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R.P. Johnson

Tracker Temperatures Revisited

Following the confusion apparent in last week's tracker meeting minutes regarding the sidewall thermal conductivity, I decided to try to summarize the situation as it stands.

First of all, following the preproduction MCM run, we have some good statistics on MCM power consumption, since the currents are measured on each and every MCM. The measurements were made with VDD=2.5 V. From 27 MCMs (the 28th was bad with very high currents and rejected) we get the following average currents:

	Voltage	Current; Address=0	Current; Address=5
DVDD	2.5 V	51.99 mA	50.13 mA
AVDDA	1.5 V	48.62	48.60
AVDDB	2.5 V	13.57	13.54

This corresponds to power of 237 mW for the lowest layer and 232 mW for all other layers, or 8.37 W per tower, for a total of 134 W for the Tracker.

In fact, in flight we will have to run with VDD=2.6 V, to have good data-transfer margins. In a worst-case estimate the power would increase by $(2.6/2.5)^2$, for a total of 145 W for the Tracker. This is surely an overestimate, since the load is not really resistive. Most of the currents are due to transistor current sources, which are weakly dependent on voltage, so the true value should be closer to 140 W.

From CDR, the hot-case thermal model was done for 167 W dissipation. The cold case was for 140 W. Hence we appear to be falling much closer to the cold case than the hot. In the hot case the temperature rise in the walls was predicted to be 6 K.

This prediction was based on a thermal conductivity of the sidewall panel of 298 W/m·K. In the note HTN-102070-0015, written 3 years ago, Hytec estimated a conductivity of for our K13D panels of 272 W/m·K, based on a layup identical to the YS90 panels fabricated for the original mechanical prototype tower, with 60% fiber volume, but using K13D fibers for all but the outer fabric layers. This is the same layup that we are using in our design now, the only difference being that the fiber volume is now only 52%. Note that the coupons tested from the YS90 panels had conductivity about 20% higher than the Hytec estimate, leading me to suspect that Hytec was conservative and Jeff Wang's estimate of 298 W/m·K may be closer to the mark. We will find out in a few days, when we get the test results back on the Plyform coupons.

In any case, if we take the conservative Hytec estimate of 272 W/m·K and correct it for the fiber volume by a factor of 52/60, then we get 236 W/m·K. Applying this to the hot case would lead to a temperature rise up the wall of 7.6 K instead of 6.0 K. The hottest point in the Tracker would be 25.8°C instead of 24°C. This does not appear to me to be a difference to get very excited about, especially since our power is coming in more along the lines of the cold case.

Furthermore, I remind everybody that our upper temperature limit is a soft point chosen somewhat arbitrarily, not a brick wall. The limit is imposed by the silicon-strip detectors, which have leakage currents that are exponentially sensitive to temperature, as is typical for a reverse biased PN junction. The leakage current also depends on radiation dose. Our specifications are based on leakage current at end of life, where we assume an integrated radiation dose five times what is actually expected. The leakage current produces shot noise, which adds in quadrature with the amplifier thermal noise. If the noise starts to increase to a level that cannot be tolerated, then it becomes necessary to raise the threshold, resulting in a loss of efficiency. See LAT-TD-02320 for an analysis of this effect. The analysis shows about a 2% loss of efficiency for a 10 K increase in temperature above the CDR model. I think even that analysis was conservative, as it assumed that the discriminator threshold would have to be kept at least 5 times the noise. Such a ratio results in nearly zero noise rate, but the data acquisition can tolerate a higher rate.

In summary, unless we find something very anomalous in the coupon test, I do not see any reason to consider changing the sidewall specification with respect to what we produced for the engineering model.