A user friendly VMEbus Based Data Acquisition System

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Abstract

A data acquisition system based on VME standard modules has been designed for a detector array for the measurement of high energy gamma rays (1-30 MeV) based on 8 big BaF$_2$ crystals (HECTOR) [1].

The system is composed of a VME crate housing tdc, adc, cfd, scaler, amplifier control board and of a personal computer physically interfaced to the VME by means of a gigabit fiber optic as interconnecting technology.

VME transactions are handled by a DSP server sequencer that collect data from tdc and adc sources organizing them into buffers. The person operating the client desktop computer uses Kmax [2] to view, store, and manipulate data from available buffers without need to know where and how those data are made available to the system.

Integration in a more complex acquisition system [3] is complete. Diagnostic functions and error report messages are also available to detect hardware failures or incorrect setting for the used modules. System extensions, for more complex detectors can be simply accomplished writing the front-end readout code.

I. INTRODUCTION

A. General Considerations

A common characteristic of recent experiments in nuclear physics is to develop more and more complex detector systems to be assembled together to form multidetectors [4,5,6]. The large number of detectors in these arrays and the different parameters analysed by each detector call both for a powerful and versatile data acquisition system to handle multidetectors parameters and also for dedicated acquisition systems specialised to setup individual detectors in order to guarantee the best performances. Requirements for these dedicated acquisition systems are:
- detector setup procedures, usually not easy to be implemented in a more general acquisition system,
- good performances in order to collect a physically meaningful statistic,
- simplicity of use to allow detector controls also from not specialist persons,
- integration with the general data acquisition system in order to minimize the number of cables and the time required to switch from the dedicated system to the general one,

These requirements have been fully accomplished in the acquisition system here presented and called Hector@Rising. It can be used as an independent acquisition system as well as in combination with other DAQs as in the last RISING measurement campaign that have taken at the GSI laboratory (Darmstadt).

B. The detector and the experiment

The RISING [3] array is located at the GSI (Darmstadt, Germany) at the exit of the Fragment Mass Separator (FRS) [7]. Rising consists of 15 EUROBALL cluster HPGe detectors [8], 8 BaF$_2$ detectors of HECTOR array[1] and the Cate calorimeter [9].

HpGe detectors measure low energy discrete transitions ($E_\gamma < 4$ MeV) with a full energy absolute efficiency of approximately 3% at 1.3 MeV, BaF2 detectors are used to measure high energy gamma rays ($E_\gamma > 4$ MeV) with an estimated absolute full energy peak efficiency of approximately 1% at 10 MeV. Cate is a system of $E_1/E_2$ telescopes located at the end of the beam line to identify the final nuclei in mass and charge.

The RISING array has been designed to measure the gamma emission from exotic nuclei produced via the SYS/FRS facility. Such system provides secondary beams of unstable radioactive nuclei via fragmentation or fission of relativistic heavy ions. In the first RISING campaign beams of radioactive nuclei with energies between 100 – 400 MeV/A has been exploited to perform relativistic Coulomb excitation and to produce exotic nuclei with nuclear reactions like multifragmentation.

C. The MBS Data Acquisition System

The data acquisition system developed for the first RISING campaign is based on the MBS (Multi Branch System) [10] GSI standard, already used in nearly 100 others systems. The acquisition is presently composed of three branches corresponding respectively to the EUROBALL cluster HPGe detectors, the Fragment Separator facility (FRS) together with the Cate detector in the second branch and the Hector high energy gamma detectors in the third branch [3]. The branches run independently as fully operational acquisition systems with their individual trigger source and local dead time during readout. Front end digitized data are read out by a VME processor [11] and stored in a sub-event pipe. Event identification is made through the three 48 bit Time Stamp
modules [12] placed in each of the branches. One of them is set as a master, the other are slaves and synchronize themselves via a synchronization bus. They allows a time granularity of 20 ns, and their values are read out for each trigger accepted in the individual branches. The event data are sent via a TCP socket to the branch event builder; a master event builder collect and sort all the data coming from the sub-system into a single output stream. Events are ordered by rising time stamps values.

II. THE HECTOR BRANCH

Figure 1. shows the hardware configuration of the Hector ancillary VME crate. It is composed of the three MBS default modules (cpu, trigger, time stamp, placed in the left part of the crate) and by the following Hector dedicated front end boards:
- the V878 32 channel TDC [13]
- the V879 32 channel ADC [14]
- the V812 16 channel CFD [15]
- the V560E 16 channel Scaler [15]
- the V288 Caenet VME Controller [15]

These boards can be read out and controlled both from the RIO3 CES CPU when used within the full MBS acquisition during the experiment running or from a separate dedicated PC running Windows 2000 when used for detector check and setup. The PC, placed in a radiation free area (100 m apart from the experimental area) where the user can stay while the experiment is running, is connected to the VME crate, placed as close as possible to the detectors in the experimental area, through a high performance PCI-VME optical fibre link [16].

This connection consists of a PCI circuit interface (SIS1000) placed on the PC in the acquisition room and a VME circuit card (SIS3100) inserted in the VME crate placed in the experimental area, connected by 2 different optical gigabit wires, one for upload and one for download, each 100 meter long. On the SIS3100 the actual VME transactions are handled by a sequencer that executes VME cycles under control of the ADSP21061L Digital Signal Processor (DSP).

A kmax application running on the PC allows the user to control and initialize hardware modules through a very simple and intuitive interacting menu as will be described in the “User’s point of view” paragraph. It performs detectors diagnostics, spectra visualization and allows the user to setup Hector detector before experiments.

III. SOFTWARE IMPLEMENTATION

The software is composed of two parts: the first one runs on the PC while the other one control the DSP. The first one is written using Kmax 7.2, an environment for instrument control and data management with high level support for modular instrumentation, event-by-event data acquisition, data sorting, histogramming and analysis [2].

This environment is a pure Java application designed to run in any Java Runtime Environment (JRE).

A native driver elements has been developed to communicate with PCI-VME hardware attached to our computer. It is loaded at compile-time and allows both single read/write VME access and block direct memory access (DMA) data move.

A lot of native extension has been also added to the standard command sequence language (CSL) in order to improve histograms visualization, importing/exporting histograms in dedicated format and perform suitable fitting.

The software controlling the DSP has been written in assembler by means of Analog Devices VisualDSP++ Development Software[18].

Once the system starts, an automatic procedure downloads the DSP executable code into the DSP program memory. DSP variables like memory usage, number and dimension of sort and save buffers, front end board base address and presence are initialized by the pc code.

Communication between the kmax code and the DSP code is realized through a common command memory area.

Some commands requires immediate execution from the DSP that inform the pc user of the operation’s results.

Other commands transport the DSP in a loop cycle, where the pc, as a consequence of the user request, ask the DSP for the status of operation. The DSP reads TDC and ADC parameters organizing them into dedicated sort and save buffers placed into the 512 Mb SDRAM memory located on the SIS1000 board. Access to these buffers is controlled by structures composed of semaphores, status registers, pointers to start and end address and to the number of collected events.

The system is designed to allow communication between DSP and Kmax asynchronously through the use of ‘polling’. The DSP utilizes multiple flip-flop buffers so as to speed up data transfer both for sorting and saving. When the buffers are filled, buffer’s structure is updated by the DSP and the data are made available to the Kmax user. Kmax pulls the data from that buffer and then declares it as free. The speed of the system enables the client to be able to look at the data as it is being collected.
IV. USER'S POINT OF VIEW

User starts the applications simply double clicking on the Hector@Rising icon. An automatic procedure verify the presence of the front end boards, initialize them in their default configuration, load and start the DSP and carries the user in the “Control Panel”.

User interaction with the front end boards and the detector has been simplified collecting controls, parameters field and histograms in group of interest. Figure 2. shows a list of the available panels.

The first four of them has been dedicated to the VME hardware control. TDC, ADC, CFD and SCALER parameters like thresholds, tdc range, adc rise time protection and reset time, width of logic signals can be changed on individual channels, grouped channels or on all channels. Most part of the parameters can be modified even if acquisition is running. In the event of unwanted signals to be converted as noise (pedestal noise, spikes, defect or flickering channels...) unused channels can be suppressed. The user has the faculty to reject current physical event by giving a fast clear signal on the front panel “control connector”. The FAST_CLEAR slider set the time window available to the user to provide the kill signal.

Figure 3. shows the “CFD Settings” panel where user control all the functionality of the constant fraction discriminator.

The AUTOMATIC_CFD_THR_CUT button is used to starts an automatic software procedure whose goal is to provide the correct CFD threshold setting corresponding to the user wished energy threshold cut.

After acquisition of a sufficient number of data, the user evaluates the required energy thresholds on some histograms placed in the “Slow” panel and sets the left cursor of each histogram near the wished energy level. Afterwards he acts on the EV_Fraction control to select the percentage of the events below the selected left cursor threshold. Finally he can start the AUTOMATIC_CFD_THR_CUT procedure.

The “Scaler” panel gives the user the possibility to have sixteen 32 bit counter channels. They can be jumpers twinned in order to have 64 bit counters. Since this information is readable by software, user must not worry about hardware changes because the scaler panel automatically displays 32 or 64 bit field. For every selected channel is also displayed the “Current Rate” (channel’s rate in the last 10 seconds) and the “Total Rate” information (channel’s rate since the last start acquisition command).

The Amplifier Control panel allows to control the CAEN N568 shaping amplifiers. These are 16 channels NIM module that can be fully remotely handled by the V288 VME caenet controller. As usual, user can act on individuals, groups, or all channels. Combo boxes allows to select coarse gain, shaping time, signal inversion and output polarity while buttons control fine gain, pole-zero cancellation and dc output voltage offset. Predefined values can be simply downloaded on the target modules. New amplifier modules (for a total of 100 modules) can be simply added and controlled just adding two simple statements that specify the amplifier label and it’s number in the kmax command sequence language.

The “Control Panel” is the default panel at the system start up (Figure 4). It contains a lot of functions and status widgets that allows the user to control both acquisition parameters and histograms properties. Acquisition can be started and stopped using the two top left control/status button. The start command is sent to the DSP that starts collecting and formatting events in buffers. Number of sort and save buffers and their dimension can be selected by the user through dedicated control buttons.

If something goes wrong the acquisition is automatically stopped and an error message is reported in the “Acquisition_Info” text pane. User can monitor the DSP activity by simply pressing the “Show_Job” button.
Acquisition and sorting are based on the Get_Data event that is recursively called according to the “Test_Timer (ms)” value. User specify how often kmax software has to check for a buffer green semaphore and a full status register of the current buffer. The “Not_Full_Rate” allows the user to have a feedback for the set value of the “Test_Timer (ms)”; it shows the percentage of the accesses in condition of front end buffer not full. This value is updated every 10 seconds through the “UPD_Info” event. It also updates the fields Acquired_Events, Current_Rate and Total_Rate. These last three values are reset each time the acquisition is started and represent, respectively, the total number of acquired events, the acquisition rate in events per second in the last 10 seconds and the acquisition rate since the last start acquisition command.

Sometimes it can be useful to run the acquisition system for a predefined time. This has been accomplished through the “Preset_Timer” control. Before running the acquisition the user specify the amount of time expressed in seconds. The progress bar “Elapsed Time” placed under the “Preset_Timer” control gives the user the feedback for this feature.

Normally TDC and ADC modules give data value even if no signal is presented at their inputs. This is due to a DC analog base level call pedestal. The “Pedestal Subtraction” control starts an automatic procedure that individually increases the thresholds values of all the TDC and ADC channels till pedestal suppression. Sometimes system can hangs while getting data because of hardware failure, front-end boards disalignement, wrong trigger or veto hardware settings. In order to restart, you can restore the starting configuration in the front-end boards by pressing the “Front End Reset” control.

The user usually defines a lot of histograms; position of their cursors can be set all together to a predefined values using dedicated controls. The same applies to histogram’s regions of interest whose boundaries can be set in the same way. Spectra can be saved and reload through the two controls “Save Hist” and “Load Hist”.

“Show Event” control dumps events in the “Acquisition_Info”; it allows to have an idea of the number of channels fired in a general event. “Pattern_Hist” is a built histogram whose contents display the SUM of counts for the Slow, Fast and Time histograms for the 8 BaF. Default conditioned or unconditioned 1D and 2D histograms for the Hector@Rising application have been collected into different panels according to their group of interest. In order to save CPU time they selectively refreshed only after a user selection.

Two dedicated panels “Mono Hist” and “Matrix” have been created in order to better display 1D or 2D histogram characteristics. User can load the wished one according to their respective dynamically created ComboBox controls.

Typical information like display of cursors counts, total counts, sum, maximum, minimum, centroid and FWHM on the whole spectra and in selected regions and common used functionality like exporting histograms, fitting and overlaying, X and Y projection has been implemented. Contrast slider will emphasise or decrease the contrast of the selected histograms.

A dedicated panel has been reserved to determine the detector linearity performances as a function of the bias voltage.

Default front end setting values are automatically loaded at startup and user is prompted to save current values before exiting the working session. An initialization text file is also created to be used by the general acquisition system. Software running on the CES CPU reads this file and properly initialize the front end modules for the RISING experiment.

V. SYSTEM PERFORMANCES

It is usually difficult to estimate data acquisition performances since they strongly depends of the number of channel firing and how often the user requests to save, export histograms, fitting..

One important parameters is also the number and the dimension of the used buffers that allows to full benefits of the use of the dma during data transfer. Figure 5 shows acquisition system performances as a function of source rate and firing channels. Random trigger have been generated moving a CO$_{60}$
source far and near a BaF$_2$ crystals. Number of firing channels have been achieved forcing dc level for adc and stop signal for tdc. All acquired data have been sorted and stored. Data integrity have been online checked for every event.

In a normal use, the developed system is capable to handle random source data at a rate of 7-8 KHz, with a reasonable dead time, independently of the number of firing channels.

VI. CONCLUSIONS

A data acquisition system for the Hector detector has been designed and assembled. The user friendly interface allows a full use of the system in 10 minutes also for beginners users. The good performances completely satisfy the experiment requirements. The modularity of the VME environment allows a simple expansion of the system adding more front end boards and including in the dsp code the readout routine. The system is completely integrated with the general Rising acquisition system; no cables needs to be removed nor modules must be jumper modified.

The generality of the developed system (standard front end board) allows its use in small and medium size nuclear experiments or as good performances multiparameters systems.

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Figure 5. System performances