



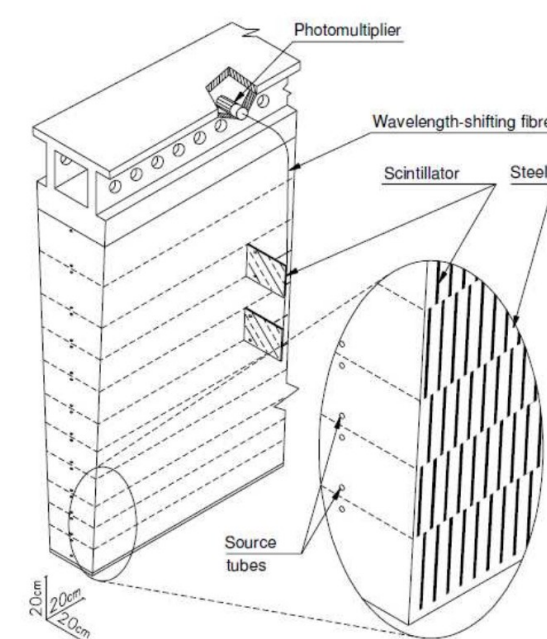
Noise Characterization of the ATLAS Tile Calorimeter Readout System



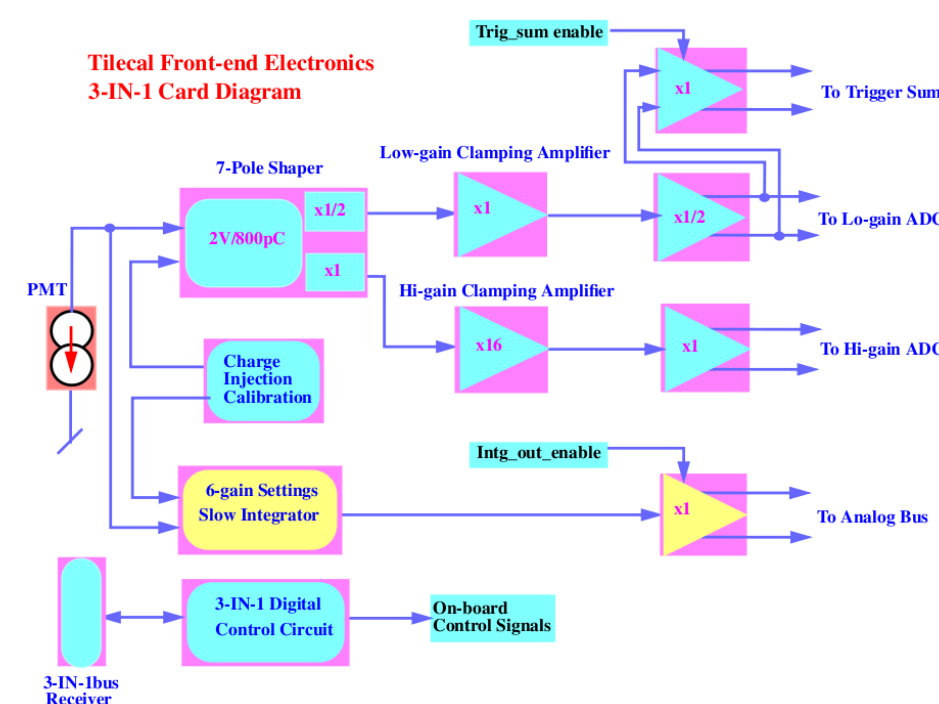
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Introduction

ATLAS, a detector at the Large Hadron Collider (LHC) in Geneva, Switzerland is set to start operations in September 2009. The University of Chicago has been largely responsible for the Tile Calorimeter, a steel-scintillator hadronic calorimeter, and in particular the readout system.

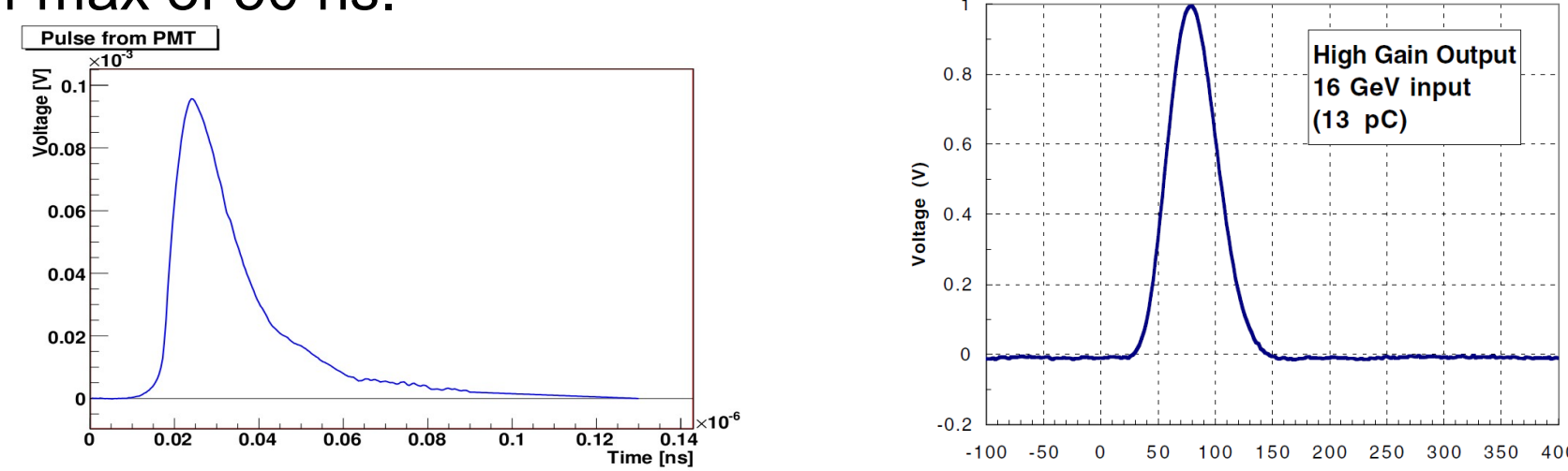


After energy is deposited in the scintillating material it is transferred via fiber optics to photo multiplier tubes. The pulse from these tubes goes into a 3-in-1 card which (1) shapes, (2) amplifies, and (3) outputs a differential signal which is sent to the Analog to Digital Converter (ADC). Once converted into a digital signal it is serialized with data from other PMTs and read out. Since the 3-in-1 card is where the most processing is done on the analog signal it is important that it introduce as little noise as possible.



3-in-1 Card

The pulse coming out of the PMT has a 5.5 ns rise time and 11 ns fall time with jagged edges due to photo-electron effects. The 7 pole shaper takes this signal and reshapes it so it has a full width at half max of 50 ns.

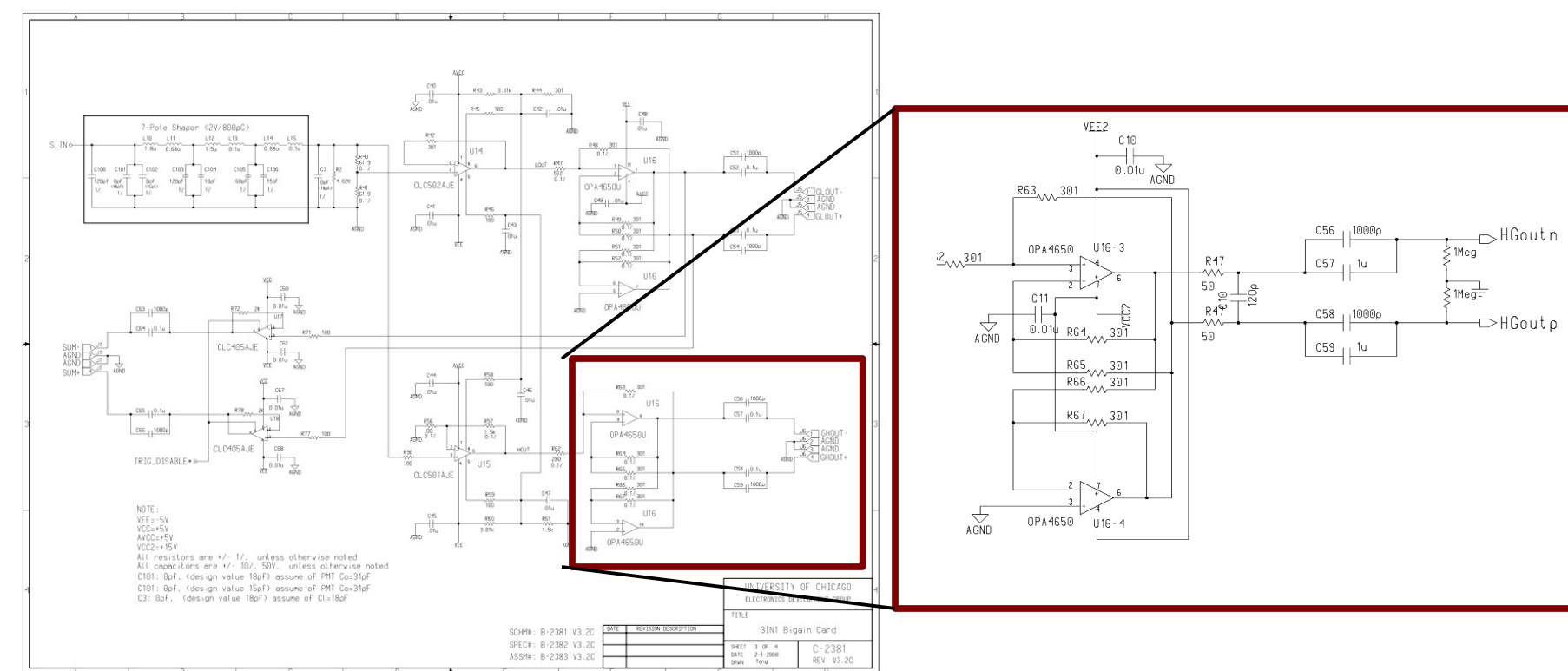


The signal is then split and put through low and high gain amplifiers with a relative gain of 64. To cut noise picked up in the transfer from the 3-in-1 card into the ADC the signal is put into differential mode before leaving the circuit.

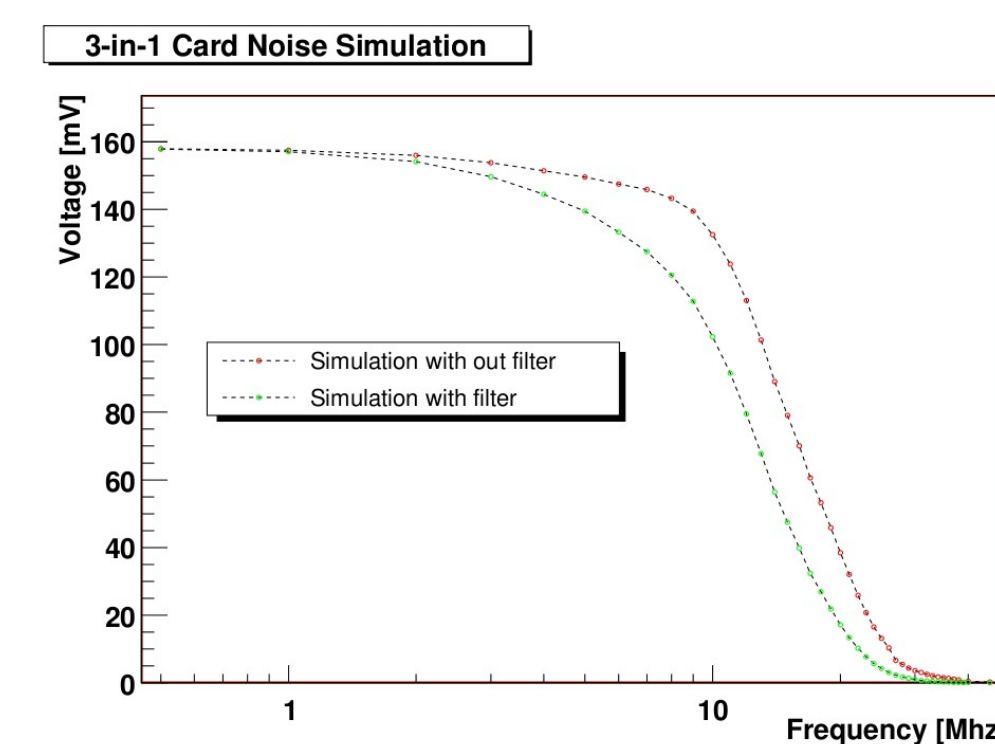
The relative gain of 64 was chosen so that 16-bits of dynamic range could be achieved on the input signal from the PMT. Because only a 10-bit ADC is used the extra 6 bits comes from the bi-gain system difference of 64. 16 bits are needed to accurately sample the range between 30 MeV and 2 TeV expected for a given calorimeter cell.

Circuit Simulation

The original circuit and modification:



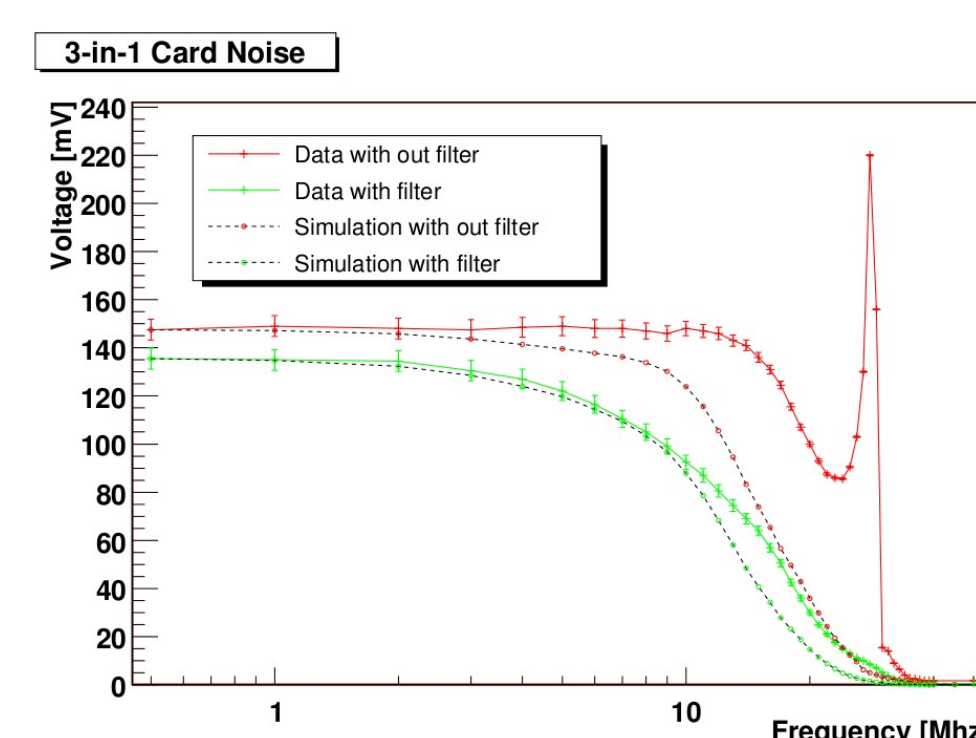
A simple low pass filter with $R=50 \Omega$ and $C=120 \text{ pF}$ was used in the output stage of the differential driver. Mentor graphics was used to simulate the circuit with and without the modification.



The design 3dB point of the filter is 13 Mhz. This is consistent with the simulation of the filtered circuit (above, green). Since the purpose of the circuit is to pass pulses of approximately 10 Mhz care will need to be taken that that frequency is not overly suppressed in attempts to cut out noise in other regions.

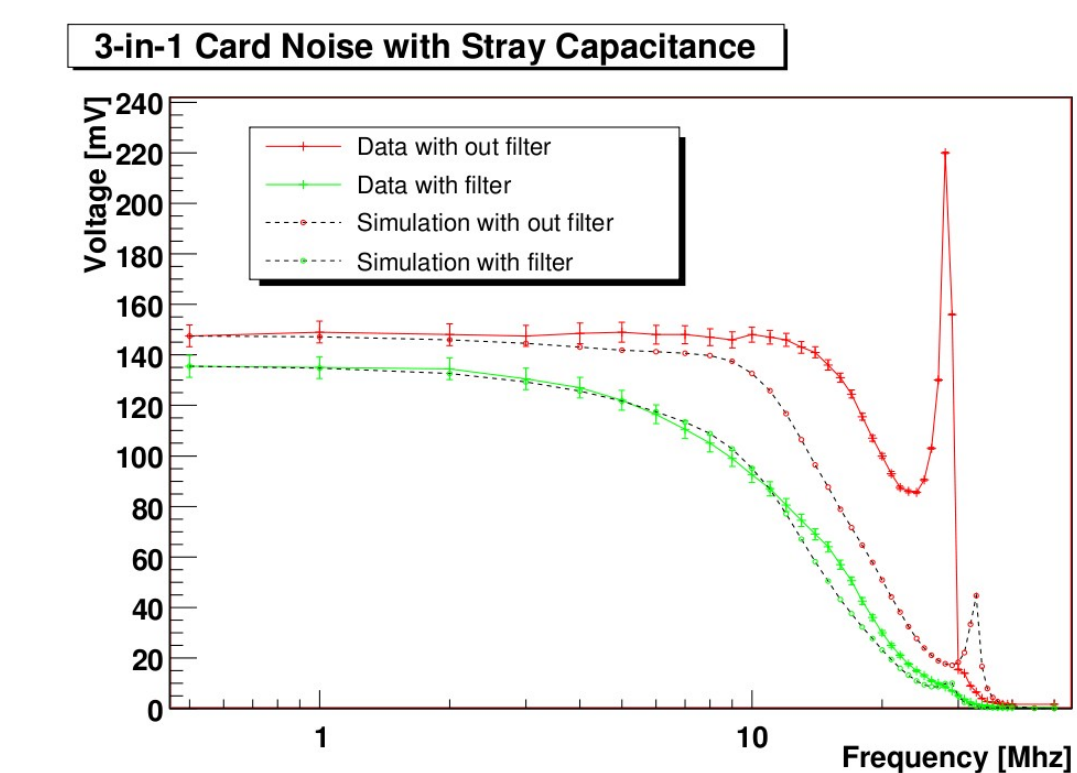
Results

A Tektronix AWG 2040 function generator was used to input sinusoidal "noise" in the PMT input and a Tektronix 3054B oscilloscope to read the voltage from GHOUT+. An amplitude of $\pm 10 \text{ mV}$ was fed in with varying frequency.



The filtered circuit behaves similarly to expectations. The unfiltered circuit develops a peak at 29 Mhz that was neither in the design specifications nor did it show up in the simulations.

Stray capacitance sometimes develops when a circuit is printed on an actual board due to proximity of components and leads. As a simple toy model a 33 pF capacitor was placed between the input stage and ground to see the effect on the circuit.



This introduces a peak in the higher frequency range as well as bringing the 3dB point up, the same behavior we see in the circuit. Similar to the actual circuit, the filter suppresses this peak!

Conclusions

Introducing a low pass filter with bandwidth at -3dB of 13 Mhz decreases overall noise in the system. A previously unknown resonance in the circuit was discovered in the process, but the filter has the effect of almost completely suppressing it.

Acknowledgements

Thanks to Professor Mark Oreglia, Kelby Anderson, Fukun Tang and The Tilecal group for their help and support along the way.

References

- [1] ATLAS Collaboration, JINST 3 **S08003** (2008)
- [2] Anderson, K. et al., Front-end Electronics for the ATLAS Tile Calorimeter (1998)
- [3] The Tilecal Group, ATLAS TileCal Front End Electronics sLHC Upgrade Environment (2009)

Further Information

The full report can be found online at: hep.uchicago.edu/~cjmeyer/noise.pdf

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