Neutron Detector Electronics

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Outline

• Preliminary Comments
• SNS Electronics and History
• What’s Used Elsewhere
• Common needs and general trends.
Neutron Detector/Electronics Biggest Bang for the Buck.

• “It is well known that there are three ways to improve neutron scattering experiments:
  – ....
  – ....
  – With large area position sensitive detectors which cover the total scattering regime.”

This sentiment is echoed by Jack Carpenter
ORNL Neutron Scattering School 2008

• Doubling the capability of detectors to double the effectiveness of a neutron scattering instrument at a cost of, say, $1M, is far more effective than doubling the intensity of a neutron source for $1B. “
What We Will Focus On.

- Electronics for detectors actively used at neutron scattering facilities.
- Other Focus areas we will not discuss
  - Detection of high energy neutrons.
  - Variations for homeland security.
Electronics at SNS

• Work started in 2000.
• Basic concepts complete and first articles in 2002 using best available discrete components.
• Tech transfers to private firms in 2008 and 2011.
• Most electronics have undergone 1 major electronics revision. (Better FPGA).
• A large installed base provides a reasonable measure of reliability of the electronic systems including operation under vacuum.
Some Basic SNS Specifications

- Time Stamp to 100nsec accuracy.
- Handle non-steady state signals. Peak rate 10x average rate.
- Can deliver data in real time. (At average rate acceptable.)
- Some system have electronics in vacuum.
Pulse Structure (Neutron Signal)

- Now marketed by GE
- Optimize rate capability, position resolution, linearity
- Vacuum operation
  - Low power

![Diagram of Pulse Structure](image-url)

**Rate**

**Resolution**
Pulse Structure (Accelerator/Moderator)

Flux in neutrons/sec

Proton on Target (P.O.T.)

10Hz to 60Hz Depending Upon Facilities

One or more could be missing

Peak Rate can be 10x average rate.
Some instrument have a delta function of high energy neutrons and gammas at P.O.T.
Some SNS Developed Electronics

Only board not having a FPGA
SNS Detectors

High Rate 2D Gas Detector
Uses time division for position determination.

Cross Fiber Detector Pixel Detector
With analog and digital threshold.
Gamma pulse shape discrimination done Digitally.

Anger Camera Detector
Light Division used for position determination

SANS LPSP Gas Tube Array
Charge division used for position determination.

Rate >> 1MHz

.25M pixels per detector

Tested to 1M events/sec
New Model 5x rate 2x Resolution

MILAND MWPC at D16 Uses individual readouts for each pixel dimension
With T.O.T. for interpolation

Preamp, Filter, BLR

VME Bus Interface/Data Aggregation

Contact Bruno Guerard for more information

Table 2. Main parameters of “world-class” detectors in the MILAND category
Brookhaven Gas Detectors
In use at SNS, LANSE, ANSTO

Uses charge division for position determination + unique boundary electronics

New Prototype 20x rate

Tests are taking place using a 2D Ionization Mode Detector
Rates > 1MHz.
ASIC In Gas Design
Due to
Signal To Noise Requirements

Contact Graham Smith for more information
Imaging Detectors

Nova, Sensor Sciences have a TOF capable, delay line MCP.

CCD based imaging system at PSI

Commercial CCD, Interface card

Quad TimePix (Pixelated Detector With 1KHz frame rate)

Interface Board With Virtex 5 FPGA
ISIS Detector Electronics Chain

Neutron interacts in the detector
- Produces a signal
  - Amplifier / discriminator decides whether it is a neutron event
If yes – sent to Data Acquisition Electronics
- Event is time stamped with respect to T0
  - Time when proton beam hits target
    - Time resolution down to 100 ns, but typically 10 us
- Appropriate detector / time descriptor is stored in ping – pong memory
  - On TS 1 frame typically lasts for 20 ms
  - On TS 2 frame will last for 100 ms
- At the end of the frame ping is uploaded into histogram memory whilst pong records data of the next frame

Contact Nigel Rhodes for more information
KEK GEM Detector

Pixelated detector with custom ASIC

Block diagram for readout board

Detector signal

FE2009 ASIC

Digital signal

Sampler 100MHz

Noise Filter

Readout board

TCP/IP Protocol without CPU

Ethernet Interface

Coincidence Logic

Data Format

SiTCP

Threshold Control

Time 10nsec unit

10MHz count rate.

Ethernet Interface

Contact Shoji Uno for more information
Newer KWS Electronics (2009)

New Electronics provided
Faster Pulse Processing,
Higher Count Rate,
And includes an GB Optical Link

Contact R. Engels for more information
What Do The Electronics Have In Common?

• Preamp stage/amplification and shaping

• Middle Layer ADC stage, discriminator/trigger, baseline correction.

• Position Calculation and TimeStamp Layer

• Data Aggregation Layer, Computer Bus Interface for delivery of data to computer memory.

• First three are usually redesigned for a new detector.
Position Determination Methods

• Charge Division
• Pixelated Detectors (digital yes/no).
• Time Division (delay line)
• Light Division.

• Most require some type of digital processing; either directly (position determination) or indirectly (pulse shape analysis).
SNS Electronics Chain

Failure In Any Part of the Electronics Means the Detector Doesn’t Work

If I run at 1 million + events/sec

And I don’t, there’s a problem
Phenix Detector Electronics Chain

Same Electronics Chain Seen In High Energy Physics

Figure 2. MVD Front End Module Block Diagram

FEM (Preamp + Middle Layer ASICs) → DCIM (Data Aggregation) → DCM (Bus Interface) → VME Crate
ASIC or Off The Shelf?

Higher Pixel Densities are pushing more designs to ASICS

KEK GEM ASIC

Typical “first article” run 20K-50K depending upon many variables.

ILL Preamp/Shaper/BLR
Schematic is for illustrative purposes only

Typical first article about 1K depending upon many variables
Other Hidden System Costs

• Many if not for most cases there are no vendors to fix things. It’s up to you and your collaborator.

• Spares are needed for everything—not only for repair but for troubleshooting.

• ASICs are interesting but are not generally available (Application and it turns out Facility Specific).

• Most systems benefit greatly from an upgrade cycle that follows the electronics industry. (5-10 years).
  – Good example is Brookhaven 2D gas detectors used at SNS which saved ~250K.
General Trends In Detector Electronics

• Higher Pixel Density and more Pixels
  – Lower power and more designs needing ASICS
  – Use of high speed serialized interfaces to decrease cabling

• Higher Data Rates
  – Use of larger gate count FPGAs especially for position determination or signal processing.

• General Trend to 1 Gig Ethernet data delivery.
  – Tech Transfer Partners are also pushing this.
Conclusions

• No single elegant off the shelf electronics solution.

• Higher pixel rates require development of entire data delivery system.

• Higher pixel densities are pushing designs to use ASICS.

• Availability of 1Gig-Enet interface should be required and expected for most systems with migration to 10Gig for very high rate systems.