Trigger System for BaF$_2$ Detector Array
Readout Electronics at CSNS-WNS

Trigger system based on PXIe

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Introduction

White Neutron Source (WNS) is one of the experimental terminals deployed at China Fusion Innovation Source (CSNS). A sequential 10 detector array consisting of 32 BaF$_2$ crystal segments is being constructed for neutron capture cross-section measurement at WNS. It is designed to detect the complete y-ray cascade emitted in neutron capture events as well as measure the flight time of neutron.

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

Overview of the Trigger System

The raw data produced by the detector arrays is 15 MHz per channel for each trigger pulse. Then the total data stream of 32 channels is up to 480 Gbps. However the valid data amount is no more than 34 MHz. Allowing some range to background noise, the raw data rate should be decreased to the level of 200 MHz or lower by the trigger system.

The whole readout electronics are housed in 4 PMU chassis, making the trigger system a distributed architecture. The distribution network is as illustrated in Fig. 1. GTMC is the root of the trigger distribution network, where trigger signal is generated based on trigger information extracted from each sub-module. Once a trigger signal is generated, it is distributed from GTMC to LMCM via optical length coaxial cables, and then to FDMs through distributed differential star triggers.

Trigger Information Extraction

The signal processing in FDM is as shown in Fig. 2. Each analog input is transferred into two synchronized signals using a 12-bit digital amplifiers. The positive signal will be connected to a comparator. And then the digital comparing result of 16 channels will be fed into FDMs, and uploaded to GTMC through differential star trigger on the backplane. The negative signal will be integrated and then added together. The results will be transmitted to GTMC via a coaxial cable.

Fully Digital Trigger System

When GTMC receives the TR signal from accelerator, it opens a time window with 50 milliseconds width, within which signal from detector array is considered as valid. Once the total charge exceeds a set threshold, a pre-trigger pulse will be generated and distributed to all SMMs, which starts the transmission of the digital comparing result of each SMM. 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 GTMC to LMCMs via optical length cables. Then the trigger signal will be further sent to all FDMs by LMCM 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.

Conclusion

Benefits from high-speed digitization of detector signals, a fully digital trigger system is also available. Trigger algorithm in SMM can be fulfilled at FDM using digital signal processing. Fig. 3 shows the digital data flow of the digital trigger system. Once raw pulse is detected, the trigger information will be extracted and uploaded to GTMC. The trigger information is a serial data which includes the time over threshold and the total energy of the pulse. Trigger information obtained from 32 channels will eventually be aggregated to GTMC. If the cascade multiplicity and more energy must be requirements of trigger algorithm, a trigger signal that includes hit time and trigger number will be generated and distributed.

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

Takings advantages of the dedicated resource on FPGA backplane, the structure of trigger distribution is much more compact. Moreover, benefits 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 suitable algorithms.

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