Gamma Sensor Q ＆ A revised version

1. Will environmental conditions affect the life span of mini gamma sensors?

The lifespan of mini gamma sensors is primarily affected by environmental factors and the main ones are aging and corrosion. Mini gamma sensors can continue operating as long as the enclosure and internal circuitry are not damaged by corrosion and their sensitivity remains unchanged. The expected lifespan stated in the datasheet refers to the warranty period and does not necessarily reflect the actual operational lifetime. The performance of mini gamma sensors will remain unaffected over time as long as there is no material damage, and they continue to operate.

2. Gamma sensor proper nouns explanation:

T90/Response Time:

T90 represents the time or how fast gamma sensors respond to radiation source. We usually use other standards of T90 (like less than 30 seconds) in other sensor type but this is not strict to gamma sensors. Actually, 90 percent of mini gamma sensors' response time (T90) are less than 10 seconds. The term "90% confidence level" originates from quality control and refers to the duration required to capture total counts that are stable and repeatable within a specified time frame. The time taken for the curve to grow from zero to this horizontal line is defined as the response time, T90. This metric indicates how quickly the sensor responds to the radiation source with 90% confidence.

Radioactive source (Cesium-137/0.250 uCi):

0.250 uCi represents response of sensor to the radiation source: Cesium-137. Notice that
The sensor is positioned 10 mm away from the radiation source, irrespective of its orientation.

Middle Column:

The middle column represents the sensitivity of mini gamma sensors to the radiation source used in the test (Cesium-137, 0.250 μCi). The distance between the sensor and the radiation source is maintained at 1 cm, regardless of the sensor's orientation.

Baseline(uR/h):

The baseline represents the ambient radiation level in the environment where the sensor is operating. The data from the sensor is adjusted by a correction factor of 10x. For example, if the table shows 1 μR/h, this corresponds to an actual background radiation level of 10 μR/h in the testing environment. If a mini-gamma sensor records 14 pulses in one minute, this is interpreted as a background radiation level of 14 μR/h. When multiple mini-gamma sensors are used together, the number of pulses recorded over a defined time period by this group can be used to establish the natural background radiation level detected by these sensors.

CPS:

CPS or Counts Per Second, is a critical metric for quantifying the number of gamma photons detected by a sensor per second, which provides a real-time measure of radiation intensity and is directly influenced by the sensor's sensitivity and the strength of the radiation source. CPS reflects the rate at which the sensor registers individual gamma photon interactions, also referred to as "events," over time.A higher CPS value corresponds to a stronger radiation field or source and is proportional to the radiation source's activity and the sensor's proximity to it.

CPS readings can often be calibrated into specific radiation dose rate units, such as micro-sieverts per hour (μSv/h) or micro-roentgens per hour (μR/h), through a conversion factor established during sensor calibration. This calibration enables CPS values to be accurately interpreted in relation to radiation safety standards and exposure levels.

FWHM:

The Full Width at Half Maximum (FWHM) is a key parameter that defines a sensor's energy resolution, measuring its ability to distinguish between gamma-ray energies. This capability is critical for identifying specific isotopes or radiation sources.

FWHM represents the width of a gamma-ray energy peak at half its maximum height and is typically expressed in energy units such as kiloelectronvolts (keV) or as a percentage of the peak's centroid value. A lower FWHM value signifies superior energy resolution, enabling the sensor to more accurately resolve closely spaced energy peaks. It is widely used to differentiate between isotopes emitting gamma rays with similar energies and serves as a standard metric for comparing the resolution performance of different gamma sensors.

Full Width at Half Magnitude (FWHM) often refer to width of pulse at half of its maximum height. Despite different pulse sizes, the FWHM of all pulses generally tends to be the same, which suggests that the pulse shape remains consistent, regardless of the pulse's size. By measuring the FWHM, we will find that pulses, regardless of their amplitude, tend to have a consistent width when measured at half of their maximum value.

3. How are the wires connected internally to the gamma sensor?

The wires are attached to the printed circuit board (PCB) by melting solder, which forms a solid electrical connection between the wires and the board. Then the area around the wires and the connections is covered with epoxy resin. This serves to protect the wires, the soldered connections and the PCB from environmental factors like moisture, dust, or physical damage.

4. What’s the operating condition’s impact on gamma sensor performance ?

Mini gamma sensors are very sensitive to vibrations, which lead to undesired noise or distortions in the reading results due to microphonic effect. The microphonic effect often occurs when mechanical vibrations generate electric noise in the sensors and this will impact the performance. Mini gamma sensors could be vulnerable to electromagnetic interference (EMI) from wireless communication devices, which can disrupt sensor operation. This will lead to unreliable and inaccurate reading results. As a result, mini gamma sensors are not recommended to use near wireless instruments.

5. Has the module a preferred direction of irradiation?

The crystal inside sensor is long (likely elongated or linear in shape) and placed laterally at one end of the sensor, which is the end opposite to where the sensor's output (or outgoing end) is located and crystal is placed along the side of the sensor rather than center or at the output end.
The top, bottom and front orientations of sensors are basically the same, which means that mini gamma sensors' response is nearly identical no matter how people position it in relation to these directions. The left and right orientations show small response that is less sensitive to changes or signals coming from these directions.

6. Have any energy compensation for mini gamma sensors?

Mini Gamma sensors detect gamma radiation and convert radiation into electrical impulses or signals. This is the core function of the sensor, where it detects and registers the energy from the incoming gamma rays. They do not adjust or correct for variations in the energy of the incoming radiation, without factoring in or compensating for any fluctuations in the intensity or energy levels of the incoming radiation.

7. How can we understand the mini gamma sensor circuit and principle?

Mini sensors' output is the pulse that resembles a Gausman shaping pulse. This is a special type of signal used in radiation detection field, The amplitude (height) of the pulse is proportional to the energy of the incident gamma photon that the sensor detects. The stronger the gamma photon energy, the larger the pulse amplitude will be. Gamma sensors don't need to measure the exact energy of each gamma photon. Instead, it focuses on counting the events (gamma photons) and analyzing their intensity through the counting rate. The discriminator circuit is used to filter out unwanted signals or noise. Max 9119 is the key component, which compares the pulse amplitudes against the threshold level to determine which pulses should be passed through and which should be blocked. The threshold level is set by the DAC (Digital-to-Analog Converter) output from the MCU (Microcontroller Unit). This sets the minimum amplitude required for pulses to pass through the system.

Pulse with amplitudes higher than the threshold pass through the comparator and are counted. The ones with lower amplitudes (which might not be caused by noise or weak gamma events) are blocked and not counted, which ensures only meaning pulses are analyzed. After the discriminator, a counting system collects the valid pulses and counts them over a period. This pulse counting rate is then used to calculate the gamma dose rate, which is a measure of the intensity of gamma radiation.

8. What is voltage reference that needs to be set on inverting input (Pin 4) of the MX9119 according to mini gamma circuit diagram?

The voltage reference on Pin 4 of MX9119 is not fixed value. It is required to be set based on the magnitude of the sensor's electronic noise pulse. The reference voltage is adjustable and should be tailored to the specific noise level of the sensor in the environment where it is operating. To set this reference voltage properly, the magnitude of the noise pulses generated by the sensors should be measured. This can be done by using an oscilloscope, which allows users to observe the amplitude of the electronic noise (unwanted pulses) produced by the sensor when there's no radiation present.

9. What is the typical output bias without any interaction with a radioactive source when following the recommended circuit?

The sensor's output signal is not centered around zero volts; It has a constant voltage offset. DC bias could be due to the way the sensor is designed or due to inherent properties of the sensor's internal electronics. It's essentially a constant voltage that shifts the signal away from zero volts.

It's recommended to use blocking capacitors (MAX9119) between sensor output and following circuits. Many circuits (like amplifiers or ADCs) might only care about the fluctuations in the signal (the AC component), not the constant DC level. By using a blocking capacitor, DC bias can be effectively removed, ensuring that only the useful, changing signal is sent to the following circuits. The comparator could be used to process the signal after the DC bias has been removed by the blocking capacitor. It helps to convert the AC signal into a binary output, which is easier to process in digital circuits.

10. Why does it sometimes get higher than expected background counts?

In gamma sensor system, many small pulses are often generated by electronic noise, which are random fluctuations in the circuit – meaningless signals. These pulses can interfere with the detection level of real signals, especially when there's no radiation source.

Discrimination threshold is the voltage level at which the comparator decides whether a pulse is signal-worthy or just noise. We can increase the reference voltage on the comparator's negative pin to raise the threshold for what the comparator considers to be a valid signal. Then it's required to choose a threshold high enough to block all noise pulses but not so high that it also blocks meaningful signals. This is to filter out noise and keep the only real signals.

In practical applications, the threshold should be adjusted dynamically based on the performance of the sensor. For example, different sensors might have different levels of noise or sensitivity, so the threshold must be calibrated to suit each sensor's specific characteristics. The reference voltage (threshold) is not fixed value, and it should be set depending on the magnitude of the electronic noise that the sensor is generating. If the noise level is high, the threshold should be raised to avoid detecting it as a signal. To set the right threshold, an oscilloscope to measure the magnitude of the noise pulses and this will allow users to visualize the noise and determine the appropriate threshold level by examining the pulse heights. When radiation source is absent, we should observe the size of the noise pulses in the natural environment (e.g., environmental radiation or other electromagnetic interference). Based on these observations, then set the reference voltage to filter out these noise pulses.

11. How to explain gamma sensors' linear regression?

Linear regression is a statistical methos used to model the relationship between sensor output (CPS) and radiation levels, which shows how well the sensor's output follows a straight-line pattern as radiation increases. This helps in understanding how the sensor responds to different radiation strengths. To evaluate the sensor's linearity, a sample batch of sensors is tested by exposing them to different radiation levels. The resulting measurements are plotted as data points on a chart. The linear regression line fitted to the data points best represents how the entire lot of sensors behave in terms of their response to radiation, ensuring that all sensors in that batch are assessed for their linearity. With 95% confidence level, all sensors in the batch will have their performance (measured CPS vs. radiation) within ±30% of the linear regression line, which means that the sensor's readings are expected to be within 30% of ideal response as defined by the linear model. If the sensor's linearity (as defined by the regression line) is integrated into systems like gamma or X-ray detectors, the accuracy of the overall system will be ±30%.

CPS (Counts Per Second) is the measure used to track the number of events (radiation counts) detected by the sensor in one second. This data can be utilized to create a linear regression model. One data point represents the average CPS over a period of time to reduce noise from short-term fluctuations. CPS fluctuates due to the random nature of radiation detection, so to smooth the data and make it more stable, a moving average filter is applied. The filter window size is adjusted depending on the CPS value to account for these fluctuations.

For weaker radiation sources, larger samples are required to get accurate average because fewer events are detected. For stronger sources, fewer CPS are needed for each data point because the number of detected events is higher. In high radiation environments (with high CPS, like greater than 1000 CPS), the data points are more frequent, so a small window (2–3 data points) can be used for averaging without losing stability. But in low radiation environments, a larger window is required to gather enough data for stable reading when the CPS is lower. The exact size of the filter window depends on the specific user's requirements for how stable the readings need to be. Therefore, it cannot be fixed and should be adjusted based on the situation.

12. How to explain the Quadratic function aX^2+bX+C about gamma sensors?

Calibration is essential for ensuring sensor performance accurately. Without calibration, users may not get reliable readings for the sensors and each one may behave slightly differently so that they're required to do individual calibration. When the sensors are calibrated, measurements (dots) are taken at different points of sensor output vs. a known reference or input. These measurements are plotted on a chart (graph). A mathematical curve (quadratic function) is then fitted to these data points to best represent the sensor's response.

Once this quadratic function is applied to sensor's data points, sensor's actual readings should be close to this curve with an acceptable error margin of ±10%. It means that sensor's reading should generally fall within 10% of what quadratic model predicts.

Every sensor features their own unique characteristics, so each one should have own quadratic function that best fits its calibration data. Sensor's calibration curve is specific to it but not to other sensors, even if they are of the same model.

13. Why is there sometimes a significant difference in the sensor-to-sensor variation for the CoC data?

A slight shift in the position of the sensor relative to the radiation source can cause changes in how much radiation the sensor detects. The sensor might receive more or fewer pulses, leading to variations in the CPS reading. Sensors that are closer or at a different angle to the source may detect different levels of radiation. If you have multiple sensors of the same type, the reading may depend on their replacements.

In environments with high radiation intensity, the radiation pulses detected by the sensor may overlap—meaning two or more pulses occur very close to each other in time, which will cause issues in accurately counting them. If pulses overlap too much, it becomes difficult for the sensor to distinguish between individual pulses. If pulses overlap, the sensor might misinterpret them as a single pulse. This results in the sensor "losing count" of individual pulses, leading to an inaccurate CPS measurement. If there are two pulses occurring in quick succession and the sensor only counts them as one, the CPS reading will be much lower.

Each sensor might capture radiation pulses with different widths due to slight variations in the electronic components of the sensor. Pulse width refers to duration of the pulse (how long the sensor detects the radiation). The variation can affect sensor's ability to accurately count pulses, especially when pulses are close to each other. The risk of overlapping pulse will increase if a sensor captures wider pulses because it takes more time for other another pulse to occur during it when there's wider pulse. Therefore, wider pulses make it easier for the sensor to become saturated, which can lead to a loss in the accuracy of the CPS readings. In low radiation fields, pulses tend to be spaced further apart in time, and this means that the chance of overlap is reduced, which allows sensors to detect and count each pulse more accurately because there's less chance of saturation and overlap.

14. Why mini gamma sensors sometimes meet the circumstance that the sensitivity will decline after long-term use?

The possible reason for the sensitivity decline is as follows:

1. Cold Weather Environment: Especially in winter, the sensitivity of gamma sensors will be influenced by harsh temperatures. Extreme cold can affect physical properties of the sensor, potentially reducing the ability to detect gamma radiation accurately.
2. Half-life of a radiation source: SemeaTech mini gamma sensor uses Cesium 137 as radiation source, which features 16 years half-time. The sensitivity of sensor is directly linked to the activity of source. If these sensors are used for longer than 16 years, the sensitivity of the gamma sensor will naturally decline.

To solve such sensitivity issues, it's recommended to do the following actions:

1. Ensure the half-life of Cesium137 is within its effective operational period.
2. Employ a set of 'golden samples'(calibrated reference sensors) to perform the comparison tests, which helps identify deviations in sensitivity and ensure accurate performance over time.

15. Why SemeaTech choose Cesium137 as radiation source for gamma sensors?

Cesium 137 is utilized as a radiation source for SemeaTech gamma sensors because Cesium is the source in medium energy level. These are widely used in industrial and environmental applications and also the environmental monitoring and calibration standards for radiation detectors. As a result, for only response detection, we choose Cesium 137 as radiation source for validation test.

Other radiation sources like Cobalt-60 and Americium-241 have different characteristics:
Cobalt-60: High-energy gamma rays, this is suitable for deep penetration and sterilization of medical equipment and food irradiation. High-energy gamma rays penetrate deeply, making it effective for sterilization and inspection. They are usually used to perform the gamma detection instruments' calibration.
Americium-241: Low-energy gamma source, ideal for close-range applications like smoke detector (ionization type), thickness gauging in manufacturing processes.

Low-energy gamma rays are suitable for short-range applications where precision is critical. The long half-life ensures durability and reliability in continuous operation.

16. What ADC/DAC resolution should we use for the temperature measurement and DAC0 output? Is 8-bit sufficient for 3cc gamma sensors?

8-bit ADC resolution is sufficient for temperature measurement. An 8-bit ADC can produce 256 discrete levels (since 2^8 = 256), which means it can measure the temperature in 256 different steps or levels. This resolution might be adequate for temperature measurement in many applications, depending on how precise the measurements is required.

17. Will the recommended specifications for inductor L1 affect performance of the boost circuit?

In this circuit, L1 works in conjunction with the transistor (Q1) and other components to form boost converter. The inductor temporarily stores energy as a magnetic field when Q1 is conducting and then releases this energy to the load when Q1 turns off. This process "boosts" the voltage to a higher level. Noise (EMI or switching noise) from the inductor can affect the stability of the circuit, cause signal distortion, or create issues in other parts of the system, which ensures the circuit runs efficiently and without significant electromagnetic interference.

The recommended specifications for L1 (inductor) are crucial for the boost circuit's performance. An inductor with appropriate inductance, current-handling capability and low noise characteristics ensures efficient energy transfer, stable voltage output, and minimal interference, which are all essential for the reliable operation of the circuit.

18. Is there any factory calibration service for gamma sensors?

In production, gamma sensors are not precisely calibrated because calibration is not critical for sensor itself and is more relevant for the application system in which sensors will be used. The reference resource is used to verify the sensor's performance: ensuing sensor's noise level and gamma ray response meet user's requirements. Verification means that check that the sensor works as expected within defined limits (e.g., noise and response).

19. Does temperature affect radiation measures? Should we calibrate the sensor with a single source over a -20Cto 60C temperature or expose the sensor to multiple types of sources to calibrate across all energy levels?

Temperature does not really affect radiation measurements and radiation detection relies on physical interactions that are not temperature sensitive. However, electronic noise increases with higher temperatures, which may impact measurement's accuracy or stability. Radiation sources are not needed for temperature calibration. Instead, focus on verifying the sensor's performance across the temperature range. This involves testing and validating how the sensors' noise levels behave under different temperatures to ensure the specifications are met.

20. Does 3cc gamma sensor's lifespan refer to the manufacturing date or the date the sensor was supplied to users?

Sensor's lifespan is engineered to function optimally for 5 years, and this is the expected operational period under normal conditions. The warranty of 15 months means that this starts from the date the sensor is shipped from the manufacturing facility and this is also the assurance of sensor's performance during this time frame.

Despite the specified lifespan and warranty, the 3cc gamma sensor is likely to have prolonged functional lifetime because this is constructed with a cesium-iodide crystal. This kind of material does not degrade overtime, which suggests that sensor's longevity may exceed its design expectation in suitable conditions.

21. What conditions should be maintained to ensure 3cc gamma sensors remain within their effective operational range?

The 3cc gamma sensors have very long shelf life because of the construction using cesuim-iodide crystal, which is one kind of highly stable material. There's no special storage condition requirement and they can be stored under standard environmental conditions without risking degradation.

22. If recalibration is not an option, what methods or tools are available to verify the sensor's readings and ensure its functioning properly?

If calibration process cannot be processed, there are alternative methods which can be used to check sensor's performance and bump tests using low-dose radiation sources are very possible. These methods involve testing sensors' response to know radiative materials. Commonly, readily available items containing weak radioactive materials, such as:

1. Smoke Detector Ionization Chamber: containing Americium-241, a weak radioactive source. We also sometimes use one or two pieces of a smoke detector ionization chamber that utilizes a small amount of radioactive material for bump tests.
2. Lantern Mantle: Some mantles contain thorium, which emits low levels of radiation. This works as a check source for radiation detection instruments.

Since these materials emit weak radiation, stacking multiple items may be necessary to produce a detectable radiation level sufficient for testing sensor's response.

23. Is there any risk that the sensor could become a radiation source after exposure to radioactive materials during its operation?

There's no risk of sensors becoming radioactive because of the construction materials and components, for example:

1. Cesium Iodide Crystal: Stable material that does not emit radiation or become radioactive upon exposure.
2. PIN Diode and Electronics: Such components are non-radioactive and don't interact in a way that would make them emit radiation.

3cc gamma sensors don't contain any radioactive substances and are not made from materials prone to activation. （becoming radioactive after exposure to radiation source）.

24. What best practices and safety precautions should we follow while handling radioactive materials during testing to ensure safety and compliance?

We provide the following guidelines for gamma sensors' precautions:

1. Sealed Storage During Use:

Please always keep radioactive materials in a sealed plastic bag and this will minimize the risk of contamination by preventing the material from coming into direct contact with other surfaces or spreading particles.

2. Exposure Limitation:

Keeping materials sealed and handling them minimally helps reduce the risk of radiation exposure to personnel and the environment.

3. Post-use Storage:

Radioactive materials should be placed in a metal container for storage after testing.
Metal containers provide shielding, which limits the radiation emitted from the materials and ensures safe storage.

25. What is Temperature effect on SemeaTech gamma radiation sensors？

Gamma photons possess high energy making their detection and energy conversion largely unaffected by variations in ambient temperature. Within the operating temperature range of the sensor, temperature fluctuations have minimal impact on the crystal's gamma photon detection efficiency and the pulse amplitude produced by photoelectric conversion. However, photodiode noise is sensitive to temperature. When the temperature is above 40℃, the amplitude of the noise of the photodiode increases significantly. If the temperature reaches 50 ℃, the noise of the photodiode drowns out the pulses generated by the low-energy gamma rays.

When sensors transition from a high-temperature environment to a low-temperature environment, the noise gradually decreases until thermal equilibrium is achieved between the interior and exterior of the sensor. Conversely, when the sensor goes from a low-temperature environment to a high-temperature environment, the noise will increase. If temperature compensation is not completed, pulse count rate will get smaller when changing from high-temperature environment to low-temperature environment. In contrast, during a transition from a low-temperature to a high-temperature environment, the pulse count rate will increase.

Pulse amplitude screener is typically used to distinguish pulse generated by the gamma radiation from the noise, with the screening level of the pulse amplitude screener set to the noise height of the photodiode. When the temperature rises, the noise amplitude of the photodiode increases, requiring an increase in the screening level. This adjustment can block some low-energy gamma photon pulses, leading to a decrease in the count rate observed in the user's application system (not the gamma sensor itself) as the temperature rises. There are no fixed quantitative metrics for the noise ratio change with temperature changes. Each gamma sensor must be calibrated for its specific application, as the performance of individual photodiodes varies.

26. If the gamma sensor is striked during operation, is there a corresponding effect? How can this be resolved?

Devices are highly sensitive to microphonics, which refer to vibrations or mechanical shocks that induce noise or fluctuations in the sensor 's output signal.

For example, striking the sensor during operation causes the output rail to oscillate between saturation and ground (GND) multiple times, which indicates that mechanical shock leads to significant signal disturbances, or "vibrations," that can disrupt system performance.

To mitigate these effects, gamma sensors should be mechanically mounted in a way that minimizes the transmission of vibrations. Here's the recommended solution list:

1. Using Rubber Socket: Rubber Socket can absorb mechanical shocks and reduce direct impact of vibrations on the sensor.
2. Fixing the Cable: Secure sensor's cable to prevent additional movement or vibrations that could exacerbate the issue.
3. Optimizing Placement: Place the sensor in a location that is less prone to mechanical shocks or vibrations during system operation.
4. Isolating the Sensor: Put the sensor on a vibration-damping platform or use shock-absobing materials in the housing to isolate it from external mechanical disturbances.

These operations help enhance sensor's stability and reduce the impact of microphonics on the performance.

27. What best practices and safety precautions should we follow while handling radioactive materials during testing to ensure safety and compliance?

Here're the following two recommendations to ensure safety and compliance:

Metal Container Storage: Storing radioactive materials in a metal container provides shielding against radiation. These can significantly reduce radiation levels outside the container protecting personnel and the environment.

Sealed Plastic Bag: Keeping radioactive materials in a sealed plastic bag minimizes the risk of contamination by containing any potential particles or residues. This method can help limit exposure to radiation.

The importance of these practices is that it can prevent radioactive particles from spreading to other surfaces, tools or personnel and reduce the dose received by individuals to meet the demands of safety regulations.

28. Can gamma sensors operate underwater and also waterproof?

SemeaTech gamma sensors cannot be directly utilized underwater but can detect gamma radiation signal. Gamma sensors can be used underwater if properly encapsulated with epoxy, but several critical factors must be considered:

1. Selection of Epoxy; Waterproof, chemical resistance and transparency
2. Requirement of Epoxy Encapsulation: epoxy must fully cover the sensor's exterior without bubbles or gaps to ensure a complete seal and the layer should not be too thick because excessive thickness can attenuate gamma radiation and affect measurements.
3. Environmental conditions for underwater use: withstand high water pressure, avoiding too much temperature variations (causing epoxy to expand or contract, potentially compromising the seal.
4. Gamma ray attenuation: Although water has minimal impact on gamma ray attenuation, the epoxy's thickness and water depth could slightly affect measurement accuracy. Calibration should account for these factors in the application environment.

29. If it is not possible to perform calibration or alarm function tests during the manufacturing process, what test methods or approaches are recommended to ensure the functionality of the sensor?

There are several methods to confirm the basic operational capability of a sensor without requiring full calibration. One approach is to use low-dose radiation sources for impact testing. The goal is to expose the sensor to a small, stable radiation source to verify its ability to detect gamma radiation and produce the corresponding signal. For example, a lantern mantle contains trace amounts of thorium, often used as a low-radioactivity check source, and the ionization chamber in smoke detectors contains small amounts of radioactive material (such as Americium-241), which can be used as a simple detection source.

These methods are cost-effective, easy to obtain, and do not require precise calibration, yet they can confirm the sensor's response to gamma radiation. However, these tests only validate basic functionality and cannot provide detailed performance metrics, such as precise calibration.