New External Triggering Options Instructions for Spectrometers with Firmware Version 3.0 and Above

Overview

Ocean Optics spectrometers with FPGA Firmware Version 3.0 and above provide several methods of acquiring data (see table below). In the Normal/Free-Run mode, the spectrometer is "free running." That is, the spectrometer is continuously scanning, acquiring, and transferring data to your computer, according to parameters set in the software. In this mode, however, there is no way to synchronize the scanning, acquisition, and transfer of data with an external event. However, trigger pulses for synchronizing an external event with the spectrometer are available.

To synchronize data acquisition with external events, other modes of acquiring data are available. Each mode involves connecting an external triggering device to the spectrometer and then applying an external trigger to the spectrometer before the software receives the data. The length of the integration time and the source for the integration clock depend upon the mode chosen. All other acquisition parameters are set in the software.

Also see the **External Triggering Options Instructions** for triggering information for other Ocean Optics spectrometers with firmware versions below 3.0.

Triggering Mode	Description	Use This Trigger Mode When You ...
Normal/Free-Run	Spectrometer acquires spectra continuously.	No synchronization to other events is needed
Software	Integration time is set in the software. Software receives a trigger event and transmits spectra obtained in the data acquisition cycle in which the trigger occurred.	Are using a continuous illumination source, and the light intensity is constant before, during, and after the trigger. Need to set the integration time in the software.

Triggering Mode	Description	Use This Trigger Mode When You …
External Hardware Level Trigger	Integration time set via software on a chip in spectrometer. The spectrometer waits for a sharp rise in voltage on the trigger input pin, and then acquires spectra until the voltage is removed.	Need a continuous acquisition whenever a certain condition is met, such as: - when reacting to a sample being present or - when a sample reaches a specific state that you want to measure
External Synchronous Trigger	Spectrometer acquires data from an external trigger event (such as a push button) until the next time the trigger is activated, at which time the spectrometer ceases spectral acquisition and begins a new acquisition. Integration time cannot be set, since the trigger can fire at random intervals.	Must synchronize your scans to an external clock source Are using a lock-in amplifier Are using a chopper
External Hardware Edge Trigger	Integration time set via software on a chip in spectrometer. The spectrometer waits for a sharp rise in voltage on the trigger input pin, and then acquires spectra. This trigger acquires one spectrum each time that there is a sharp rising edge (if an acquisition is not already in progress).	Are using a pulsed excitation source or light source in your experiment (such as a laser or flash lamp) Are doing LIF (fluorescence with pulsed excitation) or phosphorescence experiments Need to synchronize an acquisition with an external event

Setting Up for External Triggering

IMPORTANT: Voltage Regulation

The *maximum* recommended voltage on the Triggering Pin is 5.5 V. If your triggering device exceeds this voltage, you must regulate or condition the signal (via transistor buffering, transformer isolation or opto-isolation, for example) or isolate the signal from the spectrometer.

Note

To use one of the External Triggering options, you must know the specifications and limitations of the triggering device. The design of the triggering device may prevent you from using one of the external triggering modes as it is described in these pages.

Pinout Diagrams for Ocean Optics Spectrometers

HR2000+, Maya2000Pro, NIRQuest, QE65000, QE65 Pro, and QE *Pro*

For external triggering, supply a line from Pin 10 of the multi-pin connector on the spectrometer to your triggering device. Be sure to also use the Ground Pin when triggering. See the appropriate spectrometer Data Sheet to locate the ground pin(s).

2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
1	3	5	7	9	11	13	15	17	19	21	23	25	27	29

Pin-out Diagram of 30-pin Connector on HR2000+, NIRQuest,
Maya2000Pro, QE65000, QE65 Pro, and QE *Pro* Spectrometers

USB2000+ and USB4000

For external triggering, supply a line from Pin 7 of the multi-pin connector on the spectrometer to your triggering device. Be sure to also use Ground Pin 6 when triggering

| 20	18	16	14	12	10	8	6	4	2	A2
19	17	15	13	11	9	7	5	3	1	A1

Pin-out Diagram of 22-pin Connector on USB2000+ and USB4000
Spectrometers

Setting Integration Time in Software

Software, External Hardware Level Trigger and External Hardware Edge Trigger modes can have the integration time set via OceanView or SpectraSuite.

Set Integration Time with OceanView

Use the Main Controls of the Set Acquisition Parameters in OceanView to select the trigger mode and to set the integration time. The **Automatic** button in the **Integration Time** control box automatically adjusts the spectrometer's integration time to bring the highest point of the signal to 85% of full saturation value. This value is represented by the horizontal blue line on the preview graph.
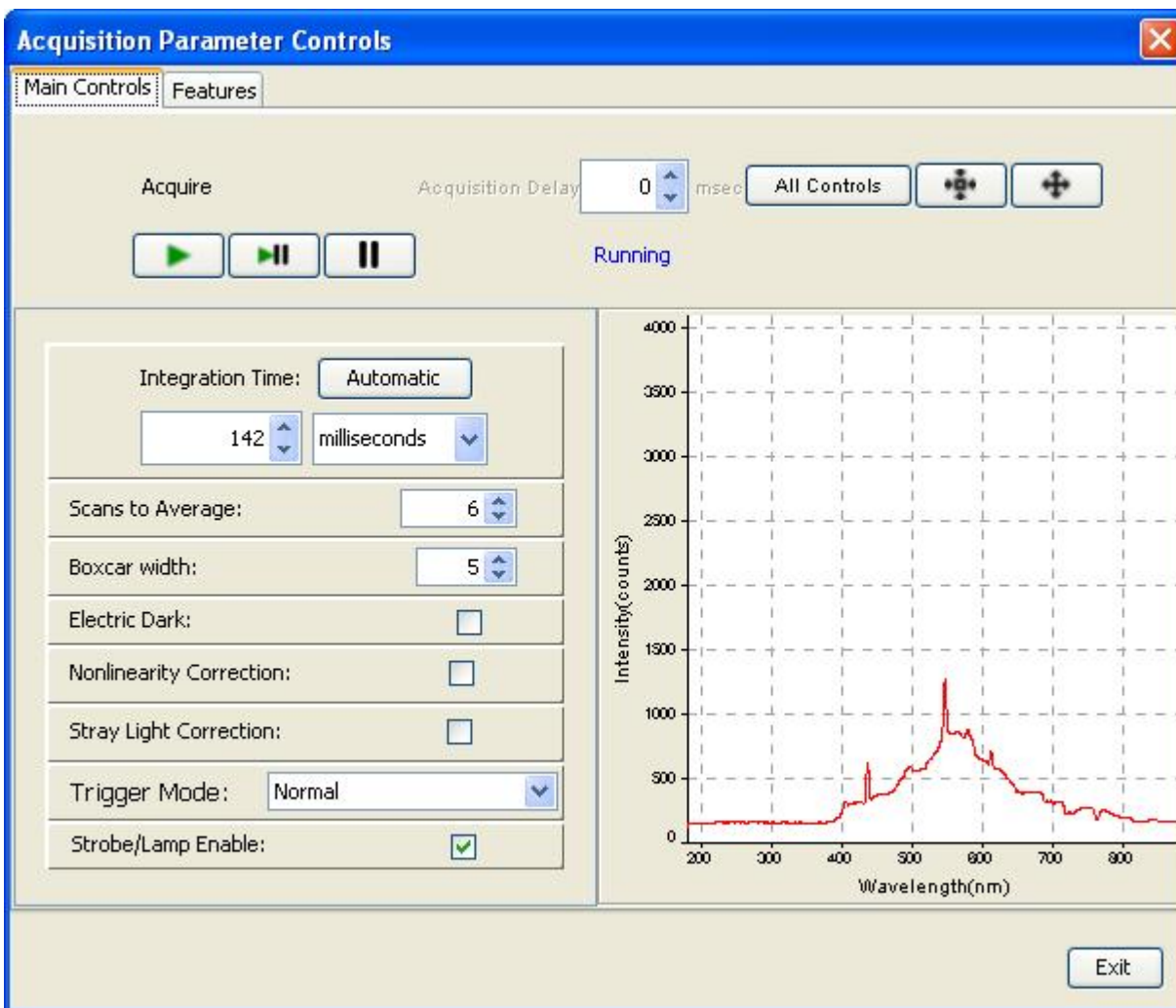
The integration time may also be set manually by using the numeric spinner control and the drop-down units menu. Note that the **Nonlinearity Correction** control is grayed out until the **Electric Dark** control is enabled. Also note that once a triggering mode for the spectrometer has been set, the device will wait for an external trigger before continuing. It will appear as though the spectrometer has locked up and no further data acquisitions will occur until the External Trigger pin on the device receives a signal.

Set Integration Time with SpectraSuite

Use the External Trigger selection box on the Trigger toolbar to set the trigger mode of the spectrometer to **Software**.
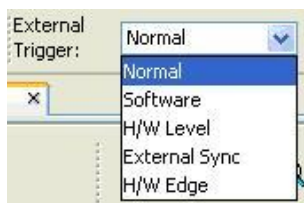
Note

Once you select an external trigger mode, your computer will appear unresponsive. This is normal, as the computer is waiting for a trigger. You must apply one more trigger to the spectrometer after selecting a new trigger mode.

External Triggering vs. Triggering an External Event

There could be some confusion between the concepts of External Triggering and triggering an external event. The following sections explain each of these concepts:

- **External Triggering** – An event outside the sampling system (such as a push button, lever activation, or laser pulse) triggers the voltage level on the spectrometer's trigger pin and instructs the spectrometer to begin spectra acquisition.

- **Triggering an External Event** – When triggering an external event, the spectrometer instructs an external device (typically a lamp such as the PX-2 or the LS-450) to illuminate immediately prior to spectral acquisition.

Trigger Mode Descriptions

The following sections specify the Trigger modes for Ocean Optics spectrometers with firmware versions 3.0 and above and associated timing sequences.

For the Maya2000Pro, NIRQuest, HR2000+, USB2000+ and USB4000, the timing sequences specified are for the trigger mechanism interacting with a single-depth FIFO. The hardware implementing these Trigger modes may enhance the capability and performance by implementing buffering schemes using larger or multiple FIFOs.

For the QE65000, the timing sequences specified are for the trigger mechanism interacting with a triple-depth FIFO. The hardware implementing these Trigger modes enhances the capability and performance by implementing a buffering scheme using multiple FIFOs. In addition, the QE Pro has a 15,698-deep buffer.
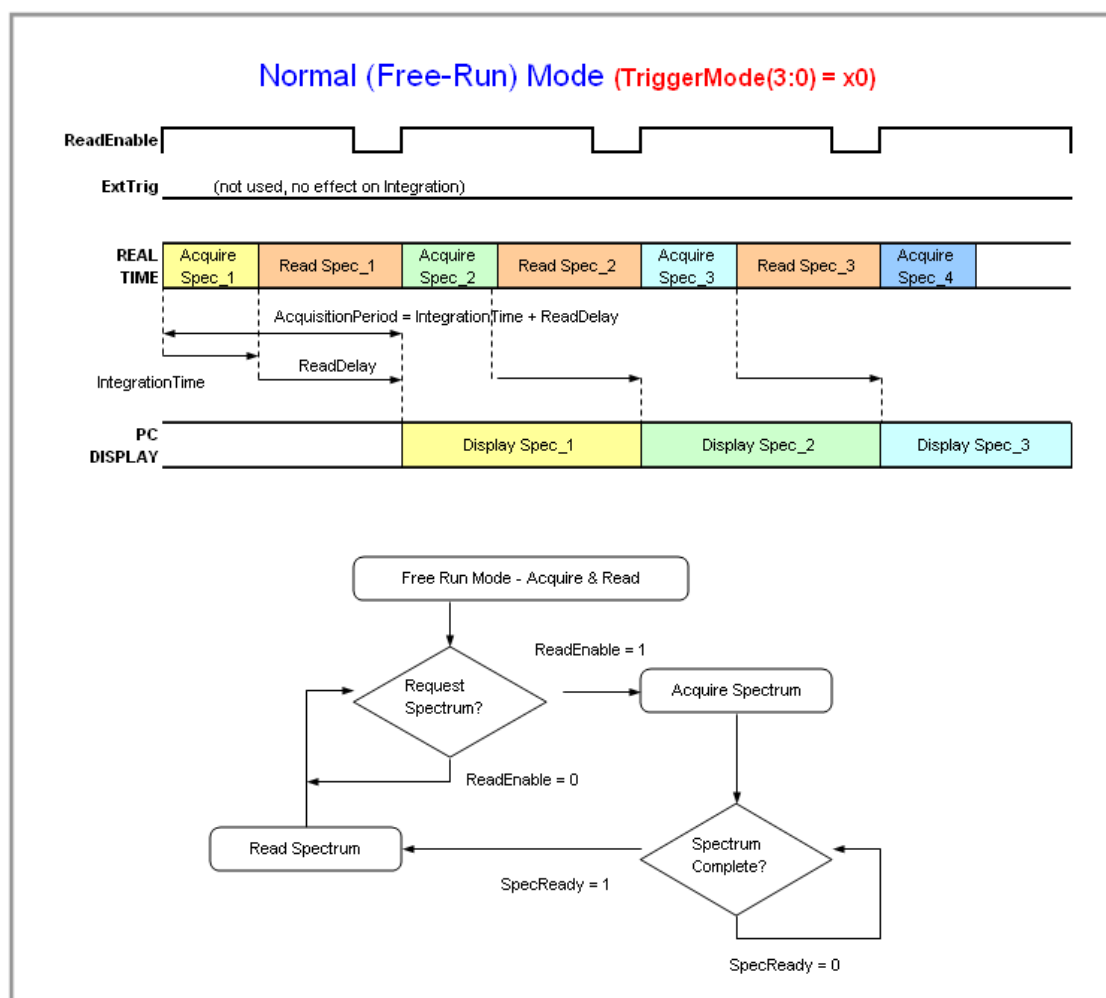
Normal Mode

In the Normal (Free-run) mode, the spectrometer will acquire back-to-back spectra based on the integration period specified. After the Integration Cycle completes, the data is read out of the detector and written into an internal FIFO where it is available for reading. In parallel to this read/write operation, another integration is occurring. If the data from the FIFO is completely read before the parallel integration completes, a back-to-back operation will occur. If the data is not read (FIFO Empty) in this time period, the FPGA will generate an Idle Cycle which is equivalent to one integration period and the data from the detector is discarded. After the Idle Cycle has completed, the FIFO Empty status is

checked. If the FIFO is empty and a new spectrum is requested by the software, a new acquisition will begin. If either condition is false, additional Idle Cycles will be generated until both conditions are true.

For the HR2000+, NIRQuest, USB2000+, and USB4000, this is also referred to as the nonbuffering mode because only one spectrum is stored within the FPGA and not multiple spectra. In this scenario, ReadEnable is generated by the software/firmware to initiate each new acquisition. Since only one spectrum is stored at a time in the FPGA, a new integration cannot be started until the FIFO data has been fully retrieved by the software.

For the QE65000 and Maya2000Pro, integrations are continuously performed with the most recent three spectra available to the software. If the software fails to retrieve spectra as new data is acquired, older data gets dropped in favor of newer data.

For the QE *Pro*, there are no idle cycles that drop new spectra; all new spectra are stored in the buffer and are available to the user (if buffering is enabled). If the buffer limit is exceeded (15,698), the oldest spectrum is automatically discarded to make room for the new spectrum. The user can clear the buffer at any time.


Normal Mode Timing Sequence

Software Trigger Mode

In this level-triggered mode, the spectrometer is "free running," just as it is in the Normal mode. The spectrometer is continually scanning and collecting data. With each trigger, the data collected up to the trigger event is transferred to the software. If you continuously apply triggers (for example, by holding down the button on via an external switch), this mode is equivalent to operating in the Normal mode.

In the Software Trigger mode, you set the integration time (as well as all other acquisition parameters) in the software. The source for the integration clock comes from the A/D converter.
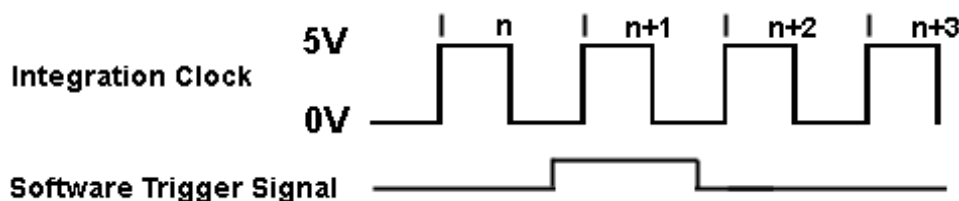
*If the software trigger is asserted during integration cycle **n**, the photons from this integration period will be read out and digitized at the start of integration cycle n+1*

External Software Triggering – Trigger Timing

External Synchronous Trigger Mode

In the External Synchronous Trigger Mode, two external triggers are required to complete a data acquisition. The first rising edge starts the integration period and the second rising edge stops the integration while starting the next integration. Thus the integration time is the period between the two external trigger pulses. After the each integration period, the spectra is retrieved and written to the FIFO in the FPGA.

For the Maya2000Pro, HR2000+, and USB2000+, as in all nonbuffered modes, no further integrations are possible until the software has read the entire contents of the FIFO.

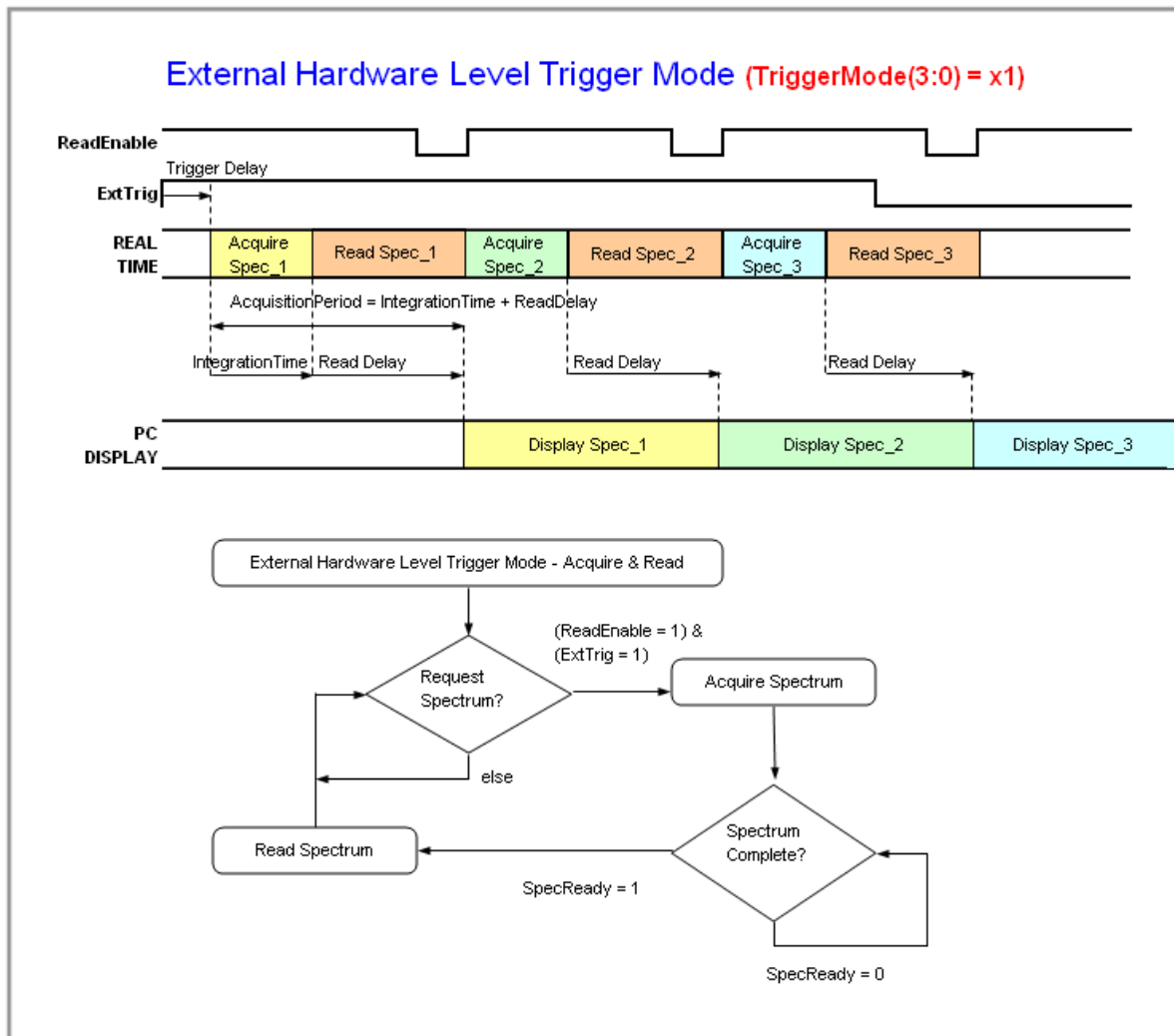For the QE65000, three spectrum buffers provide software with the most recent spectral acquisitions.
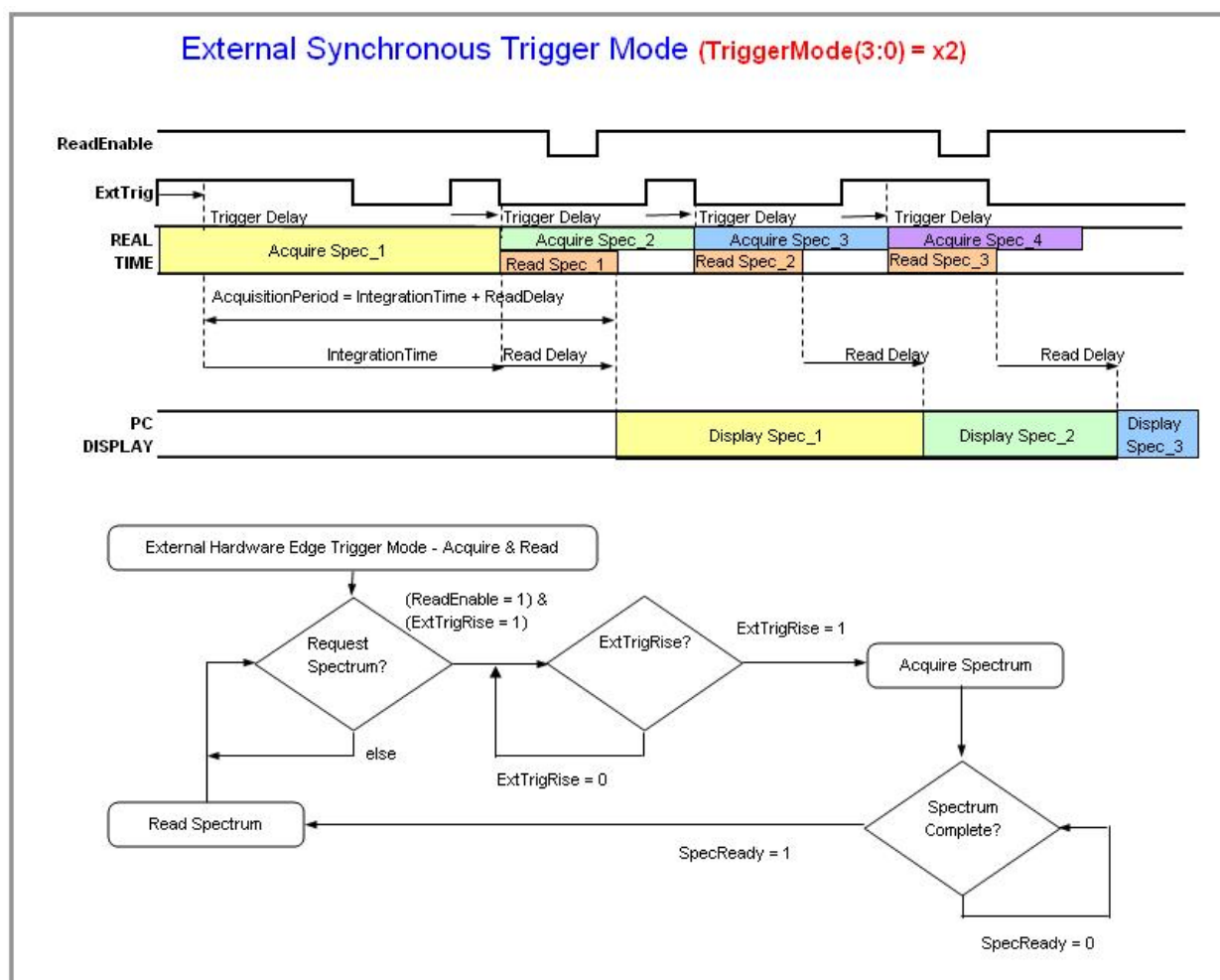
External Synchronous Trigger Mode Timing Sequence

External Hardware Level Trigger Mode

In the External Hardware Level Trigger mode, a rising edge detected by the FPGA from the External Trigger input starts the Integration Cycle specified through the software interface. After the Integration Cycle completes, the spectrum is retrieved and written to the FIFO in the FPGA. As long as the trigger level remains active in a logic one state, continuous acquisitions will occur with the following exception. Each subsequent acquisition must wait until a minimum CCD Reset Cycle completes. This Reset Cycle insures that the CCD performance uniform on a scan-to-scan basis. The time duration for this reset cycle is relative to the Integration Cycle time and will change if the integration period is changed. So the timing sequence is Trigger, Trigger Delay, Integration Cycle, Read/Write Cycle, Reset Cycle, Idle Cycle(s), and Integration Cycle (if trigger is still high). The Idle Cycle will on last 2 μs if the trigger remains high and the FIFO is empty and a spectrum request is active, otherwise the Idle Cycle will continue until all 3 conditions are satisfied.
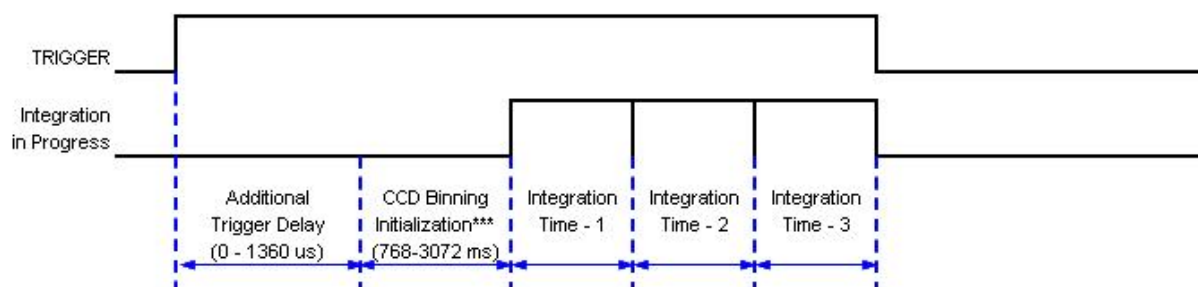
For the Maya2000Pro, HR2000+ and USB2000+, as in all nonbuffered modes, no integrations are possible until the software has read the entire contents of the FIFO.

External Hardware Level Trigger Mode Timing Sequence

For the QE65000, three spectrum buffers provide software with the most recent spectral acquisitions.

QE65000 Hardware Level Trigger Mode

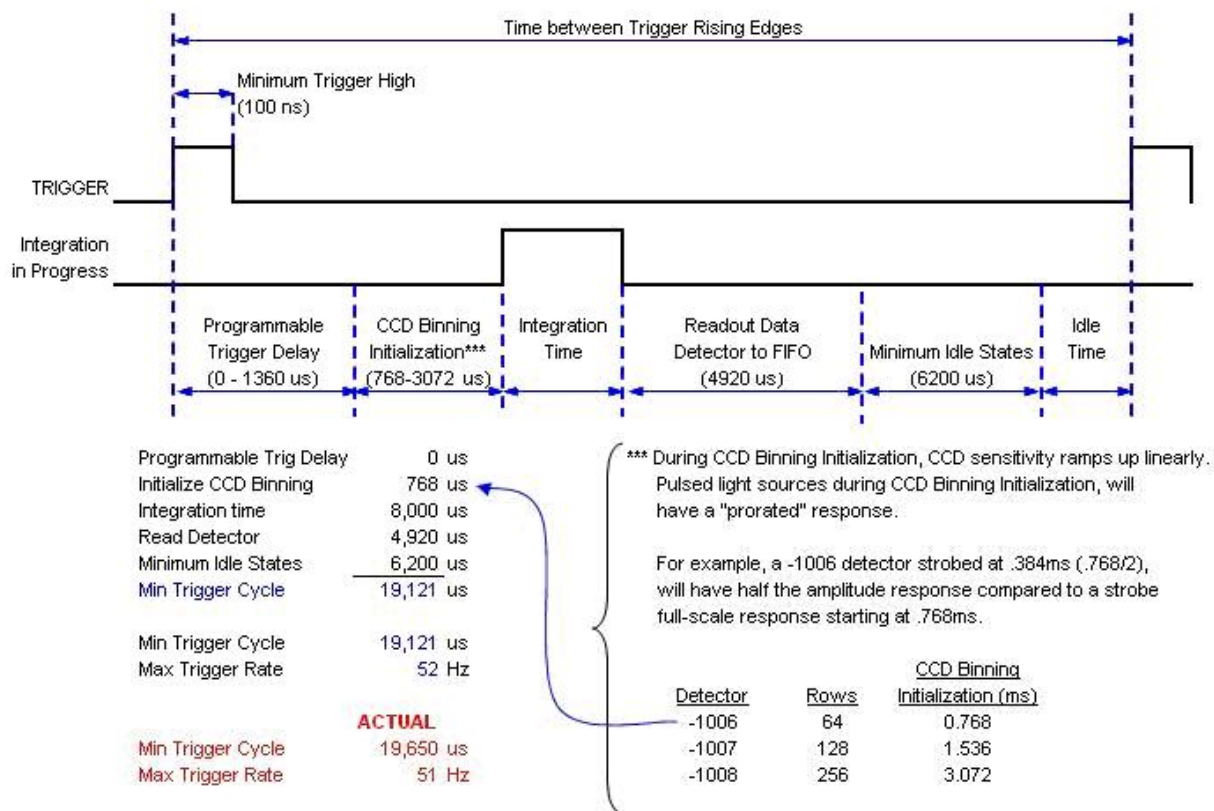**QE *Pro* Hardware Level Trigger Mode**

External Hardware Edge Trigger Mode

In the External Hardware Edge Trigger mode, a rising edge detected by the FPGA from the External Trigger input starts the Integration Cycle specified through the software interface. After the Integration Cycle completes, the spectrum is retrieved and written to the FIFO in the FPGA followed by a CCD Reset Cycle. Only one acquisition will be performed for each External Trigger pulse, no matter what the pulse's duration is. The Reset Cycle insures that the CCD performance uniform on a scan-to-scan basis. The time duration for this reset cycle is relative to the Integration Cycle time and will change if the integration period is changed. So the timing sequence is Trigger, Trigger Delay, Integration Cycle, Read/Write Cycle, Reset Cycle, and Idle Cycle(s). The Idle Cycle will until the next trigger occurs.
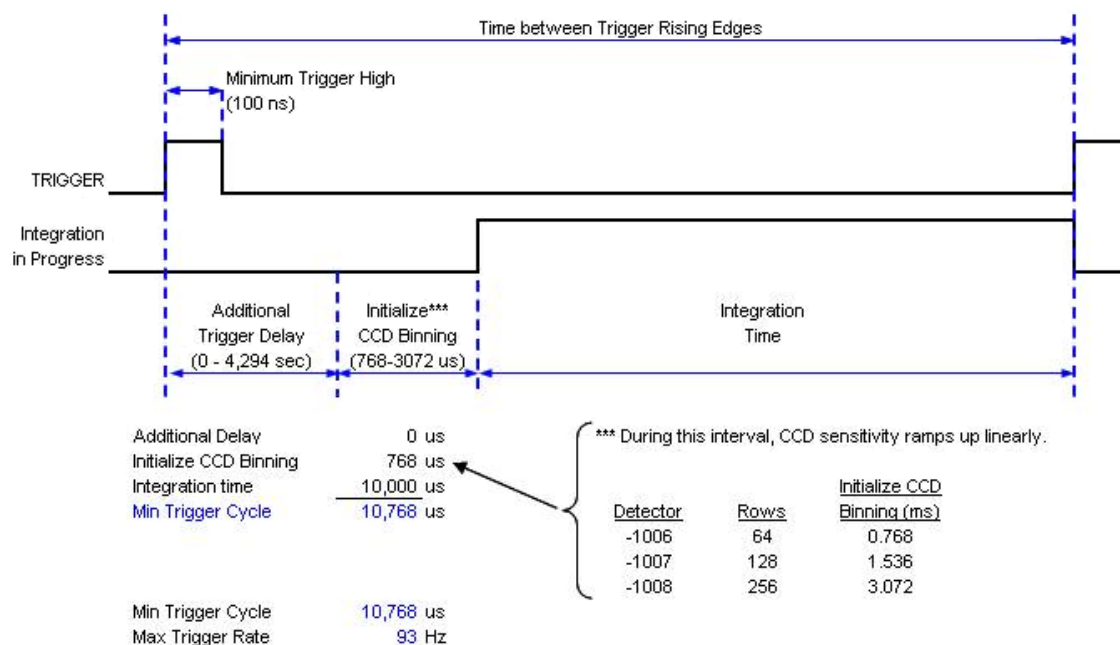

Note

For the QE *Pro*, jitter between external edge trigger and start of column binning (or trigger delay) is 40ns.
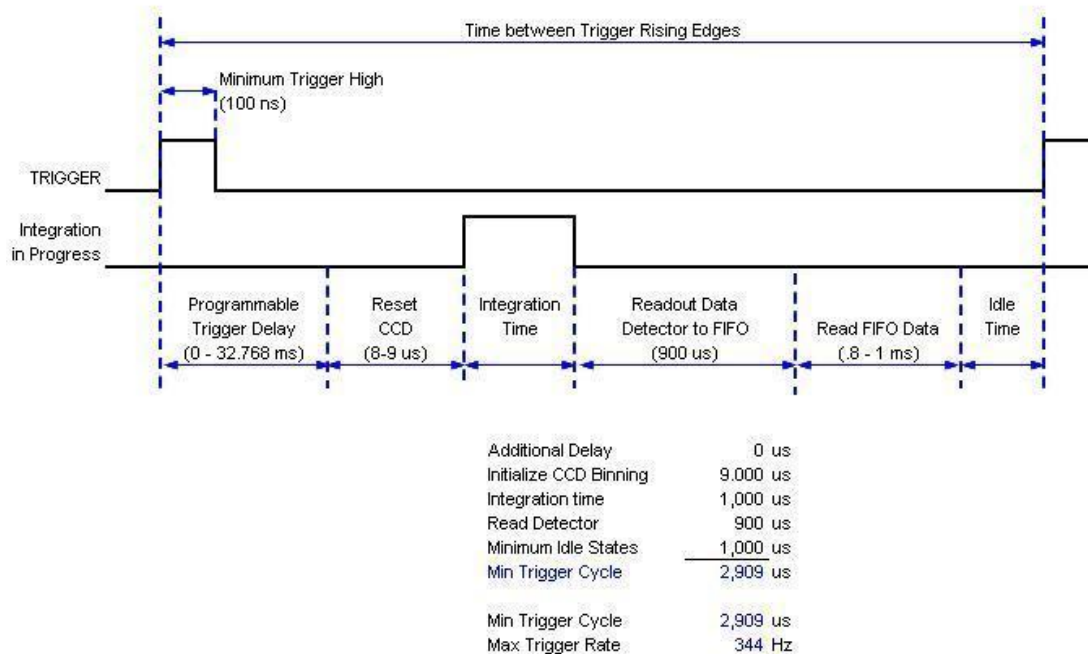

Maya2000Pro and QE65000 Hardware Edge Trigger Mode Time Table

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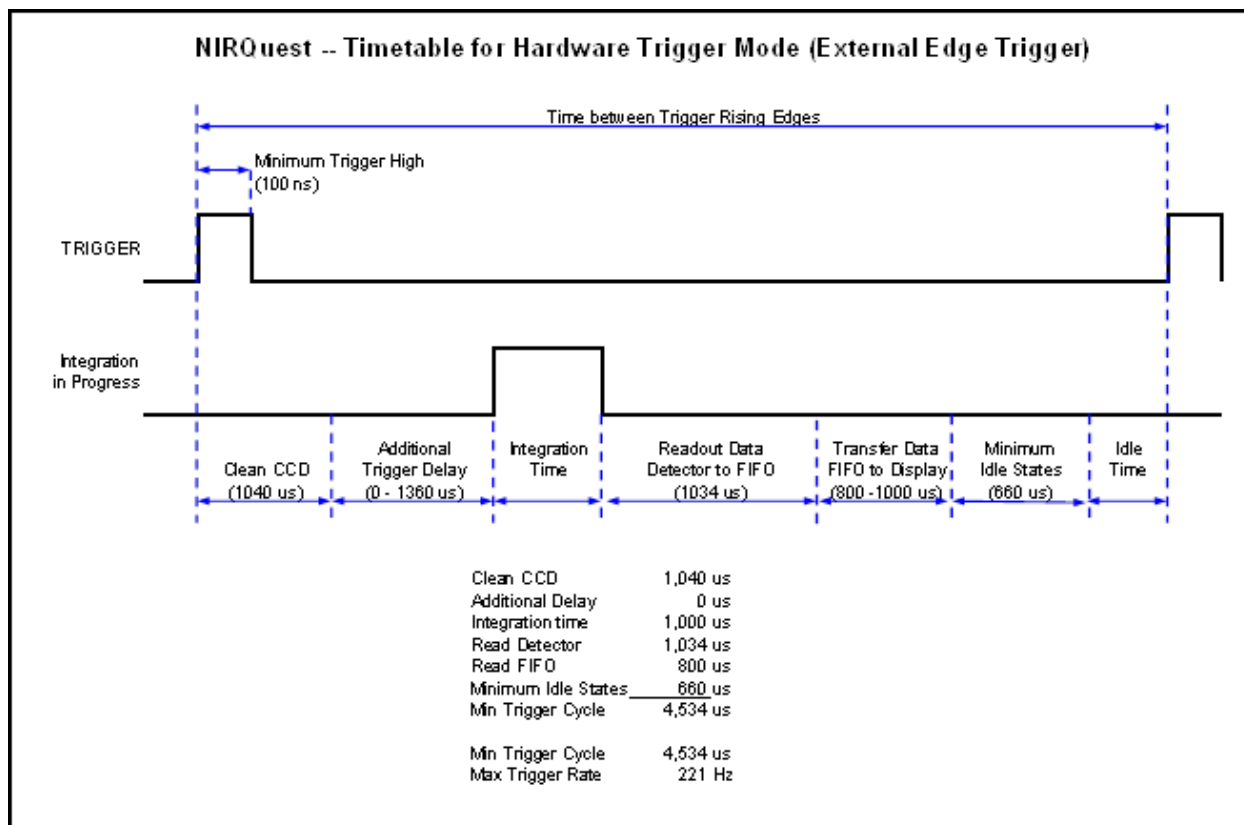## QE *Pro* -- Timetable for Hardware Edge Trigger Mode

QE *Pro* Hardware Edge Trigger Mode Time Table

HR2000+ and USB2000+ -- Timetable for Hardware Edge Trigger Mode

HR2000+ and USB2000+ Hardware Edge Trigger Mode Time Table

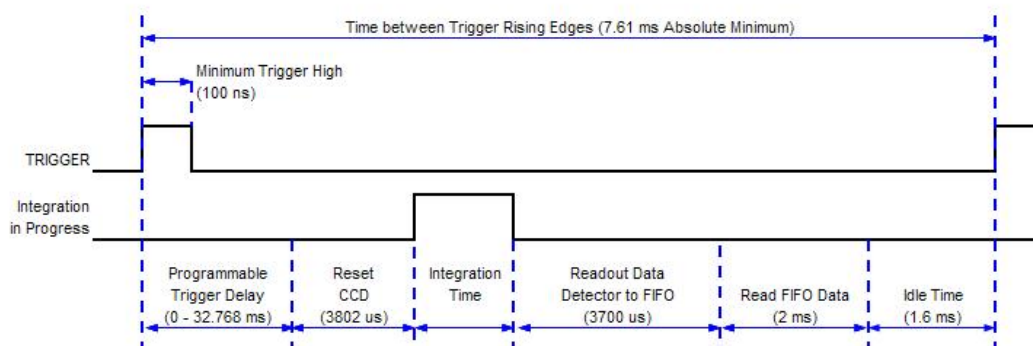**NIRQuest Hardware Trigger Mode Time Table**

USB4000 Timetables

It is important to note that the trigger timing in the USB4000 will vary depending upon the integration time. This is further detailed in the Time Tables that appear below. These tables reveal that the trigger timing will be different for the following ranges of integration times:
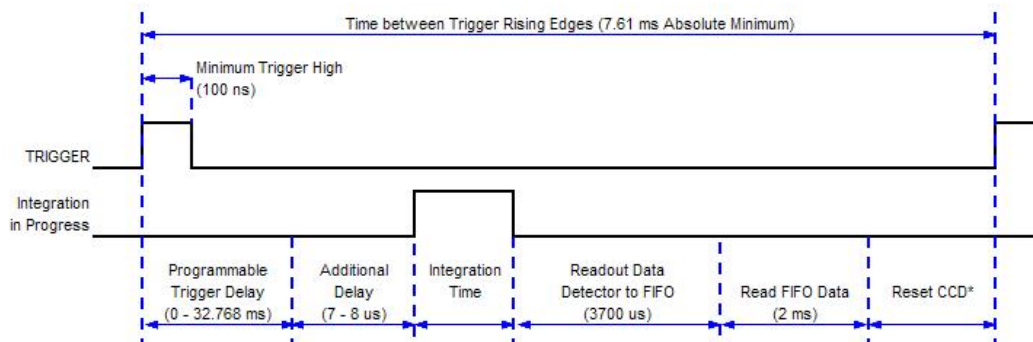
- < 3.8 ms
- 3.8 ms to 199 ms
- 200 ms to 2097 ms
- 2097 ms

USB4000 -- Timetable for Hardware Trigger / Normal Shutter Modes (Integration Times < 3.8 ms)

Reset CCD	3,802	us
Integration time	10	us
Read Detector	3,700	us
Read FIFO Data	2,000	us
Min Idle Time	1,800	us
Min Trigger Cycle	11,312	us
Min Trigger Cycle	11,312	us
Max Trigger Rate	88	Hz

USB4000 -- Timetable for Hardware Trigger / Normal Shutter Modes (Integration Times 3.8 ms to 199 ms)

Additional Delay	7	us
Integration time	3,800	us
Read Detector	3,700	us
Read FIFO Data	2,000	us
Min Reset Time*	375	us
Min Trigger Cycle	9,882	us
Min Trigger Cycle	9,882	us
Max Trigger Rate	101	Hz

* Minimum Reset Time(us)=
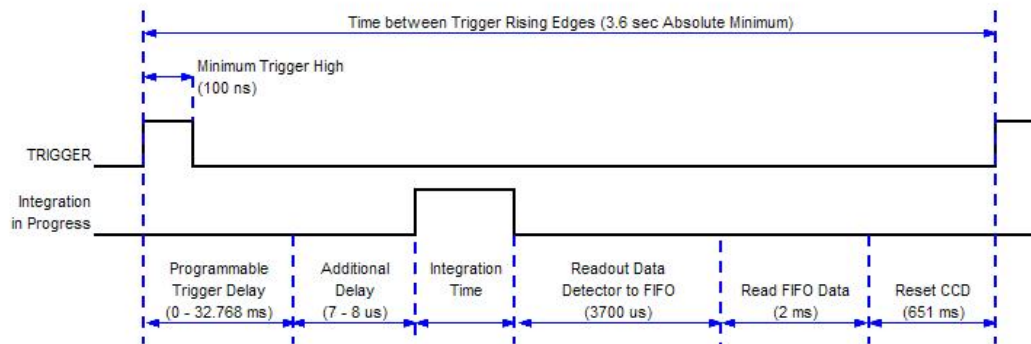((Integration Time(us) /16) * 10) –
Read FIFO Data Time(us))

USB4000 -- Timetable for Hardware Trigger / Normal Shutter Modes (Integration Times 200 ms to 2097 ms)

Time between Trigger Rising Edges (206.26 ms Absolute Minimum)

Minimum Trigger High
(100 ns)

TRIGGER

Integration
in Progress

| Programmable Trigger Delay (0 - 32.768 ms) | Additional Delay (7 - 8 us) | Integration Time | Readout Data Detector to FIFO (3700 us) | Read FIFO Data (2 ms) | Reset CCD* |
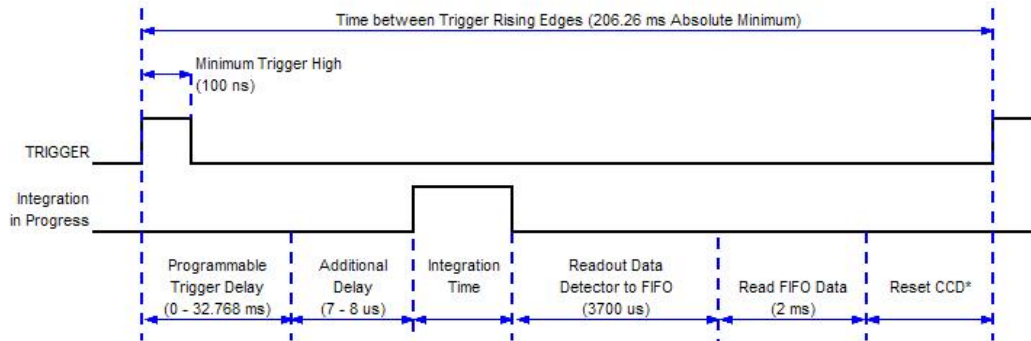
Additional Delay	7 us
Integration time	200,000 us
Read Detector	3,700 us
Read FIFO Data	2,000 us
Min Reset Time*	59,100 us
Min Trigger Cycle	264,807 us

* Minimum Reset Time(us) =
  ((Integration Time(us) /32) * 10) –
  Read FIFO Data Time(us))

| Min Trigger Cycle | 264,807 us |
| Max Trigger Rate | 3.78 Hz |

USB4000 -- Timetable for Hardware Trigger / Normal Shutter Modes (Integration Times >2097 ms)

Time between Trigger Rising Edges (3.6 sec Absolute Minimum)

Minimum Trigger High
(100 ns)

TRIGGER

Integration
in Progress

| Programmable Trigger Delay (0 - 32.768 ms) | Additional Delay (7 - 8 us) | Integration Time | Readout Data Detector to FIFO (3700 us) | Read FIFO Data (2 ms) | Reset CCD (651 ms) |

Additional Delay	7 us
Integration time	2,900,000 us
Read Detector	3,700 us
Read FIFO Data	2,200 us
Min Reset Time	651,200 us
Min Trigger Cycle	3,557,107 us

| Min Trigger Cycle | 3,557,107 us |
| Max Trigger Rate | 0.28 Hz |

USB Command Description for Triggering

The USB command Set Trigger Mode sets the spectrometer trigger to one of the trigger mode states as shown below.

HR2000+ and USB2000+ Set Trigger Mode

Data Value = 0 ➔ Normal (Free running) Mode

Data Value = 1 ➔ Software Trigger Mode

Data Value = 2 ➔ External Hardware Level Trigger Mode

Data Value = 3 ➔ External Synchronization Trigger Mode

Data Value = 4 ➔ External Hardware Edge Trigger Mode

USB4000 Set Trigger Mode

Data Value = 0 ➔ Normal (Free running) Mode

Data Value = 1 ➔ Software Trigger Mode

Data Value = 2 ➔ External Hardware Level Trigger Mode

Data Value = 3 ➔ Normal (Shutter) Mode

Data Value = 4 ➔ External Hardware Edge Trigger Mode

Maya2000Pro, QE65000, QE65 Pro, and QE *Pro* Set Trigger Mode

Data Value = 0 ➔ Normal (Free running) Mode

Data Value = 1 ➔ External Hardware Level Trigger Mode

Data Value = 2 ➔ External Synchronous Trigger Mode*

Data Value = 3 ➔ External Hardware Edge Trigger Mode

  *Not yet implemented on the QE *Pro*

NIRQuest Set Trigger Mode

Data Value = 0 ➔ Normal (Free running) Mode

Data Value = 3 ➔ External Hardware Edge Trigger Mode