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Abstract

For the high resolution gamma ray detector array EUROGAM new data acquisition solutions are being developed. Large volume high purity Ge detectors, with new shapes for increased efficiency, have been proposed and prototypes are now being tested. High resolution analog and digital electronics will be integrated within the VXIbus system to be used as the front end instrumentation bus. Also, distributed processing solutions are adopted in order to cope with the high data rates.

1 Introduction

Nuclear Spectroscopy and the study of nuclear reactions, have benefitted tremendously by the improvements in Accelerator and Detector Technology. The introduction of large detector arrays and their subsequent improvement have lead to the discovery of extreme nuclear shapes (Superdeformation) and to the understanding of other phenomena. With the conception of the VIVITRON in Strasbourg and other accelerators of similar performance, a new spectroscopy tool became necessary. Considerations of size and cost made it clear, that a common European effort was indispensable: thus the EUROBALL Collaboration was born. Financial timing problems as well as the many technological challenges presented by a project of this scale lead to the decision to build as a first stage the EUROGAM detector system.

In the current concept the EUROGAM detector system will consist initially of 50 and finally of 75 high purity germanium (HPGe) detectors, each surrounded by ten Compton shielding BGO detectors. The planned physics requires the detection of γ-rays from $\approx$ 30 keV up to 20 MeV within an individual Ge-detector and a time resolution of a few nano-seconds. In addition, special purpose detectors (e.g. Recoil) would normally be incorporated in this array to fulfil experimental requirements.

The first problem to be faced was the size of the front end electronics. Using currently available high resolution spectroscopy equipment the EUROGAM detector system will require an enormous amount of space – currently one high resolution Ge-channel occupies ≈ 1/2 NIM crate. The required infrastructure would make it impossible to move the EUROGAM around different laboratories as planned. Also, cabling connections between modules, would create serious problems of reliability and serviceability. Other disadvantages would be the lack of automatic adjustment and setup possibilities, as well as the very poor monitoring and control possibilities.

The flexibility required to exploit the physics possibilities of this new system, as well as the logistics problems with such a large system, demanded computer controlable and monitorable high density electronics.

A modular system was designed, consisting of computer controlable integrated electronics modules and of distributed processors with high speed bus and data link connections. Concise communication protocols will ensure the possibility of expanding the system or replacing components by others of higher performance as technology advances. The novel idea of integrated electronic cards, as well as the powerfull distributed processing of the data introduced by EUROGAM , will be presented here.

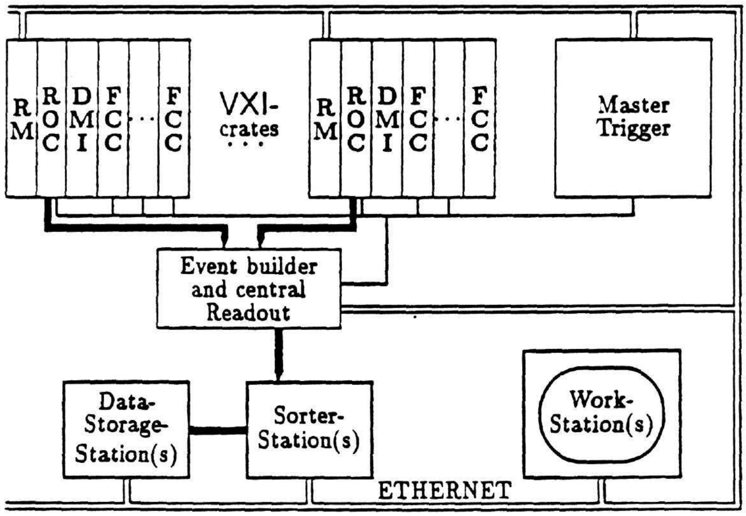

Fig. 1: Data Aquisition System Overview

RM – ***Resource Manager and Crate controller,***
ROC – ***Readout controller and interface to the Trigger,***
FCC – ***Front end Channel Card for several Detector channels,***
DMI – ***Direct Memory Increment Controller.***

2 DATA ACQUISITION SYSTEM OVERVIEW

The Data Acquisition system is designed in a hierarchical modular way, which allows the selection of components within the data acquisition system to meet the different experimental needs (Fig. 1). It also allows replacement of components as new technologies or new detectors become available.

The front end will be built on VXI cards, specific for each detector. The difference will be the pulse shaping, which differs for each detector type, and the number of channels which can be packed on one card. Each channel will receive the output of the appropriate preamplifier and process it through to digital outputs for Energy and TAC, sending the data to a Crate Readout Controller.

One of the central elements is the event builder, which concentrates the ROC outputs. It is responsible for the event readout and formatting of the event data stream to an intermediate structure. The events are forwarded from this stage, using optical fiber links for electrical isolation, to the Sorter, a set of number crunching processors, for further event selection, analysis, storage and monitoring. It is planned to use VME based systems for this task.

The master trigger section is the second central element. Each channel of the detector system provides information (e.g. CFD signals) on which decisions can be performed. The trigger section outputs some signals, like the master trigger signal, validations and readout signals, and generates patterns and other useful information (event number, time of event), which are inserted into the event data stream.

There are two bus systems, as can be seen from figure 1:

- A dedicated unidirectional Data Bus, which will have to cope with the high data rates expected, and
- a slower control bus. This will be Ethernet and it will link the Crate Resource Managers, the Event Builder, the Sorter, the Tape Server and several Graphics Work Stations. It will allow presetting of control registers, monitoring of system conditions and graphic presentations of the Data

3 VXI MODULE DESIGN

Each Module (Card) contains several channels and the interface to the VXI bus system, which allows a flexible automatic configuration. In addition several functional blocks common to all channels are providing other central functions. One common block is the setup, responsible for the generation of all computer setable analogue parameters like threshold levels. A diagnostic ADC is used for the purpose of checking these parameters. As a general rule, all computer settable registers are also computer readable. Another common block is the shared digital rate monitoring using scalers. They are used for measuring the actual counting rate of one detector channel, the current pileup rate and the deadtime.

3.1 Channel level

With the exception of the preamplifier, all the electronics is designed on small cards (channel building blocks), which are plugged onto a VXI card, containing between 5 and 8 high resolution channels or up to 32 low resolution channels (for anti Compton shielding detectors) and the common control and readout logic.

Each channel building block contains several replaceable analog processing elements for the energy and the time path, including the digitization. For simpler system handling the channel readout logic of each sub-channel has the same interface to the readout and the trigger, regardless of the type of special electronic and digitizing elements used.

Each channel is controlled by a local programmable trigger section, which is responsible for channel timing and the interaction with the main trigger system. This section allows each channel to operate and generate all timing signals without the need for a common trigger signal. The effect of the common trigger signals from the master trigger is to allow the start of digital processing. The local control block is also responsible for pileup detection, and to provide pattern informations. This additional information can be inserted, again programmable, into the output data stream as so called qualification bits.

In addition to standard electronics the thresholds, gains, offsets, and time allignement of each channel will be computer controllable. Also automatic DC zero level adjustment and walk adjustment is foreseen. Analogue signals at each interesting point within a channel, for example the signal after the input stage, the time filter, or the timing signals can be switched to an inspection bus via computer control, to allow checking of the timing and the analogue signals on an oscilloscope.

The individual modules are read out by the Crate Read Out Controller (ROC) and forwarded to the Event Builder. This is the most time-critical part of the system. It receives the full data stream from the ROC's and it must somehow reduce the data rate before forwarding the event to the Sorter.

4 Sorting and Data Storage

The concept of modularity is taken to the extent of separating the event building from the sorting task. One reason is operational: the Event Builder must be as close as possible to the electronic front end in order to make parallel transfers from the ROC's possible, while the sorting task must be as close as possible to the experiment control area and the permanent storage devices (Tapes), which will need frequent replacement. A secondary reason is the expectation, that very fast work stations may soon become available. Then the sorting task may be incorporated in the same station as the experiment control reducing system complexity.

In any case, all experiment dependent processing will be incorporated into the Sorter, which will receive as input event blocks from the event builder and will produce various streams of sorted or raw data, directed either to the permanent storage (Tape) or histogramming one- and two-dimensional memories.

The Liverpool Sorting language, now in use in Daresbury and other UK laboratories has been adopted as the basis for the EUROGAM sorting language. The main advantage of creating a proprietary language, is that procedures written in it and tested on any system which implements it, will be transportable to the on-line acquisition system. On the other hand, if a general purpose, higher level language like FORTRAN were adopted, the portability would be only theoretical - everybody is aware of the essential differences in the FORTRAN implementation by various machine manufacturers. A second advantage is that, each implementation of the language for a different processor, can exploit the strong points of the particular processor in a form transparent to the physicist. Especially, if Transputers are used in the sorter, their inherent potential for parallel processing can only be exploited by programming in OCCAM, a language little known to the physicists.

The need for several output streams will exist, as long as the only available storage medium is EXABYTE. This is a video type recording device, which stores 2 Gbytes of data in a small 1/4 inch tape cassette. Sustained (average) tape speed is 512 kbytes/sec, while - in EUROGAM phase I - the expected data rate of $\approx$ 15 kevents/sec, with an average multiplicity of 4, will produce an average of $\approx$ 1 Mbyte/sec for Compton suppressed γ-ray recording. It is, therefore, clear that at least two output streams will be needed and that this number can not be increased beyond reasonable limits. This means, that strong data filtering and raw data reduction is needed, unless the storage technology produces a new, faster, medium of high capacity, which could permit writing of large amounts of raw data.

5 Software and Networking

As mentioned from the beginning, the design of the EUROGAM data acquisition system was based on the principle of modularity and replaceability of system blocks. These blocks communicate via data links for the transfer of Data or controll information.

As shown in fig.1 a central part of the described data acquisition system is the local area network which connects the different system components for setup and controlling. A network based communication system will allow to support the interconnection between a heterogenous, arbitrary set of workstations, the data acquisition crates, the trigger, and the event builder. It was decided to use Ethernet as the communication link and to create a reduced standard protocol to improve the speed of transfers. This has the additional advantage, that if better data links become available, they can replace Ethernet, without the need to change all the system software.

For most of the applications running within the data acquisition crates no operating system will be necessary. Only for the database server, and for the user applications an operating system is required. Currently OS/9 and UNIX are the operating systems used, but other choices are possible in the future, due to the modularity of the system. As UNIX is not a real-time system, all real time data acquisition functions are left to the VME- and VXI-based processors. On the other hand all file handling, preparation and down-loading of programs for the processors, graphics and communications can be performed within the UNIX environement.

We will not restrict the choice of the workstations and other computers to a certain type, but this makes it necessary to use as far as possible a common user interface to the system. It has been decided that the X-Window system will be used as the general base interface to the system. Also the graphics and command interface, already operating in Daresbury, was accepted as the standard and it is beeing converted to the X-Window environement. This will be transported to the computer systems of the collaborating laboratories, making a standard interface to the EUROGAM data both for on-line acquisistion and off-line analysis.

6 Summary

The main objective of this presentation was, to stress the importance of modularity in the design of the data acquisition system of a large detector array. This modularity has a number of advantages, of which the most obvious are:

(a) The mechanical construction of such an array, as well as the procurement of the detectors, the testing and assembly, are very long operations. A modular design allows parts of the project to proceed in parallel, thus reducing the time to the completion of the project.

(b) Technology - especially digital technology - progresses with such a pace, that it makes the original plans from 'old fashioned' to obsolete. A modular design allows the replacement of old, or the integration of new technology as it becomes available.

(c) The modules can be designed in a way, which can accomodate the products from several producers. This can have some influence to the total cost of the project. It definitely makes the project independent from the abilities of support of one producer only.

The essential requirement for the beneficial use of modularity, is the carefull definition of the interfaces between the modules, as well as, the protocols of communication across these interfaces. Only then, all other benefits can be realized.