Transactions of the Korean Nuclear Society Autumn Meeting
Changwon, Korea, October 20-21, 2022

Development of Charge Sensitive Amplifier and Pulse Shaper for Mössbauer Spectrometer Equipped with Si-PIN Diodes

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1. Introduction

Mössbauer spectrometers can measure any sample containing iron (^{57}Fe) with ^{57}Co sources emitting γ-rays of 14.4 keV. Most commercial Mössbauer spectrometers use scintillation detectors or proportional counters due to their count rates and high signal-to-noise ratio. A portable Mössbauer spectrometer can be applied to *in situ* extraterrestrial and terrestrial measurements [1]. For these applications, spectrometers should be lightened and downsized. Semiconductor detectors like Si-PIN and CdTe are proper because of their small size and high efficiency in counting low-energy γ-rays. This research aims to design charge sensitive amplifier (CSA) and pulse shaper for Si-PIN diodes and to measure low-energy γ-rays.

2. Materials and Methods

2.1. Circuit Simulation

To design the most proper CSA and pulse shaper circuits, the TINA-TI simulator freely offered by Texas Instruments was used to test circuits. This program includes basic electronic elements and real device models sold in Texas Instrument.

2.2. Charge Sensitive Amplifier

A charge sensitive amplifier is proper for photodiode detectors because the input capacitance is variable with temperature, bias voltage, etc. The output voltage V_{CSA} equals to

$$V_{CSA} = -\frac{Q}{C_f} \tag{1}$$

where Q is the charge generated by an incident radiation and C_f is the feedback capacitance [2]. The decay time constant τ is equal to $R_f C_f$, where R_f is the feedback resistance. In this study, the R_f was 250 MΩ and C_f was 200 fF, which yielded time constant of 500 μs^{-1}. Fig. 1. shows the circuit diagram of the CSA.

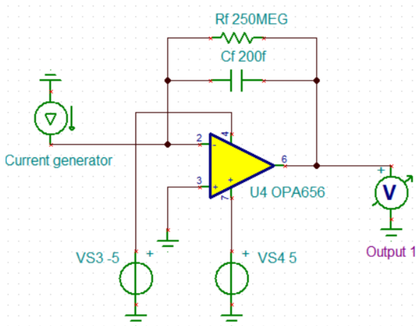

Fig. 1. CSA circuit diagram drawn in TINA-TI

2.3. Pulse Shaper

A pulse shaper is necessary for the baseline restoration of the pulse signal and the prevention of pile-up effect. Generally, a pulse shaper contains one differentiator and n integrators. All differentiators and integrators consist of the same resistor and capacitor, of which the product, RC, is related to the shaping time. The best shaping time depends on the parameters like count rates. The output voltage V_{out} with the input voltage V_{CSA} is

$$V_{out} = V_{CSA} A^{n+1} \frac{n^n}{n! e^n} \tag{2}$$

if there's n integrators and the DC gain of a differentiator and integrators is A [2]. Fig. 2 shows the circuit diagram of the pulse shaper.

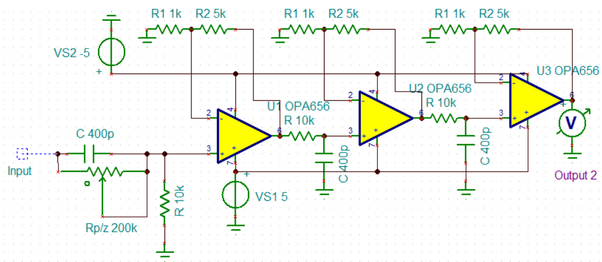

Fig. 2. Pulse shaper circuit diagram drawn in TINA-TI

3. Results and Discussion

For comparison with experimental results with a ^{133}Ba source, the current generator was set to generate current pulses equivalent to the γ-rays of 30.85 keV. The energy required for radiation to produce an electron-hole pair is 3.64 eV, so 8,475 pairs induce a total charge of 1.346 × 10^{-15} C. The output voltage of CSA and pulse shaper should be 6.78 mV and 396.39 mV from equations (1) and (2), respectively, and the simulation results showed 6.81 mV and 385.67 mV. The slight differences were induced from the approximation of the calculation of equations (1) and (2). Experimental data measured with ^{133}Ba source are expected to show the more significant differences caused by incorrect parameters from data sheets and noise sources from DC power supply, detector, etc.

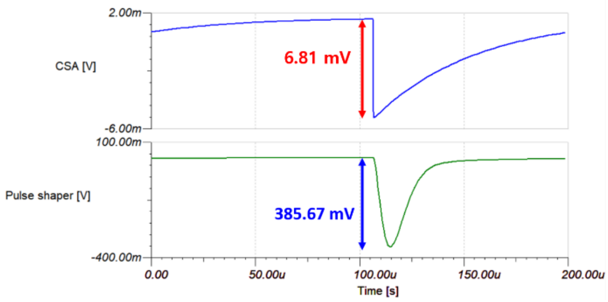

Fig. 3. Output pulses of CSA and pulse shaper assuming a γ-ray of 30.85 keV was incident

4. Conclusions

In this study, a CSA and a pulse shaper were optimized for Si-PIN photodiode detectors to detect low-energy γ-rays and to be used for portable Mössbauer spectrometers. The designed CSA and pulse shaper circuits were well simulated and showed ideal outputs as the analytical results were calculated. However, the measurement data will be tested with ^{137}Ba source and Si-PIN photodiode model S1223 (Hamamatsu, Japan) [3].

Acknowledgements

This work was supported by the Korea government (MSIT) (1711078081)

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