A Low Noise Readout System for Diamond Microstrip Detectors

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1. Introduction

Diamond is widely adopted in physics experiments as a radiation detector owing to its stable structure. Compared with traditional silicon semiconductor detectors, diamond has faster pulse response time and shorter waveform edges due to its advantages in dielectric constant and carrier mobility. However, because diamond has a larger band gap and a lower atomic number, in the interaction with charged particles, compared to traditional detectors such as silicon and germanium, the amount of signal charge generated by diamond is smaller. Therefore, in the diamond detector system, the readout electronics need to has a lower noise level to achieve a sufficient signal-to-noise ratio. In this report, a readout electronics system applied to the diamond microstrip irradiation detector based on charge sensitive amplifier (CSA) is designed and realized.

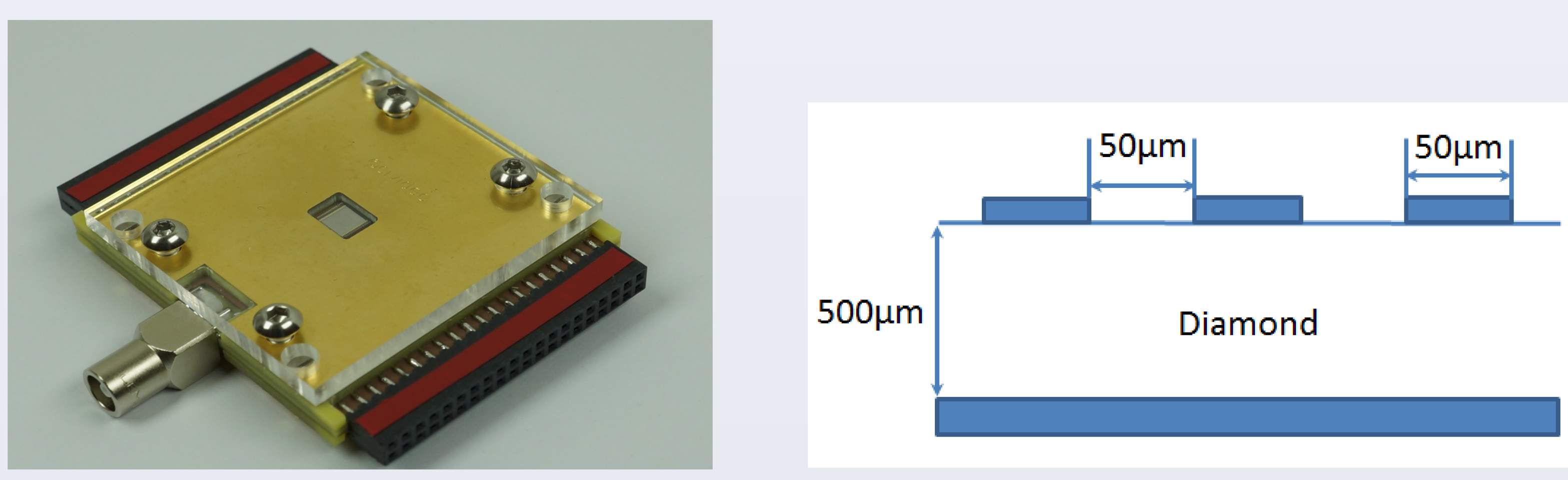

Figure-1. The image of the diamond micro-strip detector and the size of the micro-strip used in this report

The diamond detector used in this work is shown in Figure-1. Its strip width and strip spacing are both 50 microns, and the thickness of the sensitive layer is 500 microns. The deposition energy of minimum ionized particles (MIPs) passing through the detector is

$$\Delta E = \frac{dE}{dx} \cdot x = 332\ keV,$$

and the corresponding signal charge is

$$Q = \frac{\Delta E}{E_0} \cdot e \approx 4\ fC,$$

where E_0 is the ionizing energy of the electron-hole pair in diamond.

2. Design of the CSA-based readout electronics

As a highly sensitive measurement solution, CSA is widely used in charge measurement. The readout chain of the diamond microstrip detector in this report is shown in Figure-2. In order to reduce the transmission distance from the micro-strip to the CSA and ensure the flexibility of the system, the system consists of front end board (FEB) connected to the detector nearby and back end board (BEB) placed away from detector. Each FEB integrates 20 channel of CSAs and CR-RC shapers. The input stage of each CSA employs junction field effective transistor (JFET) to reduce leakage current, and the shaping time constant is 100 ns. The shaped signal is send to discriminator and ADC simultaneously for trigger generation and analog-to-digital conversion. The digital signal is pre-processed in FPGA and uploaded to the host computer via Ethernet. The block diagram and of the readout electronics is shown in Figure-3, and the physical pictures of FEB and BEB are shown in Figure-4.

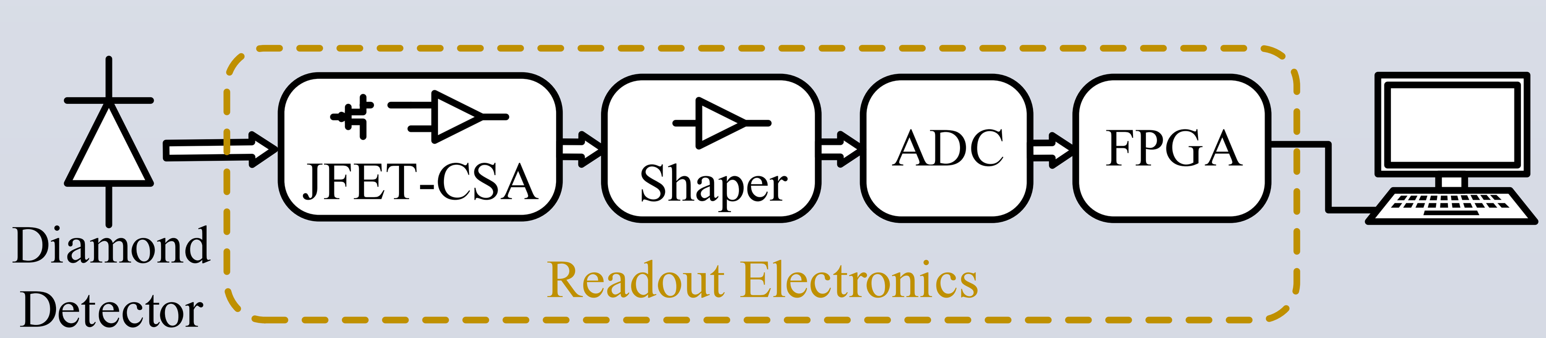

Figure-2. The readout chain of the diamond microstrip detector

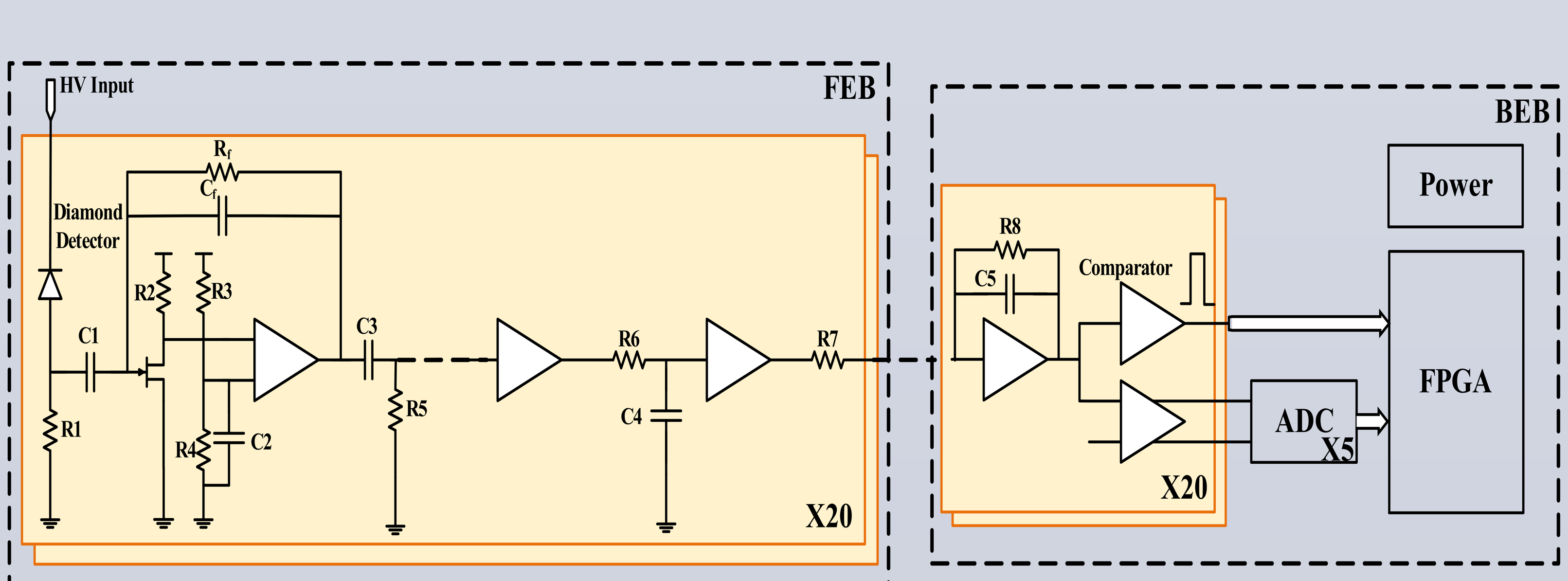

Figure-3. The block diagram and of the readout electronics

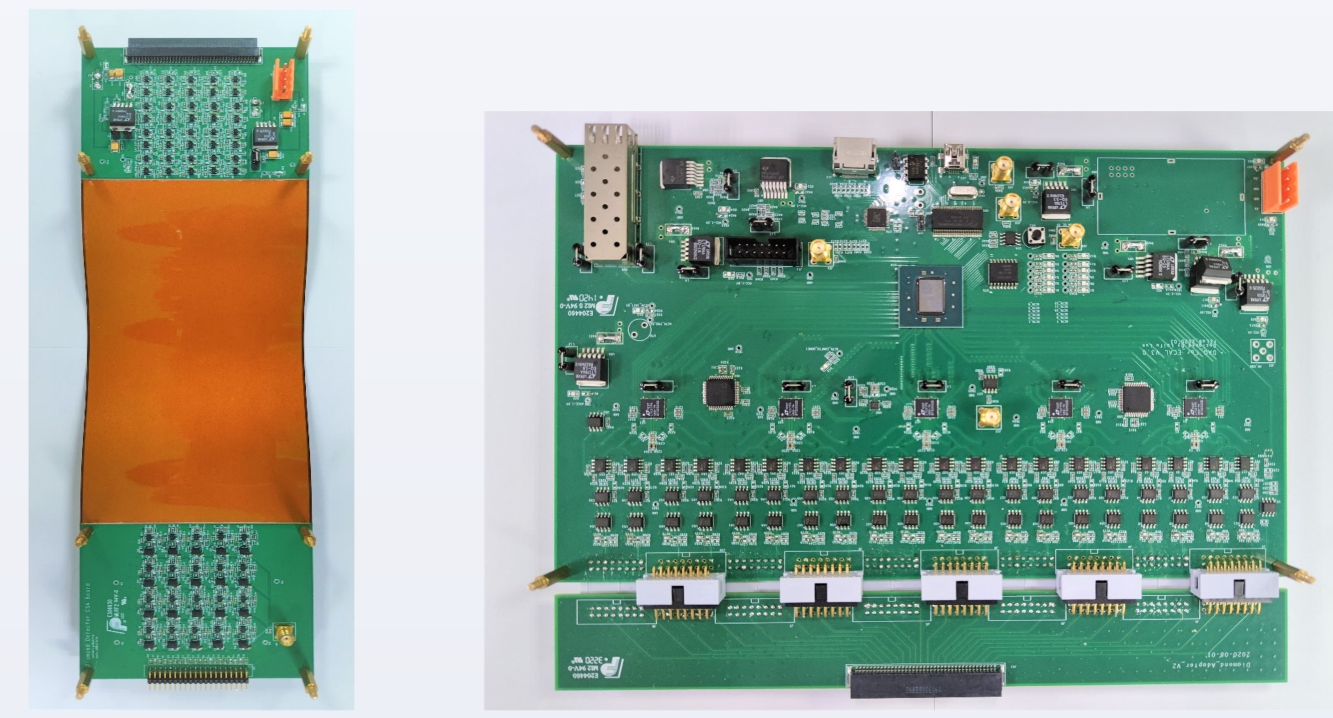

Figure-4. The physical pictures of FEB and BEB.

3. Performance and Results

The calibration and noise test results show that the system is working well. As shown in Figure-5, the nonlinearity of the charge to ADC code ratio is less than 5% among 20 channels, and the maximum equivalent input noise in the 20 channels is less than 0.104fC.

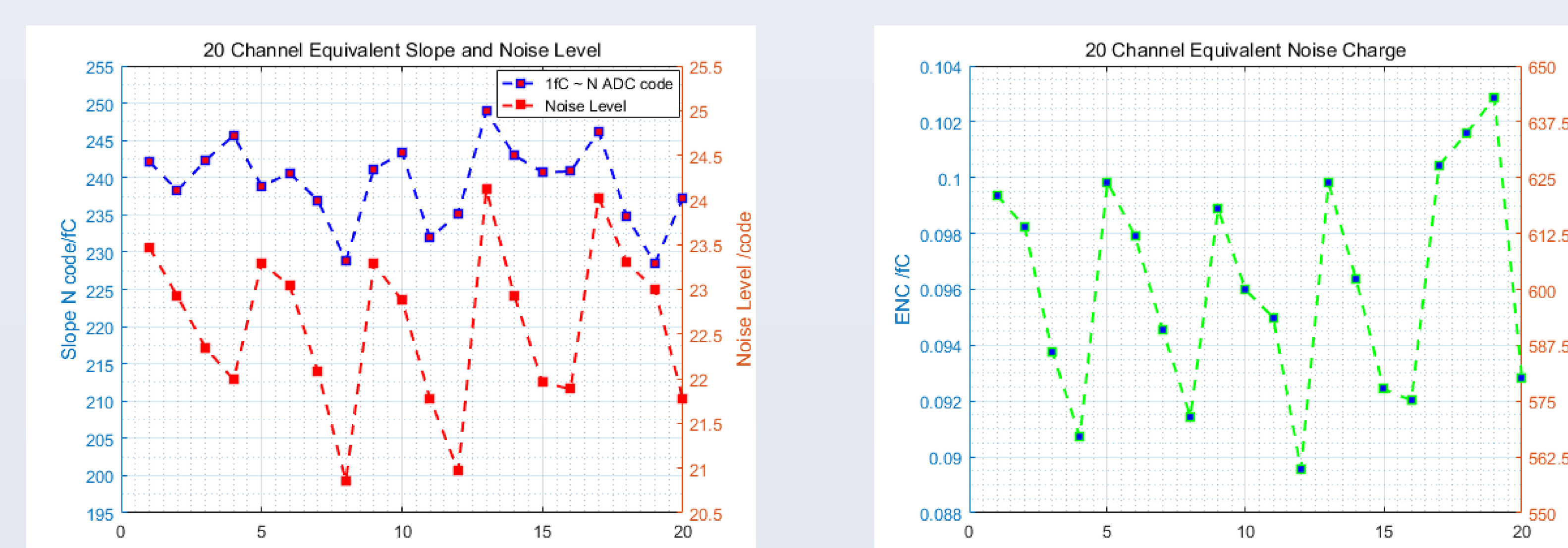

Figure-5. The calibration results and equivalent noise of 20 channels

Sr-90 has been used to verify the MIP measurement capability of the detection system. The photos of the test site and the energy spectra of the first twelve channels are shown in Figure 6. All energy spectra conform to the characteristics of Landau distribution. The statistical chart of the number of electron hits for 20 channels is shown in Figure 7. According to the characteristic that the number of hits in the electron hit spectrum increases toward the direction of the increase in the number of channels, it can be conducted that the emission center of the radioactive source deviates from the diamond detection area to the right.

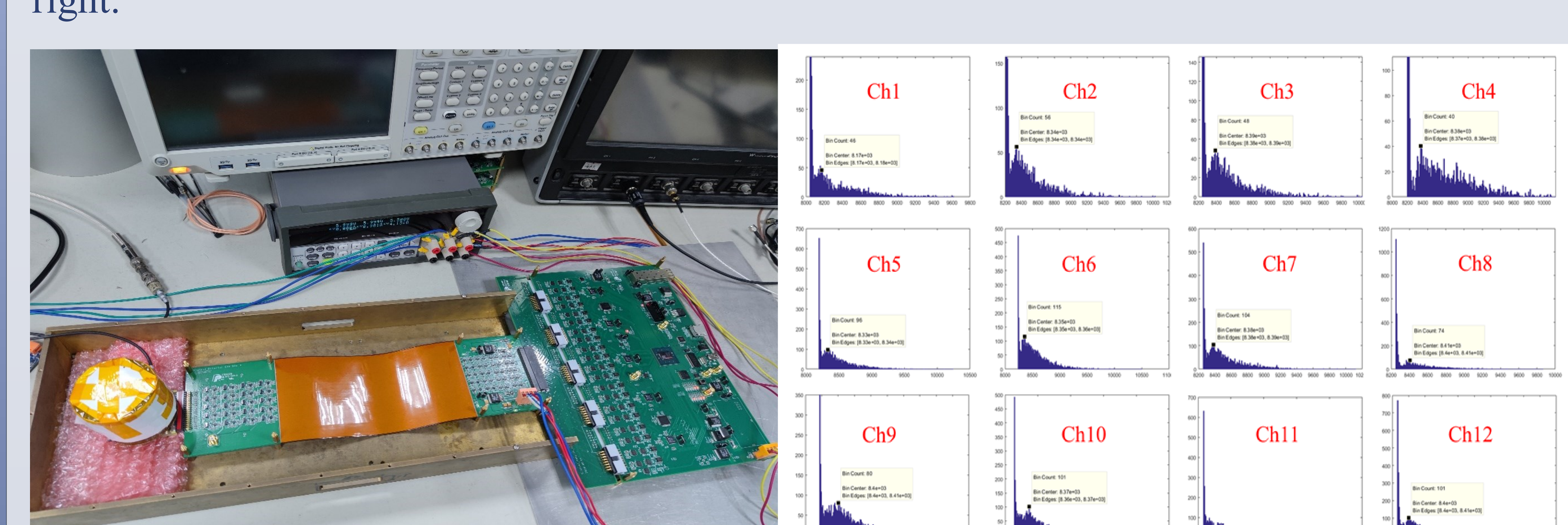

Figure-6. The photos of the test site and the energy spectra of the first twelve channels .

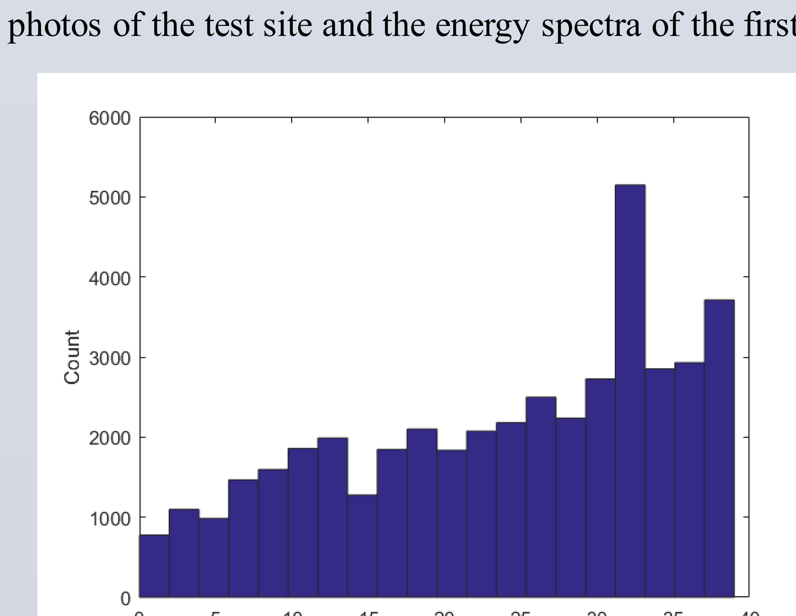

Figure-7. The histogram of the number of hit electron in 20 channels.

4. Conclusion

In this report, a CSA-based readout system for diamond microstrip detectors is designed and verified. The maximum equivalent input noise of 0.104fC is achieved in 20 channels. The test result of the radioactive source conforms to the MIP characteristics, and according to the number of electron hits on each strip, it can be concluded that the center of the radioactive source deviates from the right side of the detection area. Further experiment on position resolution can be carried out.

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