# A Low Noise Readout System for Diamond Microstrip Detectors

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**Abstract.** Diamond is widely adopted in physics experiments owing to its good radiation hardness. In this paper, a low noise electronics system based on charge sensitive amplifier (CSA) is designed to read out diamond microstrip detectors. Up to 40 channels are implemented in the system, each containing a CSA, a $CR-RC^2$ shaper, an analog to digital convertor (ADC) and a discriminator used for trigger generation. After calibration and joint test with prototype detector with a size of 4×4×0.5 $mm^3$, a noise level of less than 845 electrons is realized in all 40 channels. Furthermore, the result with $^{90}Sr$ radiation source is consistent with the theory, and a position resolution of 13 um is obtained in laser test which indicates the readout system meets the demand of the future experiment.

## 1. Introduction

Diamond detectors are widely adopted in physics experiments [1–4] owing to its good radiation hardness, fast pulse response and short waveform edges, etc. In the pre-research of Circular Electron Positron Collider (CEPC) beam energy calibration, a measurement method based on Compton Backscatter is proposed, in which a diamond microstrip detector with high position resolution is employed to measure the angle information of the scattered gammas [5,6]. However, due to the larger band gap and lower atomic number of diamond, the amount of generated charges is much smaller compared with other traditional semiconductor detectors. Therefore, to achieve enough signal-to-noise ratio (SNR) in diamond detector system, its readout electronics needs to realize an ultra-low noise performance.

To realize high precision charge measurement, in this work, a low noise electronics system based on charge sensitive amplifier (CSA) containing up to 40 channels is designed to read out a prototype detector (B10204) from Cividec Instrumentation. The prototype microstrip detector is based on single-crystal Chemical Vapor Deposition (sCVD) diamond and has a sensitive area of 4×4×0.5 $mm^3$ with both 50 um strip width and strip spacing, as shown in Figure 1.The energy of minimum ionizing particles (MIPs) deposited in a diamond of this size is about 300 keV, and hence the charge generated by MIPs is about 3.6 fC. In order to achieve high-precision position resolution with small input sinals, higher requirements are put forward for the noise performance of the CSA-based electronics.

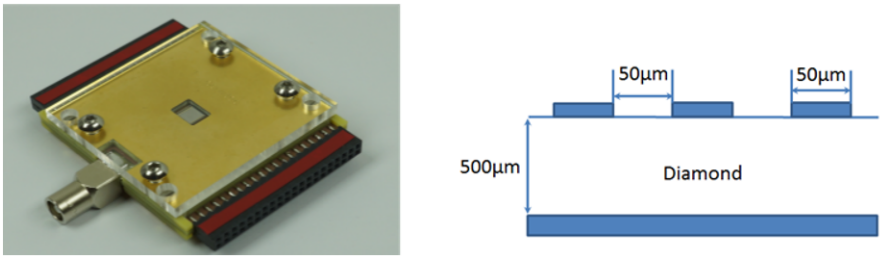


Figure 1: The picture and dimensions of the prototype diamond microstrip detector.

## 2. Design and implementation of the readout electronics

The main purpose of this work is to reduce the noise of the readout electronics. In order to reduce the transmission distance from detector to CSA and ensure the flexibility of the readout system, the prototype electronics is composed of two front end boards (FEBs), which are connected to the detector nearby, and two back end boards (BEBs) which are placed away from the detector. The block diagram of the FEB and BEB is shown is Figure 2. Each FEB integrates 20 channels of CSAs and CR-RC shapers. The input stage of each CSA employs one junction field effective transistor (JFET,2SK715W) to reduce leakage current and match the capacitance of the microstrip, which can get a lower noise level [7, 8]. The shaping time of the filter is 100ns. The pre-shaped signal is transmitted to BEB for post process. Each BEB mainly completes 20-channel analog-to-digital conversion and trigger generation. The first receiving stage of BEB is set as the second RC filter as well as an inverting amplifier. The processed analog signal is sent to an Analog-to-Digital Convertor (ADC) channel for waveform acquisition and one discriminator (AD8561) for trigger generation, respectively. Considering the integration and sampling requirements, five 4-channel ADC chips (LTC2175) with a sampling rate up to 125 MSPS are equipped on one BEB. Two BEBs of the prototype electronics work in master-slave mode. The synchronized clock, trigger, uploaded data, etc. between the master and slave BEBs are transmitted through a custom protocol based on HDMI hardware. The communication between master BEB and upper computer is completed via Ethernet. The pictures of FEB and BEB are shown in Figure 3.

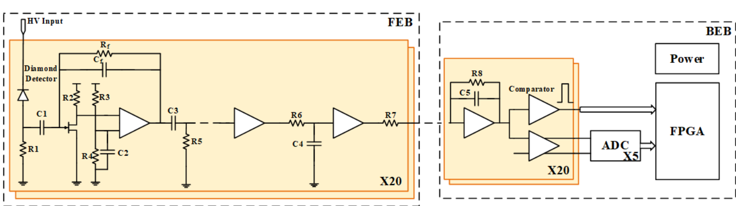


Figure 2: The block diagram of the FEB and BEB.

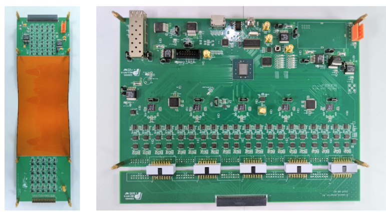

Figure 3: The pictures of FEB and BEB.

## 3. Performance of the readout electronics

After the implementation of two FEBs and BEBs, some experiments are carried out to verify the performance of the readout system. First of all, in calibration test, different input charges are generated by voltage pulses with different amplitudes passing through a 1pF capacitor. Figure 4 shows one typical fitting result of the output waveform amplitude in ADC code and the input charge. The calibration results of all 40 channels are displayed in Figure 5.

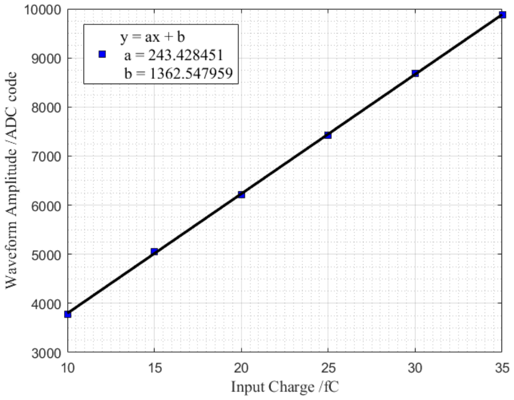


Figure 4: One typical fitting result of calibration.

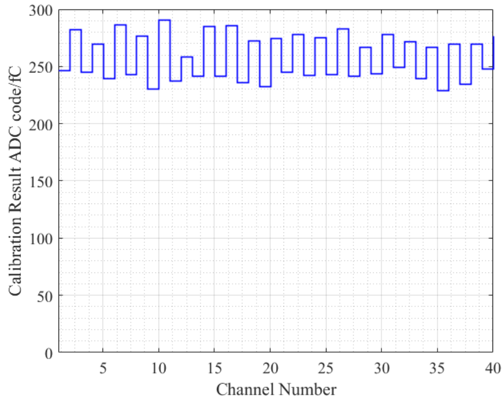


Figure 5: Calibration results of all 40 channels.

The input equivalent noise charges (ENCs) of the electronics system, with diamond microstrip working at a high voltage of 250 V, are shown in Figure 6. The max ENC among all 40 channels is less than 0.134 fC which is much samller than the deposited charge of MIPs. Radioactive source test using $^{90}Sr$ is conducted to verify the MIPs measurement capability of the detection system. One typical spectrum among 40 channels is shown in Figure 7, which conforms to the characteristics of Landau Distribution. The most probable charge is 1.8 fC about half of the theoretical value, which indicates the beta rays are incident obliquely and the charges generated by ionization are collected by multiple strips.

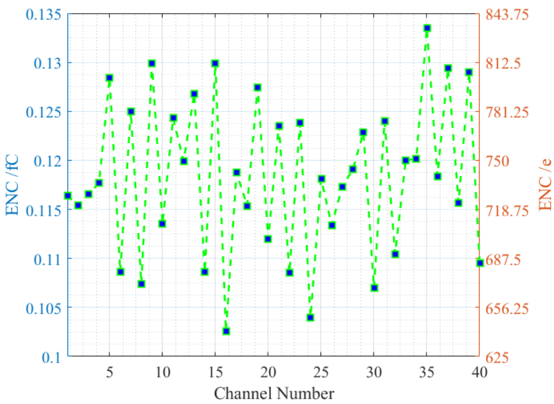


Figure 6: The ENCs of all 40 channels of the system.

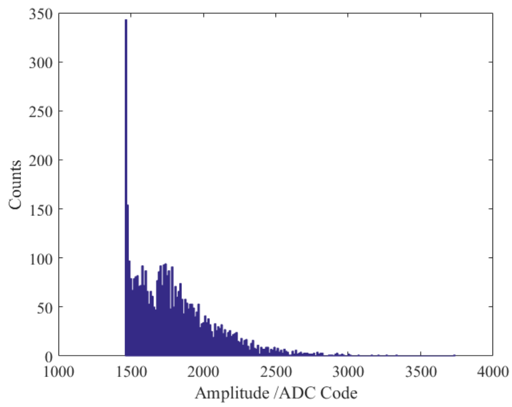


Figure 7: Typical spectrum of $^{90}Sr$ radioactive source at one microstrip.

Ultraviolet laser is adopted to test the position resolution of the detection system. As shown in Figure 8, the laser generates continuous 220 nm, 20 Hz laser pulses, which are reflected by the optical path and incident perpendicularly to the collimator, and then the collimated photons are detected by the diamond microstrip. The collimator is made of stainless steel with a diameter of 50 mm and a thickness of 2.5 mm, and there is a collimating hole with a diameter of 10 um in the center. The collimator is placed on a high-precision linear moving platform, whose cumulative error of movement is less than 15 um/50 mm. Move the collimating hole several times with a specific step, and by measuring the step multiple times, the position resolution of the diamond microstrip system can be obtained. The test result is shown in Figure 9. The most probable value for the measurement of 1 mm step is 0.9827 mm and the standard deviation is 18 um, which indicates the position resolution satisfies the requirements.

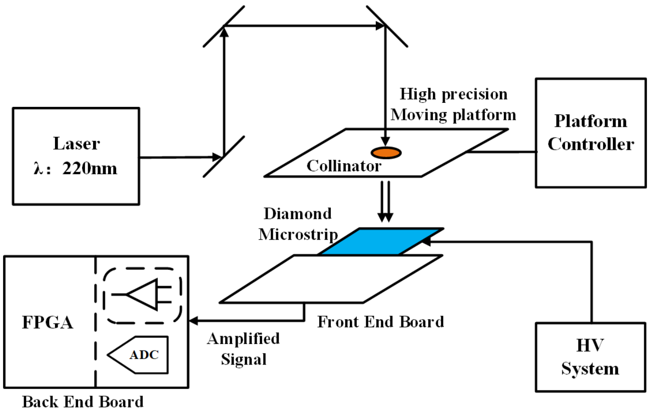


Figure 8: The block diagram of the laser test.

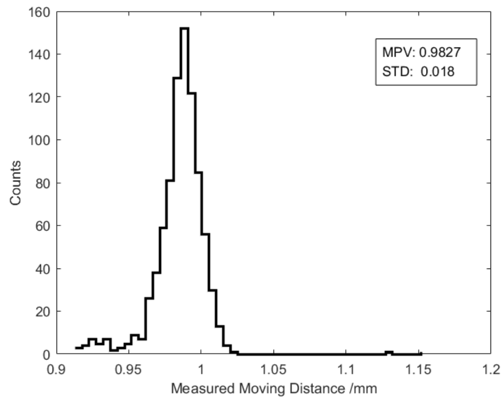


Figure 9: Measured result of the moving step of 1mm.

## 4. Conclusion

In this report, a CSA-based readout system for diamond microstrip detectors is designed and verified. The maximum equivalent input noise of 0.134 fC is achieved in 40 channels. The test result of the radioactive source conforms to the MIP characteristic, which indicates the readout system works well. The position resolution test with ultraviolet laser shows that the diamond microstrip system can achieve resolution of 13 um which meets the demand of future experiment.

## 5. Acknowledgements

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