DØ Note 3248

Increase in Supply Currents due to Signal Response for Run 2 Calorimeter Preamplifiers

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1 Introduction

We use the SPICE circuit simulation program to estimate the transient supply currents drawn by the Run 2 calorimeter preamplifiers when responding to signal. We simulate the response to infrequent but large input signals produced by high energy particles, and frequent small signals due to energy flow from minimum bias events.

2 Preamplifier Design

The schematic of the preamplifier circuit that we simulate is shown in figure 1. This schematic differs in some respects from the prototype circuit actually built, due to differences between the SPICE device models and the actual components. Hence we expect small differences between the calculated and measured quiescent DC bias voltages and currents, however the transient response calculation is sufficiently reliable. We simulate the signal produced by the calorimeter cells as a sequence of triangular current pulses. The current pulses have a fast rising edge and a falling edge that ramps down linearly to zero in 430 ns (charge drift time in the liquid argon gap). The outputs of stage 1 and 2 are loaded with 100 kΩ as we are not currently planning to use these outputs. The stage 3 output is terminated into 115 Ω. The supply voltages are +8V, +12V and -6V. The charge-integrating feedback capacitor (C3) is 10 pF in this case, as would be used for EM layers 3 and 4.

3 Supply Current Transients during Large Signal Response

An input current pulse with peak amplitude of 180 μA causes this preamplifier to produce the maximum output swing, which is $\sim$5V at the Baseline Subtractor (BLS) input (C25 in the schematic). This produces a transient load current $\sim$ 50 mA which is supplied by +12V (V5) and sunk by -6V (V2) due to the AC coupling of the output.

Over short time scales we expect some part of these large transient currents to be supplied by the power filtering capacitors. Over longer time scales the capacitors will be charged by the power supplies. Figure 2 shows the currents drawn by the supplies. There is minimal change in the +8V supply current. The maximum current change from the -6V supply and the +12V supply is $\sim$5.4 mA.

We have assumed that the 2.2 μF filtering capacitors are effective at these high frequencies. If one uses polar (tantalum or electrolytic) capacitors which have poor high frequency response, then their ability to supply the transient current rapidly is suspect. In this case, the extra transient currents must be supplied by the power lines from outside the preamplifier, or the power voltages will sag.

To simulate the extreme case, we remove the 2.2 μF filtering capacitors from the schematic and repeat the calculation. Figure 3 shows the results. We now see peak current requirements of 40 mA from the 12V supply, and 27 mA peak current on the -6V supply. We also notice voltage sags on the power lines due to the drop across the 10 Ω filtering resistors. It is therefore preferable to use ceramic 2.2 μF or larger capacitors for filtering because they are expected to have good high frequency response.

The rate of such large signals is unlikely to be more than a kiloHertz. Since the currents transients are of the order of 100 μs in duration, we expect an increase in the average current due to large transients of no more than 0.5 mA.

4 Supply Current Transients for Small Repetitive Signals

Minimum bias interactions produce energy flow and occur frequently, producing small signals at high rate. The transient currents produced in response to these signals can also increase the average supply current.

The total energy measured in the central calorimeter (CC) at an instantaneous luminosity of $20\times10^{30}/\mathrm{cm}^2/\mathrm{s}$ is taken to be 20 GeV [1]. Taking the minimum bias cross section to be 50 mb, we get 1 minimum bias interaction per 5.7 $\times10^{30}/\mathrm{cm}^2/\mathrm{s}$ instantaneous luminosity in Run 1. Therefore we have 5.7 GeV/interaction in the CC, or 4.5 MeV/tower/interaction. At a luminosity of $10^{33}/\mathrm{cm}^2/\mathrm{s}$ in Run 2, the calorimeter will integrate over approximately 30 interactions, thereby sensing 135 MeV/tower. Most of this energy is deposited by low p_t particles in the inner layers of the calorimeter. We assume the worst case where all the energy in a tower is deposited in a single cell. Assuming 100 GeV full scale on the preamplifier output, this corresponds to 0.14% of the full scale input.

Figure 4 shows the preamplifier response for 0.056% full scale inputs at a repetition rate of 500 ns. In the CC this would correspond to an instantaneous luminosity of $4\times10^{32}/\mathrm{cm}^2/\mathrm{s}$. The stage 1 output develops a positive bias of 65 mV, which is AC-coupled to the stage 3 output on a time scale of $\sim$100 μs. As long as the luminosity is constant over time scales longer than $\sim$100 μs, the average supply currents would not change. If the luminosity changed over the time scale of 1 ms, the 1 mA output transient current over 100 μs would produce an average supply current of 0.1 mA on the +12V and -6V.

Figure 5 shows the response for 0.28% full scale inputs, corresponding in the CC to an instantaneous luminosity of $2\times10^{33}/\mathrm{cm}^2/\mathrm{s}$. The stage 1 output bias is now 330 mV. Depending on the time profile of the instantaneous luminosity, this can cause an increase in the supply current of up to 0.5 mA in the CC on the +12V and -6V.

The energy deposition in the endcap calorimeters (EC) is about eight times larger than the CC [1]. The minimum bias energy flow is roughly constant in transverse energy/cell for cells of constant area in $\eta\phi$ space. This means that the energy/cell increases with the cosecant of the angle. Therefore the voltage biases and current drains mentioned above are obtained at the corresponding lower luminosity for the EC channels.

5 Conclusions

The increase in the supply currents when the Run 2 calorimeter preamplifiers respond to signal is simulated. The two cases of infrequent large signals due to physics events and the frequent small signals due to minimum bias interactions are simulated separately. There is minimal change in the +8V supply current. Response to physics signals and the minimum bias energy would each contribute an increase of 0.5 mA (1mA total) in the +12V and -6V supply currents in the CC at TeV33 luminosity. The increase in the supply currents for EC channels would be approximately eight times larger at the same luminosity due to the boosted particle energies.

References

[1] DØ Note 3112, *Calorimeter Studies,* Joan Guida, Dean Schamberger, Jan Guida (October 21, 1996).