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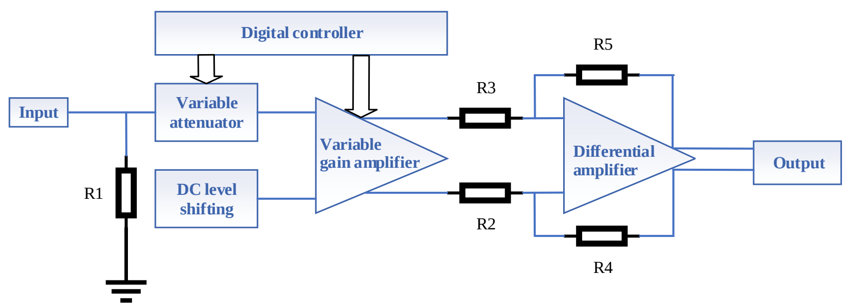

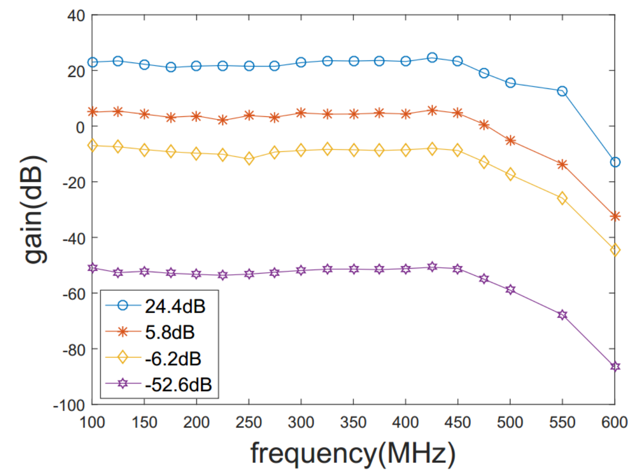

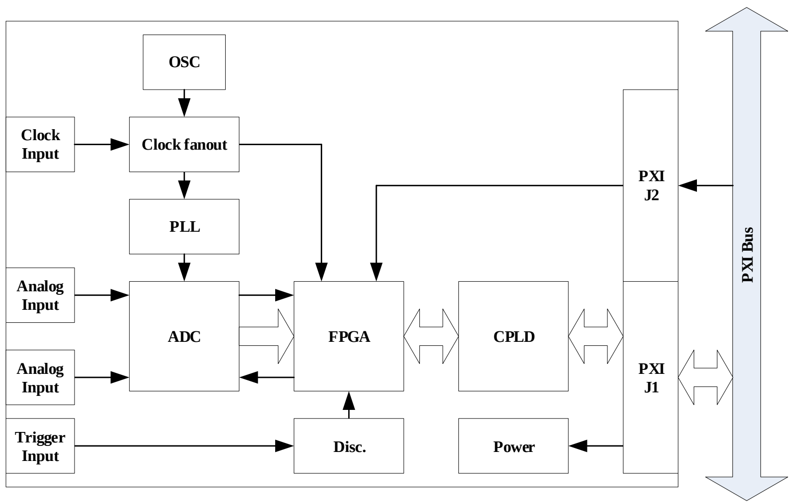

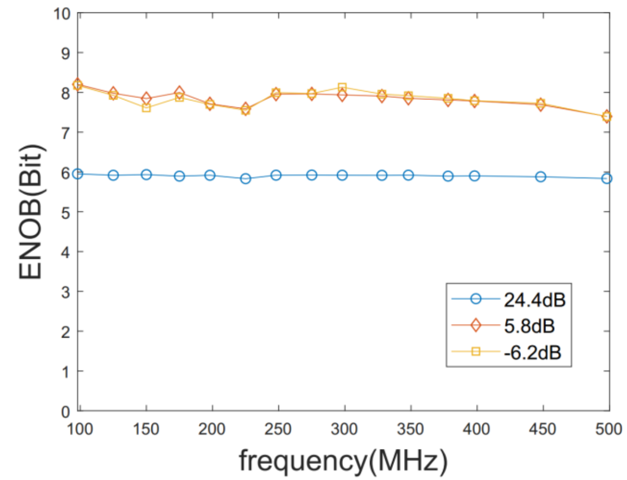

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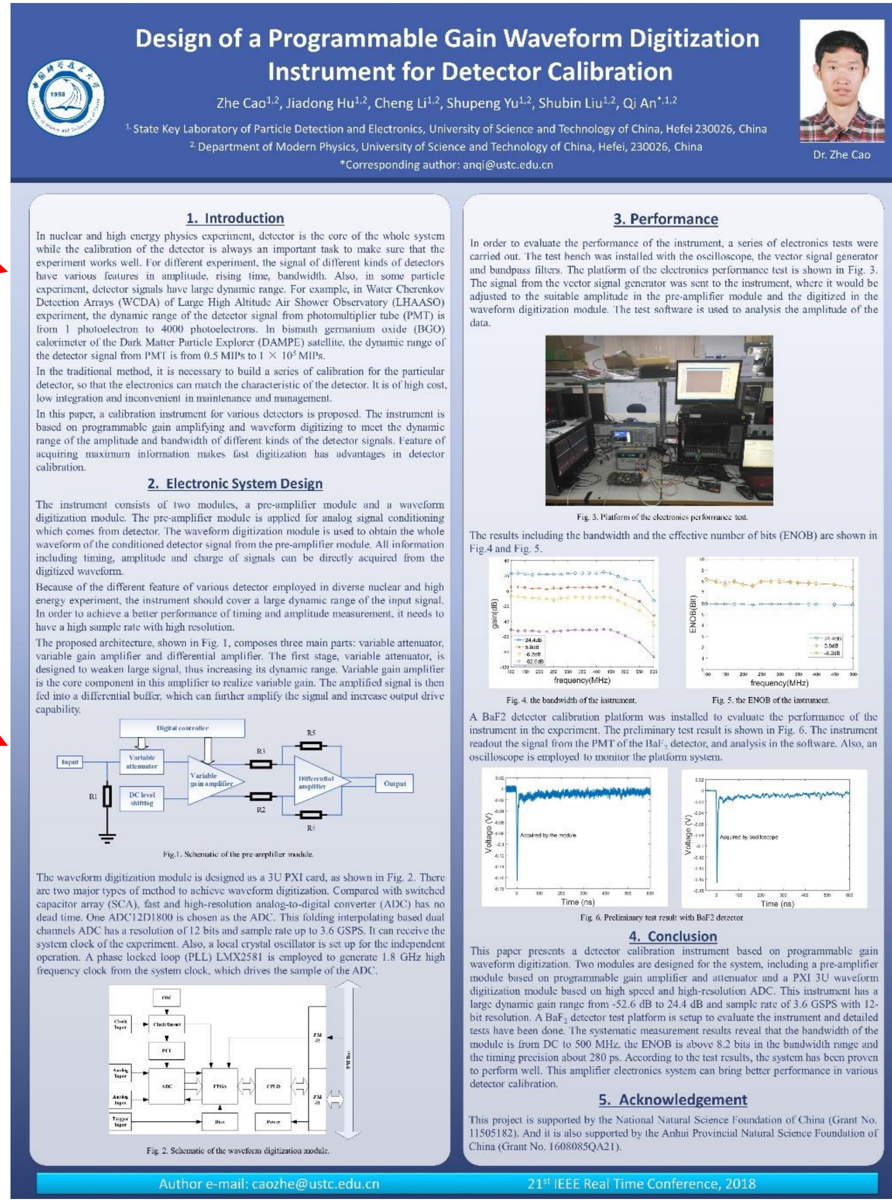

Design of a Programmable Gain Waveform Digitization Instrument for Detector Calibration

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1. Introduction

In nuclear and high energy physics experiment, detector is the core of the whole system while the calibration of the detector is always an important task to make sure that the experiment works well. For different experiment, the signal of different kinds of detectors have various features in amplitude, rising time, bandwidth. Also, in some particle experiment, detector signals have large dynamic range. For example, in Water Cherenkov Detection Arrays (WCDA) of Large High Altitude Air Shower Observatory (LHAASO) experiment, the dynamic range of the detector signal from photomultiplier tube (PMT) is from 1 photoelectron to 4000 photoelectrons. In bismuth germanium oxide (BGO) calorimeter of the Dark Matter Particle Explorer (DAMPE) satellite, the dynamic range of the detector signal from PMT is from 0.5 MIPs to 1×10^5 MIPs.

In the traditional method, it is necessary to build a series of calibration for the particular detector, so that the electronics can match the characteristic of the detector. It is of high cost, low integration and inconvenient in maintenance and management.

In this paper, a calibration instrument for various detectors is proposed. The instrument is based on programmable gain amplifying and waveform digitizing to meet the dynamic range of the amplitude and bandwidth of different kinds of the detector signals. Feature of acquiring maximum information makes fast digitization has advantages in detector calibration.

2. Electronic System Design

The instrument consists of two modules, a pre-amplifier module and a waveform digitization module. The pre-amplifier module is applied for analog signal conditioning which comes from detector. The waveform digitization module is used to obtain the whole waveform of the conditioned detector signal from the pre-amplifier module. All information including timing, amplitude and charge of signals can be directly acquired from the digitized waveform.

Because of the different feature of various detector employed in diverse nuclear and high energy experiment, the instrument should cover a large dynamic range of the input signal. In order to achieve a better performance of timing and amplitude measurement, it needs to have a high sample rate with high resolution.

The proposed architecture, shown in Fig. 1, composes three main parts: variable attenuator, variable gain amplifier and differential amplifier. The first stage, variable attenuator, is designed to weaken large signal, thus increasing its dynamic range. Variable gain amplifier is the core component in this amplifier to realize variable gain. The amplified signal is then fed into a differential buffer, which can further amplify the signal and increase output drive capability.

Fig.1. Schematic of the pre-amplifier module.

The waveform digitization module is designed as a 3U PXI card, as shown in Fig. 2. There are two major types of method to achieve waveform digitization. Compared with switched capacitor array (SCA), fast and high-resolution analog-to-digital converter (ADC) has no dead time. One ADC12D1800 is chosen as the ADC. This folding interpolating based dual channels ADC has a resolution of 12 bits and sample rate up to 3.6 GSPS. It can receive the system clock of the experiment. Also, a local crystal oscillator is set up for the independent operation. A phase locked loop (PLL) LMX2581 is employed to generate 1.8 GHz high frequency clock from the system clock, which drives the sample of the ADC.

Fig. 2. Schematic of the waveform digitization module.

3. Performance

In order to evaluate the performance of the instrument, a series of electronics tests were carried out. The test bench was installed with the oscilloscope, the vector signal generator and bandpass filters. The platform of the electronics performance test is shown in Fig. 3. The signal from the vector signal generator was sent to the instrument, where it would be adjusted to the suitable amplitude in the pre-amplifier module and the digitized in the waveform digitization module. The test software is used to analysis the amplitude of the data.

Fig. 3. Platform of the electronics performance test.

The results including the bandwidth and the effective number of bits (ENOB) are shown in Fig.4 and Fig. 5.

Fig. 4. the bandwidth of the instrument.

Fig. 5. the ENOB of the instrument.

A BaF2 detector calibration platform was installed to evaluate the performance of the instrument in the experiment. The preliminary test result is shown in Fig. 6. The instrument readout the signal from the PMT of the BaF_2 detector, and analysis in the software. Also, an oscilloscope is employed to monitor the platform system.

Fig. 6. Preliminary test result with BaF2 detector.

4. Conclusion

This paper presents a detector calibration instrument based on programmable gain waveform digitization. Two modules are designed for the system, including a pre-amplifier module based on programmable gain amplifier and attenuator and a PXI 3U waveform digitization module based on high speed and high-resolution ADC. This instrument has a large dynamic gain range from -52.6 dB to 24.4 dB and sample rate of 3.6 GSPS with 12-bit resolution. A BaF_2 detector test platform is setup to evaluate the instrument and detailed tests have been done. The systematic measurement results reveal that the bandwidth of the module is from DC to 500 MHz, the ENOB is above 8.2 bits in the bandwidth range and the timing precision about 280 ps. According to the test results, the system has been proven to perform well. This amplifier electronics system can bring better performance in various detector calibration.

5. Acknowledgement

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