Gamma Sensor Temperature Characteristics

SemeaTech's gamma sensors (including the 3cc sensor and mini sensor) measure gamma ray and X-ray intensity using Cesium Iodide (CsI) crystals combined with photodiodes. The CsI crystal receives incoming gamma photons and converts their energy into visible light, which is then detected by the photodiode and transformed into an electrical signal for measurement.

The sensors operate in photon counting mode, meaning each gamma photon received is converted into a transient electrical pulse. By analyzing the count and amplitude of these pulses, the gamma intensity and energy can be measured. However, due to the influence of CsI crystals and surrounding materials, gamma photons of a single energy produce a spectrum of pulse amplitudes rather than a single amplitude. This phenomenon, known as the Compton platform, makes CsI + photodiode gamma sensors unsuitable for quantitative energy analysis. Thus, these sensors are typically used for counting gamma photons and analyzing their count rates to determine gamma radiation intensity.

Gamma photons possess high energy, so changes in environmental temperature have minimal impact on their detection and energy conversion. Within the sensor's operating temperature range, temperature fluctuations do not significantly affect the crystal's efficiency in detecting gamma photons or the pulse amplitude resulting from photodiode conversion. However, the photodiode's noise is temperature-sensitive. As temperature rises, the noise amplitude of the photodiode increases noticeably, especially beyond 40°C. At 50°C, photodiode noise can overwhelm pulses generated by low-energy gamma photons.

In system applications, a pulse amplitude discriminator is generally used to separate gamma radiation pulses from noise. The discriminator level is set to match the photodiode noise amplitude. When temperature increases and photodiode noise amplitude rises, the discriminator level must also be raised. This may block some low-energy gamma photon pulses, causing a decrease in the counting rate of the user's application system (not the sensor itself). Users must consider this effect in their application systems.

The 3cc gamma sensor uses Hamamatsu's S5106, while the mini gamma sensor employs Vishay's VBP104S. The temperature characteristics of these photodiodes can be referenced in their respective specification sheets.

For the Silicon PIN photodiode (Hamamatsu S5106) used in 3cc gamma sensor. As the temperature increases, these variations become more pronounced. For instance, one gamma sensor may register 100 pulses to indicate 30 μREM/hr, while another may register 150 pulses for the same dose rate. On the other hand, the photodiode (Hamamatsu S5106) is very sensitive to ambient temperature especially when the temperature increases to 40 degree C and above. This is why gamma sensors must be calibrated after being installed in gamma monitors, and the gamma monitor must have thermistors to compensate for the ambient temperature variations.

It's worth noting that radiation sources are not required for temperature calibration. Instead, calibration involves verifying the sensor's performance across its temperature range by analyzing how noise levels behave under different conditions. Additionally, a pulse amplitude screener is commonly used to separate gamma radiation pulses from noise. The screener's threshold is typically set to the noise height of the photodiode, but as temperature rises, the increased noise amplitude necessitates raising the screening level. This adjustment can block some low-energy gamma photon pulses, potentially reducing the pulse count rate in the user's application system (not the gamma sensor itself).

Since the relationship between noise and temperature lacks fixed quantitative metrics, each gamma sensor must be calibrated in actual applications, as the performance of individual photodiodes can vary.

Fig. 1 is a graph showing the relationship between VBP104S noise (i.e., reverse dark current) and temperature. The graph clearly illustrates the exponential increase in photodiode noise with rising temperature.

Figure 2 illustrates the temperature profile of the 3cc gamma sensor's output in relation to varying ambient temperatures, with a compact Americium-241 serving as the radiation check source.

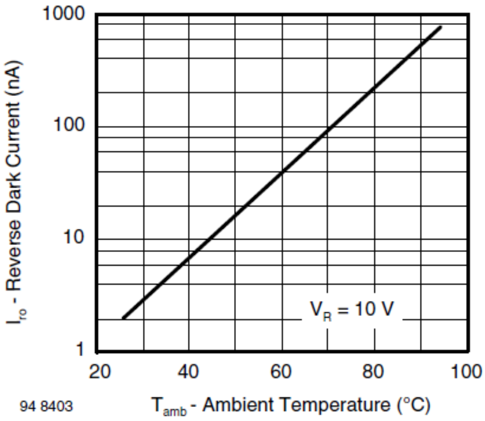

Fig. 1 - Reverse Dark Current vs. Ambient Temperature

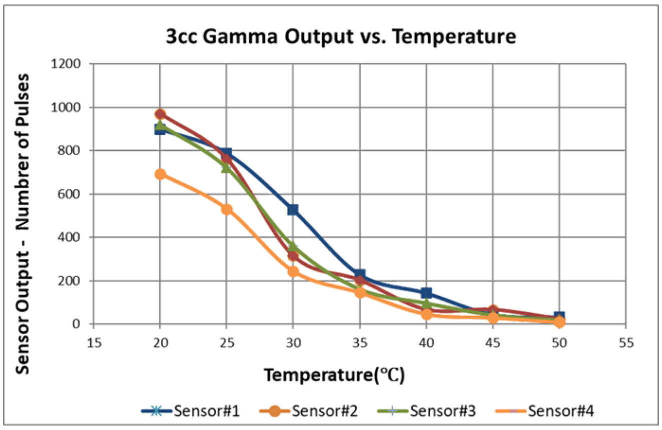

Fig. 2 – 3cc Gamma Output vs. Temperature