PROJECT PURPOSE:

Our sponsor GeneWEAVE, a Division of Roche Molecular Systems, utilizes a photomultiplier tube (PMT) to detect bioluminescent bacteria in a test tube for medical diagnostics. PMTs are expensive and bulky, so our job was to procure and analyze an inexpensive, compact, ultra-low light detection device that could be used to replace the PMT used in GeneWEAVE’s VivoDX system. The bioluminescent bacteria emits blue light (490 nm wavelength) with a photon count rate as low as 200 photons per second. The detector device we chose was a SensL C-Series 1mm² silicon photomultiplier. To implement this device, we designed a customized signal processing circuit, detector housing, and cooling system.

PHOTOMULTIPLIER TUBES:

ADVANTAGES:
- Ultra Low Dark Count: 20Hz
- High Photon Detection Efficiency (~25%)
- High Gain

DISADVANTAGES:
- Bulky
- Damaged By Ambient Light
- Expensive

SILICON PHOTOMULTIPLIER (SiPM):

ADVANTAGES:
- Array of Avalanche Photodiodes (APDs) in Geiger Mode
- Inexpensive
- High Gain
- Compact (1mm²)
- High Photon Detection Efficiency (~29%)

DISADVANTAGE:
- Moderate Noise: 30 kHz

CHALLENGES & POTENTIAL SOLUTIONS:

Compared to a PMT, our dark count of 6 kHz was low enough to detect light from GeneWEAVE’s supplied 1pW stabilized light source but too high to see a minimum count of 200 photons/sec.

OVERCOMING HIGH DARK COUNT
- SiPM Cooled to 5°C Reduced Dark Count From 32 kHz to 6 kHz
- More Cooling Would Further Reduce Dark Count

FOCUSBNG THE LIGHT SOURCE
- Using Larger SiPM Area Would Allow More Photons to Hit Detector
- Optimize Housing as Light Guide to Increase Photon Flux

MAINTAINING CONSTANT LOW TEMP OF SiPM
- Water Cooling System to Avoid Localized Heating
- Use Temperature Control Circuit to Stabilize Dark Count

DATA:

Pulse Count Sample from the SiPM

Next Generation Light Detection System

Team: Duke Nguyen, Zachary Davis, Jonathan Sladewski, Saman Salari

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DETECTOR SYSTEM:

LIGHT ISOLATION HOUSING:
- Blocks Ambient Light
- Houses Test Tube and SiPM Detector
- Contains a 40x40mm² Cooling Fan
- Reflective Tape Inside

LOW AREA HIGH SENSITIVITY DETECTOR:
- SensL SiPM 1mm² Detector Area
- Detector Attached to a Peltier Cooler to Reduce Dark Count

DARK COUNT REDUCTION COOLER:
- 40x40mm² Peltier Cooler
- At 8V Bias, Cools the SiPM to 4°C
- Opposite Side Affixed to a Heatsink
- No Significant Electrical Noise

SIGNAL PROCESSING CIRCUIT:

- Integrating Transimpedance Amplifier Followed by Differentiating Amplifier
- Output Voltage Proportional to Input Current
- High Gain with Low Added Noise
- Low Charge Injection Switches Reset Integrator

System Block Diagram

Temperature Vs. Dark Count

Pulse Count Vs.

Photon Count Rate