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DEVELOPMENT OF A TRIGGER-GATE (GATENET) MODULE FOR PULSED NEUTRON EXPERIMENTS

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ABSTRACT

A readout (NEUNET) system employing high-speed network for using a linear position-sensitive ^{3}He gas detector (PSD) has been developed at KEK, and is widely used in experiments at the Materials and Life Science Experimental Facility (MLF) of Japan Proton Accelerator Research Complex (J-PARC). The NEUNET system consists of a new neutron encode- (NEUNET) module and a trigger-gate (GATENET) module.
The GATENET module controls delivering of a trigger signal (T0-signal) to all of the NEUNET modules to synchronize data acquisition timing of start and end. Each NEUNET module makes event data of a real-time at the same time. The GATENET module is essential for the NEUNET system. This paper reports on the details of the NEUNET system and the GATENET module.

1. Introduction

The past several years have witnessed a growth in the social concern associated with the analysis of many condensed matters and the development of advanced materials by using neutrons. The precision experiments involved in such analyses and development usually require large detector systems. In particular, instruments at Japan Proton Accelerator Research Complex (J-PARC) requires large detector systems that cover very large solid angles and have a high pixel resolution and many time-of-flight (TOF) channels. More than 1,000 linear position-sensitive ^{3}He gas detectors are normally used in each instrument, such as High Intensity Total diffractometer (BL21).

A readout (NEUNET) system for using a linear position-sensitive ^{3}He gas detector (PSD) has been developed at KEK, and is widely used in experiments at the Materials and Life Science Experimental Facility (MLF) of J-PARC. The NEUNET system consists of a neutron encode- (NEUNET) module and a trigger-gate (GATENET) module. The NEUNET module can process the data of PSDs having length in the range of 60 cm to 3 m. The GATENET module controls delivering of a trigger signal (T0-signal) to all of the NEUNET modules to synchronize data acquisition timing.

2. NEUNET system

2.1. NEUENT system

The NEUNET system consists of a GATENET module, many NEUNET modules, and a DAQ system. The NEUNET system combines the neutron measurement technology [1,2] developed at the KEK Neutron Science Laboratory (KENS) and the network technology (SiTCP) [3] developed at the KEK Institute of Particle and Nuclear Studies (IPNS). The NEUNET and GATENET modules comprise the SiTCP that lends a flexibility and scalability to the DAQ system. Fig. 1 shows a block diagram of the NEUNET system. The GATENET module distributes the T0-signal to all of the NEUNET modules to synchronize event data. A beam (KP)-ID and a real-time of the T0-signal are expressed by modulation of pulse width as showing in Fig. 2. The top of the T0-signal indicates the generation time (TOF=0) of the pulsed neutron. Each of the NEUNET modules stores them to its FIFO memory as event data. The DAQ system reads the FIFO memories, and stores them to files. Because each file is made for each NEUNET module, the KP-ID or the real-time is helpful to collect the files and to make histograms.

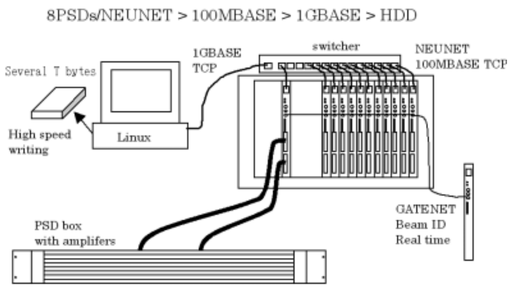

Fig. 1 Block diagram of NEUNET system.

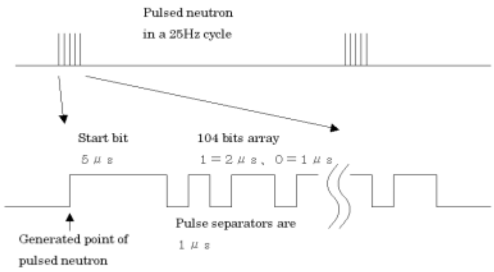

Fig. 2 T0-signal timing chart.

2.2. NEUENT module

Fig. 3 shows a picture of the NEUNET module. One NEUNET module that comprises one slot and whose height is double of that specified by Versa module Europe (VME) standards processes the data of eight PSDs. A 19″ VME rack can contain up to 20 NEUNET modules for 160 PSDs.

Four daughter boards on the right side of the module convert neutron signals into digital data. The main field programmable gate array (FPGA) on the left side controls all the parts of the module.

Fig. 4 shows a block diagram of the NEUNET module. When the PSD captures a neutron, the daughter board receives the signals of both sides (the left and the right) of the PSD, converting neutron signals into digital data by two ADCs. The FPGA on the board detects the peak of the signal to calculate the pulse height from the difference between the peak and the base-line. If the sum of the pulse heights of the left and right signals exceeds the threshold, the signals are stored as the captured neutron data. The pulse heights and a time stamp at the detected peak are sent to the main FPGA on the main board.

Fig.3 NEUNET module.

The main FPGA collects the data from the daughter boards, stores them as event data, and renews the histogram data, because the NEUNET module has the event mode and histogram mode, each of which works independently. The event data can be accessed through SiTCP, and the histogram data can be accessed through both SiTCP and the VME bus. The NEUNET module is compatible with the previous module [2] that has the histogram mode and VME bus.

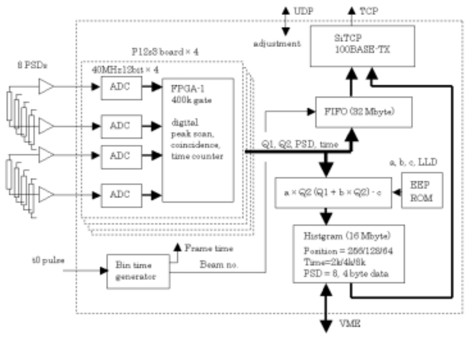

Fig.4 Block diagram of NEUNET module.

The SiTCP system transfers the data from the NEUNET module to the DAQ system by means of a high-speed network without a CPU. The network is of the 100BASE-TX standard, and it can transfer the data at almost the maximum speed (11 M-byte/s) by Transmission Control Protocol/Internet Protocol (TCP/IP). A standard PSD generates neutron data 30 K-cps (cycle per second) at the maximum. Because the NEUNET module transmits the data of eight PSDs, the maximum data rate is 8 × 30 K-cps × 8 bytes = 1.42 M-byte/s. Therefore, the NEUNET module has a fairly high network capacity.

Although SiTCP is of the 100BASE-TX standard, it is changed to the 1000BASE-T standard through a network switcher. The switcher collects many SiTCP cables of the NEUNET modules, merging them into one network cable for the control computer. The speed of individual SiTCPs is not very high; however, the network switcher changes them such that they form a high-speed network system. Furthermore, because a faster network (10G or 100G) is expected to be commonly used in the future, this system is easily able to shift to the high-speed system.

Although TCP/IP is only used for data transfer, User Datagram Protocol/Internet Protocol (UDP/IP) is used for setting module information. For example, the information such as the next data unit can be written/read.

1. The network is required to select the event/histogram mode before the data transfer. The network data path for these modes is changed by UDP/IP.

2. The position parameters used in the calculation in the histogram mode are stored to the erasable programmable read-only memory on the module.

Several limitations are set in the event mode to prevent storing unnecessary event data. The time- limitation is set for eliminating burst neutrons in the pulsed-neutron source. The threshold- limitation is set for eliminating noise. These limitations do not affect the histogram mode.

2.3. GATENET module

Fig. 5 shows a picture of the GATENET module that comprises one slot and whose height is double of that specified by VME standards. The main FPGA on the left side controls all the parts of the module.

Fig. 6 shows a block diagram of the GATENET module. The module has a trigger-gate function for the pulsed neutron, a wave pattern analysis function for a neutron beam intensity monitor, and an external clock function for recording a change of the experiment environment.

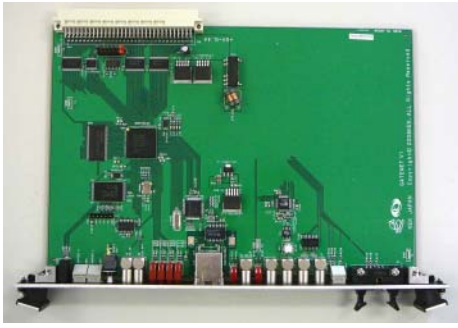

Fig.5 GATENET module.

The trigger-gate function controls the T0-signal of the pulsed neutron by two external gates and a software gate. The function produces the T0-signal which includes the KP-ID and the real-time to synchronize many NEUNET modules. Because the pulse neutron interval (25Hz) at MLF is long enough, the function can send the signal in a continuous pulse line. The NEUNET modules in line with the signal can know them at the same time. The real-time of the GATENET module is counted down from a precise clock.

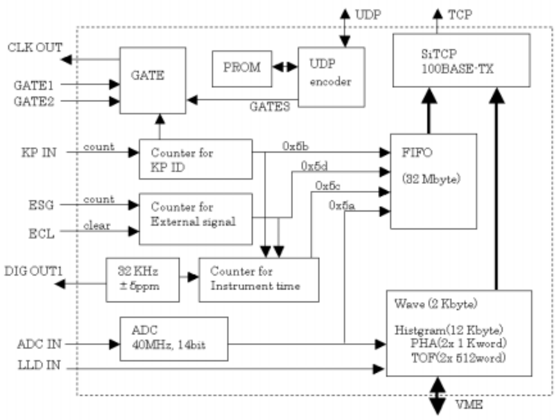

Fig.6 Block diagram of GATENET module.

The GATENET module produces the event data for a beam monitor signal from the LLD input in Fig. 6.

The function of wave-pattern has the data collection of the monitor to observe the neutron beam intensity. This function has analog and digital inputs and performs wave pattern and time analyses. The functions of wave-pattern and pulse-height analysis can be used for analyzing of the beam monitor from the ADC input in Fig. 6. The function of clock just records the time when the T0-signal inputs.

3. Event data

3.1. NEUENT module

Fig. 7 shows a command and the structures of some event data units during the transfer of an event data. Whenever the DAQ system sends the request command (64 bits) to a NEUNET module to collect the event data, the NEUNET module returns the event size (32 bits). If the module has event data, the event data of the size follows it. Although the module has a 32 M-byte FIFO memory, the event size that can be sent at a time is up to 32 K-bytes at this version.

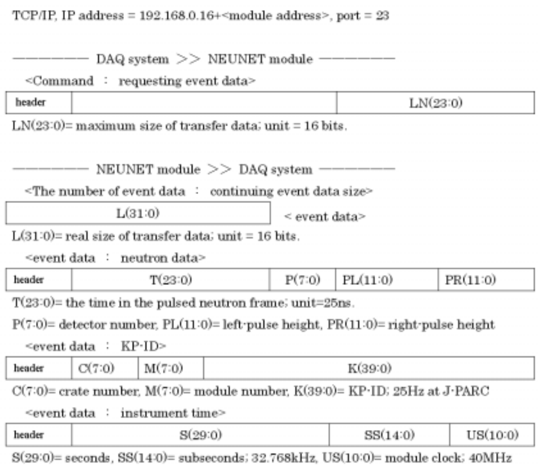

Fig.7 Example of a command and the structures of event data units during of transfer of event data.

There are several structures of the event data, and their length is standardized to 64 bits as a rule. A neutron data unit consists of the TOF time (24 bits), PSD number (8 bits), right-pulse height (12 bits), and left-pulse height (12 bits). A KP-ID event data unit consists of crate number (8 bits), module number (8bits), and the number of the pulsed-neutron frame (KP-ID: 40 bits). The KP-ID must synchronize to the 25 Hz neutron beam at J-PARC, and it can show the time up to the next 1,000 years in order to sort the neutron data. The event data of the instruments time, which is real-time data used for synchronizing all the NEUNET modules, consists of the seconds information (30 bits), the sub-seconds information (15 bits), and the module-clock (11 bits). It indicates the time since 1/1 2008 0:00. The instruments time event data must follow the KP-ID event data, and they are distributed by the GATENET module with the T0-signal.

The event data are handled by the large-scale DAQ system, whose software has been developed by the next generation DAQ group at the KEK IPNS. The control program works on Linux operating system in the event mode, and it employs robot technology. It is possible to obtain high-quality data because the event data can generate many types of different histogram data after the experiment.

3.2. GATENET module

The GATENET module also works event mode. Whenever the DAQ system sends the request command (64 bits) to the GATENET module to collect the event data, the GATENET module returns the event size (32 bits). If the module has event data, the event data of the size follows it. Although the module has a 32 M-byte FIFO memory, the event size that can be sent at a time is up to 32 K-bytes at this version.

There are several structures of the event data as Fig. 7. A neutron data unit consists of the TOF time (24 bits), PSD number (8 bits), lower pulse height (2 bits), and upper pulse height (12 bits). The KP-ID and the real-time event data are the same as the NEUNET module. They can be set to the initial data by UDP/IP.

4. Summary

The NEUNET system employing SiTCP for PSD has been developed at KEK, and is widely used in experiments at MLF of J-PARC. The NEUNET system consists of the NEUNET module, the GATENET module, and the DAQ system. The GATENET module controls delivering of the T0-signal to all of the NEUNET modules to synchronize data acquisition timing. The GATENET module is essential for the NEUNET system.

5. References

1. S. Satoh, S. Muto, N. Kaneko, T. Uchida, M. Tanaka, Y. Yasu, K. Nakayoshi, E. Inoue, H. Sendai, T. Nakatani, T. Otomo, Development of a readout system employing high-speed network for J-PARC, during a contribution to International Syposium on Pulsed Neutron and Muon Sciences (IPS 08), NIM A 600(2009)103-106.
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3. Tomohisa Uchida, "Hardware-Based TCP Processor for Gigabit Ethernet,", IEEE Transactions on Nuclear Science, 55, pp.1631-1637 2008.