3cc Gamma Sensor

1. Introduction

SemeaTech's 3cc Cesium Iodine Gamma Sensor is composed of a Cesium Iodide (CsI) crystal, a photodiode, and a high-gain preamplifier. It is capable of detecting gamma (γ) and X radiation within the energy range of 50 keV to 3 MeV. The sensor boasts high sensitivity and a rapid response time of less than one second, detecting even slight changes in X and gamma radiation (0.01 μSv/h). Its compact design and exceptional sensitivity make it ideal for integration into portable devices, such as portable monitors, for real-time or near-real-time measurement of gamma and X radiation. Detailed specifications are provided in Table 1.

The sensor's scintillation material is a cesium iodide (CsI) crystal. When gamma or X rays interact with the CsI crystal, energy is transferred to the scintillator, which then emits light (photons). The intensity of the emitted light is directly proportional to the energy of the incoming gamma or X rays, with each interaction producing a flash of green light. In a radiation field, the photons excite the CsI crystal, leading to the emission of green light (refer to Figure 1).

Energy Detection Range	50 keV ~ 3 MeV
Response Time	1 sec.
Signal Amplitude	0.9 V ± 0.1 V @ 662 keV
Detection Efficiency	25,000 ± 20% count/uSv @ 662 keV
Power Supply	3V to 5.5V
Power consumption	less than 2mW @3V power supply
Working Temperature	-20℃ ~ 50℃
Lifespan	5 years
Upper Limit of Measurable Dose Rate	20 mRem/h
Machanical Structure	45mm x 24mm x 18mm
Electric Connector	4-lines cable with 4-pin MOLEX PicoBlade 1.25mm (.049") connector (Part No.51021-0400)

Table 1 Specifications

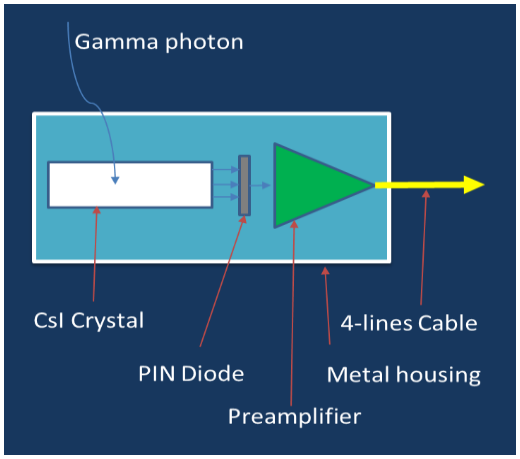

Figure 1 3cc gamma sensor principal

The process of output formation involves the following steps:

- In the radiation field, gamma photons instantly excite the CsI crystal, causing it to emit green light.
- The green light travels through the output window of the crystal and enters the PIN diode, where it generates a light current.
- The preamplifier receives the light current from the PIN diode and, through its semi-Gaussian shaping circuits, converts the light current into a pulse wave.
- These pulses are then sent to subsequent circuits for further processing.

Not all output pulses are generated by gamma photons. The dark current noise from the PIN diode and the electronic circuits in the preamplifier can also produce pulses, which are referred to as noise output pulses. Additionally, strong electromagnetic radiation and mechanical vibrations can contribute to noise outputs. Variations in the preamplifier's power supply can also result in noise pulses.

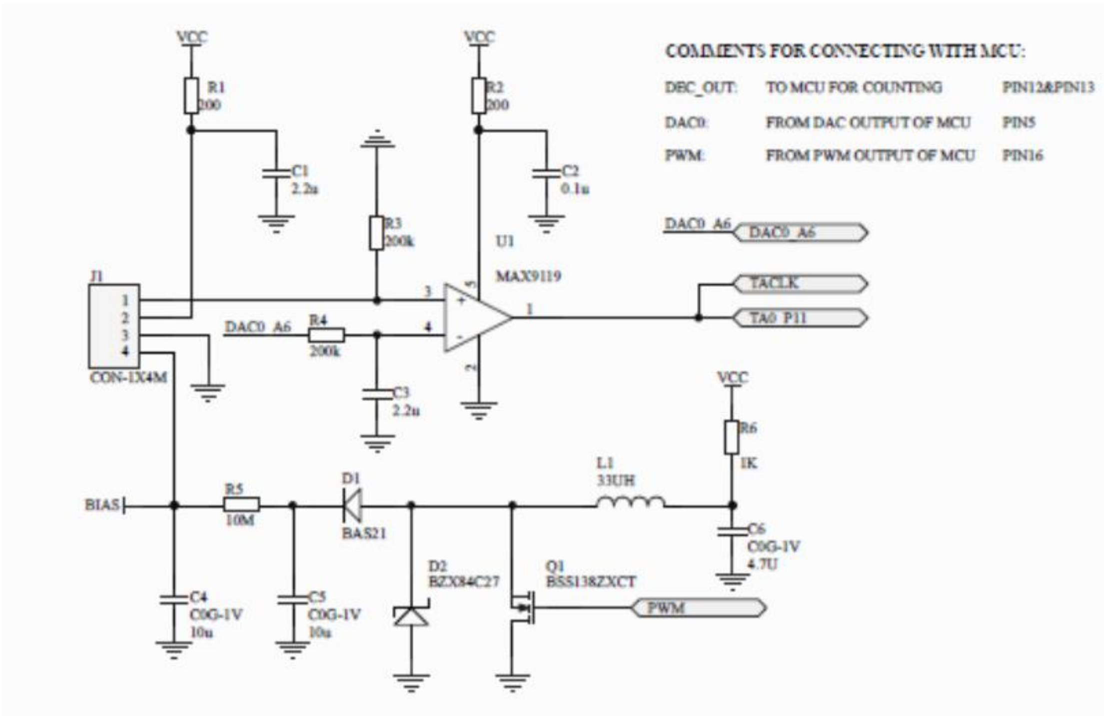

Figure 2 3cc gamma sensor recommended Schematic

2. Recommended Schematic

Figure 2 above illustrates the circuit connecting the gamma sensor to the MCU. J1 represents the MOLEX connector for the gamma sensor. Detailed information about the connector pin signals can be found in the specifications in Table 1. The circuit is divided into the following two blocks:

- The upper section, consisting mainly of U1, R4, and C3, serves as a noise discriminator. The negative pin (pin 4) of U1 is connected to DAC0, generated from the MCU's internal DAC output. This needs to be adjusted in response to environmental temperature changes, meaning that devices using the gamma sensor for radiation measurement should monitor the ambient temperature. Calibration of the DAC0 value based on temperature is necessary before application. The output of U1 can be directly connected to the MCU's pin for counting.

- The lower part is called pump power source builder, including Q1, L1, D1, C5, R5, C4. They form a complete pump power supply source system. The input PWM comes from MCU’s pulse width with the form of 2k to 4kHz sine wave. D2 limits the output bias to 27V.

3. Calibrations

The 3cc Gamma sensor is not recommended for dose measurement but is better suited for monitoring environmental radiation intensity. Typically, the sensor's output pulse counting rate is used to determine radiation intensity. However, a second-degree polynomial should be applied to accurately correlate the pulse counting rate with radiation intensity. The formula is $I = A\times R^2 + B\times R + C$, where I represents radiation intensity, R is the sensor's output counting rate, and A, B, and C are coefficients that must be determined through calibration. This calibration requires professional equipment capable of generating different radiation fields.

Another necessary calibration is for DAC0 (as mentioned in the previous page in the discriminator circuit). The relationship can be expressed using a second-degree polynomial formula: DAC0 value $= A\times T^2 + B\times T + C$, where T represents the environmental temperature, and A, B, and C are calibration coefficients. This calibration can be performed at the manufacturing facility of the device.

For intensity calibration, at least three intensity points are required to determine the A, B, and C coefficients. The recommended points are as follows:

- 100 µrem/h (low intensity),
- 5000 µrem/h (medium intensity),
- 12000 µrem/h (high intensity).

All of these radiation fields can be generated using a Cs-137 source.

For DAC0 calibration, at least three temperature points are also necessary. The recommended temperature points are:

- -10℃, as the low-temperature point
- 20℃, as the middle-temperature point
- 45℃, as the high-temperature point

This calibration does not require a radiation source and can be performed in a natural environment. To carry out the calibration, place the device at each of the three temperatures and adjust DAC0 to ensure the displayed intensity is between 10 and 13 µrem/h (China), 6 and 8 µrem/h (USA), or matches the local environmental radiation intensity.

Calibrations should only be performed once during the device's lifetime at the factory, unless additional user management requirements necessitate otherwise.

In general, the precision for radiation intensity measurements is ±30%. It is important to complete the DAC temperature calibration prior to the intensity calibration.