Trigger System for BaF_2 Detector Array Readout Electronics at CSNS-WNS

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I. Introduction

White Neutron Source (WNS) is one of the experimental terminals deployed at China Spallation Neutron Source (CSNS). A segmented 4π detector array consisting of 92 BaF2 crystal segments is being constructed for neutron capture cross-section measurement at WNS. It is designed to detect the complete γ-ray cascade emitted in neutron capture reactions as well as measure the fight time of neutrons.

A 12-bit ADC with sampling rate up to 1 GSPS is used for the readout electronics, which results in huge amount of raw data. To decrease the data rate, a distributed trigger system based on PXI Express is well designed for the detector array.

II. Overview of The Trigger System

The raw data produced by the digitizer amounts to 15 MB per channel for each proton pulse. Thus the total data stream of 92 channels is up to 34.5 GB/s. However the valid data amount is no more than 54 MB/s. Allowing some margin to background noise, the raw data rate should be decreased to the level of 200 MB/s or less by the trigger system.

The whole readout electronics are housed in 4 PXIe chassis, making the trigger system a distributed architecture. The distribution network is as illustrated in Fig. 1. GTCM is the root of the trigger distribution network, where trigger signal is generated based on trigger information extracted from six sub-trigger modules (STMs). Once a trigger signal is generated, it is distributed from GTCM to LTCMs via equal length coaxial cables, and then to FDMs through dedicated differential star triggers.

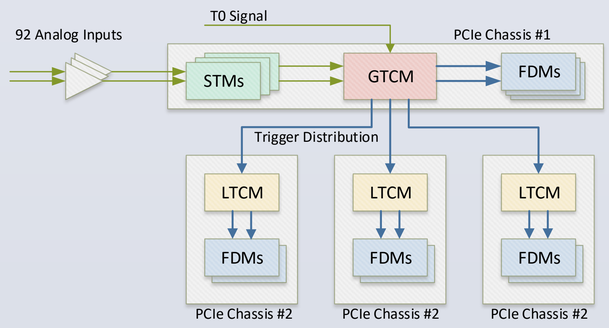


Fig. 1 Trigger distribution network based on PXIe chassis

Trigger information includes:
- E_{SUM}, integrated total energy
- N_{HIT}, cascade multiplicity

III. Trigger Information Extraction

The signal processing in STM is as shown in Fig. 2. Each analog input is transformed into two reverse signals using a fully differential amplifier. The positive signal will be connected to a comparator. And then the digitized comparing results of 16 channels will be fed into FPGA and uploaded to GTCM through differential star trigger on the backplane. The negative signal will be integrated and then added together. That results will be transmitted to GTCM via a coaxial cable.

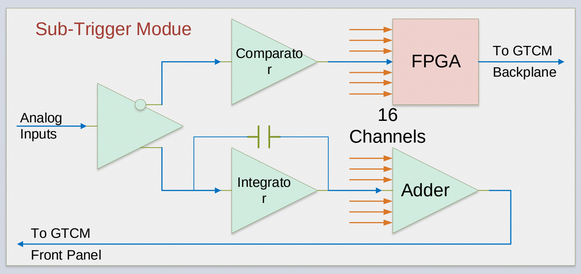


Fig. 2 Block diagram of STM

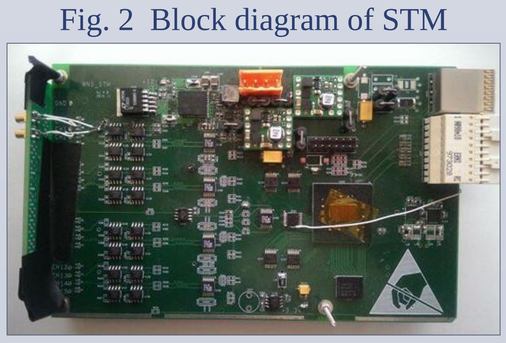
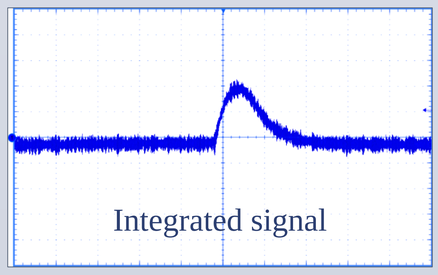
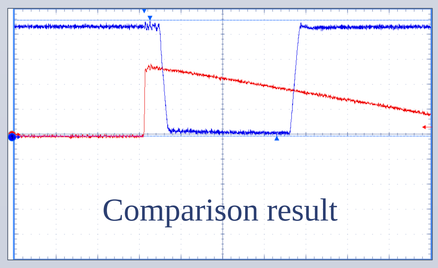


Fig. 3 Photography of STM





IV. Trigger Generation and Distribution

When GTCM receives the T0 signal from accelerator, it opens a time window with 10 millisecond width, within which signal from detector array is considered as valid. Once the total energy exceeds a set threshold, a pre-trigger pulse will be generated and distributed to all STMs, which starts the transmission of the digitized comparing result of each STM. If the number of channels over the threshold also meets the needs of the cascade multiplicity, a global trigger signal will be generated.

Trigger signal will be first distributed from GTCM to LTCMs via equal length cables. Thereafter the trigger signal will be fanned out to all FDMs by LTCM through dedicated differential star triggers on the backplane. Once FDM receives a trigger signal, the corresponding digitized data will be packed and uploaded to the controller.

Fig. 4 Photography of GTCM

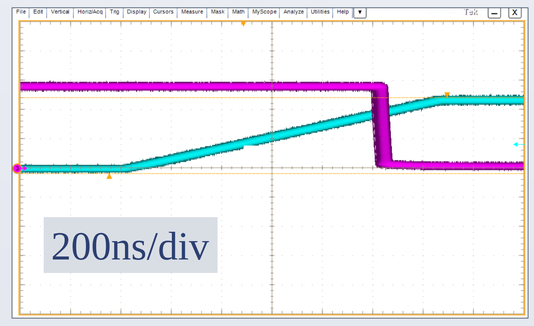


Fig. 5 Time walk of trigger generation

The time walk of the generated trigger signal is as large as 50 ns because of the slow rising time of the integrated energy. Further improvement will be made to solve the problem.

V. Fully Trigger System

Benefit from high-speed digitization of detector signals, a fully digital trigger system is also available. Trigger algorithm in STM can be fulfilled in FDM using digital signal processing. Fig. 3 shows the digital data flow of the digital trigger system. Once γ-ray pulse is detected, the trigger information will be extracted and uploaded to LTCM. The trigger information is a serial data which includes the time over threshold and the total energy of the pulse. Trigger information obtained from 92 channels will eventually be aggregated to GTCM. If the cascade multiplicity and the total energy meet the requirements of trigger algorithm, a trigger signal that includes hit time and trigger number will be generated and distributed.

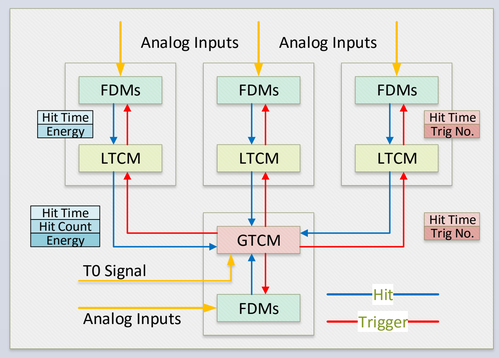


Fig. 6 Fully digital trigger system

Hit time is the time over threshold
Identify signals from different channel

Digitization of all FDMs are synchronized

Once implemented, hardware structure of the trigger system can be greatly simplified. Further research will be made on this.

VI. Conclusion

Taking advantages of the dedicated resources on PXIe backplane, the structure of trigger distributing is much more compact. Moreover, benefit from waveform digitization, a fully digital trigger system is also available. In addition to further simplifying the structure, digital trigger system is much more flexible for applying variable algorithms.

Since the whole system is not finished till now, further test will be performed to fully evaluate the trigger system.