Digital Electronics Equipment for the RIPEN Apparatus


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INTRODUCTION

Following the tests performed in 2010 and reported in [1], the update of the acquisition system of the RIPEN apparatus with a fully digital setup has been carried on.

RIPEN is an array of 40 liquid scintillators (BC501) used for neutron spectroscopy in low-energy nuclear physics experiments. The neutron energy is measured by the time of flight method and the discrimination between signals induced by neutron or gamma incoming radiation is obtained by performing pulse shape analysis [2].

As already mentioned in [1], we have recently tested the timing and the neutron/gamma discrimination performances achievable with a 250 MS/s, 12 bit digitizer (CAEN V1720) and offline pulse shape analysis.

In this report we will illustrate the first complete digital data acquisition system built using the mentioned boards and the previously implemented routines for pulse processing. Such a system is able to handle a subset of 8 BC501 neutron detectors and some ancillaries needed for a cross section measurement experiment [3].

In the following, both the data acquisition setup and multiple boards synchronization will be discussed, then the “neutron monitor” will be described, that is a ROOT-based analysis software that processes the acquired shapes and produces both on-line monitoring histograms and ROOT-Trees for offline data analysis.

DATA ACQUISITION AND BOARDS SYNCRONIZATION

A general overview of the hardware setup for the RIPEN array is given in fig. 1. The whole systems fits in one VME crate where different boards are lodged. The master one is the CAEN V2718 module that maps all the digitizers and handles the data input/output towards the acquisition PC using an optical fiber connection (Conet1 CAEN protocol).

On the same crate one can put several V1720 VME boards, each of them providing 8 digitizer channels. For the measurement reported in [3], two V1720 modules were used. Namely, the signal input used in each board came from:

- 4 BC501 neutron detectors;
- 2 silicon detectors;
- 1 time reference signal from the accelerator;
- 1 pulser;

Even using only two different boards one has to deal with the problem of their synchronization. This is done by propagating the reference clock of the first board to the following ones using specific ports of the V1720 and custom connection cables. One has also to take into account the delay between boards and this can be done at the beginning of the experiment by setting specific delay registers in each “clock-slave” module. This machinery is needed to keep a synchronized Trigger Time Tag to be stored with the data from the different boards for later global events reconstructions. The stability of this feature showed to be acceptable during two-weeks experiments.

![Fig. 1. Schematic view of the digital acquisition system.](image)

In this version of the setup the trigger logic adopted is very simple, every channel can be trigger-disabled or enabled with a proper threshold. Every time one trigger-enabled channel sees an above threshold signal, a global trigger is fired to the whole system. This can be acceptable in the setup used in [3] where one has to perform single particle measurement, but not in more complex experiments. In order to handle a higher number of channels or to require detector-detector coincidences for triggering on specific processes one has to develop a proper trigger logic. This will be done for future experiments using the software developed for the GARFIELD apparatus trigger logic [4]. The idea is to process the single channel triggers in an external logic unit (CAEN V1495 FPGA) and to send a global trigger signal to the external trigger input of each V1720 module.
In the acquisition system version used in [3], the data flow can be summarized as follows: signals coming from the detectors are acquired by the digitizers and can trigger (or not) the global data readout. If one trigger is fired, samples from all the active channels are acquired in a common time interval with a fixed pre/post trigger time ratio. The sampling rate and the input range dynamics are also fixed, while a dc-offset and trigger thresholds can be set channel by channel. Data are collected by the previously mentioned VME “bridge” and sent to the acquisition PC (where a memory buffer of 500 MB/board is allocated). One data file per board is written to disk and it contains the acquired raw shapes as well as Trigger Time Tag and general settings information. Fig. 2 shows schematically the DAQ loop for readout and storage.

![DAQ loop diagram](image)

**Fig. 2. Data acquisition loop.**

**NEUTRON MONITOR GENERAL DESCRIPTION**

Raw data are stored into disk and signals have to be processed to extract the required information like the deposited Energy, the Time of Flight and the Pulse Shape Discrimination parameters, etc.

To this aim, a ROOT-based specific software was developed. The general idea of the program is shown in fig. 3. The data acquired in different runs are the input as well as the detectors configuration and the list of the required histograms. The software computes a set of parameters using the pulse shape analysis algorithms specific of the selected detector type. Histograms are filled according to simple text configuration files where one selects board, channel and parameter to plot. This allows to easily plot any computed quantity from any detector in 1D histograms and any combination of those (even from different detectors) in 2D plots.

![Neutron monitor general features](image)

**Fig. 3. Neutron_monitor general features.**

**SOFTWARE ORGANIZATION**

Fig. 4 explains the neutron_monitor internal software organization. Boxes can be thought as instances of C++ classes while arrows are pointers to instances of other classes.

![Simplified view of the internal software organization](image)

**Fig. 4. Simplified view of the internal software organization.**

The core of the system is the “cRunAnalyzer” class that, looping on all the data files of a specific run, performs event by event the pulse shape processing (using the proper “cDetector” instance according to the detector type) and stores results in the “cEvent” class. Thereafter, the results are used to fill the corresponding histogram or output ROOT-Tree as defined in the input definition files.

This analysis works in parallel over all the selected data runs but the results are summed, hence it is necessary to specify homogenous data sets at a time. These parallel processes access to the common output files or histograms sharing the ownership of a TMutex object which is the ROOT system independent implementation of a POSIX Mutex. The same is done by the Graphical User Interface that has real time access to the up-to-date histograms (useful for on-line monitoring). Fig. 5 shows a screenshot of the neutron_monitor user interface where 1D and 2D energy spectra related to the Si detectors are plotted.

![A screen-shot of the neutron_monitor GUI](image)

**Fig. 5. A screen-shot of the neutron_monitor GUI.**

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