A Novel Optical Communication Scheme for a New Clock-less Q-Pix Detector Design

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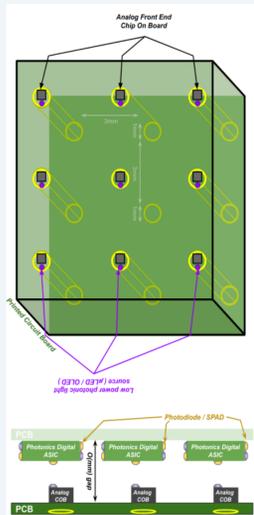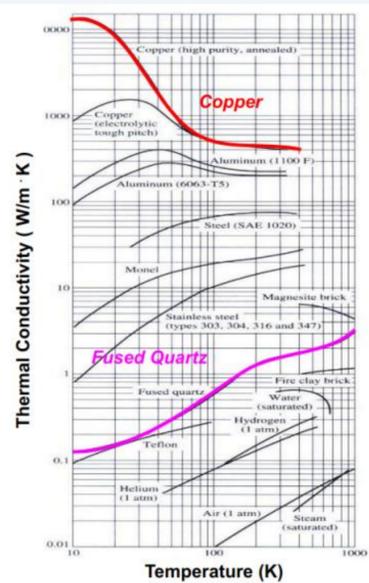
Motivation
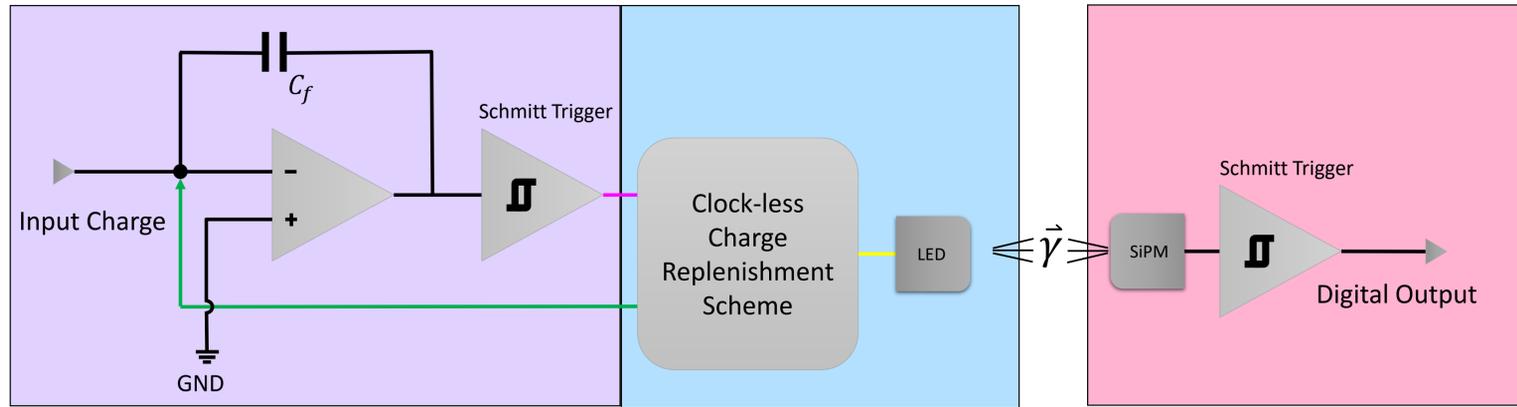
Why Optical?
- No wires into detector ASIC -> greatly reduced noise from:
  - Parasitic Capacitance
  - Analog to Digital Cross Talk
  - External Sources
- Reduction of Thermal Load into Cryogenic Detectors
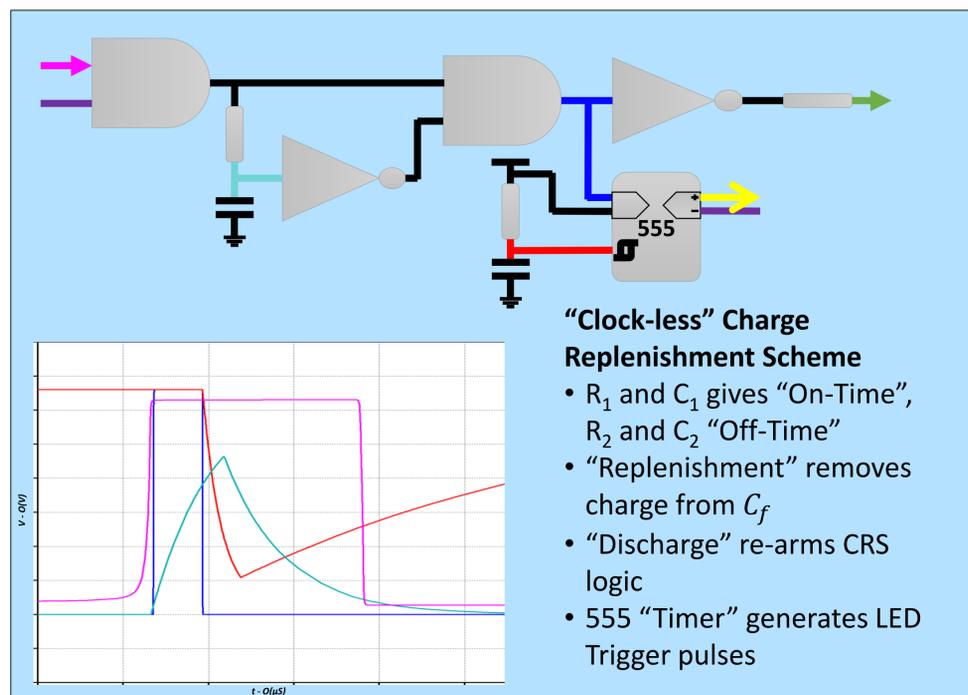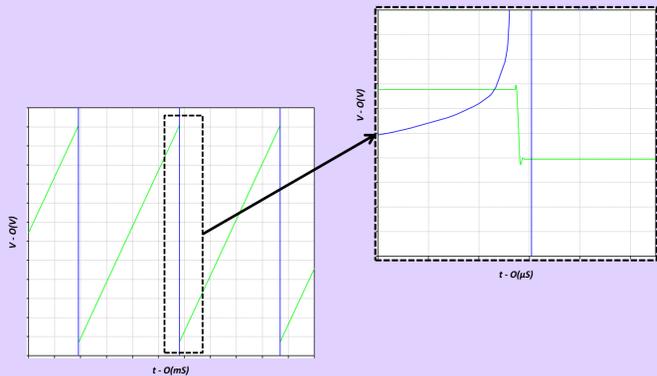- Digitization on detector-side -> greatly increased sensitivity

Scaling Up?
- µLEDs and OLEDs offer high energy efficiency, long lifespan, and improved contrast and resolution
- Single Photon Avalanche Diodes (SPAD's) and Photodiodes offer high sensitivity and high fidelity
- Creating an optically separated array of LEDs and Photodiodes -> easy scaling

Detector Design and Communication Scheme

Charge-Integrate/Replenish (CIR) Circuit
- Integration of voltage on C_f - ($Q = CV$)
- On when voltage threshold is met, off when voltage goes low
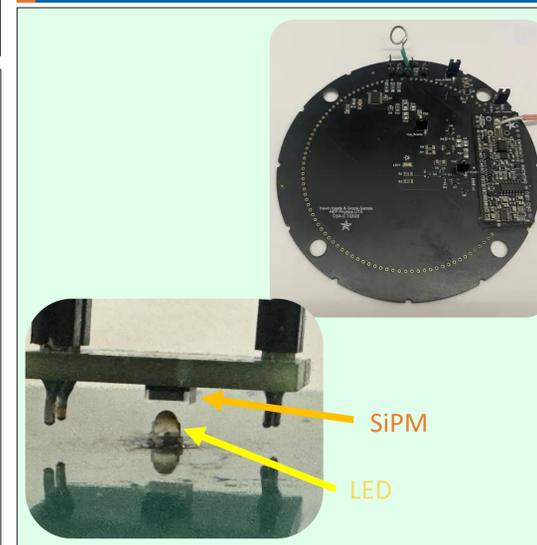- Width of the Schmitt Trigger output(s) proportional to ΔQ

Photonic Back-end
- Silicone Photomultiplier (SiPM) used to generate a signal from LED
- Schmitt Trigger converts raw signal from SiPM to digital pulse
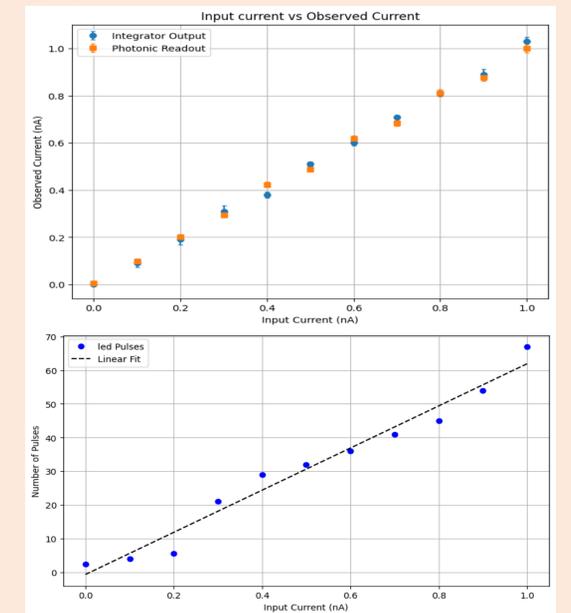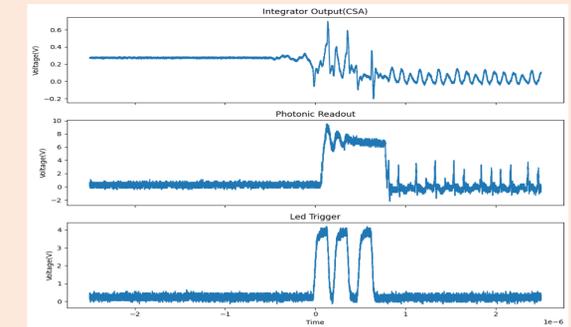- Digital pulse used for readout system (FPGA, ASIC, ect.)

"Clock-less" Charge Replenishment Scheme
- R_1 and C_1 gives "On-Time", R_2 and C_2 "Off-Time"
- "Replenishment" removes charge from C_f
- "Discharge" re-arms CRS logic
- 555 "Timer" generates LED Trigger pulses

Testbench Setup

SiPM
LED

Acknowledgments

Testing Results

Results
- CIR output matched with de-integration on input (across C_f)
- SiPM-side didn't match LED input exactly, but was able to width of the signal correctly
- Number of LED Trigger Pulses varies, but gives roughly the same width overall

Next-Steps
- More work is needed on Charge Replenishment Scheme and Photonic Back-end to successfully implement into a Q-Pix design
- Input noise needs to be minimized to increase sensitivity to targeted fC/replenishment range
- Device needs to be calibrated in cold for "Liquid Noble" testing upon successful bench calibration