A digital VME DAQ - Approach for Performance and Simplicity

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Abstract

Evolving from NIM and CAMAC over the years the detector read-out electronics and data acquisition systems became more powerful, sophisticated and much more complex. Modern digital systems often require a substantial amount of knowledge in order to master them.

With their new digital pulse processing system MESYTEC tried to provide a solution which combines highest performance and flexibility with ease of use. For this a unique concept for the on-board digital pulse processing firmware has been developed which is following the classic analog techniques.

Further a ready-to-run, platform independent and open-source DAQ software package "MVME" is in development which includes hardware configuration, run control as well as online monitoring. Most of the hardware settinge are pre-configured which allows a short learning curve. This software aims at smaller research groups without dedicated software development capabilities.

We hope that providing this to the community as "open source" will result in a wide use and even further development.
Digital Pulse Processing

Pre-amp

MDPP-16

VME

Solid State Detector
Pre-amp

PMT

MDPP-16

VME

Scintillation Detector

PMT
MESYTEC MDPP - Digital Pulse Processor

Developed to meet the following challenges:

1. Easy to use
   - Capable to directly accept any pre-amp / detector signal for wide range of detectors (HPGE, Si, scintillators, ...)
   - No knowledge of the internal signal processing required
   - Only need essential signal parameters and settings (most similar to known analog system)

2. Works together with existing DAQ
   - Accepts + creates triggers for external experiment logic

3. Very good Energy resolution
   - Amplitude resolution as good as best “analog”
   - including ballistic loss correction, pile up rejection (reconstruction in future), baseline restoration, ...

4. Very good timing
   - Good enough to replace analog CFD’s and TDC’s for most applications.
New Hardware Concept

1: **Input Stage**: Differential or unipolar
2: **Input / gain jumper**: Polarity and coarse gain
3: **Low Noise Amplifier**: High dynamic range
4: **Differentiation stage**: Variable with fast reset circuit
5: **Variable gain stage**: 1 to 24, total continuous gain 1 to 200
   - Sampling ADC (80MHz)
6: **FPGA with Digital Pulse Processing**: Up to 4 different FW

- Input range 1.5 mV to 20 V
- noise 2µV @ 2µs shaping
- support of reset pre-amps
- 15 bit energy resolution
- 75 ps time resolution
MDPP Concept

- Output E (+PSD) + T-stamp for every event
- No saving of individual waveforms!
- Sophisticated trigger / timing (16us window)
- Gain Jumpers:
  - Input impedance (50/96Ohms)
  - Amplitude / voltage range
  - Invert / non-invert
  - special for fast scintillators
- Analog monitoring outputs of reconstructed digital signals for all channels for setup / parameter optimization
SCP Software module

Processes signals from standard charge integrating preamps.

**Functionality:** Shaper, ADC + CFD, TDC

- **15 bit energy (32k) resolution**
- **CFD-timing with 75 ps rms resolution** at any delay from trigger.
- High quality trapezoidal shaping (TFA) down to 20ns rise time
- Independent trapezoidal shaping from 50ns to 25us (FWHM)
- PZ adjustment from 800ns to infinity
- High performance self adjusting Baseline restorer.
RCP Software Module

Processes signals from charge integrating reset preamplifiers. **Functionality:** Reset-Shaper, ADC + CFD, TDC,

All feature as for SCP module, and:

- Dynamic range of $1.5 \times 10^6$ reset pulse/noise
- Fast recovery from reset pulse (2µs + shaping time).
**QDC Software Module**

Processes fast signals from PMTs, channel plate...

**Functionality:** Pre-amplifier, CFD, 2 x QDC, TDC

- **Energy resolution** 12 bit
- **Timing resolution of 60 ps rms**
- Self triggered, requires no external delays
- Main integration, 25 ns to 1.6uss
- Second (leading edge) integration, 12.5 ns to 350 ns
- n/gamma Pulse shape discrimination for BC501, Stilbene, CLYC..
MESYTEC DAQ Software - MVME

- Ready-to-run DAQ software with hardware setup, data collection and online monitoring
- Platform Independent (QT)
- “Open Source”
- VME master with list sequencer: VM-USB (up to 15MB/s) SIS3135 (USB3, GB ethernet)
- Supports: MESYTEC VME modules,
- Easy configuration with scripting text files
- Graphical Analysis UI
- Live Histogramming (1D/2D)
MVME Concept
Events and Modules

- Physical VME setup described as a tree of objects

- **Events** is top-level node

- Each Event has a trigger condition (e.g. Interrupt or NIM) and contains the **Modules** to be read out on every activation of the trigger

- **Module** in mvme has a collection of VME Scripts
**DAQ Cycle**

- **DAQ START:**
  - Initialize the VME controller using information from the VME configuration (build and load DAQ stack)
  - Setup modules using the module VME scripts
  - Switch the controller into DAQ mode

- **DAQ Loop (Repeat until DAQ is stopped):**
  - Read a data buffer from the VME controller
  - Validate the structure of the received data
  - Augment the data with mvme specific meta data
  - Write data to the list file (optionally using compression)
  - Pass data to the Analysis

- **DAQ END:**
  - Tell the controller to leave DAQ mode
  - Close the list file
Data Analysis

[Diagram of data flow and parameter extraction]

**L0 Parameter Extraction**
- mdpp16
  - mdpp16.amplitude
  - mdpp16.event_counter/ts
  - mdpp16.time
  - mdpp16.trigger_time

**L1 Processing**
- Cal mdpp16.amplitude
- Cal mdpp16.event_counter/ts
- Cal mdpp16.time
- Cal mdpp16.trigger_time

**L0 Data Display**
- mdpp16
  - H1D mdpp16.amplitude_raw
  - H1D mdpp16.event_counter/ts_raw
  - H1D mdpp16.time_raw
  - H1D mdpp16.trigger_time_raw

**L1 Data Display**
- 1D
  - H1D mdpp16.amplitude
  - H1D mdpp16.event_counter/ts
  - H1D mdpp16.time
  - H1D mdpp16.trigger_time
- 2D

Histo Storage: 35.00 MiB
SCP / RCP FW – First test Results

Coaxial HPGe-Detector with reset preamplifier:

- $^{152}\text{Eu}$ source, measured free rate about 1.1kHz
- Preamp output signals: Reset pulse from +1V to -1V (typ. +35mV/MeV)
- Setup of MDPP-16:
  - Hardware config.: Gain-Jumper 0.5V, 96 Ohm, positive signals;
  - Register settings:
    - Timing filter-time = 250 ns FWHM
    - Gain=7 (-> Full range = 2 MeV)
    - Threshold = 16 keV
    - Flat top = 1 us
    - Shaping time = 4 us FWHM + 1us (4 us rise time, 1 us flat top, 4 us fall time).

121.8 keV line, 0.87 keV FWHM resolution
1408 keV line, 1.6 keV FWHM resolution
SCP / RCP FW – First test Results

Low Energy Measurement with reset preamplifier (TRIUMF):

- CANBERRA GUL0110 P detector
- $^{133}$Ba source,
- Gain Jumper 1V, 96Ohm,
- Shaping time: 4us integration, 1us flat top

Gammas from $^{133}$Ba (10.51 y 5)

<table>
<thead>
<tr>
<th>$E_g$ (keV)</th>
<th>$I_g$ (%)</th>
<th>Decay mode</th>
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<tbody>
<tr>
<td>53.161 1</td>
<td>2.199 22</td>
<td>e</td>
</tr>
<tr>
<td>79.6139 26</td>
<td>2.62 6</td>
<td>e</td>
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<tr>
<td>80.9971 14</td>
<td>34.06 27</td>
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<td>160.613 8</td>
<td>0.645 8</td>
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<tr>
<td>223.234 12</td>
<td>0.450 4</td>
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<tr>
<td>276.398 2</td>
<td>7.164 22</td>
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<tr>
<td>302.853 1</td>
<td>18.33 6</td>
<td>e</td>
</tr>
<tr>
<td>356.017 2</td>
<td>62.05 19</td>
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</tr>
<tr>
<td>383.851 3</td>
<td>8.94 3</td>
<td>e</td>
</tr>
</tbody>
</table>
QDC FW – First test Results

BC501 Liquid Scintillator – PSD
- neutron gamma discrimination for $^{252}\text{Cf}(sf)$, (*)
- Long Gate: 250 ns
- Short Gate: 12.5 ns
- Using 3V/50 Ohm gain jumper will further improve PSD!

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16 ... 64 channel portable Digital DAQ System

- **WIENER VME crate**
  - portable 4 slots, 250W...500W

- **MESYTEC MVNV4**
  - preamp power module

- **MESYTEC MDPP-16 /32**
  - Digital Pulse Processor

- **ISEG VHS/VDS**
  - 500V ...6kV BIAS/HV

- **WIENER VM-USB**
  - VME-bus controller
Summary

- MDPP-16 is a high performance digital pulse processor usable for a wide range of detectors
- It provides Energy, Time (+ PSD, +Timestamp)
- Basing the digital algorithms on classic analog principles simplifies setup and configuration
- MVME is multi-platform DAQ software with GUI, providing it as open-source to the community we hope that it will find wide use and further development.