

mesytec **MDPP-16** is a fast high resolution time and amplitude digitizer. It is internally realized as a 16 channel adjustable low noise amplifier and a variable differentiation stage, followed by filters and 80 MHz sampling ADCs. The digitized data are analyzed in an FPGA and reconstructed with highest precision. This allows to achieve unique timing and amplitude resolution.

## Hardware features:

- **Low noise variable gain input amplifiers.**
  - Input signals for maximum range (highest spectrum channel) from **1.5 mV to 20 V**.
  - Input noise down to **2  $\mu$ V @ 2  $\mu$ s** shaping.
- **Variable hardware pre-differentiation**  
Allows large offsets and signal stacking without effect on the amplitude or timing resolution.
- **Reset stage** (supports reset preamplifiers)  
Dynamical range for reset preamps: reset pulse / noise =  $1.5 \cdot 10^6$  at 2  $\mu$ s shaping time. Recovery within 2  $\mu$ s + shaping time .
- **Gain-polarity jumpers**  
determine: termination, polarity, input range and input configuration (differential / unipolar).
- **Two high resolution monitor outputs**  
for monitoring internal signals and noise via oscilloscope.
- **Two high resolution trigger inputs**  
24 ps resolution, start window, add time stamp
- **One high resolution trigger output** (1.5 ns resolution)
- **Up to 4 software modules**  
can be stored on board and can be selected by switch or VME.
- **Installation and update via USB or VME**
- **VME64X format, downward compatible to VME64**
- **SCP and QDC software allow to add sample trails up to 1000 samples**

## Software modules

**Large digital resources** allow precise wave form reconstruction.

- timing down to **60 ps rms**
- amplitude resolution better than **32k**.
- Trigger threshold down to **1/3000** of maximum range.

## FPGA software modules:

- Amplitude & time for standard preamps (SCP), 64 k/60 ps
- Amplitude & time for reset preamps (RCP) 64 k/60 ps
- QDC: charge & time & PSD , self gating, 64k/60 ps



- Peak sensing ADC, 64 k, self gating or external
- Pulse shape discrimination for CsI Scintillator

**For MDPP-16 the following software is available:****SCP = Signal Processing of Standard Charge Integrating Preamplifiers**

Outputs:

Amplitude 64k,  
Timing 64k channels with min 24ps  
From Revision FW2050 can transmit up to 1000 samples per channel

**RCP = Signal Processing of Charge Integrating Preamplifiers with Reset**

Outputs, typically germanium detectors;

Outputs:

Amplitude 64k,  
Timing 64k channels with min 24ps

**QDC = Signal Processing of fast PMT signals without preamp.**

Pulse Shape Discrimination, timing

Outputs:

Amplitude Short 64k,  
Amplitude Long 64k,  
Timing 64k channels with min 24ps  
From Revision FW3050 can transmit up to 1000 samples per channel

**PADC = Peak sensing ADC. Signal Processing of Shaped Signals.** Peak sensing ADC with Baseline Restorer, self triggering. The peak maximum is used to determine a high quality timing.

Outputs:

Amplitude Long 64k,  
Timing 64k channels with min 24ps

**CSI = Signal Processing of Standard Charge Integrating Preamplifiers**

calculates short shaped amplitudes and long shaped amplitudes and Timing. Typical signals from CsI scintillator light with PMT and Charge preamp, Signal from <sup>3</sup>He tubes for n-detection. Pulse shape discrimination of Si-Detector signals.

Outputs:

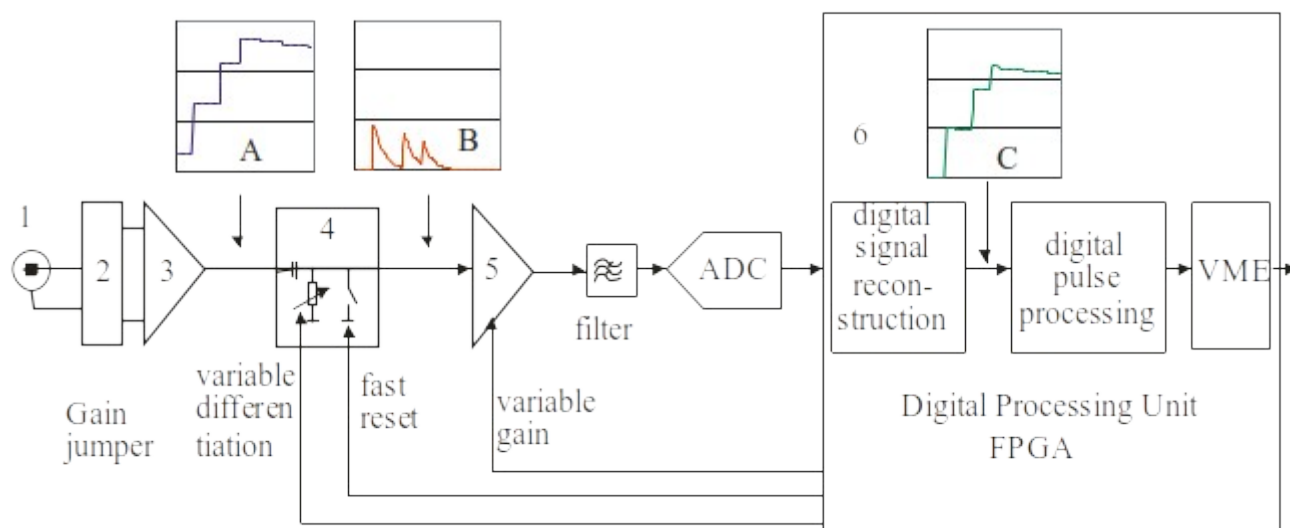
short integrated Amplitude 64k,  
long integrated Amplitude 64k,  
Timing 64k channels with min 24ps

## Hardware concept of MDPP-16

MDPP-16 was developed to meet the following challenges:

1. **Easy to use:**
  - No knowledge of the internal signal processing required.
  - Only essential signal parameters and settings required for operation.
  - Input is capable to directly accept any preamplifier signal.
2. **Works together with existing VME modules** - accepts and creates triggers for an external experiment logic.
3. **Provides very good timing** - good enough to replace external CFDs and TDCs for most applications.
4. **Amplitude resolution as good as best analog solutions**, including ballistic loss correction, pile up rejection (reconstruction), baseline restoration.

To meet those goals, a new hardware concept was required as shown in the following figure.



The input (1) was designed to allow two configurations:

- differential and unipolar input with a standard 34 pin header connector (depending on applied jumpers).
- Unipolar input with Lemo inputs.

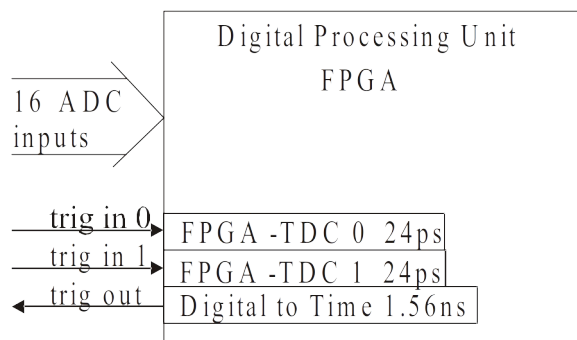
The input signal amplitude for maximum output range is from 1.5 mV to 20 V and can be set by different **input jumpers (2)**, a **variable gain stage (5)** (gain 1 to 24) and by additional scaling of the **digitized data (6)**. So a continuous gain from 1.00 to 200.00 is provided for each gain jumper set.

The input is followed by a high dynamic range, **low noise amplifier (3)**. Its signal is then differentiated by an adjustable **differentiation stage (4)**. It is part

of the shaping filter, and is set by the central logic unit. It also includes a fast reset circuit, which allows fast recovery from large overflow and underflow signals. It delivers an output which is **free of offset (B)** and eliminates the typical **stacking (A)** of charge integrating preamplifiers. So the dynamic range of the ADC can be fully used.

The **digital processing unit (6)** can be loaded with different software programs (up to 4 may be stored on board). With "SCP" software module for processing of charge sensitive preamp signals, the ADC signal is regenerated by an integration and the signal input (without offset) is fully recovered (C). Then the signal is processed with high precision and the help of 180 signal processors. Details of processing are described at another place with the software modules.

The MDPP-16 provides **further resources** to allow easy integration into a standard nuclear physics data acquisition system. It provides two high resolution trigger inputs (24 ps timing resolution). One of them may start the window of interest, while the other may add an additional time mark from an external detector.



Internally created triggers from the 16 input channels can be output to a high resolution trigger output (1.56 ns resolution). This allows to create an external experiment trigger from many modules. The trigger delay is typically 400 ns (+ TF-integration time) from the edge of analog input signal.

The externally created trigger can then be fed to one of the trigger inputs to start the window of interest. There are no problems with delay between trigger and channel input data, because the window of interest can be shifted in time by up to  $\pm 25$   $\mu$ s.

## Get sample trails

“SCP” and “QDC” software. Starting from 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).

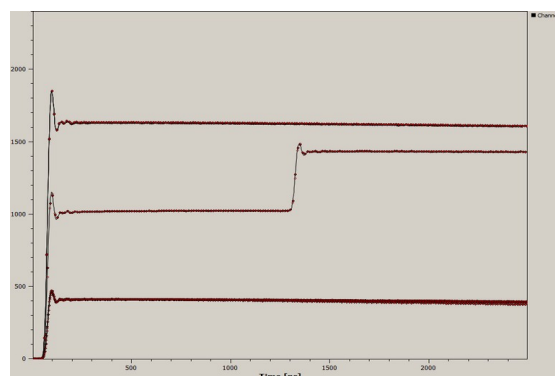
For a trail length of up to 500 samples, two traces per channel can be registered simultaneously, minimising the channel dead time. It is possible to specify a number of pre samples (before the input signal edge) and any number of samples (up to 1000) required. Up to 80 M Samples/s can be transmitted 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.

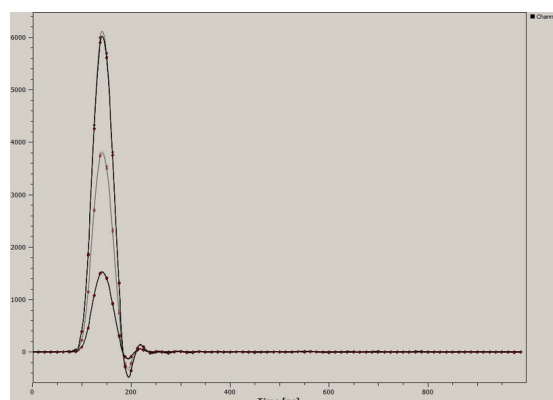
Sample source can be set to direct ADC signal, and to several internally processed signals.

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

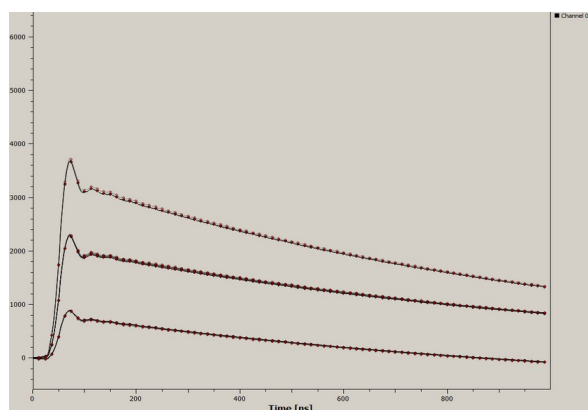
They can be displayed by mvme software in “event history” display.



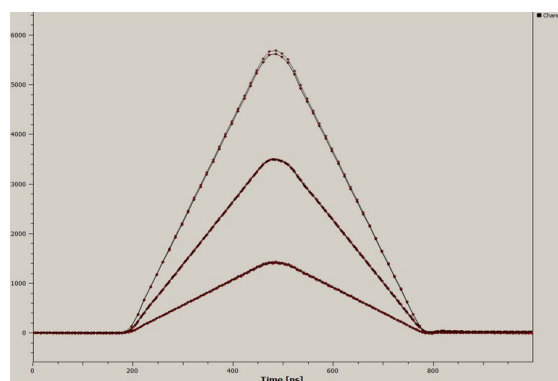
*ADC signal after first deconvolution*



*Timing Filter output, triangular shaped*



*Directly from ADC*

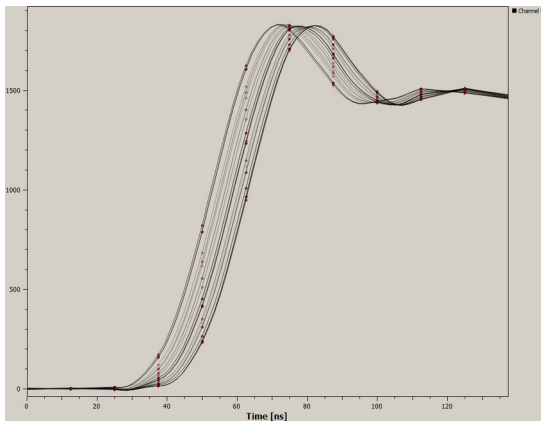


*Triangular shaper signal for amplitude*

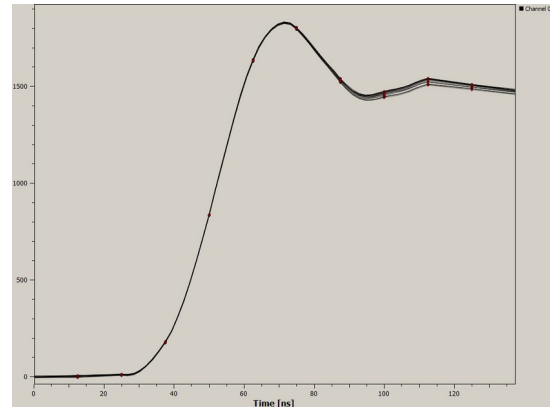
## Resampling

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.

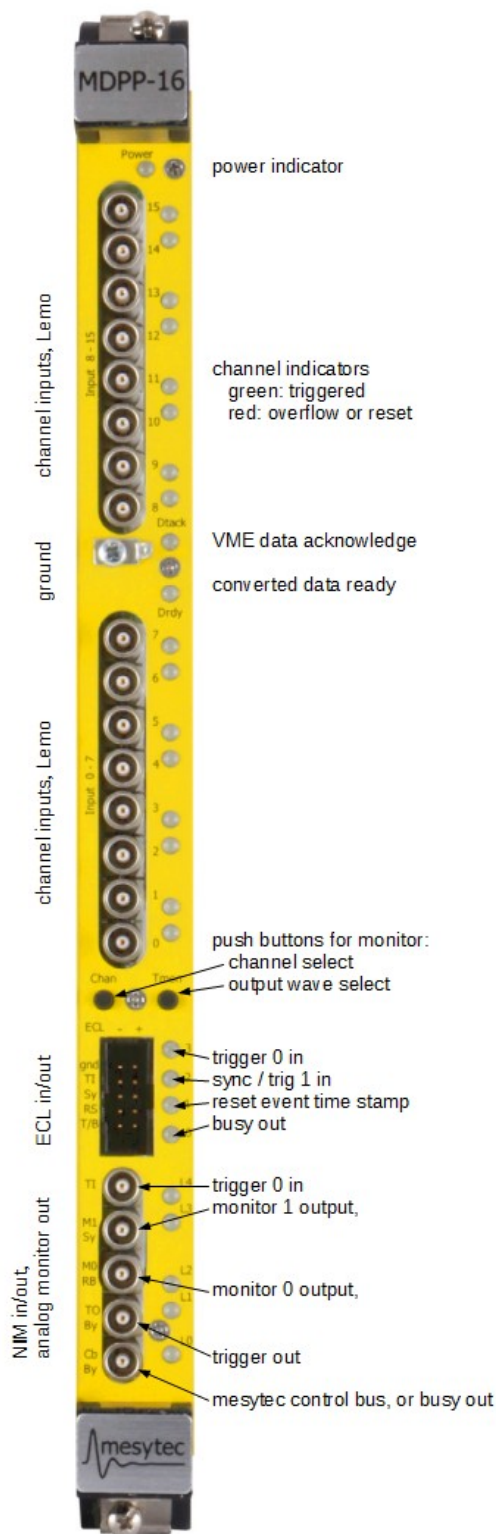
That's not required for resampling in MDPP-16. For the integrated resampling filter any number of samples is available. So for data reduction it is even possible to transmit only two samples to determine the rise time of a signal.

## 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.



## Front panel elements



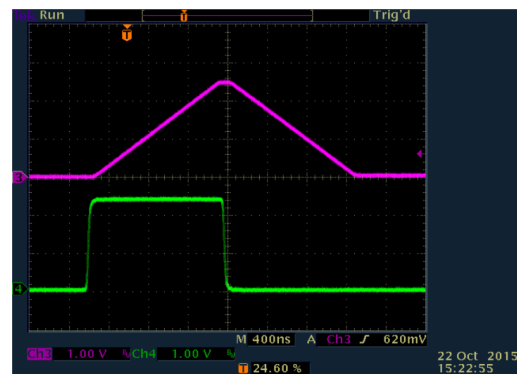
MDPP-16 provides 16 bi-color LED indicators for each channel. When lighting green the signal is within the legal range, red indicates an under- or overflow. When a channel is selected for monitoring, the LED flashes red.

There are two push buttons on the front panel to control the monitor function. One selects a channel to monitor, the other one selects a pair of wave forms.

The wave forms reflect signals generated in the pulse processing chain inside the FPGA. The signals are output at two Lemo connectors (L2, 3)

The following oscilloscope picture shows a wave form pair:

The green curve shows the differentiated signal. The magenta one shows the integral of the differentiated signal, creating the typical triangular shaping curve.



triangular shaper, differentiated sign

Also strongly amplified wave forms can be selected to monitor the structure of external noise.

### Monitor signals: mon0 / mon1

1. raw data / reconstructed signal
2. TF-output / Shaper output
3. Shaper x 32, BLR-signal x 32
4. Shaper x 32, Timing Filter x 32

### Timing and data concept - "Window of interest"

The window of interest concept is the same as for MQDC-32 and MTDC-32.

MDPP-16 creates an output trigger from any selected input channel or by a logical "or" of all or some user selectable channel inputs. The output trigger has a timing resolution of maximum 1.56 ns.

It is intended to feed a trigger logic in more complex setups.

MDPP-16 then expects an external gate from external trigger logic, which is evaluated with a high resolution (24 ps) time to digital converter (TDC).

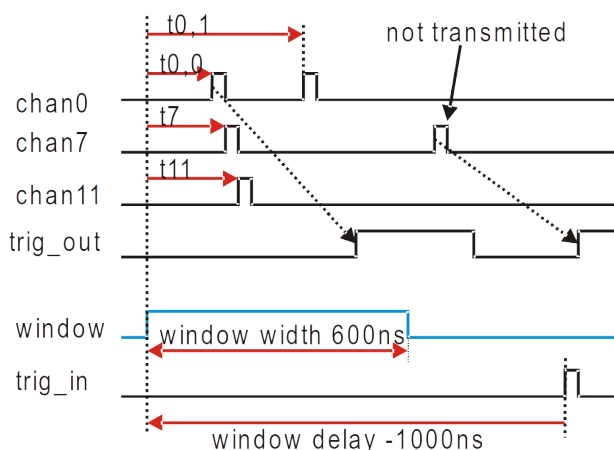
In the simplest configuration, output trigger can be fed back to the trigger input to allow self triggering.

The input trigger can be shifted internally by  $\pm 25$   $\mu$ s and starts a **window of interest** with adjustable width (1.5 ns to 25  $\mu$ s). All triggers generated by the CFD discriminators from the channel inputs, which fall into this window, are sent to a large data buffer for read out by The VME bus. The transmitted data are:

- the time difference to the window start (in 24 ps resolution)
- the converted shaper amplitude.
- over/underflow, and pileup flags

The provided buffer structure and all features like Event time stamp, event counter... are identical to all other mesytec VME-modules.

#### Example:



In the example, the internal triggers of three input channels are shown after the CFD discriminator.

Two pulses are detected in channel 0 and 7, one in channel 11. The very first pulse, which is in channel 0, starts the output trigger. This trigger may be fed through an external electronics and - if coincident to other detectors and data acquisition is not busy - returns delayed to the trigger input. It arrives with a fixed delay of 800 ns. So it has to be shifted back in time by MDPP-16 (here 1000 ns) and a coincidence time (window width) of 600 ns has to be created. As can be seen 4 hits fall into this window (2 x channel 0, 1x channel 7 and 11).

So four time differences referenced to the window start are calculated, and are sent to a data buffer together with the according amplitudes.

#### All software modules have the following features:

- Support different types of event synchronisation stamping (based on VME-clock or external clock)
- Multiplicity filter, selects events in specified multiplicity range
- mesytec control bus to control external mesytec modules
- Address modes: A24 / A32
- Data transfer modes: D16 (registers)
- D32, BLT32, MBLT64, CBLT, CMBLT64
- Multicast for event reset and time stamping start

#### Hardware features

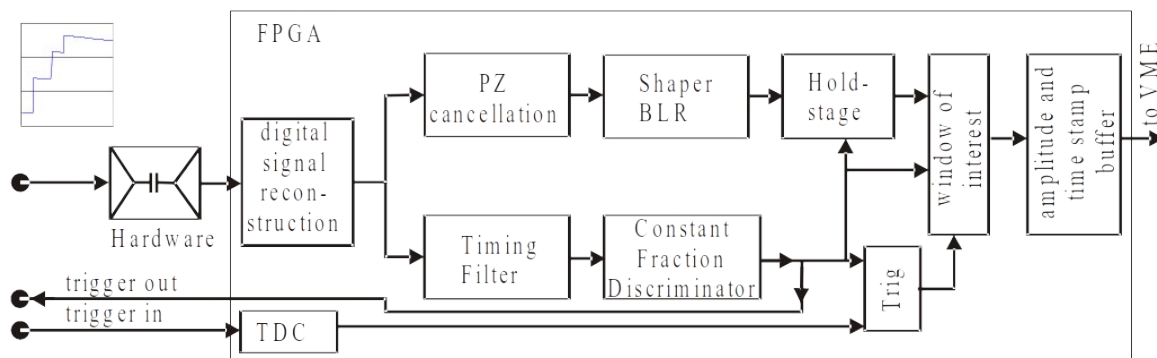
- Live insertion (can be inserted in a running crate)
- Power consumption: 14 W,  
+ 5 V, 2 A  
+ 12 V, 100 mA  
- 12 V, 200 mA.



## Software module: "SCP"

(Delivers timing and amplitude for **standard charge sensitive preamplifier** signals)  
Replaces shaper, peak sensing ADC, timing filter amplifier, CFD, and TDC.

The following picture shows a schematic representation of the software:



The signal is amplified filtered digitized and reconstructed as described in the hardware chapter. Then it is split into a timing branch, and enters a **timing filter**. It differentiates and integrated the signal with short adjustable time constant. Then a digital **CFD** (discriminator) calculates an amplitude independent time trigger (=time stamp).

In the other "slow" branch the signal is deconvoluted (**PZ cancellation**) and then enters a filter consisting of a differentiator and integrator forming a filter, which produces a **triangular shaping**. Also a **base line restorer** is implemented.

Then signal then enters a **hold stage** which holds the amplitude at a well defined time, determined by the CFD discriminator.-

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

### Short data:

- Amplitude resolution of up to 32 k (15 bit)
- Trigger to channel time resolution of **60 ps rms**, uniform at any delay.
- Channel to channel time resolution of **60 ps rms**, uniform at any delay.
- Trigger input with 24 ps timing resolution
- Extreme dynamic range (trigger 3000:1)
- Independent shaping of timing filter and amplitude branch.
- Shaping width can be set from 50 ns to 25  $\mu$ s FWHM (= 25 ns to 10  $\mu$ s sigma values) in steps of 12.5 ns.

- Timing filter from 15 ns to 1.6  $\mu$ s.
- 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.

### Only five parameters have to be set:

#### Signal properties:

1. signal rise time 15 ns to 1.6  $\mu$ s (= TF integration and diff-time)
2. signal decay time (for PZ) 800 ns to  $\infty$ .
3. Gain 1 to 200 in steps of 0.01

#### User settings:

4. Shaping time: 25 ns to 11  $\mu$ s (50 ns to 25  $\mu$ s FWHM)
5. Threshold

### Output Data

channel 0..15 Amplitude (11 to 16 bit)  
channel 16 to 31 time difference to window start (16 bit) 24 ps/chan.

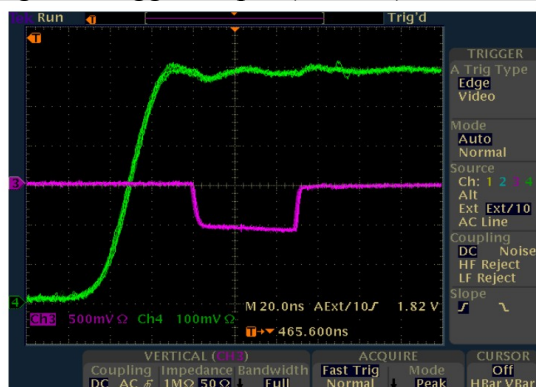
**Monitor outputs**

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

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

**Wave forms:****Tmon 0,**

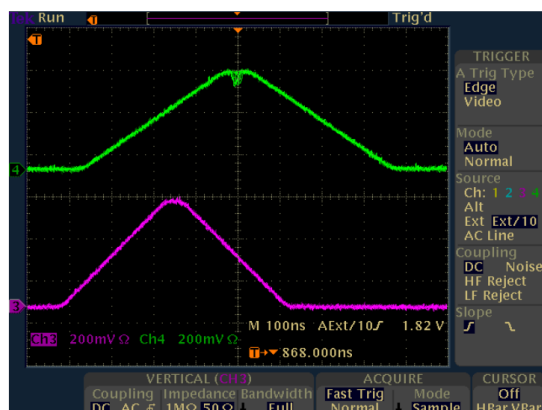
Green: preamplifier signal before ADC,  
Magenta: trigger output (Lemo 1)



Input signal, Trigger output

**Tmon 1: Check signal shape and amplitude**

Green: mon 0, triangular shaped signal with flicker mask, showing the sampling time.  
Magenta: mon 1, timing filter signal



Shaper with marker, TF output

**Tmon 2 : Check pole zero adjust and baseline****restorer**

Green: mon0, Shaper signal amplified x32.

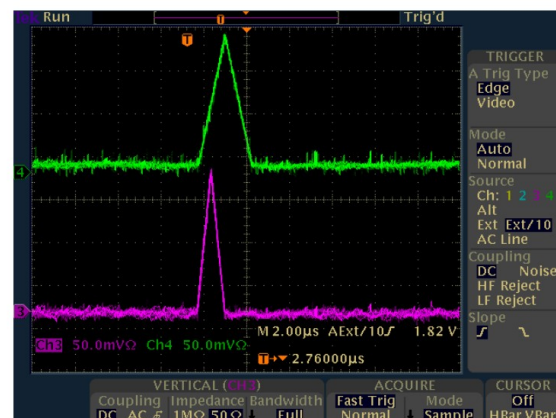
Magenta: mon 1, reconstructed baseline by the baseline restorer, x 32



Shaper x 32, reconstr. Baseline x 32

**Tmon 3: Check noise**

Green: mon 0, Shaper signal, baseline restored x32  
Magenta: mon 1, timing filter signal x 32



Noise inspect, Shaper, Timing Filter

## Control input / output

- Differential control inputs:
  - interface any differential signals: ECL, LVDS or LVPECL. They can be individually terminated ( $110\ \Omega$ ) via register setting
- NIM inputs:
  - standard NIM,  $50\ \Omega$
- NIM output:
  - $-0.7\ \text{V}$  when terminated with  $50\ \Omega$
- mesytec control bus output, shares connector with busy output.  $+0.7\ \text{V}$  terminated

Minimum trigger width for individual inputs is =  $10\ \text{ns}$

Maximum external reference synchronisation clock frequency (sync input):  $75\ \text{MHz}$

## Digital Inputs /outputs (see IO register block 0x6060) and description

### Setting VME base address:

For setting the address of a module, it is easiest to only use the 8 high bits of the address (two high bit hex coders on the mother board) and leave the lower 8 bits at 0,0..

The 8 high bits also automatically occur in the event header.

**For VME64X modules in a VME64X crate**, the geo coding can be used by setting the 4 address coders to F,F,F,F. The the slot number is then used as module address.

For example Slot 15 will create the base high address 0x0F00.

## MDPP-16 register set, SCP Firmware (processing of Standard Charge sensitive Preamp signals) 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 subhea der	3	1 SA	8 modul e id	3 TDC_resolution → 0x6042	3	1 number of following data words, including EOE
b01	b00	b000	0	modul e id	bxxx	bxxx	number of 32 bit data words

When Sampling mode is active:

b01	b00	b000	1	modul e id	16 bits, number of 32 bit data words
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### Data (4 byte) DATA event

2 data-sig	2	4	2	1	5	16
b00	01	xxxx	(pu, ov)*	Trigger Flag	channel number	ADC value

channel numbers may come in arbitrary order. \* pu = pile up flag, ov = overflow or underflow flag

### Data (4 byte) DATA event

2 data-sig	2	6	1	5	16
b00	01	xxxxxx	Trigger Flag	channel number + 16	TDC time difference

### 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

Taking the trigger flag and channel number together, this 6 bit address runs from 0 to 15 for amplitudes, 16 to 31 for time, and 32 / 33 are trigger0 / trigger1 time.

So the full channel address has 6 bits, and runs from 0 to 33. The addresses 32 is for trigger input 0, the address 33 for trigger input 1.

**Sample Transmission**

From QDC Firmware packet FW3050 and SCP packet FW2050, samples can be added to the data stream.

Enable "sampling" is done with register 0x6044, pre-samples, total samples, and source have to be specified. Note that the event header has a 16 bit data length field in sampling mode.

Samples follow the time word (order: Amplitude, time, sample header, samples, Amplitude of next channel)

2	2	6	6	16
data-sig				
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

**Samples**

When "sampling" in register 0x6044 is switched on, samples are transmitted following a channel data word. The channel data word provides the channel address.

Then a sampling header is transmitted, followed by sample pairs.

**Sample Header**

2 data-sig	2	9	9	10
b00	11	Config word	Phase	Number of Sample pairs

**Sample data**

2 data-sig	2	14	14
b00	11	Sample second	Sample first

Format of Sample: 14 bit signed integer (+-8k range)

**Config word = Word set in register 0x614A**

0x614A	sample_config	9	RW	0	{0,no_offset_corr, no_resamp,0,0,0,0,source[1:0]} source source = 0 Samples directly from ADC source = 1 Samples reconstructed input source = 2 Samples from TF-Shaper source = 3 Samples from Shaper
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For MDPP-16: when the number of samples is 500 or less per channel, two samples can be recorded simultaneously per channel. So sample recording does not block the channel.  
So for most cases, the sample recording does not add dead time to a channel.



## SCP and QDC software allows two “streaming modes” from Firmware revision SCP\_FW2050 / QDC\_FW3050.

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 backplane 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.

In streaming mode, the module is synchronised by the VME backplane clock. So all modules in one crate run synchronous. When time stamp counter is reset by a VME multicast reset to all modules, the maximum time offset may be 12.5 ns.

### Compact streaming mode:

The event frame is always 2 words long.

#### 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	Ampl[15:0]

For Trigger events (Trig flag (data[21]) is set) 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 with window of interest, but only one channel

-with 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.

Extended time stamp with extra 16 bits of time stamp (total 46 bits) is possible.

Also sample transmission is possible (0x6044 to 24).

**For RCP-Firmware a reset event is generated for each reset of the preamp**

#### Header (4 byte)

2 header signature	2 subhead er	4	8 module id	3 TDC_resolutio n → 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	12	4
b00	01	0	0	33	0	Channel index of reset

#### 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

## Registers, Starting at address x6000 (access D16)

Address	Name	Bits	dir	default	Comment
	<b>Address registers</b>				
0x6000	address_source	1	RW	0	0 = from board coder, 1 from address_reg
0x6002	address_reg	16	RW	0	address to override decoder on board
0x6004	module_id	8	RW	0xFF	is part of data header If value = FF, the 8 high bits of base address are used (always board coder).
0x6006	Fast MBLT	1	RW	1	Setting to 0 limits MBLT cycle to min 100ns. Else 65 ns are possible.
0x6008	soft_reset	1	RW		Write breaks all activities, sets critical parameters to default. <b>Wait 200ms after writing this register.</b> Read: MDPP-16 hardware ID: 0x5005
0x600E	firmware_revision	16	R		Example: RCP=1, rev 2.4 = 0x1204 SCP=2, rev 1.2 = 0x2102 QDC=3, rev 2.1 = 0x3201

	<b>IRQ (ROACK)</b>				
0x6010	irq_level	3	RW	0	IRQ priority 1..7, 0 = IRQ off
0x6012	irq_vector	8	RW	0	IRQ return value
0x6014	irq_test	0	W		initiates an IRQ (for test)
0x6016	irq_reset	0	W		resets IRQ (for test)
0x6018	irq_data_threshold	15	RW	1	Every time the number of 32 bit words in the FIFO exceeds this threshold, an IRQ is emitted. Maximum allowed threshold is "FIFO size".
0x601A	Max_transfer_data	15	RW	1	1) Specifies the amount of <b>data</b> read from FIFO before BERR is emitted. Only active for multi <b>event mode 3</b> . Transfer is stopped only after full events. Example: At Max_transfer_data = 1, 1 event per transfer is emitted.  2) Specifies the number of <b>events</b> read from FIFO before BERR is emitted. Active for multi <b>event mode 0xb</b> .  Setting the value to 0 allows unlimited transfer.
0x601C	IRQ_source	1	RW	1	IRQ source: 0 = <b>event</b> threshold exceeded 1 = <b>data</b> threshold exceeded
0x601E	irq_event_threshold	15	RW	1	Every time the number of events in the

					FIFO exceeds this threshold, an IRQ is emitted.
--	--	--	--	--	---

For multi event mode 2 and 3 the IRQ is:

- **set** when the FIFO fill level gets more than the threshold and is
- **withdrawn** when IRQ is acknowledged or when the fill level goes below the threshold.

	MCST CBLT				
0x6020	cbt_mcst_control	8	RW	0	see table
0x6022	cbt_address	8	RW	0xAA	A31..A25 CBLT- address
0x6024	mcst_address	8	R	0xBB	A31..A25 MCST- address

Bit	Name	Write		Read	
7	MCSTENB	1 0	Enable MCST No effect	0	
6	MCSTDIS	1 0	Disable MCST No effect	1 0	MCST enabled MCST disabled
5	FIRSTENB	1 in a 0	Enable first module CBLT chain No effect	0	
4	FIRSTDIS	1 in a 0	Disable first module CBLT chain No effect	1 0	First module in a CBLT chain Not first module in a CBLT chain
3	LASTENB	1 in an 0	Enable last module CBLT chain No effect	0	
2	LASTDIS	1 in an 0	Disable last module CBLT chain No effect	1 0	Last module in a CBLT chain Not last module in a CBLT chain
1	CBLTENB	1 0	Enable CBLT No effect	0	
0	CBLTDIS	1 0	Disable CBLT No effect	1 0	CBLT enabled CBLT disabled

#### CBLT Address Field

A31.....A24	A23.....A00
CBLT ADRS	8 high bits, not significant + 16bit module address space

#### MCST Address Field

A31.....A24	A23.....A00
-------------	-------------

MCST ADRS

8 high bits, not significant + 16bit module address space

**At BLT32**

When an empty module is accessed at address 0, BERR is emitted.

**At CBLT**

When no module contains data, no data are transmitted. The last module emits BERR.

FIFO handling											
0x6030	buffer_data_length	16	R		amount of data in FIFO (only fully converted events). Units → data_len_format. Can be used for single- and multi event transfer						
0x6032	data_len_format	2	RW	2	0 = 8 bit, 1 = 16 bit, 2 = 32 bit, 3 = 64 bit, 4= show number of events in FIFO. The number of 32 bit words is always even. If necessary the fill word „0“ is added. For len 0 and 1 the max value 0xFFFF is shown when number exceeds the 16 bit format. The FIFO is not affected.						
0x6034	readout_reset		W		At single event mode (multi event = <b>0</b> ): allow new trigger, allow IRQ At multi event = <b>1</b> : checks threshold, sets IRQ when enough data. Allows safe operation when buffer fill level does not go below the data threshold at readout. At multievent = <b>3</b> : clears Berr, allows next readout						
0x6036	multi event	4	RW	0	<table><tr><th>Bit[3]</th><th>Bit[2]</th><th>Bit[1:0]</th></tr><tr><td>count events not words (reg. 0x601A)</td><td>skip berr, send EOB</td><td><b>mode</b>[1:0]</td></tr></table> <p>Allow multi event buffering (bit 0, 1) <b>mode = 0</b> → <b>no</b> (0x6034 clears event, allows new conversion) <b>mode = 1</b> → <b>yes</b>, unlimited transfer, no readout reset required (0x6034 can be written after block readout). Don't use for CBLT <b>mode = 3</b> → <b>yes</b> but MDPP transfers limited amount of data. With reg 0x601A the number of data words can be specified. After word limits is reached, the next end of event mark terminates transfer by emitting Berr. So 0x601A = 1 means</p>	Bit[3]	Bit[2]	Bit[1:0]	count events not words (reg. 0x601A)	skip berr, send EOB	<b>mode</b> [1:0]
Bit[3]	Bit[2]	Bit[1:0]									
count events not words (reg. 0x601A)	skip berr, send EOB	<b>mode</b> [1:0]									

					<p>event by event transfer (Berr after each event). The next data block can be transferred after writing 0x6034 (resets Berr).</p> <p><b>Berr handling:</b> when bit[2] is set: Send EOB = bit[31:30] = bx10 instead of Berr</p> <p>Bit[3]: Compare number of transmitted events (not words!) with max_transfer_data (0x601A) for Berr condition.</p>
0x6038	marking_type	2	RW	0	<p>00 → event counter 01 → time stamp 11 → extended time stamp</p> <p style="text-align: right;">→ next page</p>

0x603A	start_acq	1	RW	1	<p>1 → start accepting triggers If no external trigger logic, which stops the gates when daq is not running, is implemented, this register should be set to 0 before applying the FIFO_reset to get a well defined status. When setting it to 1 again for data acquisition start, the module is in a well defined status.</p>
0x603C	FIFO_reset		W		Initialize FIFO
0x603E	data_ready	1	R		1 → data available

	operation mode				
0x6042	tdc_resolution	3	RW	5	<p>5 → 781 ps = 25 ns / 32 4 → 391 ps = 25 ns / 64 3 → 195 ps = 25 ns / 128 2 → 98 ps = 25 ns / 256 1 → 49 ps = 25 ns / 512 0 → 24 ps = 25 ns / 1024</p>
0x6044	output_format	2	RW	0	<p>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.</p>
0x6046	adc_resolution	0	RW	0	Always 16 bits

	<b>Trigger</b>				
--	----------------	--	--	--	--



0x6050	win_start	15	RW	16k-16	Unit: 25ns/16 = 1.56 ns Start window of interest: 0x0000 start at -25.56us 0x7FFF start at +25.56us 0x4000 = 16k no delay  < 16 k, window starts before Trigger > 16 k, window is delayed														
0x6054	win_width	14	RW	32	Unit: 1.56 ns, max 16 k = 25.56 us														
0x6058	trig_source	10		0x100	<b>Defines the trigger which creates the window of interest.</b> This can be: one or both of the trigger inputs, any of the 16 channel inputs, or a logical "OR" of all channels. <table><tr><td colspan="2"><b>Whole bank</b> 2 bits</td><td colspan="3"><b>16 channels</b> 6 bits</td><td colspan="2"><b>trig</b> 2 bits</td></tr><tr><td><b>RCP:</b> reset s</td><td>B0</td><td>active</td><td>0</td><td>Chan [3:0]</td><td>T1</td><td>T0</td></tr></table>	<b>Whole bank</b> 2 bits		<b>16 channels</b> 6 bits			<b>trig</b> 2 bits		<b>RCP:</b> reset s	B0	active	0	Chan [3:0]	T1	T0
<b>Whole bank</b> 2 bits		<b>16 channels</b> 6 bits			<b>trig</b> 2 bits														
<b>RCP:</b> reset s	B0	active	0	Chan [3:0]	T1	T0													
0x605A	trig_source_2 <i>(SCP only)</i>	16	RW	0	When above register trig_source == 0, this register allows to set any number of individual channels creating the trigger. Bit 0 corresponds to channel 0, bit 15 to channel 15. A "1" marks the channels as trigger source.														
0x605C	first_hit	1	RW	1	1 = only transmit first hit 0 = transmit all hits in the window														
0x605E	trigger_output	10	RW	0x100	<b>Defines the trigger which creates the output trigger.</b> This can be any of the 16 channel inputs, or a logical "OR" of all channels. <table><tr><td colspan="2"><b>Whole bank</b></td><td colspan="3"><b>16 channels</b></td><td colspan="2"><b>00</b></td></tr><tr><td>0</td><td>B0</td><td>active</td><td>0</td><td>Chan [3:0]</td><td>0</td><td>0</td></tr></table>	<b>Whole bank</b>		<b>16 channels</b>			<b>00</b>		0	B0	active	0	Chan [3:0]	0	0
<b>Whole bank</b>		<b>16 channels</b>			<b>00</b>														
0	B0	active	0	Chan [3:0]	0	0													

### Bank trigger source example

Trigger 0 starts the window:

Channel 3 starts window: (bit 7 enables channel trigger)

Whole bank 0 may start the window:

bank0\_trig\_source = b00 0000 00 01

bank0\_trig\_source = b00 1000 11 00

bank0\_trig\_source = b01 0000 00 00

When whole bank is selected, the channel creating the trigger is the first to trigger, but random within 12.5ns.

IO 0x6060	Inputs, outputs				
0x6060	ECL3	8	RW	0x00	INPUT lower 4 bit: 0= Off, 1= Trig0 in higher 4 bit: 0 = terminated, 1= unterminated

0x6062	ECL2	8	RW	0x00	INPUT lower 4 bit: 0= Off, 1= Sync_in, 2= Trig1 in higher 4 bit: 0 = terminated, 1= unterminated <b>when sync is selected also set reg 0x6096 !!</b>
0x6064	ECL1	8	RW	0x00	INPUT lower 4 bit: 0= Off, 1= Reset_in higher 4 bit: 0 = terminated, 1= unterminated
0x6066	ECL0	4	RW	0	OUTPUT 0 = Off, 4 = Busy, 8 = data in buffer above threshold 0x6018 (= Data ready) 9 = events in buffer above threshold 0x601E
0x6068	NIM4	2	RW	1	INPUT 0 = Off, 1= Trig0_in
0x606A	NIM3	2	RW	1	0, 1 = Off, 2 = Sync in <b>when sync is selected also set reg 0x6096 !!</b>
0x606C	NIM2	2	RW	1	0 = Off, and 1 = Trig1_in, 2 = Reset
0x606E	NIM1				always Trig_out

<b>0x6070</b>	<b>Test pulser</b>				
0x6070	pulser_status;	1	RW	0	0 = Off, 1 = On (fixed frequency of about 1.6kHz) Degrades the input signals, so only use for test. Rise time 10ns, decay time 102.4us
0x6072	pulser_amplitude	12	RW	400	maximum amplitude: 0xFFFF = 4095 Max value corresponds to about 30% at gain=1. Gain jumpers are situated before pulser coupling, so have no effect on the pulser amplitude.
0x6074	NIM0	4	RW	1	0= Off, 1= Cbus, 4 = Busy_out (= FIFO full or ACQ stopped) 8 = data in buffer above threshold 0x6018 9 = events in buffer above threshold 0x601E
0x607A	monitor_on	1	RW	0	switch monitor on
0x607C	set_mon_channel	4	RW	0	set channel to monitor
0x607E	set_wave	2	RW	0	set wave for to monitor

## IO selection Overview

The numbers in the table can be written to the corresponding register.  
For example: ECL2 should input the trigger 1: write 2 to 0x6062.

The **monitor outputs at NIM2 and NIM3** always override the register setting when they are activated by the front panel switch. When acquisition is started (0x603A), NIM2 and NIM3 fall back to their register values. But they can be reactivated by the front panel switches.

IO	default	TR0	TR1	SYN	RES	TRout	Busy	Rdy data	Rdy event	Cbus
ECL3	0	1								
ECL2	0		2	1						
ECL1	0				1					
ECL0	0						4	8	9	
NIM4	1	1								
NIM3	1			2						
NIM2	1		1		2					
NIM1	1					1				
NIM0	1						4	8	9	1

Selection of 0 always means it is unused or "Off"

## Description

TR0 = Trigger 0 input

TR1 = Trigger 1 input

SYN = external Frequency to synchronise event time stamp

RES = reset for event time stamp

TRout = trigger output

Mon0 = analog output to monitor internal filtered signals, noise, Pole zero

Mon1 = analog output to monitor internal filtered signals, noise, Pole zero

Busy = module not ready to take more triggers

Rdy dat = data in buffer above threshold register "0x6018"

Rdy eve = events in buffer above threshold register "0x601E"

Cbus = control bus to control external mesytec modules (MHV-4, MPRB-32...)

## CTRA

Time stamp counters, event counters

**All counters have to be read in the order: low word then high word !!!**

They are latched at low word read. The event counter counts events which are written to the buffer.

<b>CTRA 0x6090</b>	<b>counters A</b>				
0x6090	Reset_ctr_ab	2	RW		b0001 resets all counters in CTRA, b0010 resets all counters in CTRB, b1100 allows single shot reset for CTRA with first edge of external reset signal. the bit bx1xx is reset with this first edge  Reset of "counters A" will also reset the global 46 bit TDC time stamp
0x6092	evctr_lo	16	R	0	event counter low value
0x6094	evctr_hi	16	R	0	event counter high value
0x6096	ts_sources	5	RW	b00	[ext_reset, frequency_source] bit0: frequency source (VME=0, external=1) bit1: external reset enable = 1 <b>RCP, QDC:</b> bit4: CTRB "time" counts trigger outputs (= free triggers, selected by 0x605E)
0x6098	ts_divisor	16	RW	1	time stamp = time / ( ts_divisor) 0 means division by 65536
0x609C	ts_counter_lo	16	R		Time low value
0x609E	ts_counter_hi	16	R		Time high value

## CTRB

Counters are latched when VME is reading the low word

Output value is divided by 40 to give a 1 us time basis

<b>CTRB 0x60A0</b>	<b>counters B</b>				
0x60A8	time_0	16	R		Time [1 us] (48 bit) RCP: alternately: free triggers, selected by 0x6096 bit4, and 0x605E
0x60AA	time_1	16	R		
0x60AC	time_2	16	R		
0x60AE	stop_ctr	2	W	0	0 = run, 1= stop counter bit 0 all counter B bit 1 time stamp counter (A)

### Channel addressing for parameter setting

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

### User Channel setting for a channel pair, software module "RCP" and "SCP"

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

Parameters "threshold" and "PZ" are for individual channels, so two parameters per pair.  
When channels are all set simultaneously (0x6100 = 8) the "lower channel" parameter codes for even (0,2,4,6..), the "upper channel" parameter for odd (1,3,5,7...)

Address	Parameter.			default	Comment
6110	<b>TF_int_diff:</b>	7	RW	<b>20</b>	All times are in multiples of 12.5 ns. Common for 2 channels TF-integration/differentiation time, chan 0/1 valid values 1...125 (12.5 (15) ns to 1.6 us)
611A	<b>Gain:</b>	15	RW	<b>2000</b>	common for 2 channels, gain x 100 gain 1...200, chan 0/1; setting 100 (gain=1) ... 19000 (gain = 200)
611C	<b>threshold0:</b>	16	RW	0xff	0 to 64k (65535) . 64 k corresponds to full range. sets lower channel (ex. chan4 when pair 2 is selected)
611E	<b>threshold1</b>	16	RW	0xff	sets upper channel (ex. chan5 when pair 2 is selected)
<b>0x6120</b>					
6124	<b>Shaping_time</b>	11	RW	<b>160</b>	common for 2 channels , FWHM-width values 4...1999 (= 50 ns to 25 us)
6126	<b>BLR</b>	2	RW	2	common for 2 channels, Base line restorer setting, 0 = off, 1 = strict (int. time = 4 shaping times), 2 = soft (int. time = 8 shaping times) 3 = very strict (int. time = 1 shaping time)
6128	<b>reset_time</b>		RW	<b>1000</b>	common for 2 channels (min 16 = 200ns)
612A	<b>signal_rise_time</b>	7	RW	<b>80</b>	common for 2 channels -default = 0, for Si-detectors, constant rise time detectors -> shortest dead time -for germanium detectors with position dependent rise time, set to largest signal rise time. This results in highest resolution and ballistic loss correction.



**For SCP only, (not for RCP firmware )**

6112	<b>PZ0:</b>	16	RW	0xffff	signal decay_time0, lower channel (for PZ compensation) valid: 64...64k (65535), 0.8 us to 800 us, and infinite
6114	<b>PZ1:</b>	16	RW	0xffff	signal decay_time1, upper channel
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 reconstructed input source = 2 Samples from TF-int source = 3 Samples from Shaper

## How to set channel parameters

**TF\_int\_diff** is the integration and differentiation time for the timing filter.

It must not be set to a higher value than the shaping time!

- 1) If the timing resolution has to be optimised, the integration time should be set to the rise time.
- 2) If a very low threshold is required, it may be necessary to set it to a larger value than the rise time, maximum value is 127 (=1.6us) or the shaping time.

**PZ0 / PZ1:** (not required for reset preamps "RCP") decay time of the pulse. The parameter must be very precise to minimise under- or overshoot of the shaped signal. The value is usually not known very precisely, so the easiest way to minimise the under- or overshoot with the monitor signals (select Tmon 3). An automatic adjust run is under consideration. Example: the decay time is 25us (time the signal needs from 100% to 36.8%) so the set value is  $25000/12.5 = 2000$ .

**Gain:** The gain can be set in 1% steps. The resulting range (input voltage for highest channel in the spectrum) can be calculated as:  $\text{Range} = \text{Gain\_Jumper\_Range} / \text{Gain}$ .

For example: Gain-jumper with 3V label, Gain setting = 1000  $\rightarrow$  Gain = 10, so maximum signal will be 0.3V.

**threshold0 / 1:** Threshold setting, 64k is full range.

The threshold is required to detect a signal out of the noise. The threshold also signals an approximated noise level to the BLR.

Example: for a low noise application the noise is  $1\text{E-}3$  of the full range. Setting the threshold to 3x noise this results in a set value of  $64\text{k} * 1\text{E-}3 * 3 = 197$ .

**Shaping\_time:** is the integration time of the shaping filter. The shaping is triangular, the shaping time corresponds to the width of the pulse at half maximum (FWHM).

Compared to the traditional "shaping time" the FWHM is about a factor of 2 longer.

Example: the traditional shaping time should be 1us, the FWHM shaping time has to be set to 2us, this results in a set value of  $2000/12.5 = 160$ ;

**BLR:** can be set to

0: off

1: soft, may have slight advantages for very low noise signals

2: default, compensates also for faster baseline deviations.

**reset:** additional time the channel is reset at an overflow. The total reset time is: shaping time + reset. The default value of 16 is the shortest possible value, and usually need not to be modified.

**signal\_rise\_time:** Default = 0; only needed for detectors with large rise time variation, when the rise time is in the order of magnitude of the shaping time, and when high amplitude resolution is required. This parameter increases the flat top of the shaping pulse. Allows for ballistic loss correction when set to the largest possible rise time. Example: radial germanium detector with maximum 250 ns rise time. Set this parameter to 20.

## Special Trigger outputs

Starting with March 2021 a new feature is built into all firmware. The VME IRQ lines are mostly unused, but are very good high quality lines to the VME controller. A combination of input triggers can be sent to the 7 available IRQ lines, and can be processed in the Trigger IO of the MVLC controller. A collision of signals with other IRQ signaling of the module should be avoided. Several modules may control the same IRQ line, the outputs are then a wired OR of all participating modules. Pulse length is fixed 50ns.

VME-Addr	Name	Width	Direction	Value	Description
0x6300	<b>Trig to IRQ1</b>	16	RW	0x0000	Connect an OR of the selected channel triggers (up to 16) to IRQ line 1. Example 0b00000000 10000001 means channel 0 and 7 are Ored and sent to IRQ 1
0x6304	<b>Trig to IRQ2</b>	16	RW	0x0000	
0x6308	<b>Trig to IRQ3</b>	16	RW	0x0000	
0x630C	<b>Trig to IRQ4</b>	16	RW	0x0000	
0x6310	<b>Trig to IRQ5</b>	16	RW	0x0000	
0x6314	<b>Trig to IRQ6</b>	16	RW	0x0000	
0x6318	<b>Trig to IRQ7</b>	16	RW	0x0000	

## Data handling

The event buffer is organized as a FIFO with a depth of 64 k x 32 bit.

Data is organized in an event structure, maximum size of one event is 255x 32-bit words (Header, End of event, 251 data, extended time stamp, fill word).

### Event structure

Word # (32 bit)	Content
0	Event header (indicates # of n following 32-bit words)
1	Data word #1
2	Data word #2
...	...
n-1	Data word #n-1
n	End of event marker

### Event Header (4 byte, 32 bit)

Short #1																Short #0																
Byte #3								Byte #2								Byte #1								Byte #0								
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	
hsig		subheader						module id								tdc res		adc res			# of following words											
0	1	0	0	x	x	x	x	ii	ii	ii	ii	ii	ii	ii	ii	t	t	t	a	a	a	n	n	n	n	n	n	n	n	n	n	

hsig: header signature = b01

subheader id: currently = b00xxxx → Byte #3 = 0x40

module id: depending on board coder settings → Byte #2 = Module ID

tdc res: TDC resolution, depending on register 0x6042

adc\_res: ADC resolution, depending on register 0x6042

# of follow. words: indicates amount n of following 32-bit words: n-1 events + 1 end of event marker)

Short #1																Short #0															
Byte #3								Byte #2								Byte #1								Byte #0							
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
dsig		fix						flags		T	channel #					data (16 valid bits)															
0	0	0	1	x	x	x	x	p	o	t	c	c	c	c	c	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d	d
								u	v																						

[illegible]

This can be used to terminate a block transfer or multi block transfer.

### Initializing the MDPP-16 for basic measurement

The power up initialization if ever possible was chosen to allow easy start.

The following steps help to get an individual setting from the beginning.

1. Choose channel input signal. This may be differential input (only MDPP with header input connector) or unipolar input (MDPP with header or Lemo inputs).  
For differential input, choose the differential input jumpers and put them in positive or negative position depending on signal polarity. Connection is usually done with twisted pair cables.  
For unipolar input, use the unipolar jumpers. Depending on position they provide positive or negative inputs. For MDPP with header input connectors, an adapter to Lemo may be helpful (MAD 34\_16 SM or SF).
1. register setup of the channels (reg 0x6100 to 0x612F)  
set reg 0x6100 to 8 (copy values to all channels)  
set reg 0x6110, `tf_int_diff` to the rise time of your preamp signal. For example 50ns/12.5 - set reg to 4;  
set reg 0x6112 / 0x6114 to decay time, For example 25000ns/12.5ns = 2000;  
set reg 0x611A gain. For example max input signal is 100mV,  
gain jumper 3V -> gain = 30, set reg to 3000;  
set reg 0x611C / 0x611E threshold. For example threshold should be 0.5% of max range,  
 $64k * 0.005 = 328$ ;  
set reg 0x6124 shaping time. For example 1us shaping time = 2us FWHM width;  
 $2000ns/12.5ns=160$ ;  
registers 0x6126 to 0x612A can be left at default.
2. Choose trigger source. The trigger starts a window of interest, which can start in the past or in the future shifted by 25 us, and can have a width of 1.6 ns to 25 us. The two trigger inputs can be used, but also any channel and the whole bank. To select the trigger source, reg 0x6058, `trig_source` is used. In easiest case the module is self triggering. Then set the register to 0x100 (whole bank triggers) ;
3. Choose trigger timing:  
**Window start**, for example the signals which belong to one event arrive within 1us at the different channel inputs. The first signal to arrive will trigger. So the window start should be at -50 ns in the past and should last for 1000 ns. So set 0x6050 `win_start` =  $16384 - (50ns / 1.56ns) = 16352$   
**Set width** 0x6054 `win_width` =  $(1000ns / 1.56ns) = 640$ .
4. For timing **Resolution**, you may choose a channel width of 100 ps (set 0x6042 = 2), so the data will fill a 10 k spectrum. The triggering channel will create a peak in timing spectrum at 50ns (chan 512).  
Amplitude **Resolution is fixed 64k (16 bits)**.
5. See chapter "**The MDPP-16 read out**" to initialize the readout section of the MDPP.



## The MDPP-16 read out in two modes

### Single event readout

In this mode the data are collected within the window of interest, starting with an external trigger. The data are then stored in a memory and the module waits for the VME readout. After readout of the data at 0x0000 the register 0x6034 is written and allows a new gate to start the conversion. Gates coming within the time from first gate to writing the 0x6034 register are ignored.

For dead time the conversion time plus latency and VME readout time add up.

1. Assumed: 32 bit read (D32 or BLT32)  
Wait for IRQ to start readout of an event  
Read register #6030 for event length  
Read from buffer event\_length + 1  
Write reset register 0x6034
2. After IRQ, start block transfer until BERR on VME-bus  
Then write reset register 0x6034

### Example

Stop acquisition: start\_acq 0x603A = 0; Stop

Set multi event register 0x6036 = 0 (default).

At power up reset or after soft reset, the IRQ register is set to 0 (no interrupt)

Initialize IRQ (for example to IRQ1, Vector = 0):

set IRQ:

set reg 0x6012 to 0 (IRQ Vector)

set reg 0x6010 to 1 (IRQ-1 will be set when event is converted)

Reset FIFO: write register 0x6034 (any value)

start\_acq: 0x603A = 1; Start

Now module is ready for IRQ triggered readout loop:

→ IRQ

Read register 0x6030 for event length (D16)

Read from buffer event\_length + 1 (BLT32)

Write reset register 0x6034 (D16)

Or:

→ IRQ

Start block transfer (BLT32) until BERR on VME-bus

Then write reset register 0x6034 (D16)

The above procedure works completely unchanged **with multi event mode 0x6036 = 3 and**

**0x601A = 0**. In this mode the buffer is used but the data are read out event by event.

After each event a Berr is emitted, which is removed by writing the 0x6034 readout reset.

### Multi event readout

In multi event readout mode (0x6036, multi\_event = 1 or 3) the input is decoupled from output by an 48 k words buffer. So the input is ready for a new trigger after trigger dead time.

When several converter modules are used in one setup, there has to be a way to identify coincident

data from different modules which belong to the same event.

### Event synchronisation

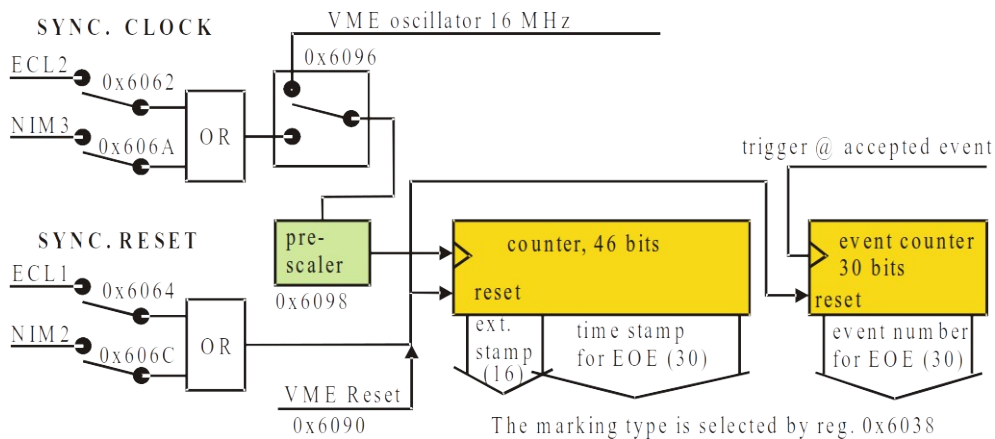
One method is **event counting**.

Each module has an event counter and counts the incoming gates. In complex setups, the gates are best initiated by the individual detector timing signals and significant amount of logic and timing modules have to be established and adjusted to coordinate the detector triggers. A single timing error in all the experiment run time, which will allow an additional gate to come to some module or a suppression of a gate, will corrupt the complete data set, as data gets asynchronous.

The better one is **time stamping**.

A central synchronization clock (sync) (for MDPP-16 this can be the VME built in clock of 16 MHz or an external clock up to 75 MHz) is counted to create a time basis. At experiment start the time counters of all modules are reset via a VME multicast write instruction to reset register 0x6090, or by an external reset signal.

All incoming events are then labeled with a 30 bit long time tag (when extended time stamp is set, an extra 16 bits are added). At data analysis the data streams from different modules are analyze and correlated events are grouped for further processing.



The graphics shows how event counter and time stamper are operated. At high sync clock frequencies, the 30 bit time stamp may overflow. In this case another 16 bit of time stamp can be added to the data.

The synchronization methods allow the different modules to be completely independent from each other. It gets now possible to use large data buffers in the front end modules, and do the readout when the VME data bus is not occupied. The MDPP-16 allows to set a buffer fill threshold which emits an interrupt when the data fill level in the buffer exceeds the threshold.

### Data transfer

In principle any amount of data can be read at any time from the buffer, but then events may be split to two consecutive readout cycles, which normally is no problem.

When only full events should be read in one readout cycle, there are two possibilities.

1. multi event mode = 1: read "buffer\_data\_length" (0x6030) and transfer the amount of data read there.
2. multi event mode = 1: The buffer must be read to the end which means to the Berr mark. Note that this in principle requires to read an infinite number of words, as the conversion can produce more data than can

be read via VME-bus.

3. So if high rates can appear, the data acquisition should at least be tolerant to splitted events.  
an easier way to overcome those problems is to use multi event mode = 3 and limit the data transfer via register 0x601A to a reasonable amount (for example 1000 Words). A “Berr” is then emitted after the next “EOE” marker exceeding the word limit. After readout, 0x6034 has to be written to allow transmission of a new data block.

## IRQ

For many setups it is useful to control the readout via interrupt requests (IRQ) defined by VME.

For MDPP-16 an IRQ is initiated when the buffer fill level gets above the “irq\_threshold” (0x6018). The IRQ is acknowledged by the VME controller, then the controller starts a readout sequence. When not using the readout reset (0x6034) at the end of a readout cycle, the MDPP does not know when the cycle ends. The IRQ is then set again when the data fill level exceeds the IRQ-threshold. When not enough data are read from FIFO to drive the FIFO fill level below the threshold, no new IRQ will be emitted.

So for a readout which is stable against any external influences (readout delays, high input rates), we recommend to write the readout\_reset after each readout sequence. For several mesytec modules in a VME bin, this can also be done with a single multicast write.

### Example 1, multi event readout

#### 1. Stop acquisition

start\_acq 0x603A = 0; Stop

#### 2. Time stamping

The module will use here an external reference synchronization clock and will be reset (synchronized) via VME command.

Set synchronization clock input	ECL2	0x6062 = 1;
Set sync clock source, reset source	ts_sources	0x6096 = 1; (ext osc, int reset only)
Show time stamp in EOE mark	marking type	0x6038 = 1;
Synchronization:	Reset_ctr_ab	0x6090 = 3; reset all counters

#### 3. IRQ

Initialize IRQ (for example to IRQ1, Vector = 0):

set IRQ:

set reg 0x6012 to 0 (IRQ Vector)

set reg 0x6010 to 1 (IRQ-1 will be set when event is converted)

set reg 0x6018 to 200 (IRQ emitted when more than 200 words in FIFO)

#### 4. Set Multi event

Multi event 0x6036 = 3

Max\_transfer\_dat 0x601A = 200

multi event with limited data transfer

transmit maximum 200 words + rest of event before sending Berr

#### 5. Buffer initialization, start

FIFO\_reset 0x603C = 0;

Readout reset 0x6034 = 0;

start\_acq 0x603A = 1; Start

**6. Readout loop**

→ IRQ

Start multi block transfer (BLT32) until BERR on VME-bus  
Then write reset register 0x6034 (D16)

**Example 2, chained block transfer**

Describes multi event readout but with 3 MDPPs and chained block transfer

To operate several modules in one VME bin, each module has to be given a different address.  
The 4 coders on the main board code for the highest 16 bits of the 32 bit address. Best way is, to use only the highest 8 bits for coding (2 rotary coder marked with high). It makes sense to use the slot number as high address. So:

MDPP1 in slot 1 gets 0x0100

MDPP2 in slot 2 gets 0x0200

MDPP3 in slot 3 gets 0x0300

If you don't change the module ID default, the modules will now also have the ID 1...3 which will be transmitted in the data header.

Now initialize the individual modules:

MDPP1: set 0x0100 6020 to 0xA2 (CBLT first module, Multicast enable)

MDPP2: set 0x0200 6020 to 0x82 (CBLT mid module, Multicast enable) also any further module in the middle of the readout chain is initialized this way.

MDPP3: set 0x0300 6020 to 0x8A (CBLT last module, Multicast enable)

When you don't change the default addresses for CBLT and MCST, the modules will have the CBLT start address of 0xAA00 0000 and the MCST start address of 0xBB00 0000.

You can now do the initialization 1) to 5) of Example 1 via multicast at the offset address 0xBB00.

The readout loop has to be modified slightly:

→ IRQ

Start multi block transfer (BLT32, MBLT64) at address 0xAA00 0000 until BERR on VME-bus

Then write reset register 0xBB00 6034 (D16) at the multicast address.

**Note:** use multi event mode 0 or 3 for CBLT (mode 1 will not work !)

## **Special VME Operation**

### **MBLT64**

MBLT64 is defined by the address modifier. The word alignment within the transmitted 64 bit words is kept by adding fill words at odd word numbers.

### **CMBLT64**

Is intrinsic when chained block transfer is used with MBLT64.

### **Dead time**

the present SCP firmware needs 380 ns for calculations and event building. This dead time has only effect when the shaping time (FWHM) is less , otherwise (starting from 380 ns shaping time) the device adds no dead time.

Another aspect is the window of interest. While it is open, no further window can be opened, and some processing time is required. The trigger dead time is window width + 300 ns.

### **Trigger output delay.**

The trigger output delay measure from rising edge of the input signal is 400 ns + the timing filter integration time.

## **Software keys:**

MDPP-16 has 4 memory ranges to store Software. At delivery you have the most common 4 loaded (CsI, SCP, RCP, QDC). Others can be loaded or updated via loader program "MVP" on a windows PC and with a micro-USB cable (see web page for download of programmer and software).

The softwares are enabled with a "key" which is a data string loaded on a specific MDPP-16. MDPP can hold any number of keys. One of you choice is for free when purchasing a module.

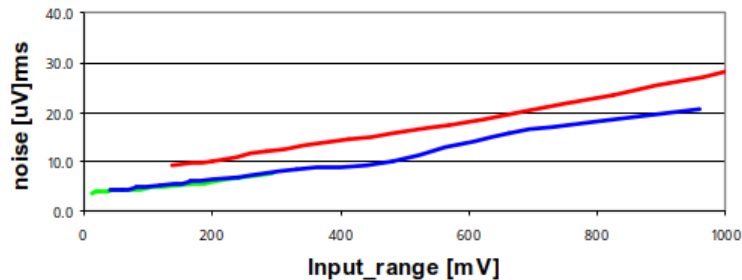
When you need more keys, just order them, and you will get key files by email to load to the MDPP-16. The keys are linked to a specific MDPP-16 serial number. When ordered when purchasing the module we will load the keys and required softwares.

If you don't have a key for a software, you can run it for a few minutes, then it goes to DAQ stop until power cycle.

## Detailed measured data from software module "SCP"

### Amplitude resolution

Due to low input noise, The MDPP-16 allows very high amplitude resolutions.  
Measured input noise with Lemo input configuration:



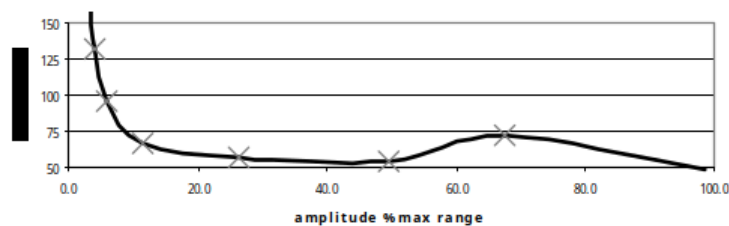
*red: with jumper 3V, blue with jumper 1V, green with jumper 0.3V.  
Input related noise at 2 µs shaping time (= 4.5 µs FWHM).*

Example: The maximum required input signal is 1 V, then the input noise is about 30 µV. So the resolution (signal to noise) is  $1 \text{ V} / 30 \cdot 10^{-6} \text{ V} = 3.310^{-4}$  or 1 channel in 32 k spectrum.

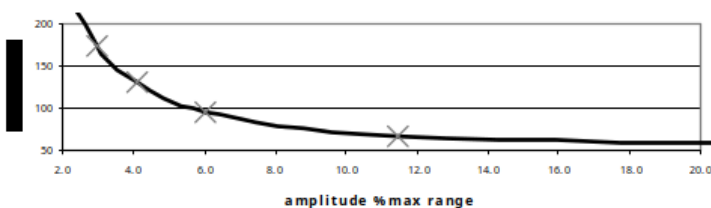
### Timing resolution

MDPP-16 provides a very good timing resolution of 75 ps rms for the time difference between two channels. The resolution of time difference between input trigger and one channel is less than 75 ps rms in the amplitude range of 10% to 100% .

( Measurement condition: maximum range = 2 V, rise time 20 ns, TF integration 25 ns)



*Timing resolution, trigger input starts, one channel stops.*



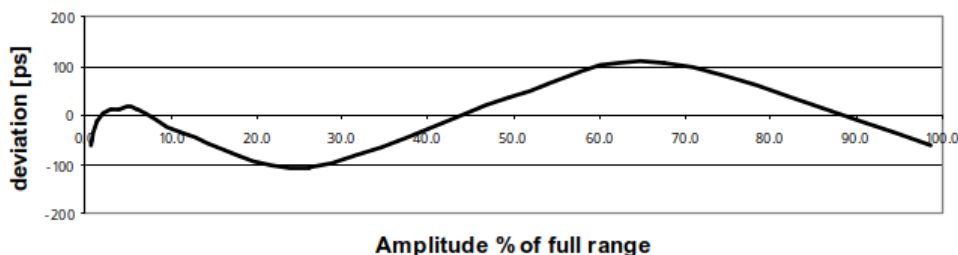
*Amplitude of the channel input from 3% to 100% of full range.  
As upper figure, zoomed to lower 20% .*

In contrast to other approaches, the timing resolution is independent of the signal delay between channels.

**Timing walk** (time drift with amplitude)

The MDPP-16 has implemented a numerical constant fraction discriminator, so the timing walk is mostly eliminated. From 3 % to 100 % of full amplitude range, the walk is  $\pm 110$  ps.

( Measurement condition: maximum range = 2 V, rise time 20 ns, TF integration 25 ns)



*Timing walk, trigger input starts, one channel stops*

*The amplitude of the channel input is increased from 3% to 100% full range.*

### Further Software Modules:

Software module analyzing signals of reset preamplifiers

- Fast recovery from overflow / underflow
- Hardware pre- differentiation preserves the full dynamic range
- Reset pulse amplitude / noise  $1.5 \cdot 10^6$  for 5V reset pulse.

Self timed QDC and TDC to analyze fast pulses

- Amplitude resolution 4 k
- Timing resolution 60 ps rms trigger to channel

Peak sensing ADC

- No dead time beyond input pulse width.
- 16 k resolution
- low INL and DNL

### MDPP Gain Jumpers:

For our standard jumpers both conditions have to be fulfilled:

- 1) A 50R terminated jumper tolerates pulses ( $< 10\mu s$ ) up to 30V.
- 2) The input stages Voltage limit is  $\min + 14V$  or Jumper range  $\cdot 8$  whatever is larger.

We can build special jumpers with the following condition:

- 1) 50R terminated, up to 55V pulses ( $< 10\mu s$ )
- 2) The input stages Voltage limit is  $\min + 14V$  or Jumper range  $\cdot 8$  whatever is larger.

For the jumpers, a range from 300mV up to 100V can be built.