A Low Cost SIPM Evaluation and Control Prototyping System including accurate bias voltage generation, leakage current measurement, and temperature control using Peltier cooling.

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We describe an electronics system to operate SIPMs in the laboratory. The system is comprised of a single channel amplifier board (SIPM Amp) and a 4-channel control board to which up to 4 SIPM Amp boards can be connected. The control board supplies a common low voltage power for the amplifiers. All channels feature individually regulated bias and Peltier power voltages, along with Pt10K RTD readout.

A graphical user interface allows control of the bias voltages, amplifier voltage, Peltier voltages, and also provides for readback of leakage currents and other voltages. The GUI app has a feedback loop to measure the SIPM temperature (with the PT10K) and generate correction voltages to the Peltier to regulate the temperature. The temperatures, which can be achieved by Peltier cooling depend on the thermal design of the setup, the practical limit being about 50°C below ambient.

The SIPM Amp board is a small (3x5cm) PCB that has a single SIPM readout channel. The SIPMs can be surface mounted on the pcb or connected to a 2-pin 0.100" socket. The area around the SIPM footprint is thermally isolated by perforations in the PCB. The RTD is located inside the thermal break. Onboard is BV and LV filtering.

The 10X amplifier is based on MiniCircuits' GALI-S66+ integrated circuit, tweaked for a 6V power. The amplifier was selected for a combination of high bandwidth, low noise, and low power. An ac-coupled amplifier output is connected to an SMA connector. For best operation of this inverting amplifier the output signal should be in the range of 0 to -1V.

The Amplifier board is connected to the Control board with a 10-conductor 0.025" pitch ribbon cable, carrying all the services. Peltier power for currents more than 1A should use a separate 2-contact connector.

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1. SIPM Amp BOARD

Description

The SIPM AMP board is a small (3x5cm) PCB that accommodates a single SIPM. The SIPM can be surface mounted for several size footprints. Also sockets can be added to mount SIPMs on pins. The area around the SIPM is thermally isolated by perforations in the PCB. Onboard is BV and amplifier filtering. There is a ~10X ~2GHz inverting amplifier accepting positive voltages in the range 0 to 0.1V (for best operation.) Close to the SIPM mount is a PT10K platinum resistor to read out temperature. The BV, LV are supplied by a ribbon cable (mating to the Control board). The PT10K is connected across 2 conductors of the ribbon cable so temperatures can be read out remotely. Power to an optional Peltier is provided on 2 conductors of the ribbon cable.

Specs of the SIPM AMP board:
+6V power @ 16mA is required for onboard amplifier.
10K PtRTD for temperature readback
Services connector type: CNC Tech 3221-10-0200-00
Signal connector: SMA
SIPM footprint: S13360-2050VE/3050VE/6050VE and a 0.100” socket.
Gain ~ 10X
Amplifier bandwidth ~2.4GHz
Maximum output voltage (for linear operation) -1.0V. It is important to note that the SIPM AMP is a more linear amplifier for charge than for voltage.
SiPM Amp Circuit Diagram

CNC Tech. 1A rated connector
30AWG wire is 0.35ohm/m
SIPM AMP Board Photos
Frequency response plot. SIPM AMP-Gain-40db-Input.jpg a gain plot vs. frequency without a low-pass filter. BW(-3db)=2.37GHz, Gain(100MHz)=19db (x8.9)
Noise. Output noise spectrum measured (in dbm per 1MHz) with an additional external gain of x96.6 and BW=1.16GHz, an equivalent input noise of 0.73nV/sqrt(Hz), 16.3uV rms for BW=500MHz, 145uV rms output noise.
Voltage Linearity (non-linearity) plot. Horizontal and vertical scale volts. Normal operation is input signals less than +0.1V
Charge linearity vs input pulse voltage. Pulse generator with a 40db attenuator, 4.7ns rise time, 65ns decay time. The SiPM board amplifier is very linear for input signals with voltage up to 0.1V.

![Output Charge vs. Input Peak Voltage](chart1)

$y = 783.73x + 0.3083$

$R^2 = 1$

Residuals for charge linear fit in percent.

![Residuals for Charge Linear Fit](chart2)
Oscilloscope waveforms for the SiPM AMP board. 500MHz oscilloscope

Noise. 1mV/division 100ns/division

Dark counts from SiPM. 1mV/division. 100ns/division.
2. Control Board

Description

The Control board controls 4 channels of SIPM AMP boards. It has 4 ribbon cable connectors to mate with cables to the SIPM AMP. For each SIPM AMP it supplies

- Low voltage for the amplifier (All 4 channels share the same voltage.) 0V–12V @ 2A. The set voltage is read back.
- SIPM bias voltage 20V–100V @ 2mA. The set voltage is read back.
- Readback of leakage current of the SIPM with resolution 5nA
- Readback of PT10K on the SIPM AMP board
- Power to an optional Peltier cooler 0-12V@2A, fused at 0.75A for the ribbon cable, full power at an additional 2-contact connector

The control board implements full galvanic isolation for both the USB and external power connection, which minimizes EMI to the sensitive FE electronics.

The control board uses a USB interface to communicate with the slow control hardware. The whole system is powered by a wall-brick DC power supply, 12V, 4A or equivalent.
<table>
<thead>
<tr>
<th>Component description</th>
<th>Spec</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear LTM2884 USB isolator</td>
<td>Output power &lt;200mA@5V is used for ICs</td>
<td></td>
</tr>
<tr>
<td>Microchip MCP2221 is a USB-to-I2C protocol converter</td>
<td>3.5V @ 15mA</td>
<td></td>
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<tr>
<td><strong>Power</strong></td>
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<tr>
<td>External PS (say 12V/48W adapter L6R48-120400)</td>
<td>1x 12V @ 4A</td>
<td></td>
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<tr>
<td>+12V DC to +15V DC isolated Power converter</td>
<td>+15V @ 2A</td>
<td></td>
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<tr>
<td>Cockcroft-Walton 15V to 120V converter</td>
<td>1x 120V @ 10mA, 2.5W consumption</td>
<td></td>
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<tr>
<td>Peltier/Amp power - combination of switching/linear regulator</td>
<td>5x 0-12V/2A, 10W max</td>
<td></td>
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<tr>
<td><strong>DAC settings (9 channels)</strong></td>
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<td></td>
</tr>
<tr>
<td>BV voltage</td>
<td>4x 100V @ 2mA</td>
<td>(1)</td>
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<tr>
<td>Peltier/Amp voltage</td>
<td>5x 12V @ 2A</td>
<td></td>
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<tr>
<td><strong>ADC measurements (18 channels)</strong></td>
<td></td>
<td>(2)</td>
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<tr>
<td>BV voltage</td>
<td>4x 100V</td>
<td>Of primary User interest</td>
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<tr>
<td>Peltier/Amp voltage</td>
<td>5x 20V</td>
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<td>Peltier/Amp current</td>
<td>5x 2.5A</td>
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<td>RTD readout</td>
<td>4x 0-10V</td>
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<td><strong>Other ADC measurements (5 channels)</strong></td>
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<tr>
<td>External PS voltage</td>
<td>0-20V</td>
<td>For debugging only</td>
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<td>Isolated +15V voltage</td>
<td>0-20V</td>
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<tr>
<td>MCP2221 generated 5V power</td>
<td>0-10V</td>
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<tr>
<td>3.9V generated from the MCP2221 5V</td>
<td>0-10V, also used for RTD temp. calculation</td>
<td></td>
</tr>
<tr>
<td>Cockcroft-Walton output voltage</td>
<td>0-200V</td>
<td></td>
</tr>
</tbody>
</table>

(1) These have to be manually calibrated, also the BV measurements (pedestal and slope)
Everything else is 1% or better by design
(2) Reserve 2 channels for voltage and current of possible negative power rail for Amp
3. GUI / software control interface

Description of program

A graphical user interface program has been written in Python. It allows for control of SiPM bias and amplifier voltages, control of Peltier voltages, read-back of these voltages as well as temperature and SiPM leakage current.

The GUI is composed of 5 tabs, the main tab and 4 tabs. One for each SiPM.

The GUI main tab screenshot:

Voltages are displayed in Volts. Temperatures are in degrees C. The leakage currents are displayed in μV. Note there is a “disable” button for each SiPM. To operate a SiPM, the SiPM must be enabled. Then a desired bias voltage is entered and “set”.

A single voltage for all connected SiPM AMP board amplifiers is settable and should normally be +6V. The current drawn for this power should be about 16mA per connected SiPM AMP board.
Screen shot of a dedicated SIPM tab of the GUI.

Controls from the main tab are duplicated on this screen. Additionally there are independent fields for calibration of the bias voltage read and write. Also there are fields to calibrate the readback temperature.
Appendix 1.
Control Board Circuit Diagram
needs adjustment. Currrent hardware limited to 2mA.

Maximum measured output current is limited to which up to 25mA.

For R2 = 3.6k, BYN = 100V (1.526V/kS)