Noise Analysis of a Fabricated Charge Sensitive Amplifier for a Semiconductor Radiation Detector

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Introduction

All semiconductor radiation detector systems include the same basic functions. The signal from each sensor must be amplified and processed for storage and analysis. The signal charge can be quite small, about 50 aC for 1 keV X-ray. The magnitude of the sensor signal is subject to statistical fluctuations, and electronic noise [1, 2].

Since radiation detectors are typically used to measure charge, the system's noise level is conveniently expressed as an equivalent noise charge (ENC, Q_n), which is equal to the detector signal that yields a signal-to-noise ratio of one. The ENC is commonly expressed in Coulombs, the corresponding number of electrons, or the equivalent deposited energy(eV) [1, 2].

A charge sensitive amplifier (CSA) was designed and fabricated for a semiconductor radiation detector. An equivalent circuit was composed for an ENC measurement. In this study, The feasibility of a fabricated CSA for a semiconductor radiation detector was discussed by analysis of a measured ENC. The performance of a fabricated CSA was also addressed by using a fabricated PIN-type Si semiconductor radiation detector.

Materials and Methods

A circuit diagram of an equivalent circuit for an ENC measurement is shown in figure 1. An ORTEC Model 448 research pulser, a 572 amplifier, and a spectrum master MCA were used to an ENC measurements. 2 mV, 4 mV, and from a pulser were fed to CSA via 1 pF calibration capacitor. To match impedence between an CSA and pulser, 47 Ω resistor was connected. Shaping time was also varied from 0.5 μs to 10 μs.

5.5 MeV alpha particle was also measured with a fabricated CSA by using a PIN Si semiconductor radiation detector in air with respect to detector bias. A fabricated PIN Si semiconductor radiation detector had 1.1% energy resolution at 5.5 MeV alpha particle in a vacuum at previous experiments

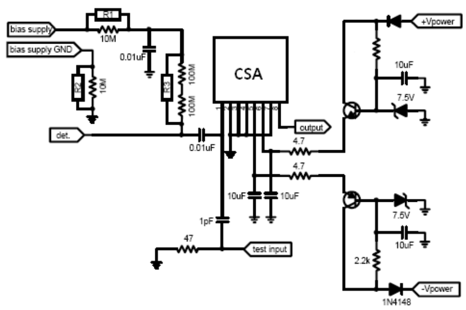

Fig. 1. An equivalent circuit for an ENC measurement.

Results and Discussion

To measure the system noise except a CSA, a pulser was directly connected to a shaper. The energy spectra in case of pulser-Shaper connection and a fabricated pulser-CSA-Shaper connection were shown in figure 2 and 3. ENC can be calculated by using two peak channel and their FWHM. The equations are as follow. The measured average ENC of a fabricated CSA was about 2500.

$$Avg.V/Ch. = \frac{1}{2} \times \frac{(FWHM@H.V. + FWHM@L.V) \times (H.V - L.V)}{(Peakchannel@H.V - Peakchannel@L.V)} \quad (1)$$

$$ENC(FWHM) = \frac{C_c \times (Avg.V/Ch.)}{q} = \frac{Q_N}{1.602 \times 10^{-19}} \quad (2)$$

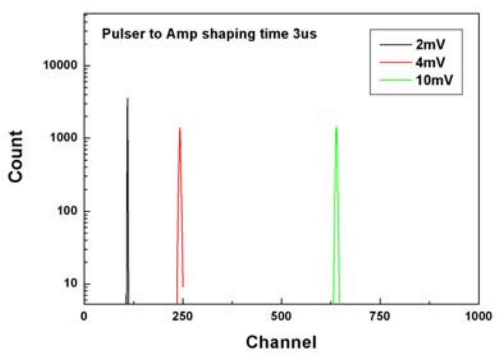

Fig. 2. The energy spectra in case of pulser-shaper connection to measure the system noise except a CSA.

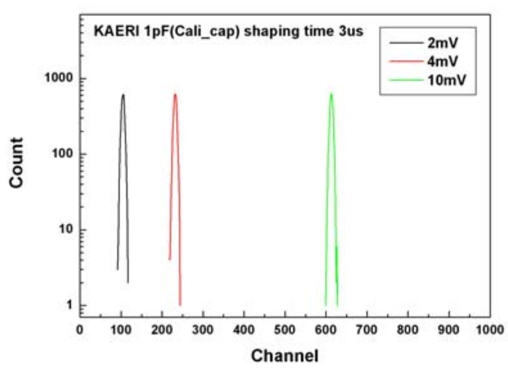

Fig. 3. The energy spectra in case of pulser-CSA- shaper connection.

The energy spectrum for 5.5 MeV alpha particles from ^{241}Am measured with a pulser in air are shown in figure 4.

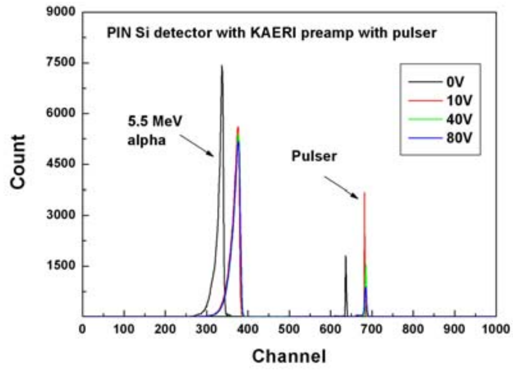

Fig. 4. The energy spectrum for 5.5 MeV alpha particles with a pulser in air..

Conclusion

A CSA was designed and fabricated for a semiconductor radiation detector. An ENC was measured by composing an equivalent circuit. 5.5 MeV alpha spectra were also measure with respect to detector biasing voltage. A fabricated CSA can be used for a semiconductor radiation detector from the ENC and alpha spectra results.

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Reference

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