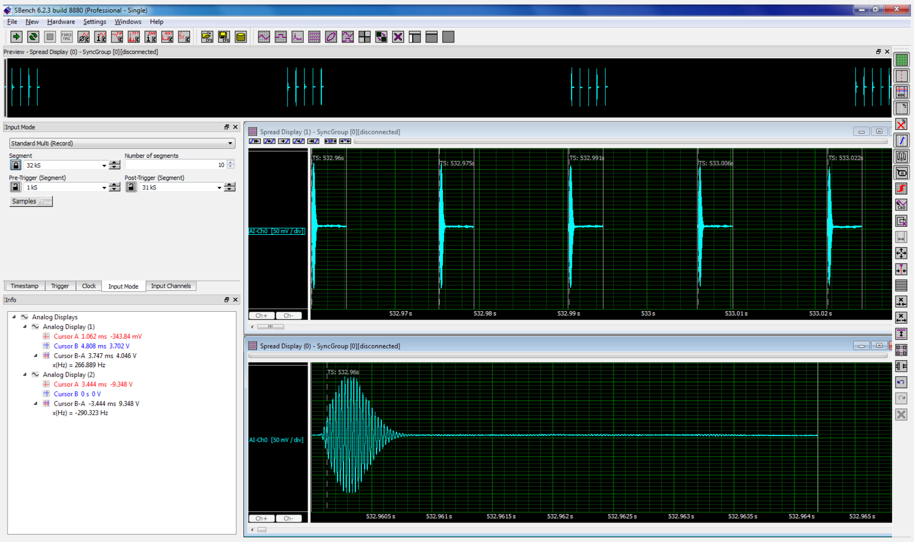

Figure 3: a Multiple Recording capture of the 40 kHz acoustic output of an ultrasonic range finder.

If the data between the acquired segments had some importance then the ABA mode should be employed as shown in Figure 4. In this mode the data is recorded using two different sampling rates. The ABA mode generates two data channels from each input. The primary data channel, called the 'B' channel, contains a Multiple Recording acquisition with one segment of data for each trigger that was detected. The B data acquisition is running with the selected sampling rate. The second data channel (called 'A' data) runs continuously with a divided sampling clock and acquires a slower continuous signal. The time synchronization between A and B data is based on the acquired timestamps. The resulting display has a full acquisition over the complete run time

with the slow A sampling clock while at each trigger event a B segment is generated, sampled at a higher rate, and providing more information on the area of interest.

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The upper trace in Figure 4 is the preview which shows the entire acquisition. The center display is a single segment of data recorded at the selected sample rate (B sampling clock). The time stamp shows the trigger time. The bottom trace is the continuous 'A' data sampled at one sixteenth the selected sample rate. Note the continuous record shows information between pulses that is not evident in Figure 3 where Multiple Recording mode was used.

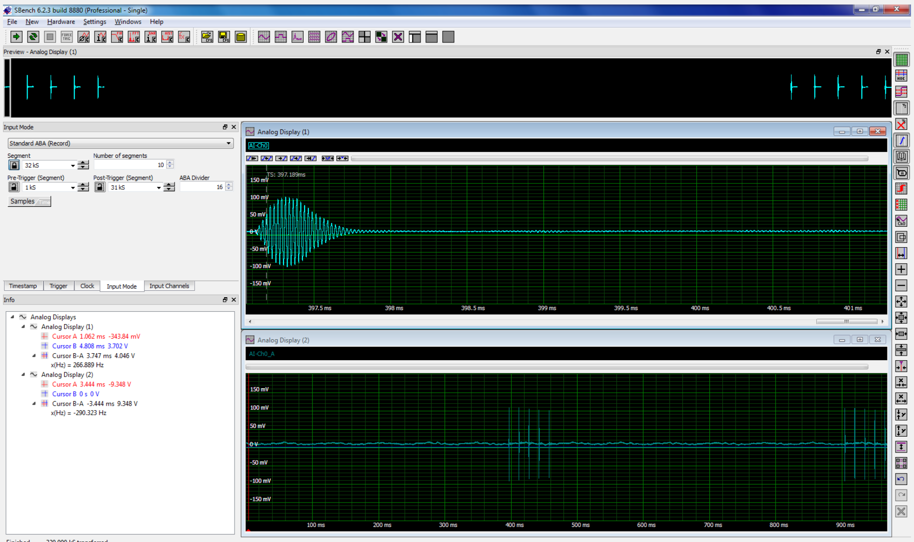

Figure 4: The same ultrasonic burst captured using the dual time base ABA acquisition mode. Note the lower 'A' trace has the continuous signal data captured at the slower sample rate. The upper trace is a single segment taken at the higher (B time base) sampling rate.

The next example shows the Gated acquisition mode. This mode allows data recording that is controlled by an external gate signal which replaces the conventional trigger signal. Data is recorded if the gate signal meets the trigger threshold settings. Since the gate width may not exactly match the duration of the signal a user set pre and post gate area can be added and acquired. The number of gate segments is only limited by the available acquisition memory and is unlimited when using FIFO mode.

Figure 5 provides an example of a Gated acquisition being used with a simulated laser signal. The gate signal marks the laser being triggered. The gate signal has been applied to the second channel of the digitizer and that channel is set up as the trigger source. The trigger threshold level is set to be 150 mV. The resultant acquisition includes both the laser pulse and the gate signal on the display. Note that a pre and post area of 128 samples adds additional samples to the gate area. As in

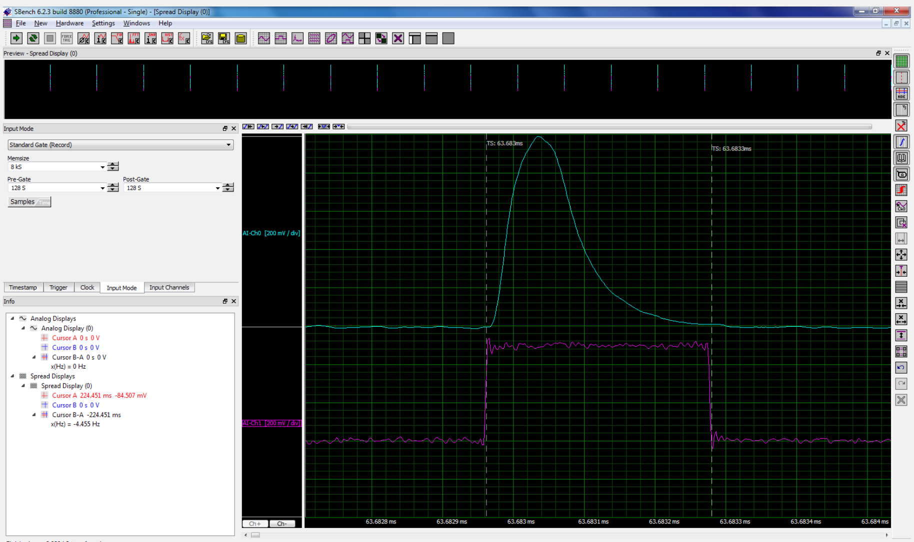

Figure 5: An example of a gated mode capture of a simulated laser pulse. The gate signal, on the second digitizer channel triggers the start and stop of the acquisition which also includes 128 samples pre and post gate.

the previous cases, the upper trace is the preview mode. It shows multiple firings at a 10 Hz rate. When using the Gated acquisition mode the timestamps are associated with the start and stop edges of the gate. This is seen on the zoom view of the segment. Segment duration is equal to the gate time plus the 128 samples of the pre and post gate areas.

Use of the Gated acquisition mode allows the capture of eighteen pulses (with a total duration of 1.8s) using only 8kS of acquisition memory.

Re-arm Time

None of the example presented so far has required a fast re-arm time. Multiple Recording and Gated mode are totally controlled in hardware. There is a very small re-arm time between the end of one segment and the trigger being re-armed for the next acquisition. Consider the sine wave with an 88 ns period shown in Figure 6. It was acquired in Multiple Recording mode. The time stamps for all ten segments show a difference of 88 ns, the sine period. This means that no cycles of the 88 ns sine were missed. Remember that the re-arm time is a function of the sample period and the pre-trigger delay. The update rate is the reciprocal of the 88 ns or 11.36 MHz.

Figure 6: A test of the digitizer's re-arm time in multiple acquisition mode showing the capture of every cycle of a sine wave with an 88 ns period.

Conclusion:

The use of these special acquisition modes, Multiple Recording, Gated acquisition, and ABA, reduces the memory required to capture and analyze low duty cycle signals. Since only 'significant 'events are captured this improves the efficiency of acquisition. In general, less time is needed for data transfer and analysis. Smart acquisition modes also help to ensure important events are not missed. Fast trigger re-arm times and optimized acquisition efficiency allows you to capture complex bursts of signals even when they occur at very high event rates. It makes modular digitizers the instruments of choice for a wide range of echo-ranging and stimulus-response type measurement applications.

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