

The software module MDPP-16-QDC provides the functionality of a fast charge integrating ADC, a CFD+TDC and a pulse shape discrimination unit. It also works with short pulses of plastic scintillators and provides neutron/gamma pulse shape discrimination with liquid scintillators

MDPP-16 with QDC software module:

- **Gain-polarity jumpers**
determine: termination, polarity, input range and input configuration (differential / unipolar).
Special QDC jumpers available to get best amplitude resolution for plastic scintillators.
- **Low noise variable gain input amplifiers.**
Input signals for maximum range (highest spectrum channel)
Plastic scintillators pulse width 5ns (QDC jumpers 2V):
200mV to 5V (20pC to 500pC)
LYSO, Pulse width 30ns (any input jumper possible)
15mV to 3V (10pC to 1.5nC) (other jumpers on request)
- **Timing resolution**
down to 60ps channel to channel resolution,
CFD timing, TF integration / differentiation time down to 25ns
- **Pulse shape discrimination**
delivers two amplitudes: one is the standard integrated pulse amplitude (integration time 25ns to 1.6us), the second is a short integration of the rising edge of pulse. Integration as short as 12.5 ns to 350 ns. This is fast enough to give good neutron / gamma separation for liquid scintillators
Also works for Stilbene, CLYC.
- **AC-coupled and baseline restored**
Offsets of the input signals have no effect. Even at highest rates, the amplitude keeps stable.
- **Dead time / rate capability**
Channel dead time is 390ns, (integration time up to 300ns included). For longer integration time dead time is integration time + 100ns.
- **Two high resolution monitor outputs**
for monitoring input signals and integrals of signals.
- **Two high resolution trigger inputs**
24 ps resolution, start window, add time stamp
- **One high resolution trigger output** (1.5 ns resolution)
- **Installation and update via USB**

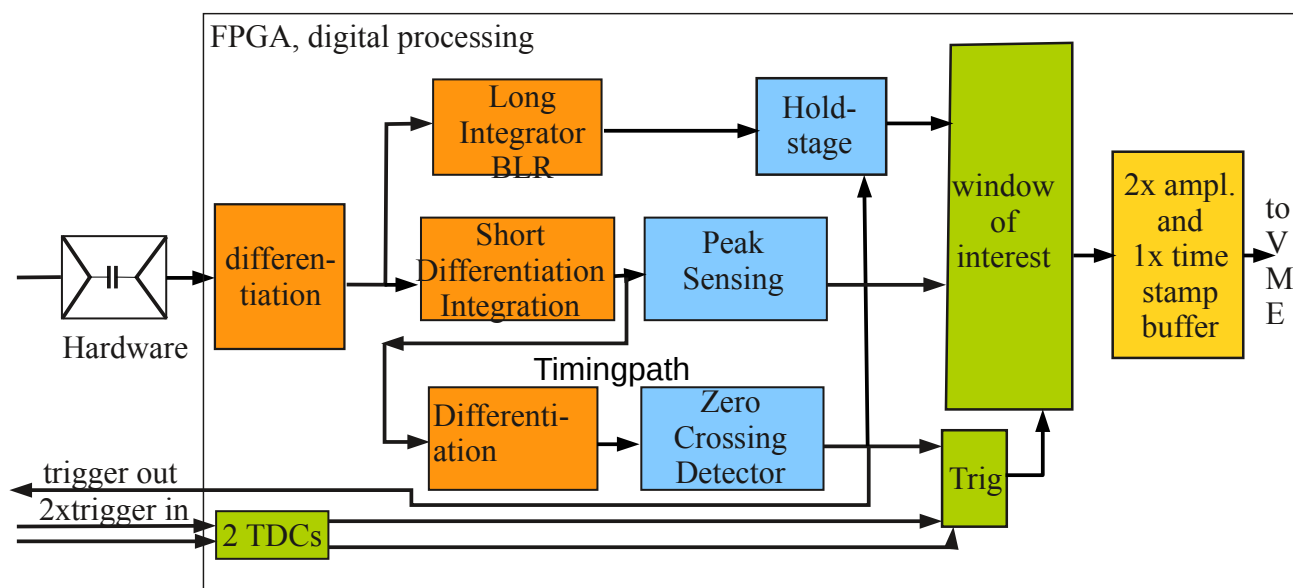


Software module: "QDC"

Delivers timing and amplitude and pulse shape analysis for signals from fast charge amplifying Detectors. For Example Photo multipliers, GEM, Channel plate..

Replaces Fast amplifier, CFD, QDC, TDC.

The following picture shows a schematic representation of the software:



The signal is amplified filtered digitized. Then it is split into three branches: timing branch, short integration and long integration. The timing branch takes the shaped signal from short integration branch. It consists of a **differentiation stage**, which differentiates the signal with a short time constant. Then a digital **Zero crossing detector** calculates an amplitude independent time trigger (=time stamp).

In the "short integration" branch the signal is differentiated with a time constant down to 12.5ns. This allows to extract a very short time interval at the beginning of the pulse, which even allows to perform pulse shape discrimination with liquid scintillators.

The "long integration" path is the QDC-(Charge to digital converter) part of the processing software. Usually the full input pulse is integrated here. Integration times of 25 ns to 6400 ns are possible. As the input is AC-coupled a baseline restorer is required, to preserve a stable pulse amplitude at very high rates. The integrated signal is sampled at a well de-

fined time, determined by the timing branch.

Then the two amplitude and timing values are filtered by a **window of interest** and stored in a **buffer**.

Short data:

- Amplitude resolution of up to 16 k
- Trigger to channel time resolution of < 75 ps rms, uniform at any delay.
- Channel to channel time resolution of < 75 ps rms, uniform at any delay.
- Trigger input with 24 ps timing resolution
- Can be operated self triggered or externally triggered
- Outputs internal raw trigger with 1.5 ns time resolution

As easy to operate as all mesytec modules and fully data compatible.

Get sample trails

Sample trails are available for “SCP” and “QDC” software since Package SP0043.

In the updated software packets “SCP” for charge integrated signals and “QDC” for direct PMT and similar high gain sources, an extension is implemented allowing to add up to 1000 sample values per channel (12.5us trail length).

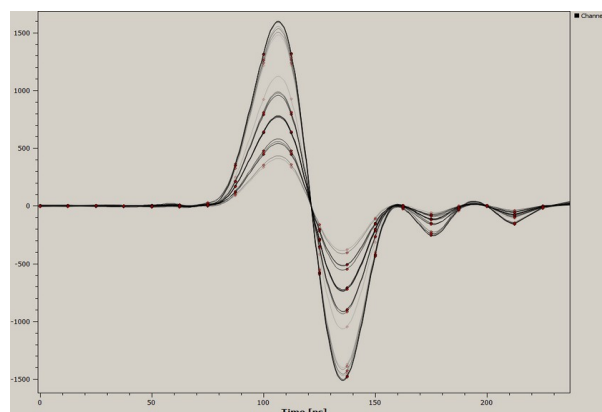
For a trail length of up to 500 samples, two traces per channel can be registered simultaneously, minimising the channel dead time. It is possible to specify a number of pre samples (before the input signal edge) and any number of samples (up to 1000) required. Up to 80 M Samples/s can be transmitted to the VME bus when 2ESST readout mode is used. This results in up to 320 MBytes/s of data transferred via VME bus.

The sample trails are simply added to the channel data. The powerful trigger system via window of interest, internal/external triggering is unchanged. The high resolution timing and amplitude(s) are emitted simultaneously.

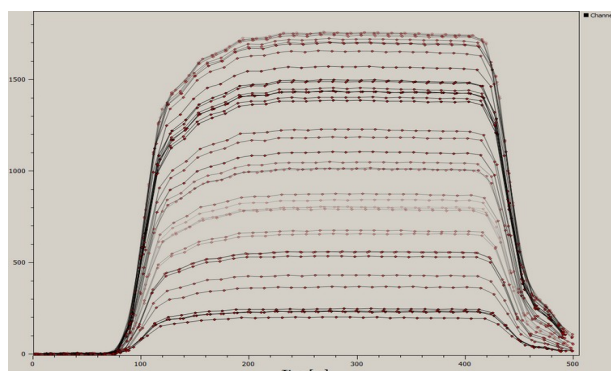
Sample source can be set to direct ADC signal, and to several internally processed signals.

The following pictures show sample trails from “SCP” software with different sources selected.

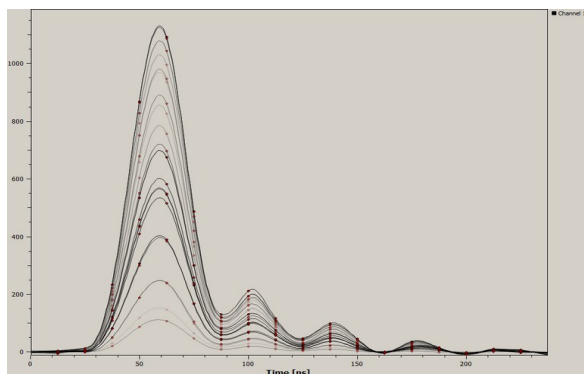
They can be displayed by mvme software in “event history” display.



Short integration output, triangular shaped bipolar



Long integration signal for amplitude

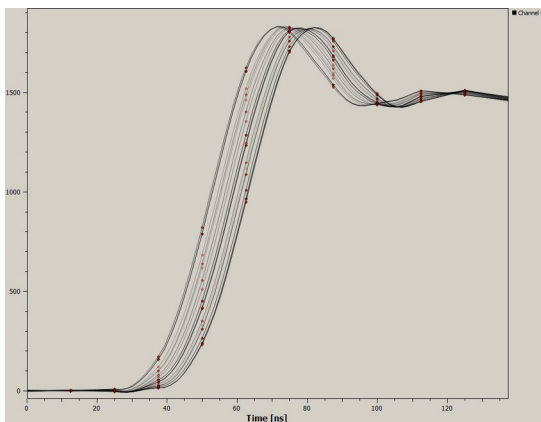


Directly from ADC

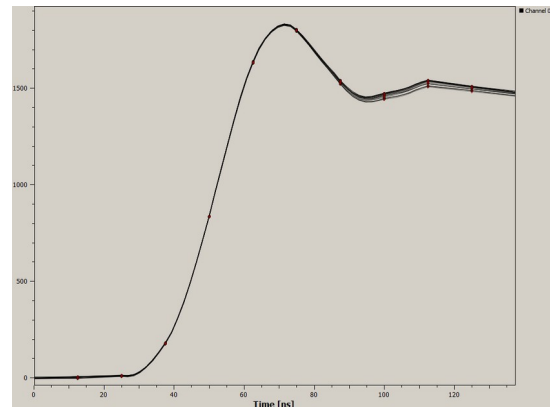
Resampling

Usually the input signals are asynchronous to the sampling frequency. This results in a jitter of the digitized signal by the sampling period in time. To get a stable display there are two possibilities:

- 1) MDPP can do a resampling. So it calculates new sampling points related to the precise time measured by the digital discriminator in the timing path.
- 2) In the sampling header, a "phase" showing the time difference between discriminator time and sample time is transmitted. In the mvme display the curve is shifted by this time to give a stable display as usually shown by an oscilloscope.



Display of 20 traces without resampling



Display with resampling in MDPP-16

Interpolation / reconstruction

A $\sin(x)/x$ interpolation (order 6 is used here) of traces requires four samples before and 3 samples behind the interpolated time slice between two samples. So in the mvme display (first approach) the first 3 and last 3 samples are interpolated linear. So for a time slice to be precisely interpolated there are 6 neighbour samples needed.

That's not required for resampling in MDPP-16. For the integrated resampling filter any number of samples is available. So for data reduction it is even possible to transmit only two samples to determine the rise time of a signal.

Offset correction

The 4 samples before transmitted samples are used for offset subtraction: mean value of the 4 samples is subtracted from all following samples.

Only 8 parameters have to be set:

In Hardware:

Polarity of the signal,
set Jumper to correct position

Register Settings

Signal properties:

1. signal width [ns]
2. maximum signal amplitude [mV]

Analysis property

3. required long integration
4. required short integration
5. threshold

Hardware Property:

Gain jumper sensitivity [mV]
QDC-Gainjumper used ?

Output Data

Amplitude:

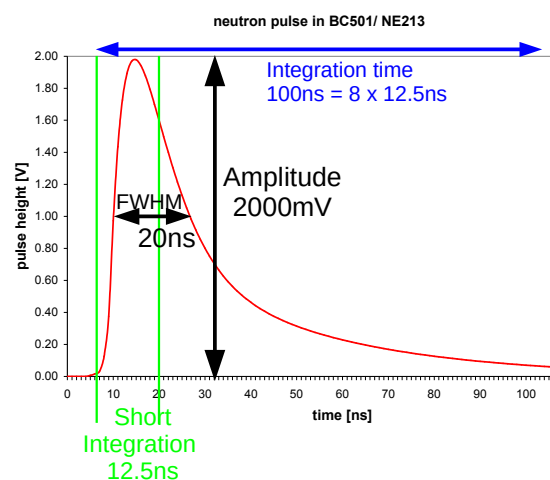
channel 0..15 Amplitude Long int. (16 bit)
channel 48..63 Amplitude Short int. (16 bit)

Timing: Difference to window start:

channel 16 to 31 channel time difference (16bit)
Chan 32,33 Trigger input 0,1 time diff. (16 bit)

Example: The following diagram shows the

charge pulse as it is produced by a liquid scintillator when detecting a neutron interaction.



The initialization data for MDPP-16-QDC are:

| |
|---|
| Signal_width = 20 |
| Input_Amplitude = 2000 |
| Jumper_range = 3000 // for 3V-Jumper |
| QDC_Jumper = 0 // 0 = standard jumper |
| Integration_long = 8 |
| Integration_short = 1 |
| threshold0 0x200 // = 1/128 of full range 0xFFFF |

Monitor outputs

(Lemo 2 = mon 0, and Lemo 3 = mon 1)

Switching on the monitor: press pus button "chan", then select a wave form with "Tmon" button. The button "chan" allows to switch through the individual channels.

As the monitor output has limited bandwidth, the adjustment parameters (signal width) should be measured by oscilloscope.

Wave forms:

Tmon 0,

Green: mon0, signal before ADC,
Magenta: mon1, differentiated input signal.
The differentiation time (here it is the distance between positive peak and negative peak) corresponds to the long integration time.



Tmon0, green=inp.,mag.=differentiated

Tmon 1:

Green: mon 0, short integration signal, which is calculated from differentiated signal shown above with a following trapezoidal filter. The first positive maximum is peak sensed and converted.

Magenta: mon 1, long integrated signal. An integral of the differentiated Signal of T0 magenta.

The flicker mark shows the sampling time.

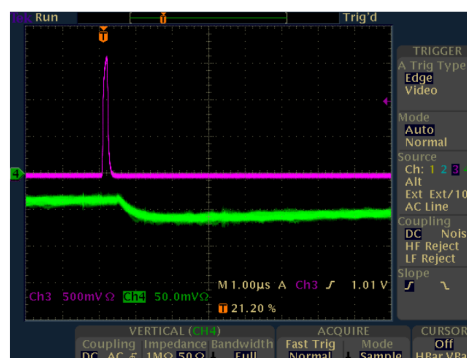


Tmon1, green=Shortint; mag.=Longint

Tmon 2 :

Green: mon0, baseline from BLR, multiplied x8.

Magenta: mon 1, Long integration signal, baseline corrected.



Tmon2, green=Baseline, mag. =Longint



Tmon3, green=Z-cross, mag.=TF-out

Tmon 3: Check noise

Green: mon 0, signal from short shaping, differentiated. Trigger and timing is generated from zero crossing of this signal.

Magenta: mon 1, signal from short shaping, same as Tmon1 green.

MDPP-16 register set, QDC Firmware.**Only registers which are different to RCP and SCP software modules are listed.**

Data FIFO, read data at address 0x0000 (access R/W D32, 64)

only even numbers of 32 bit-words will be transmitted. In case of odd number of data words, the last word will be a fill word (= 0).

FIFO size: $48\text{ k} - 1\text{ k} = 48128$ words with 32 bit length

Header (4 byte)

| | | | | | | |
|--------------------------|----------------|------|----------------|---------------------------------|---------------------------------|---|
| 2 header signature | 2 subheader | 4 | 8 module id | 3 TDC_resolution → 0x6042 | 3 ADC_resolution → 0x6046 | 10 number of following data words, including EOE |
| b01 | b00 | xxxx | module id | bxxx | bxxx | number of 32 bit data words |

Data (4 byte) DATA event

| | | | | | |
|---------------|----|------|---------------|-------------------------|----------------------------|
| 2 data-sig | 2 | 4 | 2 | 6 | 16 |
| b00 | 01 | xxxx | (x, overflow) | channel number 0..15 | ADC value long integration |

Data (4 byte) DATA event

| | | | | | |
|---------------|----|------|---------------|--------------------------|-----------------------------|
| 2 data-sig | 2 | 4 | 2 | 6 | 16 |
| b00 | 01 | xxxx | (x, overflow) | channel number 48..63 | ADC value short integration |

Data (4 byte) DATA event

| | | | | |
|---------------|----|--------|--------------------------|---------------------|
| 2 data-sig | 2 | 6 | 6 | 16 |
| b00 | 01 | xxxxxx | channel number 16..31 | TDC time difference |

Data (4 byte) DATA event

| | | | | |
|---------------|----|--------|--------------------------|--------------------------------|
| 2 data-sig | 2 | 6 | 6 | 16 |
| b00 | 01 | xxxxxx | channel number 32, 33 | Trigger time difference T0, T1 |

Data (4 byte) Extended time stamp

| | | | |
|---------------|---|----|----|
| 2 data-sig | 2 | 12 | 16 |
|---------------|---|----|----|

| | | | |
|-----|----|----------------|----------------------------|
| b00 | 10 | xxxx xxxx xxxx | 16 high bits of time stamp |
|-----|----|----------------|----------------------------|

Data (4 byte), fill dummy (to fill MBLT64 word at odd data number)

| | |
|---------------|----|
| 2 data-sig | 30 |
| b00 | 0 |

End of Event mark (4 byte)

| | |
|-----|----------------------------|
| 2 | 30 |
| b11 | event counter / time stamp |

Sample Transmission

From QDC Firmware packet FW3050 samples can be added to the data stream.

Samples follow the time word:

| | | | | |
|---------------|-----|------------------------------------|--------------------------|---------------------|
| 2 data-sig | 2 | 6 | 6 | 16 |
| b00 | b01 | xxxxxx | channel number 16..31 | TDC time difference |
| b00 | b11 | Sample header[27:0] | | |
| b00 | b11 | Sample1[13:0], Sample0[13:0] | | |
| .. | .. | .. | | |
| b00 | b11 | Sample_2N[13:0], Sample_2N-1[13:0] | | |

Sample header: { 0, sample_config[7:0], phase[8:0], following_sample_words[9:0] }

Following_sample_words[9:0]: (= N) up to 500 sample pairs may follow = 1000 samples.

Phase[8:0]: a phase with range 0 to 511 is transmitted, showing the distance between trigger point to the ADC sampling time. If “resampling” is active this word is not needed. If resampling is switched off, it can be used to shift samples for jitter free display of wave forms.

Sample config[7:0]: { not_offset, not_resample, 0, 0, 0, 0, source[1:0] }
source = 0 Samples directly from ADC

SCP

source = 1 Samples from reconstructed input signal
source = 2 Samples from timing filter shaper
source = 3 Samples from main shaper

QDC

source = 1 Samples from short integration
source = 2 Samples from long integration

Extract samples:

- extract time word, extract channel address from time word
- next word with data[31:28] == 0x3 is the sample header
- following words with data[31:28] == 0x3 are the samples for the detected channel

QDC software allows two “streaming modes” from Firmware revision FW2041.

Setting Register 0x6044 to 4 switches on compact streaming mode, 0x6044 = 8 the standard streaming mode. In streaming mode the timing of MDPP-16 is synchronised to the VME back plane clock.

All 16 channels and the 2 trigger inputs are now completely independent and output an independent event frame. Window of interest is switched off. The event frame is 2 words long

Compact streaming mode:

Header (4 byte)

| | | | | |
|--------------------------|----------------|--|---------------------------|----------------------------|
| 2 header signature | 6 module id | 6 Address[4:0] {trig_flag,0,address} | 2 Pile_up, overflow | 16 Amplitude |
| b01 | module id | T0AAAA | P,O | Long integrated Ampl[15:0] |

For Trigger events (address 0b10000 and 100001) the number of events, which were skipped due to buffer overflow since last trigger is emitted in at the place of “amplitude”.

End of Event mark (4 byte)

| | |
|-----|-------------------------------------|
| 2 | 30 |
| b11 | Fine time stamp (set in reg 0x6042) |

Standard streaming mode

Setting Register 0x6044 to 8

Has the same data format as standard mode described on the page before, but only one channel (long + short amplitude) or trigger (address 0b10000 and 100001, skipped events[15:0]) is emitted in a packet. The “module time stamp” is the precise time stamp set in register 0x6042. Also extended time stamp with extra 16 bits is possible. As for both streaming modes, time is the precision time with resolution set with reg 0x6042

Registers

| | operation mode | | | | |
|--------|----------------|---|----|---|---|
| 0x6044 | output_format | 2 | RW | 3 | 0 = standard window of interest mode. from FW2050: 4 = SCP only, compact Streaming mode 8 = standard streaming mode 16 = window of interest with samples 24 = standard streaming with samples. |
| 0x6046 | adc_resolution | | | 4 | 0 = 64k |

Channel addressing (select channel which are set)

| 0x6100 | select_chan_pair | 4 | RW | 8 | channel to be modified: 0..7 channel pairs; 0 = chan 0,1 1 = chan 2,3 ... 8 = all channels (set to common values) |
|--------|------------------|---|----|---|--|

Channel settings for pairs of channels,

*** After writing a register in this page, 20us wait time is required *****

| Address | Parameter | | | | |
|---------|-----------------------|----|----|------|--|
| 0x6110 | Signal_width | 10 | RW | 16 | [FWHM, ns], |
| 0x6112 | Input_Amplitude | 16 | RW | 1024 | [mV], input amplitude 0 to peak in mV |
| 0x6114 | Jumper_range | 16 | RW | 3072 | [mV], Range printed on jumper top |
| 0x6116 | QDC_Jumper | 1 | RW | 0 | 1= yes, 0=no |
| 0x6118 | Integration_long | 7 | RW | 16 | [12.5 ns], 2..506 ⁽¹⁾ in clock steps of 12.5ns |
| 0x611A | Integration_short | 5 | RW | 2 | [12.5 ns], 1..127 ⁽¹⁾ in clock steps of 12.5ns must be < than long integration |
| 0x611C | threshold0 | 16 | RW | 0xFF | 1...0xFFFF; example: 0.8% = 0x200; |
| 0x611E | threshold1 | 16 | RW | 0xFF | 1...0xFFFF; for odd channel in pair |
| 0x6128 | reset_time | 10 | RW | 32 | multiple of 12.5ns; default is usually good |
| 0x612A | long_gain_correction | 12 | RW | 1024 | 256: divide by 4, 4096 multiply by 4, 1024 neutral; |
| 0x612C | tf_gain_correction | 12 | RW | 1024 | |
| 0x612E | short_gain_correction | 12 | RW | 1024 | |
| 0x6146 | pre_samples | 10 | RW | 4 | 0..1000, samples before trigger |

| | | | | | |
|--------|---------------|----|----|----|---|
| 0x6148 | tot_samples | 10 | RW | 12 | 0...1000, total number of samples |
| 0x614A | sample_config | 8 | RW | 0 | {no_offset_corr, no_resamp,0,0,0,0,source[1:0]} source source = 0 Samples directly from ADC source = 1 Samples from short int source = 2 Samples from long int |

How to set channel parameters

Signal_width This is the width of the input pulse at half the peak amplitude in ns. The pulse must be measured with a **terminated** oscilloscope. Do not measure at the monitor output of MDPP-16! It does not have the bandwidth to properly measure the pulse width.

Input_amplitude: This is the amplitude of the input pulse measured from base line to peak in mV. Offsets of the signal have no effect. The pulse must be measured with a terminated oscilloscope. Do not measure at the monitor output of MDPP-16! It does not have the band width to properly measure the pulse width.

Jumper range: The value is printed on the jumper. multiply the value by 1000 to get the mV unit.

QDC_Jumper: set 1 if you used a QDC-Jumper; This is printed on the jumper. QDC jumpers give better amplitude resolution and linearity if the signal width is less than 15ns. The QDC jumpers have a band width limit of 30MHz, so increase the width of input pulses to about 25ns. They should not be used for pulse shape discrimination.

Integration_long: is the integration time to get the full charge of the input pulse. It is specified in multiples of internal clocks, so 12.5ns. Allowed range is 2 (25ns) to 127 (1.6us)

Integration_short: is the integration time to get the first fast part of the input pulse. It is specified in multiples of internal clocks, so 12.5ns. Allowed range is 1 (12.5ns) to 31 (387ns) It must be smaller than the long integration time.

Threshold0/1: The threshold parameter can be set separately for the two addressed channels. Full range is 64k (65535) = 0xFFFF; So a 1% of full range threshold is 65535/100 = 655;

reset: At overflow and underflow the input preamplifier and digital section is resetted. The default time is usually good.

Gain_corrections: The internal gains and hardware gain are calculated based on the signal width and amplitude. This should give a quite good start value. Details of the signals will have an effect on the real amplitude. So there are 3 scaling factors to correct the gains. The default of 1024 is the neutral setting, a lower value decreases the amplitude in a spectrum, a higher one increases it. It is possible to decrease the gain by a factor of 4 (->256), or increase it by a factor of 4 (-> 4096).