Prototype Printed Circuit Board for Readout of a Handheld Dual Particle Imager

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Introduction

Abstract

A handheld dual particle imager (H^2DPI) is being designed and built for nuclear nonproliferation and safeguards applications. The design has been made compact through the use of silicon photomultiplier (SiPM) arrays coupled to stilbene crystals. To meet the requirements of the H^2DPI, the readout electronics for this imager must:

- Be durable
- Be compact
- Output pulses with precise timing and height proportional to deposited neutron energy

To that end, a custom printed circuit board (PCB) is being designed to read out signals from SiPM arrays for further data processing.

SiPM Array

- SensL ArrayC-60035-64P
- 64 SiPM pixels, which can be individually read out
- Each pixel is composed of 18,600 light-sensitive photodiodes
- Microcells sum together to produce a pulse at the anode of the pixel when struck with light
- Each measured pulse contains information about the position, time, and deposited energy of the interacting particle
- Proper readout from the sensor array is essential for accurate imaging

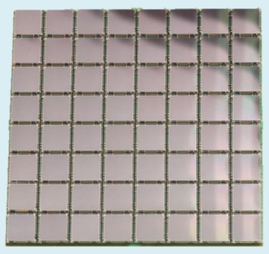

Figure 1: SensL ArrayC—64P SiPM Array

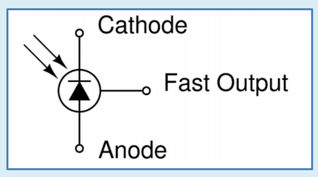

Figure 2: SensL SiPM component

8-Pixel SiPM Readout PCB

- Simultaneously reads out eight strategically placed pixels
- Preserves accuracy of signal shape and timing through impedance matching and trace length matching
- Accepts voltage bias from and reads out SiPM signals through independent SMA jacks

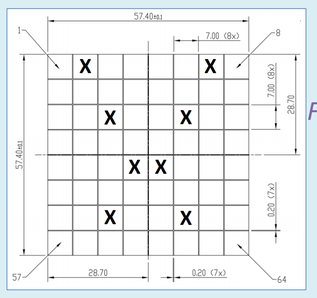

Figure 3: 8-pixel array layout

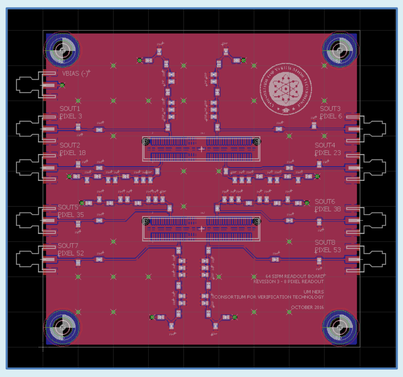

Figure 4: 8-Pixel SiPM Readout PCB in CadSoft Eagle

Design Process

Simulation

- LTSpice SiPM model produces simulated waveforms of a single pixel
- Observed effects of changing readout methods on signal:
  - Rise time
  - Peak height
  - Signal shape
- Facilitates optimizing readout circuit for accurate timing and pulse height response

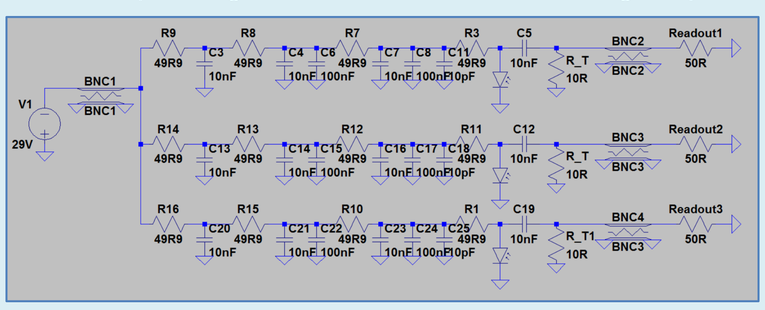

Figure 5: LTSpice simulated 3-pixel readout circuit

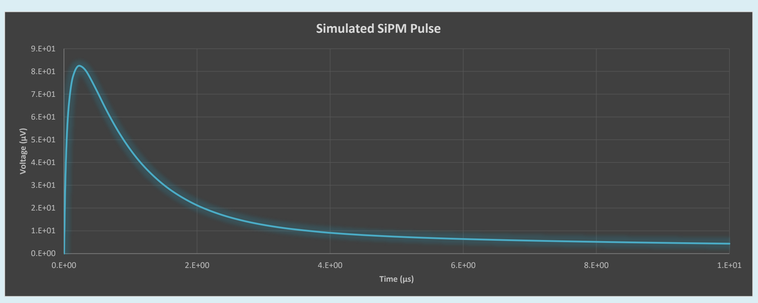

Figure 6: Simulated pulse

Prototyping

Stage 1 Experimental Setup:

- Perfboards
- Through-hole components
- SensL ArrayC-60035-64P Breakout Board
- Power supply
- Oscilloscope
- Dark box

Figure 7: Oscilloscope measurement setup

Stage 1 Results:

- Observed similar pulse shape and height to simulation
- Small, but significant crosstalk – product of lower quality construction

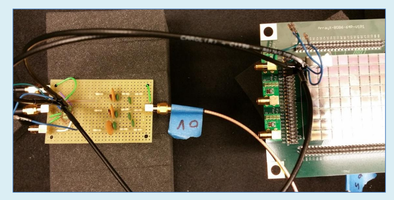

Figure 8: Perfboard / breakout board measurement setup

Stage 2 Experimental Setup:

- Printed circuit boards
- Surface mount (SMT) components
- SensL ArrayC-60035-64P SiPM Array
- Power supply
- Digitizer
- Dark box

- Generated schematic and board files in Eagle
- Printed boards via external supplier
- Assembled board and components via reflow soldering
- Evaluated boards: TB-1, TB-2a, TB-2b

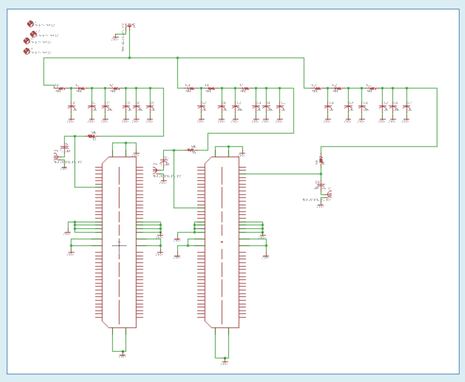

Figure 9: Prototype TB-1 Eagle schematic

TB-1 Results: Standard voltage bias filter

- Largest noise of all stage 2 prototypes
- Strong timing resolution
- No observed crosstalk

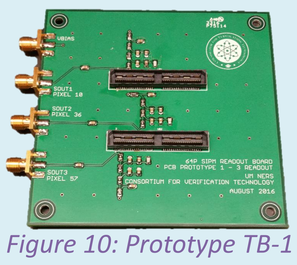

Figure 10: Prototype TB-1

TB-2a Results: Resistors removed from bias filter

- Least noise
- Appreciable crosstalk observed
- Strong timing resolution

TB-2b Results*:* Standard filter, "timing resistor"

- Moderate noise
- Strongest timing resolution
- No observed crosstalk
- Small pulses

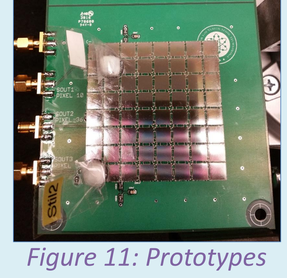

Figure 11: Prototypes TB-2a and TB-2b

Further Work

- Determine optimal readout circuit, taking findings from prototypes into consideration
- Apply this design to 8-pixel readout PCB
- Construct H^2DPI to deliver maximum timing performance, energy resolution, and robustness

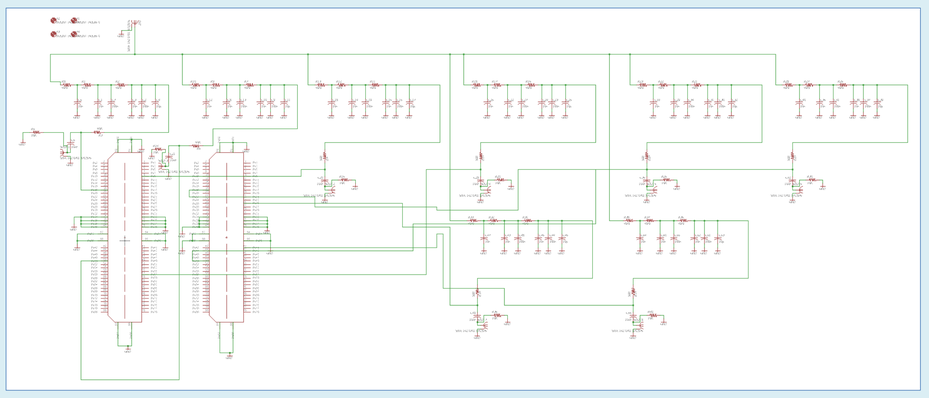

Figure 12: 8-pixel readout board preliminary schematic

Conclusions

- Prototype PCBs produce faithful readout signals for 3 pixels
- Several designs are being tested, with different timing and pulse height responses
- Expanding to 8 pixel readout is trivial once a design is selected

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