mesytec psd

A Readout System for Position Sensitive Neutron Detector Tubes

Hardware
Users Manual

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Contents

1 mesytec psd

mesytec psd is a complete readout system for arrays of neutron detector tubes or photo multipliers. Position sensitive tubes can be readout as well as "standard" tubes - even a mix of types is possible in one setup.
The modular system consists of up to 64 amplifier/digitizer modules (MPSD-8 or MPSD-16), an intelligent central processing device (MCPD) for system control, histogramming and network interfacing and a data acquisition software running on LINUX systems. Up to 512 position sensitive tubes or 1024 standard tubes can be read out. Even larger systems can be relized by using several central processing devices.
Customer specific systems based on mesytec PSD for the readout of neutron sensitive multiwire chambers are already running.

1.1 Main features

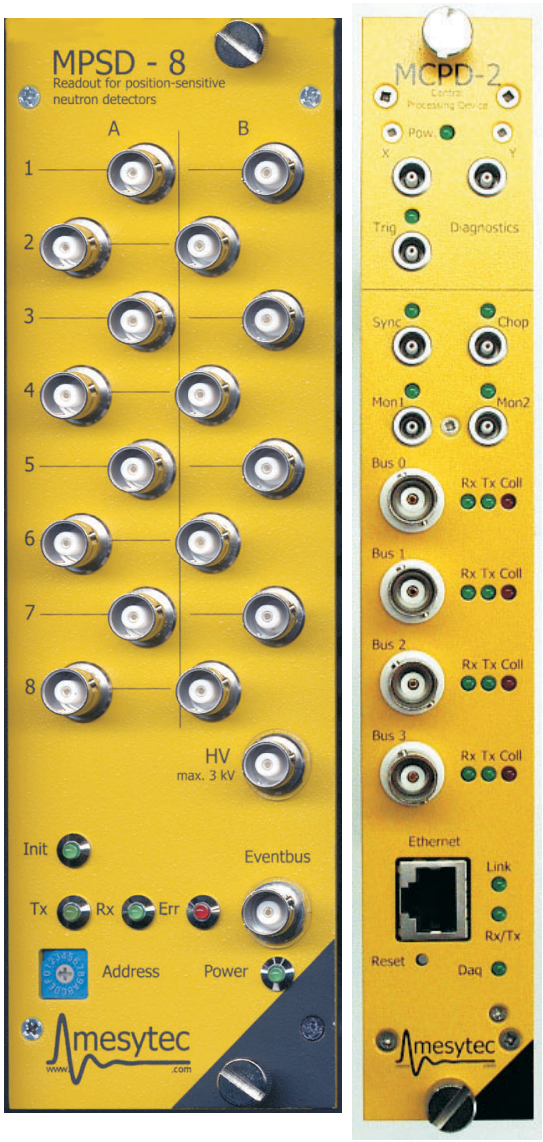


fig. 1: Left: the amplifier module for 8 detectors. Right central processing device wit ethernet output

Modularity:
16-fold preamp/shaper/window discriminator units for standard tubes
8-fold preamp/shaper/window discriminator units for position sensitive tubes
Central processing device

Scalability:
Up to 512 PSD / 1024 standard channels per MCPD on four serial event buses
Multiple central processing devices can be connected to a single pc

Flexibility:
For PSD and/or TOF systems
Chopper-, monitor- and sync- options
Pulseheight- or position spectra
Histogramming and listmode
NIM-modules or stand alone
Diagnosis analog signal output
Freely usable ADC inputs, DAC outputs and RS232

Ease of use:
Control and data acquisition on a PC connected by standard ethernet
Control and display software included (LINUX open source)

1.2 Functional Overview

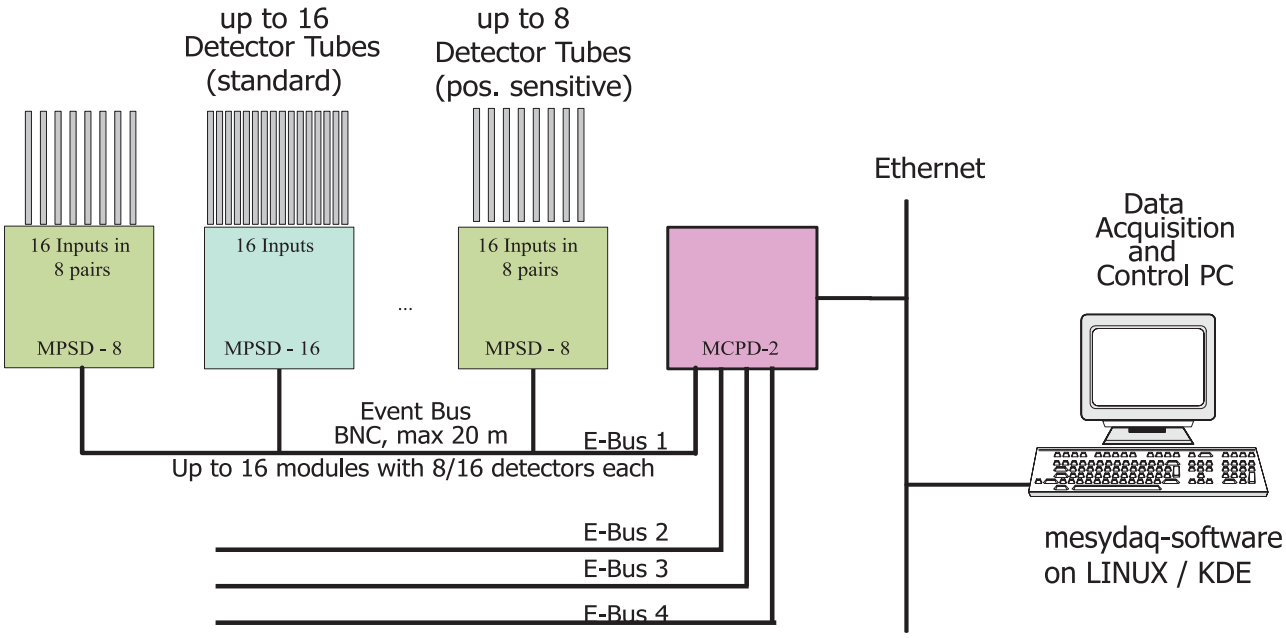


fig2 : typical sytem with position sensitive and standard detector tubes read out by a mesytec psd system.

Readout path
The position sensitive detector tubes are read out in groups of eight which are connected to a single NIM module: "MPSD-8". Up to 16 of those modules can be connected per fast serial bus to transmit the data to the central NIM-module, the MCPD-2 (mesytec central processing device). The event bus is physically a BNC koax wire. The MCPD buffers the data and transmits it via Ethernet to a PC. The Mesydaq software runs on linux and handles the incoming data. They are stored on harddisk and are displayed in histograms.

Remote control
For controlling the complete system, a data path, back from the PC via Etehrnet and eventbus, was established. It is possible to configure gains, thresholds and pulsers from the PC, make pulser testruns, and store the complete data set in a configuration file which is downloaded to the peripheral modules at the beginning of a new run.

Position or amplitude
There are two main modes which can be set by remote control: amplitude readout or position readout. In amplitude mode the sum signal of the detector tubes is transmitted. In this mode it is easily possible to optimise thresholds and gains and check the functionality of a detector.
Then, for the normal run the position mode is used.

2 MPSD-8, the 8-fold amplifier and digitizer

2.1 Main features

- Includes all elements from charge sensitive preamplifiers up to a digital position converter
- Readout of position sensitive detector tubes
- Up to 3m of cable length (RG59) to the detectors without position resolution degradation
- Electronical resolution at the physical limits due to low noise amplifiers
- Very low position cross talk of neigbouring events coming closely in time
- Highest and stable efficiency due to clearly settable and stable amplitude thresholds
- Low deadtime and immediate recovery within deadtime
- Remote gain adjust and threshold setting for window discriminator
- Central HV-input for all tubes (≤ 3 kV)
- Diagnostic LEDs for initialisation and bus activity
- 8 channels per amplifier module
- Maximum 128 position sensitive channels per branch

2.2 Functional Overview

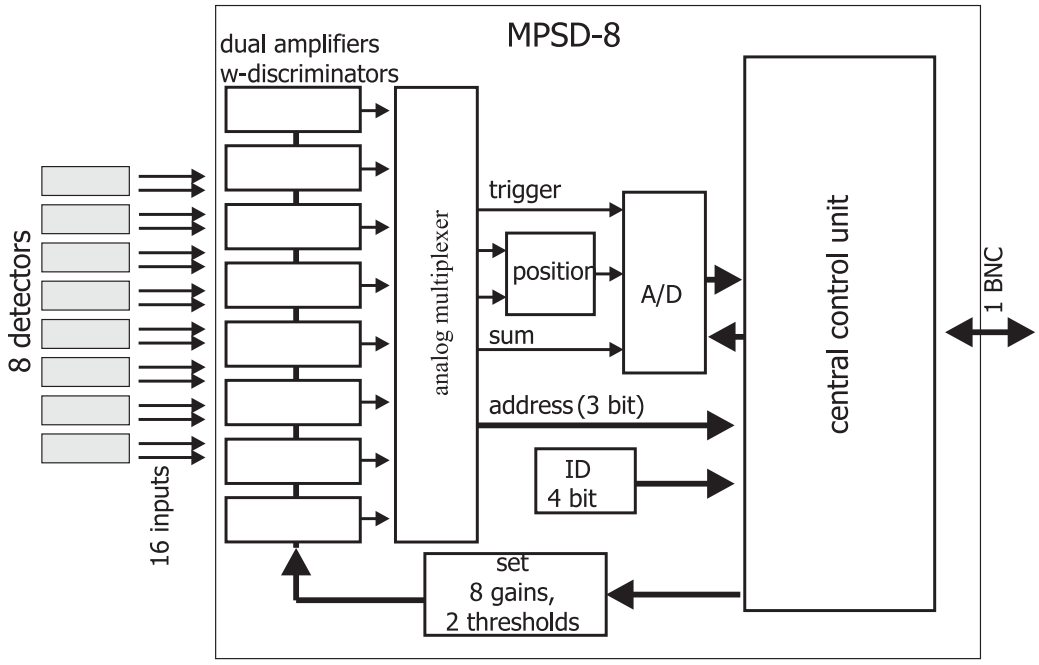


fig. 3 : internal design of a MPSD-8 module.

The MPSD-8 module consists of eight dual channel amplifiers (fig3) with window discriminators. Their signals are digitized by a central control unit and transmitted on the event bus. The central control unit also gets configuration data from the event bus which are sent by the MCPD. The configuration data: thresholds, gains, pulser information are internally transmitted to the dual amplifier units.

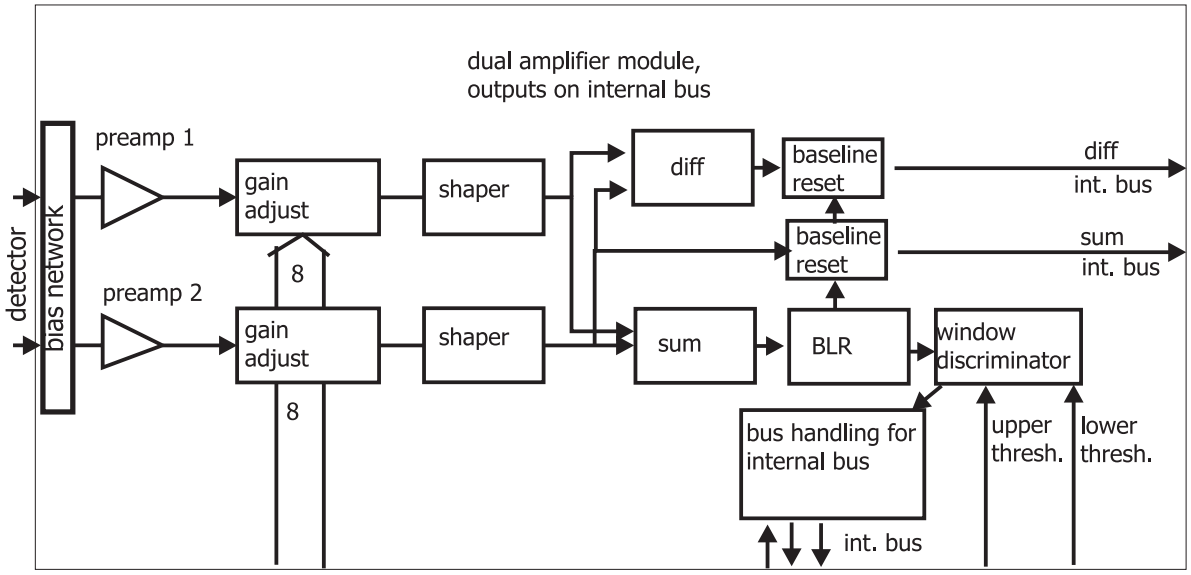


fig. 4 : internal structure of a dual amplifier unit

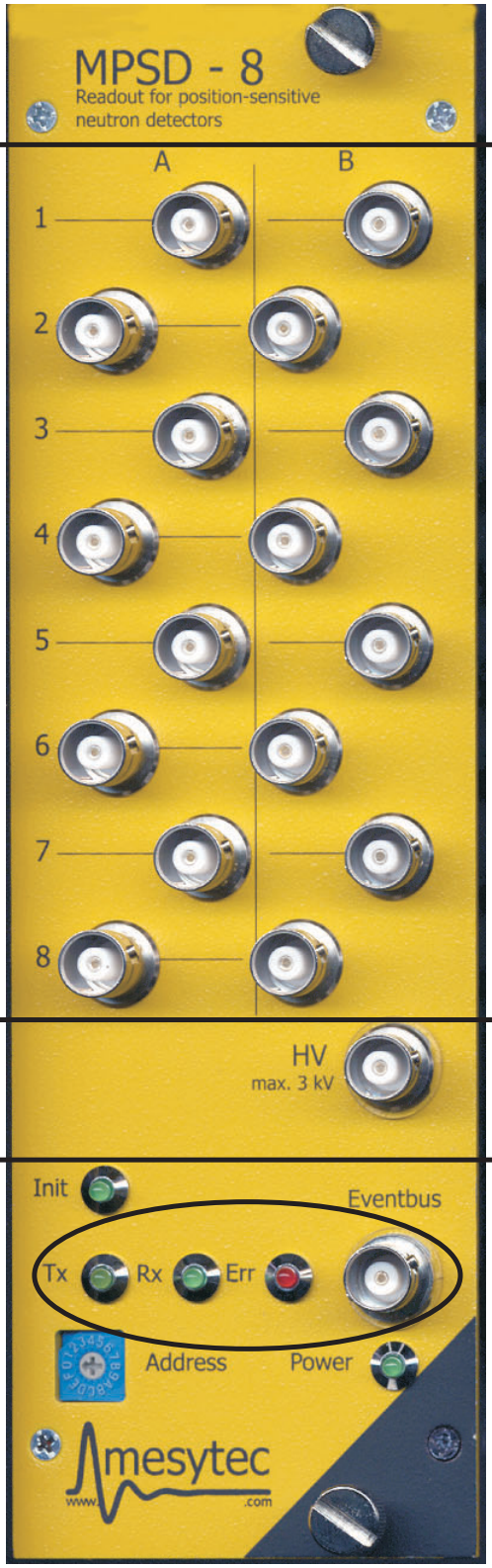
A dual amplifier unit (fig. 4) consists of several sub units.

The detector charge signals are amplified by two low noise charge sensitive preamplifiers, which are matched in gain to 0.2%. The preamp signals are adjusted in amplitude by a dual digital potentiometer.
The signals from the gain adjust stage are filtered by gaussean shapers. Then the sum and the difference of the two signals are calculated.
The sum signal runs trough a baseline restorer and then to the window discriminator. The digital output of the discriminator is used to actively restore the sum and difference signal. This is very important at high rates to reduce "crosstalk" of subsequent neutron signals.
The digital and analog signals are transmitted by the internal bus to the control unit.

2.3 Front panel elements

Detector inputs

MHV connectors for
8 position sensitive detector
tubes



HV

max voltage: 3000V
max operation Voltage 2500V

Event bus / adjustment

Init = module initialised
off after power up

Module ID
all modules on the bus
need different IDs !
The ID is the more
significant part of the
X- coordinate value

Event bus connector,
high ohmic in-/output

TX = module transmits
RX = module receives
Err = module produces
collisions on bus.

Power = power applied
(not a real power check !)

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2.4 MPSD-8 data sheet

Detector input specification

- high virtual input capacity of ~4nF
- ESD protected (but a high voltage spark from detector bias will destroy them !)
- MHV connectors (will be changed to SHV connectors in the version 2003)

Sensitivity

- can be varied by a factor of 2 (optional 6) by remote control
- the range ist customer specific and can be chosen in the range of $2*10^{-13}$ C to $5*10^{-12}$ C

Position digitization:

- 10bit resolution

Electronical position resolution (without physical effects like range of protons and tritons)

Position resolution
(for the thermal peak amplitude. Shaping time adapted to detector rise time)
The position resolution is very near to the theoretical limit, which is determined by the resistor chain noise.
This holds also if cable connections to the detector have a length of up to 3m (RG59).

Here a rule of thumb for the MPSD-8

$\Delta x/x = \mathrm{sqrt}(t/R) * 5*10^4 / V$

t = detector risetime (or risetime jitter)
R = resistance of resistor chain
V = electron amplification (assumption: 30eV/charge pair)
$\Delta x/x$ = relative position resolution

Example:
Typical electronical resolution for a risetime of t = 2µs, R = 3.5kΩ, V = 200 (= $8*10^{-13}$C), 2m of coax cable on each side.
$\Delta x/x$ = 0.6%

Dark rate @ U_{HV} = 2000V, no detectors connected, sensitivity $2*10^{-12}$C

- f < 60 / h for the whole module (dramatically reduced in the new version 2003)

Bias Input

- leakage current I_{HV} < 1.5uA
- maximum voltage U_{HV} = 3000V
- maximum operating voltage U_{HV} = 2500V

Event bus

- high ohmic in/out

Power consumption

- P = 4 W
- U+ = +12V, 0.04A
  = +6V, 0.35A
  = -6V, 0.22A

3 MCPD-2, the new central processing device with ethernet interface

3.1 Main features

Fully controlled from central PC console via ethernet
Translates and transmits commands from PC (Ethernet) to the peripheral modules on event bus:
- amplifier gains
- thresholds
- position/amplitude mode (MPSD-8)
- test pulser (variable in amplitude and position)

Receives data from the peripheral modules and transmits the buffered data to the PC (listmode):
- Amplitude or position
- Channel number (module number of MPSD8 + channel number)
- 17 bit timing, 100ns standard resolution (for TOF sytems, chopper triggered).

Manages the universal inputs/outputs:
two ADC (12bit) inputs,
two DAC (12bit) outputs
two digital TTL inputs
two digital TTL outputs

Histogramming mode*: histogramming done in central module (resulting in very low ethernet data rate)
- XY position histogramming
- Timing histogramming

"Analog" Diagnosis section: all data on the event buses are converted to analog signals
-address output for all channels
-position/amplitude for all channels
-trigger on event arrival

3.2 Functional Overview

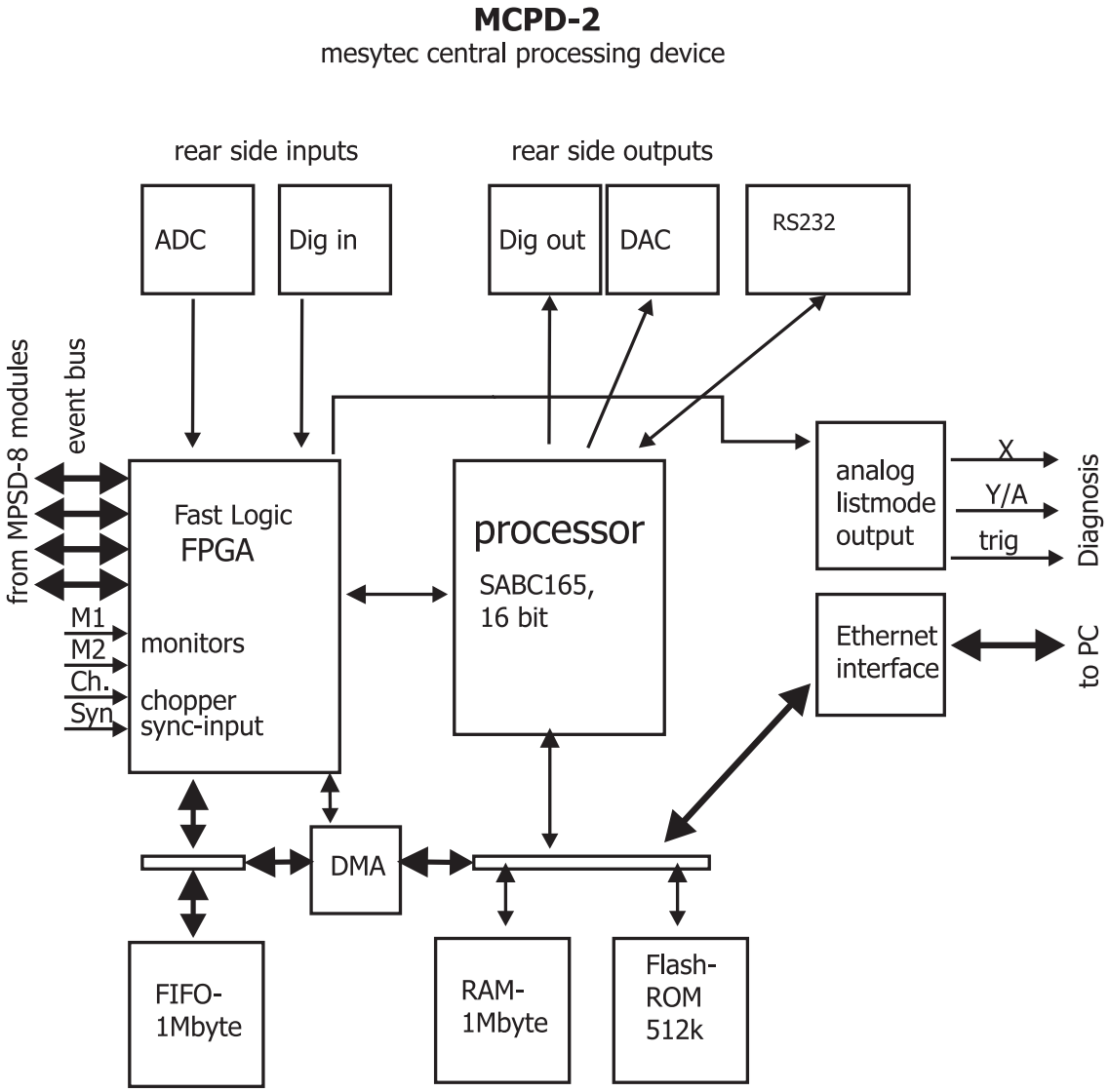
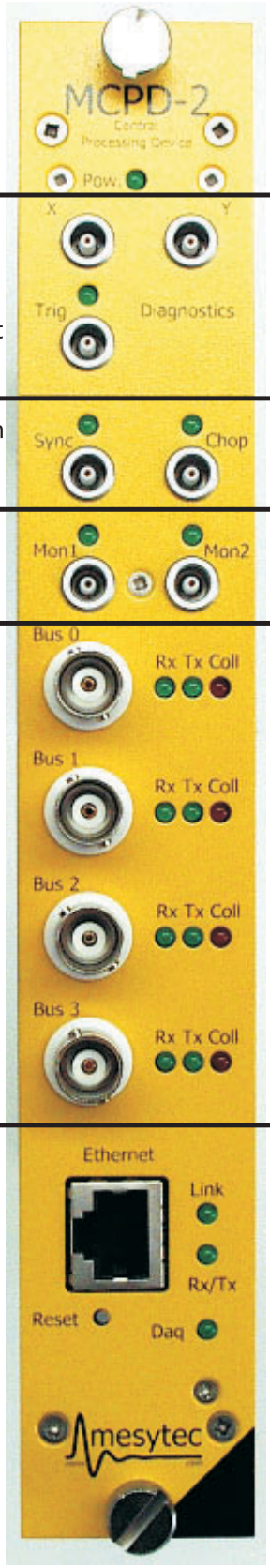


fig. 5 : internal design of the MCPD-2 module

The internal design mainly consists of two blocks. The first is a programmable logic, which services the four fast event bus, creates the time mark for chopper applications, accumulates all incoming data in a 1Mbyte FIFO (= 128kevents), and counts the external monitor signals. As additional features the MCPD-2 has two ADC inputs (12bit) and accumulates one of them in the fifo together with the event data. So you get an additional real time coordinate for the listmode data. This may be useful for fast changing experiment parameters.
The programmable logic does not add any additional dead time to the event bus. It can manage the full eventbus rate of 4*800kHz.
The second block is a fast 16 bit processor which delivers an additional buffer of up to 1Mbyte and services the ethernet. It can deliver the theoretical maximum transmission data rate of the 100 Mbit ethernet. This gets possible by a fas DMA-unit which directly dumps the lismode data from FIFO to the ethernet controller without stopping the data accumulation.
For some applications a histogramming can be implemented in the processor.

3.3 Front panel elements



Analog diagnosis section

(independent of Ethernet readout)

Power LED

analog outputs:
X = module number of incoming event
Y = position or amplitude of incoming event,

Scope trigger for neutron hit

Sync/Chopper

"Sync input" for multiple system synchronisation.

"Chopper input"
for chopper timing option

Monitors

TTL inputs for monitor counters

Event bus section

4 eventbuses available

receive up to 3.2 Mevents/s from amplifier modules MPS-8

TX= transmit data
RX= receive data
Err= collision on bus

Ethernet/Service

Ethernet connector
Rx/Tx: data transmission to or from MCPD

Link: Ethernet connected

Rx/Tx: Data on Ethernet

Processor reset.

Daq: data acquisition running.

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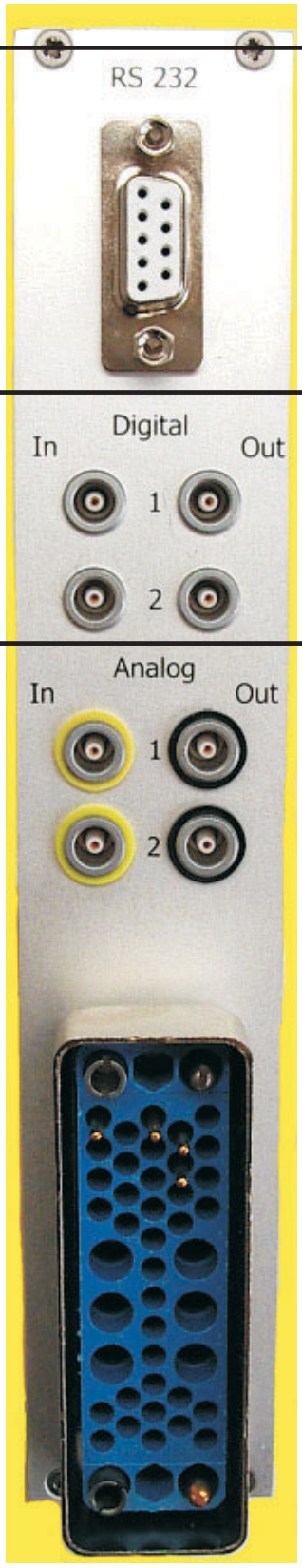
3.4 Rear panel elements

RS232

RS 232 serial interface
can be used to control external
modues (i.e. HV supplies)



Digital I/O

2 TTL inputs and 2 TTL outputs
available.
Can be used for control of
experiment equippment

Analog I/O

12bit ADCs

2 ADC inputs +-5V
for fastly changing experiment
parameters. Can be appended
to each event in listmode

12bit DACs

2 DAC outputs 0..10V

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3.5 MCPD-2 data sheet

Power consumption

- P = 3W
- U+ = +6V, 0.50A
  = -6V, 0.02A

Eventbuses

- Internally terminated with 50Ω
- Connector: BNC
- Cable type: RG58
- Maximum eventbus data rate: 800kHz
- Eventbus dead time 1.2us
- Signal level: 0 to +0.7V;

Ethernet:

- 100Base-TX
- Maximum Ethernet event rate: 1.6 or 3.2 MHz (depending on event length)

Monitor, chopper and sync inputs:

- TTL input:
- minimum High level 2.8 V
- maximum low level: 0.8V
- Minimum pulse length: 200ns

Diagnosis section:

- Scope trigger output:
  U_{out} : TTL level, 100ns
- Analog outputs
  X output:
  module 1 channel 1 = 0V,
  module 16 channel 8 = 4V
  can be terminated with 50Ω
  Y/A output:
  position or amplitude output, depends on module initialisation
  U_{out} = 0 to 4V
  can be terminated with 50Ω

4 Hardware Installation

Power consumption and cooling.
Due to the low power consumption of the modules, cooling by fans is not necessary.
This holds also for a NIM bin with six peripheral modules.

Detector cable length
The cable length to the detector tubes (30cm active length, resistance ~3kΩ) can be up to 3 meters (RG59) without degrading the position resolution

Detector installation
The input ground and the detector must be isolated from any other ground. Avoid to make large loops (ground loops) with the detctor cables. **Make sure there is a distance of at least 1m to monitors and computers around**.

Event bus
The eventbus must be connected with one end to the MCPD, on the other side it has to be terminated with 50Ω. The peripheral module should be connected directly with BNC T-pieces to the bus. Branches, even of very short legth, deteriorate the bus performance.
The peripheral modules should be connected to the bus within 10m of cable length. The distance to the central module (MCPD) can again be up to 15m. (As a very conservative limit…)
For long distances use the ethernet connection from the MCPD to the data acquisition PC.

Module ID
The Module ID is the most significant part of the X - position coordinate (the lower one are the eight internal channel numbers). The module IDs have to be different for the modules on the same eventbus.

5 Performance Measurements

5.1 Pulser

Check of linearity

The pulser is moved on a resistor chain. The resistance (x-axis) and the position output of the ADC (y-axis) is measured

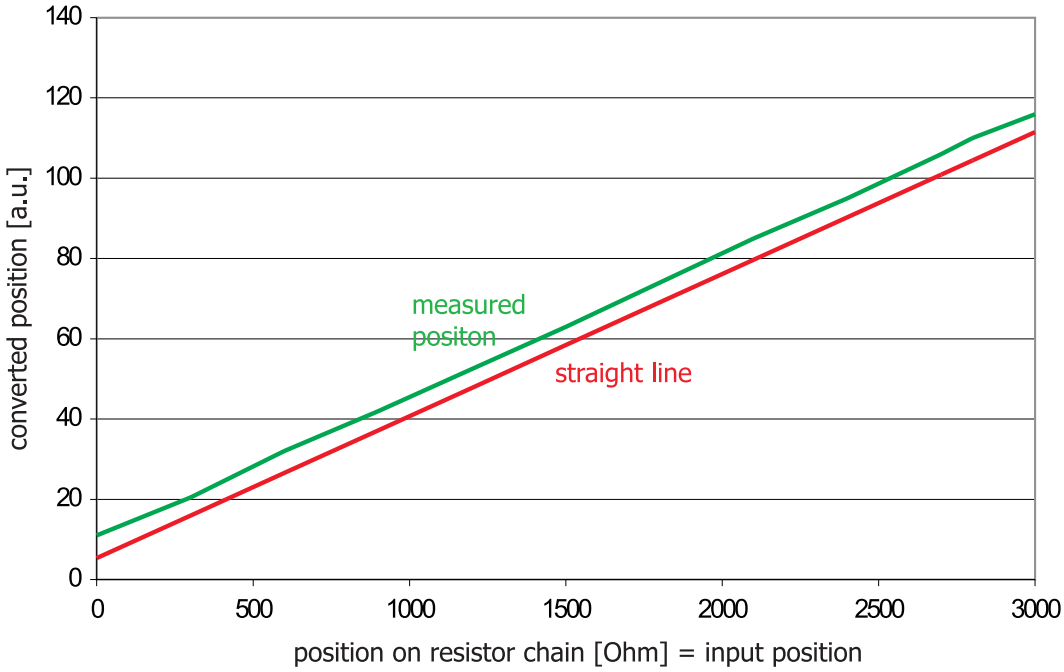


fig. 6

Resolution in dependence of detector cable length.

A tube model (3.5kOhm resistance with distributed capacity) and cable capacities on both sides was used to determine the decrease of position resolution with cable length. A gas amplification of 150 ($6*10^{-13}$C) is assumed. For two meters of cable length the effect is below 10%.

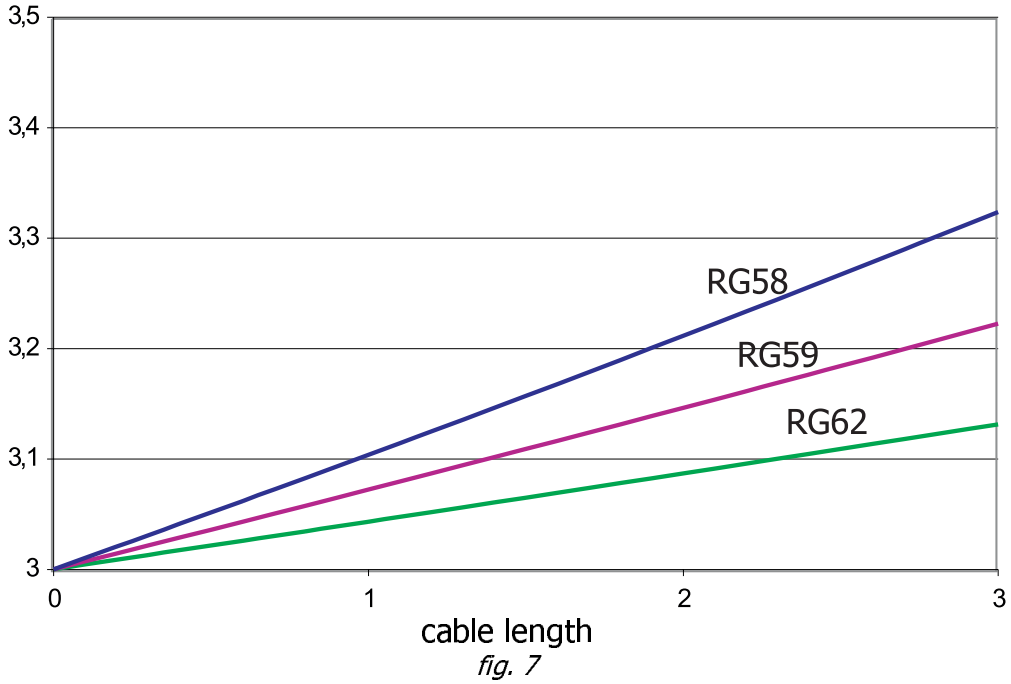


fig. 7

Electronical position resolution

A real detector with 3.5kΩ resistive wire and two cables (RG58) with 2m length were connected. The pulser position is set to three positions. Two different pulser amplitudes were measured.

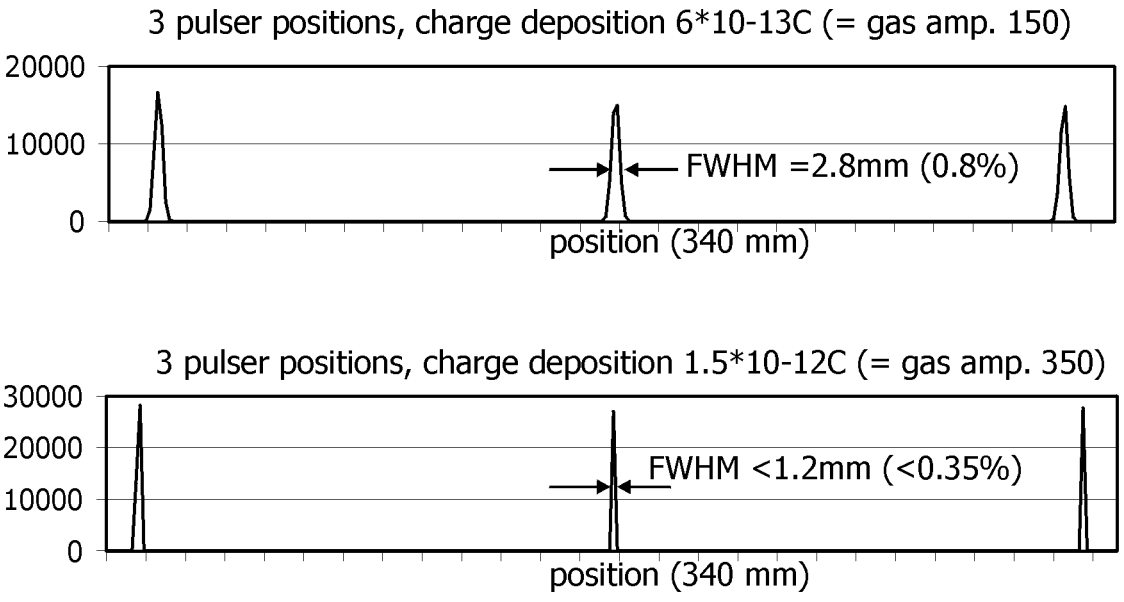


fig. 8

No variation of resolution with the pulser position can be seen. For the lower diagram the resolution is better than one channel of the 8 bit ADC. The now actual version of MPSD-8 (2002) has a 10bit resolution.

5.2 Neutron beam

Measured with Reuter & Stokes tube, 3bar Ar + 6bar 3He, 340mm active length, diameter 1 inch, wire resistance 3.5k, coax cable RG58, length 2m on both ends.

Resolution measurement: gas amplification = 150

- Cd mask with two 1.5 mm slits, slit distance 10mm.

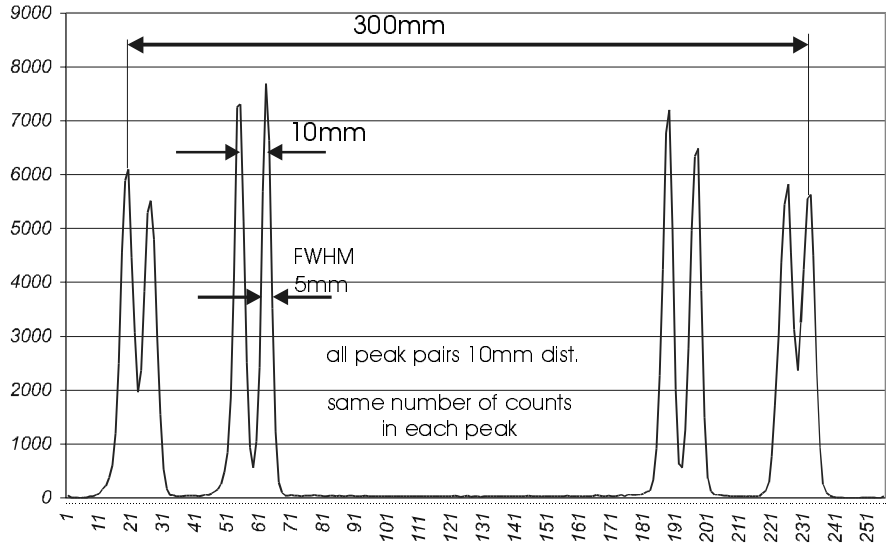


fig. 9

A decrease of resolution at the sides of the tubes can be seen. This is a property of the tubes, as the pulser measurements with a capacitive resistor chain show homogenious resolution over the position range.

Resolution measurement: , gas amplification = 350

- Cd mask with two 0.5mm slits, slit distance: 6.5mm

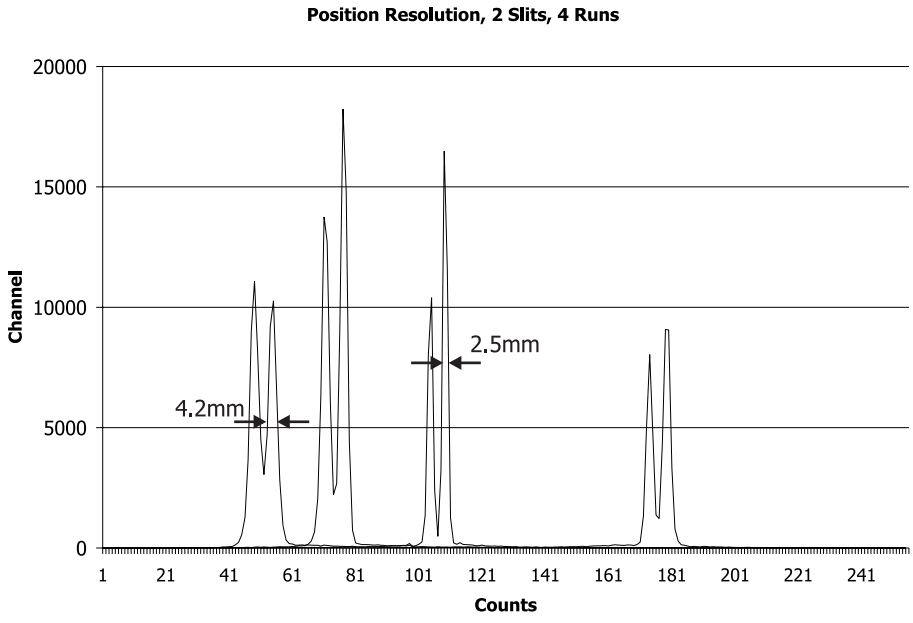


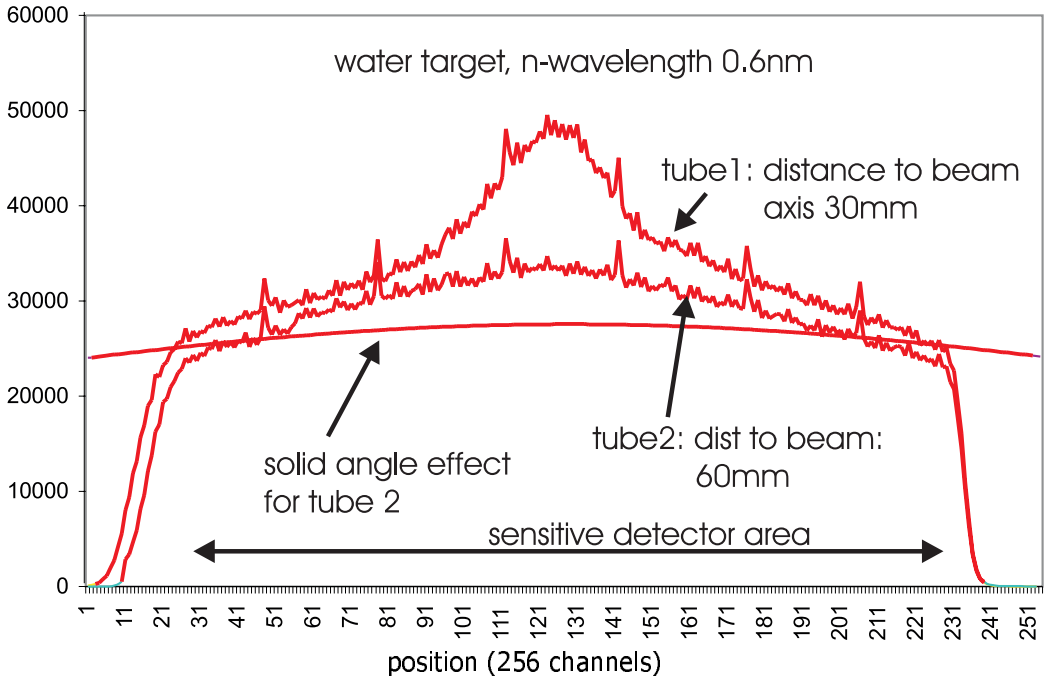
fig.10

Like in fig. 9, a decrease of resolution at the sides of the tubes can be seen.

Test of differential linearity in position spectra

Setup: neutron beam on water target. Far from beam axis, an isotropical scattering is expected.

The small peaks show the differential nonlinearity which is typical for the formerly used flash ADC. **In the actual version of MPSD-8 this is completely eliminated by using a sliding scale converter.**



Amplitude spectrum.

Measurd in amplitude mode of the PSD system, gas amplification = 150.