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CAEN MC²Analyzer

User Manual UM3182

MC2Analyzer User Manual

Software for digital Multi Channel Analyzer

Rev. 10 - December 13th, 2019

Purpose of this Manual

This User Manual contains the full description of the MC²Analyzer software for CAEN 724, 725, and 730 digitizer families, DT5770, 780, 781, 782, and Hexagon MCA families. The description is compliant with DPP-PHA firmware release **4.15_128.36 (discontinued)** and **4.19_128.71** for 724, 780, 781, and 782 series, firmware release **4.15_139.8 (discontinued)** for 725 and 730 series, firmware release **4.21_139.128** for 725S and 730S series, firmware release **5.03_5.02** for DT5770 series, firmware release **0.99.5** for Hexagon and MC²Analyzer software release **2.1.4**. For future release compatibility check the firmware and software revision history files.
NOTE: MC²Analyzer supports also *γstream* MCA tube-base. All the software functionalities for *γstream* are described in **[RD11]**.

Change Document Record

Date	Revision	Changes
April 14th, 2014	00	Initial release
January 26th, 2015	01	Added support to 730 and 781 series. Fully revised the Principle of Operation Chapter. Added Quick Start Guide, and Appendices.
November 4th, 2016	02	Added support to 725 digitizer family and DT5770 MCA. Modified Channel Aggregate data format for 725 and 730 series.
January 11th, 2017	03	Revised Sec. Histogram and list energy format. Added ADC calibration for 725 and 730 series.
June 20th, 2017	04	Revised Sec. GUI Description and Appendix B Memory Organization
December 20th, 2017	05	Added support to Hexagon. Added DT5780SC to Tab. 1.1. Removed Rise Time Discrimination window. Modified Aggregate format for x725-x730 (Appendix B)
November 15th, 2018	06	Revised Section GUI description.
January 28th, 2019	07	Added support to V1781.
July 2nd, 2019	08	Modified table of supported boards.
July 31st, 2019	09	Discontinued support to V1781, replaced by V1782.
December 13th, 2019	10	Added support to x730S and x725S boards.

Symbols, abbreviated terms and notation

ADC	Analog to Digital Converter
CSP	Charge Sensitive Preamplifier
DAC	Digital-to-Analog Converter
DAQ	Data Acquisition
DPP	Digital Pulse Processing
DPP-QDC	DPP for Charge to Digital Converter
DPP-PHA	DPP for Pulse Height Analysis
DPP-PSD	DPP for Pulse Shape Discrimination
HPGe	High Purity Germanium
MCA	Multi-Channel Analyser
OS	Operating System
PC	Personal Computer
PHA	Pulse Height Analysis
PMT	Photo Multiplier Tube
TTF	Trigger and Timing Filter
USB	Universal Serial Bus

Reference Documents

[RD1] Jordanov, V.T. et al., Nuclear Instruments and Methods A 353 (1994) 337-345

[RD2] UM2606 – DT5780 Digital MCA

[RD3] GD2783 – First Installation Guide to Desktop Digitizers & MCA

[RD4] M. Morhac et al.: Identification of peaks in multidimensional coincidence gamma-ray spectra. Nuclear Instruments and Methods in Research Physics A 443(2000), 108-125.

[RD5] GD2827 - How to make coincidences with CAEN digitizers

[RD6] AN2086 - Synchronization of a multi-board acquisition system with CAEN digitizers

[RD7] UM1935 - CAENDigitizer User & Reference Manual

[RD8] UM5469 780 DPP-PHA Legacy Registers Description

[RD9] UM5407 724-781 DPP-PHA Legacy Registers Description

[RD10] UM5678 725-730 DPP-PHA Registers Description

[RD11] UM3904 - Gamma stream User Manual

[RD12] UM3185 - CAENDPP Library User & Reference Manual

[RD13] UM6505 – Hexagon Quick Start Guide

[RD14] UM6771 780 DPP-PHA Registers Description

[RD15] UM6769 724 781 782 DPP-PHA Registers Description

All CAEN documents can be downloaded from: www.caen.it/support-services/documentation-area

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MADE IN ITALY: We remark that all our boards have been designed and assembled in Italy. In a challenging environment where a competitive edge is often obtained at the cost of lower wages and declining working conditions, we proudly acknowledge that all those who participated in the production and distribution process of our devices were reasonably paid and worked in a safe environment (this is true for the boards marked "MADE IN ITALY", while we cannot guarantee for third-party manufactures).

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1 Introduction

Nuclear radiation detectors are able to generate electronic pulses containing information on the nuclear radiation that interacted with them. Depending on the radiation and detector types, the relevant information can be contained in the shape of the pulse (i.e. a Pulse Shape discrimination is possible between neutrons and gammas in a detector sensitive to both radiations, by looking at the shape of the corresponding pulses), in some timing information (i.e. arrival of the pulse compared to a reference starting time “T_0”, as in Time Of Flight detectors measurements or in Position Sensitive Detectors), and in the *pulse height*, for those detectors where the relationship between incident radiation energy and detector output pulse height can be re-conducted to direct proportionality (if needed through a calibration curve). For example, a radio-isotopic source emits gamma radiations of different energies and the corresponding different heights of the pulses at the output of the detector can be histogrammed during the counting time.

The Multi-Channel Analyzer (MC^{2}Analyzer) software has been designed as a user-friendly interface to manage the acquisition with pulse height algorithms. Indeed, MC^{2}Analyzer puts the acquisition power of the fast digitizers, such us CAEN DT5780 at the fingertips of users concerned with the acquisition of energy spectra from one up to multiple channels of nuclear radiation detectors systems. The selected format recalls the familiar operation of a conventional analog Nuclear Multi Channel Analyzer, although with some differences which will be described in this manual.

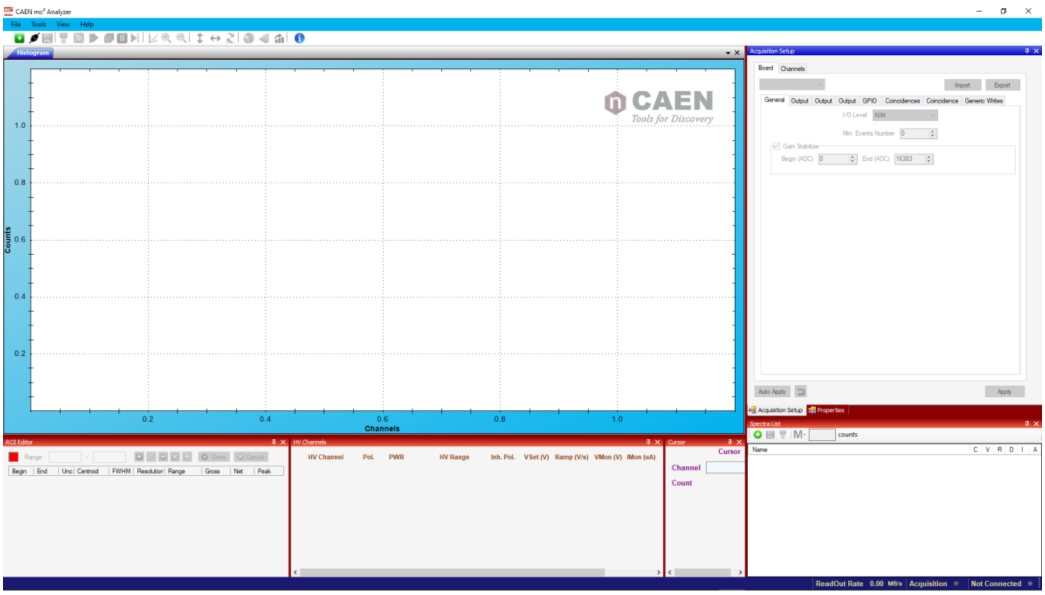


Fig. 1.1: MC^{2}Analyzer main screen

The MC²Analyzer Software supports CAEN DT5770, 780, 781, and 782 MCA Series, as well as 724, 725, and 730 digitizer families equipped with the DPP-PHA (Digital Pulse Processing for Pulse Height Analysis) firmware. The complete list of supported boards is shown in **Tab. 1.1**.

Note: MC²Analyzer software supports also *γstream* MCA tube-base. All the software functionalities for *γstream* are described in **[RD11]**.

Desktop Digitizers and MCAs	Description
DT5724(*)	4 Ch. 14 bit 100 MS/s Digitizer: 512kS/ch, C4, SE
DT5724A(*)	2 Ch. 14 bit 100 MS/s Digitizer: 512kS/ch, C4, SE
DT5724B	4 Ch. 14 bit 100 MS/s Digitizer: 512kS/ch, C20, SE
DT5724C	2 Ch. 14 bit 100 MS/s Digitizer: 512kS/ch, C20, SE
DT5724D(*)	4 Ch. 14 bit 100 MS/s Digitizer: 4MS/ch, C4, SE
DT5724E(*)	2 Ch. 14 bit 100 MS/s Digitizer: 4MS/ch, C4, SE
DT5724F	4 Ch. 14 bit 100 MS/s Digitizer: 4MS/ch, C20, SE
DT5724G	2 Ch. 14 bit 100 MS/s Digitizer: 4MS/ch, C20, SE
DT5725(*)	8 Ch. 14 bit 250 MS/s Digitizer: 640kS/ch, CE30, SE
DT5725B(*)	8 Ch. 14 bit 250 MS/s Digitizer: 5.12MS/ch, CE30, SE
DT5725S	8 Ch. 14 bit 250 MS/s Digitizer: 640kS/ch, CE30, SE
DT5725SB	8 Ch. 14 bit 250 MS/s Digitizer: 5.12MS/ch, CE30, SE
DT5730(*)	8 Ch. 14 bit 500 MS/s Digitizer: 640kS/ch, CE30, SE
DT5730B(*)	8 Ch. 14 bit 500 MS/s Digitizer: 5.12MS/ch, CE30, SE
DT5730S	8 Ch. 14 bit 500 MS/s Digitizer: 640kS/ch, CE30, SE
DT5730SB	8 Ch. 14 bit 500 MS/s Digitizer: 5.12MS/ch, CE30, SE
DT5780N	2 Channel Digital MCA - Negative HV (5kV/300uA)
DT5780P	2 Channel Digital MCA - Positive HV (5kV/300uA)
DT5780SDM	2 Channel Digital MCA - Mixed HV (500V/3mA)
DT5780SDN	2 Channel Digital MCA - Negative HV (500V/3mA)
DT5780SDP	2 Channel Digital MCA - Positive HV (500V/3mA)
DT5780SCM	2 Channel Digital MCA - Mixed HV (4kV/3mA)
DT5780SCN	2 Channel Digital MCA - Negative HV (4kV/3mA)
DT5780SCP	2 Channel Digital MCA - Positive HV (4kV/3mA)
DT5781	Quad Digital MCA
DT5781A	Dual Digital MCA
DT5000M - HEXAGON	Dual Digital MCA - Mixed Dual Range HV (5kV/30uA, 2kV/1mA)
DT5000N - HEXAGON	Dual Digital MCA - Negative Dual Range HV (5kV/30uA, 2kV/1mA)
DT5000P - HEXAGON	Dual Digital MCA - Positive Dual Range HV (5kV/30uA, 2kV/1mA)
DT5001M - HEXAGON One	Digital MCA - Mixed Dual Range HV (5kV/30uA, 2kV/1mA)
NIM Digitizers and MCAs	**Description**
N6724(*)	4 Ch. 14 bit 100 MS/s Digitizer: 512kS/ch, C4, SE
N6724A(*)	2 Ch. 14 bit 100 MS/s Digitizer: 512kS/ch, C4, SE
N6724B	4 Ch. 14 bit 100 MS/s Digitizer: 512kS/ch, C20, SE
N6724C	2 Ch. 14 bit 100 MS/s Digitizer: 512kS/ch, C20, SE
N6724F	4 Ch. 14 bit 100 MS/s Digitizer: 4MS/ch,C20, SE
N6724G	2 Ch. 14 bit 100 MS/s Digitizer: 4MS/ch, C20, SE
N6725(*)	8 Ch. 14 bit 250 MS/s Digitizer: 640kS/ch, CE30, SE
N6725B(*)	8 Ch. 14 bit 250 MS/s Digitizer: 5.12MS/ch, CE30, SE
N6725S	8 Ch. 14 bit 250 MS/s Digitizer: 640kS/ch, CE30, SE
N6725SB	8 Ch. 14 bit 250 MS/s Digitizer: 5.12MS/ch, CE30, SE
N6730(*)	8 Ch. 14 bit 500 MS/s Digitizer: 640kS/ch, CE30, SE
N6730B(*)	8 Ch. 14 bit 500 MS/s Digitizer: 5.12MS/ch, CE30, SE
N6730S	8 Ch. 14 bit 500 MS/s Digitizer: 640kS/ch, CE30, SE
N6730SB	8 Ch. 14 bit 500 MS/s Digitizer: 5.12MS/ch, CE30, SE
N6780M	2 Channel Digital MCA - Mixed HV (5kV/300uA)
N6780N	2 Channel Digital MCA - Negative HV (5kV/300uA)
N6780P	2 Channel Digital MCA - Positive HV (5kV/300uA)
N6781	Quad Digital MCA
N6781A	Dual Digital MCA
VME Digitizers and MCAs	**Description**
V1724(*)	8 Ch. 14 bit 100 MS/s Digitizer: 512kS/ch, C4, SE
V1724B(*)	8 Ch. 14 bit 100 MS/s Digitizer: 4MS/ch, C4, SE
V1724C(*)	8 Ch. 14 bit 100 MS/s Digitizer: 512kS/ch, C4, DIFF
V1724D(*)	8 Ch. 14 bit 100 MS/s Digitizer: 4MS/ch, C4, DIFF

V1724E	8 Ch. 14 bit 100 MS/s Digitizer: 4MS/ch, C20, SE
V1724F(*)	8 Ch. 14 bit 100 MS/s Digitizer: 4MS/ch, C20, DIFF
V1724G	8 Ch. 14 bit 100 MS/s Digitizer: 512kS/ch, C20, SE
V1725(*)	16 Ch. 14 bit 250 MS/s Digitizer: 640kS/ch, CE30, SE
V1725B(*)	16 Ch. 14 bit 250 MS/s Digitizer: 5.12MS/ch, CE30, SE
V1725C(*)	8 Ch. 14 bit 250 MS/s Digitizer: 640kS/ch, CE30, SE
V1725D(*)	8 Ch. 14 bit 250 MS/s Digitizer: 5.12MS/ch, CE30, SE
V1725S	16 Ch. 14 bit 250 MS/s Digitizer: 640kS/ch, CE30, SE
V1725SB	16 Ch. 14 bit 250 MS/s Digitizer: 5.12MS/ch, CE30, SE
V1725SC	8 Ch. 14 bit 250 MS/s Digitizer: 640kS/ch, CE30, SE
V1725SD	8 Ch. 14 bit 250 MS/s Digitizer: 5.12MS/ch, CE30, SE
V1730(*)	16 Ch. 14 bit 500 MS/s Digitizer: 640kS/ch, CE30, SE
V1730B(*)	16 Ch. 14 bit 500 MS/s Digitizer: 5.12MS/ch, CE30, SE
V1730C(*)	8 Ch. 14 bit 500 MS/s Digitizer: 640kS/ch, CE30, SE
V1730D(*)	8 Ch. 14 bit 500 MS/s Digitizer: 5.12MS/ch, CE30, SE
V1730S	16 Ch. 14 bit 500 MS/s Digitizer: 640kS/ch, CE30, SE
V1730SB	16 Ch. 14 bit 500 MS/s Digitizer: 5.12MS/ch, CE30, SE
V1730SC	8 Ch. 14 bit 500 MS/s Digitizer: 640kS/ch, CE30, SE
V1730SD	8 Ch. 14 bit 500 MS/s Digitizer: 5.12MS/ch, CE30, SE
VX1724(*)	8 Ch. 14 bit 100 MS/s Digitizer: 512kS/ch, C4, SE
VX1724B(*)	8 Ch. 14 bit 100 MS/s Digitizer: 4MS/ch, C4, SE
VX1724C(*)	8 Ch. 14 bit 100 MS/s Digitizer: 512kS/ch, C4, DIFF
VX1724D(*)	8 Ch. 14 bit 100 MS/s Digitizer: 4MS/ch, C4, DIFF
VX1724E	8 Ch. 14 bit 100 MS/s Digitizer: 4MS/ch, C20, SE
VX1724F(*)	8 Ch. 14 bit 100 MS/s Digitizer: 4MS/ch, C20, DIFF
VX1725(*)	16 Ch. 14 bit 250 MS/s Digitizer: 640kS/ch, CE30, SE
VX1725B(*)	16 Ch. 14 bit 250 MS/s Digitizer: 5.12MS/ch, CE30, SE
VX1725C(*)	8 Ch. 14 bit 250 MS/s Digitizer: 640kS/ch, CE30, SE
VX1725D(*)	8 Ch. 14 bit 250 MS/s Digitizer: 5.12MS/ch, CE30, SE
VX1725S	16 Ch. 14 bit 250 MS/s Digitizer: 640kS/ch, CE30, SE
VX1725SB	16 Ch. 14 bit 250 MS/s Digitizer: 5.12MS/ch, CE30, SE
VX1725SC	8 Ch. 14 bit 250 MS/s Digitizer: 640kS/ch, CE30, SE
VX1725SD	8 Ch. 14 bit 250 MS/s Digitizer: 5.12MS/ch, CE30, SE
VX1730(*)	16 Ch. 14 bit 500 MS/s Digitizer: 640kS/ch, CE30, SE
VX1730B(*)	16 Ch. 14 bit 500 MS/s Digitizer: 5.12MS/ch, CE30, SE
VX1730C(*)	8 Ch. 14 bit 500 MS/s Digitizer: 640kS/ch, CE30, SE
VX1730D(*)	8 Ch. 14 bit 500 MS/s Digitizer: 5.12MS/ch, CE30, SE
VX1730S	16 Ch. 14 bit 500 MS/s Digitizer: 640kS/ch, CE30, SE
VX1730SB	16 Ch. 14 bit 500 MS/s Digitizer: 5.12MS/ch, CE30, SE
VX1730SC	8 Ch. 14 bit 500 MS/s Digitizer: 640kS/ch, CE30, SE
VX1730SD	8 Ch. 14 bit 500 MS/s Digitizer: 5.12MS/ch, CE30, SE
V1782	Octal Digital MCA
DPP Firmware	**Description**
DPP-PHA (4/2ch x724)	DPP-PHA - Digital Pulse Processing for Pulse Height Analysis (4/2ch x724)
DPP-PHA (8ch x724)	DPP-PHA - Digital Pulse Processing for Pulse Height Analysis (8ch x724)
DPP-PHA (8ch x725)	DPP-PHA - Digital Pulse Processing for Pulse Height Analysis for (8ch x725)
DPP-PHA (16ch x725)	DPP-PHA - Digital Pulse Processing for Pulse Height Analysis for (16ch x725)
DPP-PHA (8ch x730)	DPP-PHA - Digital Pulse Processing for Pulse Height Analysis (8ch x730)
DPP-PHA (16ch x730)	DPP-PHA - Digital Pulse Processing for Pulse Height Analysis (16ch x730)
DPP-SUP (8ch x730)	DPP-SUP - Super Licence for 8ch x730 Digital Pulse Processing
DPP-SUP (16ch x730)	DPP-SUP - Super Licence for 16ch x730 Digital Pulse Processing
DPP-SUP (8ch x725)	DPP-SUP - Super Licence for 8ch x725 Digital Pulse Processing
DPP-SUP (16ch x725)	DPP-SUP - Super Licence for 16ch x725 Digital Pulse Processing

Tab. 1.1: Supported CAEN boards for DPP-PHA firmware

(*) The board is currently obsolete.

2 Principle of Operation

Traditional Analog Approach

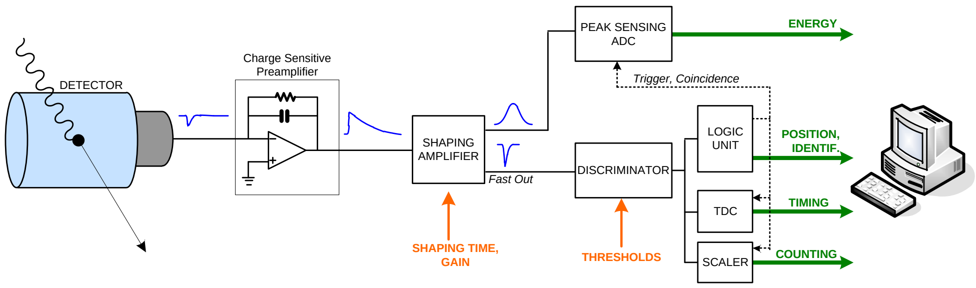


Fig. 2.1: Nuclear Radiation Detector (with Charge Sensitive Preamplifier) Analog Chain Block Diagram

The traditional analog chain for signal readout from nuclear radiation detector usually makes use of almost all-analog chains, where the electronics rely upon three fundamental devices: the Charge Sensitive Preamplifier, the Shaping Amplifier and the Peak Sensing ADC (refer to **Fig. 2.1**).

The Charge Sensitive Preamplifier (**Fig. 2.2**) integrates the signal coming from the detector, as the HPGe, thus converting the collected charge into a voltage step. The integrating capacitor is put in parallel with a discharging resistor, so that the preamplifier output will have pulses with a fast rise time and a long exponential tail with decay time τ. The charge information (proportional to the energy released by the particle in the detector) is therefore represented by the pulse height. The charge-amplitude proportionality is set by the capacitor value $V_{out} = \frac{Q}{C}$ and the decay time of the output signal is $\tau = RC$.

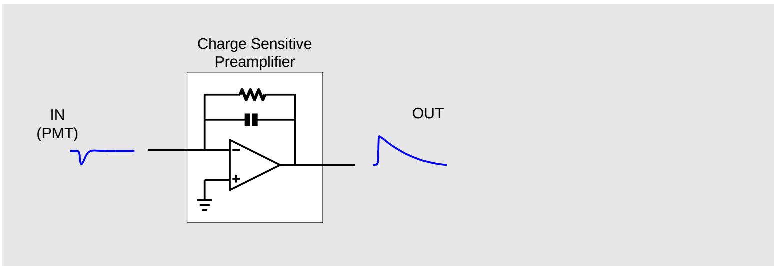


Fig. 2.2: Simplified schematic of a RC-type Charge Sensitive Preamplifier

To have a good charge-amplitude conversion and to minimize the noise, the decay time τ is much larger than the width of the detector signal, typically 50-100 µs, and for this reason pile-up of different particle detections can arise (**Fig. 2.3**).

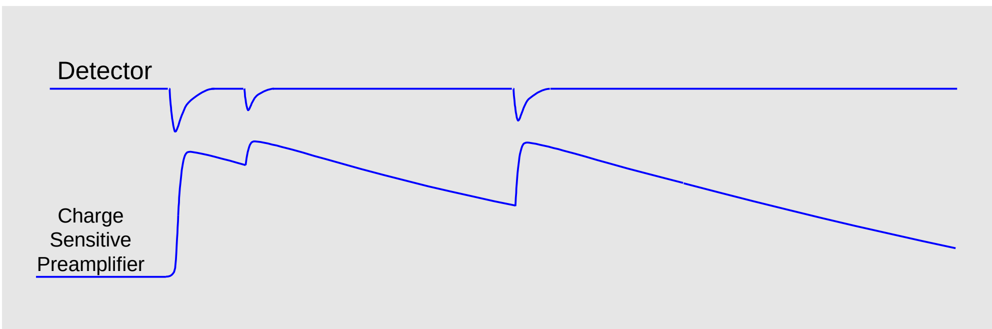


Fig. 2.3: Pile-up of detector signals due to the large decay time of the Preamplifier output

Another drawback when using a Charge Sensitive Preamplifier is when the peak is too sharp for the Peak Sensing ADC to be detected with the required precision.

To avoid these problems the pre-amplified signal is usually feed into a Shaping Amplifier, that provides out a quasi-Gaussian output whose height is still proportional to the energy released by the detected particle.

Finally, the signal from the Shaping Amplifier is fed into a Peak Sensing ADC, which is able to evaluate and digitize the height of the pulses, and filling a histogram with these values, which corresponds to the *energy spectrum*.

To preserve the timing information, the fast component of the signal (rising edge) is usually treated by a Fast Amplifier (or Timing Amplifier) that derives the signal; the output of the fast amplifier usually feeds a chain made of a Discriminator (CFD), a TDC and/or a Scaler for the timing/counting acquisition. Further modules can be present to implement logic units, to make coincidences (giving the position and the trajectory of the particles), to generate triggers or to give information about the pulse shape (time over threshold, zero crossing, etc.) for the particle identification. Usually the Fast Amplifier is included into the Shaping Amplifier module and the relevant signal is provided as a separate fast output (or timing output).

The typical signal shapes from the analog chain is shown in **Fig. 2.4.**

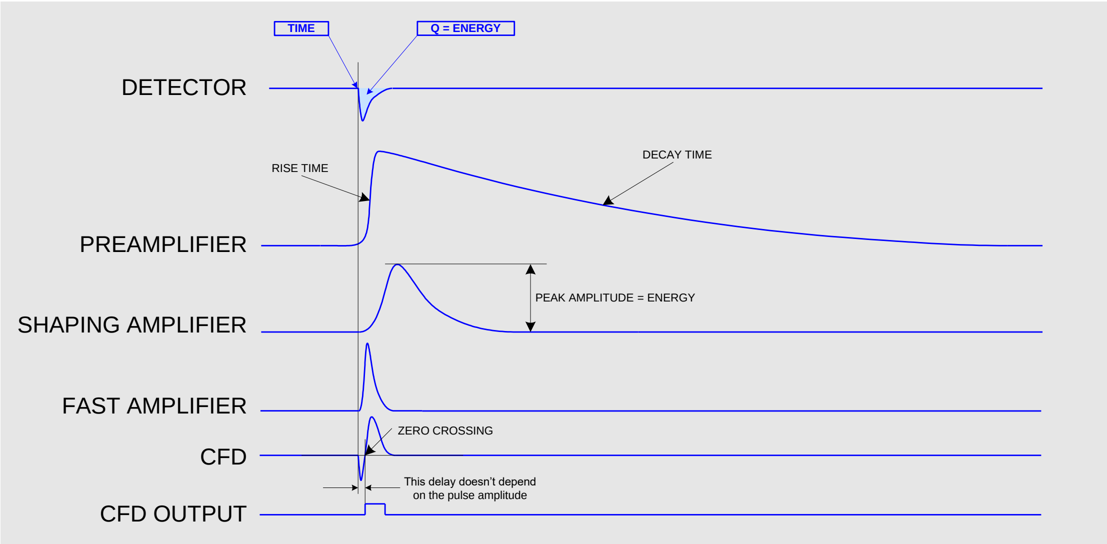


Fig. 2.4: Signals in the traditional analog chain

CAEN Digital Approach

In the CAEN digital approach all blocks from the shaping amplifier to the PC are synthetized into a single device, the digitizer (see **Fig. 2.5**).

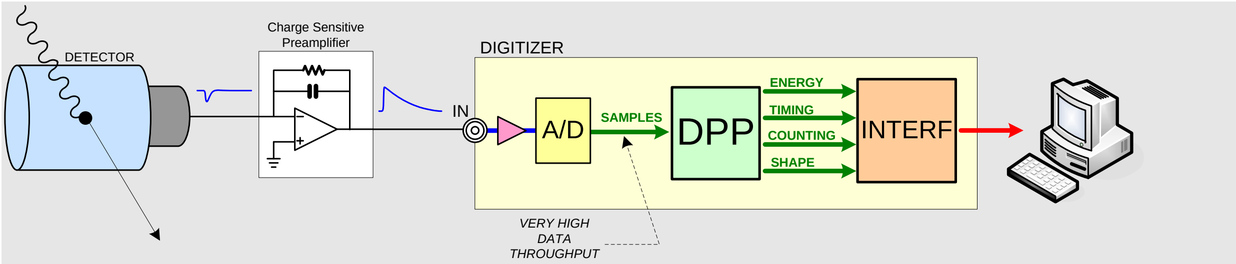


Fig. 2.5: Block Diagram of a Digitizer-based Spectroscopy System

Indeed, the new FPGA based techniques allow the user to change the readout parameters according to the detector characteristics, thus enabling the measurement of different radiations with different detectors using the same hardware. The digitizer becomes itself a Digital Multi Channel Analyzer (MCA).

In the technique called Multi Channel Analysis the energy spectrum histogram X- axis can be segmented in “bins” or “Channels”, each one representing a pulse height value, in V (or, if calibrated, the corresponding radiation Energy in Kev). The maximum number of available “bins” or “channels” is dictated by the resolution of the ADC. A 14-bit (1:16384) ADC resolution allows a 16 K “Channels” Spectrum to be generated. The spectrum resolution should be matched with the detector Energy resolution for optimal results (i.e. a 1K Channels Spectrum is good enough of basic gamma spectroscopy with NaI detectors while at least an 8K Channels Spectrum is needed to appreciate the intrinsic Energy resolution of HPGe Detectors). The histogram Y-axis values indicate the number of counts accumulated during the measuring time in the corresponding x-axis “bin” or “Channel”.

Fig. 2.6 shows an example of a typical spectrum of a ^{60}Co source from HPGe detector, acquired with a DT5780 and the MC²Analyzer software.

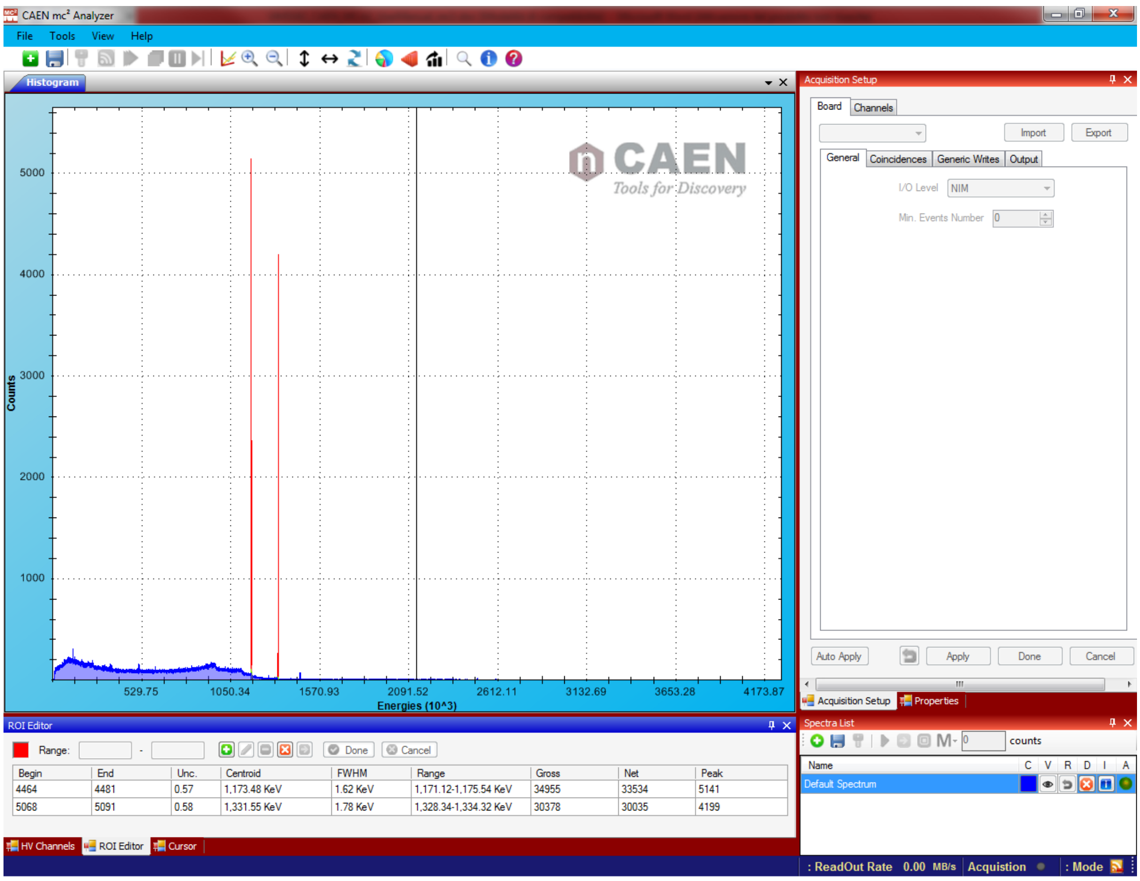


Fig. 2.6: ^{60}Co energy spectrum from HPGe detector

The algorithm implemented in the digitizer FPGA is based on the Jordanov trapezoidal filter **[RD1]** and it is called DPP-PHA (Digital Pulse Processing for Pulse Height Analysis). The trapezoidal filter is a filter able to transform the typical exponential decay signal generated by a charge sensitive preamplifier into a trapezoid whose flat top height is proportional to the amplitude of the input pulse (that is to the energy released by the particle in the detector) (see **Fig. 2.7**). This trapezoid plays almost the same role of the shaping amplifier in a traditional analog acquisition system. There is an analogy between the two systems: both have a "shaping time" constant and must be calibrated for the pole-zero cancellation. For both, a long shaping time gives a better resolution but has higher probability of pile-up. Both are AC coupled with respect to the output of the preamplifier whose baseline is hence removed, but both have their own output DC offset and this constitutes another baseline for the peak detection.

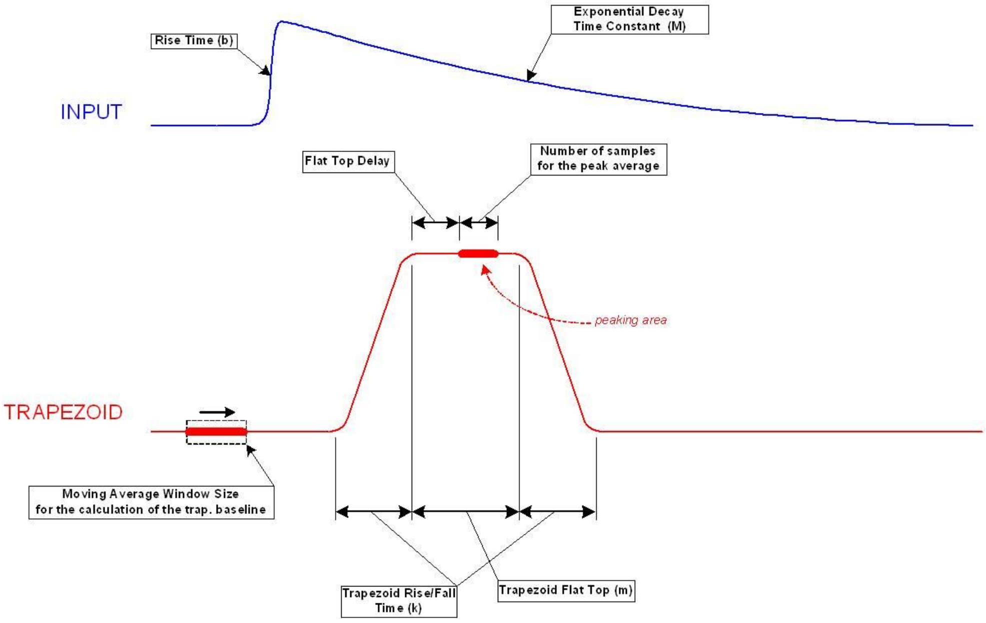


Fig. 2.7: Pulse Height Analysis with Trapezoid Method

The block diagram of the processing chain inside the digitizer FPGA is shown in **Fig. 2.8**.

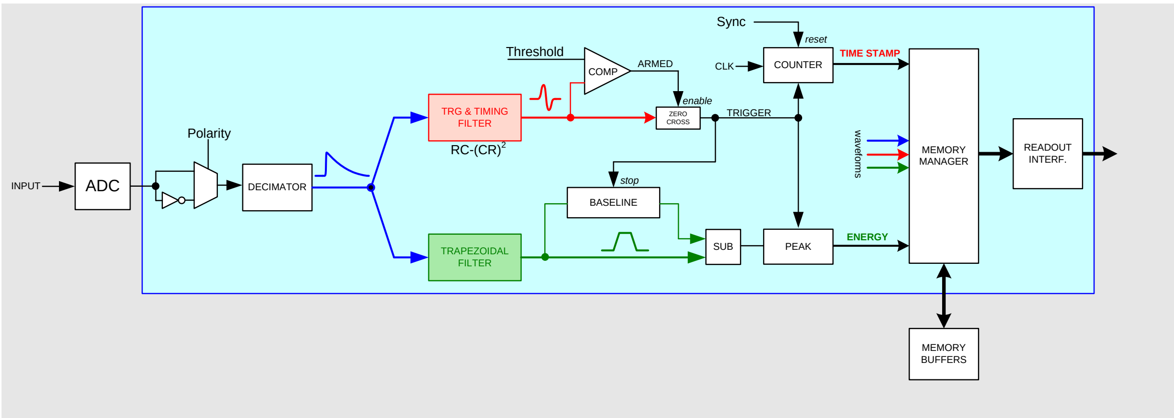


Fig. 2.8: Block Diagram of the processing chain programmed into the Digitizer's FPGA

In case of DT5770 the block diagram modifies as follows.

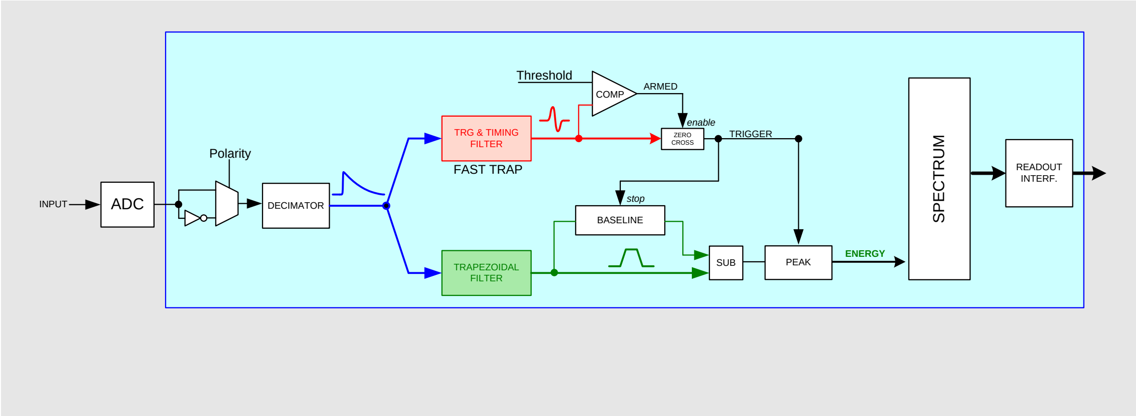


Fig. 2.9: Block Diagram of the processing chain programmed into the DT5770 FPGA

Decimator

The first block after the polarity selector is the decimator filter; this can be used in the case the signal is particularly slow, hence it is necessary to set values for the DPP time parameters that are not within the allowed range. The effect of the decimator is to scale down the sampling frequency of a factor 2, 4 or 8; it might have also benefits in terms of noise, since it averages a certain number of samples to make a new sample for the data stream.

The decimation applies to the energy filter only (i.e. to Decay Time (Pole-Zero Compensation), Trap. Rise Time, and Trap. Flat Top). Timing filter (RC-CR2), Baseline, Trigger Hold-Off, and Record Length are not affected.

Note: The decimation is not available for 770 series.

Note: The decimation is no longer supported for DPP-PHA firmware revision higher than 128.64 (724/780/781/782 series) and for Hexagon. It can be used only to rescale the record length but has no effect in the energy and timing filters.

Trigger and Timing Filter

Note: For the DT5770 and Hexagon MCA check the next sections.

After the decimator, there are two parallel branches: one for timing and triggering, the other one for the energy. The aim of the Trigger and Timing Filter (TTF) is to identify the input pulses, generate a digital signal called trigger that identifies the pulse, and calculate the time of occurrence of the event (*trigger time stamp*).

The TTF performs a digital RC-CR^2 filter, whose zero crossing corresponds to the trigger time stamp. In analogy with a CFD – Constant Fraction Discrimination – the RC-CR^2 signal is bipolar and its zero crossing is independent of the pulse amplitude. The integrative component of the RC-CR^2 is a smoothing filter based on a moving average filter that reduces the high frequency noise and prevents the trigger logic to generate false triggers on spikes or fast fluctuation of the signals. The derivative component allows to subtract the baseline, so that the trigger threshold is not affected by the low frequency fluctuation. Moreover, the pile up effect is significantly reduced.

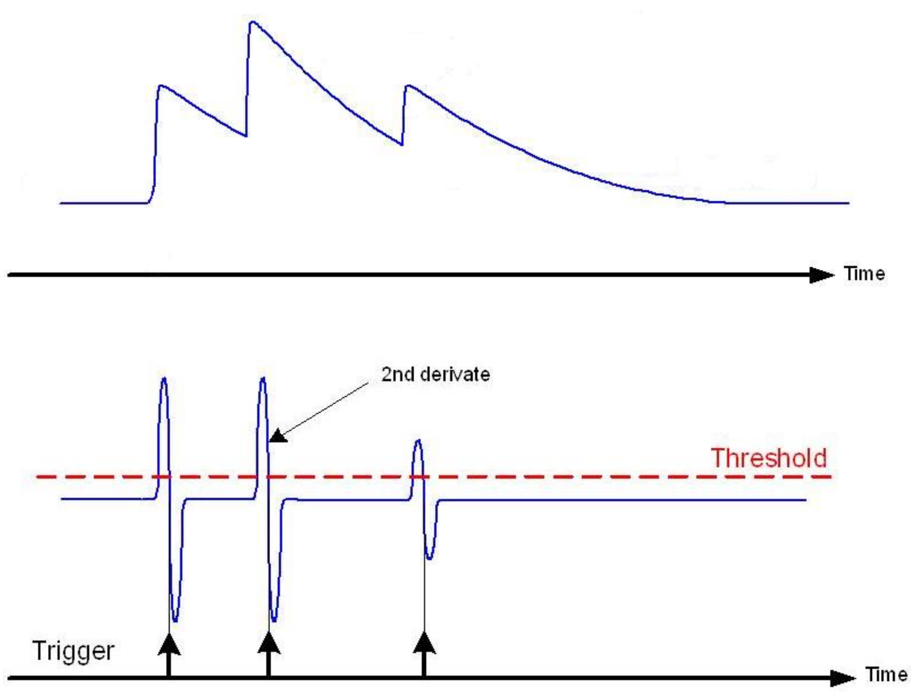


Fig. 2.10: The Trigger and Timing Filter allows to detect pulses on the zero-crossing of the RC-CR2 signal, which corresponds to a 2nd derivative of the input pulse. The derivative component of the RC-CR2 subtracts the baseline and makes easier to perform a zero-crossing calculation**.**

The trigger logic gets armed at the **Threshold** crossing, then it generates the trigger signal at the RC-CR^2 zero crossing. Setting the threshold value corresponds to set the LLD (lower level discrimination) of the energy spectrum. The user can check from the histogram which value corresponds to the set threshold level. Refer to Sec. **How to set the Trigger** for further details on how to set the threshold.

Note: In case of 725 and 730 series a linear interpolation of the RC-CR^2 signal is performed by default using the samples before and after the zero crossing.

Another important parameter for the trigger logic is the **RC-CR² smoothing**, corresponding to the number of samples used for the RC-CR^2 signal formation. Increasing this parameter may help in reducing high frequency noise, but have the drawback to make the signal slower and smaller, due to the smoothing.

Finally, the **Input Rise Time** is the time the RC-CR^2 reaches its maximum value. This value should correspond to the input rise time, in such a way the RC-CR^2 peak value corresponds to the height of the input signal. Examples on how to proper set the trigger and timing filter can be found in Sec. **How to set the Trigger**.

Trigger and Timing Filter for DT5770

The DT5770 MCA series discriminates events based on a **fast trapezoid** signal, whose rise time can be defined by the user. The fast trapezoid rise time ranges from 10 ns up to 300 ns.

The **trigger threshold** is then referred to the fast trapezoid itself, and the threshold crossing arms the event selection. To get higher precision in the trigger position, a subsequent derivative of the fast trapezoid is created. The trigger fires at the zero crossing of the derivative signal itself. The user can only see the fast trapezoid trace on the signal inspector, while its derivative is implemented onboard and it is not available for the visualization.

A trigger hold-off window is then opened to inhibit other triggers due to noise.

Check **Fig. 2.11** and **Fig. 2.12** for a diagram of the trigger filter in the DT5770.

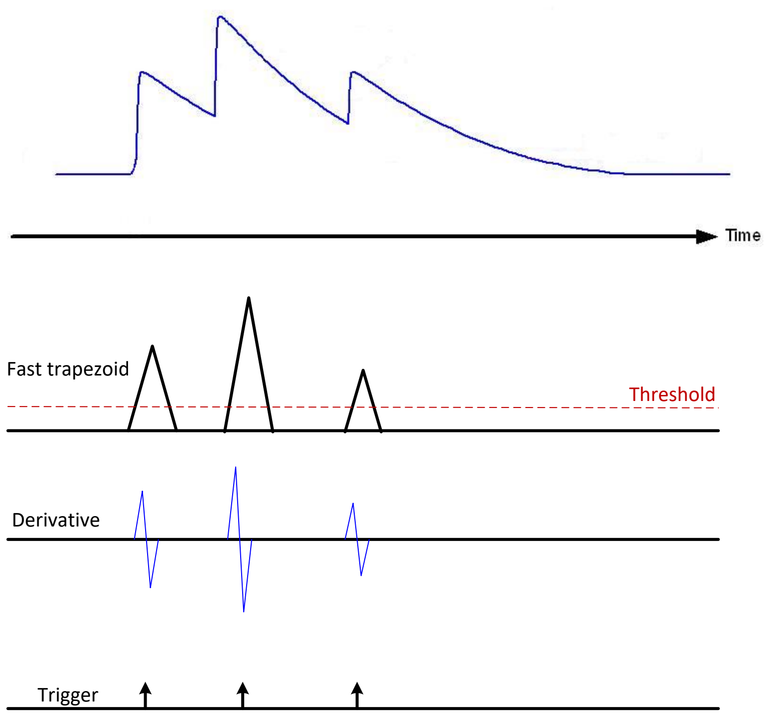


Fig. 2.11: Triggering on the fast trapezoid signal (DT5770 only)

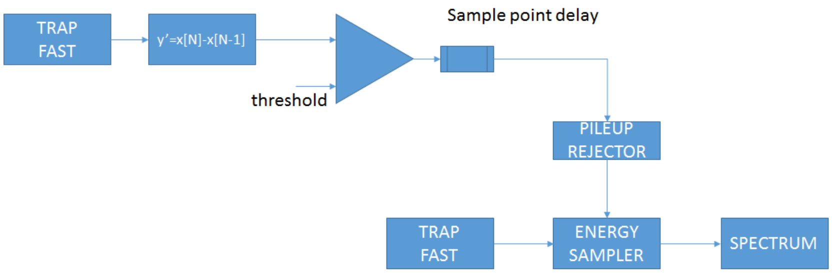
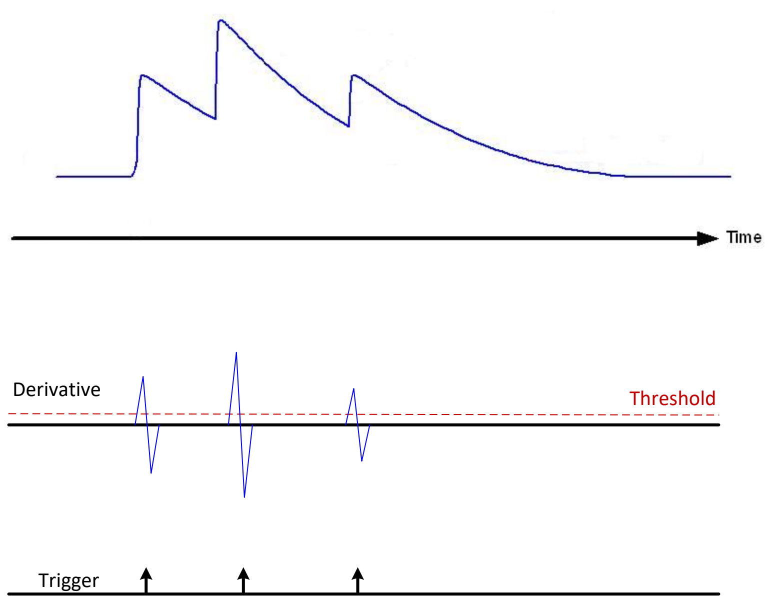


Fig. 2.12: Block diagram showing the DT5770 trigger management

Setting the threshold value corresponds to set the LLD (lower level discrimination) of the energy spectrum. The user can check from the histogram which value corresponds to the set threshold level. Refer to Sec. **How to set the Trigger filter (DT5770 only)** for further details on how to set the threshold.

Trigger and Timing Filter for Hexagon

The Hexagon MCA series discriminates events based on a **triangular** signal, whose rise time can be defined by the user in the range 0.01 to 2.4 µs.



The **trigger threshold** is then referred to the derivative of the triangle itself, and the threshold crossing arms the event selection. The trigger fires at the zero crossing of the derivative signal itself. The user can see the derivative trace on the signal inspector.

In addition, Hexagon embeds an algorithm based on a slower triangle that allows to optimize the signal over noise ratio and the pulse pair resolution.

Note: The user should pay attention to the fact that the trigger threshold, usually known as LLD, it is applied to the triangular filter so does not correspond exactly to the same cut value on the energy spectrum.

Trapezoidal Filter (Energy Filter)

As in the traditional analog chain, the Shaping Amplifier is able to convert the exponential shape from the Charge Sensitive Preamplifier into a Gaussian shape whose height is proportional to the pulse energy, in the same way the Trapezoidal filter is able to transform it into a trapezoidal signal whose amplitude is proportional to the input pulse height (energy). In this analogy, the **Trapezoid Rise Time** corresponds to the Shaping Time times a factor of 2/2.5. Therefore for an analogic shaping of 3us the user can set a trapezoid rise time of 7-8 us (see also Sec. **How to set the Energy Filter** and **Acquisition Setup**).

In case of high rate signal the trapezoid rise time value should be reduced in order to avoid pile-up effects (see Sec. **Pile-up Rejection**), choosing a compromise between high resolution (high value of trapezoid rise time) and pile-up rejection (and corresponding dead time).

The energy value of the input pulse is evaluated as the height of the trapezoid in its **Flat Top** region. The user must take that the flat top is really flat and that the **Peaking** (i.e. the samples used for the energy calculation) is in the flat region. Moreover the correct setting of flat top and peaking helps in the correct evaluation of the energy especially when large volume detectors are involved and the ballistic deficit may cause a significant error in the energy calculation. In this case it may be convenient to increase the flat top duration and delay the peaking time to wait for the full charge collection.

Fig. 2.13 summarizes the settings for both the Trigger and Timing Filter and for the Trapezoid Filter.

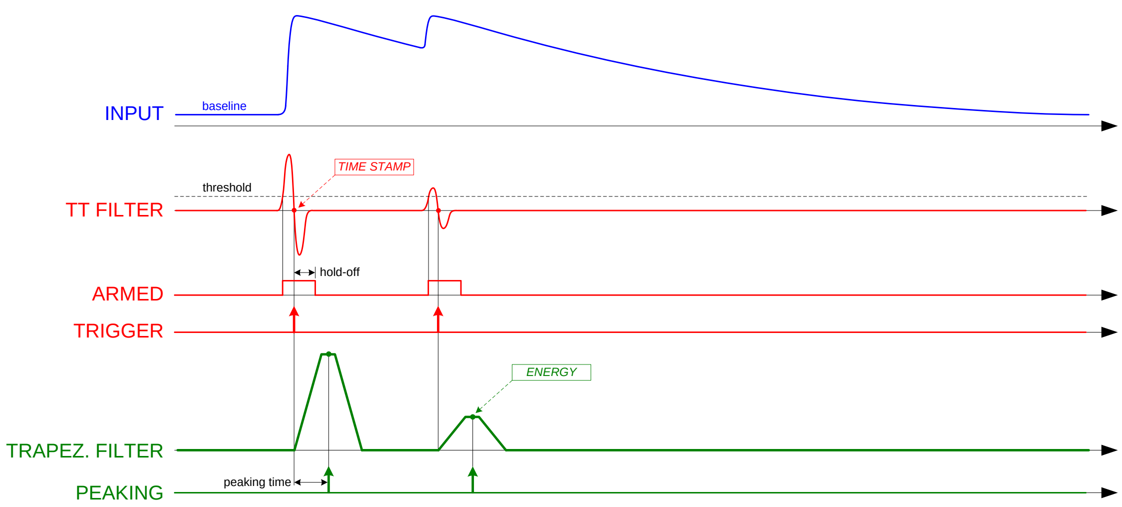


Fig. 2.13: Simplified signals scheme of the Trigger and Timing filter (red) and the Trapezoidal Filter (green). In blue the input pulses from Preamplifier. In case of DT5770 and Hexagon the TTF corresponds to a fast trapezoid.

Pole-Zero Adjustment

Like the Gaussian pulse of the Shaping Amplifier, also the trapezoid requires an accurate pole-zero adjustment to guarantee the correct return to the baseline at the end of the falling edge. To correctly set the pole-zero the user must take care of setting the proper **Trapezoid Decay Time** value (which corresponds also to the Input Decay Time) to avoid either undershoot or overshoot effects (as can be seen in **Fig. 2.14**). Pole Zero Adjustment can reduce signal artifacts due to pulses pile up occurring when the counting rate is high compared to the pulse decay.

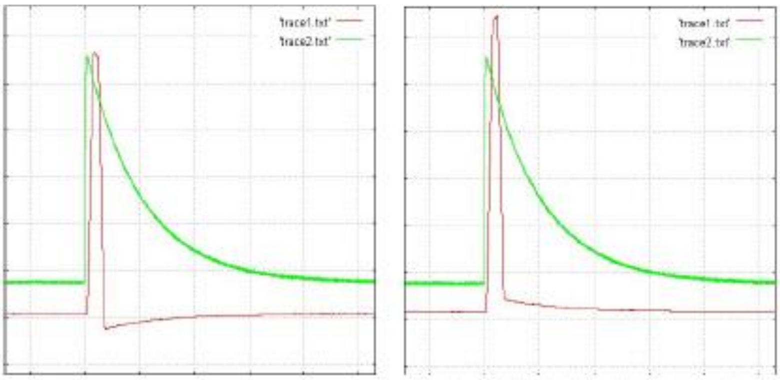


Fig. 2.14: Pole Zero effects of undershoot (left) and overshoot (right) of the trapezoid (red curve)

Baseline Restoration

The energy filter includes also a baseline restorer that operates on the trapezoidal filter output and calculates the baseline by averaging a programmable number of points before the start of the trapezoid. The baseline is then frozen for the trapeze duration and used for the height calculation. Once the trapezoid is returned to the baseline, the averaging restarts to run.

The pulse height (i.e. the trapezoid amplitude) is given as the distance between the flat top and the baseline taken in the programmed position; to further reduce the fluctuation of this distance due to the noise, it is possible to average a certain number of points in the flat top before subtracting the baseline.

In case of high-resolution measurements, it is strongly suggested to increase the number of **Baseline Mean** samples at the maximum allowed value. Furthermore, the user can also set the **Baseline Hold-Off** value to freeze the baseline calculation beyond the trapezoid end, thus reducing the noise on the baseline calculation. In case of high rate those values must be reduced to avoid pile-up effects.

Pile-up Rejection

If two events are separated by less than the trapezoid duration, then the relevant trapezoids overlap. The trapezoid duration pkrun is defined as pkrun = RT + FT + pkho, where RT is the trapezoid Rise Time, FT is the trapezoid Flat Top, and pkho is the Peak Hold-Off, which starts at the end of the Flat Top. There are four different cases (**Fig. 2.15**):

1. ΔT > pkrun, the two events are well separated and none of them is flagged as pile-up;
2. RT + FT < ΔT < pkho, the rising edge of the 2nd trapezoid overlaps on the pkho of the 1st one. In this case only the first event has a correct value of energy, while the second one is tagged as pile-up (see bit *"PU"* in Sec. **Channel Aggregate Data Format for 724, 780, 781 series (FW release <128.64)**, **Channel Aggregate Data Format for 724, 780, 781, and 782 series (FW release >128.64),** and **Channel Aggregate Data Format for 725 and 730 series**).;
3. 1.5 * IRT < ΔT < RT + FT, where IRT is the Input Rise Time, which corresponds to the time the RC-CR2 signal reaches its maximum value, and 1.5 * IRT is the time the RC-CR2 signal crosses the zero. The two events are both flagged as pile-up, since the two trapezoids overlaps (see bit *"PU"* in Sec. **Channel Aggregate Data Format for 724, 780, 781 series (FW release <128.64)**, **Channel Aggregate Data Format for 724, 780, 781, and 782 series (FW release >128.64),** and **Channel Aggregate Data Format for 725 and 730 series**).

Note: It is also possible to acquire the energy values (not corrected) of the piled-up pulses by setting bit[27] = 1 of register 0x1n80. Refer to **[RD8]**, **[RD9]**, **[RD10]**, **[RD14]**, and **[RD15]** for additional details. Register writes can be performed through tab "Generic Writes" of MC2Analyzer software (see Sec. **Generic Writes Tab**).

4. ΔT < 1.5 * IRT, the two pulses are too close and the trigger filter is unable to resolve the double pulse condition. In this case, the pile-up cannot be recognized, and the two pulses are treated as a single pulse. The algorithm returns only one time stamp and one energy, whose value corresponds to about the sum of the two energies ('sum peak' in the spectrum).

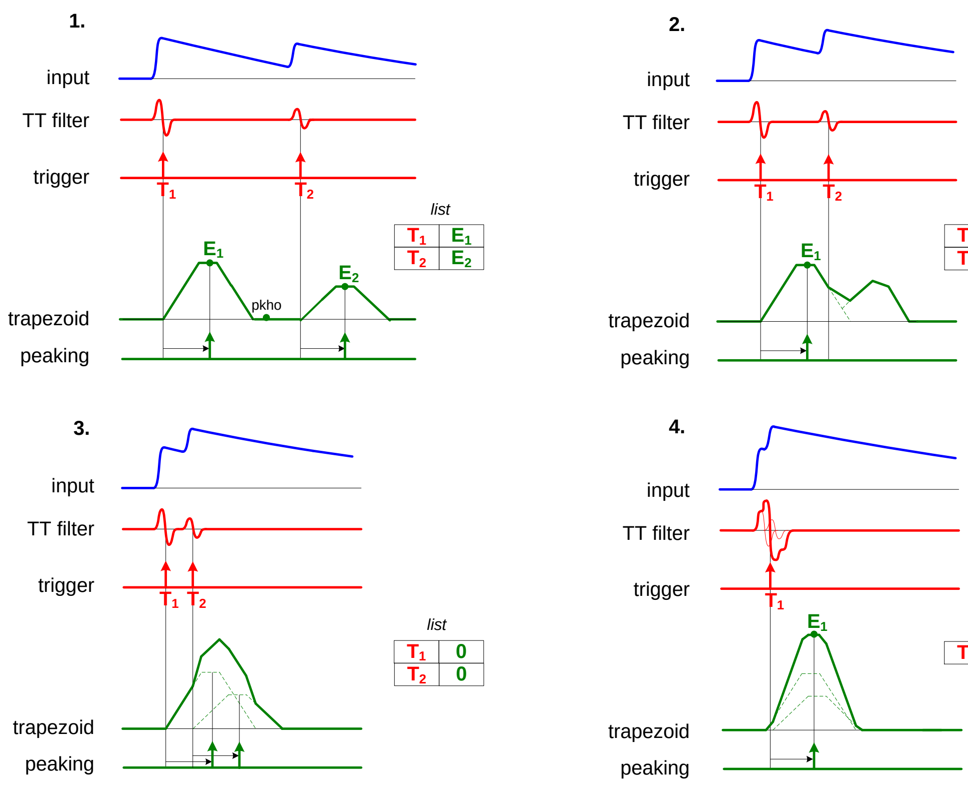


Fig. 2.15: The effect of trapezoid overlapping in the four main cases: 1. The two trapezoids are well separated (top left); 2. The second trapezoid starts on the falling edge of the first one (top right). 3. The second trapezoid starts on the rising edge of the first one (bottom left). 4. The two input pulses pile-up in the input rise time (bottom right)

Except for case 3, the DPP-PHA algorithm is able to save into the memory buffer all the incoming events, including the piled-up pulses; the energy value is anyhow meaningless. During the readout of the event list, these events won't be accumulated into the histograms (that are calculated in the software), although they participate to the total count, thus giving an accurate estimation of the Input Count Rate. Furthermore, the energy spectrum can be corrected run-time by a statistical redistribution of the missed energies over the spectrum acquired within a specific time slot.

Note: In case of **DT5770** the board does not provide the list of time stamp and energy, but it provides only the energy spectrum. When the energy of the pulse cannot be calculated due to pile-up, the corresponding event is not represented into the spectrum. The piled-up event is anyway counted into the "Incoming Counting Rate" value.

Dead Time

When a pulse is processed by an analog chain block, the maximum read-out rate is limited by the need to complete the processing of the current pulse before being able to process a successive valid signal. When the processing time of a pulse is larger than the time interval before the arrival of the next pulse, the analog chain is "temporarily blind" and misses one or more successive pulses. The actual live counting time is therefore smaller than the total counting time, and the difference between total time and live counting time is called "Dead time".

The Digital MCA read out capability is rather independent from the ADC sampling time and processing speed than from the signal width, and in general allows for higher counting rates than the analog chain. The digital MCA dead time is also an information on the relationship between total measurement time and live counting time values.

The MC^{2}Analyzer software is able to automatically evaluate the dead-time including the contributions of pile-up events, dynamics saturation (see Sec. **Channel Aggregate Data Format for 724, 780, 781 series (FW release <128.64)**, **Channel Aggregate Data Format for 724, 780, 781, and 782 series (FW release >128.64),** and **Channel Aggregate Data Format for 725 and 730 series**), and Trigger Hold-Off. In the latter two cases the software evaluates the corresponding probability (Poisson Distribution) to take into account missing events during the board "blindness".

Transistor Reset Preamplifiers

Germanium detectors today are usually equipped with RC feedback charge sensitive preamplifiers. These preamplifiers are cost effective and provide very good resolution, making them an excellent choice for low and moderate input count rate applications. However, RC preamplifiers are rate limited and in high input count rate conditions are easily saturating the dynamic range.
The RC preamplifier output is a tail pulse. The information is carried in the amplitude of the pulse while the tail contains no information.
The arrival of a second pulse prior to the first completely decaying is normally not an issue because it sits upon what is left of the tail of the first pulse. This will cause the average dc level of the signal baseline to rise slightly, but this is not as issue as long as the sum of any residual tailing plus the amplitudes of the new pulses does not exceed the dynamic range of the preamplifier.
However, when the events are coming at such a rate and with such an energy that the dynamic range is exceeded, a preamplifier saturation occurs. The preamplifier then stops operating and will stay dead until the incoming energy rate slows down sufficiently to allow the feedback resistor to draw the baseline dc level down to within the operating range.

The decay time of the tail pulse is related to the value of the feedback resistor. One way to decrease the decay time is to lower the value of the feedback resistor however this also increase the noise in the preamplifier degrading the resolution of the detector.

A solution to this preamplifier saturation problem is to use the so-called Reset preamplifier. In this case the feedback resistor is replaced with a reset circuit that monitors the dc level of the preamplifier and discharges the feedback capacitor whenever it starts to approach saturation.

At moderate to high count rates - above a few tens of kcps - the Transistor Reset Preamplifier (TRP) offers two distinct advantages in comparison to traditional RC feedback preamplifiers:

1. **Improved Resolution**. By eliminating the feedback resistor, its noise and secondary time constant contributions, TRPs offer better resolution and reduced spectrum broadening at high count rates.
2. **Increased Count Rate Capability**. TRPs are not energy rate limited like RC type preamplifiers, so they virtually never shut down due to saturation; at even the highest of count rates some pulses will always get through

While the TRP never completely shuts down due to saturation, its reset process and the amplifier overload which it causes does induce intervals of dead time into the counting system. Depending upon the nature of the sample being analyzed and the specific preamplifier/amp combination being used, these dead time intervals can be as insignificant as a couple of µs every few hundred pulses or as great as hundreds of µs every ten pulses.

While the former situation, which adds only a few percentage points to the system dead time may be a reasonable compromise to pay for the throughput and resolution benefits gained with a TRP, the latter could be a significant issue.

The output of a TRP has characteristics to note:

1. The output is a step function, rather than the tail pulse associated with an RC preamplifier.
2. The Dynamic Range of the preamplifier output is much lower than that of an RC preamplifier
3. When the output of a TRP reaches its reset threshold, it is automatically reset. There is no saturation and for most applications, no energy rate limit. The time required to reset contributes to overall system dead time.

To minimize system deadtime, two steps should be taken:

1. Choose a TRP with the widest possible dynamic range. This basically allows more pulse steps to occur before reset is required.
2. Choose an amplifier with the best possible overload recovery characteristics.

3 Getting Started

Hardware setup

We are going to describe a typical application of DPP-PHA algorithm and MC^{2}Analyzer software for the characterization of HPGe detectors response in a measurement of resolution of the ^{60}Co source photo-peaks.

The high and low voltages are provided by the DT5780 which integrates in a single unit both the high voltage power supply, the low voltage, and the readout channels. A scheme of the hardware setup is shown on **Fig. 3.1**.

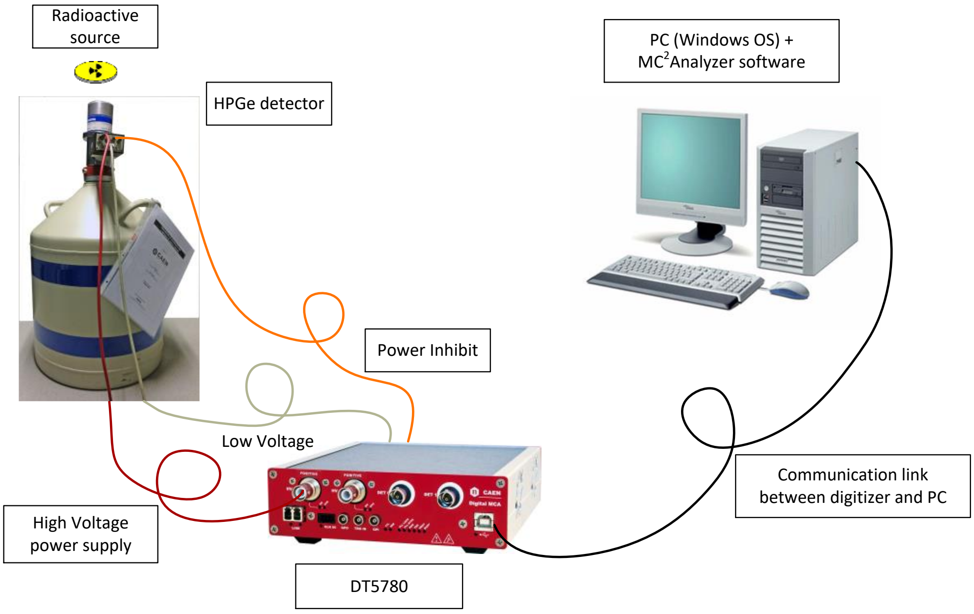


Fig. 3.1: Typical **setup for resolution measurements using HPGe detectors and the digital MCA DT5780**

Note: The description of this chapter is compliant also with the 724, 725, and 730 digitizer families, DT5770, 781, 782, and Hexagon MCA families. Any difference will be explicitly indicated.

Note: In case of 724, 725, 730 digitizer families, 781, and 782 MCA, the high and low voltage should be provided externally. In case of DT5770 MCA family, the low voltage for the preamplifier can be provided by the board itself.

Connect the SHV cable for the high voltage power supply to the HV0/HV1 connector of the DT5780. Connect the low voltage and the inhibit (if any) to the back-panel connectors of the DT5780. Finally connect the MCA to the PC with the preferred communication interface between USB and Optical link.

Refer to the DT5780 User Manual for further details about the connectors of the digital MCA **[RD2]**.

Software setup

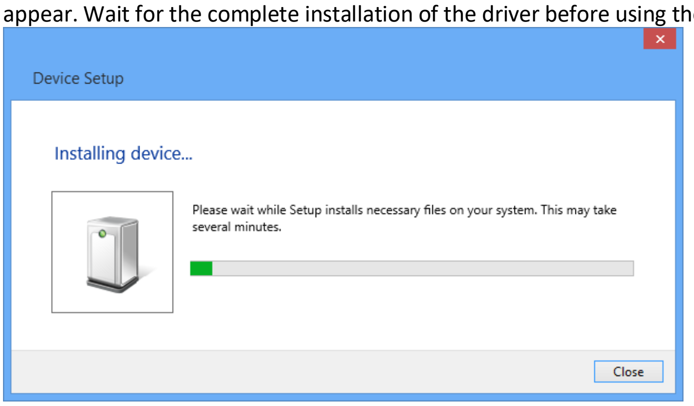
Drivers

To deal with the hardware, CAEN provides the drivers for all the different types of physical communication interfaces featured by the specific digitizer and compliant with Windows OS:

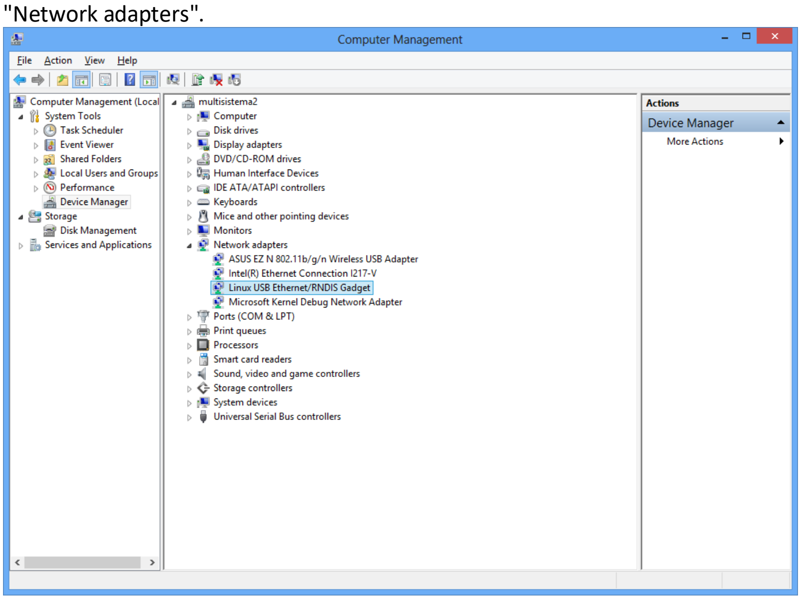
- **USB 2.0 Drivers for NIM/Desktop** boards are downloadable on CAEN website (www.caen.it) in the “Software/Firmware” tab of the digitizer/MCA web page (**login required**).

Note: Windows OS USB driver installation for Desktop/NIM digitizers is detailed in **[RD3]**.

Note: In case of **DT5770** the miniUSB driver has to be downloaded from the product web page. At the first connection of the DT5770 to the PC, Windows will try to automatically install them. The user have to provide to the drivers installation process the path to the downloaded driver folder. Then a message like this should appear. Wait for the complete installation of the driver before using the device.



Note: In case of **Hexagon** the miniUSB driver will be automatically installed when the board is connected to the computer for the first time. The device will be recognized under the "Device Manager" window among "Network adapters".



Note: the USB connection to Hexagon is recognized as a virtual Ethernet connection, whose default IP Address is: **172.24.0.126**

- **USB 2.0 Drivers for V1718** CAEN Bridge, required for the VME boards interface, is downloadable on CAEN website (www.caen.it) in the “Software/Firmware” tab of the V1718 web page (**login required**).

Note: For the installation of the V1718 USB driver, refer to the User Manual of the Bridge.

- **Optical Link Drivers** are managed by the A2818 PCI card or the A3818 PCIe card. The driver installation package is available on CAEN website in the “Software/Firmware” area at the A2818 or A3818 page (**login required**)

Note: For the installation of the Optical Link driver, refer to the User Manual of the specific Controller.

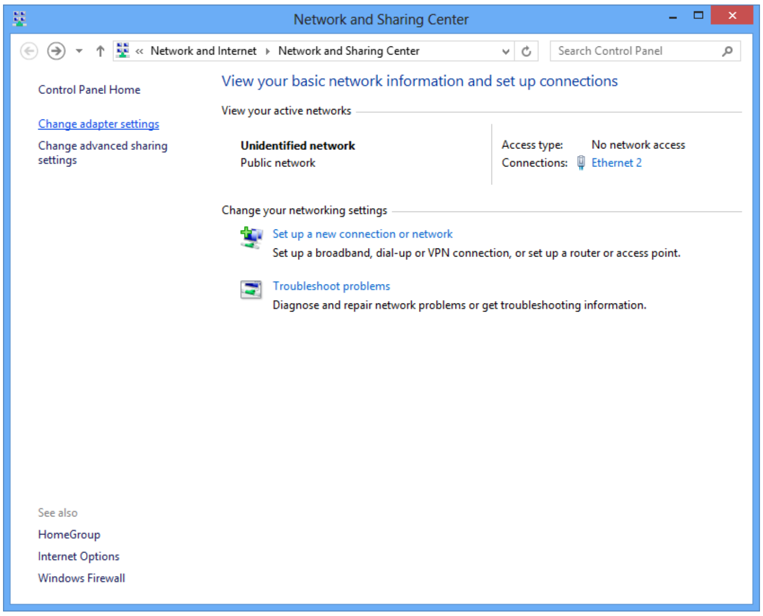
Network configuration

With the DT5770 and Hexagon MCAs it is also possible to communicate via Ethernet communication interface. The connection can be done through a server or it can be a point-to-point connection to the PC. In the latter case the connection can be done using a crossed cable, a switch, or a computer with a Gigabit Ethernet port. Connect the Ethernet cable from the MCA to the computer and configure the network according to the following instructions.

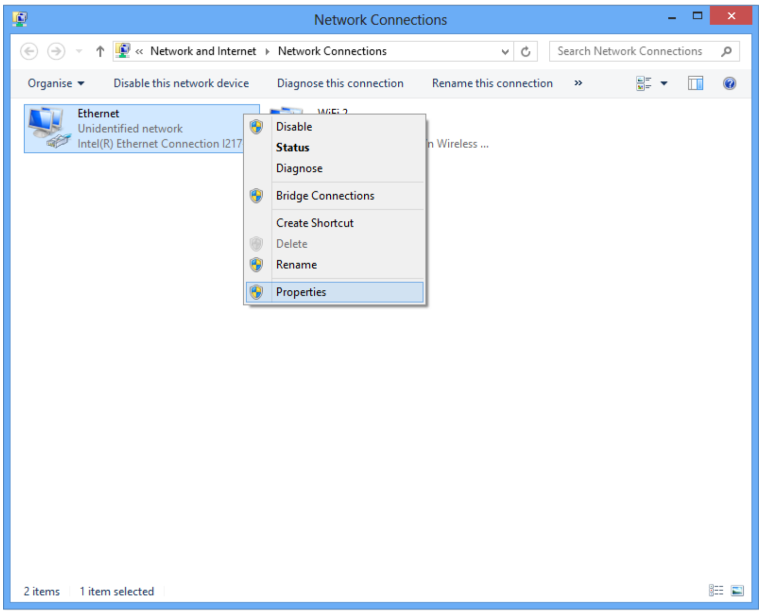
Note: The default IP Address of DT5770 MCA is: **192.168.0.98**, while the the default IP Address of Hexagon is: **172.16.0.2**

1. Open the path:

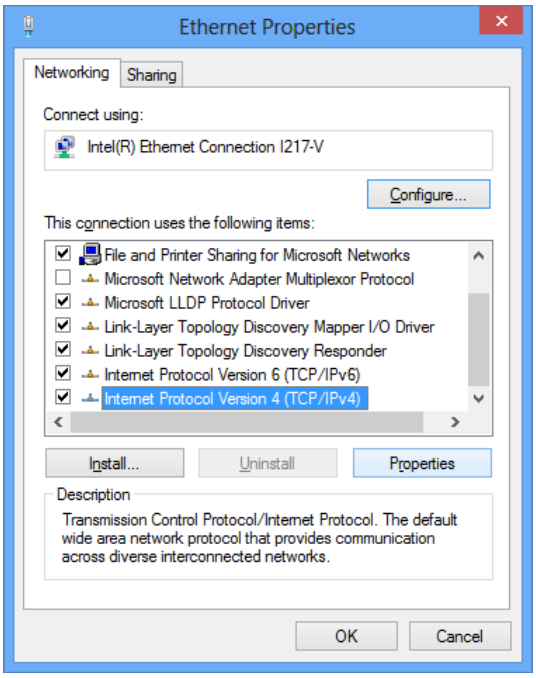
   `Control Panel - Network and Internet - Network and Sharing Center`



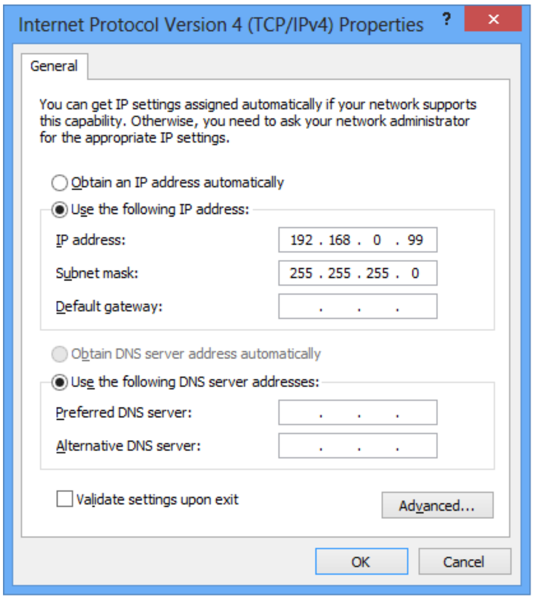
2. Click on “Change adapter settings”.
3. Right click on the Ethernet icon and select “Properties”:

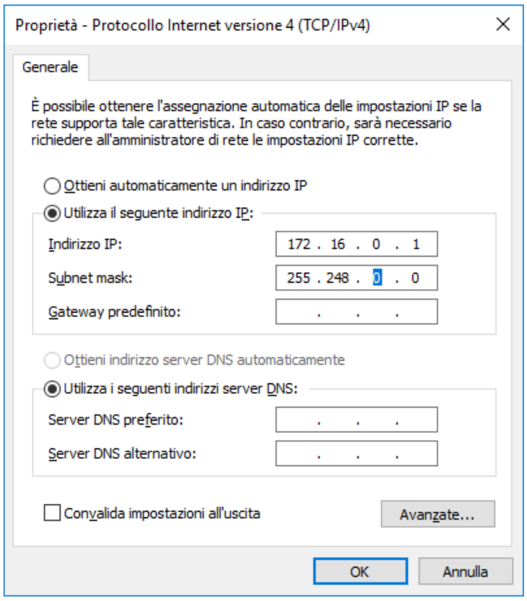


4. Click on “Internet Protocol Version (TPC/IPv4)”, and select “Properties”:



5. Copy the following configuration on the “Internet Protocol Version (TPC/IPv4) Properties” window (for **DT5770** on the left and for **Hexagon** on the right):





Libraries

The MC2Analyzer software relies in the following additional set of C libraries which are embedded into the software **setup**. The user does not need to install them aside, apart in the case he/she wants to write its own readout software:

- **CAENComm** library manages the communication at low level (read and write access). The purpose of the CAENComm is to implement a common interface to the higher software layers, masking the details of the physical channel and its protocol, thus making the libraries and applications that rely on the CAENComm independent from the physical layer. Moreover, the CAENComm requires the CAENVMELib library (access to the VME bus) even in the cases where the VME is not used. This is the reason why **CAENVMELib has to be already installed on your PC before installing the CAENComm**.

  The CAENComm installation package is available on CAEN website (www.caen.it) in the "Download" tab at:

  Home / Products / Firmware/Software / Software Tools / Software Libraries / CAENComm Library

- **CAENDigitizer** is a library of functions designed specifically for the Digitizer family and it supports also the boards running the DPP firmware. The CAENDigitizer library is based on the CAENComm library. For this reason, **the CAENComm libraries must be already installed on the host PC before installing the CAENDigitizer**.

  The CAENDigitizer installation package is available on CAEN website (www.caen.it) in the "Download" tab at:

  Home / Products / Firmware/Software / Software Tools / Software Libraries / CAENDigitizer Library

- **CAENDPP** is a high-level library of C functions designed to completely control exclusively the digitizers running the DPP-PHA firmware.

  The CAENDPP installation package is available on CAEN website (www.caen.it) in the "Download" tab at:

  Home / Products / Firmware/Software / Software Tools / Software Libraries / CAENDPP Library

Currently, the CAENComm (and so the CAENDigitizer) supports the following communication interfaces (see also **Fig. 3.2**):

PC → USB → Digitizer Desktop and NIM form factors

PC → USB → V1718 → VME → Digitizer VME form factor

PC → PCI (A2818) → CONET → Digitizer all form factors

PC → PCI (A2818) → CONET → V2718 → VME → Digitizer VME form factor

PC → PCIe (A3818) → CONET → Digitizer all form factors

PC → PCIe (A3818) → CONET → V2718 → VME → Digitizer VME form factor

CONET (Chainable Optical NETwork) indicates the CAEN proprietary protocol for communication interface using Optical Link.

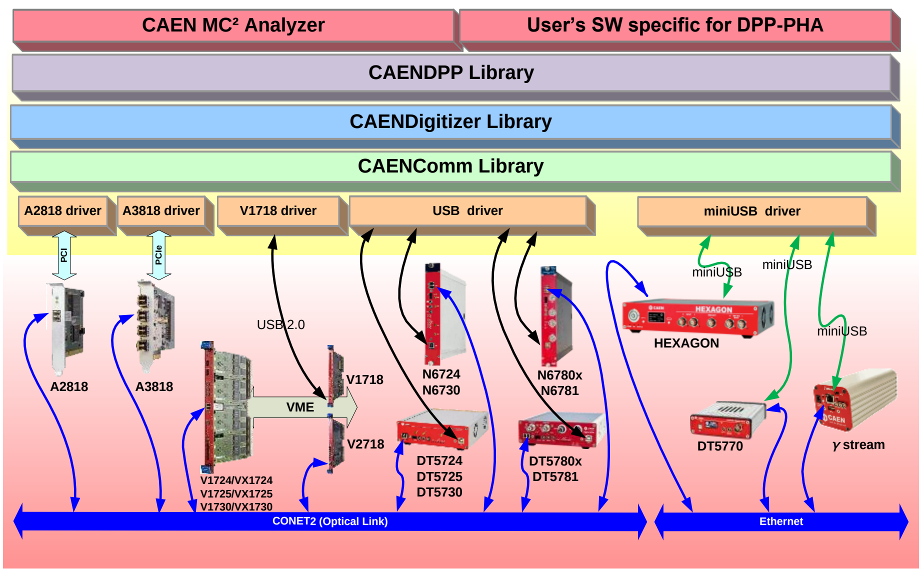


Fig. 3.2: Libraries and drivers required for MC²Analyzer

Software Installation

To manage with the MC²Analyzer software, the host station needs a Windows OS. The Linux version is not supported yet. The software requires the third-party software **.NET Framework 4.0 or later**, downloadable from Microsoft© website.

- **Make sure** that your **hardware** (Digitizer and/or Bridge, or Controller) is **properly installed** (refer to the related User Manual for hardware installation instructions).
- **Make sure** you have installed the **driver** for your OS and the physical communication layer to be used. Driver installation packages are downloadable from CAEN website (**login required**) as reported in the section **Drivers** (refer to the related User Manual for driver installation instructions).

Note: Hardware and USB drivers installation instructions for desktop digitizers and DT5780 are detailed in **[RD3]**.

CAEN provides the full installation package for the MC²Analyzer Software in a **standalone version** for **Windows OS**. This version installs all the binary files and required libraries.

1. Download the MC²Analyzer Software from CAEN Website under the path:

   Home / Products / Firmware/Software / Digitizer Software / Readout Software / MC2 Analyzer

2. Extract the files and run the executable **"MC2Analyzer_x.x.x.exe"**.
3. The CAEN MC²Analyzer **Setup Wizard** will guide you throughout the installation procedure.

Note: the following screenshot are taken with Window 7 OS, and they can be generalized for Windows 8 and Windows 10.

Fig. 3.3: MC²Analyzer Wizard Dialog Box- Start Installation

Left click on **"Next"** (or left click on **"Cancel"** any time during the installation process to abort the installation).

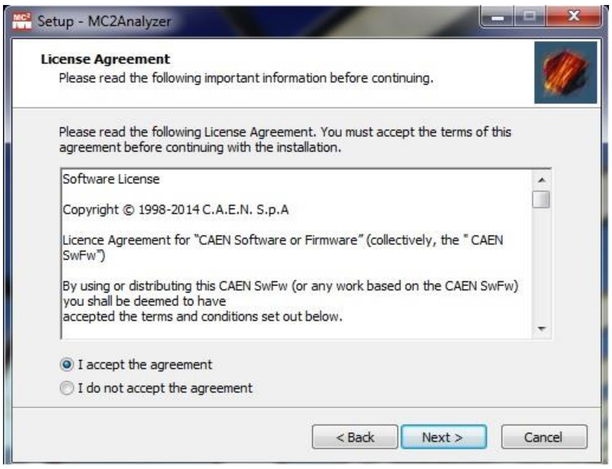


Fig. 3.4: MC²Analyzer Wizard Dialog Box - License Agreement

Please read the MC^{2}Analyzer Software License Agreement and select **“I accept the agreement”** to continue the installation. Left click on **“Next”** (or left click on **“Back”** at any time during the installation process to modify the previous settings).

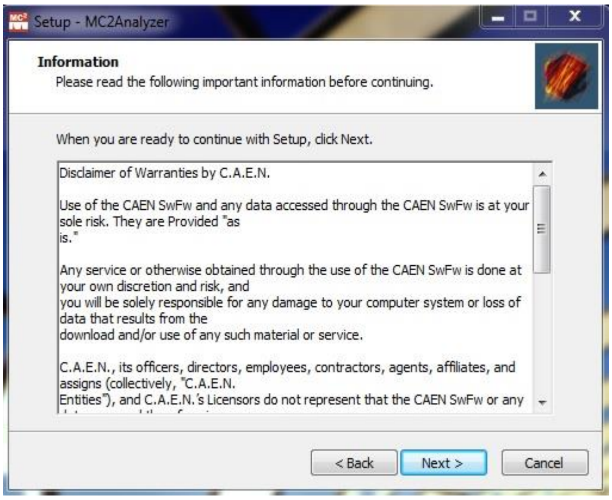


Fig. 3.5: MC^{2}Analyzer Wizard Dialog Box - Disclaimer

Please read the CAEN Disclaimer information then left click on **“Next”** to continue.

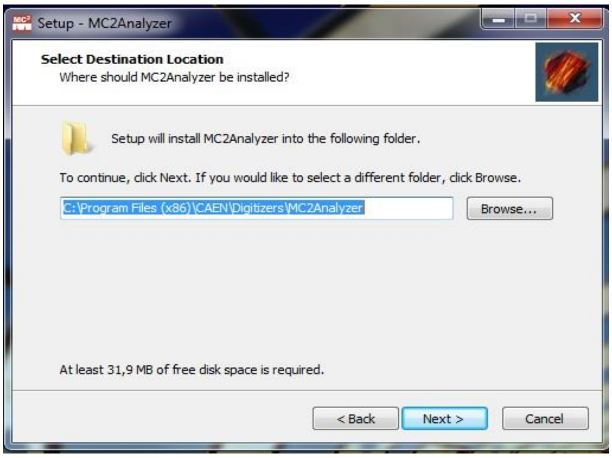


Fig. 3.6: MC^{2}Analyzer Wizard Dialog Box – Installation Folder Selection

To install the MC^{2}Analyzer Software, a minimum free space of about 32 MB of free Hard Disk space is required. Select a folder for the installation of the CAEN MC^{2}Analyzer Software by using the **“Browser”** button or by typing the desired path in the white entry box. The default path is:

C:\Program Files\CAEN\Digitizers\MC2Analyzer (Windows 32 bit)

or

C:\Program Files (x86)\CAEN\Digitizers\MC2Analyzer (Windows 64 bit).

Left click on **“Next”** to continue.

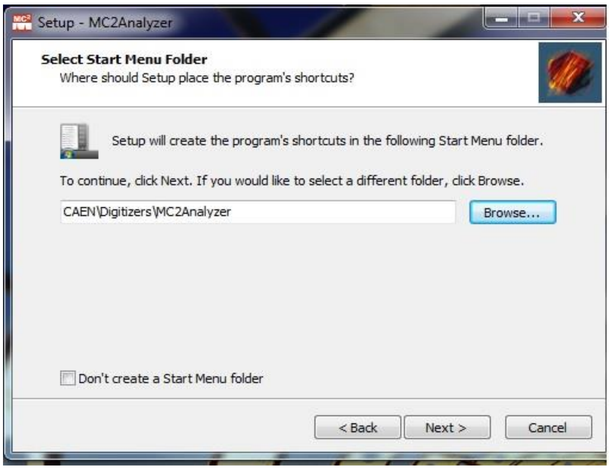


Fig. 3.7: MC^{2}Analyzer Wizard Dialog Box – Shortcuts

Optionally, select a Start Menu folder for the installation of the CAEN MC^{2}Analyzer Software Shortcuts by using the **"Browser"** button or by typing the desired path in the white entry box. The default path is: *C:\Program Files\CAEN\Digitizers\MC2Analyzer* (Windows 32 bit) or *C:\Program Files (x86)\CAEN\Digitizers\MC2Analyzer* (Windows 64 bit). If you do not wish to create a Start Menu folder mark the checkbox labelled "Don't create a Start Menu folder".

Left click on **"Next"** to continue.

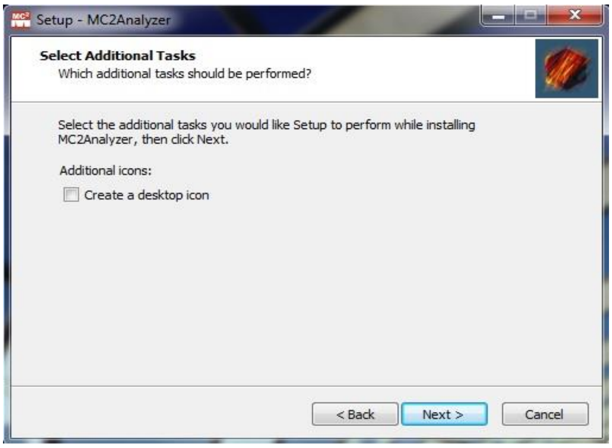


Fig. 3.8: MC^{2}Analyzer Wizard Dialog Box – Desktop Icon Selection

Optionally, mark the checkbox labelled "Create a desktop icon" to create an MC^{2}Analyzer icon on your computer Desktop. Left click on **"Next"** to continue.

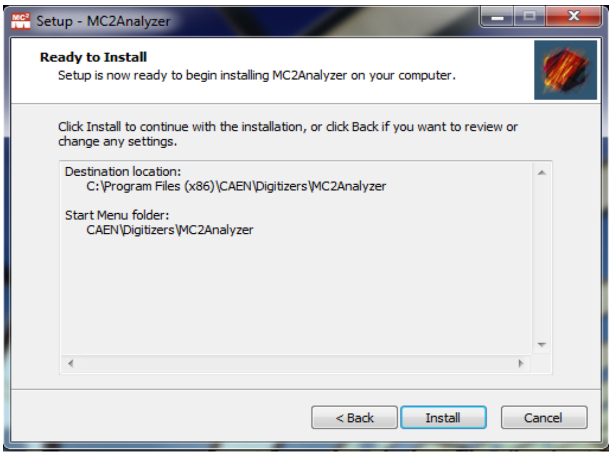


Fig. 3.9: MC^{2}Analyzer Wizard Dialog Box – Installation

Please revise the MC²Analyzer Program Destination path and the Start Menu folder you have selected, if any.

Left click on **"Install"** to install the CAEN MC²Analyzer Software.

The CAEN MC²Analyzer Setup Wizard will extract and install the relevant files. At the end of the installation, the following Dialog Box will appear:

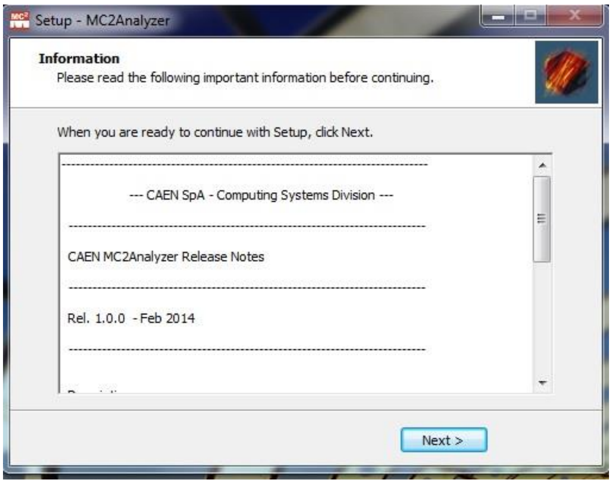


Fig. 3.10: MC²Analyzer Wizard Dialog Box – Software Release Version Notes

Please read the Release Notes of the MC²Analyzer Software before continuing. This document is updated for every official release of MC²Analyzer and it contains various updated information specific to this software which may not be found in the User's Manual, available together with the software or on the CAEN web site: www.caen.it.

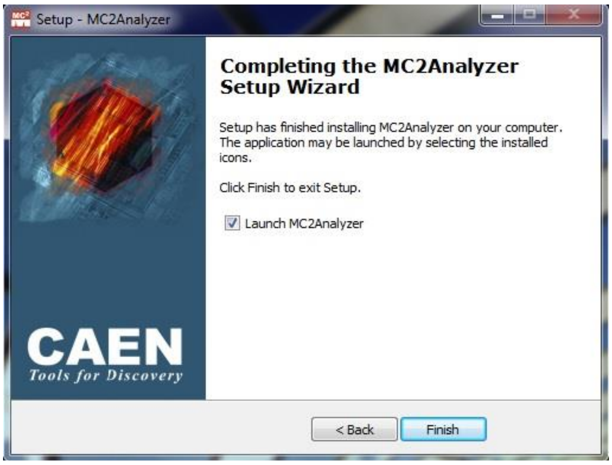


Fig. 3.11: MC²Analyzer Wizard Dialog Box – Finish Installation

To complete the MC²Analyzer Installation left click on **"Finish"**. The MC²Analyzer Program can be launched by marking the check box "Launch MC2Analyzer Analyzer" before finishing the installation, or by left clicking on the installed icons in the Start Menu Folder.

Software connection

Once you have installed the required driver for the communication interface and the MC²Analyzer software you can launch the MC²Analyzer software and connect it to the DT5780.

Note: The software requires an active rule in the **firewall**. Click **Allow** to permit the MC²Analyzer connection.

From the main panel of the MC²Analyzer software GUI select

FILE -> Add Spectrum, or press the button .

The following window will appear.

Select **"Online Spectrum"** and **"New Board Connection"** to connect the software to the digital MCA.

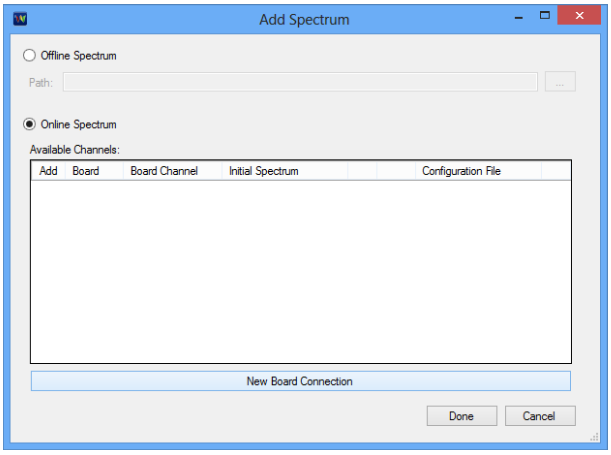


Fig. 3.12: the "Add Spectrum" window to add an offline spectrum from file or an online spectrum from board

Set the device connection parameters. In this example the USB connection interface has been used.

Press **"Connect"** when ready. The device is then recognized by the software and a green line shows that the connection has been successfully established.

Then **"Close"** the **"Device Connection"** window.

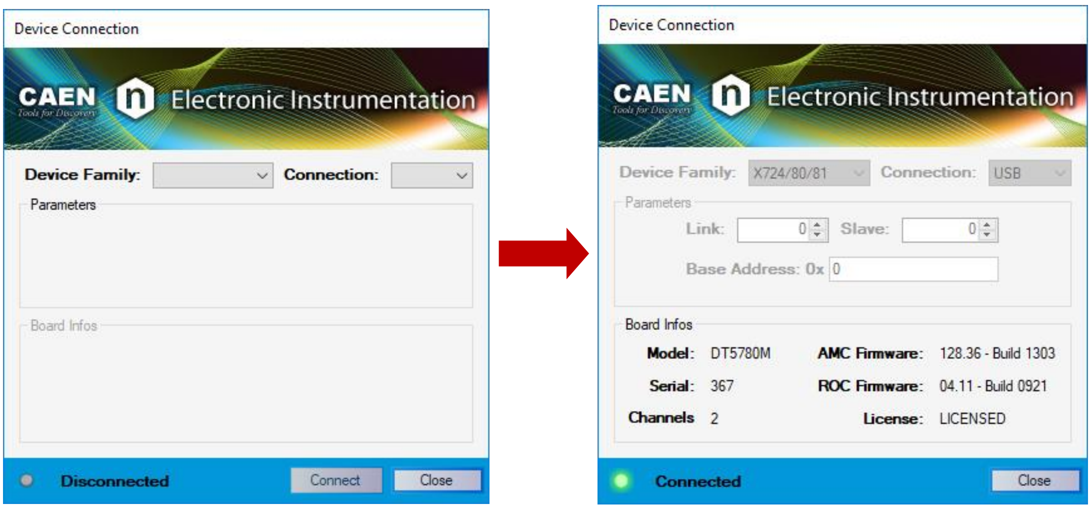


Fig. 3.13: "Device Connection" window. Once connected to the board the link becomes green

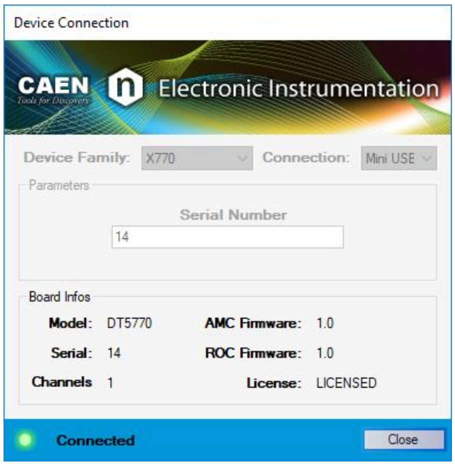
Select the **board channels** you want to enable to acquire the desired spetrum.

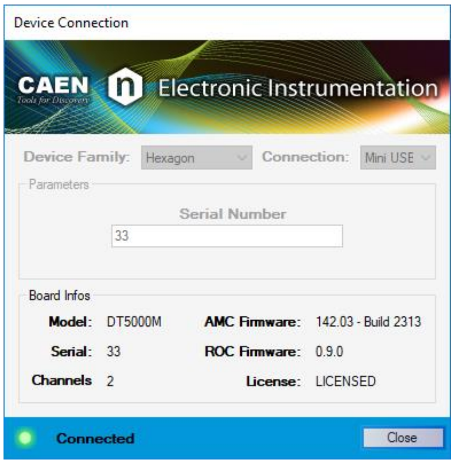
Press **"Done"** when ready.

Software connection to the DT5770 and Hexagon MCA

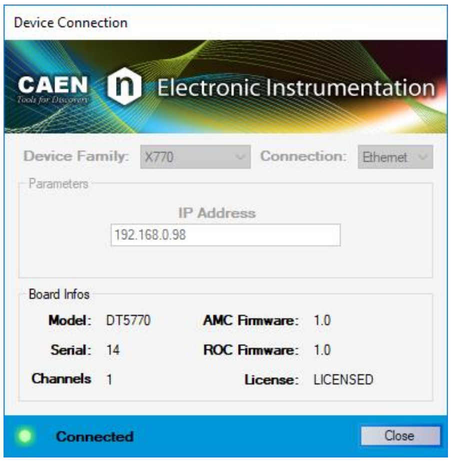
According to the preferred communication interface it is possible to connect to the MC²Analyzer software via:

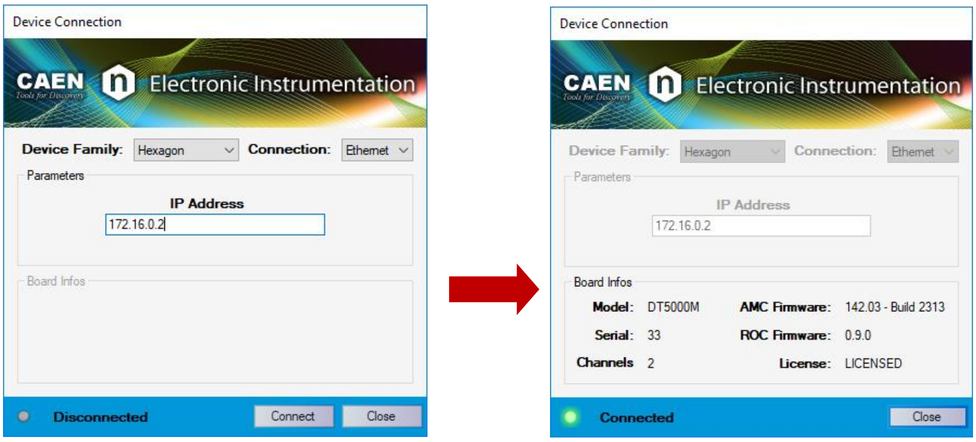
1. **Mini USB** interface. Select **Connection = MiniUSB**, and write the device serial number **S/N**, which is available on the bottom panel of the DT5770 and Hexagon. Press **Connect** when ready.





2. **Ethernet** interface. Select **Connection = Ethernet**, and write the device **IP Address = 192.168.0.98** for the DT5770 **and IP Address = 172.16.0.2** for Hexagon. Press **Connect** when ready. Refer to Sec. **Network configuration** to configure the network in the host PC.




Device Connection
CAEN
Electronic Instrumentation
Device Family: Hexagon
Connection: Ethernet
Parameters
IP Address
172.16.0.2
Board Infos
Disconnected
Connect
Close
Device Connection
CAEN
Electronic Instrumentation
Device Family: Hexagon
Connection: Ethernet
Parameters
IP Address
172.16.0.2
Board Infos
Model: DT5000M
AMC Firmware: 142.03 - Build 2313
Serial: 33
ROC Firmware: 0.9.0
Channels 2
License: LICENSED
Connected
Close

Channel selection and default GUI layout

From the “Add Spectrum” window select the channels for the acquisition

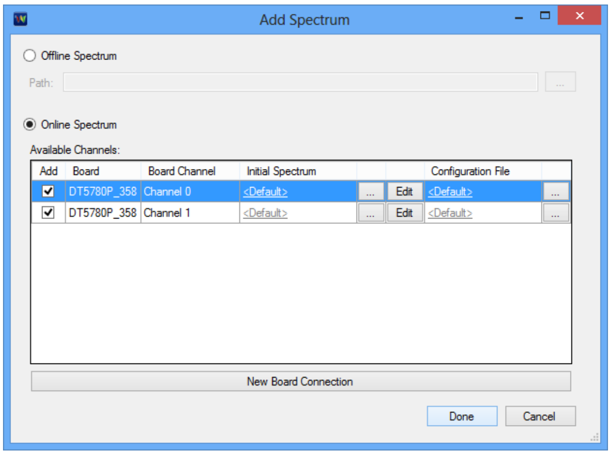


Fig. 3.14: this window allows to select the desired board channels for the acquisition

The default GUI interface will be then available.

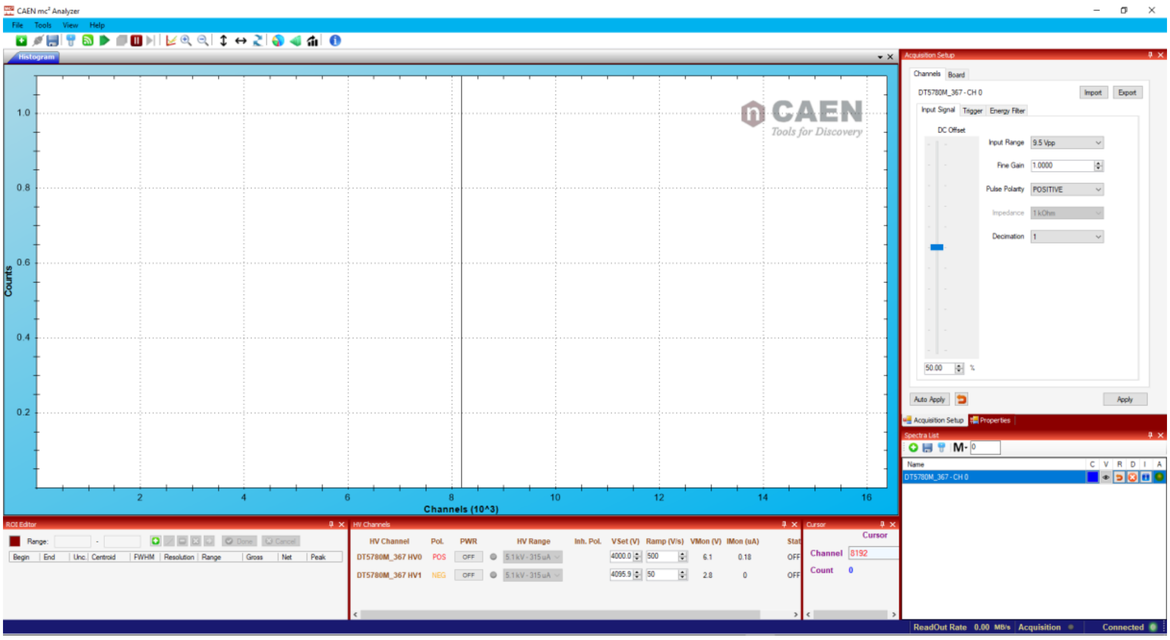


Fig. 3.15: the default GUI at the first connection

Note: In case of **Hexagon**, the MC²Analyzer software restores the latest configuration and adds the channels previously added. If the user wants to add the second channel he/she can use the “Add Spectrum” window.

How to power ON the high voltage (780 family and Hexagon only)

Note: MC²Analyzer software supports also *γstream* MCA tube-base. All the software functionalities for *γstream* are described in **[RD11]**.

Open the **"HV Channels"** window.

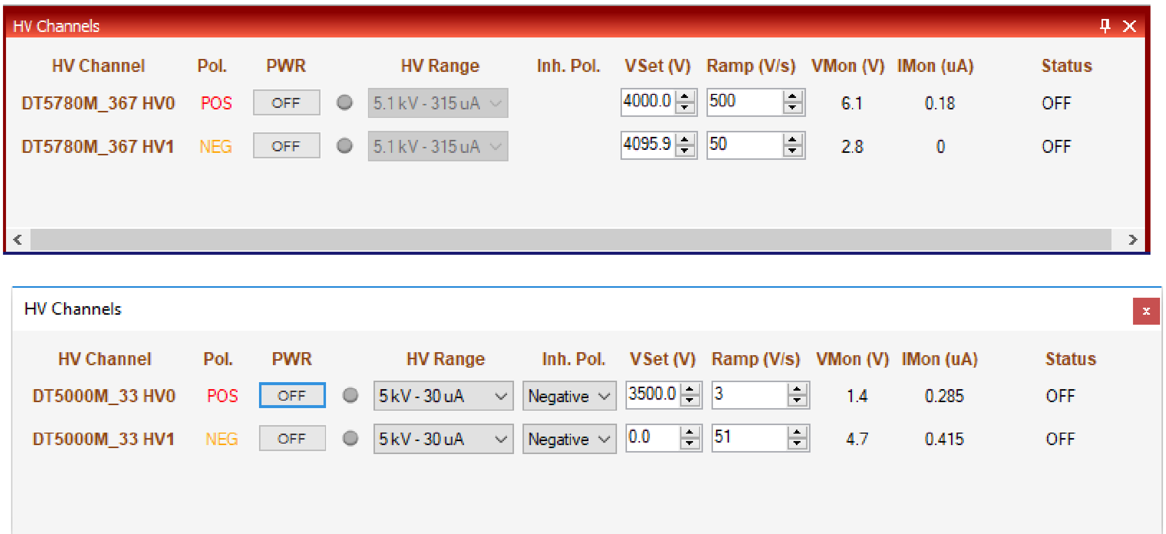


Fig. 3.16: "HV Channels" window for the setting and monitoring of the HV channels of the DT5780 (top) and Hexagon (bottom)

Set the desired High Voltage value **VSET** according to your detector specifications.

Set the desired **HV Range** (Hexagon only).

Set the required Inhibit Polarity (**Inh. Pol.**) according to the detector specifications (Hexagon only).

Select the proper value for the Ramp corresponding to the value of V/sec of voltage ramp.

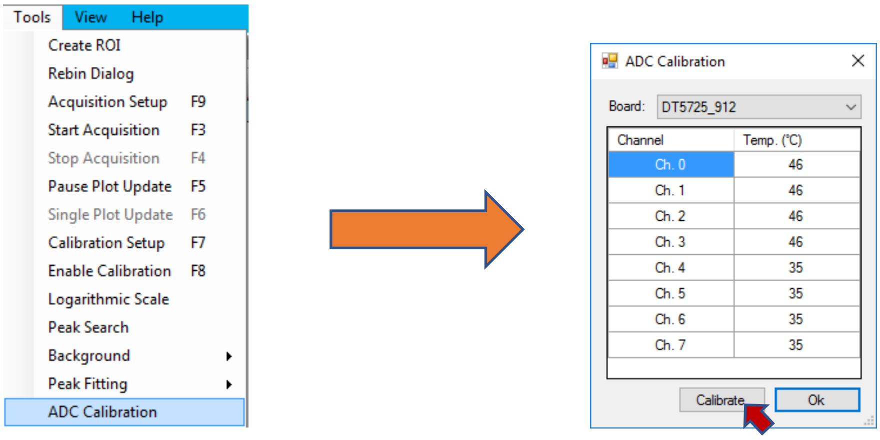
Press **ON** when ready and the check the HV status from the **VMON**, **IMON** and **STATUS** flags.

Note: The **HV remains ON** even if the user disconnects the software from the digitizer. When connected again the software automatically reloads the last HV settings.

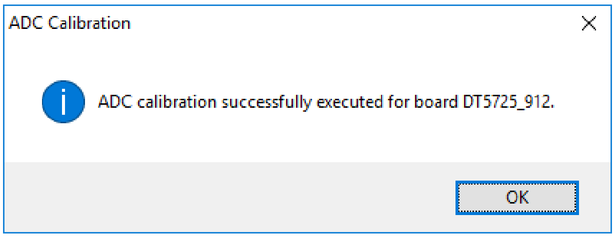
ADC Calibration (725 and 730 series only)

In case of 725 and 730 series it is required to perform the ADC calibration before starting the acquisition. The board already performs a calibration at power-on, anyway the ADC is very sensitive to the temperature variations, and the calibration must be performed again by the user once the temperature gets stabilized.

From the **Tools** menu select **"ADC Calibration"**



A window with the ADC temperature for each channel will appear. Monitor the temperature, and once it is stable press "**Calibrate**". A successful pop-up message will appear.



Before starting the acquisition

It is **very important** to check the preamplifier output in an **oscilloscope** device before feeding the pre-amplified signal into the digitizer input. The user must check that:

- there are no grounding loops;
- the preamplifier output dynamics is not saturated.

In the unlikely event one of the above conditions is found the user must take care of the proper work around.

How to configure the channel settings

The correct configuration of the channel settings allows to reach very precise resolutions in spectroscopy measurement. For this reason, it is very important to set them properly. This section will guide the user throughout the settings configuration. The first step is to enable the “Signal Inspector” window to check the effects of the setting modifications on the digital filters.

Open the Signal Inspector window

To open the **“Signal Inspector”** window press the button in the icon bar.

Look at the displayed note. Then press **“Continue”**.

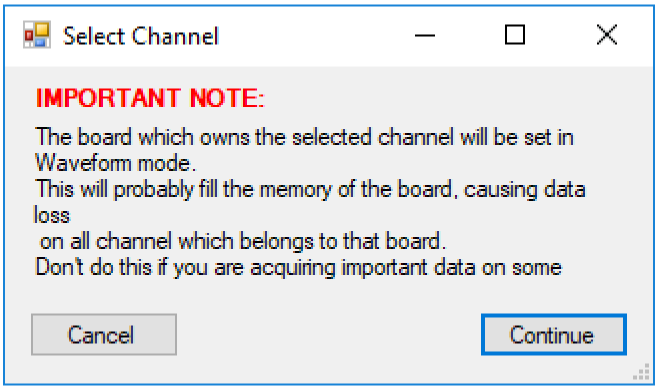


Fig. 3.17: “Select Channel” window note.

It is possible to visualize a set of analog and digital traces.

Start with the visualization of:

- “Input” as “Analog Trace 1”
- “Trapezoid-Baseline” as “Analog Trace 2”
- “Peaking” as “Digital Trace 1”
- “Trigger” as “Digital Trace 2”

Note: Any time you change one setting always press **“Apply”** to apply the setting. Otherwise press **“Auto Apply”** once for automatically applying the changes.

Note: “Gain” and **“Offset”** of the **“Digital Traces”** affect only the traces visualization, while have no impact in the internal board filters.

Note: move the **“Waveform and Pre-Trigger Length”** slider to increase or decrease the waveform visualization length.

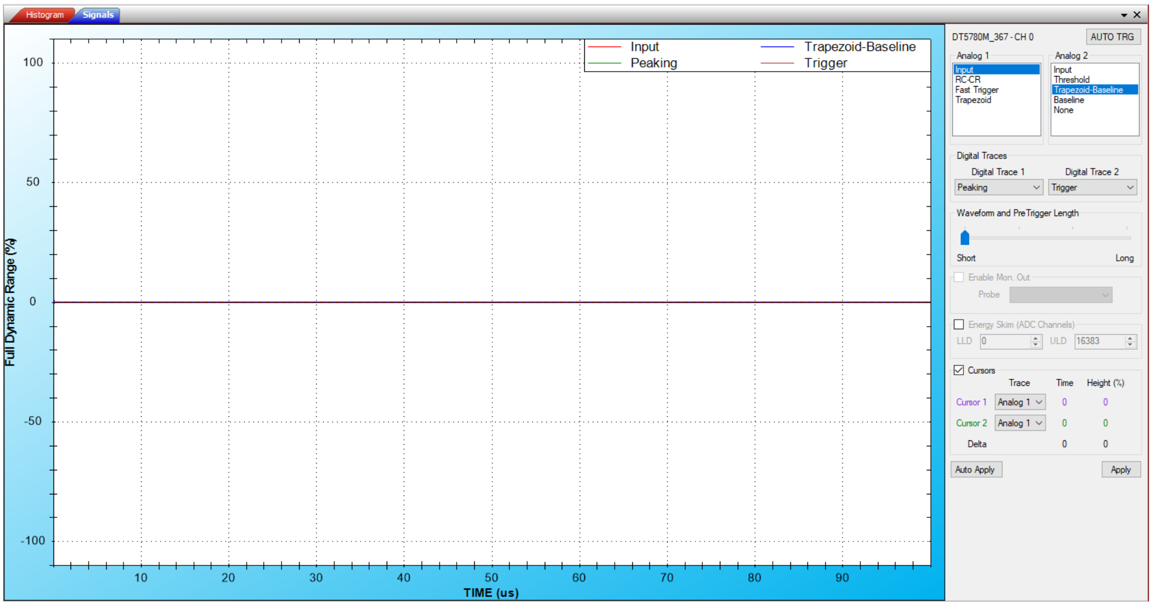


Fig. 3.18: default signal inspector graphical interface

Press PLAY to start the waveforms visualization.

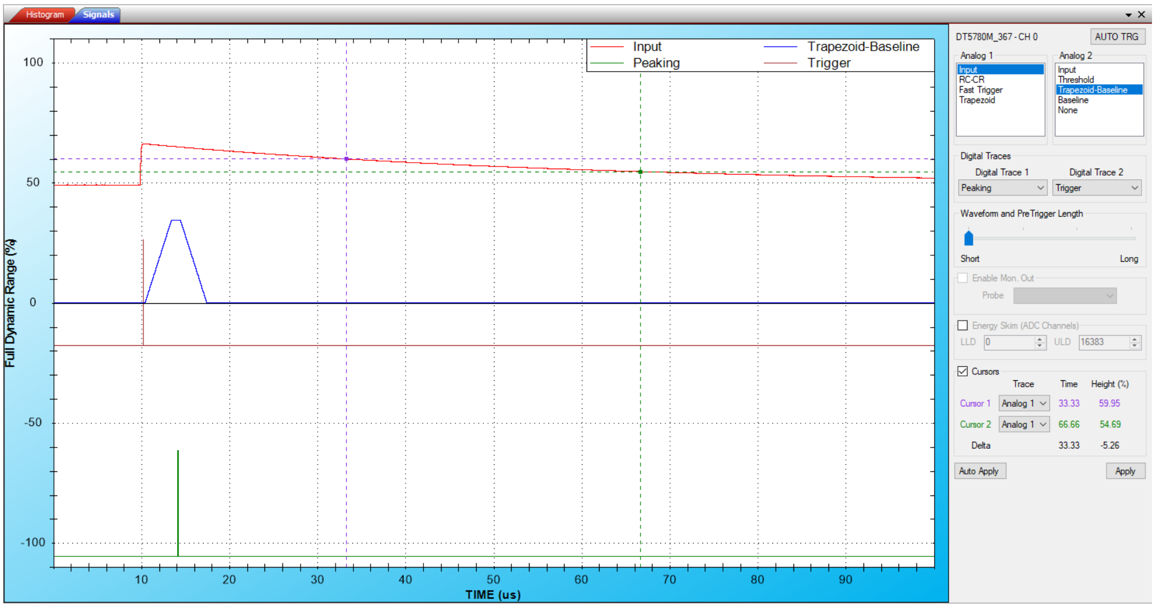


Fig. 3.19: signal inspector visualization of Input, Trapezoid-Baseline, Peaking and Trigger traces

Note: In case you don't see any signal press **"AUTO TRG"** to enable the software-trigger. The software will force the board to trigger the events. Then adjust the channel settings as described in the following sections. Once the parameters are correctly set release the AUTO button to disable the software-trigger.

Adjust the record length for a better visualization.

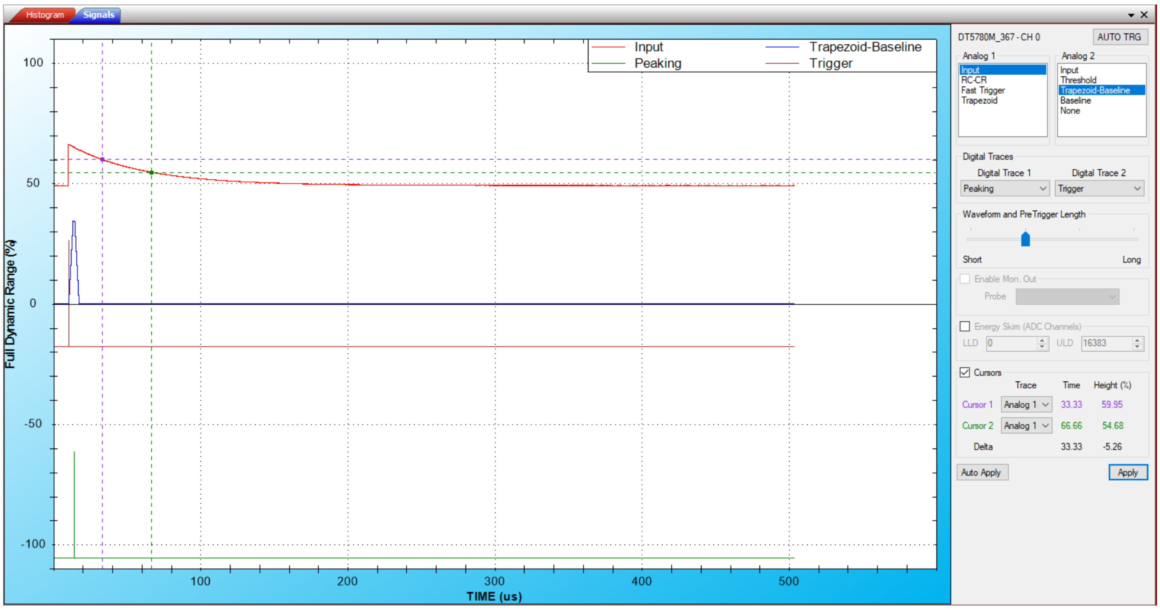
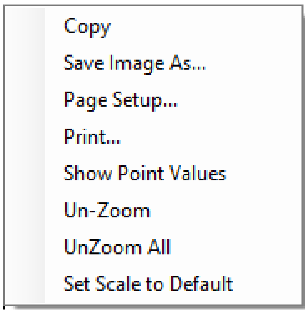


Fig. 3.20: modification of the "Waveform and Pre-Trigger Length" slider for a better visualization of the waveforms

Drag and release to **zoom in** a region of the plot.
Right click and select **"Un-zoom"** or **"Un-zoom all"** to zoom out.



How to configure the Input Signal settings

The first settings to be configure are those related to the Input Signal.

1. Open the **"Acquisition Setup"** window, either from the button or from **"Tools -> Acquisition Setup"**.

The channels for which settings are going to be modified is automatically selected according to the currently active spectrum selected in the **Spectra List** window. The channel is identified by label *Digitizer Family_Serial Number – CH n* **"DT5780M_367 – CH0"** in the current example. The input signal settings are in the first tab **"Input Signal"**.

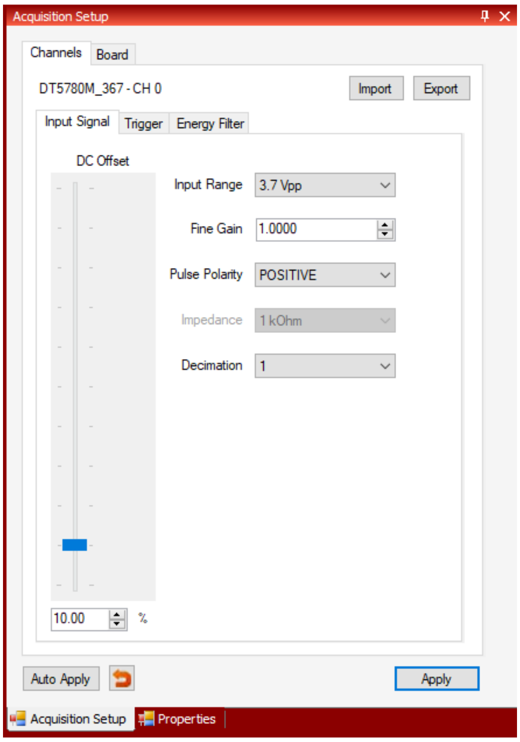


Fig. 3.21: The Acquisition Set Up Window – Channels Tab – Input Signal Tab

2. Using the measurement of the pre-amplified pulses from an oscilloscope device (refer to Sec. **Before starting the acquisition**) it is possible to check what is the pulse height range.

It is important to select the proper **"Input Range"/"Coarse Gain"**, which corresponds to the input dynamic range of the digitizer/MCA in order to get all the pulses, even in pile-up. Possible choices are 0.6, 1.4, 3.7, 9 Vpp for x780 (0.3, 1, 3, and 10Vpp for x781; 0.5, 2 Vpp for 725 and 730 family; 1.25, 2.5, 5 and 10 Vpp for the DT5770; x0.25, x0.5, x1, …, x256 for Hexagon, x1, x2, x4, x8 for the V1782, not available for 724 digitizer family). The correct setting of the Input Range/Coarse Gain is a compromise between the digitizer/MCA dynamics saturation and the use of too few channels of the spectrum. The input range corresponds to the *Coarse Gain* of the analog chain.

In our example we choose the 9.5 Vpp.

3. Keep the **"Fine Gain"** value to one. It can be adjusted later to move the spectrum peaks to the desired position.
4. Select the input **"Pulse Polarity"** choosing among **"Positive"** and **"Negative"**. Since the algorithm works with positive pulses only, by setting "Negative" the algorithm will invert the digital samples of the input.

5. Adjust the **"DC Offset"** to have the input signal baseline around **1000 LSB** counts. You can safely go below this value, only check that the input does not saturate around 0. In that case the algorithm stops any calculation and increases the dead-time. It is also important to check that the signal does not saturate in the upper limit of the dynamics (16k LSB). In our example we set DC Offset = 90%.

The result of these settings is shown in the following figure.

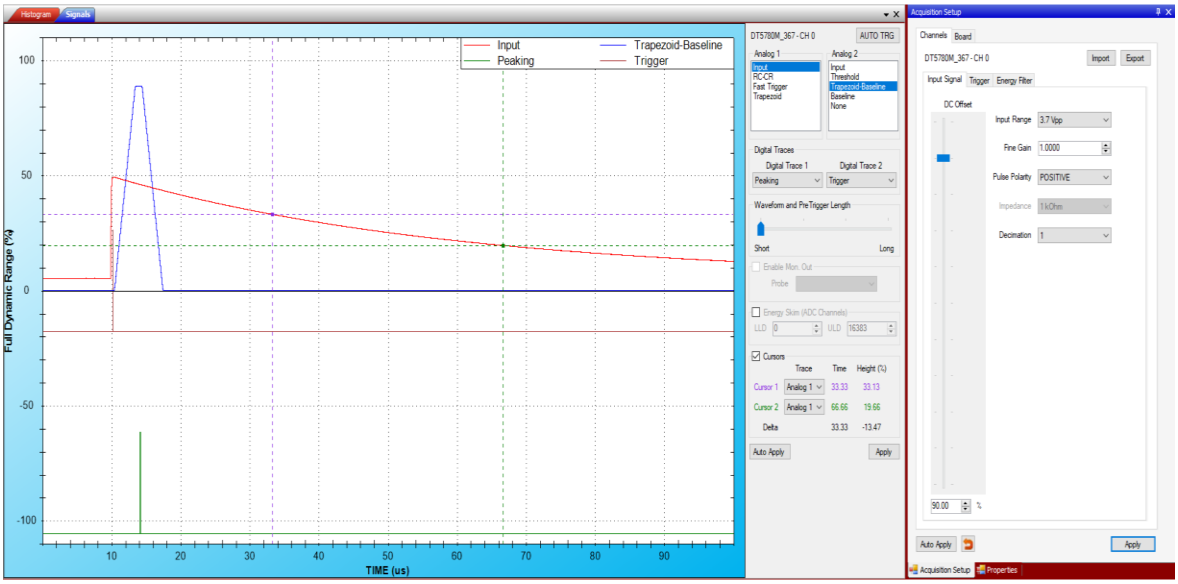


Fig. 3.22: "Input Signal" settings and corresponding effect on the signal inspector window

How to set the Trigger

Since the trigger fires at the zero-crossing of the RC-CR^2 signal (refer to Sec. **Trigger and Timing Filter** for further details) first enable the visualization of the:

- "Fast Trigger" as "Analog Trace 1"
- "Input" as "Analog Trace 2"

Select the tab "Trigger" from the "Acquisition Setup" window.

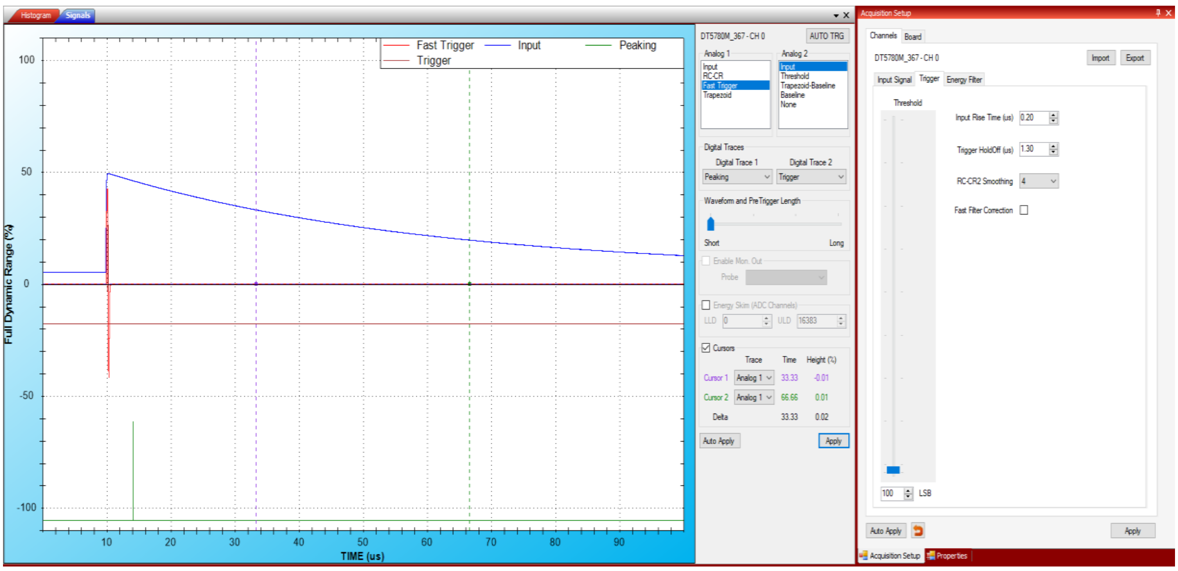


Fig. 3.23: "Trigger" tab settings and the visualization of the RC-CR2 settings and corresponding effect on the signal inspector window

1. Start by setting the **"RC-CR^2 Smoothing"** factor to **16**. All the other settings have to be tuned according to the smoothing factor (i.e. once you change this value you have to repeat the whole procedure described in this section).
2. Set the **"Input Rise Time"** value (see Sec. **Trigger and Timing Filter** and **Acquisition Setup** for further details) to have the same height of RC-CR^2 signal and the input pulse. Try to avoid cases where the "Input Rise Time" is too short (the RC-CR^2 height will be less than the input) and where the "Input Rise Time" is too long, which are represented in the following figure. On the left the value is underestimated, on the right it is overestimated.

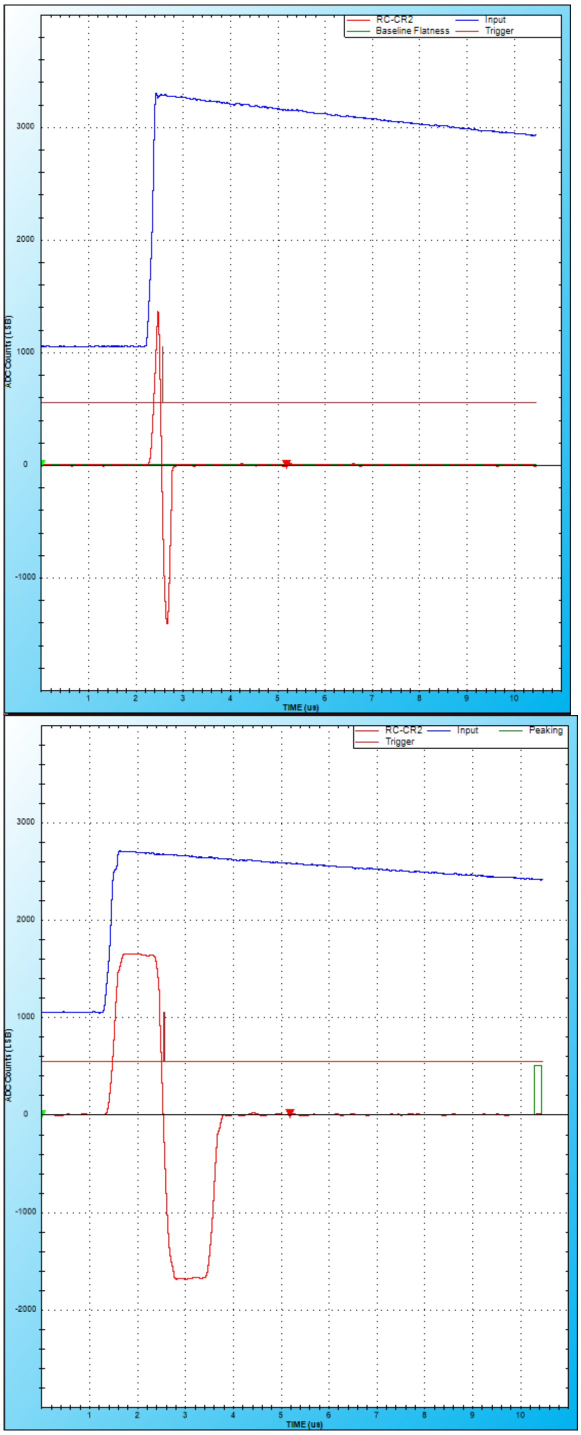


Fig. 3.24: two examples where the "Input Rise Time" is not correctly set. In the left the value is underestimated, on the right it is overestimated

The correct value for our example is **0.3 us**.

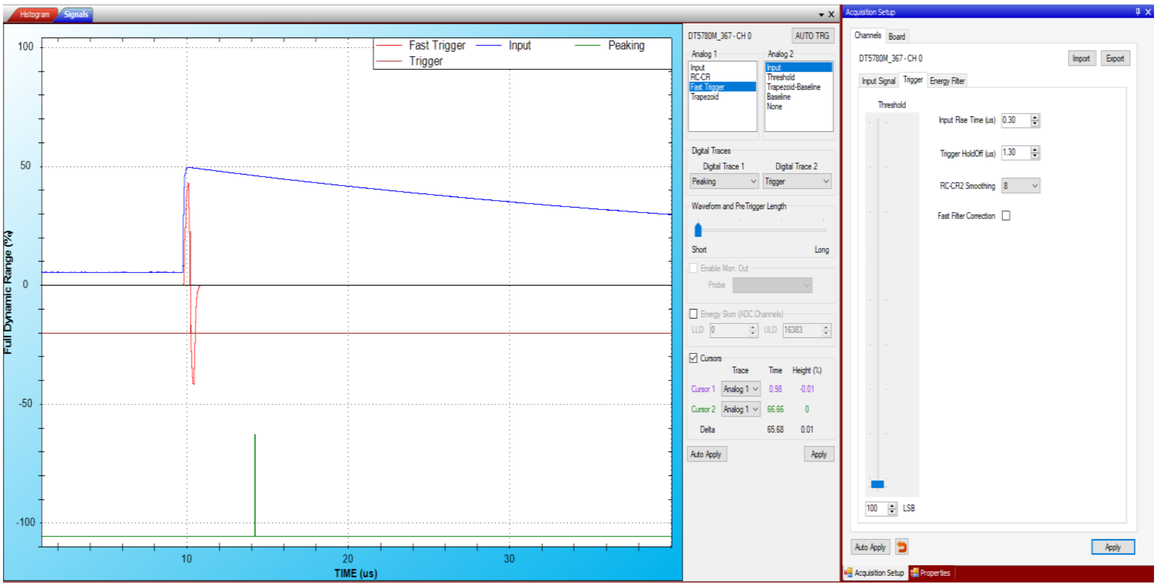


Fig. 3.25: Set the Input Rise time to have the same pulse height of the input signal and the RC-CR² signal

3. In case the RC-CR² shows an overshoot (see **Fig. 3.26**), set the **"Trigger Hold-Off"** value as long enough to eventually include the overshot inside it. The algorithm then inhibits any trigger occurring during the whole "Trigger Hold-Off" duration.

Check the correct value by enabling the visualization of the "Trigger Hold-Off" as "Digital Trace 1".

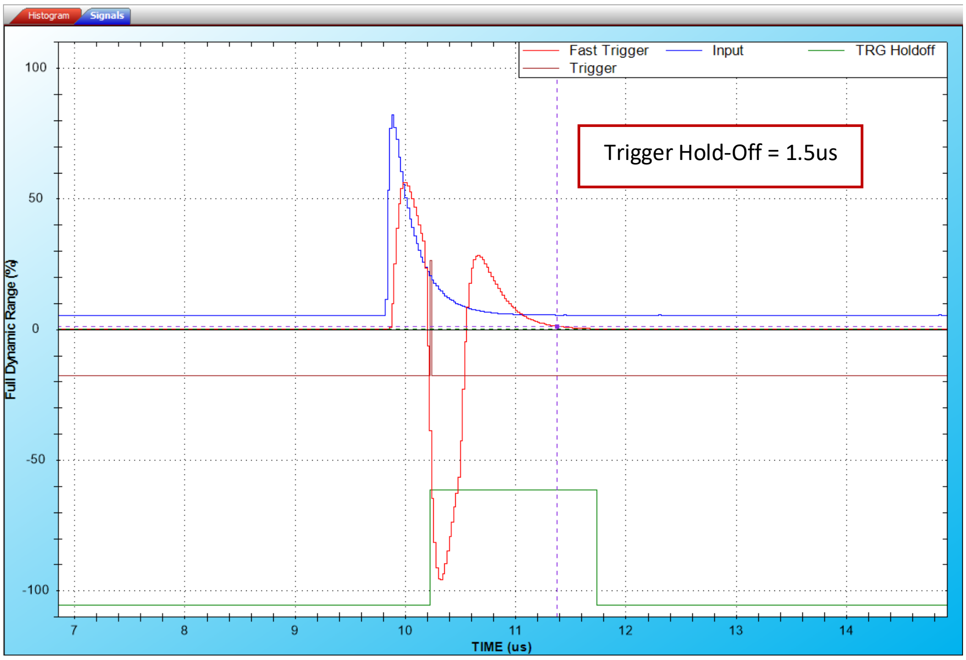


Fig. 3.26: RC-CR² signal with an overshoot. Set the Trigger Hold-Off to cover the overshoot and avoid re-triggering

In case there is no overshoot set the minimum value of Trigger Hold-Off to cover the RC-CR² signal.

In our example, we set **0.7 us**.

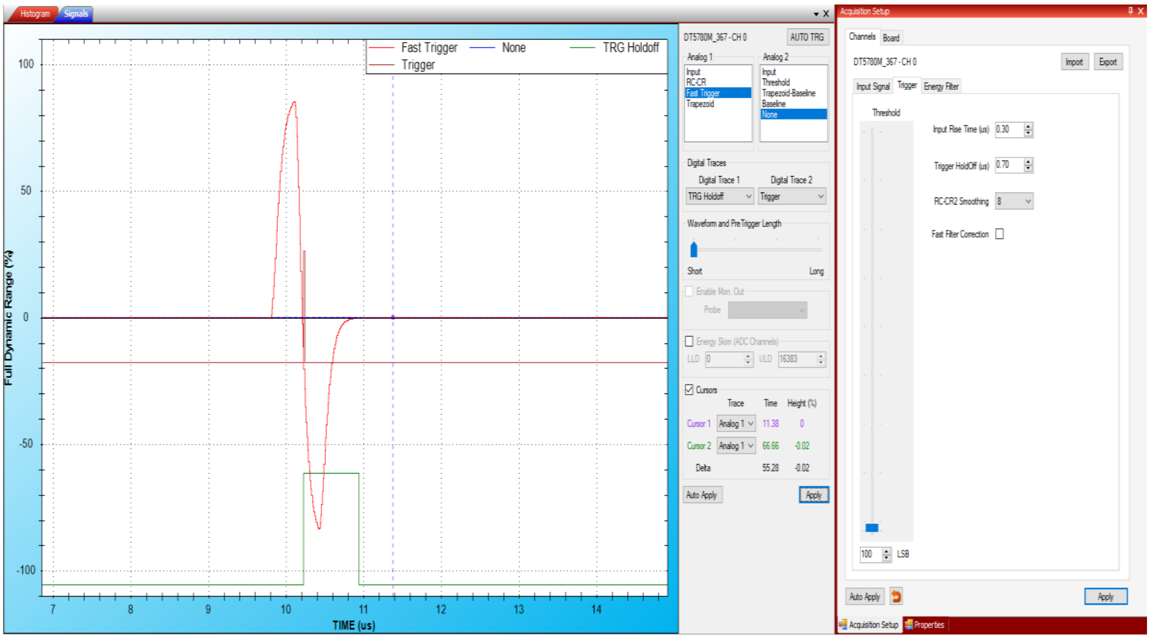
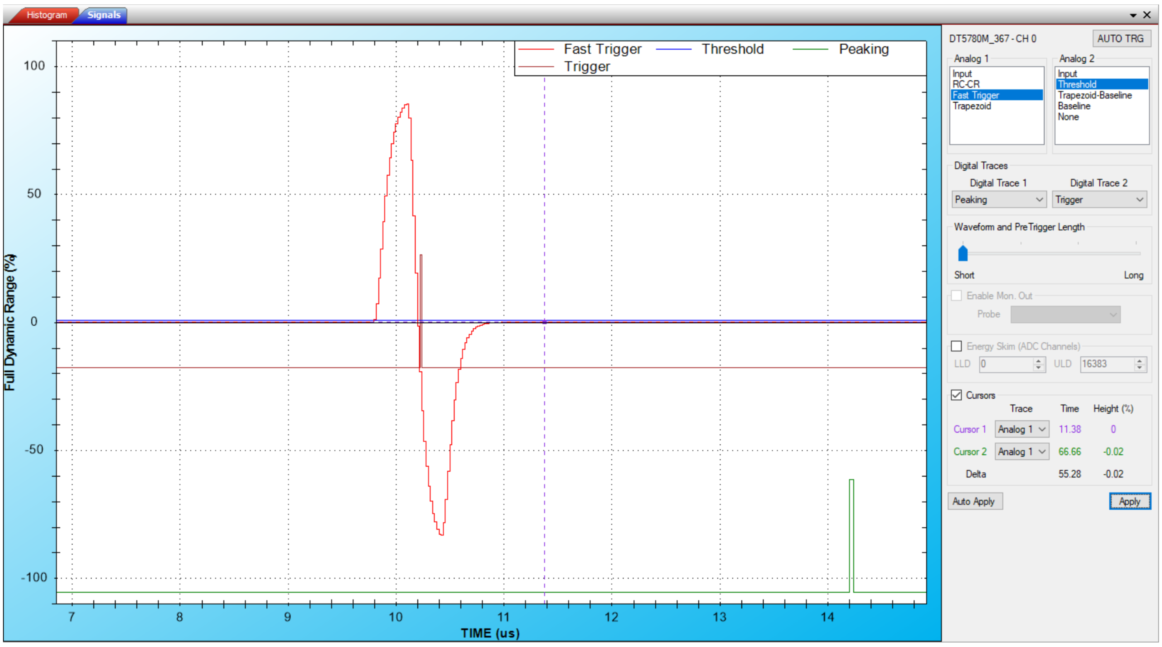
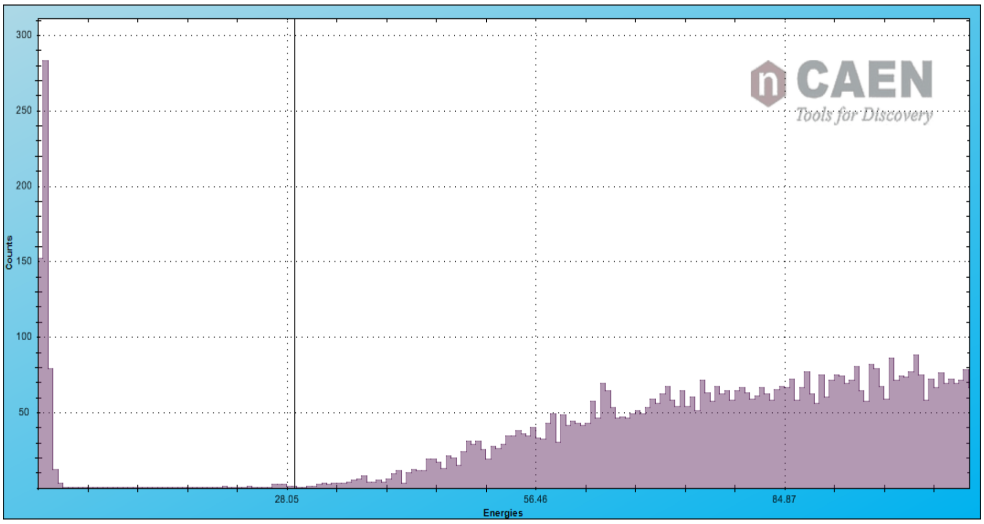


Fig. 3.27: RC-CR² signal with no overshoot. Set the Trigger Hold-Off to cover the RC-CR² signal width

4. Set the **"Threshold"** value to avoid the noise level of the RC-CR² signal. You can visualize the "Threshold" Analog trace on the Signal Inspector Window.

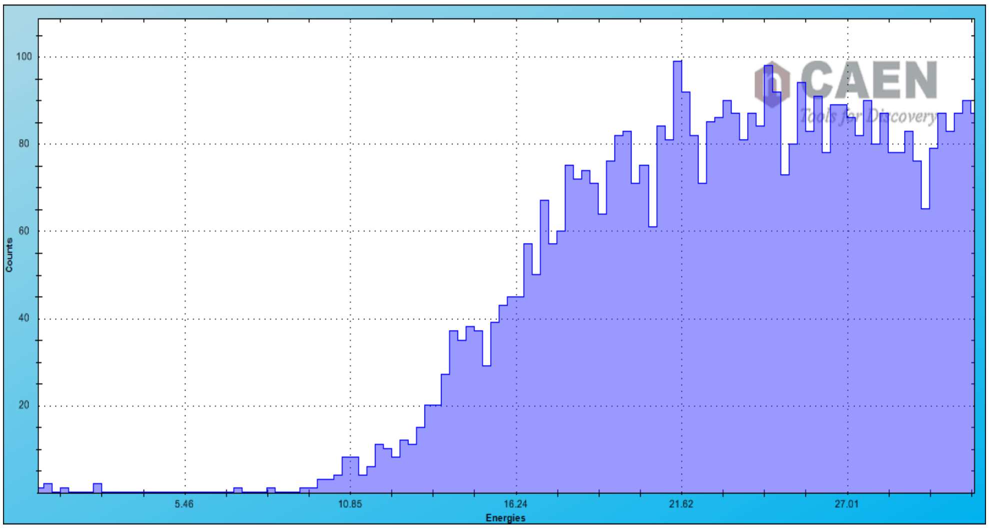


To correctly set the Threshold value, switch to the **"Histogram"** window. Zoom in in the lowest region of the spectrum and reduce the threshold level until you get a peak close to zero. You are now triggering below the noise level. Set then a value slightly higher to trigger on real pulses.



Note: According to the detector / pre-amplifier conditions it is possible to have particularly noisy input signals. In this case the *lower region of the spectrum is cut off*. To overcome this issue set a greater value of RC-CR^2 smoothing to use a greater number of sample for the RC-CR^2 signal. In this way high frequency noise will be significantly reduced. Remember to adjust again the Input Rise Time and Trigger Hold-off in case you change the smoothing factor.

In our example, we can reach up to about 10 keV.



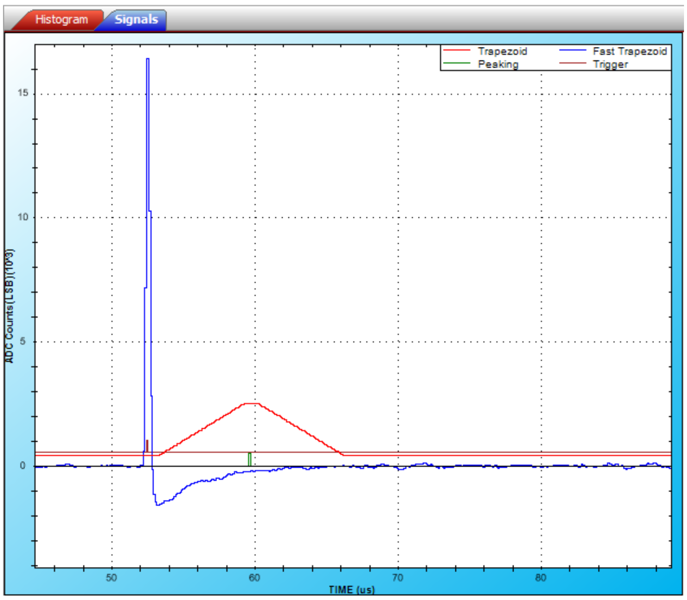
How to set the Trigger filter (DT5770 only)

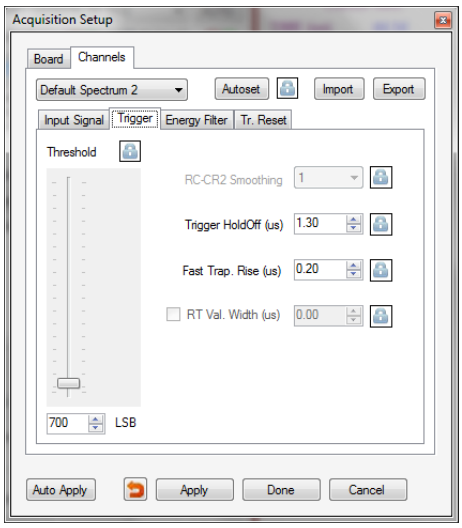
The trigger on DT5770 fires on the zero crossing of the fast trapezoid derivative (refer to Sec. **Trigger and Timing Filter for DT5770** for further details). Since it is not possible to see the derivative, just enable the visualization of the fast trapezoid:

- "Input" as "Analog Trace 1"
- "Fast Trapezoid" as "Analog Trace 2"

Select the tab "Trigger" from the "Acquisition Setup" window.

Note: The fast trapezoid uses the same decay time of the trapezoid. Carefully check that the decay time is correctly set, otherwise the fast trapezoid is not correctly shaped and the board does not acquire events.





Choose the desired value of **"Fast Trapezoid Rise Time"** from a range of 10 ns up to 300 ns.

Set the **Threshold** value to avoid the noise level of the fast trapezoid itself and arm the trigger filter. The trigger will fire on the derivative signal of the fast trapezoid.

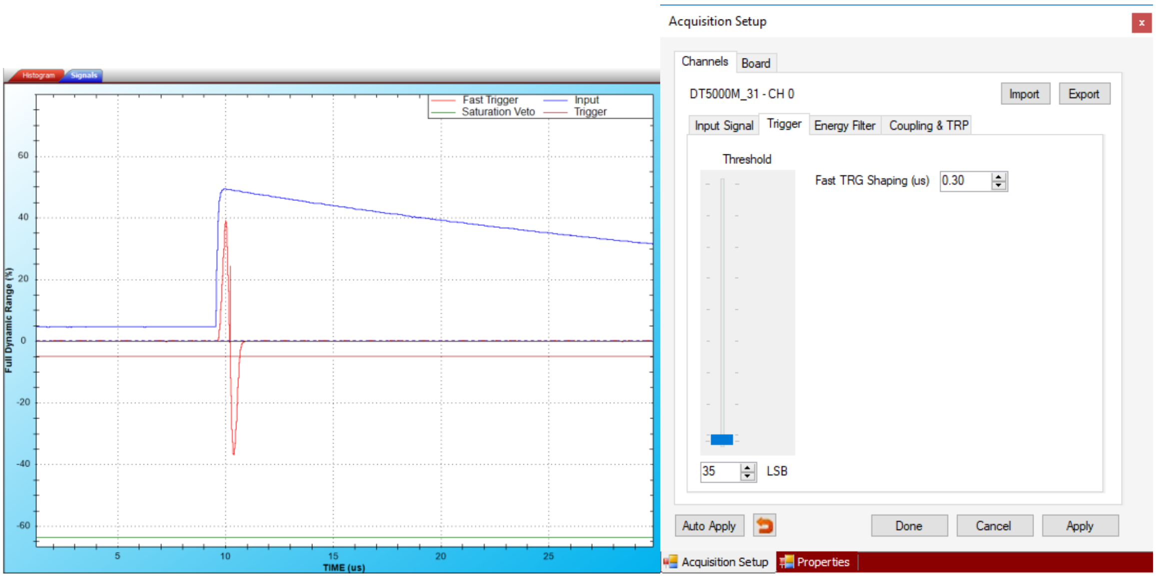
It is also possible to set a **Trigger Hold-Off**. Triggers occurring during the Trigger Hold-Off duration are inhibited.

How to set the Trigger filter (Hexagon only)

The trigger on Hexagon fires on the zero crossing of the triangle derivative (refer to Sec. **Trigger and Timing Filter for Hexagon** for further details). The user can see the derivative trace just enabling the visualization of the fast trigger:

- “Input” as “Analog Trace 2”
- “Fast Trigger” as “Analog Trace 1”

Select the tab “Trigger” from the “Acquisition Setup” window.



Choose the desired value of **“Fast TRG Shaping”** from a range of 0.01 to 2.4 µs.

Set the **Threshold** value to avoid the noise level of the fast trigger itself and arm the trigger filter. The trigger will fire on the derivative signal of the fast trapezoid.

How to set the Energy Filter

The precise configuration of the Energy Filter strongly affects the final resolution measurement; therefore it is very important to fine tuning the Energy Filter settings. The user must take care of:

- Checking that the trapezoid is correctly shaped;
- Evaluating the energy value (see the Peaking trace) in the flat top region of the trapezoid.

The two typical measurement setups that we are going to discuss are:

1. Low rate (up to few hundreds of Hz) and very high precision measurement;
2. High rate (up to tens of kHz), where the result is a compromise between high resolution and dead-time.

Before starting, set an approximate value of **“Decay Time”**. The fine tuning of this parameter is described in section **Pole-Zero Adjustment**.

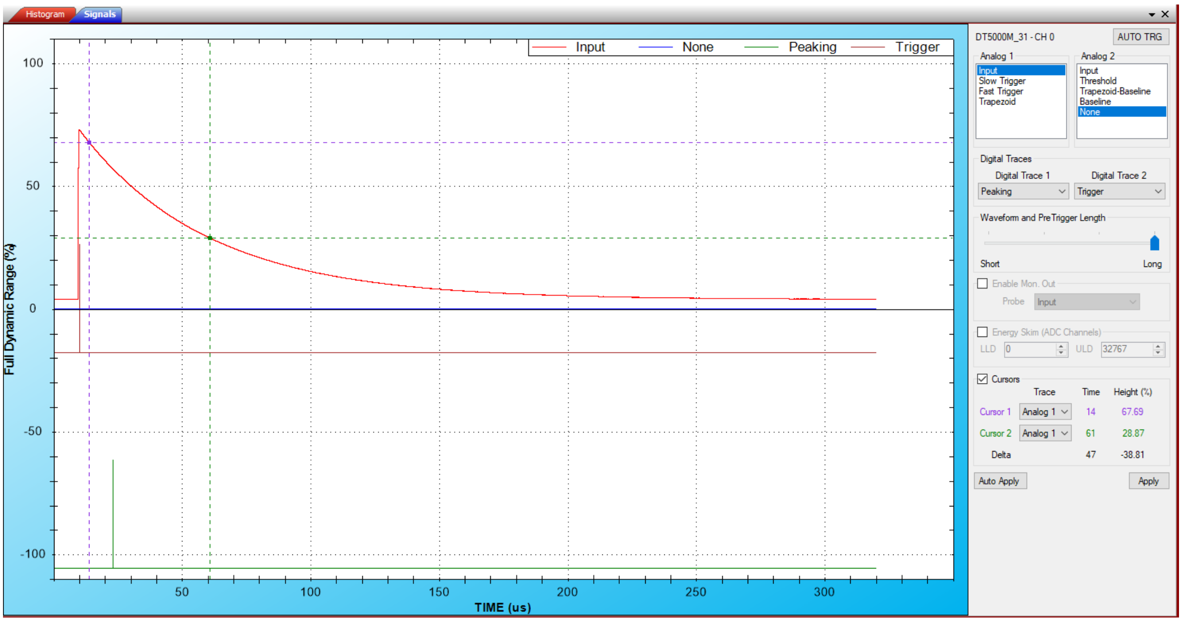
To evaluate the decay time value the user can enable the “Input” visualization from “Analog Trace 1”, and measure the input *half-time* using the “Signal Inspector Cursors”. From the half time it is possible to calculate the decay time according to the formula: $T_{1/2} = \ln(2)\ \tau$, where $T_{1/2}$ is the half time, and τ is the decay time.

The cursors are automatically displayed on the Signal Inspector window

Left click to point the **violet cursor**.

Press the “Shift” key and left click to point the **green cursor**.

Check the corresponding cursor values and their difference in the “Cursor” section. In the same section the user can also select at which trace (analog or digital) the cursors have to be applied.



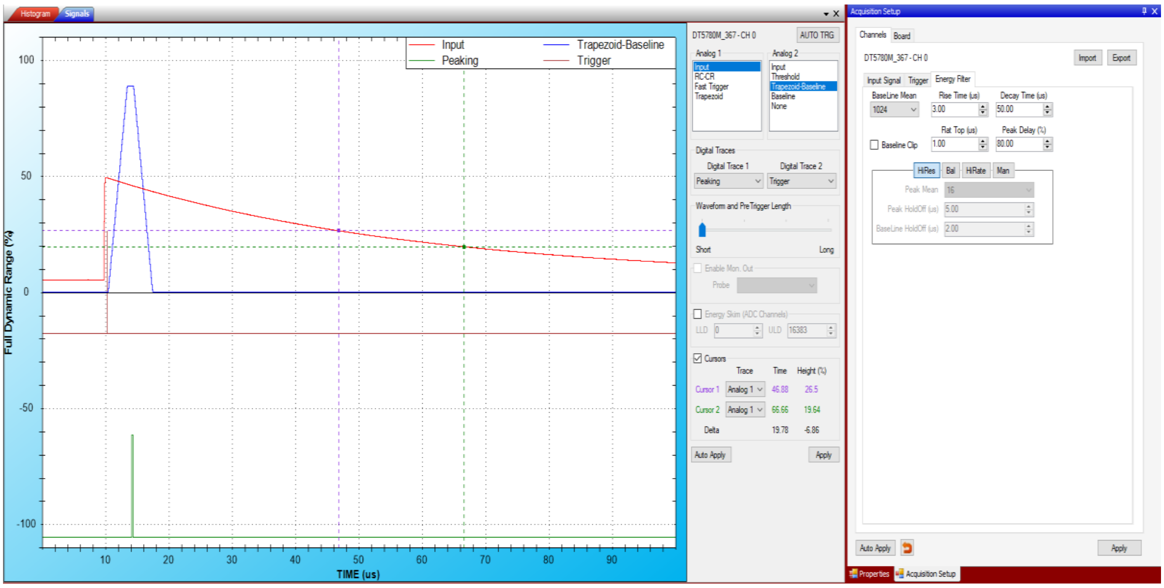
Select now:

- "Input" as "Analog Trace 1"
- "Trapezoid-Baseline" as "Analog Trace 2"
- "Peaking" as "Digital Trace 1"
- "Trigger" as Digital Trace 2

Note: The baseline of "Trapezoid - Baseline" trace should be at 0.

1. In the *low rate case* it is recommended to set a high value of **"Trapezoid Rise Time"**, as for example **8 us**. Considering it in the analogy of the analog chain (refer to Chapter **Principle of Operation)** it corresponds to about 3 us of shaping time.
   Then set a value of **"Trapezoid Flat Top"** between **1-2 us**, only check that the flat top region is really flat.
   Adjust – if necessary – the Peaking position (**"Peak Delay"**) and the number of samples (**"Peak. Mean"**) for the energy mean calculation.
   Finally for very low rate set the maximum value of **"Baseline Mean"** (i.e. the number of samples for the baseline calculation), i.e. 16K.

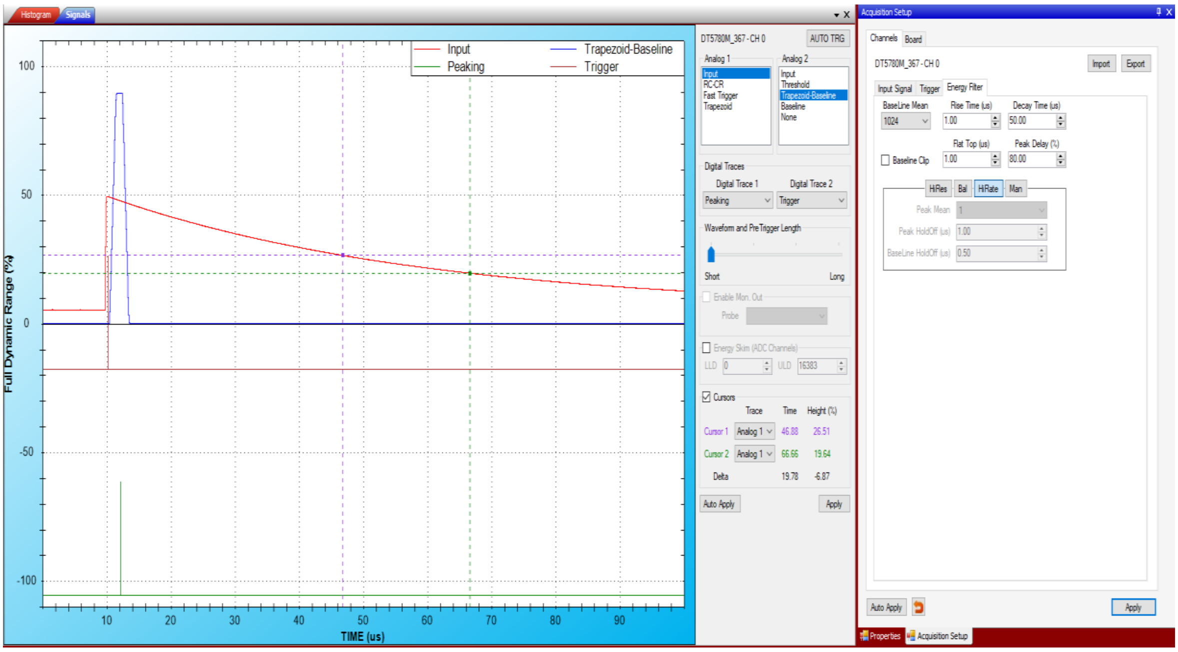
   You can either choose the preset **"HiRes"** for high resolution settings, or the **"Man"**. For high resolution measurement it is strongly recommended to set the maximum value of **"Baseline Hold-Off"**



Note: The Trapezoid Rise Time and Flat Top Time have a maximum value of about 10 us. In any case their sum should not exceed 15 us for x724, DT5780 and x781 if the firmware release is <128.64.
In case of **x730** the sum of Trapezoid Rise Time and Flat Top Time should not exceed 8 us. Suggested settings for x730 are **7 us of Rise Time** and **1 us of Flat Top**.
In case of **Hexagon** Trapezoid Rise Time and Flat Top Time have a maximum value of about 40.95 and 20.47 us. The same holds for x724, DT5780, x781, and x782 if the firmware release is >128.64.

1. In the *high rate case* (tens of kHz) it is recommended to set a lower value of **"Trapezoid Rise Time"**, as for example **3-4 us**. For a rate greater than 20 kHz it might be convenient to set **"Trapezoid Rise Time" = 1 us**.
   Set also **"Trapezoid Flat Top" = 1 us**, only check that the flat top region is really flat.
   Adjust – if necessary – the Peaking position (**"Peak Delay"**) and the number of samples (**"Peak. Mean"**) for the energy mean calculation in the flat region.
   Finally decrease the value of **"Baseline Mean"** (i.e. the number of samples for the baseline calculation). A dedicated study of the impact of the Baseline Mean in the final resolution can be made.

   You can either choose the preset **"HiRate"** for high rate settings, or the **"Man"** settings for manual adjustments.

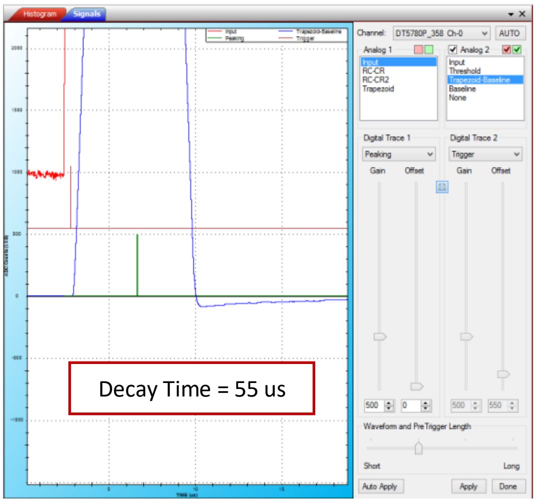


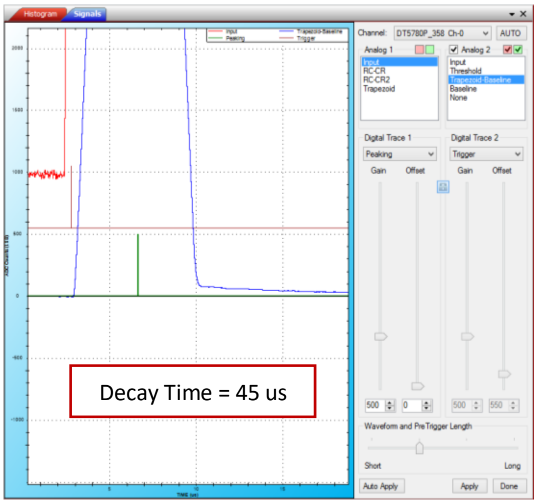
Both in case of low rate and high rate it is very *important* to have a flat “Flat Top” region. The **“Peaking”**, which corresponds to the samples where the pulse energy is evaluated, should be taken in the flat region. Adjust the **“Peak Delay”** and the **“Peak Mean”** values accordingly.

Pole-Zero Adjustment

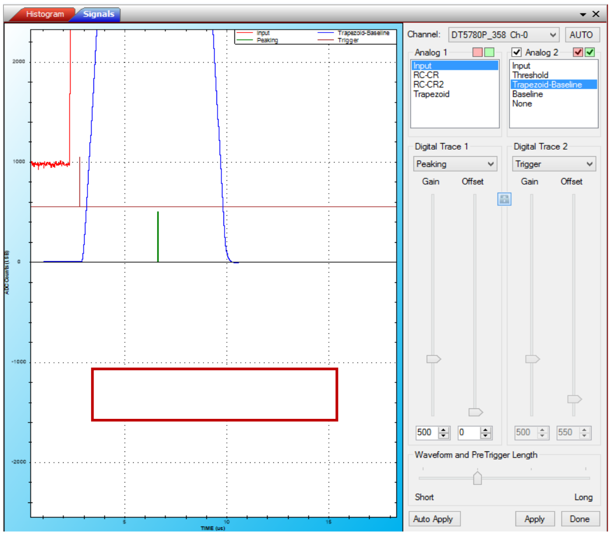
The pole-zero adjustment is very important for a correct evaluation of the trapezoid baseline and consequently for a correct evaluation of the energy value.

The user must adjust the **"Decay Time"** according to the Pre-Amplifier decay time. Fine adjustments can be done looking at the zoom of the Trapezoid trace (or Trapezoid-Baseline) in order to have no undershoot nor overshoot. The two cases are shown in the following figure, where on the left the Decay Time has been set too high giving an undershoot, and on the right the Decay Time has been set too low thus giving an overshoot.





When the Pole-Zero is correctly compensated, the Trapezoid will not make any overshoot nor undershoot.

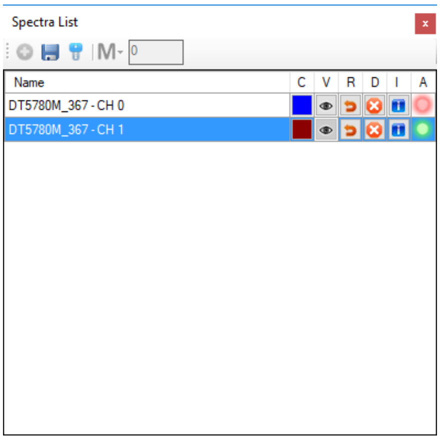


Start/Stop the acquisition

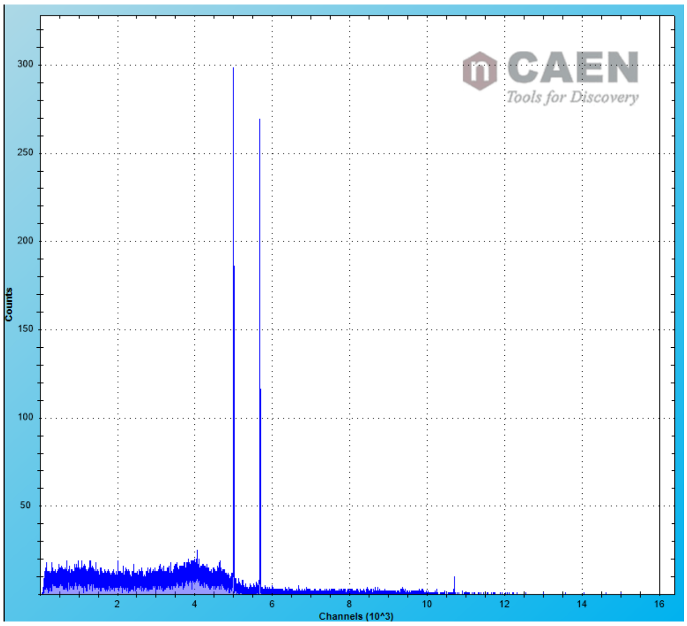
Once you have configured the acquisition, close the **"Signal Inspector"** Window.

Select **"Default Spectrum"** from the **"Spectra list"** window. Click **"R"** to reset all spectra, or to reset the single spectrum.

Then press PLAY to start the acquisition, STOP to stop it. When you select them from the Spectra List window you start/stop only the selected spectrum. If you select them from the main GUI you start/stop all channels.

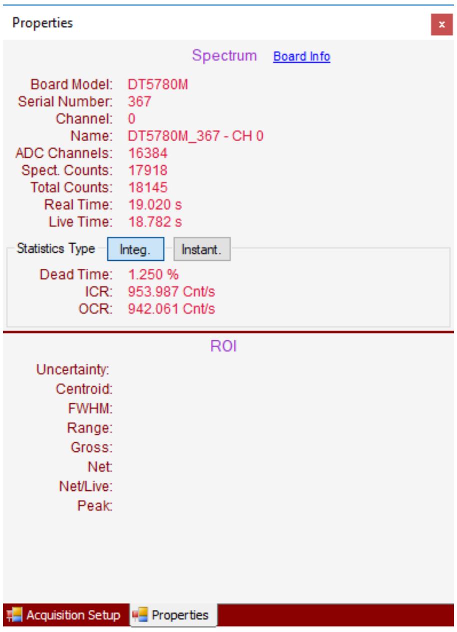


Note: The circle under "A" becomes RED in case of dynamics saturation or busy of the data throughput. Refer to Sec. **Troubleshooting** to reduce this effect.



Enable the **"log scale"** if needed , and the **"vertical auto-scale"**

Check the spectrum properties from the **“Properties”** window:



How to calibrate a spectrum

The software allows the user to calibrate a spectrum from counts to keV using two interpolating functions: Linear and Quadratic. For the first function the user must define at least a couple of values, while for the second the user must define at least three values. It is also possible to define more points; the algorithm will then compute the best fit of the defined points. For more details about the energy calibration refer to Sec. **MC2Analyzer Energy Calibration**.

The user can select a Region of Interest (ROI) of the spectrum and take the mean value of the distribution for the energy calibration.

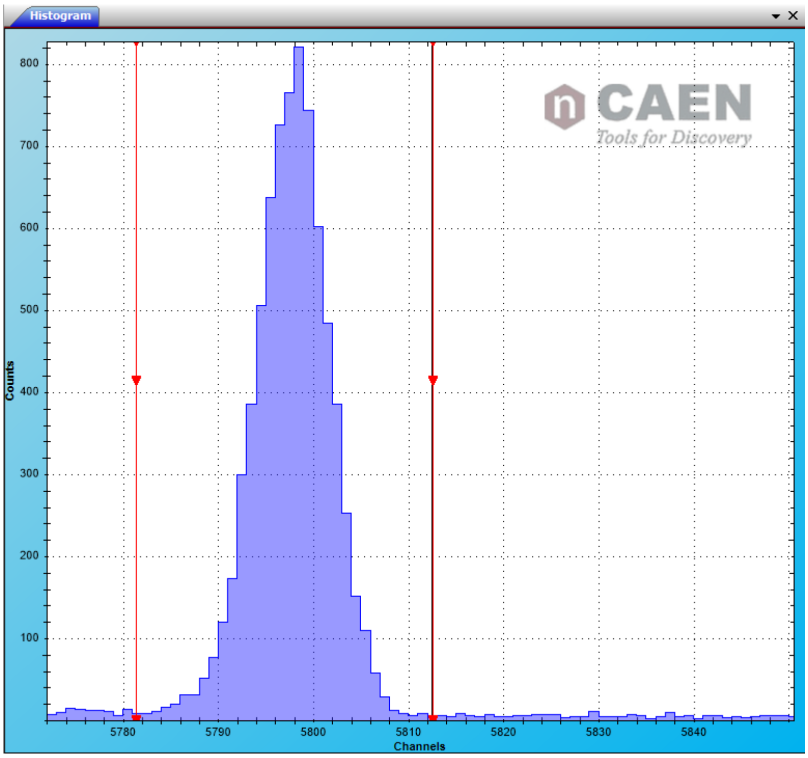
How to select a ROI

Zoom in (drag and release the mouse to zoom in) in the region of the relevant peaks to select the ROI.

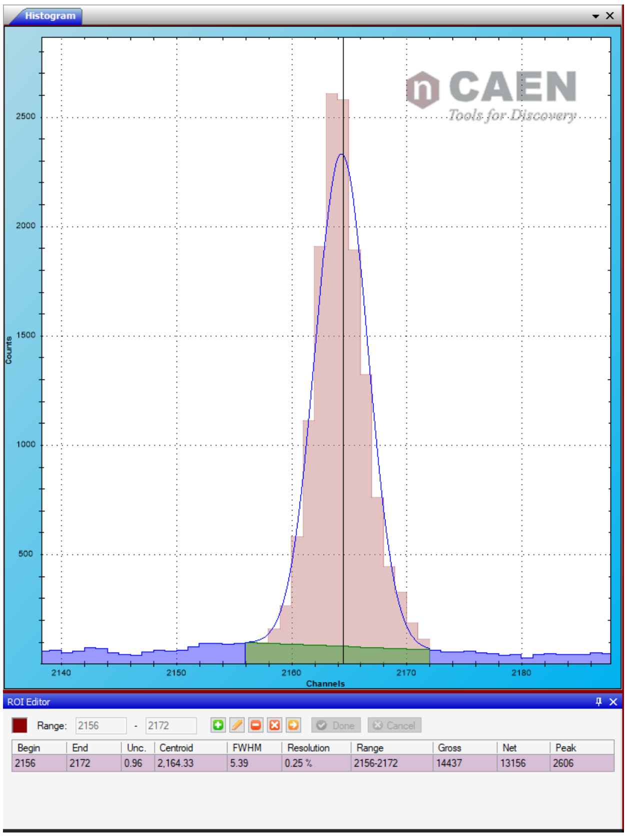
From the "ROI Editor" window select "Add" .

Click on the histogram to select the left and right limits of the ROI.

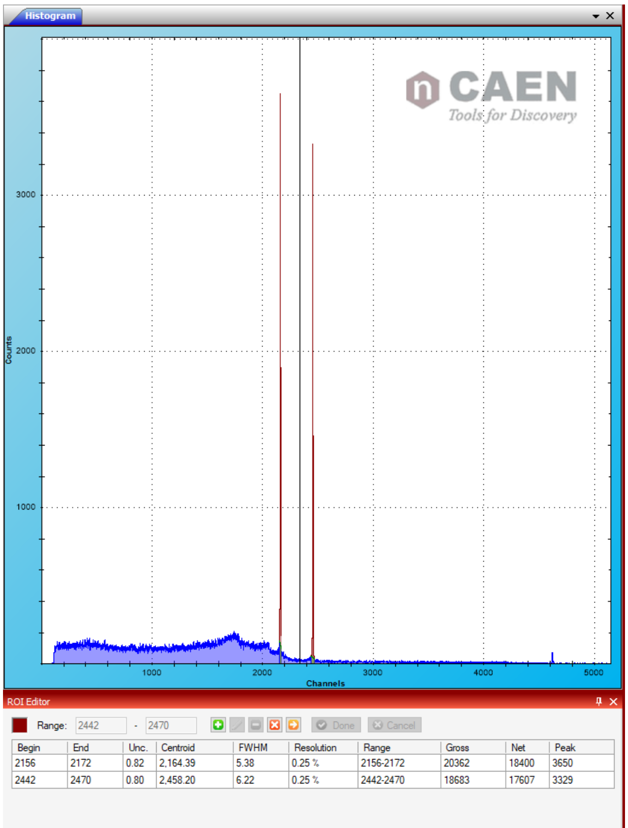
Then press "Done" from the ROI Editor window.



Left click on the ROI to check the fit and to get the parameters. Check Sec. **Menu Bar Items** for more details about the ROI fitting.

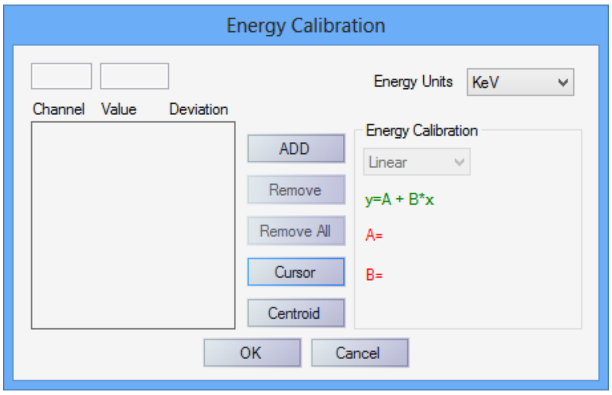


Repeat the same procedure for the second peak:

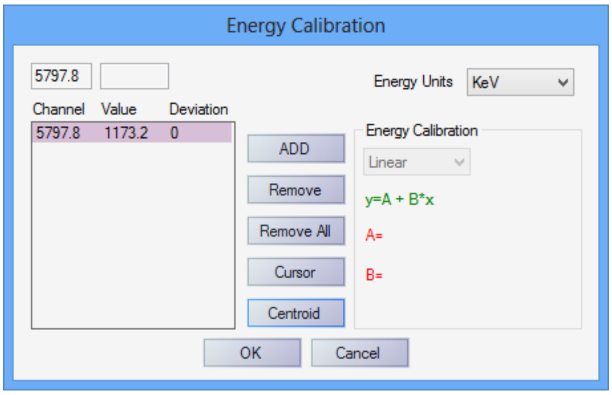


Energy calibration

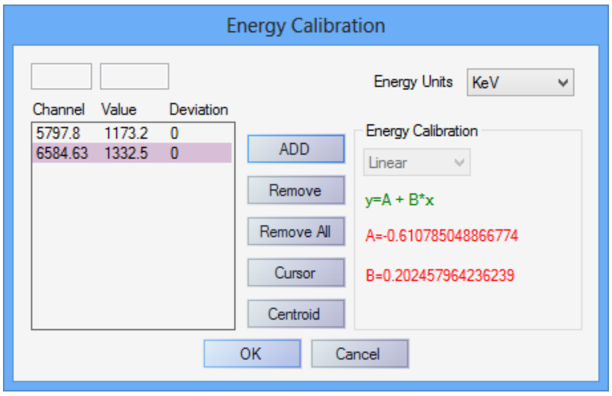
Pause the spectrum and open the **"Energy Calibration"** window :



Click on the first ROI and select **"Centroid"** to use the centroid value of the distribution. Write the desired value of energy, then click **ADD.**



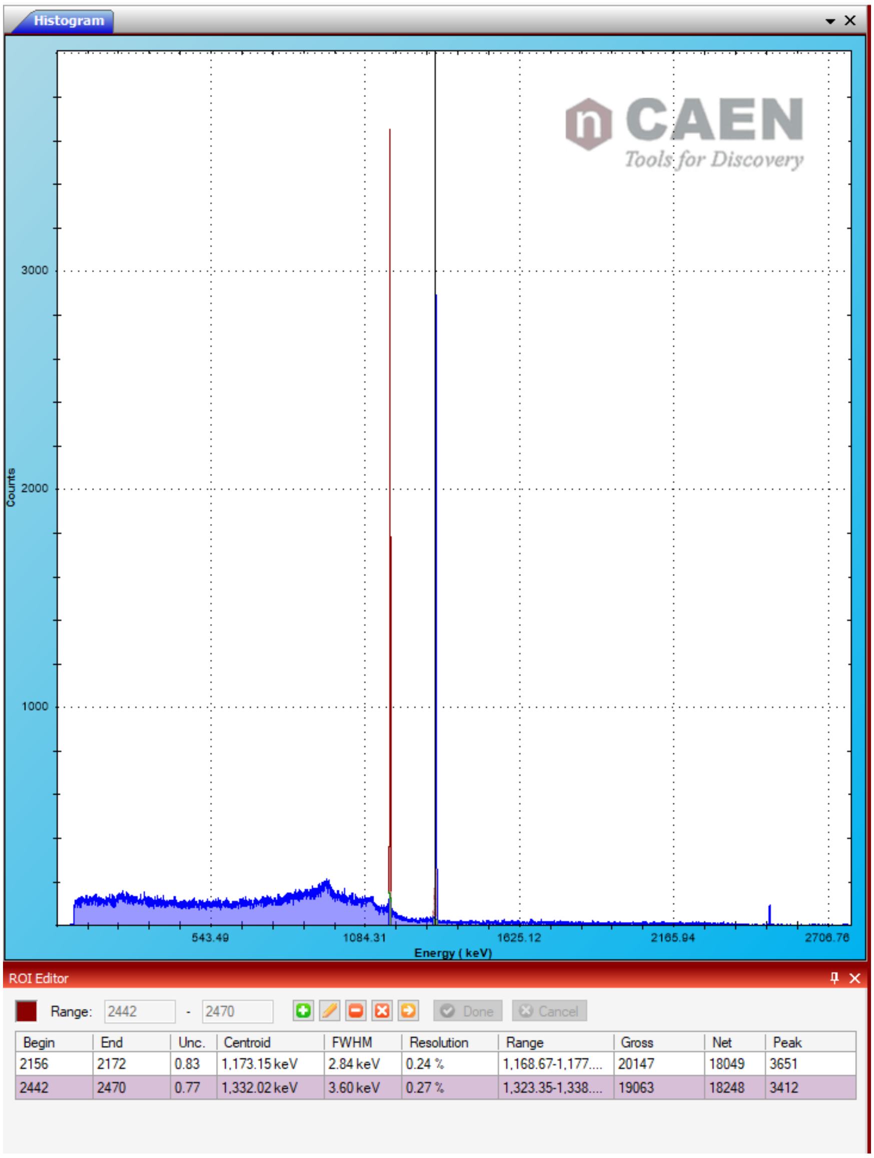
Repeat for the second ROI, then click **OK**



Press "Enable Calibration" to enable the calibration of the spectrum. All the values on the ROI Editor window are automatically converted.

Note: The user can choose more than two points to perform the calibration. In case two points are used it is usually recommended to use values in a wide energy range. The more the difference is high the more the linear calibration will be accurate.

Note: It is also possible the perform a calibration with a single peak, by setting the second point to 0. Set "Channel" = 0 and "Value" = 0.


Histogram
CAEN
Tools for Discovery
Counts
3000
2000
1000
543.49
1084.31
1625.12
2165.94
2706.76
Energy (keV)
ROI Editor
Range: 2442 - 2470
Done
Cancel
Begin End Unc. Centroid FWHM Resolution Range Gross Net Peak
2156 2172 0.83 1,173.15 keV 2.84 keV 0.24 % 1,168.67-1,177.... 20147 18049 3651
2442 2470 0.77 1,332.02 keV 3.60 keV 0.27 % 1,323.35-1,338.... 19063 18248 3412

How To use Decimation

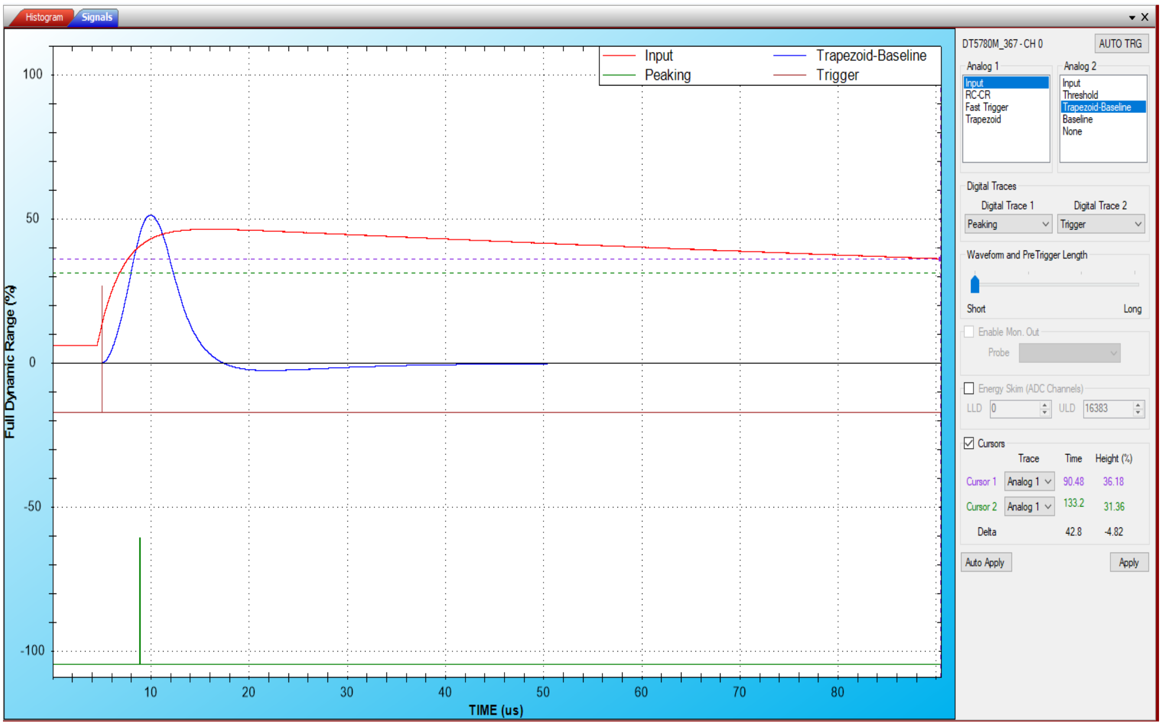
The decimation reduces the sampling rate of the board by means of performing an average value of a programmable number of consecutive samples.

Note: The decimation is not available for 770 series.

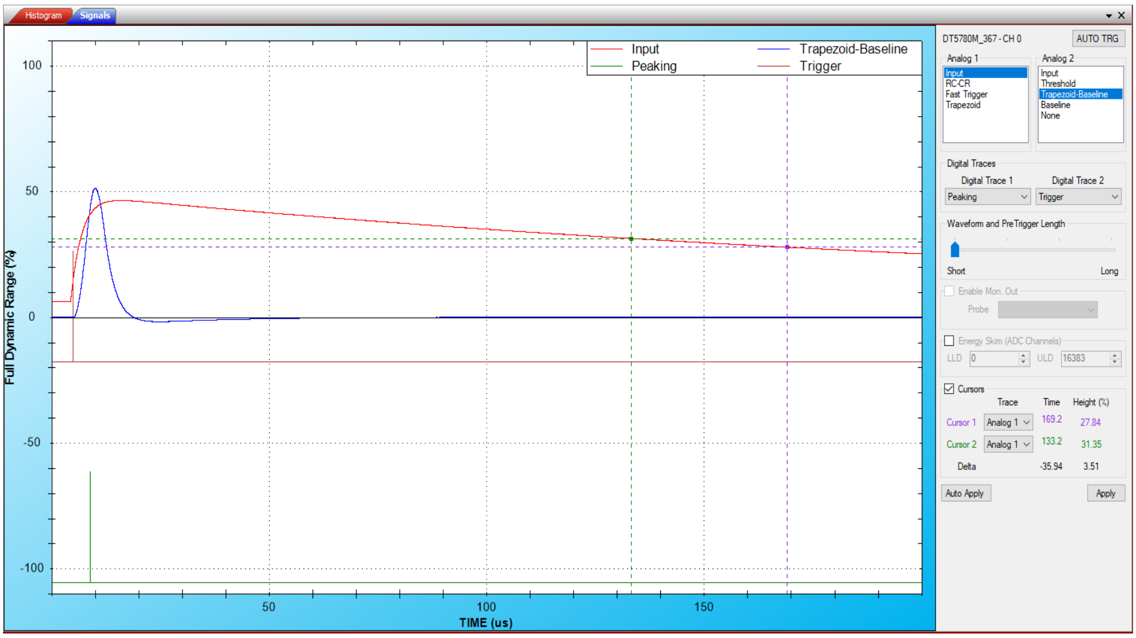
Note: The decimation is no longer supported for DPP-PHA firmware revision higher than 128.64 (724/780/781/782 series) and for Hexagon. It can be used only to rescale the record length but has no effect in the energy and timing filters.

The decimation is quite convenient for those who want to measure very long signals, or signals with long rise time. Moreover, the decimation allows to increase the range of the trapezoid and timing parameters, as the Trapezoid Rise Time, Input Rise time, Flat Top, etc. by the same factor of the decimation value.

Usually the user can recognize the need of decimation when he/she set the maximum rise time and he/she cannot get a correct trapezoid, as shown in the following picture. In the typical situation, the baseline of the "Trapezoid-Baseline" trace is not zero, the trapezoid is in overshoot, and there is no flat region.

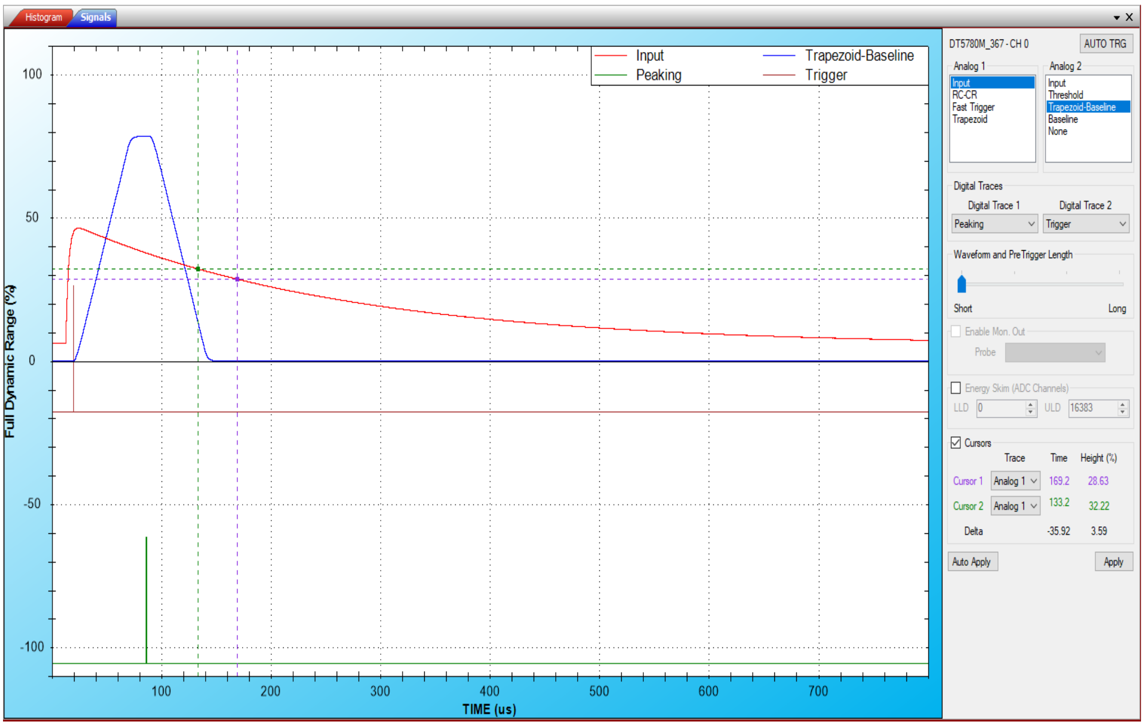


Start with **"Decimation"** = 2.



For our example we set the **"Input Rise Time" = 5 us** (check the overall procedure of **How to set the Trigger**).

Increase the "Trapezoid Rise Time" and "Flat Top" until you reach a correct trapezoid. In this particular case we have to increase the **Decimation** up to **8**, and set **Trapezoid Rise Time = 50 us**, **Flat Top = 20 us** and **Decay Time = 250 us**.



How to save data

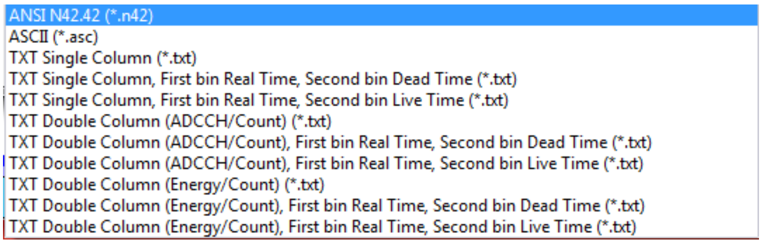
It is possible to save data in different ways:

1. Save the energy spectrum;
2. Save the list of Trigger Time Stamp and Energy for each event;
3. Save an image of the energy spectrum.

Save the energy spectrum

It is possible to save the energy spectrum through the path: **File->Save**, or using the command .

Supported file formats are: .n42, .asc, .txt. For the .txt file there are several options, as shown in the following table.



In the .n42 file, the spectrum and the relevant properties are saved.

Save the list file

Note: This option is NOT available for DT5770 MCA.

You can save the list file from the **"Acquisition Setup"** window, under the **"Board"** tab, select **"Output"**.

Click on **"Enable List Mode"** to enable the window.

The user can select the information to be saved among: **Time Tag**, **Energy**, and **Extras**, where Time Tag corresponds to the trigger time stamp, i.e. the time of arrival of the pulse, energy is the pulse height, and extras correspond to flags of the event (refer to Sec. **Channel Aggregate Data Format for 724, 780, 781 series (FW release <128.64)**, **Channel Aggregate Data Format for 724, 780, 781, and 782 series (FW release >128.64),** and **Channel Aggregate Data Format for 725 and 730 series** for more information).

Binary and **ASCII** writing are selectable.

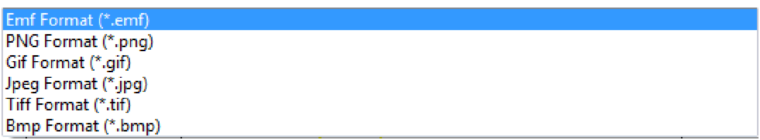
<u>Start the acquisition to start dumping the list file</u>. The dump will stop with the stop acquisition.

To avoid useless file generation, a warning message appears at the bottom of the GUI when the list dumping is enabled.

Note: remember to increment the file name index. In case of a new "start acquisition" the new data events will be added to the previous list file.

Save the Image

The user can export the spectrum in various image format, as listed in the following table.



From **"File"** click on **"Export"**. Otherwise right click on the spectrum and select **"Save Image As".**

Troubleshooting

n	Issue	Possible Causes	Fixes
0	It is strongly recommended to first check from an oscilloscope device the signal from the pre-amplifier and check whether there is no grounding issue, and the pre-amplifier dynamics is not saturated. Check also Sec. **Before starting the acquisition** .		
1	Though I decrease the "Threshold", I cannot reach lower values in the energy spectrum	The input signal is noisy and the trigger fires on the noise	Try to increase the **RC-CR² smoothing** factor to average the noise samples. Remember to perform all the steps described in Sec. **How to set the Trigger** when you modify the RC-CR² smoothing.
2	Values in the high region of the energy spectrum are cut off before the limit	The input signal is saturating the dynamics	Check from the **"Signal Inspector"** whether the **"Input"** pulse saturates the dynamics. Try to first adjust the **DC Offset**. Then you can try to increase the **"Input Range"** (not available for x724 series). It is preferable to modify the **"Fine Gain"** for a fine adjustment of the dynamics.
3	The peaks in the spectrum show an asymmetric left (right) tail	The pole-zero cancellation might be not correct. The baseline restoration can be overestimated/underestimated	Check from the **"Signal Inspector"** whether the **"Trapezoid"** trace correctly returns to zero. Moreover it is suggested to set the maximum value for **"Baseline Hold-Off"**, and the minimum value of **"Trigger Hold-Off"**. This is more evident in case of high rate signal.
4	The resolution is worse than expected	Some settings might be better tuned	In case of low rate it is worth to set high value of **"Trapezoid Rise Time"**, as well high value of **"Baseline Mean"**
5	The BUSY led is ON, i.e. the "A" circle under the Spectra List window is red	There might be a saturation or a memory full	Check point 2. Also check that the **Signal Inspector** window is closed.
6	There is too much dead-time in the acquisition	The input signal is saturating the dynamics	Check from the **"Signal Inspector"** whether the **"Input"** pulse saturates the dynamics. Try to first adjust the **DC Offset**. Then you can try to increase the **"Input Range"** (not available for x724 series). It is preferable to modify the **"Fine Gain"** for a fine adjustment of the dynamics.

Tab. 3.1: Troubleshooting table. For any other specific issue not listed in the table please contact CAEN at the support mailing list (Chapter Technical support)

4 Software Interface

GUI Description

MC2Analyzer Initial Main Screen Description

When the MC²Analyzer program is launched, the following Initial Main Screen is displayed:

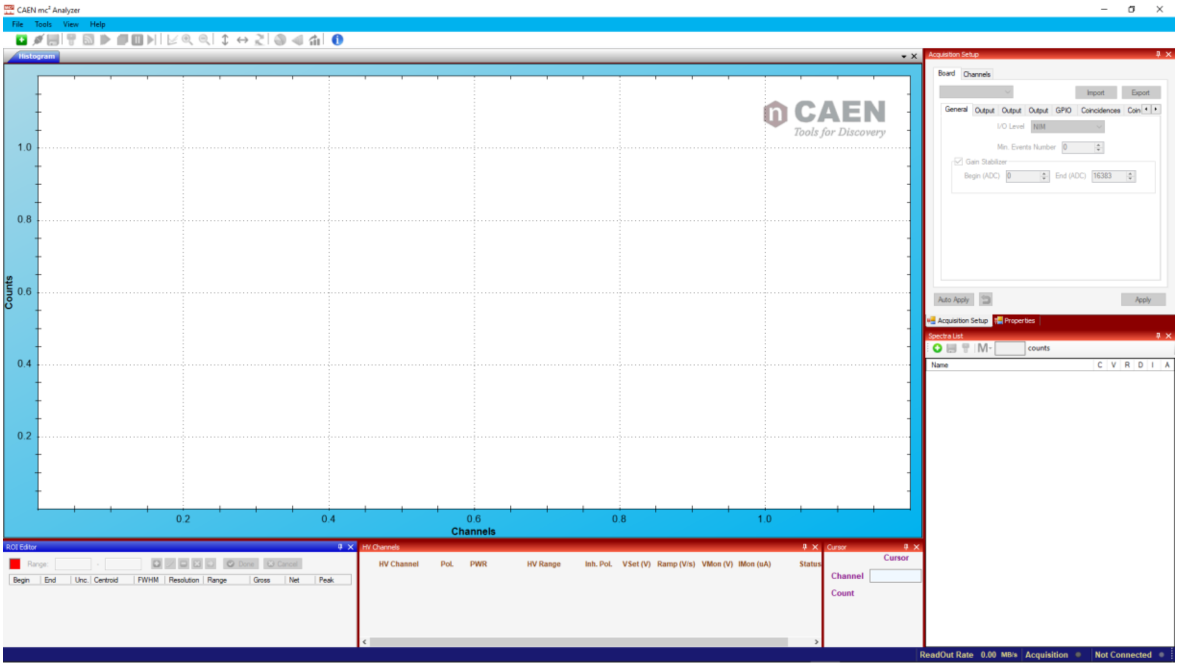


Fig. 4.1: MC²Analyzer Initial Main Screen

The CAEN MC²Analyzer Initial Main Screen is composed of one **Menu Bar**, one **Icon Bar** and 7 adjacent windows with the following functions (by default, clockwise):

- **Histogram Window**
- **Spectra List**
- **Properties Window**
- **HV Channels Window**
- **Cursors Window**
- **ROI Editor Window**

Each of the above indicated 7 windows can be left floating, re-positioned and closed independently at the operator convenience. Each window can be recalled to the main screen by using the Menu Bar pull down menu from the items: View/Windows. Mark or unmark the items on the “Windows” pull down menu respectively to show or to hide the corresponding Window on the Main Screen.

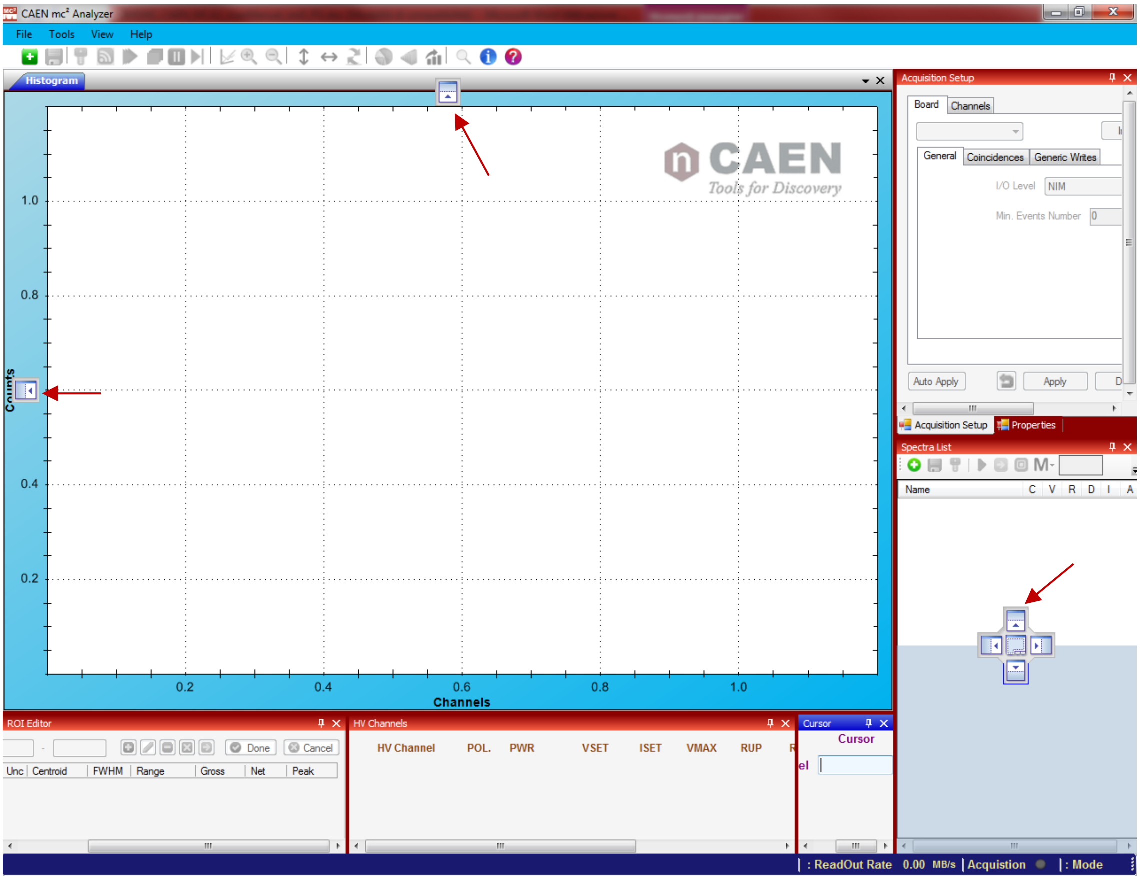


Fig. 4.2: MC²Analyzer floating windows

To interact with a window, click on it with the mouse pointer. The upper frame of the active window will turn blue. When another window is activated, the upper frame of the previously selected window turns light brown.

Note: The full Initial Main Screen appears when the MC²Analyzer program is launched for the first time. Successively, upon launching the MC²Analyzer program, the Main Screen will display only the windows that were active upon the previous shutdown of the MC²Analyzer program. To return to the full Initial Main Screen display, all windows need to be checked for display from the **View/Windows** pull-down menu (see Sec. **Menu Bar** Items).

Note: AutoHide Function. Each window can be set to AutoHide by clicking on the vertical Tack Pin icon in the upper right frame of the window itself. When enabled, the window will reduce to a Tab along the bottom frame of the Main window. It can be recalled by clicking on that tab, becoming then the active window (frame turns blue). It will AutoHide again when cursor is clicked on another window. When AutoHide is enabled the Tack Pin icon is horizontal. AutoHide is disabled by clicking on the horizontal Tack Pin icon or, automatically, when the window is closed.

At the bottom of the MC²Analyzer Main Screen a blue **System Status Bar** displays the following information about the current activity of the System: Rebin Enabled or Disabled./Read-out Rate in MB/sec. /Acquisition Status (LED) /System Mode : Spectrum

Menu Bar Items

The menu bar is constituted by the following items: **File**, **Tools**, **View**, and **Help**.

✓ **FILE**: the pull-down Menu shows the following items**: Add Spectrum/Save/Export/Exit**

- **Add Spectrum:** This function allows the user to recall an acquired spectrum or initiate a new spectrum acquisition.

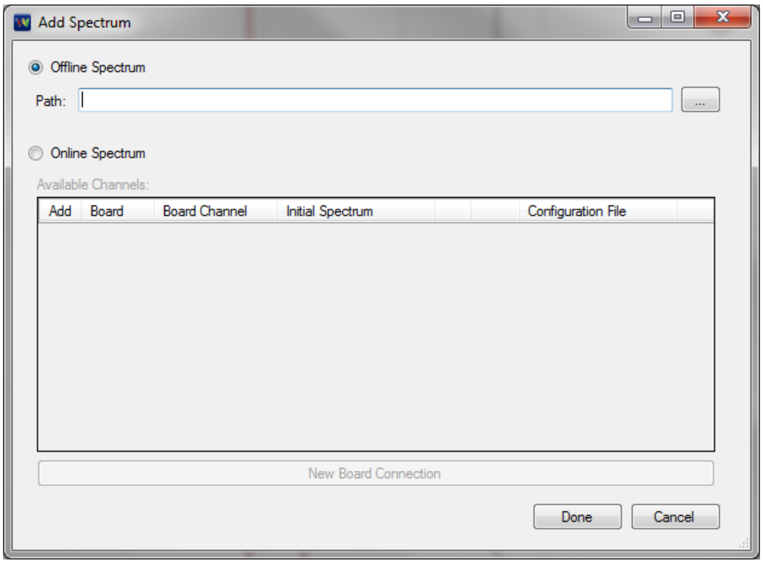


Fig. 4.3: MC^{2}Analyzer Menu Bar – “File/Add Spectrum” Dialog Box

To recall and display a recorded spectrum, select the **“Offline Spectrum”** button. The recorded spectra files can be recalled either by typing the file path in the **Path** entry box either by left clicking on the **“…”** button on the right of the **Path** entry Box. When clicking on the **“…”** button, a Windows Directory window will open, allowing the retrieval of a recorded spectrum file from a previously created storage folder.

Accepted file formats are:

- .n42, CAEN Channel Settings;
- .asc, ASCII.

Left click “Done” when the file path is entered or the file path is selected, to recall the file data to the display screens. The recalled spectrum will then be displayed in the Histogram window and a line with the corresponding Spectrum filename will be added to the **Spectra List** window.

To set up a new acquisition, select **"Online Spectrum"**. Left click on **"New Board Connection"**. The following dialog box will appear:

Fig. 4.4: MC^{2}Analyzer Menu Bar - "File/Add Spectrum/New Board Connection" Dialog Box

Select **"Add New Device"** from the **"Select Device"** Pull down menu. Select the proper connection parameters. In the following example, we used USB connection to the DT5780, therefore: Type = USB, Link, Slave, VME Base Address = 0. Left click on **"Connect"**.

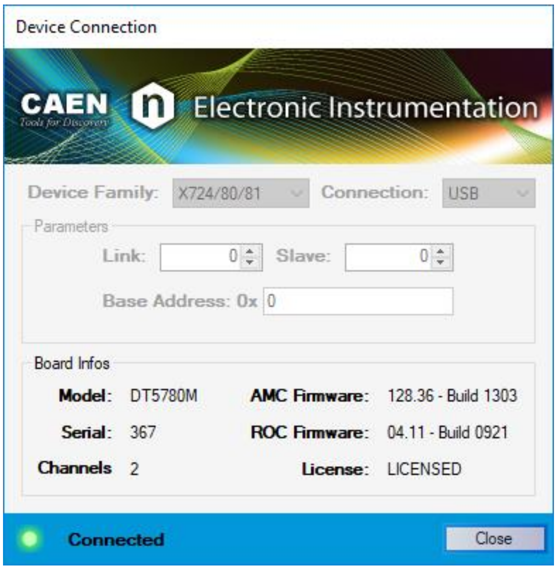


Fig. 4.5: MC^{2}Analyzer Menu Bar - "File/Add Spectrum/New Board Connection/Connect" Dialog Box

Upon successful connection, a green **"Connection OK"** message will appear. Underneath it, a dotted green link will appear between the Computer Screen Icon, the Settings Icon and the Hardware icon, indicating that the system connections for data acquisition and display have been correctly configured.

Repeat this operation separately for all the hardware devices that have to be connected. Additional devices can be added later at any time by repeating the above procedure after left clicking on the **"New Board Connection"** indicated in **Fig. 4.3**. When done, left click on the **"Close"** button.

The following dialog box will then appear (see **Fig. 4.6**), allowing the user to select and mark the digitizer channels to be enabled for the acquisition and display of new live spectra:

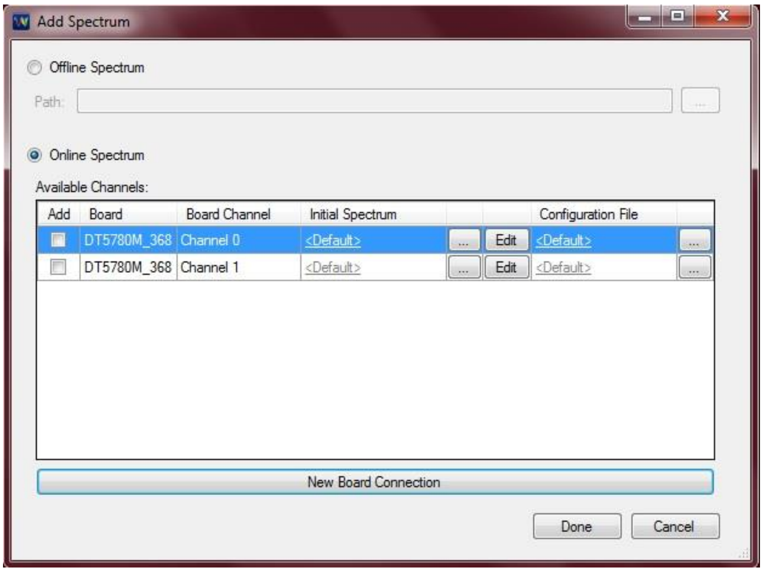


Fig. 4.6: MC²Analyzer Menu Bar - "File/Add Spectrum/New Board Connection/Connect/Close" Dialog Box

After the connection is made correctly, the Add Spectrum Window will show each acquisition channel recognized by the system. Five columns are available:

- **Add**, that allows to add a specific channel. Click on **"Add"** itself to add all channels;
- **Board**, where the board model and serial number are specified;
- **Board Channel**, where the channel number is specified;
- **Initial Spectrum**, that allows to upload an initial spectrum to be added to the online spectrum. The **"…"** button allows to browse a spectrum to be loaded. The button **"Edit"** allows to modify the spectrum properties. See **Fig. 4.7** and **Fig. 4.8**;
- **Configuration File**, allows to upload a configuration file.

Note: The configuration settings can be modified in the GUI itself.

Recorded Initial Spectrum Files and Configuration Files can be loaded by left clicking on the **"…"** button to the right of the respective entry boxes, from folders located in the Windows directory. Each channel can then be activated by marking the correspondent check box to the right of the channel line. Only the activated channels can be set and read by the acquisition system. To deactivate a channel, the user can unmark the check box on its line at any time.

Unless a different Spectrum File is loaded, the "defaultSpectrum.n42" file is recalled and the Initial Spectrum Column will show "<Default>" on the Channel lines. This is the File containing the Data and the Settings of the Spectrum from the last acquisition made before the MC²Analyzer program was turned off. To upload a different file, right click on the "…" key to the right of the Initial Spectrum column and access the desired "filename.n42" file in the Windows directory that opens up.

Unless a different Configuration File is loaded, the "defaultChannel.ccs" file is recalled and the Configuration File Column will show "<Default>" on the Channel lines. This is the File containing the Data and the Settings of the hardware Channels from the last acquisition made before the MC²Analyzer program was turned off. To upload a different file, left click on the "…" key to the right of the Configuration File column and access the desired "filename.ccs" file in the Windows directory that opens.

The user can tag the spectrum files by left clicking on the **"Edit"** key of the corresponding channel line. The **Add Spectrum Edit Properties** Dialog Box will appear as in **Fig. 4.7**. The five Pull Down menus allow the user to indicate:

- The Number of Channels in the Spectrum, choosing among: 1024,2048,4096,8192,16384;
- The Type of Instrument used for the data acquisition;
- The Nuclear Radiation detected: Alpha, Beta, Gamma, Neutron, X-Ray;
- The Detector Type;
- The Type of Measurement executed.

The ADC Channels pull down menu allows the user to select the number of channels of the histogram, i.e. the energy resolution ranging from 1024 channels (10 bits, NaI grade) to 16384 channels (14 bit, HPGe grade).

The Instrument Type pull down menu allows the user to tag the type of equipment being used.

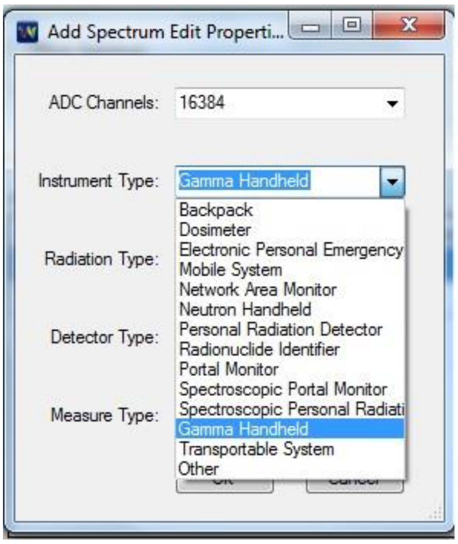


Fig. 4.7: MC²Analyzer Wizard Dialog Box – "File/Add Spectrum/EditProperties" Dialog Box - Instrument Type Pull Down Menu

The Radiation Type pull down menu allows the user to tag the type of radiation to be measured.

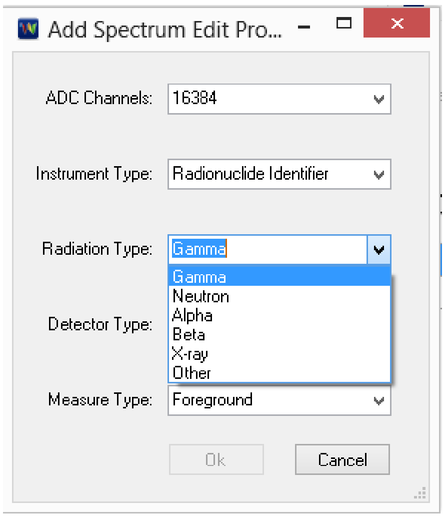


Fig. 4.8: MC²Analyzer Wizard Dialog Box – "File/Add Spectrum/EditProperties" Dialog Box - Radiation Type Pull Down Menu

From the **Detector Pull Down Menu** (See **Fig. 4.8**) the user can associate to the recorded file the type of Detector that was used to execute the measurement.

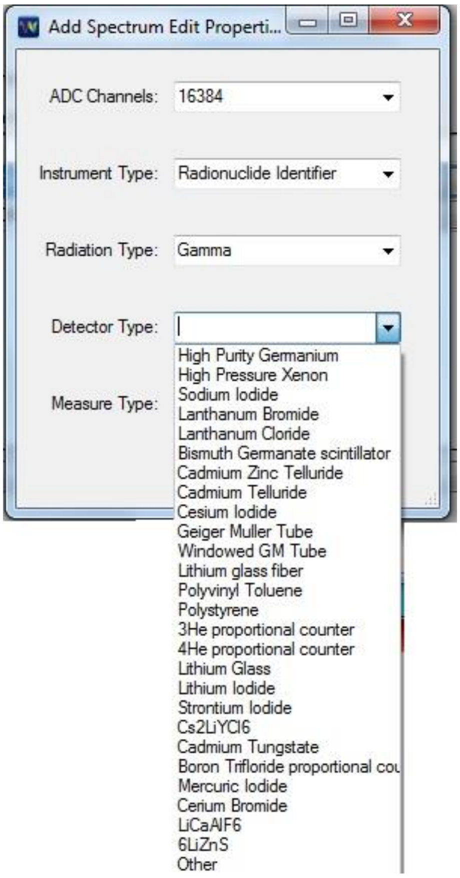


Fig. 4.9: MC²Analyzer Wizard Dialog Box – "File/Add Spectrum/EditProperties" Dialog Box - Detector Type Pull Down Menu

Finally, the Measure Type pull down Menu allows the user to select the type of measurement.

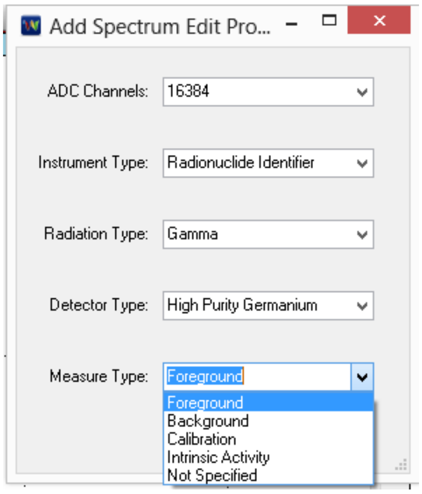


Fig. 4.10: MC²Analyzer Wizard Dialog Box – "File/Add Spectrum/EditProperties" Dialog Box - Measure Type Pull Down Menu

- **Save:** This Pull-Down Menu item allows the user to save an acquired spectrum. To save a new acquisition, left click on **“Save”**. A Windows Directory window will appear, allowing the user to save the acquired file in the desired directory. Accepted file formats are:
    - .n42, ANSI N42.42;
    - .asc, ASCII;
    - .txt, various text file format with single or double column, as shown in the following table.

      TXT Single Column (*.txt)
      TXT Single Column, First bin Real Time, Second bin Dead Time (*.txt)
      TXT Single Column, First bin Real Time, Second bin Live Time (*.txt)
      TXT Double Column (ADCCH/Count) (*.txt)
      TXT Double Column (ADCCH/Count), First bin Real Time, Second bin Dead Time (*.txt)
      TXT Double Column (ADCCH/Count), First bin Real Time, Second bin Live Time (*.txt)
      TXT Double Column (Energy/Count) (*.txt)
      TXT Double Column (Energy/Count), First bin Real Time, Second bin Dead Time (*.txt)
      TXT Double Column (Energy/Count), First bin Real Time, Second bin Live Time (*.txt)

- **Export:** This Pull-Down Menu item allows the user to export the acquired spectrum as an image. The same menu is available at the **“Save Image As”** (right click on the spectrum). Accepted file formats are:
    - .emf, EMF;
    - .png, PNG;
    - .gif, GIF;
    - .jpg, JPEG;
    - .tif, TIFF;
    - .bmp, BMP.

- **Exit:** This Pull-Down Menu item allows the user to exit the MC²Analyzer Program. When it is used, the MC²Analyzer program will save automatically the data acquired, the Spectra settings and the channels configuration to the corresponding Default files.
- **Connect Instance:** This Pull-Down Menu item allows the user to connect the MC²Analyzer Program to Hexagon. Refer to Sec. **Software connection** for more details.

✓ **TOOLS**: the pull-down Menu shows the following items: **Create ROI/ Rebin Dialog/ Acquisition Setup/ Start Acquisition/ Stop Acquisition/ Pause Plot Update/ Single Plot Update/ Calibration Setup/ Enable Calibration/ Logarithmic Scale/ Background/ Peak Fitting/ ADC Calibration/Reset Active Spectrum/Reset All Spectra**

- **Create ROI:** This function allows the user to define a Region Of Interest (ROI). Left clicking on the Create ROI item opens the ROI Editor window (unless it was already open). Default position is leftmost under the Graph Window. See Section **ROI Editor Window** for ROI creation procedures.
- **Rebin Dialog:** Clicking on the “Rebin Dialog” allows the user to transform a High-Resolution Spectrum (i.e. a 16K channels spectrum) into a lower resolution spectrum (i.e. a 2 K channel spectrum) by clustering the values of the counts in the adjacent bins according to the rebin factor (i.e. the counts values of 8 adjacent bins of a 16K spectrum are summed into the corresponding single bin in a 2 K channels spectrum). Accepted vales are: 16K, 8K, 4K, 2K, 1K. The same menu is available from the **“Edit”** function of **Fig. 4.6**, at the pull-down menu **“ADC channels”**.
- **Acquisition Setup:** When clicking on the “Acquisition Setup” item, the following window opens:

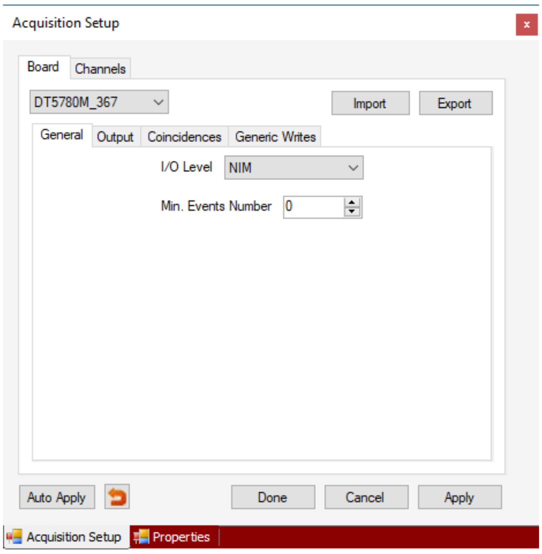


Fig. 4.11: MC²Analyzer Menu Bar/Tools/Acquisition Setup/Board Tab

The **Acquisition Setup** features the **Board** Tab, allowing the user to select the Unit being set from the Pull Down Menu on the upper left corner of the Tab. Current settings values can be imported from the selected hardware unit and values set in MC²Analyzer can be exported to the selected hardware unit by using the "Import" and "Export" keys respectively, located in the upper right corner of the Board Tab. See Section **Acquisition Setup** for details about the Acquisition Set Up Dialog Box description.

- **Start Acquisition**: This function enables the digitizer unit to start the acquisition on all channels. When the unit is ready to acquire data the icon bar the triangle icon is green. Upon clicking on the **Start Acquisition** item, data acquisition begins and on the Icon Bar the Start Acquisition icon turns grey while the Stop Icon turns red.
- **Stop Acquisition:** This function enables the digitizer unit to stop the acquisition on all channels. When the unit is acquiring data the icon bar the square Stop Acquisition icon is red. Upon clicking on the **Stop Acquisition** item, data acquisition stops on all channels and on the Icon Bar the Stop Acquisition icon turns grey while the Start Icon turns green.
- **Pause Plot Update:** This item function freezes the graphic update of the spectra being displayed. The acquisition on the corresponding hardware channels still continues.
- **Single Plot Update:** This item function performs a single update of the spectra being displayed
- **Calibration Setup:** This item function enables the user to enter the relevant energy calibration data. See Sec. **MC2Analyzer Energy Calibration** for a complete description of the procedure and system features.
- **Enable Calibration:** This item function enables the energy calibration. See Sec. **MC2Analyzer Energy Calibration** for a complete description of the procedure and system features.
- **Logarithmic Scale:** This icon function allows the user to toggle between Linear and Logarithmic Scale on the Y-axis.
- **Background:** This item has a Pull-down Menu with the following items: **Simple/Advanced/ Configure**

  The user can toggle between **"Simple"** and **"Advanced"**.

  In the Simple option the background is evaluated as a simple line between the ROI edges.

  The **"Advanced"** option allows the user to access the **"Configure Background"** item. By clicking on the Configure Background the following Dialog Box appears:

Fig. 4.12: MC²Analyzer Menu Bar/Tools/Background/(Advanced)Configure Dialog Box

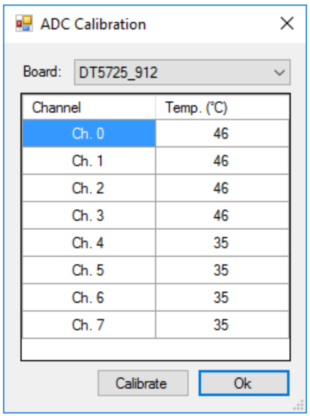
The user can enter the **LLD** (Lower Level Discriminator) and **ULD** (Upper Level Discriminator) background values in the corresponding entry boxes as well as the desired Number of Iterations **niters** for the Background calculation. While in the Simple option the background is evaluated only in the ROI range, the Advanced option allows the user to include in the background calculation the full spectrum included into the LLD and ULD range. The more the niters value is increased, the more the background shape is smoothed. Decreasing this value will probably discard lower peaks. The user should find the proper compromise.

- **Peak Fitting:** this function determines how the peaks are fitted, choosing between **Simple/Advanced**.

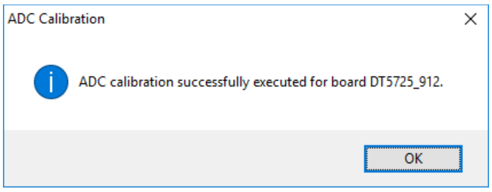
  Simple: the algorithm makes use of a Gaussian shape, whose centroid is evaluated as the weighted average, and the sigma is evaluated as the distance from the mean value, as the RMS;

  Advanced: this function enables the Gaussian fit of the ROI using the minimum chi square method.

- **ADC Calibration:** this function allows the user to perform the ADC Calibration in case of 725 and 730 series (see Sec. **ADC Calibration (725 and 730 series only)**).



Monitor the ADC temperature, and once it is stabilized press "Calibrate". A successful pop-up message will appear.



- **Reset Active Spectrum**: this function allows the user to reset the active spectrum
- **Reset All Spectra**: this function allows the user to reset all the spectra

✓ **VIEW**: the pull-down Menu shows the following items: **Windows/ Zoom In/ Zoom Out/ Autoscale/ Full X Range/ Restore Scale**

- **Windows:** Allows the user to select the Windows to be displayed on the MC²Analyzer Main Screen from the following Pull Down Menu: Spectrum Properties/ Spectrum List/ Histogram/ HV Channels/ ROI Editor/ Cursor
- **Zoom In:** Allows the user to expand horizontally (and, in proportion, vertically) an area of the Histogram Graph symmetrical with respect to a central vertical marker line which can be set by positioning the crosshair marker in the desired central point and left clicking on it. Upon release the "horizontal expansion center" vertical marker line will remain set until a new position is selected by repeating the above procedure.
- **Zoom Out:** Allows the user to reduce horizontally (and, proportionally, in vertical) an area of the Histogram Graph symmetrical with respect to the previously set central vertical marker line.
- **Autoscale:** When enabled, this command will automatically resize the vertical (counts) Y-axis to fit the highest counts peak into the visible Graph area.
- **Full X Scale:** When selected, this command will restore the graph display to the full X- axis original dimension.
- **Restore Scale:** When selected, this command will restore the graph display to the full original scale.

✓ **HELP**: shows the **About** item

- **About:** dialog box containing information about the manufacturer and the Version of the MC²Analyzer Software.

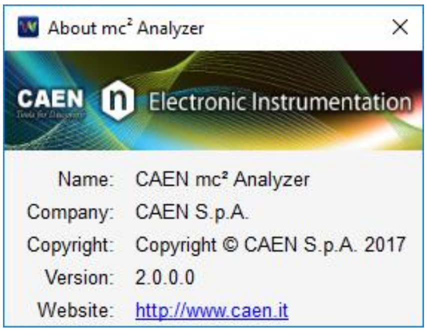


Fig. 4.13: MC²Analyzer Menu Bar/Help/About Dialog Box

Icon Bar

The following Icon Bar is present under the MenuBar:

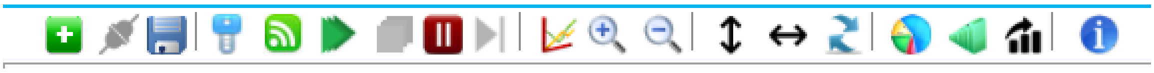


Fig. 4.14: MC²Analyzer Icon Bar

The above icons correspond to the following functions (from left to right):

1) **Add Spectrum** : This icon has the same function of the Menu Bar/ File/ Add Spectrum command (see above)
2) **Reconnect Last Channels** : This icon allows the user to automatically reconnect to the latest used module, if present
3) **Save Spectrum** : This icon has the same function of the Menu Bar/ File/ Save Spectrum command (see above)
4) **Configure Acquisition** : This icon function allows the user to Configure the Acquisition Parameters of the Board. (See Section **Acquisition Setup**)
5) **Signal Inspection** : This icon function enables the user to visualize on the graphic screen the actual shape of the raw electronic signal(s) coming from the nuclear radiation detector(s)
6) **Start Acquisition for All Channels** : This icon function enables the MCA unit to start the acquisition on all channels. When the unit is ready to acquire data this triangle icon is green. Upon clicking on the icon, data acquisition begins and the icon turns grey while the Stop Icon turns red. **Keyboard shortcut F3.**
7) **Stop Acquisition for All Channels** : This icon function enables the MCA unit to stop the acquisition on all channels. **Keyboard shortcut F4.**
   When the unit is acquiring data, this square icon is red. Upon clicking on this icon, the acquisition is stopped and the icon turns grey while the Start Icon turns green.
8) **Pause Plot Update** : This icon function freezes the graphic update of the spectra being displayed. The acquisition on the corresponding hardware channels still continues.
9) **Single Plot Update** : This icon function performs a single update of the spectra being displayed.
10) **Logarithmic Scale** : This icon function allows the user to toggle between Linear and Logarithmic Scale on the Y-axis.
11) **Zoom In** : Allows the user to expand a selected area of the graph. The graph is expanded symmetrically with reference to the position of the vertical bar cursor activated by right clicking with the crosshair cursor in the desired position of the graph area. It is also possible to click on the spectrum and press the keyboard command "+".
12) **Zoom Out** : Allows the user to reduce a previously enlarged area of the graph. It is also possible to click on the spectrum and press the keyboard command "-".
13) **Enable Vertical Autoscale** ↕ : When enabled, this command will perform an automatic resizing of the Y-axis scale, according to the largest spectrum peak height (highest number of counts in a "bin").
14) **Horizontal Autoscale** ↔ : When enabled, this command will perform an automatic resizing of the X-axis scale, according to the number of the highest channel containing significant data.
15) **Restore Scale** : This icon function restores the Graph scale to its originally dimensions, both on the X and the Y axis.

16) **ROI Editor** : This icon function is a shortcut to recall to the MC²Analyzer Main Screen the ROI Editor window, in case it had been removed.
17) **Enable Calibration** : This icon function enables the energy calibration. See Section **MC2Analyzer Energy Calibration** for a complete description of the procedure and system features.
18) **Calibration Setup** : This icon function enables the user to enter the relevant energy calibration data. See Section **MC2Analyzer Energy Calibration** for a complete description of the procedure and system features.
19) **About** :This Icon opens a dialog box containing information about the manufacturer and the Version of the MC²Analyzer Software.

Histogram Window

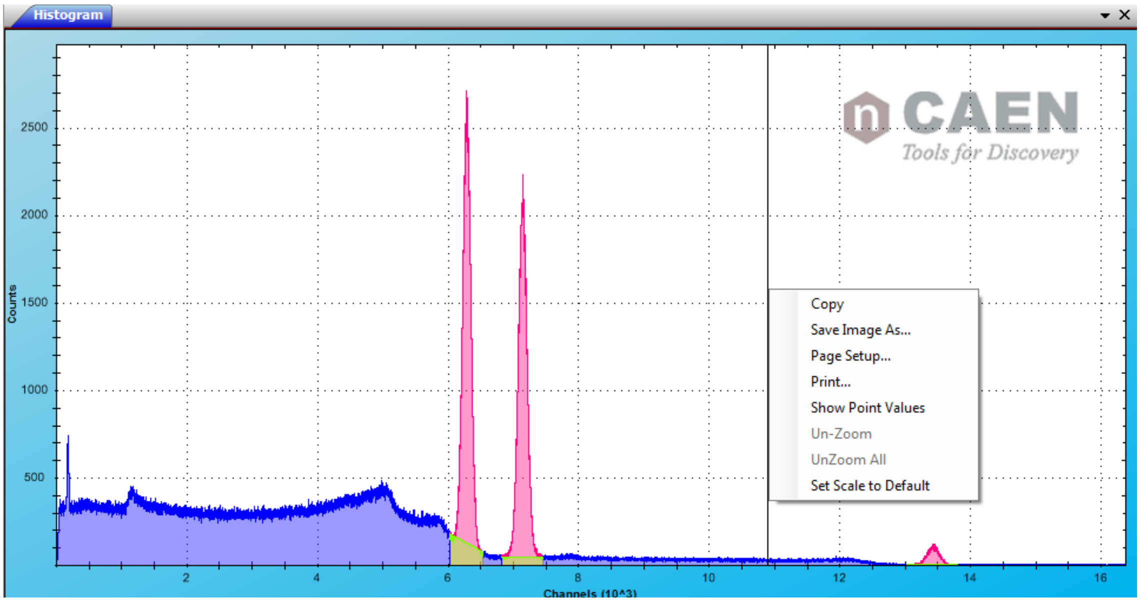


Fig. 4.15: The Histogram Window

The Histogram Window allows the user to display the histogram of the **Counts vs Energy** “bin” or “Channel” when the spectrum is Uncalibrated, and the Counts vs Energy in keV or MeV when the spectrum is calibrated.

Note: In case of Hexagon the spectrum is displayed over 32k channels.

Crosshair cursor: a crosshair cursor is present on the graph window. By left clicking on it a vertical marker bar is set on the graph. The marker bar can be moves by left clicking in the desired position of the graph, any time.

Zoom: any section of the graph can be expanded by positioning the crosshair cursor to the leftmost point of the section of the graph to be expanded, left clicking and holding down while dragging the cursor to the rightmost point of the region of interest. By releasing then the mouse left key the graph section will be expanded.

By positioning the computer pointer on the Graph and right clicking on it, a pull-down menu is activated, allowing the user to perform the following functions:

Copy
Save Image As...
Page Setup...
Print...
Show Point Values
Un-Zoom
UnZoom All
Set Scale to Default

- **Copy:** The Histogram Window image is copied into the clipboard. A Dialog Message will confirm that the image has been copied. Click on “OK” to close the Dialog Message.
- **Save image as…:** This command opens a Windows Directory window allowing the user to store the Graph as a graphic image file in the desired folder. The default format is “filename.emf”. Other available formats are:
  Emf Format (*.emf)
  PNG Format (*.png)
  Gif Format (*.gif)
  Jpeg Format (*.jpg)
  Tiff Format (*.tif)
  Bmp Format (*.bmp)
- **Page setup…:** This command allows the user to set up the page for printing the graph, by selecting the size, margins, page orientation and margins of the print out.
- **Print…:** This command allows the user to print the graph page.

- **Show Point Values:** When enabled, this selection enables the visualization on the graph next to the crosshair cursor of its position (X,Y) values.
- **Un-Zoom:** This command will un-zoom the last previously expanded section of the graph, in successive steps. If this command is in grey shaded color, then there is no current zoom applied to the spectrum.
- **Un-Zoom All:** This command will un-zoom the last previously expanded section of the graph at once to the initial scale. If this command is in grey shaded color, then there is no current zoom applied to the spectrum.
- **Set Scale to Default:** This command restores the Default Scale on the graph.

HV Channels Window

Note: This window can be used only when the acquisition system includes the CAEN DT5780 and Hexagon MCA units.

Upon starting the MC²Analyzer program and when the "HV Channels" window is enabled in the View/Windows Pull-down Menu, the **"HV Channels"** window will list all the HV Channels that are available for set-up.

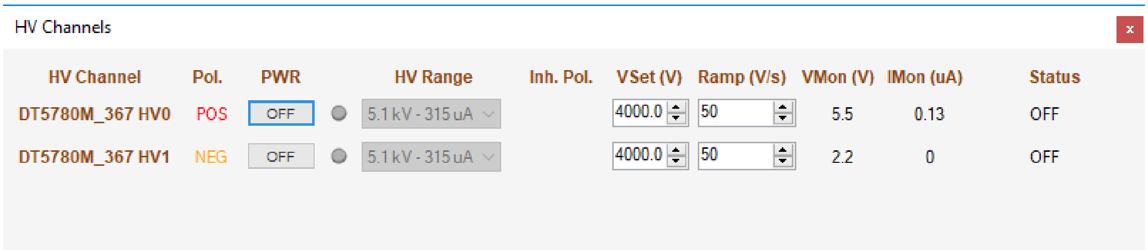


Fig. 4.16: The High Voltage Window

By positioning the pointer on each of the Header Line items VSET, ISET, VMAX, RUP, RDWN, VMON, and IMON, a label with relevant information concerning the engineering values in which the value is expressed, is displayed (i.e. V, microA, V/sec). Each HV Channel line contains the following information:

- **HV Channel:** The HV Channel is identified by the Hardware Model Number, Serial Number and Channel Number (in the format HV*X* where *X* is the Channel Number indicated near the Hardware output of the unit).
- **POL:** Indicates the HV Output Polarity (Positive or Negative).
- **PWR:** Allows the user to turn ON and OFF the High Voltage Output on the unit. The LED light the right of the ON/OFF key of a Positive HV Channel turns red when the HV Output is turned ON. The LED of a Negative HV Channel turns orange. When the HV are switched OFF the LEDs remain lighted and turn grey only when the HV Output ramp down is finished and the HV Output is OFF.
- **HV Range:** Allows the user to select between the HV channels operative ranges if more than one otherwise it indicates the maximum voltage and current that the HV channel can provide
- **Inh Pol:** Allows the user to select the HV Inhibit Polarity if supported
- **VSET (V):** Allows the user to set the required Voltage in steps of 0.1 Volt. The value can be either typed into the entry box or increased and decreased by using the up and down arrows. This is the actual value of the Voltage that will be applied to bias the Nuclear Radiation Detector HV input. However, if the value entered is larger than the VMax set value, the VMax value will overrule the VSET request and limit the maximum HV output to the VMax value.
- **Ramp (V/s):** Upon power up the HV Units outputs are always initialized at V=0 Volts. When the HV output is enabled thru the PWR ON/OFF key, the voltage at the channel output will ramp up at the speed set in the Ramp by the user, indicated in Volts/second. Correspondingly when the HV output is disabled thru the PWR ON/OFF key, the voltage at the channel output will ramp down at the speed set in the Ramp by the user. The Ramp value can be set in steps of 1 V/sec by typing it into the entry box or by increasing or decreasing it by using the up and down arrow keys.
- **VMON:** Indicates the actual Voltage at the Output of the corresponding channel, in Volts.
- **IMON:** Indicates the actual Current at the Output of the corresponding channel, in microA.
- **STATUS:** When a Channel is turned ON, the STATUS column will display the "Ramp up" message until the VSET value is reached, then the ON Status of the corresponding HV Channel is displayed.

When a Channel is turned OFF, the STATUS column will display the "Ramp down" message until the 0 value is reached, then the OFF Status of the corresponding HV Channel is displayed.

If the system Output tries to exceed the VMax value (for example upon a VSET request for a value larger than VMax) then the "VMax protection" warning message is displayed in red in the STATUS column line of the protected channel.

WARNING: When shutting off the HV, it is recommended to wait until the HV ramp down of the HV Outputs is completed before exiting the program.
It is mandatory to verify that all the HV Outputs are turned OFF (all LEDs of the HV window must be grey) before connecting or disconnecting the SHV outputs to or from other equipment, to avoid shock hazard.

Note: The HV remains ON even in case the user disconnects the software from the digitizer before pressing **OFF**. When connected again the software automatically reloads the last HV settings.

Properties Window

The Properties window is divided in two sections. The upper one is dedicated to information concerning the Acquisition Set-Up and time measurement values. The lower one provides information about the selected ROI, if applicable.

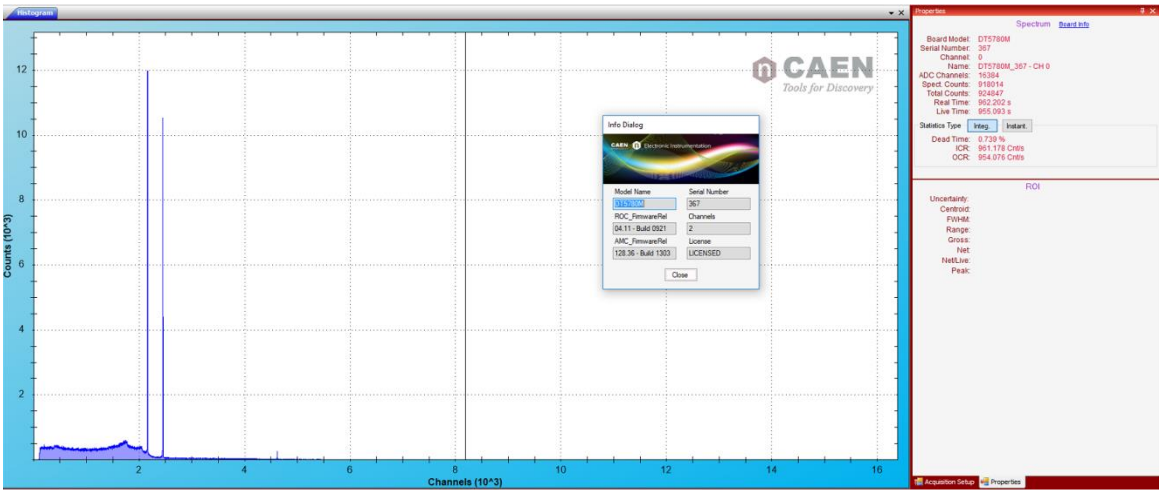


Fig. 4.17: The MC²Analyzer Main Screen with the Properties Window on the upper right side and the Board Info Dialog Box overlapping the Histogram Window

In the first section of the Properties window, the following information is displayed:

- **Properties:** Spectrum. The following information is available:
  - Board Model
  - Serial Number
  - Number of Input Channel being displayed
  - Name of the Input Channel being displayed
  - Number of Channels ("bins" on the X-axis) of the ADC
  - Spectrum Counts: Number of events converted and histogrammed
  - Total Counts: Total number of events detected during the full Acquisition Time
  - Real Time: Full Acquisition Time
  - Live Time: Time Available for Data Taking
  - Dead Time: Time unavailable for Data Taking as % of Full Acquisition Time (Integral and Istantaneous)
  - ICR: Input Counting Rate, number of Valid triggers at the input (Integral and Istantaneous)
  - OCR: Output Counting Rate, number of Valid Events read (Integral and Istantaneous)

- **Board Info link:** By clicking on it, a Info Dialog Box is displayed with the following Hardware related information:
  - Model Name
  - Serial Number
  - ROC Firmware Release Version and Build
  - Number of Board Input Channels
  - AMC Firmware Release Version and Build
  - License Status

If an active ROI is available, the lower section of the Properties window contains information concerning that **ROI**:

- Uncertainty: related to the Centroid Calculation. Smaller contents of the bins yield larger uncertainty on the centroid value calculation.
- Centroid: the value of the peak centroid "bin" is indicated.
- FWHM: the peak Full Width at Half Maximum value is displayed.
- Range: The upper and lower limits of the ROI are displayed.
- Gross: The total number of counts in the ROI is displayed.
- Net: The number of counts in the ROI after the background subtraction is displayed.
- Net/Live: The number of counts in the ROI after the background subtraction and divided by the Live Time is displayed in counts/sec.
- Peak: The Peak Channel Value is displayed in counts.

Signal Inspector Window

The Signal Inspector tool allows the user to visualize the signal coming from the Nuclear Radiation Detector as well as the trapezoid filter signal applied to it, thus giving the user the capability to optimize if needed the filter parameters to ensure the best measurement conditions and the best read out resolution for any specific detector. Those settings can then be recorded to a "settings" file for successive data taking with that specific detector.

The **Signal Inspector Tool** can be accessed from the Icon Bar by clicking on the 4th Icon from the left

WARNING: when opening the Signal Inspector tool, a pop up window will inform the user that turning on the Signal Inspector sets the selected channel to Waveform Mode. This means that all raw signal digitized points are sent to the digitizer memory (instead of the reduced processed data that create the energy histogram in MCA Mode). This memory clogging may cause data loss in all the channels data acquisitions. Therefore, this procedure must not be carried on any channel of a board currently involved in important data acquisition. If this is the case, click on the "Cancel" key of the pop up window and return to the main program until the important data acquisition is finished.

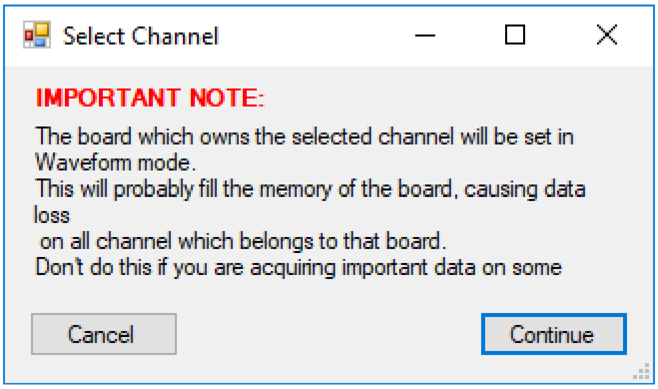


Fig. 4.18: The Select Channel window of the Signal Inspector

To proceed with the Signal Inspector tool click on the "Continue" key. The following Signal Inspector Screen will then appear, overlapping the area of the Histogram Screen. In order to select the channels to display, select the desired one in the **Spectra List** tab.

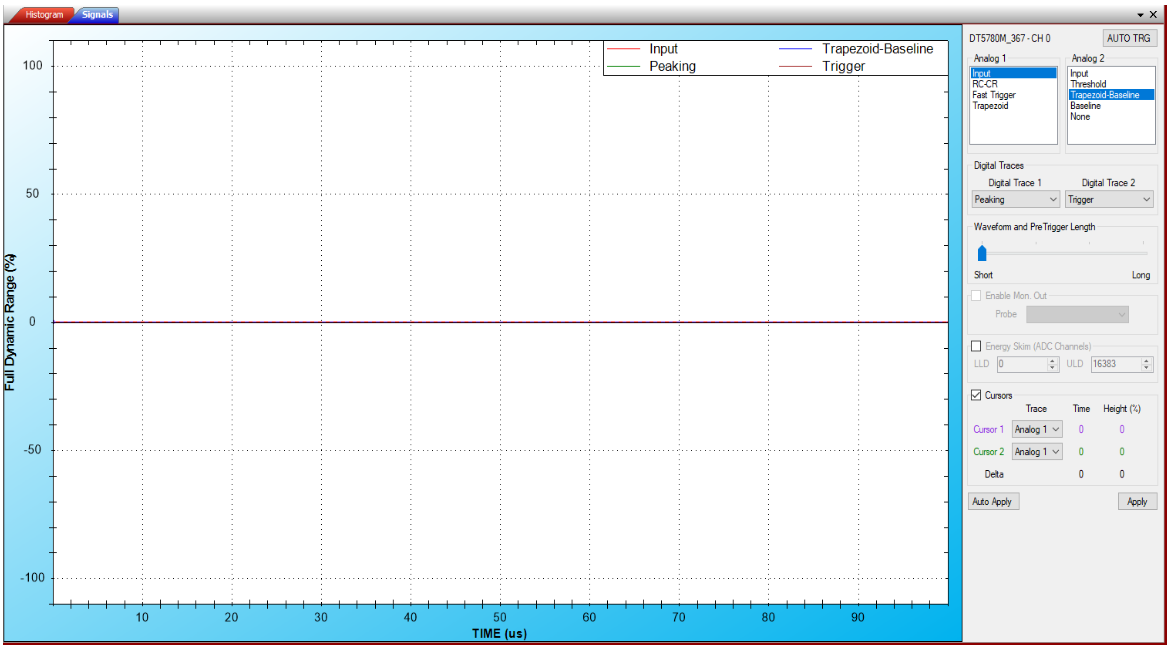


Fig. 4.19: The Signal Inspector Window

In the upper left corner of the window a **"Signals"** Tab is visible together with an **"Histogram"** Tab, allowing the user to toggle between the Signal Inspector and the Histogram screens to verify the results of the acquisition parameters set up on the acquired histogram.

The Signal Inspector Window is divided in two sections. To the left, a graphic display allows the user to visualize the waveforms as in a digital oscilloscope. To the right, a set up panel allows the user to set up the acquisition parameters and adapt them to the specific detector signal characteristics for an optimized result of the measurements. For the meaning of the acquisition parameters and to do this optimization properly refer to Chapter **Getting Started**

Acquisition Set-up procedure with the Signal Inspector Tool

The user can change at any time the Channel being inspected by selecting it on the Pull-Down Menu at the top of the Acquisition Set Up panel.

Note: To activate a command from the Acquisition Set up Panel, the **Apply** Key must be clicked after any selection to be implemented. If the user doesn't want to have to confirm each individual selection then the **AutoApply** key should be clicked at the beginning of the selections, then all selections made by the user will be immediately activated.

To operate with the Signal Inspector tool, the user must start the acquisition on the selected channel by clicking on the **Start Acquisition Icon** ( ). A first Analog trace will be visualized on the Histogram Screen.

- **AUTO:** This key enables a software Auto Trigger function, helping the user to find the signal when the trigger conditions are not still set.

The user can select the signal to be visualized on the Analog 1 selection box. Signals that can be chosen are (refer also to **Fig. 4.20**, and **Fig. 4.21**):

- **Input**: Displays the actual Input signal of the inspected board channel.
- **RC-CR**: Displays the First Derivative of the Input Signal.
- **Fast Trigger**: Displays the Fast Filter Signal.
- **Trapezoid**: Displays the Trapezoid Filter Signal.

A second Analog trace can be activated by ticking the Analog 2 check box. The Analog 2 Trace signals that can be selected are:

- **Input**: Displays the actual Input signal of the inspected board channel.
- **Threshold**: Displays the Trigger Threshold Level.
- **Trapezoid**: Displays the Trapezoid Filter Signal.
- **Trapezoid-Baseline**: Displays the Trapezoid Filter Signal at the Baseline Level.

In case of **DT5770** the user can select among the following Analog Traces 1 list:

- **Input**: Displays the actual Input signal of the inspected board channel.
- **Trapezoid**: Displays the Trapezoid Filter Signal.
- **Fast Trapezoid**: Display the Fast Trapezoid signal used to select the event.
- **Baseline**: Corresponds to the baseline of the Trapezoid trace.
- **Energy Out**: Displays the energy level sampled by the Trapezoidal filter.
- **Trapezoid-Baseline**: Displays the Trapezoid Filter Signal at the Baseline Level.

A second Analog trace can be activated also for the **DT5770**, choosing among:

- **Input**: Displays the actual Input signal of the inspected board channel.
- **Trapezoid-Baseline**: Displays the Trapezoid Filter Signal at the Baseline Level.
- **Baseline**: Corresponds to the baseline of the Trapezoid trace.
- **Fast Trapezoid**: Display the Fast Trapezoid signal used to select the event.
- **Trapezoid**: Displays the Trapezoid Filter Signal.
- **Energy Out**: Displays the energy level sampled by the Trapezoidal filter.

In case of **Hexagon** the user can select among the following Analog Traces 1 list:

- **Input**: Displays the actual Input signal of the inspected board channel.
- **Slow Trigger**: Displays the Slow Trigger signal used to improve the Signal/Noise Raion and Pulse Pair Resolution.
- **Fast Trigger**: Display the Fast Trigger signal used to select the event.
- **Baseline**: Corresponds to the baseline of the Trapezoid trace.
- **Trapezoid-Baseline**: Displays the Trapezoid Filter Signal at the Baseline Level.

A second Analog trace can be activated also for the **Hexagon**, choosing among:

- **Input**: Displays the actual Input signal of the inspected board channel.
- **Threshold**: Displays the Trigger Threshold Level.
- **Trapezoid-Baseline**: Displays the Trapezoid Filter Signal at the Baseline Level.
- **Baseline**: Corresponds to the baseline of the Trapezoid trace.
- **None**: does not display any trace.

Two additional Traces can be activated allowing the user to visualize the Digital Outputs available from the Board. The Digital signals will have a High or Low Status respectively when the corresponding function is enabled or disabled.

The Digital Trace 1 selections are (refer also to **Fig. 4.20**, and **Fig. 4.21**), if the firmware release is **<126.64**:

- **Armed**, digital input showing where the RC-CR2 crosses the Threshold;
- **Peak Run**, starts with the trigger and last for the whole event;
- **Pile Up Flag**, shows when a pile-up event occurred;
- **Peaking**, shows where the energy is calculated;
- **Trigger Validation Window**, shows the trigger validation acceptance window (refer to **[RD5]**);
- **Baseline Hold Off**, shows the baseline hold-off parameter;
- **Trigger Hold Off**, shows the trigger hold-off parameter;
- **Trigger Validation**, shows the trigger validation signal TRG_VAL (refer to **[RD5]**);
- **Saturation Veto**, shows when a saturation occurred that vetoed the acquisition;
- **Baseline Flatness**, monitor the oscillation of the baseline;
- **External Trigger**, shows the external trigger signal, if any.

The Digital Trace 1 selections are, if the firmware release is **>126.64**:

- **Armed**, digital input showing where the RC-CR2 crosses the Threshold;
- **Peak Run**, starts with the trigger and last for the whole event;
- **Pile Up Flag**, shows when a pile-up event occurred;
- **Peaking**, shows where the energy is calculated;
- **Trigger Validation Window**, shows the trigger validation acceptance window (refer to **[RD5]**);
- **Trigger Hold Off**, shows the trigger hold-off parameter;
- **Trigger Validation**, shows the trigger validation signal TRG_VAL (refer to **[RD5]**);
- **Saturation Veto**, shows when a saturation occurred that vetoed the acquisition;
- **External Trigger**, shows the external trigger signal, if any.

In case of **x725/x730** possible choices for Digital Traces 1 are:

- **Peaking**, shows where the energy is calculated;
- **Armed**, digital input showing where the RC-CR2 crosses the Threshold;
- **Peak Run**, starts with the trigger and last for the whole event;
- **Pile Up Flag**, shows when a pile-up event occurred;
- **Trigger Validation Window**, shows the trigger validation acceptance window (refer to **[RD5]**);
- **Trigger Hold Off**, shows the trigger hold-off parameter;
- **Trigger Validation**, shows the trigger validation signal TRG_VAL (refer to **[RD5]**);
- **Saturation Veto**, shows when a saturation occurred that vetoed the acquisition;
- **Baseline Flatness**, monitor the oscillation of the baseline;
- **External Trigger**, shows the external trigger signal, if any.
- **Baseline Freeze**, shows the time interval in which the baseline evaluation is freezed
- **Busy**, shows board busy condition due to a saturation or a memory full condition
- **Programmable Veto**, shows the duration of the VETO condition, if any.

The Digital Trace 2 allows to visualize only the **Trigger** output signal.

In case of **Hexagon** possible choices for Digital Traces 1 are:

- **Armed**, digital input showing where the Fast filter crosses the Threshold;
- **Peak Run**, starts with the trigger and last for the whole event;
- **Pile Up Flag**, shows when a pile-up event occurred;
- **Peaking**, shows where the energy is calculated;
- **Trigger Validation Window**, shows the trigger validation acceptance window (refer to **[RD5]**);
- **Baseline Freeze**, shows the time interval in which the baseline evaluation is freezed
- **Trigger Validation**, shows the trigger validation signal TRG_VAL (refer to **[RD5]**);
- **Saturation Veto**, shows when a saturation occurred that vetoed the acquisition;
- **Inhibit:** show the duration of the Inhibit signal;
- **External Trigger**, shows the external trigger signal, if any;
- **Busy**, shows board busy condition due to a saturation or a memory full condition.

The Digital Trace 2 allows to visualize only the **Trigger** output signal.

In case of **DT5770** possible choices for Digital Traces 1 and Digital Trace 2 are:

- **Peaking**, shows where the energy is calculated;
- **Energy Accepted**, shows whether the pulse is accepted or rejected;
- **Baseline Hold Off**, shows the baseline hold-off parameter;
- **Pile Up Flag**, shows when a pile-up event occurred;
- **Saturation**, shows when an event saturated the dynamics vetoing the acquisition;
- **Trigger**, shows the position where the input pulse is detected;

- **Reset**, shows where a reset occurred due to a transient reset.

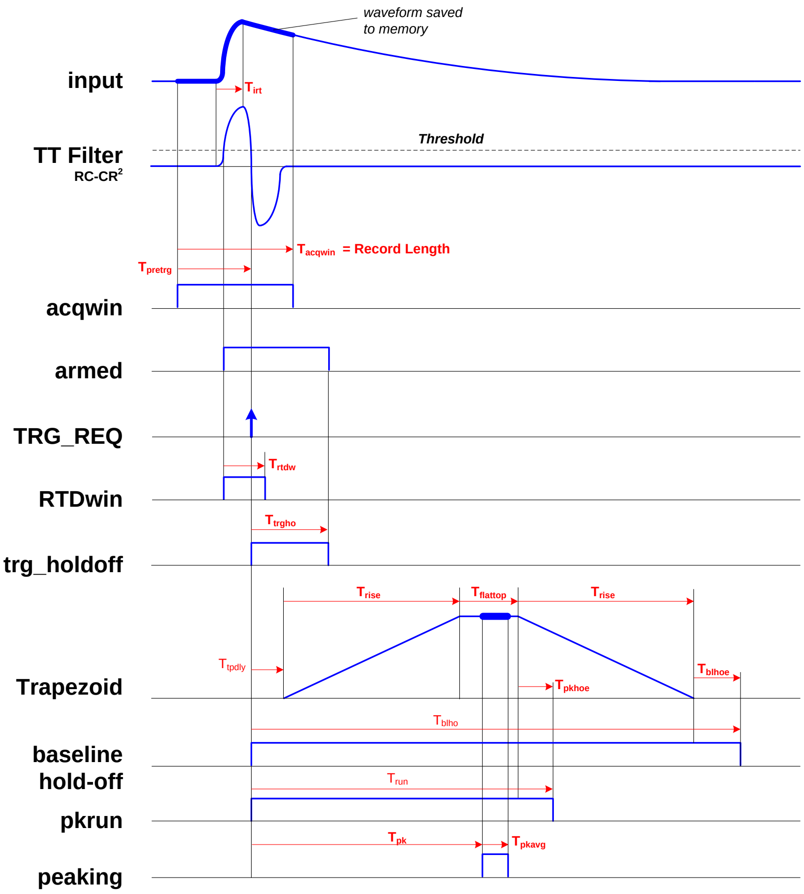


Fig. 4.20: DPP-PHA significant parameters

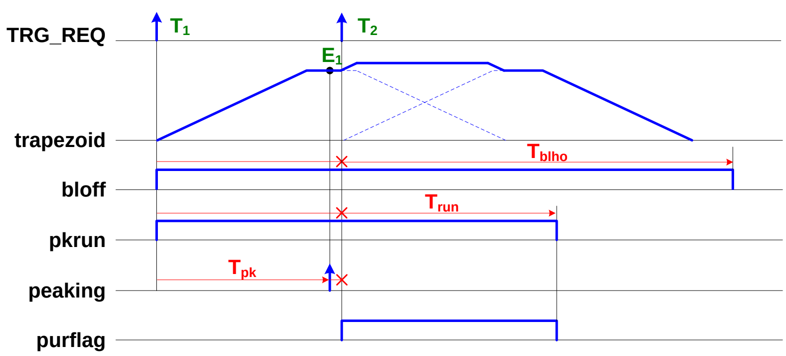


Fig. 4.21: DPP-PHA significant parameters for pile-up

The user can change the **Gain** and the **Offset** of the Traces being visualized by entering the desired values in the corresponding entry boxes “Gain” and “Offset”, for each trace independently. The changes can be operated as well with the up and down cursors on the side of the entry boxes, and does not affect the final acquisition.

The user can change the waveform record length and the pre-trigger length by operating on the sliding rule **“Waveform and Pre-Trigger Length”**

The User can also enable and set the **Energy Skim (ADC)**. The Energy Skim allows the user to select a region in the (not calibrated) energy spectrum and to inspect the waveforms that provides the energy values falling into the selected interval.

Note: The Energy Skim does not have any effect for x724-x780-x781 DPP-PHA firmware release less than 128.64.

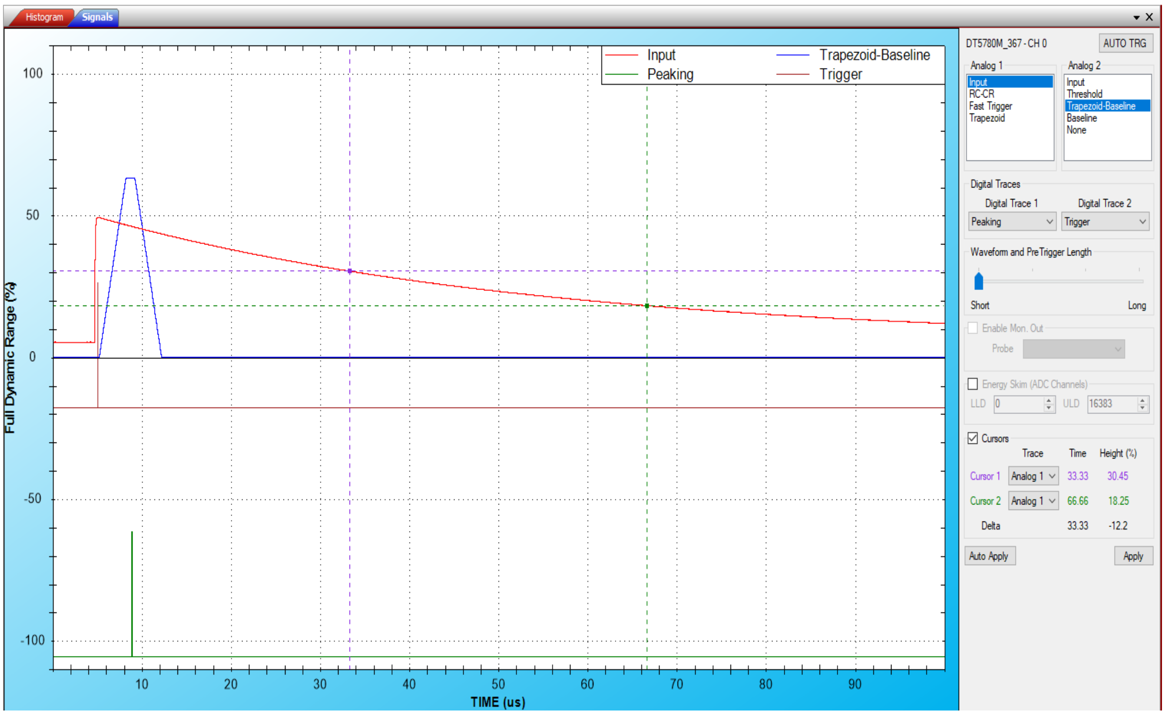


Fig. 4.22: Example of Signal Inspector acquisition

Acquisition Setup

The Acquisition Set Up Window can be accessed from the Acquisition Set Up Icon in the Icon Bar (3rd icon from the left) or from the Spectra List window Icon Bar.

To apply the selected parameters to the Hardware the user must Click on the **Apply** key after every selection. To avoid this step by step procedure the **Auto Apply** key can be clicked at the beginning of the selections, for all windows. Clicking on the **"Done"** key closes the Acquisition Set Up window and the hardware is set to the parameters that were entered until then.

At any time the user can cancel the last Entries Selection from the last set confirmed by the **"Apply"** key with the **"Cancel"** key. All other parameter settings entered until the last **"Apply"** confirmation will anyhow remain as set. At any time the user can restore the system parameters to the Default ones by using the **Brown Return Arrow Key**.

Upon clicking on the Acquisition Set Up icon, the Acquisition Set Up Window will appear as in **Fig. 4.23**:

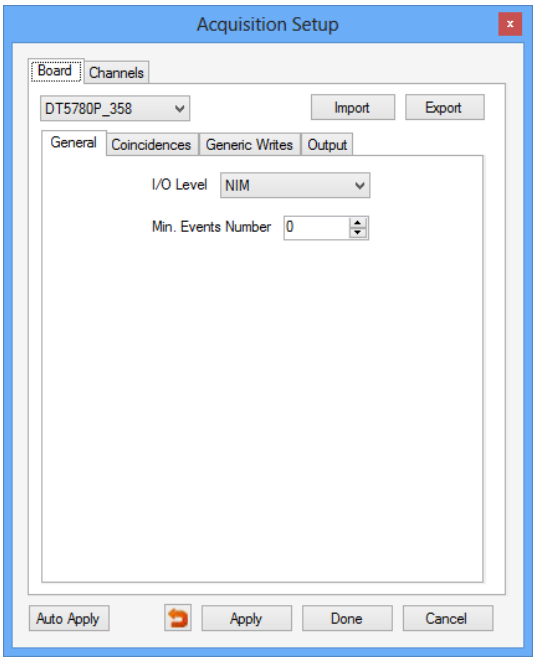


Fig. 4.23: The Acquisition Set Up Window – Board Tab - General Tab

The Acquisition Set Up window features a **Board** Tab and a **Channels** Tab

Board Tab

This tab allows the user to select the Board being set up, from the Pull-Down Menu.

The current settings can be Exported to a File in the desired Windows Directory by using the Export key. A set of parameters can be imported to the hardware from a previous Set Up File by using the Import key.

The **Board Tab** features the Tabs: **General, Coincidences, Generic Writes, Output.**

In case of DT5770 only the **GPIO** tab is available.

General Tab

The **I/O Logic Level** of the Board Digital Inputs/Outputs can be selected between NIM and TTL.

The **"Min. Events Number"** corresponds to the number of events per aggregate (refer to **Appendix A**) and corresponds to the minimum number of events to be acquired in the memory buffer before performing the read-out from the board. A larger value setting optimizes the data transmission system bandwidth while a smaller value improves the display rate. In case of very low rate input signals (few Hz) it is recommended to set a small value, like 1 or 2.

The **0** value indicates the automatic set up of the system.

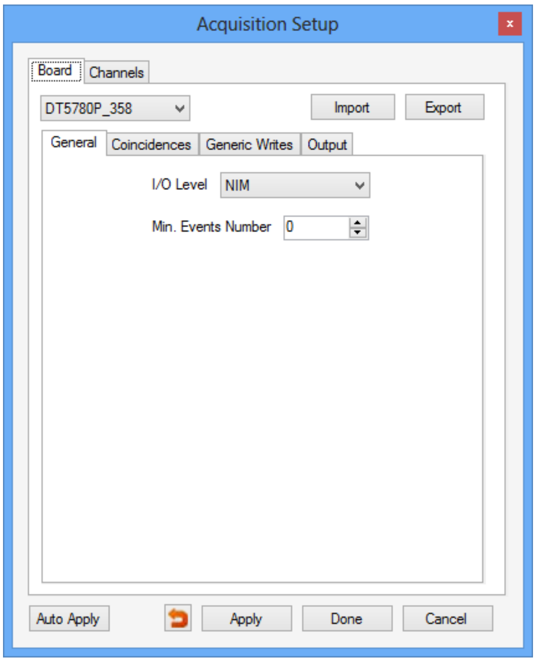


Fig. 4.24: The Acquisition Set Up Window – Board Tab - General Tab

The **"Apply"** button should be enabled to apply the settings. Press **"Auto Apply"** for the auto apply feature.

Settings can be saved through the **"Export"** command, and loaded through the **"Import"** button.

Coincidences Tab

Coincidence management among channels is described in **[RD5]**. In the normal acquisition mode, each individual channel is able to trigger with its individual self-trigger. When the coincidence mode is enabled, each channel continues to self-trigger, and the event is saved only when a validation signal occurs. The validation is made at the mother board level by configuring the desired operation among channels (choosing among OR/AND/MAJORITY) and the operation of COINCIDENCE/ANTICOINCIDENCE.

In case of 725 and 730 series channels are managed at couple level, and the validation might come also from the other channel of the couple with no mother board processing. The mother board controls the coincidence logic among couples, thus the two channels of couple cannot have different coincidence logic with the other couples.

Note: Coincidences with 725 and 730 series are not supported by the Coincidence window tab. User must set the relevant register writes using the Generic Writes Tab. Refer to **[RD5]** for all the details.

In the coincidence tab of the MC²Analyzer software (724/780/781 and 782 series only), the user can set the validation signal through a matrix (**C**), where for each row it is possible to write the corresponding validation mask. If an external trigger is available, it can be selected through the **E** box. **INV** allows to set the "anti-coincidence" acquisition mode, while the following pull down menu allows to select the operation (AND/OR/MAJ)

Coinc. Win. sets the "shaped trigger" width in us (**[RD5]**), corresponding to the coincidence window.

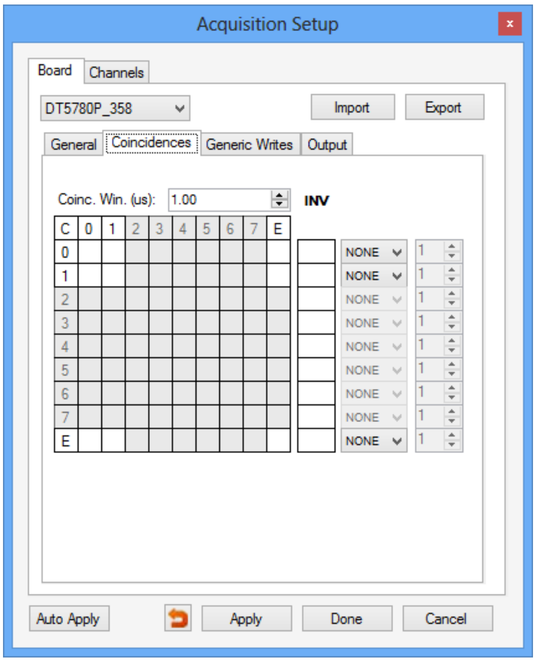


Fig. 4.25: The Acquisition Set Up Window – Board Section - Coincidences Tab

For example, to enable *the coincidence among channel 0 and channel 1*, the tab coincidence should appear as from **Fig. 4.26**. See more examples in **[RD5]**.

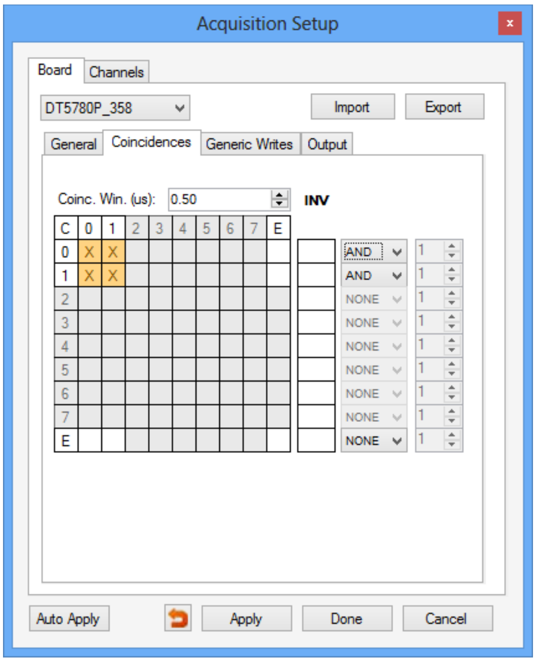


Fig. 4.26: The Acquisition Set Up Window – Board Section - Coincidences Tab. Coincidence on channel 0 and channel 1 enabled

In **Hexagon** the Coincidence tab allows additional functionalities.

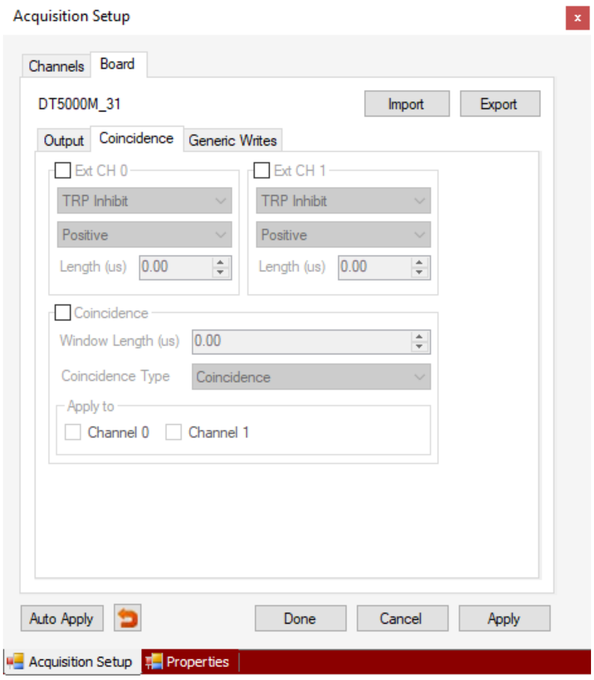


Fig. 4.27: The Acquisition Set Up Window – Board Section - Coincidences Tab (Hexagon Only).

The top section of the tab allows the user to enable the two front panel TRP-INH/GATE input, to select the desired functionality (TRP-Inhibit or Gate), the signal polarity and length (in µs).

The bottom section of the tab allows to enable or disable the coincidence mode setting the coincidence Windows Length (in µs), the Coincidence Type (Coincidence or Anticoincidence) and the channel at which this mode has to be applied.

Generic Writes Tab

The “Generic Writes” tab allows the user to direct access to board registers.

Click on **“Enable Generic Writes”** to enable this function.

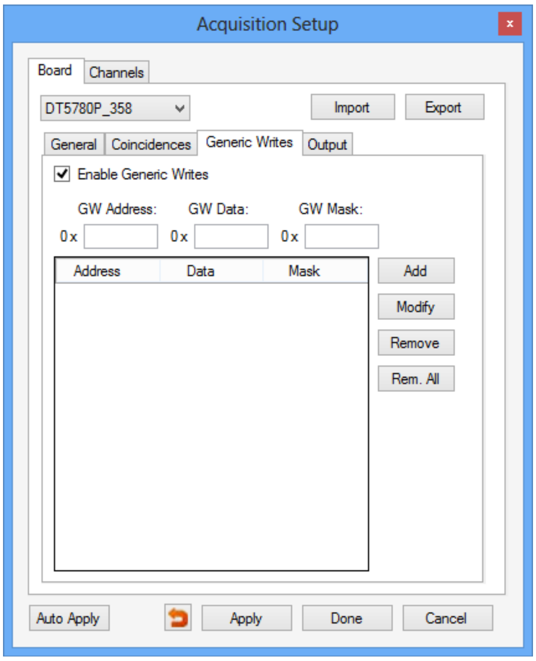


Fig. 4.28: The Acquisition Set Up Window – Board Section - Generic Writes Tab

Write on **“GW Address**” box the specific register address, on **“GW Data”** the value you want to write in the register, and in **“GW Mask”** the bit mask to be written.

Here some examples:

1. Set only bit [12] of register 1080 to 1, leaving the other bits to their previous value:

   GW Address = 0x1080, GW Data = 1000, GW Mask = 1000

2. Set bit [12] = 1 and bit [13] = 0 of register 1080, leaving the other bits to their previous value:

   GW Address = 0x1080, GW Data = 1000, GW Mask = 3000

3. Set register 1080 to the value of 0x45:

   GW Address = 0x1080, GW Data = 45, GW Mask = FFFFFFFF

By clicking on the **“Add”** key the GW set line is entered in the GW table. The user can change at any time a GW set by clicking on the correspondent line and then using the **“Modify”** key.

The user can also erase any single line by clicking on it and then using the **“Remove”** key. All GW sets can be removed at once by using the **“Remove All”** key.

Output Tab

The Output tab allows the user to save the output file in List mode option (see **Fig. 4.29**). Each triggered event is then saved with the information of Time Stamp, Energy, and Extras.

Note: The list mode option is not available on DT5770 MCA.

Click on the **"Enable List Mode"** to enable the tab options.

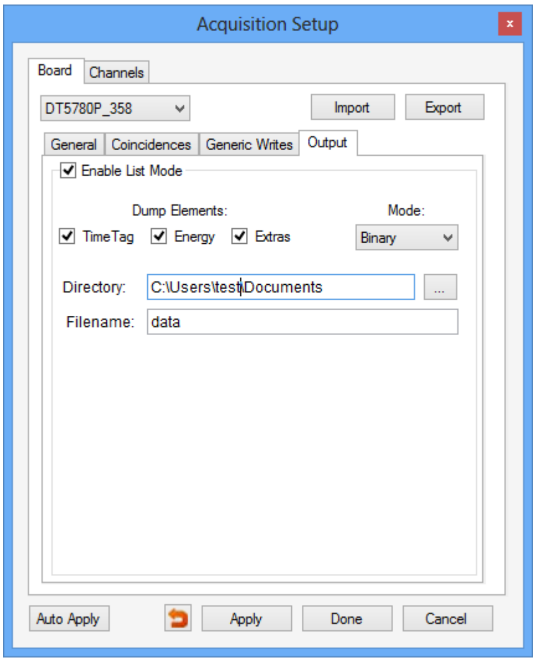


Fig. 4.29: The Acquisition Set Up Window – Board Section - Output Tab

Click on the check-box to telect which information is saved into the final output file, choosing among:

- **Time Tag**: this is the trigger time stamp, i.e. the time of arrival of the pulse. It is expressed in sampling clock unit, therefore the user has to multiply for the corresponding sampling clock to get the value in ns. Sampling clock values are: 10 ns for x724, DT5780, x781, x782, and Hexagon, 4 ns for x725, and 2 ns for x730.
- **Energy**: this is the energy value, expressed as a 15 bits number. Refer to the following Sec. **Histogram and list energy format (x724-x780-x781 DPP-PHA firmware release <128.64 only)** for more details.
- **Extras**: this is the value of the word EXTRAS, as read from the event structure. Refer to Sec **Channel Aggregate Data Format for 724, 780, 781 series (FW release <128.64)**, **Channel Aggregate Data Format for 724, 780, 781, and 782 series (FW release >128.64),** and **Channel Aggregate Data Format for 725 and 730 series** for more details.

It is possible to choose among **"Binary"** and **"ASCII"** under the **"Mode"** menu to select the output file format.

Finally the user can select the **Directory** for the data save and the **Filename**.

In **Hexagon** by default the list file includes the trigger time stamp and the energy while the user can optionally select to save the **Flags** and/or the **Fake Events.**These events are not PHA events (with Timestamp and Energy) but includes additonal information as per the following:

- MCS event: includes the information about the set Dwell time and the MCS counter (not controlled by MC2 Analyzer)
- Dead time events: includes the information about the current Real time and Dead time (useful to recalculated the live time information from the list file)
- Last event: includes the information about the actual time in which the acquisiton stops

The list file is saved in the Hexagon local memory and can be accessed and download through the Web Interface (See **[RD13]** for reference).

The Flags are the following:

- 0x1: First event after a deadtime occurrence
- 0x2: Timetag rollover
- 0x4: Timetag reset
- 0x80: Event energy saturated
- 0x400: Input dynamics saturated event
- 0x8000: Pile-up event
- 0x20000: Event energy is outside the SCA interval (only if SCA is enabled)
- 0x40000: Event occurred during saturation inhibit

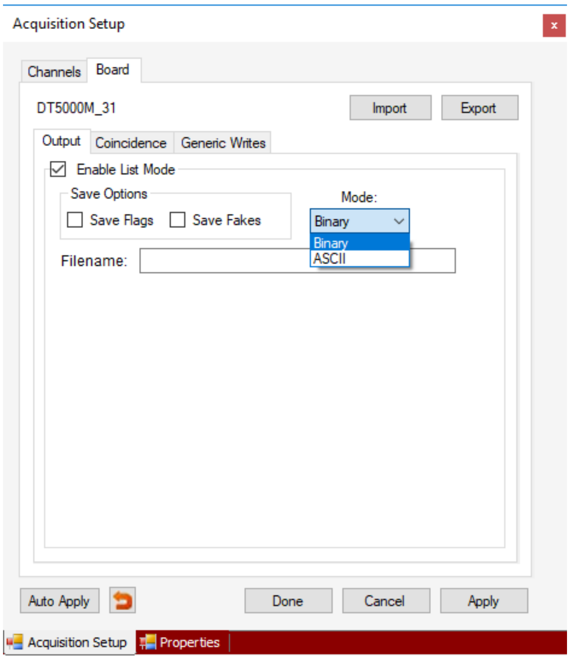


Fig. 4.30: The Acquisition Set Up Window – Board Section - Output Tab (Hexagon only).

The list file dump starts as soon the user starts the acquisition and stops with the stop acquisition.

A warning message will appear at the bottom of the GUI when the list dumping is enabled.

Note: remember to increment the file name index. A new start acquisition will increment the previous data file, without creating a new file.

Header file format

Note: Hexagon binary data format has no header. The list file begins with the event data. Per each events timestamp (if enabled), energy (if enabled) and flags (if enabled) are written in this order.

In case of binary dumping the file header has the following structure:

<table>
<tr><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td><td>BIT</td></tr>
<tr><td colspan="16"></td><td colspan="8">NWORDS HEADER</td><td colspan="8">PROTOCOL VERSION</td><td>HEADER 0</td></tr>
<tr><td colspan="24">TYPE FORMAT</td><td colspan="8">DATA TYPE</td><td>HEADER 1</td></tr>
<tr><td colspan="24">TYPE FORMAT</td><td colspan="8">DATA TYPE</td><td>HEADER 2</td></tr>
<tr><td colspan="24">. . .</td><td colspan="8">. . .</td><td>. . .</td></tr>
<tr><td colspan="24">TYPE FORMAT</td><td colspan="8">DATA TYPE</td><td>HEADER n</td></tr>
</table>

Fig. 4.31: Header file structure

The first word of the header describes the header itself, where:

- Bits[7:0] describes the protocol version number;
- Bits[15:8]: corresponds to the number of words of the header itself, including the first word;
- Bits[31:16]: reserved.

Note: the number of bits will be unchanged also for future protocol versions.

From “Header 1” to “Header n” the corresponding word identifies the type of data to be read in the list:

- Bits[7:0]: describes the **“Data Type”** of the event that has been saved into the list. Each header corresponds to a different type, i.e. to a different information saved for each event. The complete list is described below:
  - 0 = Trigger Time Tag type (which is the trigger time stamp)
  - 1 = Energy type
  - 2 = Extras type
  - 3 = Short Energy type (for DPP-PSD only)
  - 4 = DPP Code
  - 255 = Fake (in case of error)
- Bits[31:8]: corresponds to the **“Type Format”** of the corresponding type of the word. Possible choices are:
  - 0 = INT8;
  - 1 = UINT8;
  - 2 = INT16;
  - 3 = UINT16
  - 4 = INT32;
  - 5 = UINT32;
  - 6 = INT64;
  - 7 = UINT64;
  - 8 = STRING;
  - 9 = LONG;
  - 10 = DOUBLE;
  - 11 = CHAR;
  - 255 = none.

For any DPP firmware the **protocol version 1** is organized as follows, where words from “Header 1” to “Header 4” identify the type of information in the list dump. Note: not all the information is available for any DPP firmware:

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	BIT

	NWORDS HEADER	PROTOCOL VERSION	HEADER 0
Trigger Time Tag Format		Trigger Time Tag	HEADER 1
Energy Format		Energy	HEADER 2
Extras Format		Extras	HEADER 3
Short Energy Format		Short Energy	HEADER 4
DPP Code Format		DPP Code	HEADER 5

Fig. 4.32: Header file structure for DPP firmware

The order of Header words defines the order to read the data list.

For example, in case the header has the following structure:

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	BIT

	0x5	0x1	HEADER 0
0x7		0x0	HEADER 1
0x2		0x1	HEADER 2
0x5		0x2	HEADER 3
0x80		0x4	HEADER 4

the user must read 5 words of header, and the data format has to be read as:

- Trigger Time Tag (uint64);
- Energy (int16);
- Extras (uint32)

i.e. 8 Bytes of Time Tag, 2 Bytes of Energy, and 4 Bytes of Extras.

The DPP code 0x80 corresponds to the DPP-PHA for x724, DT5780, x781, x782.

Note: In the ASCII format file the header words has to be read as in the binary format. For each event in the list there is a corresponding column with the event type as described in the header.

Histogram and list energy format (x724-x780-x781 DPP-PHA firmware release <128.64 only)

The input waveform is sampled by a 14 bit ADC, then the firmware implements the digital trapezoid filter as described in Sec. **CAEN Digital Approach** to evaluate its energy. Depending to the programmed parameters, the evaluated energy inside the FPGA can be expressed as a number of maximum 48 bits.

The energy information in the list file is expressed as a 15 bit value, which is a simple truncation of the original 48 bit value, taking the most significant bits. The position of most significant bit depends on the trapezoid rise time (k) and on the input signal decay time (M). The 15 bits value is the most accurate value we can get from the DPP-PHA algorithm. Anyway, some numerical value are not decoded, therefore the energy values do not range from 0 to 2^{15}, but from 0 to a value between 2^{14} and 2^{15}, again depending on k and M.

The histogram shown in the MC^{2}Analyzer software is made with a conversion of the (hypothetical) 15 bit histogram provided by the digitizer into a 14 bit histogram. The final bin content is obtained "splitting" the content of the starting bins.

The conversion factor (F) can be get as follows. Knowing the signal decay time (M), the trapezoid rise time (k) -- both expressed in sampling unit (10 ns), and the trapezoid gain (g), it is possible to evaluate a factor G=M*k*g. This number has to be divided by the closest power of 2 to G, where the exponent is unknown. The exponent (integer) can be found through the following inequality:

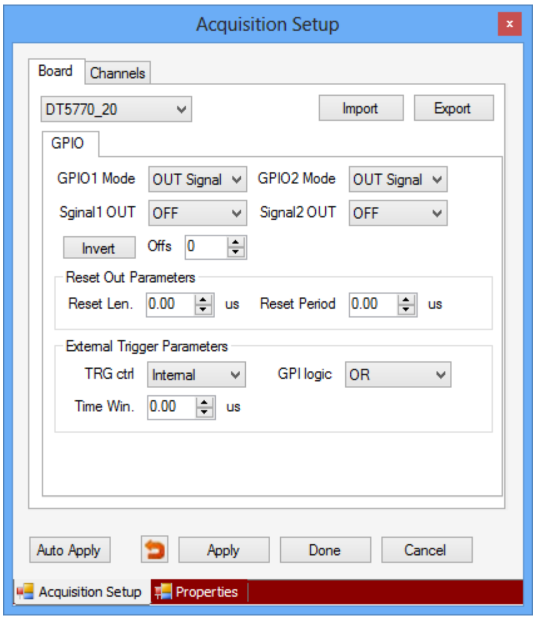
$$1 \leq F < 2, where\ F = \frac{G}{2^n}\ and\ G = M \cdot k \cdot g$$

The conversion factor is F = G/(2^n), which is a floating number.

The spectrum linearity is conserved on both spectra.

GPIO Tab

The **GPIO Tab** is available on DT5770 MCA only.



The GPIO 1/2 can be configured as:

- Signal – OUT mode;
- Trigger – IN mode;
- Reset – IN mode.

In case of Signal 1 OUT the user has a list of digital traces that can be used for many purposes. Options are:

- **OFF**: disabled;
- **Energy Sampled**: corresponds to the point where the energy of the trapezoid is evaluated;
- **Baseline Sampled**: correponds to the samples where the baseline is averaged;
- **Reset Detected**: digital probe which is high when there is a reset. It stays high for the whole reset duration;
- **Running**: digital probe which is high for the whole acquisition run;
- **Saturation**: corresponds to the signal saturation;
- **Pile Up Rej**.: this probe is high when the last event is rejected due to a pile-up condition;
- **Pile Up Inh**.: corresponds to the time the board is inhibited due to a pile-up condition;
- **Reset Periodic**: programmable output to generate a periodic reset. Settings can be configured through the above panel "Reset Out Parameters";
- **CLKHALF**: propagation of the clock out. The clock has half frequency of the internal clock;
- **Baseline Inh**.: corresponds to the samples where the baseline is not evaluated;
- **SCA 1/2**: single channel analyzer 1/2.

In addition to those digital probes the user can also choose to provide out an analog signal, through a 10 bit DAC with 62.5 MS/s (Signal 2 OUT only). Options are:

- **Input**;
- **Fast Trapezoid**;
- **Baseline**;
- **Trapezoid**;

- **Sampled Energy**;
- **Trapezoid-Baseline**.

It is possible to invert and set an offset for the traces, through the button **“Invert”**, and the field **“Offs”**.

The “Reset Out Parameters” allows the user to set the length and the period of the reset signal out through **“Reset Len.”** and **“Reset Period”** in us unit. This option is available only when the option **Reset Periodic** is enabled.

The panel **“External Trigger Parameters”** allows the user to set the Trigger IN modes, choosing among:

- **Internal**: this is the default configuration, where the external trigger is not enabled;
- **Gate/Veto**: the trigger works as a gate/veto. The trigger logic senses to the signal level;
- **Gate/Veto Win.:** the trigger works as a gate/veto. A programmable time window can be set through the box **“Time Win.”**;
- **ON/OFF**: manages the start/stop acquisition;
- **Coincidence**: the trigger enable the acquisition which stops at the first input pulse.

The two GPI can be combined through the **AND**/**OR** logic selecting the corresponding option in the box **“GPI logic”**.

Channels Tab

The **Channels Tab** allows the user to set the acquisition parameters for the active channels in the system.

The Live Channels being set are associated with the correspondent Default Spectra which appear in the Pull-Down menu in the upper left corner of the Channels Tab.

- **Autoset:** When this key is used, the system analyses the current detector signals and an evaluation algorithm is run to establish the best fit parameters. This may take some time, usually less than 1 minute for each channel. There is a timeout of 5 minutes per channel. If the system is unable to find an optimized set of parameters within the timeout, a pop up window will indicate the system inability to autoset.
  To avoid a specific parameter entry to be modified by the Autoset automatic procedure, the user can click on the Lock icon to the right of that specific entry description before applying the Autoset command. A yellow background in the Lock Icon will indicate the nearby entry is locked against changes when the Autoset function is used.
- **Import:** This key allows the user to import to the hardware a set of parameters from a saved file.
- **Export:** This key allows the user to save the current set of acquisition parameters to a file.

The **Channels Tab** features the following Tabs: **Input Signal, Trigger** and **Energy Filter**

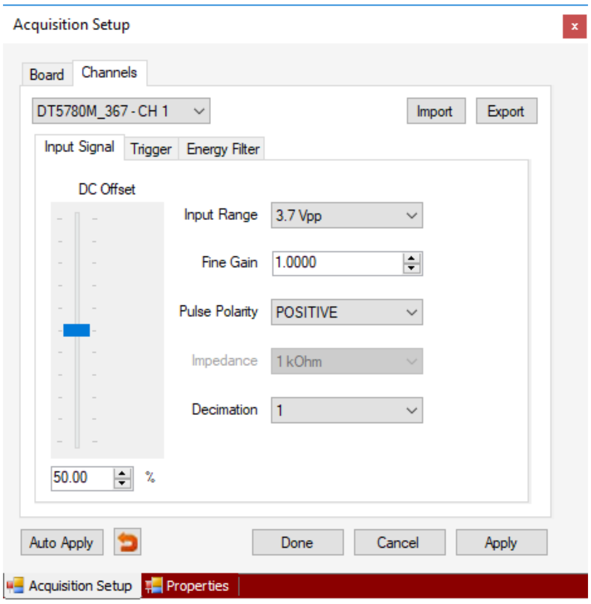


Fig. 4.33: The Acquisition Set Up window – Channels Tab - Input Signal Tab

The **Input Signal Tab** allows the user to operate on the following hardware commands:

- **DC Offset:** The DC offset value can be set using the vertical slider or entering the value in percentage in the entry box below it.
- **Input Range:** The user can select the following Input Full Scale Values. Options are:
  - 0.5, 2 Vpp for 730 family;
  - 1.25, 2.5, 5.0, 10.0 Vpp for the DT5770;
  - 0.6, 1.4, 3.7, 9 Vpp for the 780 family;
  - 0.3, 1, 3, 10Vpp for the 781 family;
  - x0.25, x0.5, x1, x2, x4, x8, x16, x32, x64, x128, x256 for Hexagon;
  - x1, x2, x4, x8 for the V1782;
  - <u>not available for x724 digitizer family</u>.
- **Fine Gain:** The user can set the Fine Gain from x1 to x10 by entering the value in the entry box or incrementing and decrementing it with the Up and Down Arrows.
- **Pulse Polarity:** The user can select the following Polarity Values: POSITIVE or NEGATIVE
- **Impedence:** The user can select the impedance of the input stage (DT5770 only)
- **Decimation:** The user can select the following Input Decimation Values: :1 - :2 - :4 - :8. <u>The decimation is not available for DT5770, for x724-x780-x781-x782 DPP-PHA firmware release higher than 128.64 and Hexagon</u>

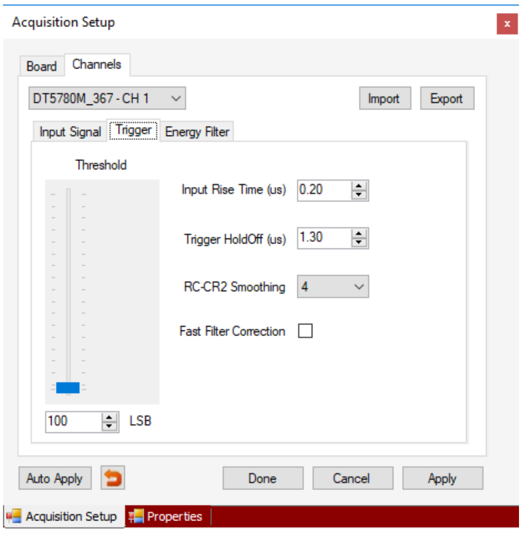


Fig. 4.34: The Acquisition Set Up Window – Channels Section - Trigger Tab

The **Trigger Tab** allows the user to operate on the following hardware trigger commands:

- **Threshold**: The threshold value con be set from 0 to the Max Number of Channels (Bins) in LSB.
- **RC-CR2 Smoothing**: The RC-CR^2 input signal second derivative smoothing value can be selected between 4 -8 – 16 and 32.
- **Trigger Hold Off**: The Trigger Hold Off Time, during which trigger signals will not be accepted by the digitizer can be set in microseconds.
- **Input Rise Time:** This is a value set to optimize the shape the RC-CR^2 signal used to trigger the board channels. Maximum allowed value is 2.55 us (1.27 us in case of Hexagon).
- **Fast Filter Correction:** It allows the user to correct the slow tail of the the RC-CR^2 taking into account the Decay Time value set on the Energy Filter Tab. It does not have any effect for x724-x780-x781 DPP-PHA firmware release less than 128.64.

In case of **DT5770** the following options are available, where the **"Threshold"**, and the **"Fast Trap. Rise"** are referred to the Fast Trapezoid trace:

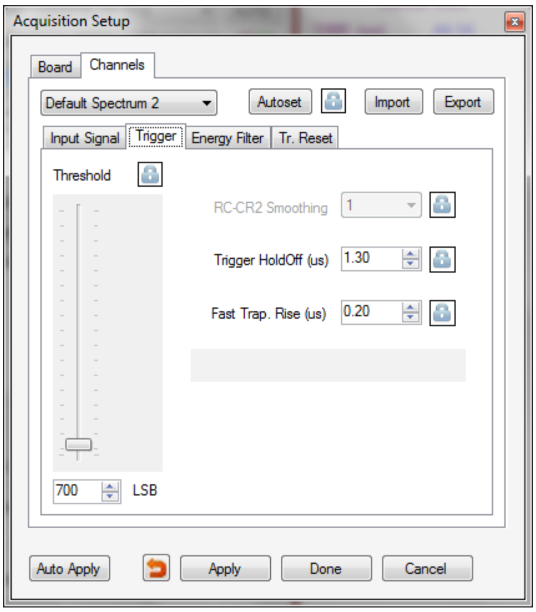


Fig. 4.35: The Acquisition Set Up Window – Channels Section - Trigger Tab in case of DT5770

The **Energy Filter** Tab allows the user to set the following Spectrum Data processing values (see **Fig. 2.7**):

- **Baseline Mean**: The baseline mean can be calculated on the following range of Spectrum Channels: 0-16-64-256-1024-4096-16484. For Hexagon, three options are available: Slow, Medium, Fast.
- **Baseline Clip**: It disable the baseline calculation in case of events whose profile is not well defined and so not triggered by the fast timing filter. It does not have any effect for x724-x780-x781 DPP-PHA firmware release lower than 128.64.
- **Trapezoid Rise Time:** The user can set the Trapezoid Rise time from 0 to 10.20 microseconds in 0.01 microseconds steps (40.95 us in case of Hexagon).
- **Decay Time:** The user can set the Trapezoid Decay time from 0 up to 655.35 microseconds, in 0.01 microseconds steps
- **Trapezoid Flat Top:** The user can set the Trapezoid Flat Top Width Value from 0 to 10.20 microseconds in 0.1 microseconds steps (20.47 us in case of Hexagon)
- **Trapezoid Delay:** The user can set the Trapezoid Peak Delay Value from 0% to 95 % in 0.1% steps.

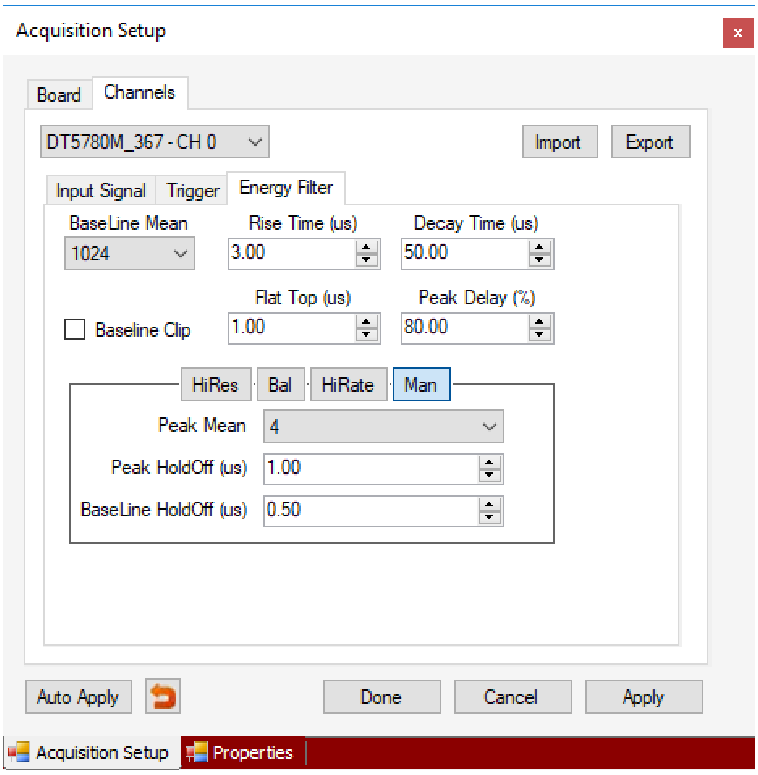


Fig. 4.36: The Acquisition Set Up Window – Channels Section - Energy Filter Tab

Note: the sum of the Trapezoid Rise Time and Flat Top should not exceed 15 us times the Decimation value for 724, 780, and 781 series (decimation no longer available for FW revision greater than 128.64), 16 us times the Decimation value for 725 series, and 8 us times the Decimation value for 730 series.

Note: the maximum values can be increased by using the Decimation. See Sec. **How To use Decimation** for a specific example.

HiRes: This key enables a Set of Hold Off Parameters optimized for the best spectrum resolution.

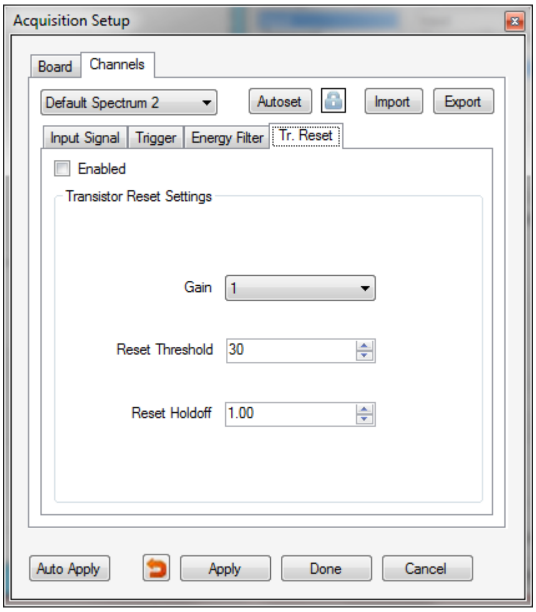
HiRate: This key enables a Set of Hold Off Parameters optimized to minimize the dead-time.

Bal(anced): This key enables a Set of intermediate Hold Off Parameters balanced for best compromise between High Resolution and High Rate acquisition.

Manual: This key enables the manual setting of the Hold Off Parameters.

In case of DT5770 an additional tab is available to control signals from transistor reset preamplifier. The tab is called **"Tr. Reset"**. The shaping time of the Transient Reset is about 1.6 us.

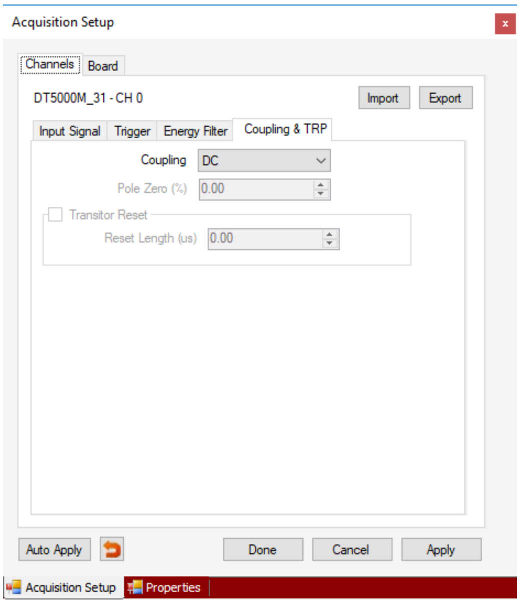
Click on **"Enabled"** to enable this feature.



It is possible to set:

- **Gain**, whose options are: 2-5-7-11-16-21-33-40-50-70-88-110;
- **Reset Threshold**, which corresponds to the input threshold under which the board enable the reset (LSB unit);
- **Reset Holdoff**, which corresponds to the holdoff due to the reset condition (us unit).

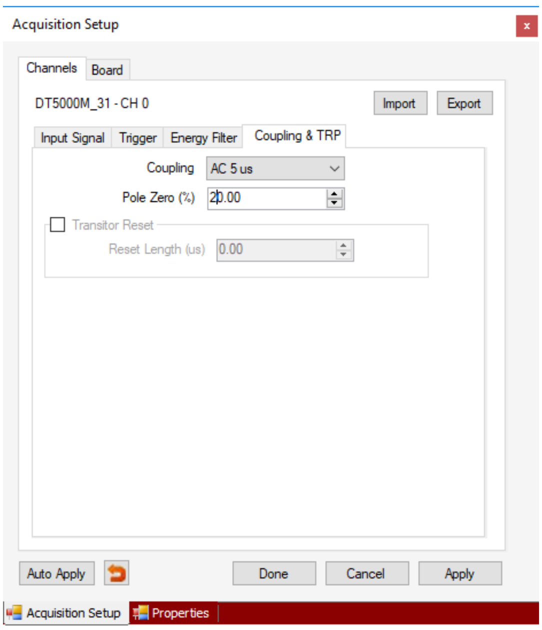
In case of Hexagon an additional tab is available called “**Coupling/TRP**”.

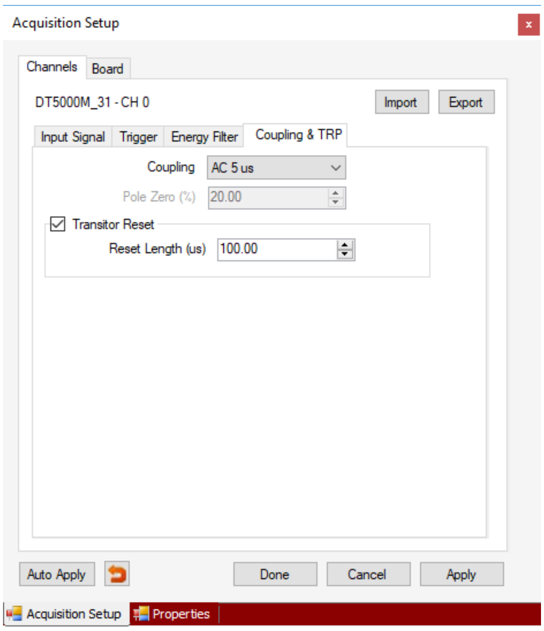


The user can select the input DC/AC coupling. **DC coupling** must be selected in case of Charge Sensitive Preamplifier, while **AC coupling** must be selected in case of Resistive Feedback and Transistor Reset Preamplifier. The user can choose between 5, 10 and 30 µs of shaping. In this case he/she must set the Trapezoid Decay Time according to set value.

In case of **Resistive Feedback** preamplifier the user have to compensate the **Analog Pole Zero** by setting the percentage value (left figure).

In case of **Transistor Reset** preamplifier there is no analog pole to compensate and the user has only to checkmark the corresponding box and set the **Reset Length**, i.e. the inhibit time due to the reset discharge. The latter should be set at a value at least equal to ten times the selected AC shaping time.





Spectra List Window

The Spectra List Windows can be accessed from the *Tools/View/Windows Pull Down Menu*.

Upon clicking on the item the following window appears:

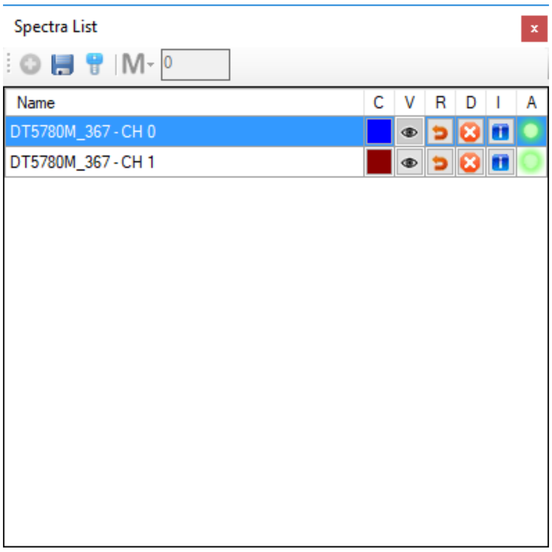
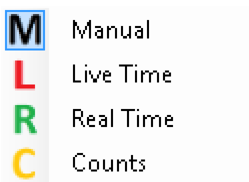


Fig. 4.37: The Spectra List Window

The Spectra List allows the user to Acquire, Save, Resume Acquisition, Recall from a Directory **the selected spectrum**. The Spectra List Window features an Icon Bar and a Spectra List Table.

Spectra List Icon Bar:

- **Save Spectrum** : Opens a Windows Directory and allows the user to save the Spectra file into the desired folder.
- **Configure Acquisition** **:** Allows the user to configure the acquisition system (see Section **Acquisition Setup** for setting procedures).
- **Stop Acquisition Criteria:** Acquisition will stop upon reaching one criteria among:



To manually stop the acquisition
To stop on a specified Live Time;
To stop on a specified Real Time;
To stop on a specified total counts number;

Note: all the spectra list commands act on a single channel. To work with all the channels simultaneously use the main GUI commands.

Under the Spectra List Icon Bar there is the Spectra List Table. Every line corresponds either to an activated live acquisition channel spectrum either to a recalled file spectrum. All Spectra Files listed in the Spectra Table are tagged by their Filename followed by 5 interactive icons and the Acquisition Status LED referred to that file.

Note: click on the letter to act to all enabled spectra in the "Spectra List" window, while click on the icon to act on the single selected spectrum.

Spectra List Table Header:

- **Name**: This is the name either of a recalled spectrum file or of the file where an active live channel acquisition is being written to. This can be determined at a glance by looking at the Acquisition Status LED color (See the Item A in the list below)
- **C: Color** . Allows the user to select a color for the corresponding Spectrum graphic representation
- **V: Toggle Visible/Invisible** . When two or more spectra are being acquired or recalled to the screen, this icon allows the user to toggle the correspondent spectrum away from the screen and back on it.
- **R: Reset spectra** . This icon allows the user to clear the selected spectrum. **Keyboard shortcut F10.**
- **D: Delete File** . This icon allows the user to delete the selected (highlighted) spectrum file.
- **I: Information** : This icon recalls the Board Information Dialog Box (see **Fig. 4.17**).
- **A: Acquisition Status LED** . This LED indicates whether the Spectrum is being acquired in real time (light green/red) or recalled from file (dark green). When it turns red the board is busy due to a dynamics saturation or to memory busy.

Cursor Window

The Spectra Cursor window allows the user to read the histogram Y-axis value in correspondence with the X-axis Channel indicated by the Crosshair Cursor. The X- axis value can be also entered into the Channel entry box. Upon confirmation with the Enter key of the keyboard, the correspondent Y-axis value is displayed.

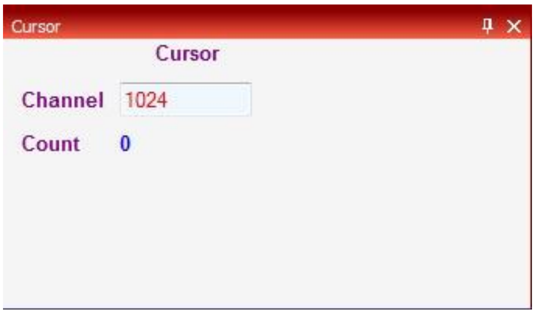


Fig. 4.38: The Cursor Window

ROI Editor Window

In the ROI Editor window the user can define one or more Regions Of Interest. Left clicking on the Create ROI item opens the ROI Editor window (unless it was already open). Default position is leftmost under the Graph Window.

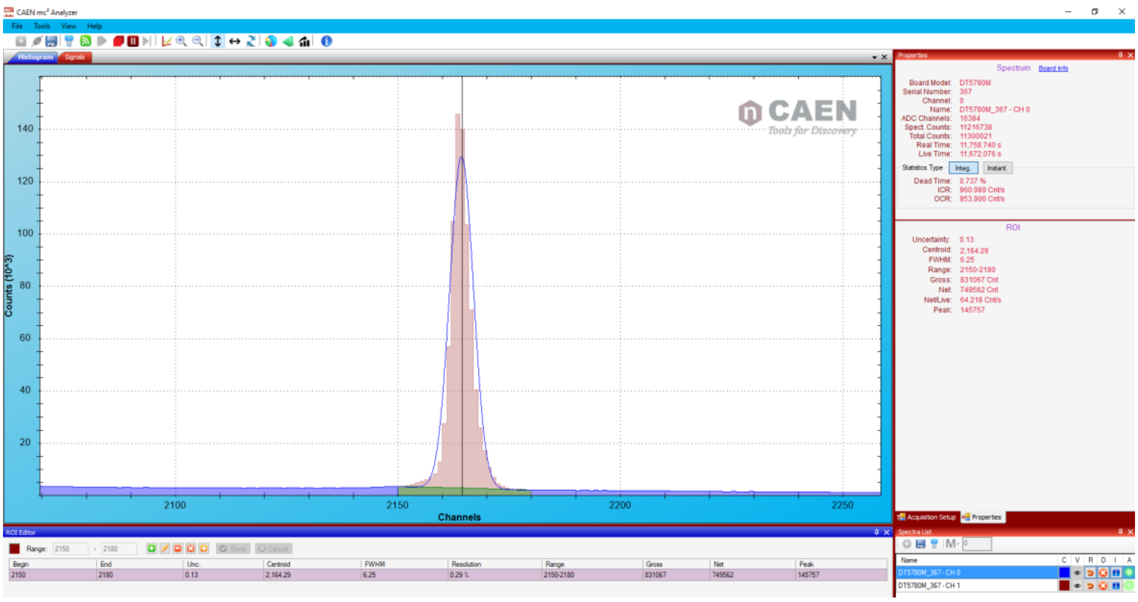


Fig. 4.39: MC²Analyzer Main Screen Graph with ROI Editor window

In the ROI Editor Window, a new ROI can be set by the user by left clicking on the green **"+"** key to the right of the Range Entry boxes and then by:

- typing the values corresponding to the leftmost channel of the ROI in the first "Range" entry box and the value corresponding to the rightmost channel of the ROI in the second "Range" entry box.
- either, placing the crosshair cursor of the graph on the leftmost point of the ROI to be defined and left clicking on it. A vertical marker line with a red arrow will indicate the left border of the ROI. Then by placing the crosshair marker on the rightmost point of the ROI being defined and left clicking on it, a second vertical line marker with a red arrow will mark the rightmost border of the new ROI. At the same time the new ROI line will be added to the table of ROIS in the ROI Editor Window, and a best fit curve of the ROI will be drawn on the graph.

The user can select a **color** to characterize the ROI regions of the graph by clicking on the square to the left of the "Range" entry boxes.

Additional ROIs can be created by repeating the above procedure, starting by clicking on the green "+" key. The selected color will apply to all the ROIs in the graph.

The user can **modify a ROI** by clicking on the second key over the ROI Table then redefining the ROI either with the crosshair marker graphic procedure or by entering the new numeric Begin and End border values in the corresponding entry boxes.

The user can **delete a single ROI** by clicking on the **"-"** red key over the ROI Table then left clicking on the correspondent line in the ROI Table and confirming the ROI cancellation in the dialog box that opens up.

The user can **delete all ROIs** by clicking on the **"X"** red key over the ROI Table then confirming the ROIs cancellation in the dialog box that opens.

Once the ROI is selected, the following data will be automatically displayed in the ROI Editor window last line:

- **"Begin":** number of the first ROI channel.
- **"End":** number of the last ROI channel.
- **"Unc.":** Uncertainty, referred to the Centroid position.
- **"Centroid":** Number of the channel corresponding to the Centroid of the Peak, calculated with the above Uncertainty.
- **"FWHM":** This is the value of the Full Width at Half Maximum of the peak, expressed in channels.
- **"Resolution":** This is the value of the peak resolution expresses in percentage.
- **"Range":** Indicates the ROI Range (from initial channel to final channel)
- **"Gross":** indicates the Gross count value, as counted in the whole ROI.
- **"Net":** indicates the net value of the counts in the whole ROI, corresponding to the Gross counts less the Background value within the ROI.
- **"Peak":** indicates the number of counts in the channel corresponding to the highest peak of the ROI.

MC2Analyzer Energy Calibration

The Energy Calibration of a Spectrum is performed by measuring the spectra of known radio isotopic sources and by assigning Energy values (In keV or in MeV) to the number of the spectrum "bins" or "channels" where the peaks of corresponding known peak energies of the radiation emitted by the source have been located. By calibrating a spectrum with at least two peaks values it is possible to interpolate the value of all other channels. For example, a classic calibration for gamma spectra includes the two photopeaks of the ^{60}Co respectively at 1,17 MeV and at 1,33 MeV, and the photopeak of the ^{137}Cs at 662 keV.

To perform the calibration on the MC²Analyzer Spectra, a calibration spectrum should be uploaded, either from file or from a channel in live acquisition from a known calibration source. The user can then left click on the **Enable Calibration Set up Icon** in the Icon Bar (see **Fig. 4.40**).

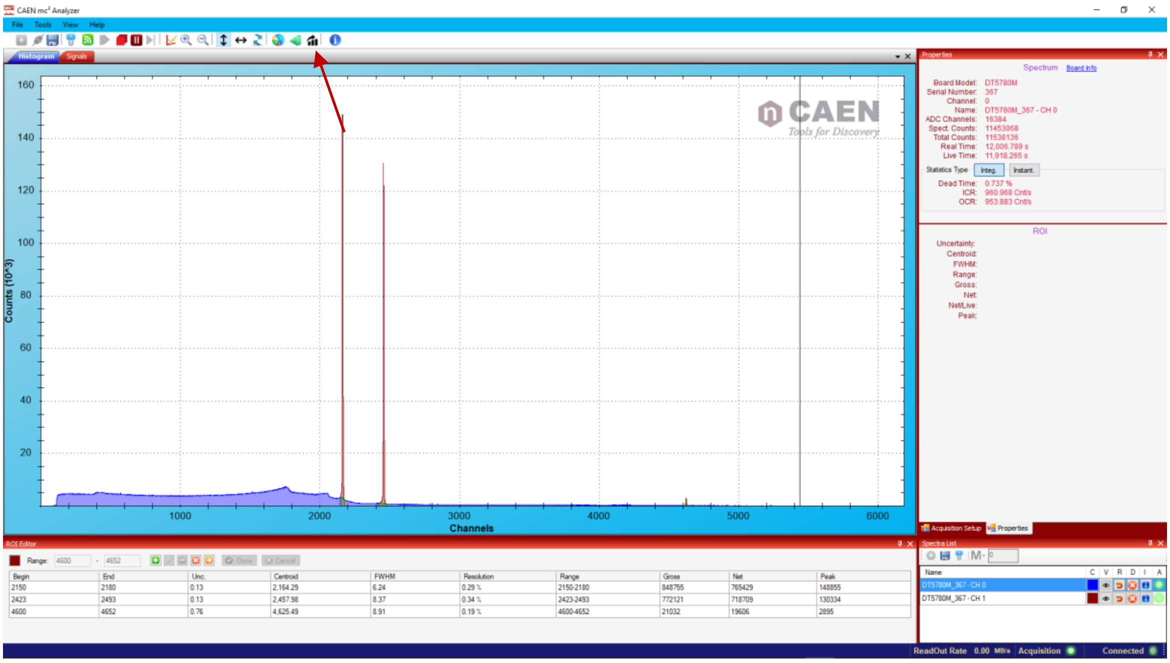


Fig. 4.40: MC²Analyzer Enable Calibration Set up Icon

This icon function enables the user to enter the relevant energy calibration data. Upon clicking on the icon, if no calibration values were previously entered in the program, the following dialog box appears:

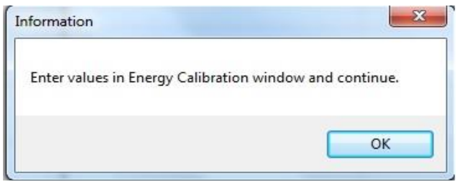


Fig. 4.41: MC²Analyzer Energy Calibration Pop Up Confirmation window

Upon clicking on "OK", or if previous values have been entered in the MC²Analyzer program, the following Energy Calibration Window appears:

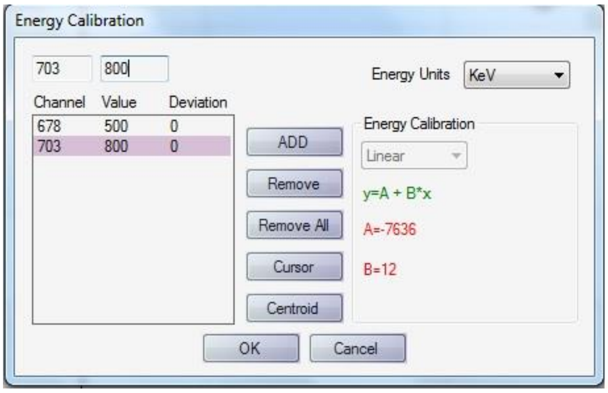


Fig. 4.42: MC²Analyzer Energy Linear Calibration Dialog window

The user can then select the desired Energy units, KeV or MeV, from the pull-down menu to the upper right corner of the window.

Then the user can locate the desired peaks of known energy on the calibration spectrum (either recalled from records either acquired live from a calibration source). By clicking on a peak the correspondent channel number will appear in the "**Channel**" value entry box. The user can then enter in the "**Value**" value entry box the Energy corresponding to that peak and associate this calibrated value by clicking on the "**ADD**" key. The corresponding values will appear on the calibration values list below the value entry boxes. This operation can be repeated to add other calibration peaks values. Any calibration line can be removed by clicking on it (this will highlight the line) and by clicking on the "**Remove**" key. The "**Remove All**" key clears all entered values at once.

If the user defines a ROI around a reference energy peak, then with the "**Centroid**" key the Peak Centroid Channel is automatically located and its value written in the channel entry box. The user can then enter the corresponding reference peak energy in the "Energy value" entry box and include this peak in the calibration by using the "ADD" key. This operation can be repeated for all available reference energies. If no ROI has been defined an error message pop up window is issued when the "Centroid" function is invoked.

Energy Calibration Interpolation Type

- **Linear** Interpolation
  If at least 2 channel values are entered, then in the Energy Calibration Pull Down Menu the **Linear** Calibration Function appears. The Energy Calibration is performed with a simple linear interpolation where the Y (Energy value) is calculated as a function of the X (energy "bin" or "channel" number) multiplied by a factor B, added to a constant A. Both the A and B values calculated from the linear interpolation best fit to the entered reference energy values are shown in the calibration window.

- **Quadratic** Interpolation
  If at least 3 channel values have been entered, then the **Quadratic** Interpolation function is also made available. The Energy Calibration is performed with a quadratic interpolation where the Y (Energy value) is calculated as a quadratic function of the X (energy "bin" or "channel" number) with the formula:

  $Y= A+ B*X+ C* X^2$.

The A, B and C values calculated from the quadratic interpolation best fit to the entered reference energy values are shown in the calibration window (see **Fig. 4.43**).

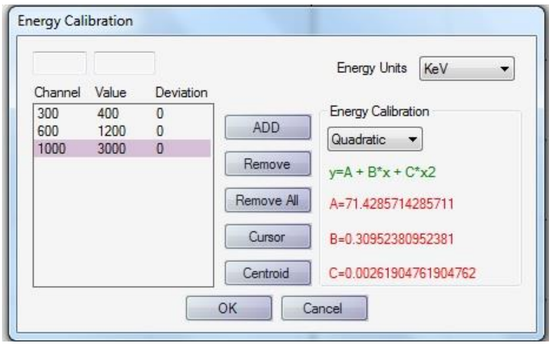


Fig. 4.43: MC²Analyzer Energy Quadratic Calibration Dialog window

Software Exit

How to exit the program

- **Stop the Acquisition.**
- **Turn off the HV** on all channels from the HV Window.
- **Exit the MC²Analyzer** program by clicking on the standard Windows red "X" key in the upper rightmost corner of the window, either use the "Exit" item in the Menu Bar "File" Pull Down Menu.

Note: The Acquired spectrum will be saved automatically together with the settings and reloaded as acquisition default file when the user restarts the MC²Analyzer program.

5 Technical support

CAEN makes available the technical support of its specialists for requests concerning the software and the hardware. Use the support form available at the following link:

https://www.caen.it/support-services/support-form/

Appendix A

Acquisition Modes

Each channel of a board running the DPP-PHA firmware can acquire events independently from the other channels. When an event is acquired, the DPP-PHA firmware applies a trapezoidal filter to evaluate the pulse energy.

The main acquisition mode is called “List mode”, where the board provides the time of arrival of the input (also called “Trigger Time Stamp”) and its Energy (“Pulse Height”). As soon as the list reaches a certain size, it is made available for readout and the acquisition continues in another buffer. Being the size of the event very small (typically few bytes), the throughput is extremely reduced. The firmware is not designed to make histogram onboard, but it can transfer the list information to the software that manages the histogram plotting. Conversely, in case of DT5770, the board is designed to make histograms on-board, and it does not produce any list file.

The DPP-PHA firmware allows also to acquire waveform samples (i.e. a sequence of samples within a programmable acquisition window) in the “Waveform” acquisition mode. This acquisition mode is mainly intended to debug and to set the DPP parameters. For each trigger (internal or external), the digitizer saves a portion of the waveform into a local memory buffer. Running in Waveform Mode, the user can view the input signal, the trapezoid, and other control signals (such as the trigger, the peaking, etc.) in the same plot, and easily adjust the parameters for the acquisition. Running in waveform mode implies a very high data throughput, due to the huge number of samples saved into the board memory and then read out by the DAQ software.

The DPP-PHA firmware can manage the two acquisition modes together in the “Mixed” acquisition mode, where it is possible to read the energy and the time stamp information together with a portion of the waveform, so that the user can retrieve further information and use it off-line, keeping a reasonable level of throughput bandwidth.

Note: In case of 725, 730 and DT5770 the Waveform mode is not available, while it is available the Mixed mode.

The MC²Analyzer software can manage both the list and the mixed acquisition mode. In the list mode, the software retrieves the list information from the board to make the relevant histogram and can save the histogram and list files. In the mixed mode, the software can show the pulses (Signal Inspector) for online adjustment of the settings, and the histogram to evaluate the effect of the settings. Once ready the user must close the Signal Inspector window, reset the spectrum and start again the acquisition, since acquiring the waveforms significantly reduces the bandwidth, thus increasing the dead-time. Waveform dump is not supported in MC²Analyzer software

Users who wants to customize the acquisition, can write their own software starting from the samples code of the CAENDigitizer library **[RD7]** and CAENDPP library **[RD12]**.

Trigger Modes

The general operating principle of a digitizer running with DPP-PHA firmware is summarized in **Fig. A.1**. Each channel of the board can trigger on the input pulse independently from the other channels. When the input is over-threshold the channel FPGA sends a “Trigger Request” (TRG_REQ) signal, that enables the event building (*“Normal (Individual) trigger mode”*).

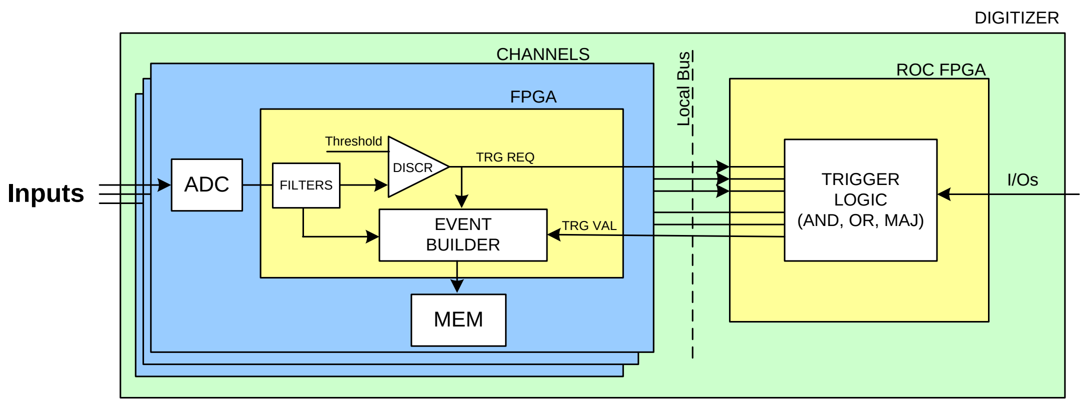


Fig. A.1: Schematic chain of the trigger architecture of a DPP system

In case of 725 and 730 series, each channel can acquire independently but it shares the same memory buffer with the other channel of the couple (0-1, 2-3, etc.) (see **Fig. A.2**). Moreover the channels of the couple share the same TRG_REQ for the coincidence logic. This means that it is not possible to set different coincidence logic among channels of two different couples (refer to **[RD5]** for further details). Anyway a great advantage comes in case of coincidences between channels of the same couple, which can be managed inside the channel FPGA, with no propagation to the mother board.

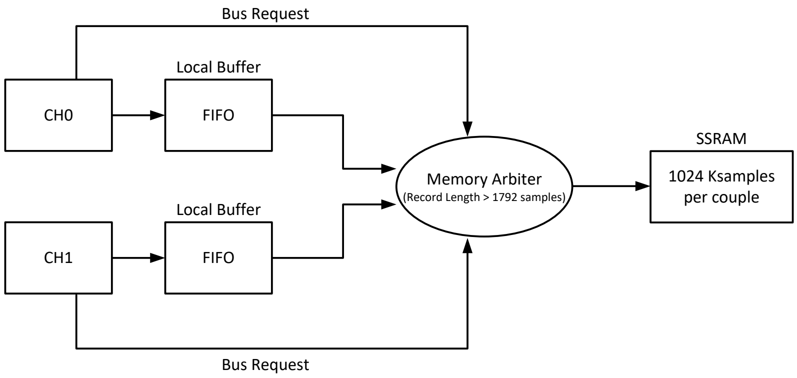


Fig. A.2: Memory management of 725 and 730 series

In the *“Coincidence/Anticoincidence Trigger Mode”* all the trigger requests can be sent to the common “ROC FPGA” for the coincidence evaluation. The Individual Trigger Logic (ITL) of the ROC FPGA performs the logic operation of AND, OR, or Majority between TRG_REQ coming from channels (724, 780, 781, and 782) or couples (725 and 730). When the coincidence condition is met, the ROC sends back one “trigger validation” signal per channel (couple). The coincidence logic is individual, so that it is possible to program different coincident conditions for each channel. If the trigger validation arrives within a programmable coincidence window (shaped trigger width), the event is saved in the memory buffer.

In case of 724, 780, 781, and 782 series, there is an additional coincidence mode, called *“Neighbour Trigger Mode”*. In this case the event building can be enabled with a TRG_VAL signal only, even if no TRG_REQ has been occurred for that channel. This may happen when a “neighbour” channel is over-threshold and generates a TRG_REQ. Then its previous and consecutive channels receive a TRG_VAL signal too, and they can start the event building with the TRG_VAL signal as reference. This is particularly useful in case of strip detector where the charge might deposit also in “neighbour” channels.

Normal (Individual) Trigger Mode

In the normal (individual) trigger mode each channel can trigger on the input pulse independently from the other channels.

Referring to **Fig. A.3** the input signal is discriminated if over-threshold (OVTH). After the discrimination, through a multiplexer, it is possible to select the output itself, or a logic pulse of adjustable time width T_{ST}. This is the *shaped trigger* that enables the "trigger request" (TRG_REQ) for data acquisition. Unlike the Coincidence or Neighbour acquisition modes, the TRG_VAL signal is always set to 1, so the event builder is activated when either a TRG_REQ, or an Individual Trigger (ITRG), or a Global Trigger (GTRG) signal arrive.

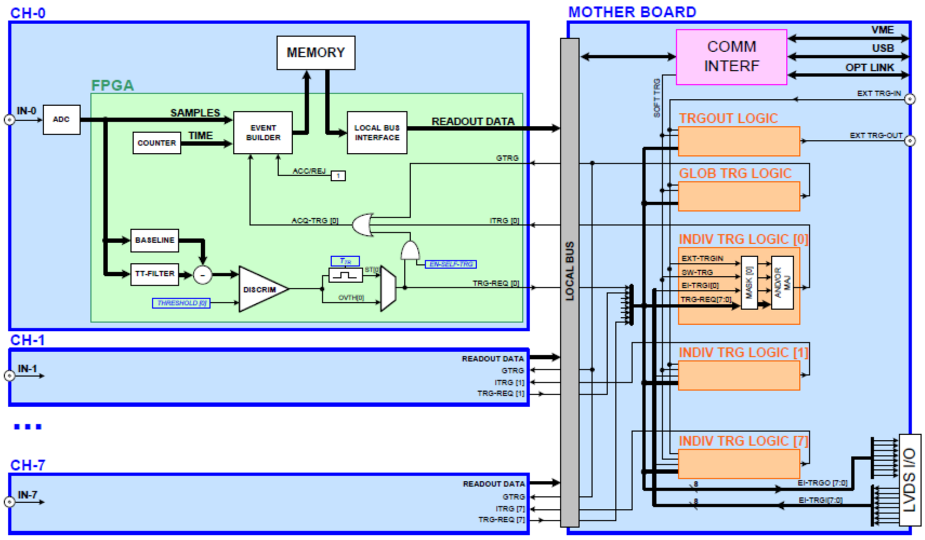


Fig. A.3: Block diagram of the Trigger Architecture in a DPP-PHA board

In the DPP-PHA the input pulse is fed into a Trigger and Timing Filter for the proper trapezoid calculation. When its output exceeds the programmed threshold, the trigger logic gets armed (the signal "armed" goes high), then it waits until the zero crossing to generate a Trigger Request TRG_REQ (**Fig. A.4**).

After the TRG_REQ, it is possible to program a trigger hold-off time window to prevent a new trigger to be generated on the tail of the RC-CR2 signal. This might happen especially when the input pulses have an over-shut that causes a small end pulse at the output of the timing filter. Another reason for using the trigger hold-off is to create a known dead-time in the acquisition.

When TRG_REQ is generated, the energy filter goes into the run state (pkrun = 1) and the calculation of the trapezoid baseline is frozen (baseline_off = 1). Note that there is a small delay (16 clock cycles) between the TRG_REQ and the start of the trapezoid; this prevents the baseline to be frozen when the trapezoid already started.

The peaking time Tpk defines the position on the flat top where the energy is calculated; in this trigger mode, Tpk starts with the TRG_REQ. Starting from the peaking time Tpk, it is possible to average a certain number of points on the flat top (Tpkavg).

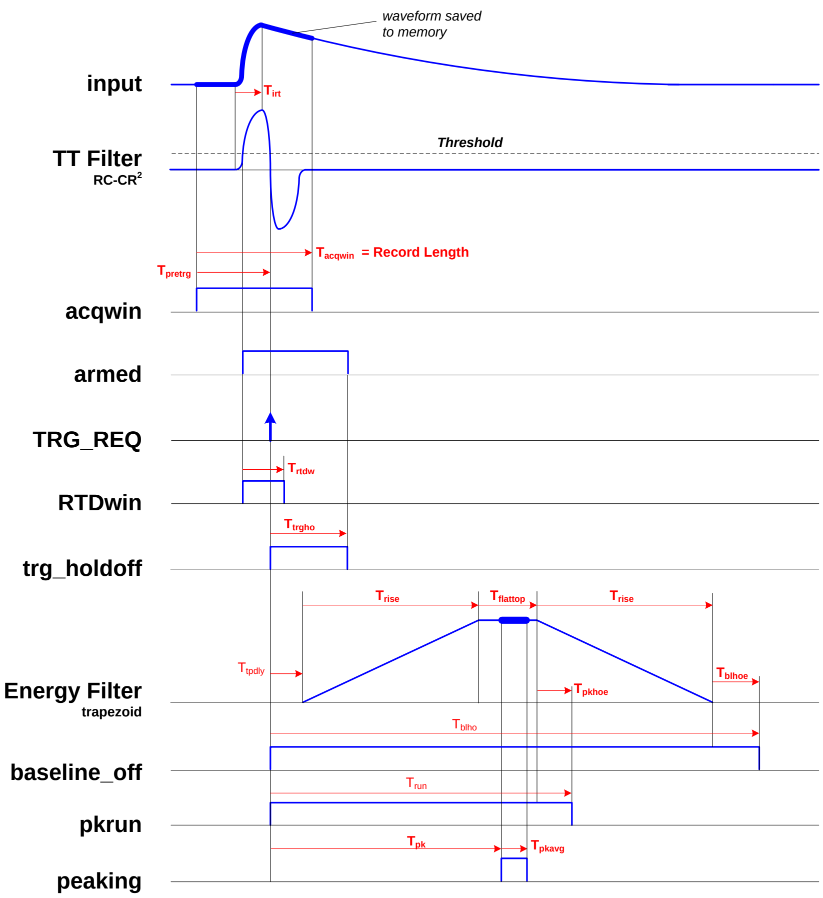


Fig. A.4: Timing diagram (Normal Trigger Mode)

According to the theory of the trapezoid filter, it is possible to accept a new trigger as soon as the flat top of the previous one is finished. However, it is always better to keep some safety margin (Tpkhoe); the effect of this parameter is to increase the width of the pkrun window. If a new TRG_REQ arrives within that window, then this event is identified as pile-up. There are three different cases, as shown in the following pictures:

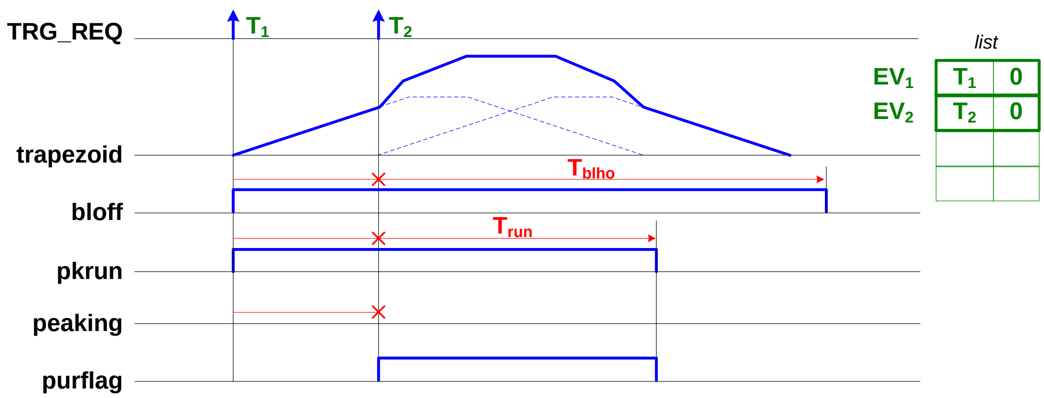


Fig. A.5: Pile-up occurred before the peaking time

When the second TRG_REQ occurs before the peaking time (**Fig. A.5**), then the energy filter output becomes meaningless and the pile-up inspector rejects both TRs. In this case, the event builder saves two time stamps and zero for the relevant energies (see the memory content represented in green). Notice that the second TRG_REQ restarts the timer for Trun and Tblho while Tpk is aborted (red crosses).

Note: It is also possible to acquire the energy values (not corrected) of the two pulses by setting bit[27] of register 0x1n80. Refer to **[RD8]**, **[RD9]**, **[RD10]**, **[RD14]**, and **[RD15]** for additional details. Register writes can be performed through tab “Generic Writes” of MC2Analyzer software (see Sec. **Generic Writes Tab**).

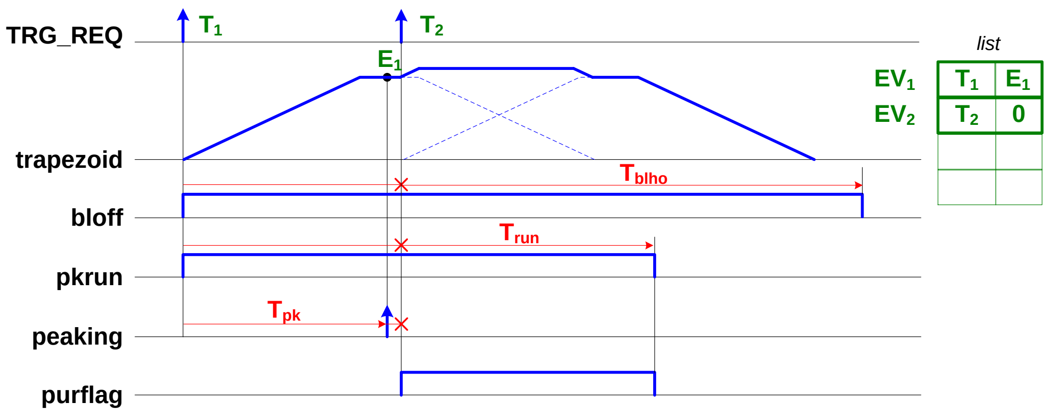


Fig. A.6: Pile-up occurred after the peaking time

If the second TRG_REQ occurs after the energy of the previous has been saved (but still before the end of pkrun), then only the second TRG_REQ will be rejected (see **Fig. A.6**).

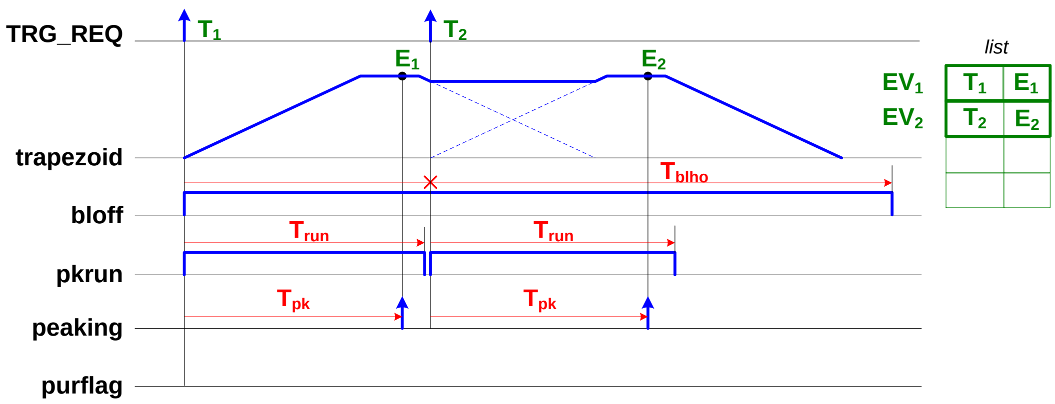


Fig. A.7: Overlapped trapezoids that don't cause pile-up rejection

If instead the second TRG_REQ occurs outside the pkrun window, although the two trapezoids are piled-up, both energies can be calculated and there is no pile-up rejection. However, in this case, the baseline of the second trapezoid cannot be recalculated, thus the same baseline calculated for the first trapezoid will be used for the second one too (see **Fig. A.7)**.

When the counting rate is high, it might happen that the baseline is kept off for many subsequent pulses and this can significantly worsen the energy resolution. In this case, it is possible to increase Tpkhoe and make pkrun longer than the full trapezoid width or even more. Doing that, the pile-up inspector will reject all the pulses but those that are well separated, thus allowing the baseline to be properly calculated for every pulse. By default, the baseline calculation starts again at the end of the trapezoid but it is possible to delay it by the Tblhoe value.

Coincidence Trigger Mode

Note: The coincidence trigger mode is not available for DT5770.

Acquiring coincident events is a common task in physics, and the DPP-PHA firmware allows you to make online coincidences among channels. As already introduced, the TRG_REQ signal can be sent to the ROC FPGA (mother board) that makes a programmable Individual Trigger Logic (ITL) calculation among the logic AND, OR, or Majority[1] (see **Fig. A.8**). The ITL has the same multiplicity of the number of channel, and each ITL can be programmed with a different logic function. Moreover the ITL can receive as input not only the TRG_REQ from all channels, but also the signal from the front panel output GPIO (line 0 to 7 of the LVDS I/O connector – VME only), the software trigger (SOFT_TRG), and the external trigger (EXT TRG-IN).

The user has the possibility to rather program a Global Trigger Logic (GTL) or a "TRG_OUT logic". The GTL and the TRG_OUT logic can receive as inputs the TRG_REQ from all channels, the EXT TRG-IN and the SOFT TRG. They cannot receive the inputs from the LVDS I/O. The "TRG-OUT logic" works as the ITL, but it has no the same multiplicity. Only one TRG-OUT signal is generated for the whole board. At the moment this logic unit can perform only the OR operation, and there is one GTL for all channels, since its output triggers all channels simultaneously.

Either the ITRG and the GTRG can generate the TRG_VAL signal. To save the event into the memory the TRG_VAL signal must arrive within a programmable time window TVAW (Trigger Validation Acceptance Window). If the TRG_VAL signal is outside the TVAW than the event is rejected.

In this trigger mode, all timings are referred to TRG_REQ, and the TRG_VAL never causes pile-up.

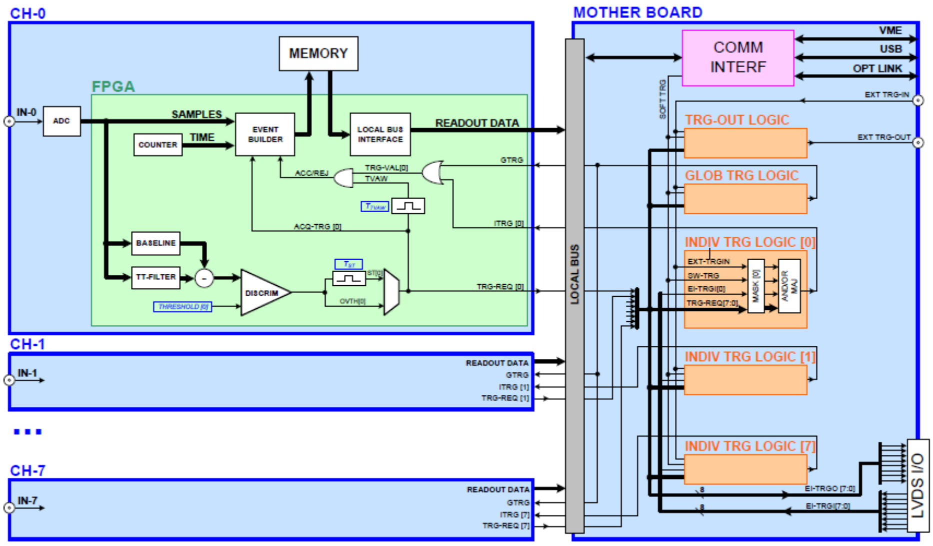


Fig. A.8: Block diagram of the Trigger Architecture in a board with DPP-PHA firmware

More information and detailed instructions on how to make coincidences among channels of the same board can be found in **[RD5]**.

Note: In case of 725 and 730 series coincidences can be performed inside couple of channels, or among different couples. Channels of the same couple share the same memory SSRAM and the same TRG_REQ; therefore a single TRG_REQ from the couple is propagated to the mother board FPGA to participate to the ITL, GTL, and TRG-OUT Logic.

Anti-coincidence Trigger Mode

The structure of the anti-coincidence trigger mode is the same of the coincidence one, the only difference being the logic operation performed between the TRG_VAL signal and the TVAW. Indeed, the event is saved into memory when no TRG_VAL signal arrives within the TVAW window.

Refer to **[RD5]** for more information and detailed instructions on how to make anti-coincidences among channels of the same board.

[1] The Majority is true when at least a programmable "majority level" number of enabled inputs are in coincidence.

Neighbour Trigger Mode

Note: The neighbor trigger mode is not available for 725, 730 and DT5770.

In the neighbour trigger mode, each channel still self-trigger on the input pulse. Moreover, its TRG_REQ generates a TRG_VAL signal that enables the data writing of the channel itself and of the "neighbour" channels, i.e. the previous and the consecutive.

Note: The neighbor trigger mode is particularly useful with strip detectors.

In order to have the same peaking times and the same waveform acquisition window in both cases (channel triggered by TRG_REQ or by TRG_VAL), Tpk and Tpretrg are referred to TRG_VAL instead of TRG_REQ. For this reason, the trigger logic that generates TRG_VAL must keep the jitter between TRG_REQ and TRG_VAL as low as possible. The time stamp saved in the event data is that one of TRG_VAL.

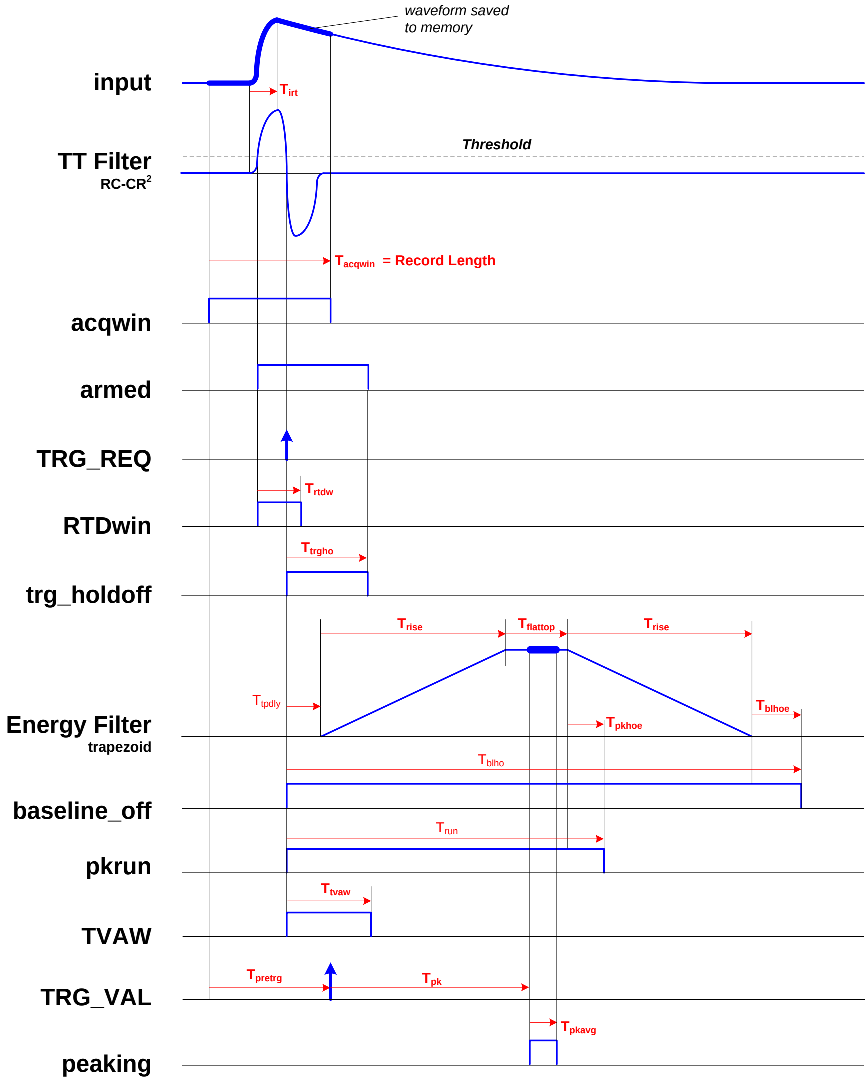


Fig. A.9: Timing diagram (Neighbour Trigger Mode)

If TRG_VAL signal arrives outside the TVAW window (see **Fig. A.10**), then the event will have the pile-up flag. Indeed TRG_VAL is not related to the event that caused the TRG_REQ in that channel and the calculated energy value is not properly evaluated.

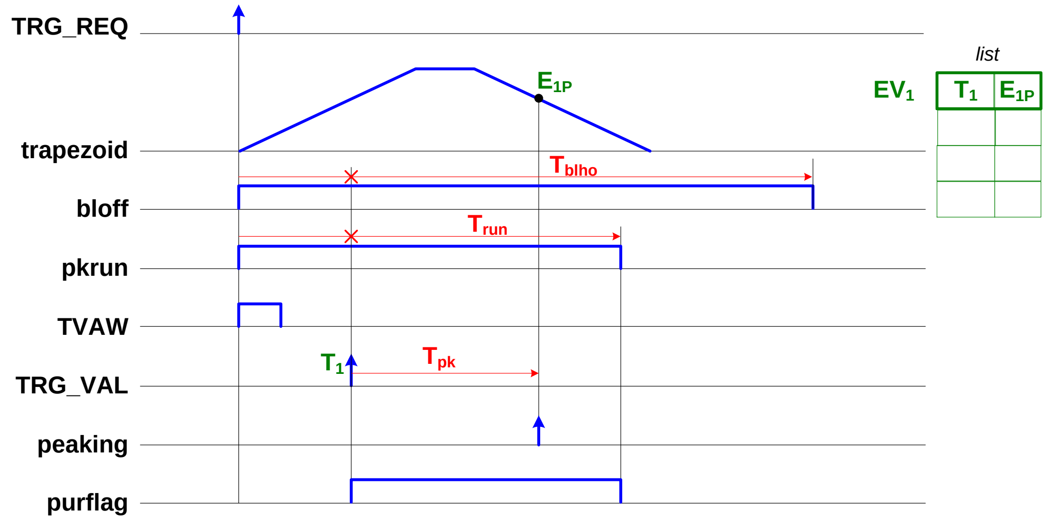


Fig. A.10: TRG_VAL outside the acceptance window

If a "neighbour" channel triggers and gets a valid TRG_VAL signal, then also the neighbour channels, even if they do not have enough charge to enable their own TRG_REQ, they receive the same TRG_VAL signal (see **Fig. A.11**). Please note that, unlike in the Normal Trigger Mode, the energy value latched at Tpk is saved into the memory with bit[15] = 1 (see Sec. **Channel Aggregate Data Format for 724, 780, 781 series (FW release <128.64)** and **Channel Aggregate Data Format for 724, 780, 781, and 782 series (FW release >128.64)**) indicating the pile-up condition. When the neighbour channel receives the TRG_VAL signal it starts its Tpk and Trun counters even though the value measured will be probably close 0.

Refer to **[RD5]** for detailed instructions on how to enable this trigger mode with DPHA.

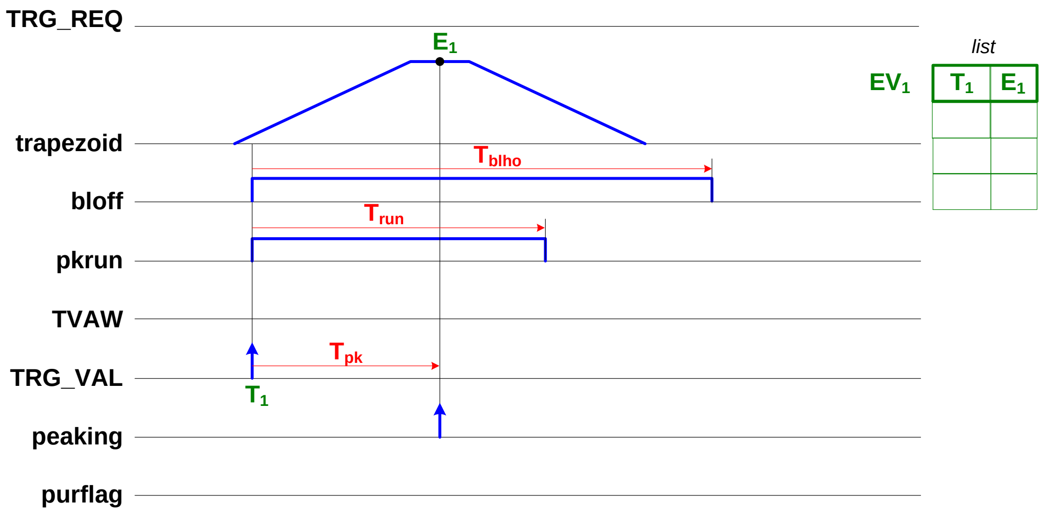


Fig. A.11: TRG_VAL without TRG_REQ

The TRG_REQ pile-up condition for the Neighbour Trigger Mode is similar to Normal Trigger Mode (see the following figures).

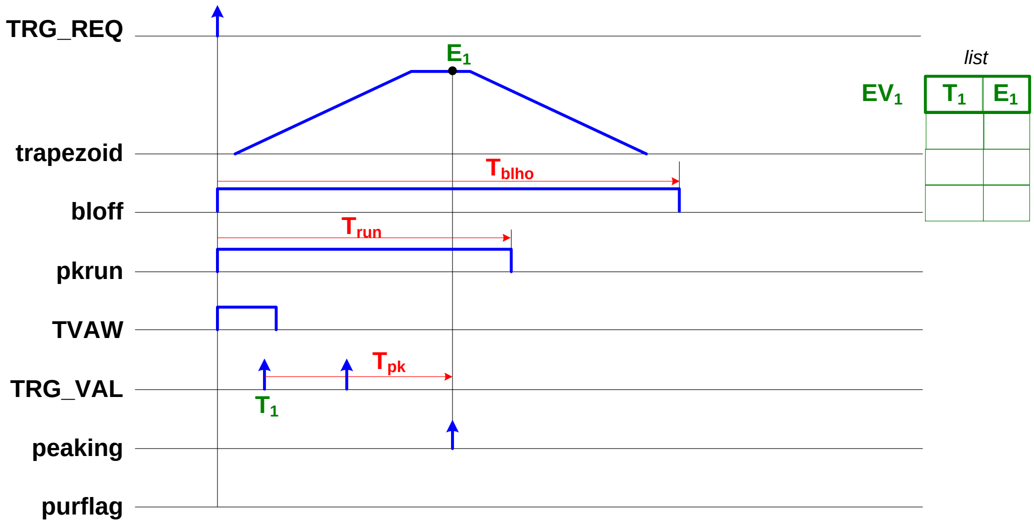


Fig. A.12: Second TRG_VAL occurring within pkrun

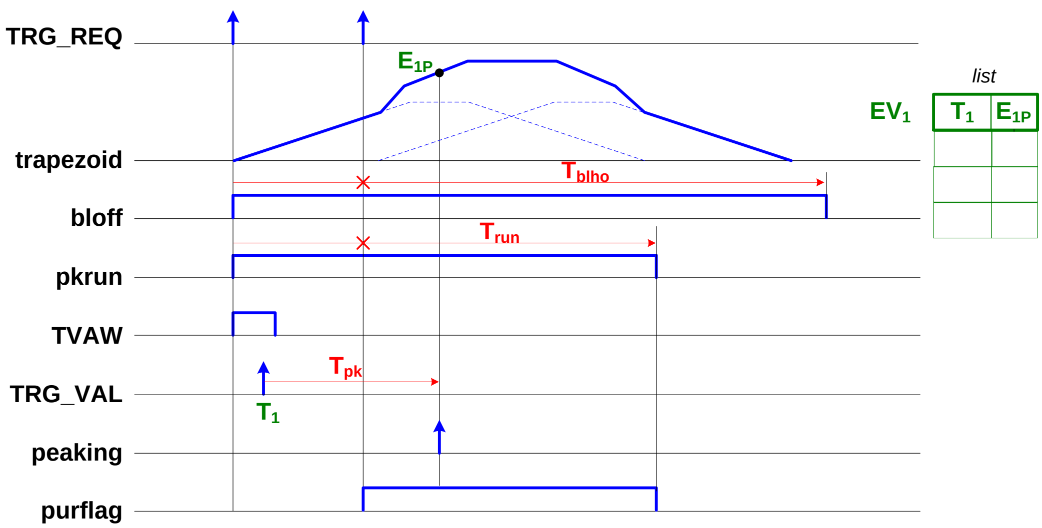


Fig. A.13: Pile-up occurred before the peaking time (Neighbour Trigger Mode)

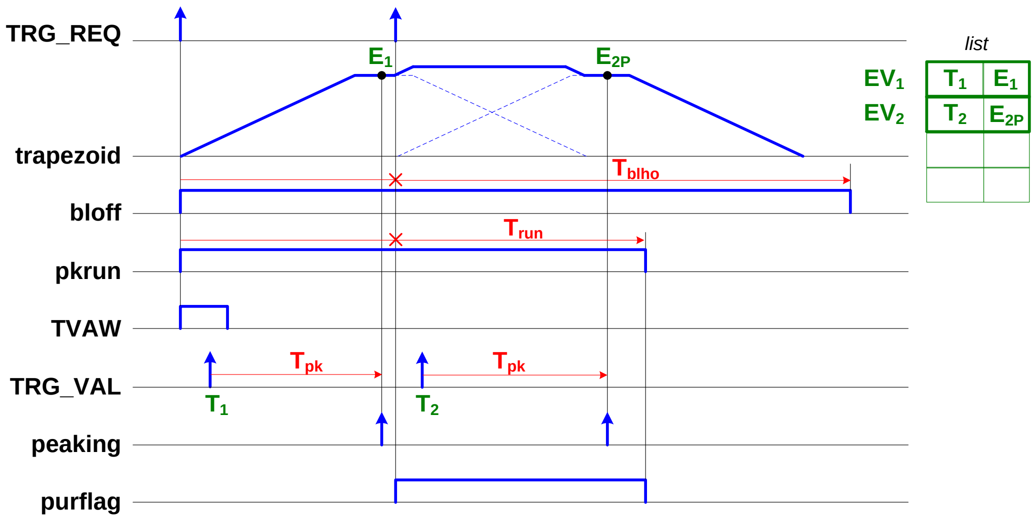


Fig. A.14: Pile-up occurred after the peaking time (Neighbour Trigger Mode)

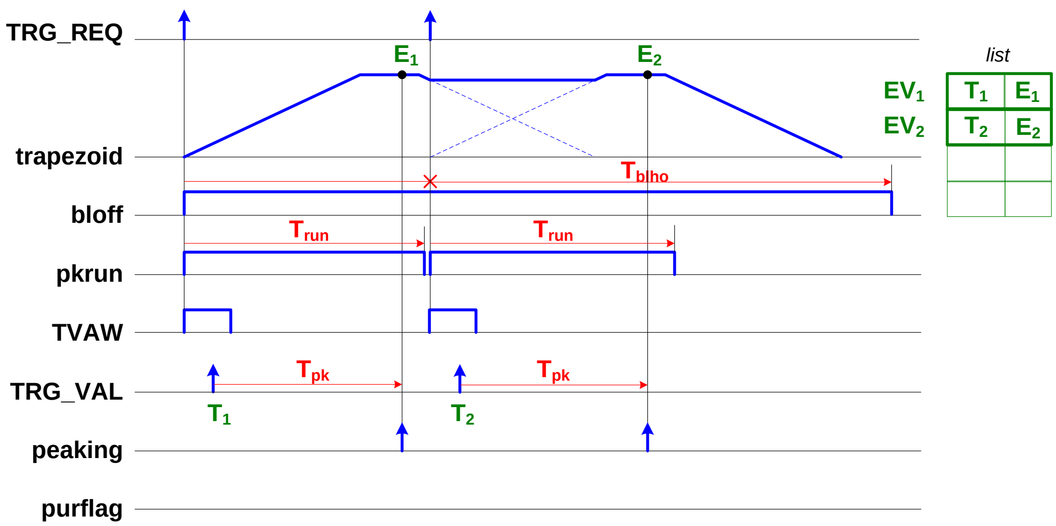


Fig. A.15: Overlapped trapezoids that do not cause pile-up rejection (**Neighbour** Trigger Mode)

Synchronization among different boards

In cases when multi-board systems are involved in the experiment, it is necessary to synchronize different boards. In this way the user can acquire from N boards with Y channel each, like if they were just one board with (N x Y) channels.

The main issue in the synchronization of a multi-board system is to propagate the sampling clock among the boards. This is made through input/output daisy chain connections among the digitizers. One board has to be chosen to be the "master" board that propagates its own clock to the others. A programmable phase shift can adjust possible delays in the clock propagation. This allows to have both the same ADC sampling clock, and the same time reference for all boards. Having the same time reference means that the acquisition starts/stops at the same time, and that the time stamps of different boards is aligned to the same absolute time.

There are several ways to implement the trigger logic. The synchronization tool allows to propagate the trigger to all boards and acquire the events accordingly. Moreover in case of busy state of one or more boards, the acquisition is inhibited for all boards.

Refer to **[RD6]** for more details on how to synchronize CAEN digitizers.

Appendix B

Memory Organization

Each channel has a fixed amount of RAM memory to save the events. The memory is divided into a programmable number of buffers (also called "aggregates"), where each buffer contains a programmable number of events. For the 725 and 730 families, each buffer is shared between two channels, i.e. channel 0 and channel 1, channel 2 and channel 3, etc. The event format is programmable as well. The board registers involved are the following (refer to **[RD8]**, **[RD9]**, **[RD10]**, **[RD14]**, and **[RD15]**):

- "Aggregate Organization" (*Nb*), address 0x800C: defines how many aggregates can be contained in the memory ($n\_aggr = 2^{Nb}$).
- "Number of Events per Aggregate" (*Ne*), address 0x1n34: defines the number of events contained in one aggregate. The maximum allowed value is 1023.
- "Record Length" (*Ns*), address 0x8020 (0x1n20 for 725 and 730): defines the number of samples for the waveform acquisition, when enabled (*rec_len = Ns * 2* for 724, 780, 781, and 782 series, *rec_len = Ns * 8* for 725 and 730 series).
- "Board Configuration", address 0x8000: defines the acquisition mode and the event data format.

According to the programmed event format, an event can contain a certain number of samples of the waveform, one trigger time stamp, the energy and the Extras information.

724 series

The following section describes the structure of the memory organization of 724 series.

The physical memory inside the board is made of memory locations, each of 128-bit (16B).

In terms of location occupancy:

Trigger Time Stamp = 1 location;

Waveform (if enabled) = 1 location every 8 samples;

Energy and EXTRAS = 1 location each.

Fig. B.1 shows the data format as saved into the physical memory of 724 series.

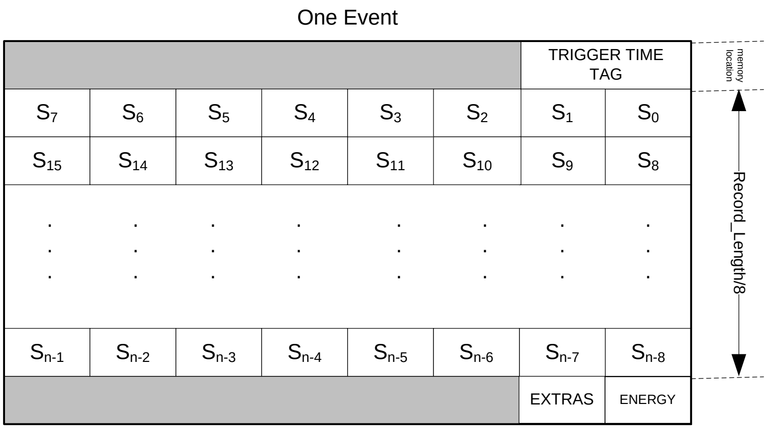


Fig. B.1: Data organization into the Internal Memory of x724 digitizer.

725/730 series

The following section describes the structure of the memory organization of 725/730 series.

The physical memory inside the board is made of memory locations, each of 128-bit (16B).

In terms of location occupancy:

Trigger Time Stamp = 1 location;

Waveform (if enabled) = 1 location every 8 samples;

Energy, EXTRAS and EXTRAS2 = 1 location each.

Fig. B.2 show the data format as saved into the physical memory of 725 and 730 series. The structure is the same as the 724 series apart for the Trigger Time Tag, that has one bit less than the 725 and 730 series. Since two channels share the same buffer, one bit is reserved to store the channel number, where 0 corresponds to the odd channel of the couple, and 1 to the even channel.

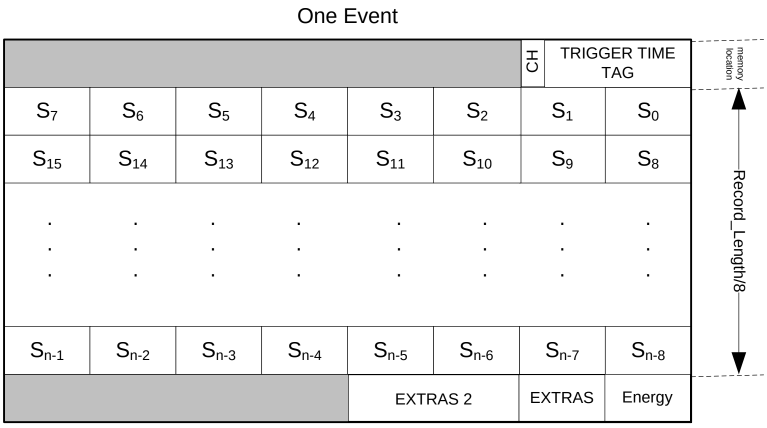


Fig. B.2: Data organization into the Internal Memory of x725 and x730 digitizers.

As previously said, the "Record Length" and the "Board Configuration" settings determine the event size; the user must calculate the number of event per buffer (*Ne*) and the number of buffers (2^{Nb})accordingly. When the board runs in List Mode, the event memory contains one location for the Trigger Time Tag and one for the Energy and EXTRAS. Therefore, it is very small and it is suggested to use a big value for *Ne* to make the buffer size as big as at least a few KB. Small buffer size results in low readout bandwidth. The only drawback of setting high values for *Ne* is that the events are not available for the readout until the buffer is complete; hence there is some latency between the arrival of a trigger and the readout of the relevant event data. Conversely, when the board runs in Oscilloscope Mode, especially when the record length is large, it is more convenient to keep *Ne* low (typically 1).

Event Data Format

When the data readout is performed, the data format will appear as follows.

Channel Aggregate Data Format for 724, 780, 781 series (FW release <128.64)

The Channel Aggregate is composed by the set of *Ne* events, where *Ne* is the programmable number of events contained in one aggregate. The structure of the Channel Aggregate of two events (EVENT 0 and EVENT 1) is shown in **Fig. B.3**, where:

"CHANNEL AGGREGATE" DATA FORMAT

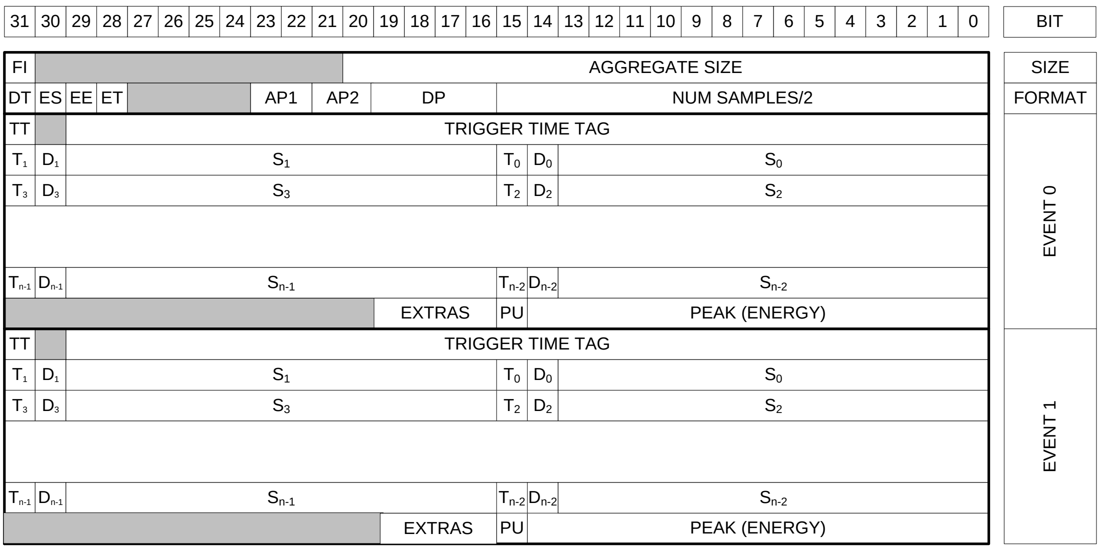


Fig. B.3: Channel Aggregate Data Format scheme for 724, 780, and 781 series (FW release < 128.64)

FI: when 1, the second word is the Format Info

DT: Dual trace enabled flag (0 = disabled, 1 = enabled)

ES: Waveform (samples) enabled flag

EE: Energy enabled flag

ET: Trigger Time Stamp enabled flag

AP1: Analog Probe 1 Selection. AP1 can be selected among:

00 = "Input": the input signal from pre-amplified detectors

01 = "RC-CR": first step of the trigger and timing filter

10 = "RC-CR2": second step of the trigger and timing filter

11 = "Trapezoid": trapezoid resulting from the energy filter

AP2: Analog Probe 2 Selection. AP2 can be selected among:

00 = "Input": the input signal from pre-amplified detectors

01 = "Threshold": the RC-CR2 threshold value

10 = "Trapezoid-BL": the trapezoid shape minus its baseline

11 = "Baseline": displays the trapezoid baseline

DP: Digital Virtual Probe Selection. DP can be selected among:

0000 = "TRG Window": not used

0001 = "Armed": digital input showing where the RC-CR^2 crosses the Threshold

0010 = "Peak Run": starts with the trigger and last for the whole event (see **Fig. A.4**)

0011 = “Pile-Up”: shows when there is a pile-up event and corresponds to the time interval when the energy calculation is disabled due to the pile-up event

0100 = “Peaking”: shows where the energy is calculated

0101 = “Trg Validation Win”: digital input showing the trigger validation acceptance window TVAW (refer to **Acquisition Modes** chapter and **[RD5]**)

0110 = “BSL Holdoff: shows the baseline hold-off parameter

0111 = “TRG Holdoff”: shows the trigger hold-off parameter

1000 = “Trg Validation”: shows the trigger validation signal TRG_VAL (refer to **Acquisition Modes** chapter and **[RD5]**)

1001 = “Acq Veto”: this is 1 when either the input signal is saturated or the memory board is full

TT: Trigger Type (0=self-trigger, 1=external trigger)

S_m (*m = 0, 2, 4… n-2*): Even Samples of AP1 at time *t = m*

$S_{m'}$ *(m' = 1, 3, 4… n-1)*: if DT=0, then $S_{m'}$ corresponds to the odd Samples of AP1 at time *t = m'*. Otherwise, if DT=1, they correspond to even Samples of AP2 at time *t = m' - 1*

T_n: bit identifying in which sample the Trigger occurred

D_n: Digital Virtual Probe for each sample. The Probe type can be read from the “DP” field in the header

PU: Pile Up. This bit is usually set to zero. The user can recognize a pile up event when also the Energy value is zero. The user can also choose to have this bit equal to 1 in case of pile-up event, by enabling bit[27] of the DPP_CTRL register (0x1n80 register address). In that case the energy value is what read from the algorithm

EXTRAS: bit[0] = DEAD_TIME. This is set to 1 when a dead time occurred before this event. The dead time can be due to either a signal saturation or a full memory status. Check **Fig. B.4** and **Fig. B.5** for more details

bit[1] = ROLL_OVER. Identify a trigger time stamp roll-over that occurred before this event

bit[2] = TT_RESET. Identify a trigger time stamp reset forced from external signals in S-IN (GPI for Desktop)

bit[3] = FAKE_EVENT. This is a fake event (which does not correspond to any physical event) that identifies a time stamp roll-over. The roll-over can be due to an external or internal reset. The user can set bit[25] = 1 of register 0x1n80 to enable the fake-event saving in case of reset from S-IN, and bit[26] = 1 of register 0x1n80 to enable the fake-event saving in case of internal roll-over. In the first case the event will have both bit[3] and bit[2] set to 1, while in the second case the event will have both bit[3] and bit[1] set to 1.

Notes:

1. DEAD_TIME in case of signal saturation (see **Fig. B.4**). If the input signal is over-range (exceeds the input dynamic range of 16k ADC channels) then the acquisition is inhibited. As soon as the input signal is in saturation an event is saved with the corresponding time stamp, and bit[15] set to 1. The energy value is set to the maximum. This event has to be discarded for the energy spectrum, anyway it can be considered for the dead-time calculation. Once the signal is out of saturation a new trigger is inhibited for a time window of 2*Decay Time. The first event after the saturation is tagged with bit[16] = 1.
2. DEAD_TIME in case of FULL board memory (see **Fig. B.5**). When the memory of the board is full (which is usually due to a write event), the board is not able any more to transfer the event data. When the board is ready again, the first event after the FULL will have the bit[16] set to 1, and the energy value as read from the algorithm. The dead-time is equal to the time difference between the last trigger occurred and the trigger after the FULL status.

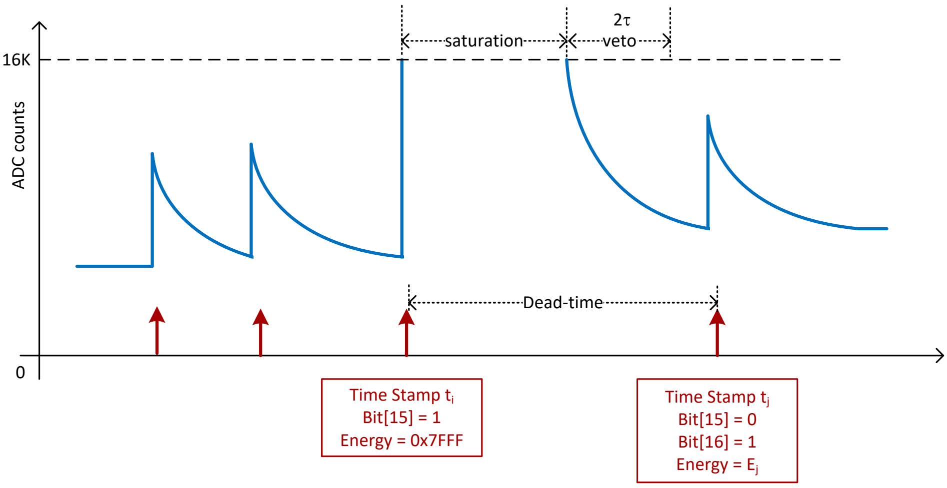


Fig. B.4: Dead-time in case of signal saturation.

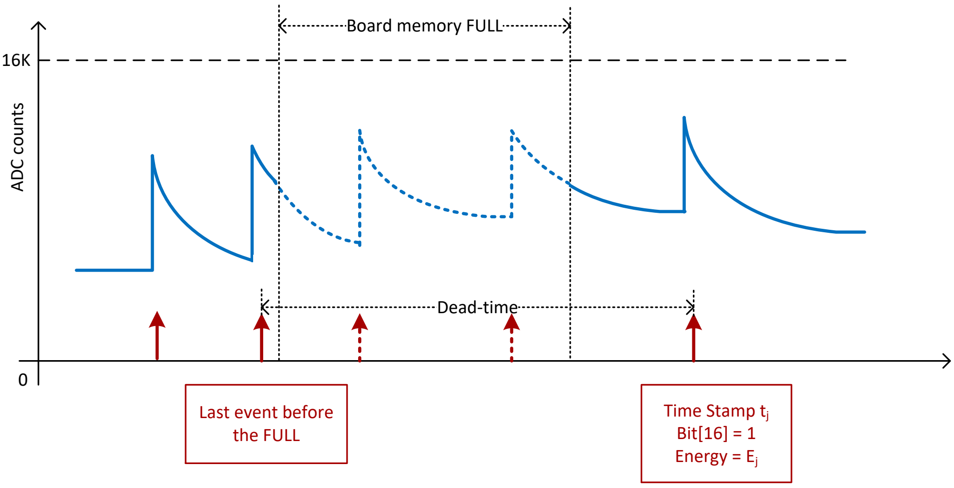


Fig. B.5: Dead-time in case of FULL memory status. Events in the FULL are identified but not saved.

Channel Aggregate Data Format for 724, 780, 781, and 782 series (FW release >128.64)

The Channel Aggregate is composed by the set of *Ne* events, where *Ne* is the programmable number of events contained in one aggregate. The structure of the Channel Aggregate of two events (EVENT 0 and EVENT 1) is shown in **Fig. B.6**, where:

“CHANNEL AGGREGATE” DATA FORMAT

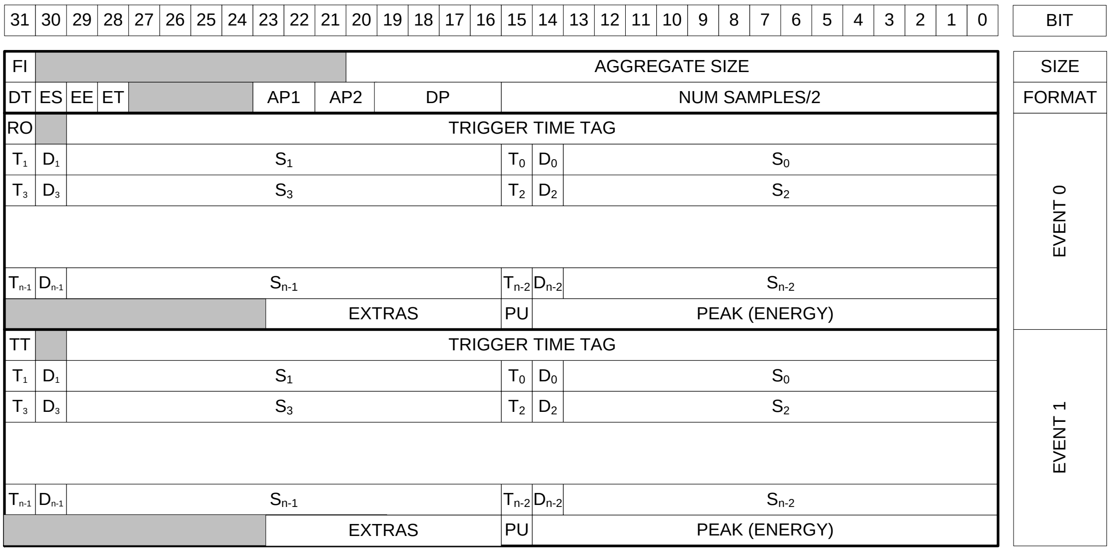


Fig. B.6: Channel Aggregate Data Format scheme for 724, 780, 781, and 782 series (FW release >128.64)

FI: when 1, the second word is the Format Info

DT: Dual trace enabled flag (0 = disabled, 1 = enabled)

ES: Waveform (samples) enabled flag

EE: Energy enabled flag

ET: Trigger Time Stamp enabled flag

AP1: Analog Probe 1 Selection. AP1 can be selected among:

00 = “Input”: the input signal from pre-amplified detectors

01 = “RC-CR”: first step of the trigger and timing filter

10 = “Fast Filter”: second step of the trigger and timing filter

11 = “Trapezoid”: trapezoid resulting from the energy filter

AP2: Analog Probe 2 Selection. AP2 can be selected among:

00 = “Input”: the input signal from pre-amplified detectors

01 = “Threshold”: the RC-CR2 threshold value

10 = “Trapezoid-BL”: the trapezoid shape minus its baseline

11 = “Baseline”: displays the trapezoid baseline

DP: Digital Virtual Probe Selection. DP can be selected among:

0000 = “Peaking”: shows where the energy is calculated

0001 = “Armed”: digital input showing where the RC-CR^2 crosses the Threshold

0010 = “Peak Run”: starts with the trigger and last for the whole event (see **Fig. A.4**)

0011 = “Pile-Up”: shows when there is a pile-up event and corresponds to the time interval when the energy calculation is disabled due to the pile-up event

0100 = “Peaking”: shows where the energy is calculated

0101 = “Trg Validation Win”: digital input showing the trigger validation acceptance window TVAW (refer to **Acquisition Modes** chapter and **[RD5]**)

0110 = “BSL Freeze” : shows the time interval in which the baseline evaluation is freezed

0111 = “TRG Holdoff”: shows the trigger hold-off parameter

1000 = “Trg Validation”: shows the trigger validation signal TRG_VAL (refer to **Acquisition Modes** chapter and **[RD5]**)

1001 = “Over Range Protection Time”, this is 1 when the input stage is saturated

1010 = “TRG Window”: not used

1011 = “Ext TRG”, shows the external trigger, when available

1100 = “Busy”, shows when the memory board is full.

1101 = ”Peak Ready”, shows after the Peak Mean time.

RO: Timestamp roll-over (1 if roll-over event, 0 elsewhere)

S_m (*m = 0, 2, 4… n-2*): Even Samples of AP1 at time *t = m*

$S_{m'}$ *(m’ = 1, 3, 4… n-1)*: if DT=0, then $S_{m'}$ corresponds to the odd Samples of AP1 at time *t = m’*. Otherwise, if DT=1, they correspond to even Samples of AP2 at time *t = m’ - 1*

T_n: bit identifying in which sample the Trigger occurred

D_n: Digital Virtual Probe for each sample. The Probe type can be read from the “DP” field in the header

PU: Pile Up. This bit is usually set to zero. The user can recognize a pile up event when also the Energy value is zero. The user can also choose to have this bit equal to 1 in case of pile-up event, by enabling bit[27] of the DPP_CTRL register (0x1n80 register address). In that case the energy value is what read from the algorithm

EXTRAS: bit[0] = DEAD_TIME. This is set to 1 when a dead time occurred before this event. The dead time can be due to either a signal saturation or a full memory status. Check **Fig. B.4** and **Fig. B.5** for more details

bit[1] = ROLL_OVER. Identifies a trigger time stamp roll-over that occurred before this event

bit[2] = TT_RESET. Identifies a trigger time stamp reset forced from external signals in S-IN (GPI for Desktop)

bit[3] = FAKE_EVENT. This is a fake event (which does not correspond to any physical event) that identifies a time stamp roll-over. The roll-over can be due to an external or internal reset. The user can set bit[25] = 1 of register 0x1n80 to enable the fake-event saving in case of reset from S-IN, and bit[26] = 1 of register 0x1n80 to enable the fake-event saving in case of internal roll-over. In the first case the event will have both bit[3] and bit[2] set to 1, while in the second case the event will have both bit[3] and bit[1] set to 1.

bit[4] = INPUT SATURATION: identifies where an event saturated the input dynamics. The event that saturates the dynamics has Energy = 0x7FFFF, while the PU flag is set to 1 only if there is also a pile-up. See **Fig. B.8.**

bit[5] = LOST_TRG: every N lost events this flag is high, where N is set from bits[17:16] of register 0x1nA0 (default value 1024);

bit[6] = TOT_TRG: every N total events this flag is high, where N is set from bits[17:16] of register 0x1nA0 (default value 1024);

bit[7] = DOUBLE_SAT: identifies an events that saturates at the same time the input stage and the trapezoid

Notes:

3. DEAD_TIME in case of signal saturation (see **Fig. B.7**). If the input signal is over-range (exceeds the input dynamic range of 16k ADC channels) then the acquisition is inhibited. <u>As soon as the input signal is in saturation</u> an event is saved with the corresponding time stamp, and bit[15] set to 1. The energy value is set to the maximum. This event has to be discarded for the energy spectrum, anyway it can be considered for the dead-time calculation. Once the signal is out of saturation a new trigger is inhibited for a time window o equal to the Decay Time. The first event after the saturation is tagged with bit[16] = 1.
4. DEAD_TIME in case of FULL board memory (see **Fig. B.8**). When the memory of the board is full (which is usually due to a write event), the board is not able any more to transfer the event data. When the board is ready again, the first event after the FULL will have the bit[16] set to 1, and the energy value as read from the algorithm. The dead-time is equal to the time difference between the last trigger occurred and the trigger after the FULL status.

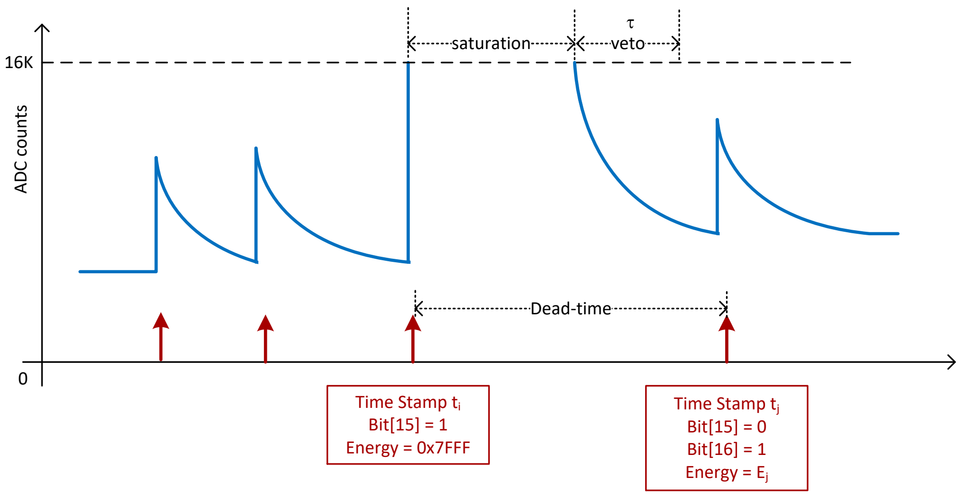


Fig. B.7: Dead-time in case of signal saturation.

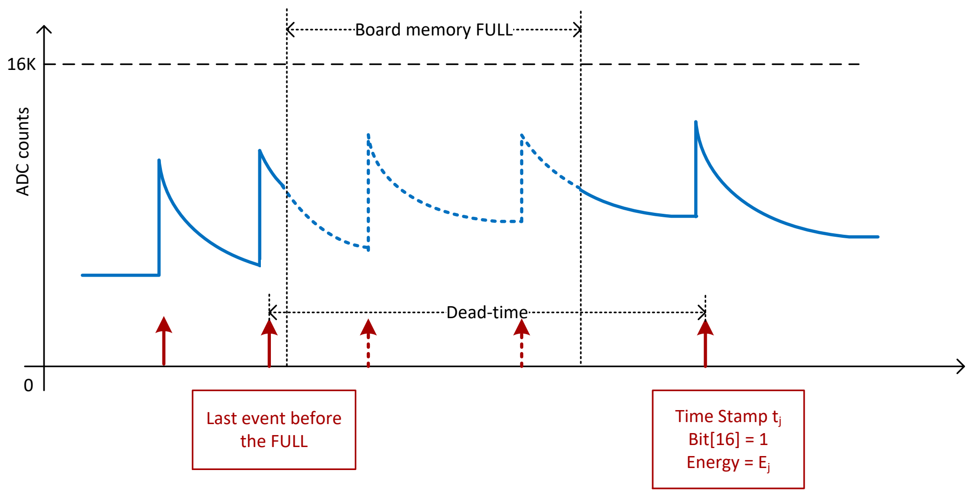


Fig. B.8: Dead-time in case of FULL memory status. Events in the FULL are identified but not saved.

Channel Aggregate Data Format for 725 and 730 series

The Channel Aggregate is composed by the set of *Ne* events, where *Ne* is the programmable number of events contained in one aggregate (see the previous section). The structure of the Channel Aggregate of two events (EVENT 0 and EVENT 1) for 725 and 730 series is shown in **Fig. B.9**, where:

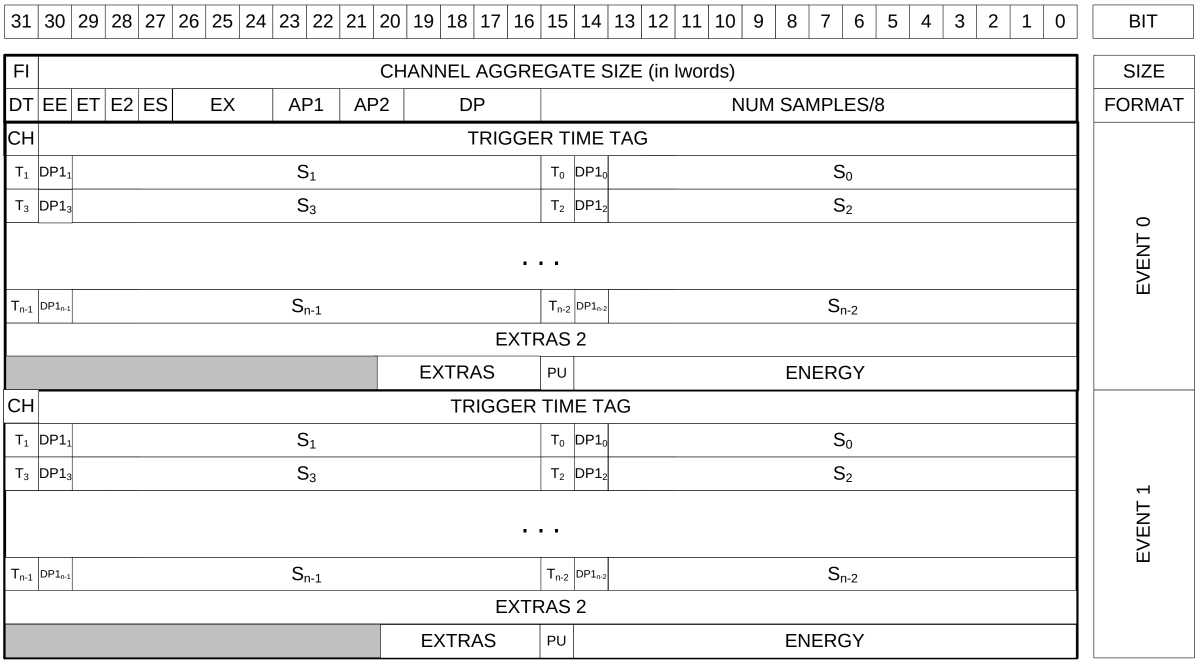


Fig. B.9: Channel Aggregate Data Format scheme for 725 and 730 series

FI: if 1, the second word is the Format Info

DT: Dual trace enabled flag (1 = enabled, 0 = disabled)

EE: Energy enabled flag

ET: Trigger Time Stamp enabled flag

E2: Extras 2 enabled flag

ES: Waveform (samples) enabled flag

EX: EXTRAS 2 option enabled flag:

000 = the word "EXTRAS 2" will be read as:

[31:16] = extended time stamp: those 16 bits must be read as the most significant bits of the time stamp, which becomes a 31+16=47 bit number;

[15:0] = the trapezoid baseline value * 4.

100 = the word "EXTRAS 2" will be read as:

[31:16] = Lost Trigger Counter;

[15:0] = Total Trigger Counter.

001 = Reserved;

010 = the word "EXTRAS 2" will be read as:

[31:16] = Extended Time Stamp (MSB);

[15:0] = Fine Time Stamp (linear interpolation of the RC-CR2 signal between the events before and after the zero crossing);

011 = Reserved;

100 = the word "EXTRAS 2" will be read as:

[31:16] = Lost Trigger Counter;

[15:0] = Total Trigger Counter;

101 = the word "EXTRAS 2" will be read as:

[31:16] = Event Before the Zero Crossing;

[15:0] = Event After the Zero Crossing;

111 = Reserved.

Note: to enable the "EXTRAS 2" word set bit[17] of register 0x8000.

AP1: Analog Probe 1 Selection. AP1 can be selected among:

00 = "Input": the input signal from pre-amplified detectors

01 = "RC-CR": first step of the trigger and timing filter

10 = "RC-CR2": second step of the trigger and timing filter

11 = "Trapezoid": trapezoid resulting from the energy filter

AP2: Analog Probe 2 Selection. AP2 can be selected among:

00 = "Input": the input signal from pre-amplified detectors

01 = "Threshold": the RC-CR2 threshold value

10 = "Trapezoid-BL": the trapezoid shape minus its baseline

11 = "Baseline": displays the trapezoid baseline

DP: Digital Virtual Probe Selection. DP can be selected among:

0000 = "Peaking": shows where the energy is calculated

0001 = "Armed": digital input showing where the RC-CR^2 crosses the Threshold

0010 = "Peak Run": starts with the trigger and last for the whole event (see **Fig. A.4**)

0011 = "Pile-Up": shows when there is a pile-up event and corresponds to the time interval when the energy calculation is disabled due to the pile-up event

0100 = "Peaking": shows where the energy is calculated

0101 = "Trg Validation Win": digital input showing the trigger validation acceptance window TVAW (refer to **Acquisition Modes** chapter and **[RD5]**)

0110 = "BSL Freeze": shows where the trapezoid baseline is frozen for the energy calculation

0111 = "TRG Holdoff": shows the trigger hold-off parameter

1000 = "Trg Validation": shows the trigger validation signal TRG_VAL (refer to **Acquisition Modes** chapter and **[RD5]**)

1001 = "Acq Busy", this is 1 when the board is busy (saturated input signal or full memory board) or there is a veto

1010 = "TRG Window": not used

1011 = "Ext TRG", shows the external trigger, when available

1100 = "Busy", shows when the memory board is full.

CH: since two consecutive channels share the same buffer, the CH flag identifies whether the even channel or the odd channel participated to the event (0 for even, 1 for odd).

S_m (*m = 0, 2, 4… n-2*): Even Samples of AP1 at time *t = m*

$S_{m'}$ *(m' = 1, 3, 4… n-1)*: if DT=0, then $S_{m'}$ corresponds to the odd Samples of AP1 at time *t = m'*. Otherwise, if DT=1, they correspond to even Samples of AP2 at time *t = m' – 1*

T_n: bit identifying in which sample the Trigger occurred

D_n: Digital Virtual Probe for each sample. The Probe type can be read from the "DP" field in the header

PU: bit identifying a pile-up event or roll-over.

EXTRAS: bit[0] = LOST EVENT. This is set to 1 when one or more events is lost due to a memory board FULL. The memory can be FULL due to a write event. The first event after the full has this bit set to 1. Refer to **Fig. B.10** for more details;

bit[1] = ROLL-OVER. This bit identifies a time-stamp roll-over. To enable this option set bit[26] = 1 of register 0x1n80. The DPP-PHA algorithm creates a fake event with Time Stamp = 0, Energy = 0, PU = 1, bit[3] and bit[1] of EXTRAS = 1.

bit[2] = RESERVED;

bit[3] = FAKE_EVENT. A fake event is generated to identify a time stamp roll-over. See also bit[1] of EXTRAS.

bit[4] = INPUT SATURATION: identifies where an event saturated the input dynamics. The event that saturates the dynamics has Energy = 0x7FFFF, while the PU flag is set to 1 only if there is also a pile-up. See **Fig. B.11.**

bit[5] = LOST_TRG: every N lost events this flag is high, where N is set from bits[17:16] of register 0x1nA0 (default value 1024);

bit[6] = TOT_TRG: every N total events this flag is high, where N is set from bits[17:16] of register 0x1nA0 (default value 1024);

bit[7] = MATCH_COINC: when bit[19]=1 of register 0x1nA0 then all the events are saved and tagged with this bit when the coincidence criteria is met;

bit[8] = NOTMATCH_COINC: when bit[19]=1 of register 0x1nA0 then all the events are saved and tagged with this bit when the coincidence criteria is not met;

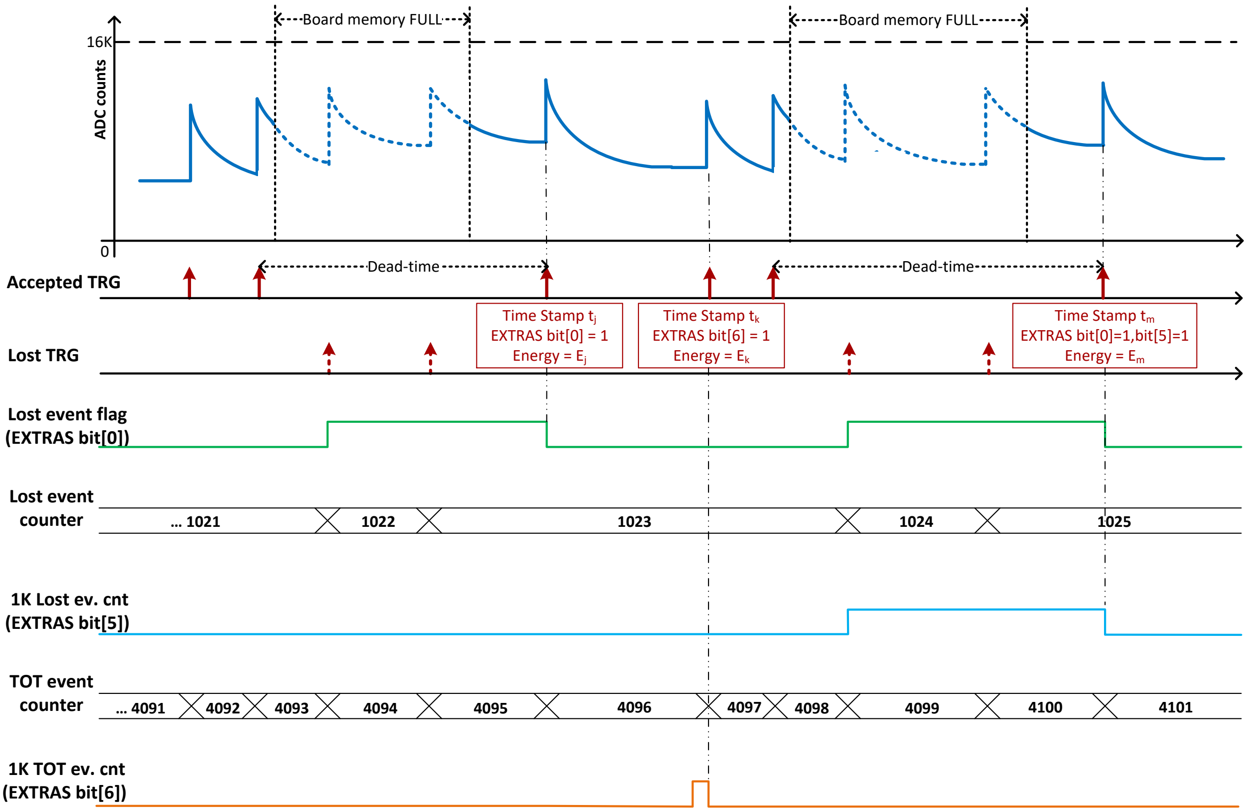


Fig. B.10: EXTRAS bit management in case of FULL memory status. The first event after the FULL has bit[0] = 1, which identifies that some events are lost due to a FULL memory status. The algorithm counts both the lost events and the to tal number of events, and rise a flag (bit[5] and bit[6] respectively) every N events.

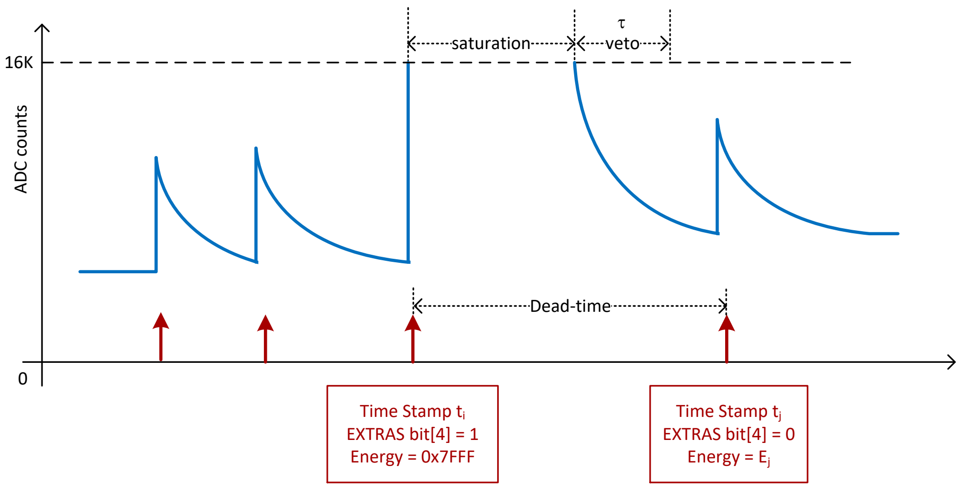


Fig. B.11: Event flag in case of input signal saturation. The events that saturates has EXTRAS bit[4] = 1 and energy = full scale.

Board Aggregate Data Format

For each readout request (occurring when at least one channel has available data to be read) the “interface FPGA (ROC)” reads one aggregate from each enabled channel memory. No more than one aggregate per channel is read each time. The set of Channel Aggregates is the Board Aggregate. If one channel has no data, that channel does not come into the Board Aggregate.

The data format when all 8 channels of a VME have available data is as shown in **Fig. B.12**, where:

“BOARD AGGREGATE” DATA FORMAT

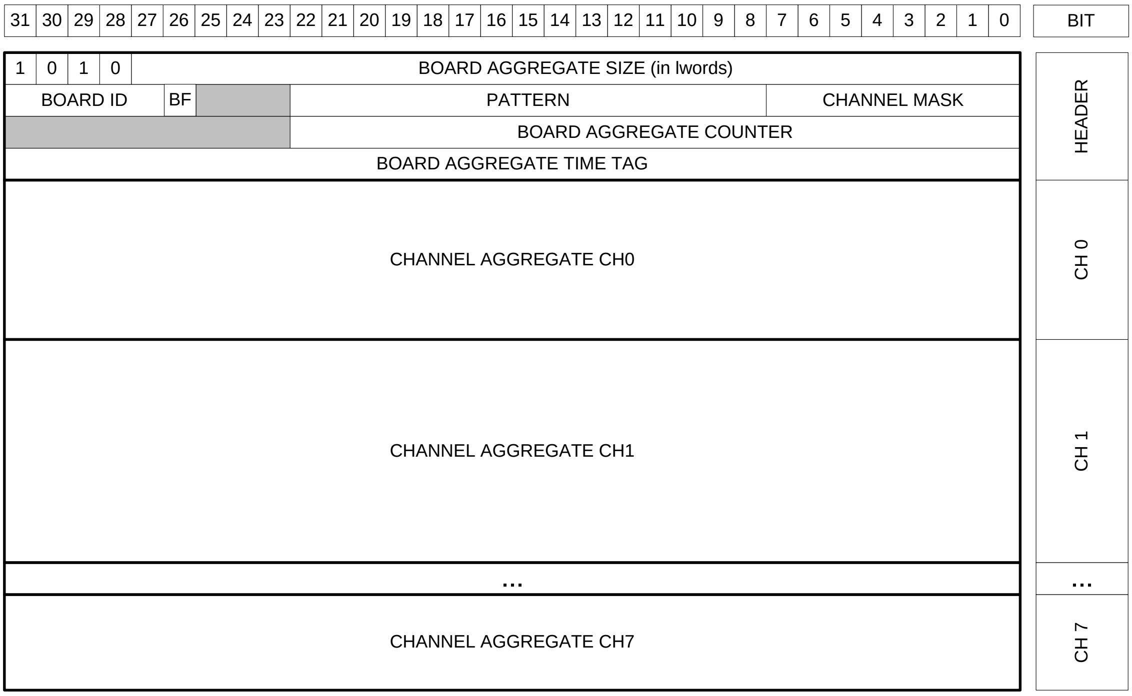


Fig. B.12: Board Aggregate Data Format scheme

BOARD AGGREGATE SIZE: total size of the aggregate

BOARD ID: corresponds to the GEO address of the board. In case of VME64X boards this number is automatically set for each board. In case of VME boards this value is by default = 0 for all boards. It is possible to set the GEO address of the boards using register 0xEF08, which is quite useful in case of concatenate BLT (CBLT) read.

BF: Board Fail flag. This bit is set to “1” after a hardware problem, as for example the PLL unlocking, or over-temperature condition. The user can investigate the problem checking the error monitor register 0x8178, or contacting CAEN support (refer to Chapter **Technical support**).

Notes: BF bit is meaningful only for ROC FPGA firmware revision greater than 4.5. It is *reserved* for previous releases.

PATTERN: is the value read from the LVDS I/O (VME only);

CHANNEL MASK: corresponds to those channels participating to the Board Aggregate;

BOARD AGGREGATE COUNTER: counts the board aggregate. It increases with the increase of board aggregates;

BOARD AGGREGATE TIME TAG: is the time of creation of the aggregate (this does not correspond to any physical quantity);

Data Block

The readout of the digitizer is done using the Block Transfer (BLT, refer to **[RD7]**); for each transfer, the board gives a certain number of Board Aggregates, consisting in the Data Block. The maximum number of aggregates that can be transferred in a BLT is defined by the READOUT_BTL_AGGREGATE_NUMBER. In the final readout each Board Aggregate comes successively. In case of n Board Aggregates, the Data Block is as in **Fig. B.13**.

DATA BLOCK

BOARD AGGREGATE 0
BOARD AGGREGATE 1
...
BOARD AGGREGATE n-1

Fig. B.13: Data Block scheme

CAEN SpA is acknowledged as the only company in the world providing a complete range of High/Low Voltage Power Supply systems and Front-End/Data Acquisition modules which meet IEEE Standards for Nuclear and Particle Physics. Extensive Research and Development capabilities have allowed CAEN SpA to play an important, long term role in this field. Our activities have always been at the forefront of technology, thanks to years of intensive collaborations with the most important Research Centres of the world. Our products appeal to a wide range of customers including engineers, scientists and technical professionals who all trust them to help achieve their goals faster and more effectively.

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