EEEMCal SiPM Board and Daughter Board Inspection and Test Plan

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Abstract

This document describes the test plan to accept the Silicon Photomultiplier (SiPM) board and daughter board modules during the construction phase of EEEMCal detector. Visual inspections of the circuit boards and component placement along with basic electronic tests of the thermistor, LED pulser, and SiPM current and gain are performed to verify functionality.

This draft plan may need slight adjustments to cutoff values and specific test criteria.

Contents

1. PRODUCT PROPERTIES

The following are the key properties of the EEEMCal SiPM and daughter boards that will be evaluated by these tests and inspections.

- **Circuit Visual Inspection:** Ensures that the circuits are the correct size and all components have been placed correctly.
- **Thermistor Room Temperature Resistance:** The thermistor resistance varies with temperature and is used for bias voltage adjustments to maintain constant gain as temperatures change in the detector.
- **LED Pulser functionality**: An LED pulser circuit flashes an on-board LED that is used to monitor SiPM gain and functionality by observing variations in the signal output of the SiPMs.
- **Breakdown Voltage**: The voltage where the SiPMs begin to have avalanche behavior. The operating voltage is set a few volts above this value. It is temperature dependent. Measured to ensure no faults occurred during circuit board assembly.
- **Dark Current:** The current caused by thermal excitations in the absence of light. Measured to find baseline operation parameters and ensure no faults were created during circuit board assembly.
- **Relative Gain**: Each SiPM is nominally placed with matched breakdown voltages to equalize gain. This test verifies and allows for adjustment of the bias voltage to ensure equal gains between all 4 SiPMs.

2. PROCESSES AND PROCEDURES

This section will describe the processes and procedures that are required to evaluate each of the properties described in the preceding section.

2.1. Physical and Visual Inspection

2.1.1. In-Process Testing

The vendor will perform their standard in process testing during board assembly.

2.1.2. Incoming Inspections or Acceptance Testing

A count of expected parts in the shipment will be made. If packaging is damaged then a quick visual check of the SiPM surfaces looking for damage like scratches will be made. If no SiPM damage is found a notation of package damage will be recorded and the delivery will be accepted.

2.1.3. Verification Testing

A visual and physical inspection will be performed. This inspection verifies that all components have been placed on the boards in the correct location and orientation. Then it verifies that the board dimensions meet the specifications.

The SiPM surfaces will be inspected for damage like scratches and then checked to ensure they are well aligned both in height and angle so that good optical coupling will be possible when attached to the scintillating crystals.

2.1.4. Failures and Non-Conformances

Boards with missing components or misplaced components will be returned to the vendor.

If tabs are present on the edges of the circuit boards that are too big, they will be removed on site before electronic tests are performed.

2.2. Thermistor Room Temperature Resistance

2.2.1. In-Process Testing

The vendor will perform their standard in process testing during board assembly.

2.2.2. Incoming Inspections or Acceptance Testing

Performed as part of 2.1.

2.2.3. Verification Testing

The thermistor resistance is measured at room temperature and compared to a reference thermistor.

2.2.4. Failures and Non-Conformances

Thermistors more than 10% off from the nominal value will be replaced by hand at the test site.

2.3. LED Pulser functionality

2.3.1. In-Process Testing

The vendor will perform their standard in process testing during board assembly.

2.3.2. Incoming Inspections or Acceptance Testing

Performed as part of 2.1.

2.3.3. Verification Testing

A light detector is used to test the light output of the LED pulser circuit. The signal height and time duration are recorded. To pass the light output must vary less than 20% from the typical circuit parameters.

2.3.4. Failures or Non-Conformances

Pulser circuits that do not pass will be noted and kept separate from the passed circuits. If these non-compliant boards are needed, they will be repaired by one of the designated testing sites.

2.4. Breakdown Voltage

2.4.1. In-Process Testing

The vendor will perform their standard in process testing during board assembly.

2.4.2. Incoming Inspections or Acceptance Testing

Performed as part of 2.1.

2.4.3. Verification Testing

A current versus voltage curve will be measured in a dark box. This test will cover the range from 35 V to 44 V. The breakdown voltage will be compared to the board's expected breakdown voltage from the SiPM vendor measurements. If a change in breakdown voltage of more than 1V is found the board will be labeled as non-compliant.

2.4.4. Failures or Non-Conformances

Non-compliant boards will be stored separately from the main allotment. If needed additional tests will be performed and repairs may be attempted in some circumstances.

2.5. Dark Current

2.5.1. In-Process Testing

The vendor will perform their standard in process testing during board assembly.

2.5.2. Incoming Inspections or Acceptance Testing

Performed as part of 2.1.

2.5.3. Verification Testing

A current versus voltage curve will be measured in a dark box. This test will cover the range from 35 V to 44 V. The breakdown voltage will be compared to the board's expected breakdown voltage from the SiPM vendor measurements. If the dark current exceeds 3 µA at the nominal operating voltage of V_{br}+ 4V, the board will be labeled as non-compliant.

2.5.4. Failures or Non-Conformances

Non-compliant boards will be stored separately from the main allotment. If needed additional tests will be performed and repairs may be attempted in some circumstances.

2.6. Relative Gain

2.6.1. In-Process Testing

The vendor will perform their standard in process testing during board assembly.

2.6.2. Incoming Inspections or Acceptance Testing

Performed as part of 2.1.

2.6.3. Verification Testing

An LED light source at a wavelength of 450 nm will be used to illuminate the SiPMs and the bias voltage will be swept from 35 to 44V and the SiPM current at each voltage will be measured. A mask is used to ensure light hits only one SiPM at a time and the test is repeated until all four SiPMs have had their current measured.

2.6.4. Failures or Non-Conformances

Boards that cannot be gain matched will be kept separately and if these boards are needed SiPMs may be replaced to better match gains.

3. EXPERIMENTAL/TEST SETUPS

All tests will need to be performed in a single test apparatus. This apparatus must be done in a dark box. In this dark box will be a mount where the SiPM and daughter boards will be connected. There will also be an LED illuminator and a light detector inside the dark box. And a system to hold a mask that can be moved to allow a single SiPM to be illuminated at a time. It is possible to create a system that can mount multiple boards for simultaneous testing. This test system will be automated to control the appropriate test equipment and collect the necessary data with minimal required interaction outside of the need to reset for each set of circuit boards to be tested.

3.1. Measurement of Thermistor Resistance

The thermistor resistance is measured using a multimeter and compared to the measurement of another thermistor serving as a reference for all local tests.

3.1.1. Resource Requirements

Indoor lab space for holding the dark box and other necessary test equipment.

3.1.2. Test Conditions

The circuit board is mounted in the dark box in preparation for other tests. The circuit is allowed to come to room temperature. Then the resistance of both the board thermistor and reference thermistor are made and recorded

3.1.3. Equipment

- Multimeter
- Circuit board mounting connector.

3.2. Measurement of LED Pulser functionality

This test confirms the operation of the LED pulser circuit on the SiPM board. The circuit under test is mounted in the circuit connector mount and a light detector such as a photomultiplier tube or another SiPM board is placed a few cm in front of the LED on the SiPM board. Then a pulse is sent to the LED pulsing circuit and the generated light signal is measured with the light detector using an oscilloscope. Operation is verified for 100 triggers and the average height and pulse width are measured and recorded. The test is run automatically by a computer control system.

3.2.1. Resource Requirements

Indoor lab space for holding the dark box and other necessary test equipment.

3.2.2. Test Conditions

The circuit board is mounted inside a dark box at room temperature. The measurement of the reference thermistor in step 3.1 should occur within a few minutes of this test so that the current operational temperature can be known if needed.

3.2.3. Equipment

- Light detector – either photomultiplier tube or SiPM
- Oscilloscope
- LED Pulse generator

3.3. Measurement of SiPM current

This method is used to measure the remaining parameters: breakdown voltage, dark current, and relative gain. The circuit is placed in the dark box in the circuit board mount. While the circuit is in the dark, the high voltage bias circuit is controlled to input a series of different bias voltages and an electrometer or source meter is used to measure the SiPM dark current at each bias voltage. These voltages and currents are recorded.

Then a grid is used to mask 3 of the 4 SiPMs and an LED is used to provide constant illumination. The bias voltage is again scanned and the current is measured in this illuminated condition. This test is repeated until all 4 SiPMs have been measured. The measured data allows for finding an operating voltage to equalize the gains for all 4 SiPMs.

3.3.1. Resource Requirements

Indoor lab space for holding the dark box and other necessary test equipment.

3.3.2. Test Conditions

The circuit board is mounted inside a dark box at room temperature. The measurement of the reference thermistor in step 3.1 should occur within a few minutes of this test so that the current operational temperature can be known.

3.3.3. Equipment

- HV Bias Voltage supply circuit
- Source meter or Electrometer capable of 100nA precision
- LED for illumination
- Light mask and mount that can move the mask to illuminate one SiPM at a time.

4. ENVIRONMENT, SAFETY & HEALTH CONSIDERATIONS

The procedures will be implemented in a way consistent with the environment, safety, and health policies of the relevant work areas. Within Jefferson Lab the process is described in the ES&H manual Chapter 3200, Work Planning and Control Program and at BNL within the SBMS: “Work Planning & Control for Experiments and Operations”.

5. RECORDS AND DOCUMENTATION

5.1. Manufacturer/Producer Records

All documentation from the vendors and suppliers will be maintained. The SiPMs will be tracked so that vendor measured operational voltages will be known for each SiPM on each circuit. The boards will have an identification mark that will allow for continued tracking of boards during the testing process.

5.2. Deliverable Documentation and Records

The measured test results: thermistor resistance, LED pulse height, LED pulse width, dark current vs voltage, and relative gain results will be retained in a database and associated with the circuit board identifier. This database will be automatically populated by the equipment control and data acquisition software that automates the tests. This database will be made available to the project.

6. REFERENCES