A Silicon Photomultiplier (SiPM) Based Readout for the sPHENIX Upgrade

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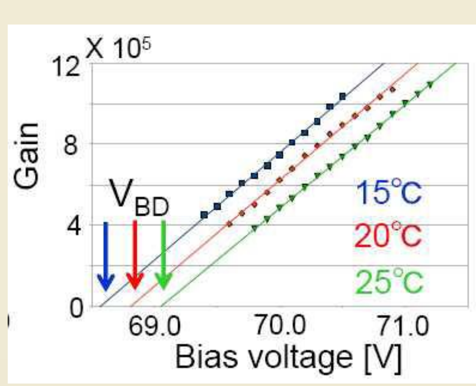
For the PHENIX Collaboration

Introduction:

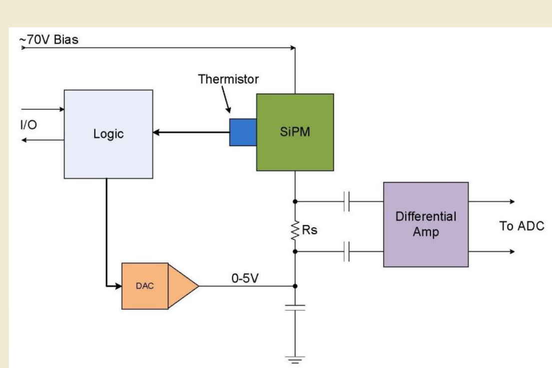
Conceived and constructed over a decade ago, the PHENIX detector was designed to discover the Quark-Gluon Plasma (QGP). Following on this discovery, the PHENIX collaboration has embarked on a number of upgrades to study the QGP properties in detail, with the next step being a significant overhaul of the PHENIX detector called sPHENIX. sPHENIX includes upgrading the central detector with a compact solenoid, electromagnetic and hadronic calorimetry to study jets produced in p+p, p+A, and A+A collisions at RHIC. The location of the calorimetry in vicinity of the solenoid requires an optical readout that is compact and immune to magnetic fields. For this reason, the sPHENIX calorimetry will use a Silicon Photomultiplier (SiPM) based readout system for both the electromagnetic and hadronic calorimeters. In this presentation, we present the current design status and performance of the prototype analog readout for the sPHENIX calorimetry based on SiPMs.

SiPM Voltage and Temperature Control:

- Hamamatsu S10362-33-25C
- Reverse breakdown voltage, Vbr ~ 70V
- Overvoltage range, Vov ~1-2V
- Vbr increases linearly with temperature, 56mV/^{0}C
- Factor of 2 gain per 1V increase in bias voltage
- Temperature compensation using closed feed-back loop
  - Thermistor
  - 10 bit ADC
  - Logic control
  - 10 bit DAC
- DAC reduces Vbr and provides full range of gain control



Gain vs temp and bias voltage
Minamino, Akihiro at al.
"T2K experiment: Neutrino Detectors"

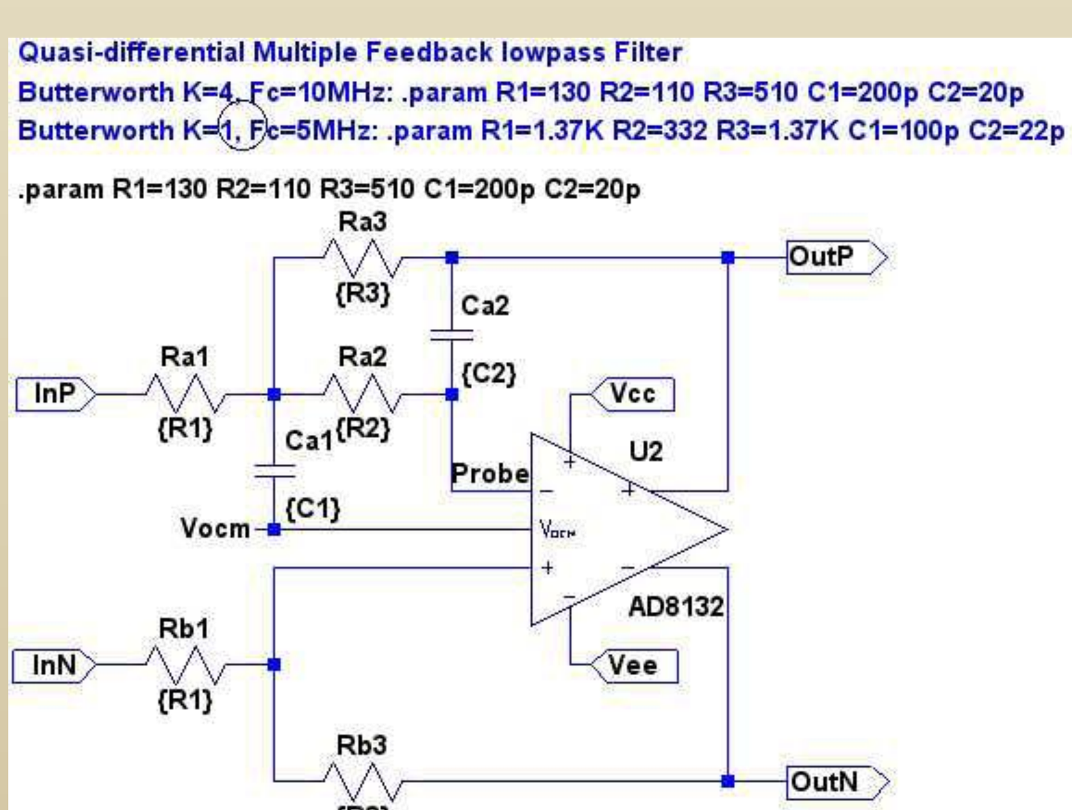


Block diagram of thermal Compensation circuit.

Preamp Circuit:

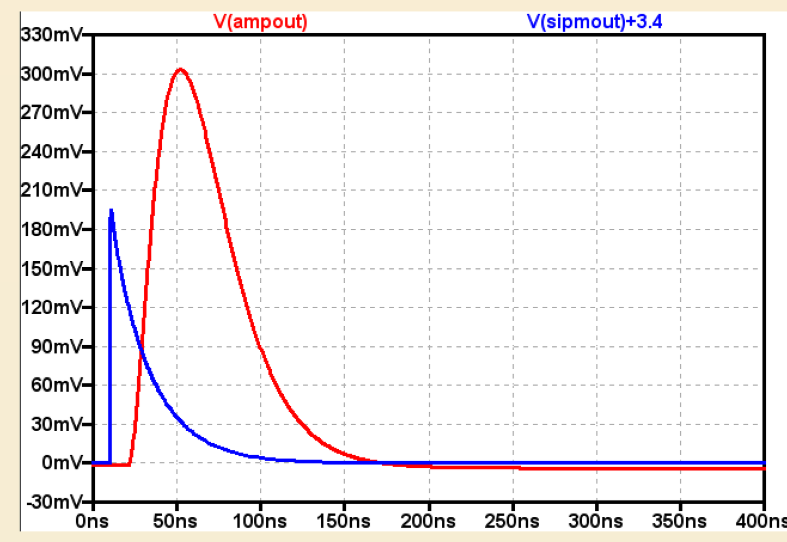
- 1 MIP = 142 MeV
- Single tower max energy: 40 GeV
- Dynamic range: 40GeV/142MeV = 282
- Measureable Energy: 40MeV
- Dynamic Range 40GeV/40MeV = 1000

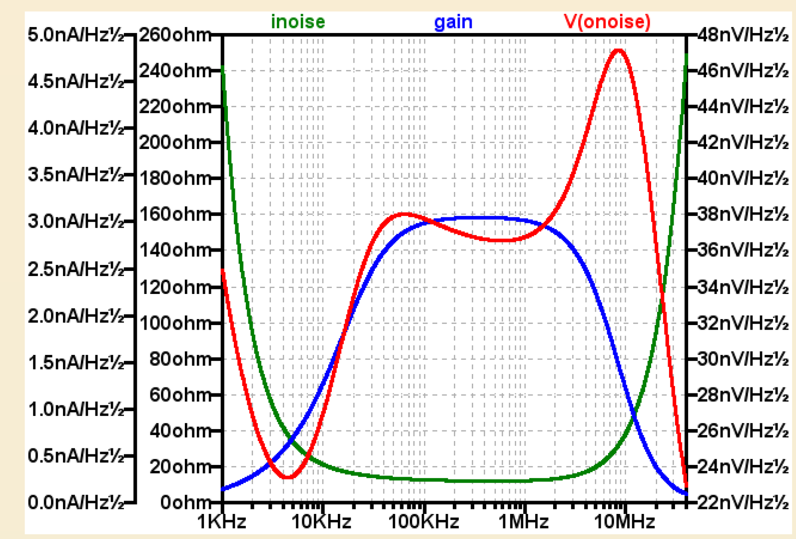
- 25 pe/Gev or 1pe = ~4MeV
- MIP Peak ~35pe
- 40 GeV ~10000pe
- ADC: 40GeV = 4000
- MIP in channel 14
- SiPM gain = 1x10^5



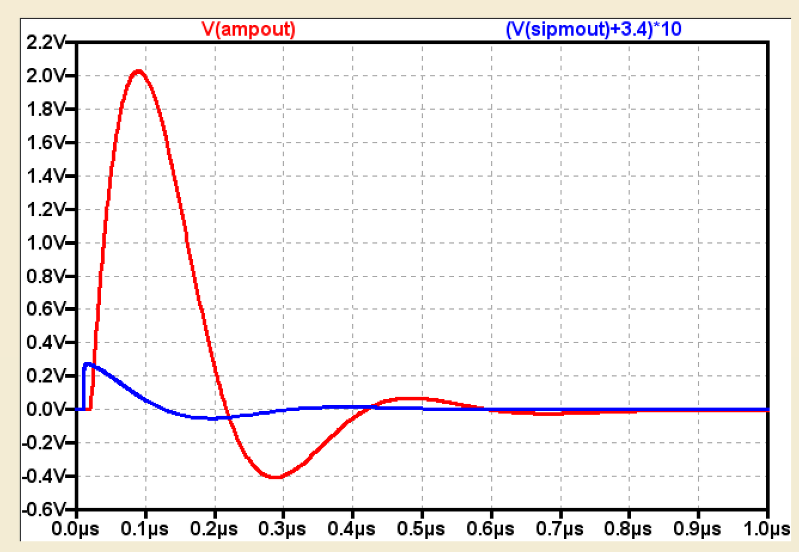
Comparison to Spice:

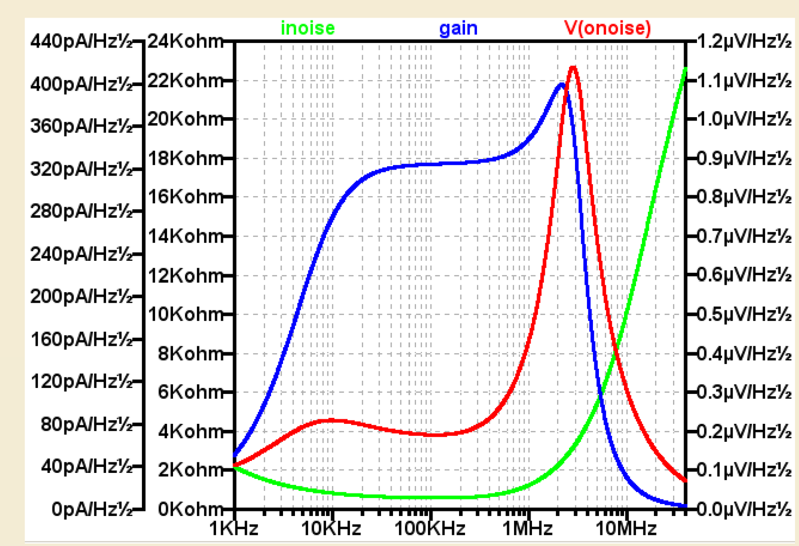
- SPICE:
  - Official SPICE model
  - Low-pass filter: K = 4, Fc = 10^6



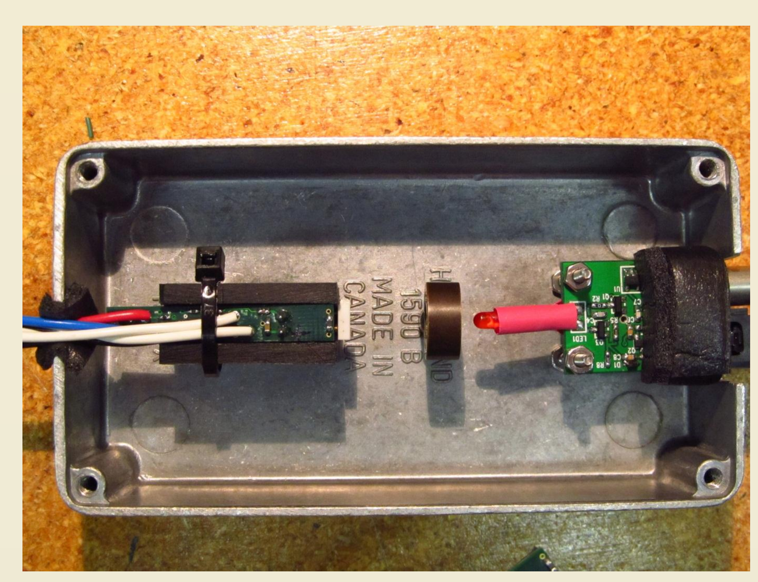


- Prototype Circuit
  - Standard Voltage amplifier: Gain = 200
  - Load Resistor: 1KOhms
  - No filter, op-amp provides bandwidth limit

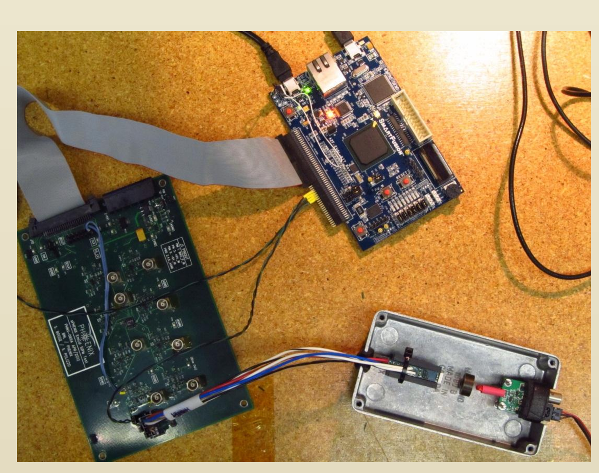




Prototype amplifier board with thermal bias compensation circuitry.



Prototype SiPM mounting. SiPM is in the center. Mounting board with thermistor on left, and LED with pulser circuit on right.



Prototype SiPM readout. SiPM with thermistor and LED pulser is in the lower right, preamplifier with thermal bias compensation is lower left, and digitization and data acquisition is top center.

Conclusions

We have designed a prototype temperature compensating voltage control and preamplifier for the Hamamatsu S10362-33-25C SiPM to be used for the EMCAL and HCAL detectors in the sPHENIX upgrade. Preliminary analysis of the prototype circuit shows that the performance is consistent with SPICE models. The next step will be to design and fabricate a 32 channel system that can be used with the EMCAL and HCAL prototype modules being constructed as part of the sPHENIX upgrade project.