Front-End Electronics and Data Acquisition for a 2nd Generation Optically Segmented Neutron Imager

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Kevin Keefe[1,2]

on behalf of the SVSC Collaboration:

E. Adamek[2], H. Alhajaji[2], J. Balajthy[1], J.A. Brown[4], E. Brubaker[1], B. Cabrera-Palmer[1], J. Cates[7], B. Crow[2], A. Druetzler[2], J. Elam[6], P.L. Feng[1], M. Folsom[3], G. Gabella[4], A. Galindo-Tellez[2], B.L. Goldblum[4,7], P. Hausladen[3], T.A. Laplace[4], J.G. Learned[2], P. Maggi[1], A. Mane[6], J.J. Manfredi[4], P. Marleau[1], J. Mattingly[5], M. Mishra[5], A. Moustafa[5], J. Nattress[3], K. Nishimura[2], B. Pinto Souza[2], E. Takahashi[2], J. Steele[1], M. Sweany[1], K.P. Ziock[3]

[1]Sandia National Labs, [2]University of Hawai'i at Mānoa, [3]Oak Ridge National Lab, [4]University of California Berkley, [5]North Carolina State University, [6]Argonne National Lab, [7]Lawrence Berkeley National Lab

Motivation For a Neutron Imager

A Single Volume Scatter Camera (SVSC) design has been shown [4] to be able to provide an order of magnitude increase in detection efficiency of double elastic neutron scatters [2]. Neutrons of interest from special nuclear material have energies of roughly 1 MeV, and detection requires spatial and temporal requirements to efficiently measure two scatters at orders of ~1cm and ~1ns [1]. These measurement constraints motivate the use of fast digitizing electronics (DRS4), fast plastic scintillators (EJ-204), and densely arrayed silicon photomultipliers (SensL SiPMs). Thus, the need to digitize many channels, and to maximize the position resolution in the plane of the SiPM strongly encourages a scalable, and modular front-end electronics design. Sandia Laboratories Compact Electronics for Modular Acquisition (SCEMA) has been designed for that purpose.

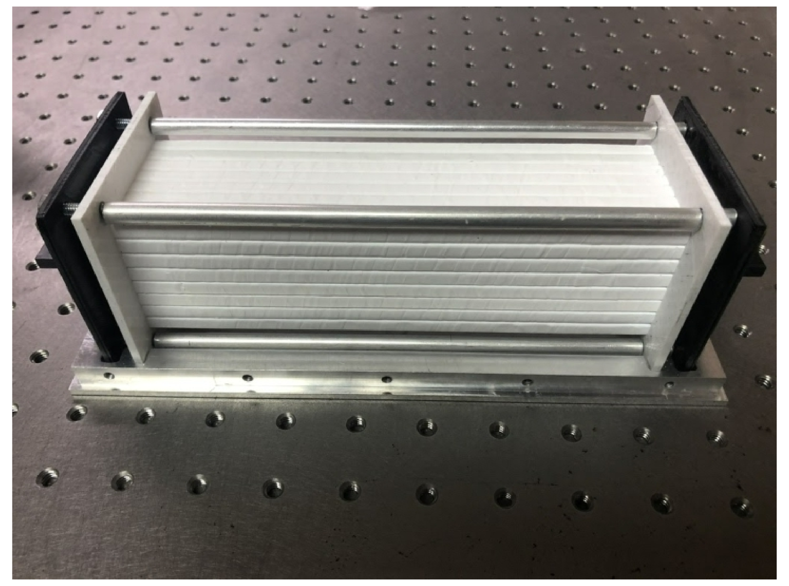


Figure 1, 1st generation Optically Segmented Neutron Imager [2]: 8x8 array of Teflon wrapped ej-204 scintillators connected to SiPM arrays.

First Optically Segmented Design

The first prototype design [2] uses a SensL J-series 8×8 array to form a compact (50mm×50mm×20cm) detector design. However, the connection design of the SiPM array induced electrical crosstalk in octants such that pixels within the octant would produce output waveforms with voltage peaks up to˜10% of the max amplitude of the target pixel.

In order to characterize the amount of electrical cross talk, a laser scan test was performed on all of the pixels in the array, the results of which are shown in Figure 1. An additional concern for the amount of noise in events is optical crosstalk.

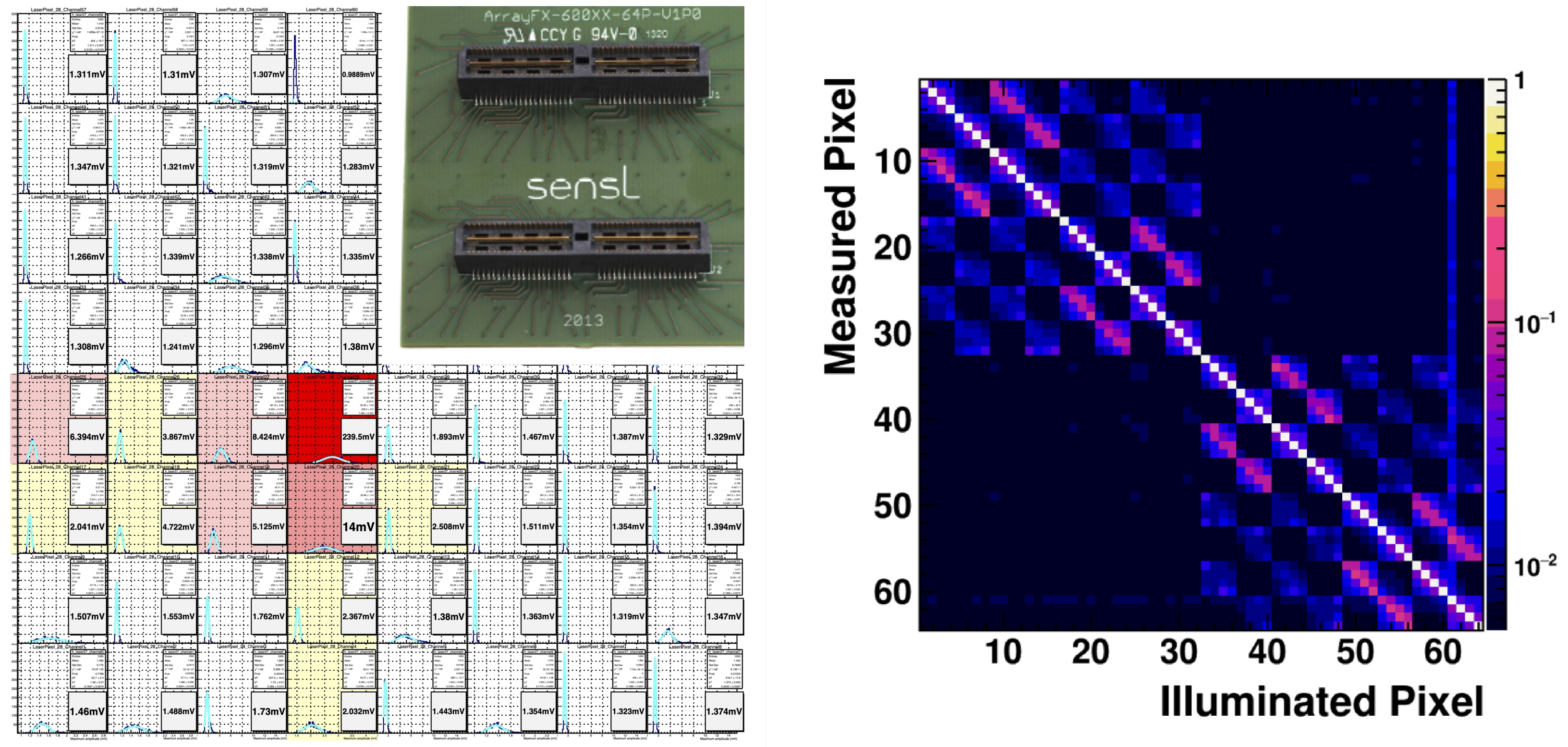


Figure 2. (Left, Main area) Waveform readouts of the 8×8 SiPM array from the first prototype. The red highlighted pixel indicates the highest peak waveform and corresponds to an incident laser focused on that pixel. The other highlighted pixels represent signals with large maximum amplitudes to the target pixel (light red, followed by yellow in intensity). The highlighted pixels indicate an octant where the electrical crosstalk is largest, which correspond to the SiPM array connector octants, as seen in the upper right inset. On the right is an image which sums the correlation matrix for the relative amplitudes for all channels.

New Optically Segmented Hardware Design

The Optical Segmented Module (OSMO) design motivation comes from the lessons learned from the first prototype construction [2]. Its main goals are to reduce electrical crosstalk, provide ease of calibration [3] for inner bars, increase mechanical robustness, and provide a modular design (both mechanically and in the DAQ). A main difficulty in the calibration procedure for the first prototype is access to inner bars. Since calibration sources are collimated beams of particles with a known energy distribution, there is no unobstructed path for particles to the inner bars with a 8×8 commercial design concept. The OSMO module provides a 2×8 design which can allow unobstructed path to any of the 16 scintillators from a collimated source, and removes the "inner bars". To address the issue of electrical crosstalk, the OSMO uses a custom built PCB to separate the anode signals from adjacent SiPMs to eliminate electrical crosstalk from adjacent pixels.

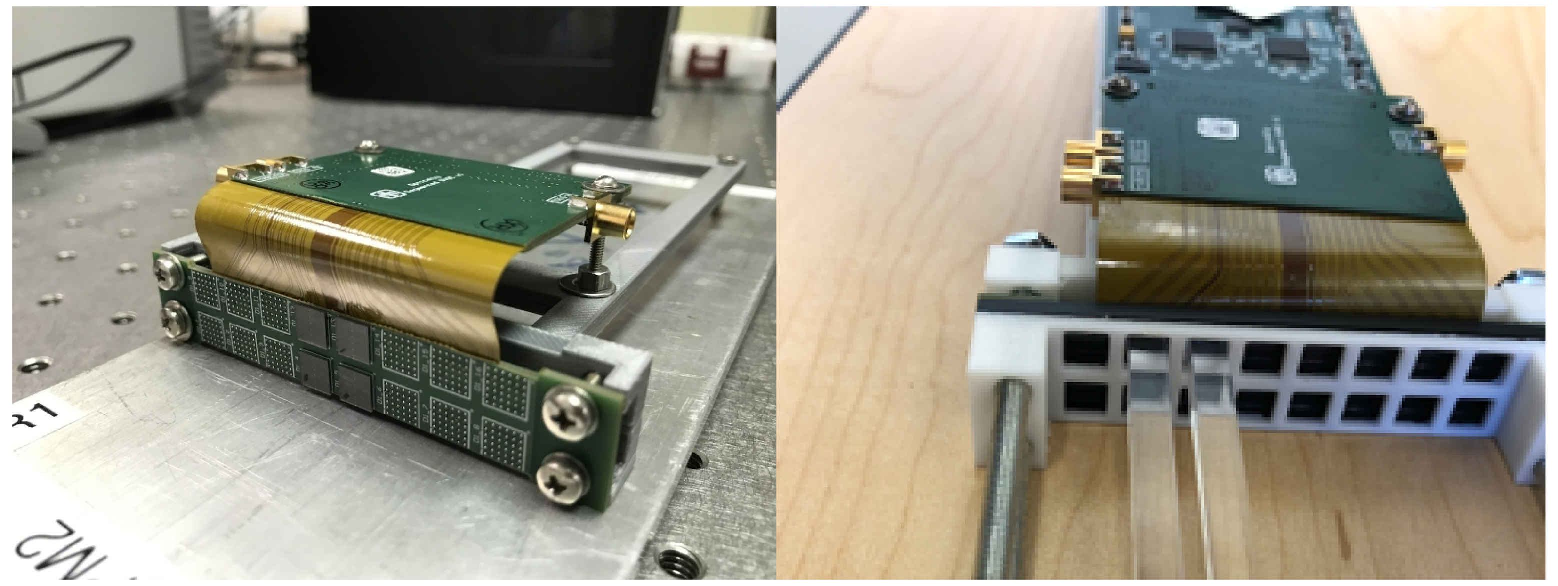


Figure 3. Photographs of the OSMO rigid-flex design. (Left) Facing the camera is a rigid section with SensL J-series SiPMs, each separated by 2mm. A flex section allows the two separate rigid PCBs to sit in orthogonal orientations without an extra connector. The two custom PCBs connected by the flex-card are responsible for electronically isolating each of the 16 SiPM anodes in the 2×8 array. Only 4 SiPMs are installed on prototype assembly on the left.

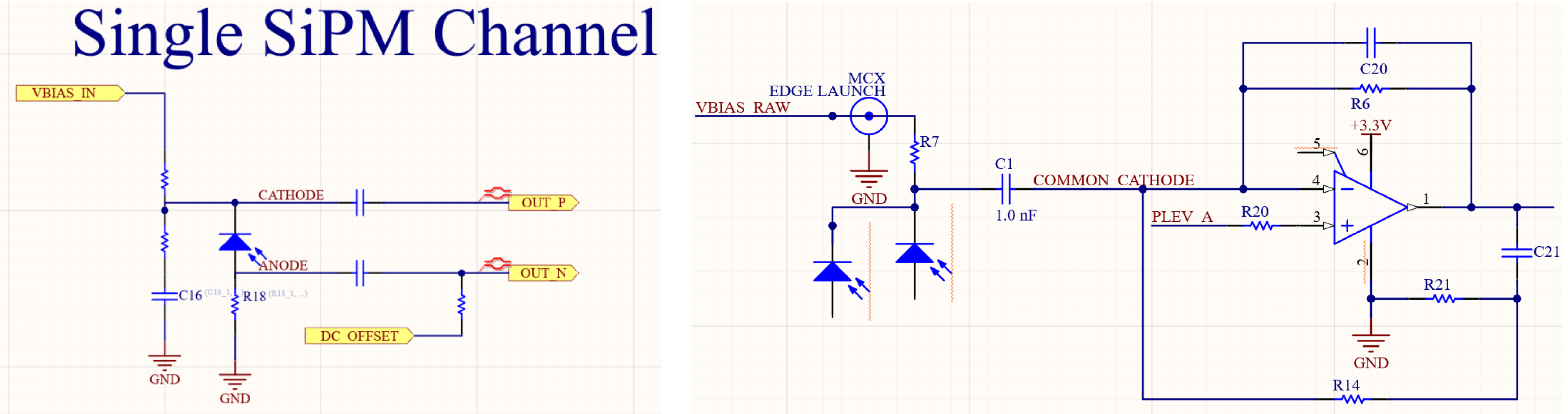
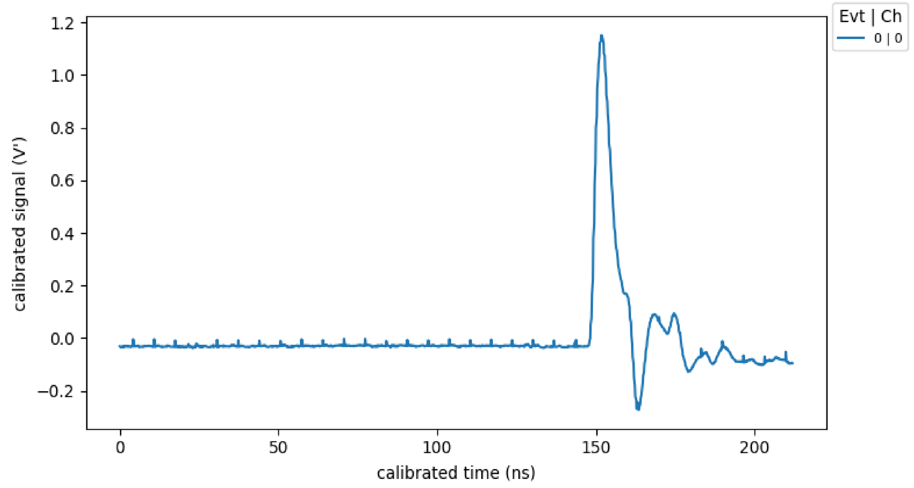


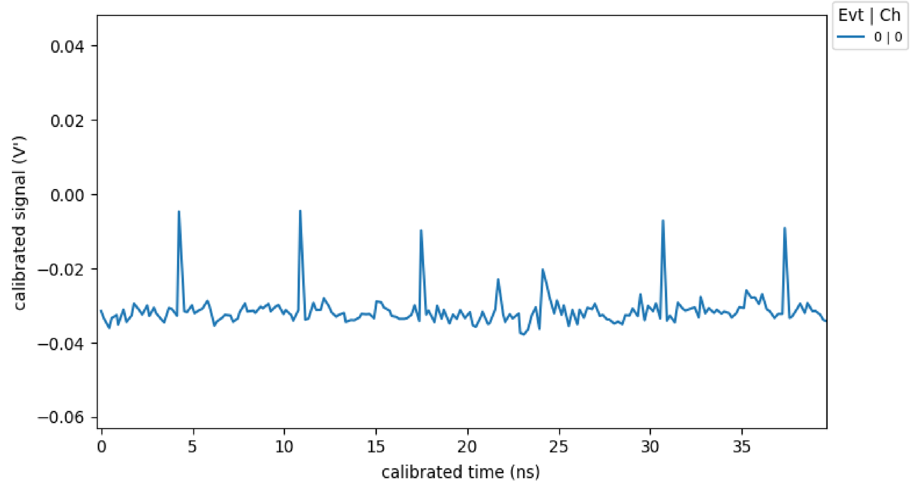
Figure 4. Above (Left) is the schematic for a single SiPM connection and a model of the output trigger circuit. (Right) The mock diodes on the right represent the 2x8 SiPMs in place on the full connected board. The "common cathode" circuit is read by reading the change in current on the interposer board.

Debug: Calibrations, Crosstalk, and Characterization

Future characterization of the electrical crosstalk in the OSMO will allow for more precise characterization of optical crosstalk, once a voltage 'spike' issue is resolved in the current sampling system. Also planned is the development of a 'concentrator' PCB which will be able to interconnect many OSMO devices into a single readout system..

Electrical Crosstalk tests are planned to start this November..





Figures 5/6 (top/bottom) Left, is a full sampled waveform digitized with a DRS4 sampled at 5 GHz. An issue with initial waveform sampling is the semi-periodic spikes that show up on the trigger waveforms.

A zoomed in graph of the above. The noticeable peaks happen at single digitized points and are the last hardware calibration step before detector calibration.

References

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Acknowledgments

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