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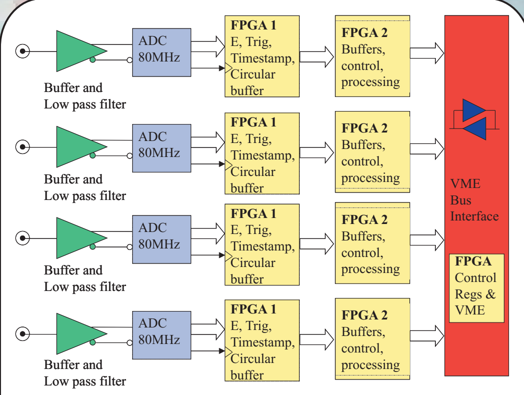
The GRT4 VME Pulse Processing Card for Segmented Germanium Detectors

Motivation

In Germanium (Ge) detectors a gamma ray typically deposits its energy in 2 or 3 places before complete absorption. The interaction mechanisms include the Compton scattering process, in which part of the initial energy is deposited, and photoelectric absorption, in which all the energy is given to the crystal. Compton scattering dominates for a wide range of energies (200 keV to few MeV) and as a result a typical Ge spectrum has only 20 % of its counts in the full energy peak. The majority of lower energy events arise when the Compton scattered gamma ray escapes the crystal. The conventional solution to the scattering problem is to surround the Ge detectors with escape suppression shields, usually made from dense scintillators, and reject events which are detected simultaneously by both the Ge and its shield.

The next generation of gamma ray arrays (AGATA and GRETA) will not use escape suppression shields- they will be made entirely of Ge detectors. They will employ a technique called gamma ray tracking to trace the scattering gamma rays around the array, adding up the energy deposited at each of the points on the track to determine the energy of the incident gamma ray. Such reconstruction is possible because the energy and direction of the scattering gamma rays are related by the Compton scattering formula. In order to determine scattering direction, we must first know the positions of each interaction position. The better the positional information, the less ambiguity in the tracking. Part of the positional information comes from segmenting the outer contacts of the coaxial detectors, typically into 24 or 36 segments. Such segmentation is still not a fine enough position determination, so it is necessary to subdivide the segments by analysing the shapes of the charge pulses collected from them.

This poster describes a VME card which has been used to investigate the pulse processing required in gamma ray tracking arrays. It digitises and processes charge pulses from segmented Ge detectors so as to determine interaction position as well as energy deposited and the time it arrived.



GRT4 Block Diagram

The GRT4 card

The GRT4 card includes four acquisition channels operating in parallel. Each channel has a 14 bit 80MHz flash ADC (AD6645). The analogue inputs are filtered with a 40MHz low pass filter and include an optional differentiation stage so that the ADC is presented with either the raw input or a differentiated input representing the detector current pulse. The processing and data buffering of the ADC output is performed by two dedicated Xilinx Spartan 2 field programmable gate arrays (FPGA) per channel. Each FPGA has 200k gates available. The first contains a circular buffer (512 samples deep) with programmable pretrigger delay, and an energy determination algorithm. A digital trigger algorithm is also implemented, based on a simplified version of the Slope Conditioned Counting principle. Each trace in the circular buffer is tagged with a 16 bit header (8 ID bits are programmable, 8 bits are the trigger counter) and a 48 bit timestamp when the trigger occurs. The second FPGA is used either for trace buffering or for further pulse processing (such as timing or interaction position). Readout takes place over the VME bus.


The GRT4 VME Card

GRT4 Specifications

Analogue Inputs: 4 SMA connectors
- In non-differentiated configuration:

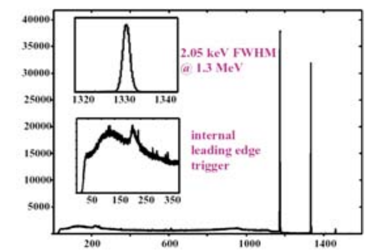
0 to ±550mV at input (i.e. 1.1V unterminated) input range
- In differentiated configuration:

±15mV/ns at the input (30mV/ns unterminated) converts to ADC full scale value
This equates to a 7.5MeV input (200mV/MeV sensitivity) switching in 50ns.

Trigger Inputs/Outputs: 3 SMA Connectors, all signal levels Fast NIM
- Trigger In
- Busy Output *(can alternatively be used as a Trigger Out under software control)*
- Gate In *(can also used to reset all timestamps simultaneously)*

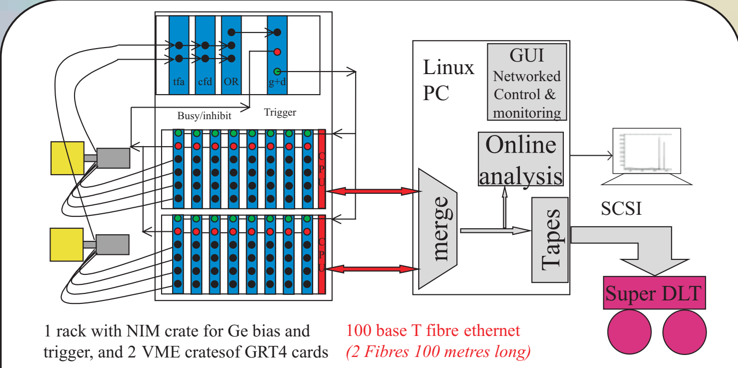
ADC:
- 14 bits 80 MHz. (Bipolar inputs generating 2's complement data)

Processing:
- 2 FPGAS (type Xilinx Spartan 2 XC2S200) per channel (400k gates)



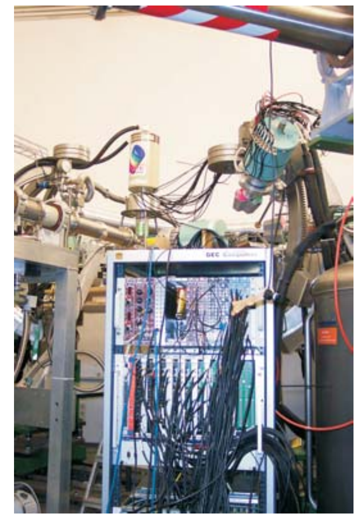
Energy resolution of a small (33% efficiency) Germanium detector has been measured using real time Moving Window Deconvolution in the GRT4 card. The results were 2.05keV FWHM for the 1.3MeV 60Co peak and 1.23keV FWHM for the 122keV peak in the 152Eu spectrum. Count rate was 800Hz in both cases. The processing time was 11us.

The 64 channel GRT4 DAQ system



Block diagram of 64 channel GRT4 data acquisition system

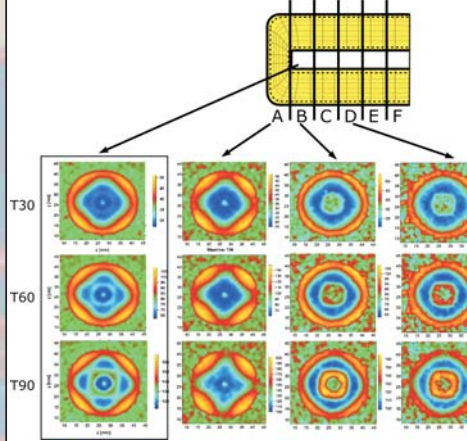
The system provides both online analysis and a way to display incoming raw data traces. The online analysis allows the processing of the data traces to extract energy and histogram it into an energy spectrum. Other analysis performed online includes plots showing the variation of rise times. The raw data traces can be displayed from any (or all) of the detector segments, for example a segment and its neighbours.


Photograph taken at IKP Cologne showing one crate of GRT4 cards and the NIM trigger with the Ge detectors in background.

An in-beam test was made at University of Cologne's tandem accelerator laboratory using 2 segmented coaxial Ge detectors, one with 36 fold segmentation and the other with 24 fold segmentation. A total of 62 channels was required including the core signals. The traces from all 62 preamplifiers were recorded every time either detector was hit by a gamma ray.

The GRT4 cards were integrated with Daresbury's MIDAS user interface and University of Liverpool's MTsort online analysis package. Data were read by VME processors and sent via fibre Ethernet links to a Linux PC which merged data from the 2 crates of GRT4 cards and wrote it to SDLT tapes. The same PC also performed online data analysis. The system was operated without problems for an experiment lasting over 1 week at a sustained total rate in excess of 7Mbytes/s to tape which equates to 120 events/second.

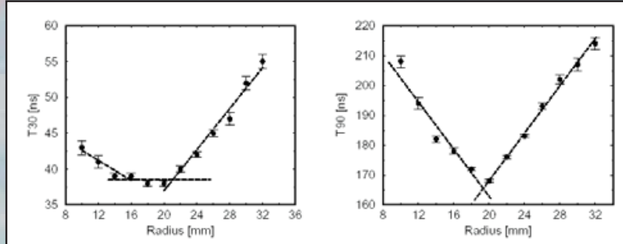
Using the GRT4 for characterisation



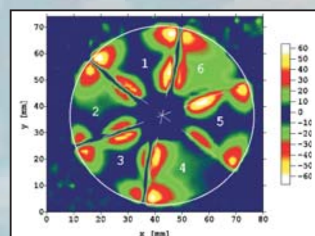
Polar plot of rise times (T30, T60, T90)

The GRT4 card has mainly been used for characterising the response of Ge detectors to gamma rays. This is done by connecting the detector's preamplifier outputs to GRT4 cards and collecting sets of traces from all the segments whilst moving a collimated source across the detector face using an X-Y scanning table. Pulse shape analysis relies on finding unique signatures in the differences between the shapes of pulses recorded in the characterisation traces. One example is the difference in time taken to reach 30%, 60% and 90% of the full pulse height (T30, T60, T90). The resulting plots (left) show the difference in the rise times at various different places within the detector, in this case the core contact, and 3 rings of segments (A,B and D).

By plotting the time to 90% of full height within one of the segment rings we can obtain a V shaped plot (right) where any one measured rise time has 2 possible values. The time to 30% of the same ring has a different shape and can be used to resolve the ambiguity in the T90. So from these 2 graphs we can determine the radial position of the interaction point in this segment.

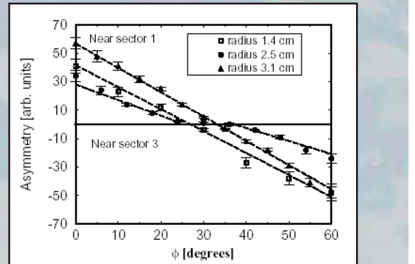


Deriving radial position from rise time



Asymmetry of image charge (polar plot)

The azimuthal position can be determined by considering the ratio of the charge (Qn) induced in the neighbouring segments. The polar plot (left) shows the ratio of the difference divided by the sum of the charge induced in neighbour segments. So for example in segment 4 the plot shows the values of (Q3-Q5)/(Q3+Q5) for many different positions of the collimated scanning source. The same information is shown in a different form (right) where just 3 radial positions are considered, and the relationship between the azimuthal position and the asymmetry of induced charge can be used to determine the azimuthal position from the measured asymmetry.



Deriving Azimuthal position from induced charge