CABLES, CONNECTORS, etc, for CAENs and OFTM

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1 Introduction

This note is intended to provide an update to the various cables and connectors for the connections between the power supplies (CAEN), the Optical Fib Transition Module (OFTM) and the Junction card (JC).

The junction card will take power from the CAEN power supplies and timing/control signals from the OFTM and merge them onto a single Cu-Kapton cable which is routed to the port card. The current design calls for four cables which run from the power supplies to the junction card, and a fifth cable which runs from the OFTM to the junction card. Below I give some of the part numbers, and a brief description of these cables and the connectors for each end of the cable. Also I give the necessary mating connector which would be mounted on the junction card.

A detailed report of the SVX cabling was presented to the cable committee and can be found in the Ref. [1]. This note is an update to the information presented there.

In the final section of this note, we present evidence that a reduction in the cable gauge for the analog and digital voltages should not cause any fire safety/hazard problems. The temperature rise in the cables is estimated for 22 and 24 AWG cables with currents of 0.5, 1.0, and 2.0 Amps per conductor. For the currents we expect to use, there should not be any problem with excessive heat generation.

2 Analog Low Voltage (ALV) Cables

The analog low voltage cables carry the voltages for the analog section of the SVX3 chip. The current for each layer scales nearly as the number of chips. The cable which carries the ALV is a flat cable, with all wires having the same gauge. Therefore, the number of wires used to carry the current in this cable increases with layer number. Below in Table 1 [2] is the expected current for each layer in the ALV and return line, the number of conductors carrying the current, and the current/wire.
Below we give the details of the cable and connectors for ALV

Cable: Amphenol #843-111-2214-024
Details: 24 conductor, 22 AWG wires, flame retardant PVC insulation, unshielded. Lead time 4-6 weeks.

Connectors for cable: Positonic #ODD26M1000Z plug
Details: Lead time: 8-9 weeks
*We reccommend the alternative AMP connectors (below), which have a much shorter lead time.

Layer #	Expected current (A)	# Cond.	Current/Cond.
0	0.32	1	0.32
1	0.48	2	0.24
2	0.64	2	0.32
3	0.80	3	0.27
4	1.28	4	0.32

Table 1: Listing of the expected current in the ALV lines and their return lines for each layer, the number of lines assigned to the layer in the flat cable, and the corresponding current per wire.

Preferred AMP connector on cable:
AMP # 748365-1 Steel shell plug
AMP # 748333-4 Pins
AMP #??????? Shell

Connector on JC:
Positronic # ODD26F3S60T2X Vertical socket
Alternative: AMP #216282-1 Vertical socket
Alternative: AMP #748481-5 Right angle socket. $10 ea. from Newark

* Note that pin assignments/board footprint differ between a vertical socket and a right angle socket.

3 Digital Low Voltage (DLV) Cables

The digital low voltage cables carry the voltages for the digital section of the SVX3 chip and the port card voltages. The average digital current consumed by the chip is significantly less than the analog section. The 3 states of the chip are ACQUIRE, DIGITIZE, and READOUT. During ACQUIRE, all the front end integrators are running, but the data is not being digitized or read out. During DIGITIZE, the date from a pipeline cell has been transferred to the back end of the chip and is being digitized. When in the ACQUIRE or DIGITIZE cycles, all chips are acquiring data or digitizing simulataneously. The third state, READOUT, means that the back end drivers are sending data to the FIB. Only 1 chip on a ladder is reading out at any given time. The currents drawn on the DLV supply during the ACQUIRE, DIGITIZE, and READOUT states are approximately 10 mA, 15 mA, and 45 mA per chip respectively. During ACQUIRE and DIGITIZE, the total DLV current scales as the number of chips. However, during READOUT, only 1 chip reads out at a time, so that a 14 chip device during READOUT has a current draw on the DLV supply of $\approx$45 mA + 13$*$10 mA = 175 mA. These numbers are based on an email from George Pope, whereas the numbers in Table 2 are from Sergio Zimmerman. There is some difference between the two estimates, so I use the higher ones from Sergio Zimmerman.

Like the ALV cable, the DLV cable is a flat cable, with all wires having the same gauge. As before, the number of wires used to carry the current in this cable increases with layer number. Below in Table 2 [2] is the expected current for each layer in the DLV and return line, the number of conductors carrying the current, and the current/wire.

Layer #	Expected current (A)	# Cond.	Current/Cond.
0	0.13	1	0.13
1	0.15	1	0.15
2	0.17	1	0.17
3	0.20	2	0.10
4	0.27	2	0.14
5V DOIM	2.0	6	0.33
2V DOIM	1.2	4	0.37
DGNDP	0.8	10	0.08

Table 2: Listing of the expected current in the DLV lines and their return lines for each layer, the number of lines assigned to the layer in the flat cable, and the corresponding current per wire. Also shown are the expected current drawn from the 5V DOIM and 2V DOIM supply, as well as the return path DGNDP. Note that for the layer currents, there are also return wires which carry the same current.

Note that the currents per wire are quite low. This was to protect against an undesirable feature of early versin of the chip in which the chip, when first powered, would go into an undefined high current state, until the chip was initialized. After the initilization, the chip would return to the low current state. This probnlem is believed to have been fixed. We therefore may consider reducing the number of lines assigned to each layer. Also, we should determine whether ten 22 AWG lines are necessary for DGNDP.

Below we give the details of the cable and connectors for DLV

Cable: Amphenol #843-111-2214-034
Details: 24 conductor, 22 AWG wires, flame retardant PVC insulation, unshileded. Lead time 4-6 weeks.

Connectors on cable: Positonic #ODD44M1000Z plug
Details: Lead time: 8-9 weeks
* We reccommend the alternative connectors, which have a much shorter lead time.

Preferred connector for cable: AMP # 748366-1 Steel shell plug
AMP # 748333-4 Pins
AMP #??????? Shell

Connector on JC: Positronic # ODD44F3S60T2X Vertical socket
Alternative: AMP #216283-1 Vertical socket
Alternative: AMP #748482-5 Right angle socket. $6 ea. from Newark

* Note that pin assignments/board footprint differ between a vertical socket and a right angle socket.

4 Sensor Bias Voltage (SBV) Cables

The sensor bias lines draw only a small amount of current, i.e., the leakage current of the detector. Each layer requires 3 lines, one for positive voltage, one for negative voltage, and a third for ground. We therefore need a total of 15 lines for this cable. Since the lines come in triplets, we decided not to go for twisted pairs.

Below we give the details of the cable and connectors for SBV:

Cable: 3M #3517/15 (custom, with drain wire?)
Details: 15 conductor flat cable, 28 AWG wires, shielded and jacketed, PVC insulation. Lead time, cost?.

Comments: This is NOT a standard 3M cable, and would be a custom order. The shield will be grounded via contact with the connector shell. Claudio Rivetta is also looking into the possibility of having a drain wire in the cable which can be attached to the screw on the side of the connector. The jacket on this cable is also too bulky, and we need to inquire about getting a thinner jacket around this cable. Lead time??
Connectors on cable: 3M # 8225/15 plug, Shell: P/N ?
Details: Lead time: ?

Connector on JC:
AMP #1-747299-4 Vertical mount receptacle
AMP #1-745782-6 Right angle mount receptacle

5 Remote Voltage Sensing (RVS) Cables

The remote voltage sensing cables are used to control the digital voltages at the junction card. That is, the power supply controls it's DLV outputs so that the voltage at the junction card is set to the desired value (i.e., 5 V). These lines draw very little current, as their inputs at the power supply are high input impedance.

We are planning to sense the five DLV's for the five layers, the 5V DOIM, and the 2V DOIM voltages. That makes a total of 7 voltages which need to be sensed. Each of the 7 lines consists of a twisted pair for added noise protection (14 lines).

Below we give the details of the cable and connectors for RVS:

Cable: 3M #1785/14 (custom, with drain wire?)
Details: 15 conductor twisted pair cable, 28 AWG wires, shielded and jacketed, PVC insulation. Lead time, cost?.

Comments: This is NOT a standard 3M cable, and would be a custom order. The lowest number of conductors for this particular cable, without going to a special order, is 20. The shield will be grounded via contact with the connector shell. Claudio Rivetta is also looking into the possibility of having a drain wire in the cable which can be attached to the screw on the side of the connector. The jacket on this cable is also too bulky, and we need to inquire about getting a thinner jacket around this cable. Lead time??

Connectors on Cable: 3M # 8225/15 plug.
Details: Lead time: ? Shell: P/N ?

Connector on JC:
AMP #1-747299-4 Vertical mount receptacle
AMP #1-745782-6 Right angle mount receptacle

6 FIB control/timing signals

The FIB control timing signal are used to carry LVDS control signals and clocks to the port card, which are used to control the SVX3 chip.

Here are the details of the "default" cable we plan to use: Cable: 3M #90201/26

Details: 26 conductor high density flat cable, 30 AWG, shielded and jacketed, TPE insulation, PVC jacket.
Cost: $750/100 feet. Quote by Avnet: $520 per 60 foot cable, with connectors and shells installed on both ends, 12-14 week lead time.

Cable Connectors: 3M # 10126-6000ec plug.
Shell: 3M #10326-1230-00 (Vince bought 100 of them)
Details: Lead time: ?

Connector on JC: 3M #10226-6212vc vertical mount receptacle.

**** Caution: For all the board mount connectors, make sure the post lengths are long enough for the PC board to which they will be mounted.

7 Reduction of Cable Gauge for ALV and DLV

As currently designed, the 22 AWG DLV cables do not fit through the 30 degree slots. The slots have a cross-sectinal area of 1.625 in. x 0.375 in. The outer diameter (OD) of the 22 AWG conductors are 0.051 in, so that 34 of them yields a width of 1.734 in.

In order for this cable to fit, we have two options. The first option is to reduce the number of conductors on the cable to 31 or less. As shown in Table 2, there appears to be enough contingency to lower the DGNDP to 7 conductors, and still only have 0.11 Amps per conductor. It is not clear at this time whether this can be done. If the total number of conductors can be reduced to 30 (0.13 Amps per conductor on DGNDP) then we can get a standard (off-the-shelf) cable from Amphenol # 843-111-2214-030. This might be a reasonable way to go.

A second alternative is to reduce the cable gauge to 24 AWG. The OD of the 24 AWG wires is 0.044 in., so that 34 conductors have a width of 1.496 in. Again, this would fit in the slot.

Because of the limitation on slots, we could consider some combination of both of these options. That is, change the gauge from 22 to 24 AWG, and reduce DGNDP to 6 wires. In this case, the average current on DGNDP wires is still only 0.13 Amps, but the voltage drop is larger because of the higher resistance in the cable.

A major concern here is the heat dissapation in the 30 degree slots. As the wire gauge increases, the resistance of the wire increases, and so does the corresponding heat generated (i.e., i^2R). One needs to be assured that for tightly packed cables in the 30 degree slot, where there is no convection, the cables will not exceed the melting point of the insulation. For PVC, one should not exceed something in the area of 80 C.

I looked at a couple of sources to get a rough idea of the current carrying capability of various size conductors. Using the technical pages from Belden Wire and Cable, and Alpha Wire and Cable, they appear to be consistent. Table 3 summarizes the results for the maximum current per wire for given temperature rises of the cable and different wire gauges. It is pointed out that these numbers serve only as a guide, but should not be used as design guidelines for engineers. One should test their specific situation, particularly when cables are packed tightly, and there is no convection.

Wire Gauge	10 °C Temp. rise	30 °C Temp. rise
22	2.4 Amps	4 Amps
24	1.8 Amps	3 Amps

Table 3: Amount of current which can be run through a conductor which has many conductors tightly packed together. Shown are the amount of current one can pass to obtain a 10°C temperature rise, and a 30 °C temperature rise. The numbers are based on listings in the Alpha Wire and Belden Wire technical pages on the web.

We compared these expectations to a model [3] in which seven, 24 conductor flat cables were packed into the 30 degree slot. The bottommost cable was assumed to be in contact with the endwall, which is at some temperature, T. The model of the cables in the slots is shown in Fig. 1. The figure shows a cross-sectional view, so that the cables run into/out of the page. Each cable is modelled thermally as follows. The central region is represented by an admixture of Copper and PVC according to their fractional area which they occupy. This region has a thickness of 0.031 in. for 22 AWG wire, and 0.024' in. for 24 AWG wire. The thermal conductivity is easily calculable as an area weighted average. The outer regions are purely 0.01 in. of PVC insulation. It is assumed that there is no convection, and, as indicated, all heat flow is through the conductors as shown in the figure.

Since it is difficult to estimate the contact resistances from cable-to-cable, and from the cable to the endwall, we varied the airgap between them and studied how the temperature rise of the cables is effected. We presume that the topmost cable is the warmest, and calculate the temperature difference between the topmost cable and the steel at the bottom.

We perform the calculations for 22 AWG and 24 AWG cables, and for several currents. These results are shown in Fig. 2.

Because the cables will be packed into the slots, it is reasonable to assume a small air gap. Let us assume 0.005 in. air gap on average. Let us assume we want to keep the hottest cable no more than 10 C above the endwall temperature. In this case, for a 22 AWG cable, we can run ≈0.9 Amps through each conductor. For a 24 AWG cable, we can run ≈0.7 Amps through each conductor. If we assume a 0.1 in. air gap, these numbers become ≈0.7 Amps for 22 AWG and ≈0.5 Amps for 24 AWG. These estimates are probably overly conservative. Also note that these currents are through every conductor in the cable. If a short were to develop, and all the L4 AVDD current (say 2 Amps) were to go through a single conductor, the temperature rise would be $< 25^oC$ for 22 AWG and $< 40^oC$ for 24 AWG, assuming a 0.005 in. average air gap.

Comparing the information in this table to the expected currents on ALV and DLV, it is clear that we have ample safety margin in the ALV and DLV to change the wire gauge to 24 AWG. The ALV has an average current draw of ≈0.3 Amps, which would result in only $<$ 10C temperature rise for even 0.01 in. air gaps. The DLV is even less, with an average around 0.2 Amps, and again, the temperature rise would be quite small.

One can ask, what if there is a short between the power line and ground, and all of the current were to go through a single wire. In this case, the temperture would increase at some rate, but, the power supply would trip off on a much quicker time scale than the cable heating up.

For a rough estimate, let us assume that 2 Amps go through a 24 AWG conductor. We will neglect the PVC insulation, as this only adds thermal mass, and will slow the heating process. Here are the relevant numbers for copper:

- I = 2 Amps
- R = Resistance for 24 AWG cable = 8.5e-4 (10.1e-4) Ω/cm at 20 (75) C
- Density of Copper = 8.96 g/cm^3
- C = Specific heat of Copper = 0.39 J/g C
- Copper cross-sectional area = 0.0029 cm^2
- Length of Copper = 300 cm (roughly)

So,

$$\begin{aligned}
\mathrm{M_{Cu}} &= 8.96 * 0.0029 * 300 = 7.8 \text{ g} \\
\text{Power} &= \mathrm{I}^2 * \mathrm{R} = 2^2 * (10.1e - 4 * 300) = 1.22 \text{ W} \\
\mathrm{dT/dt} &= \text{Power}/(\mathrm{M_{Cu}} * \mathrm{C}) = 1.22/(7.8 * 0.39) = 0.4\ ^o\mathrm{C/sec}
\end{aligned}$$

We therefore see that it would take a full minute before the temperature in the wire would rise by 24 C. The power supply will trip within a fraction of a second, so there should be no problem here.

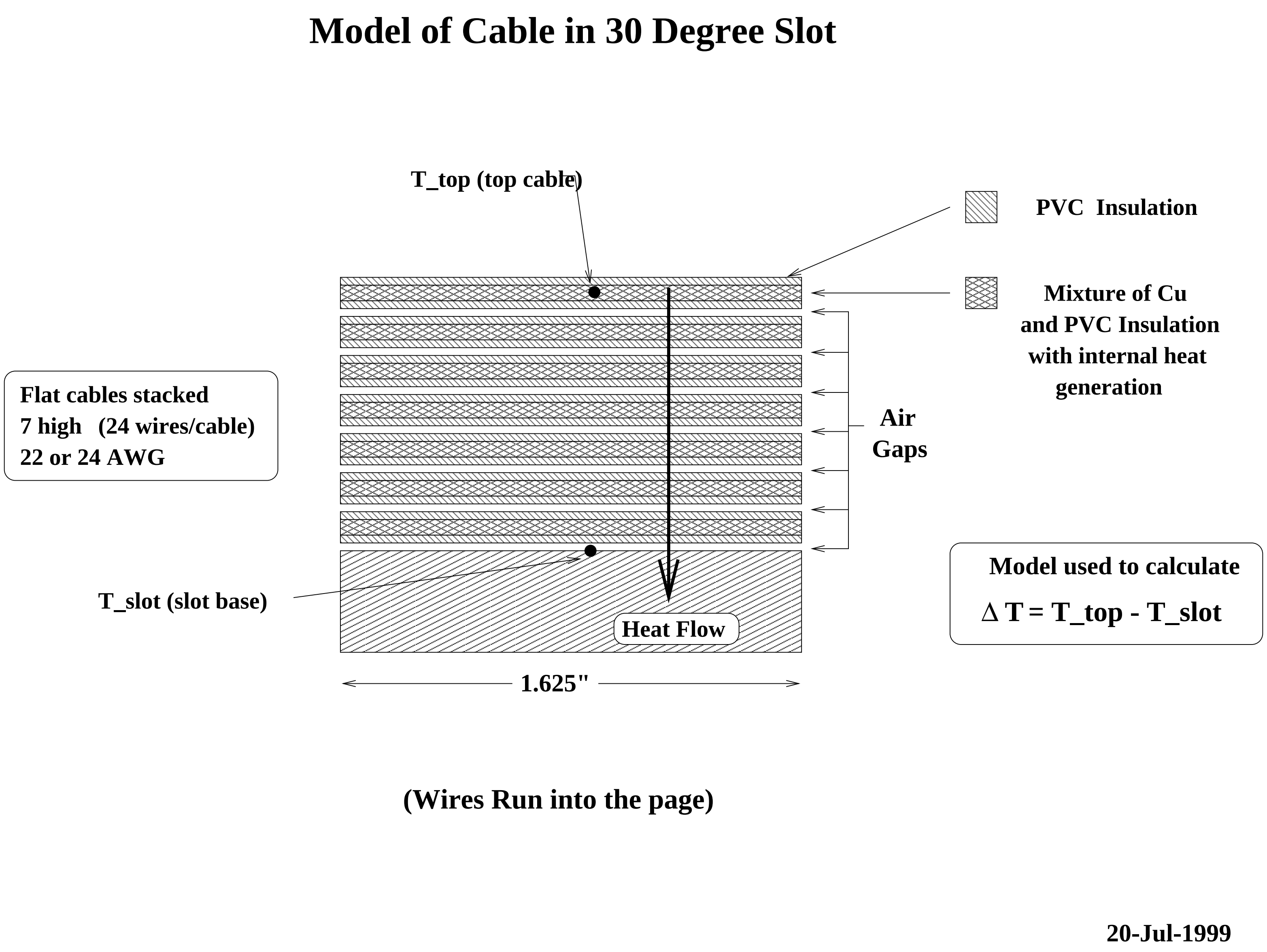

Figure 1: Cross-sectional view of the modelling of the cables in the 30 degree slot.

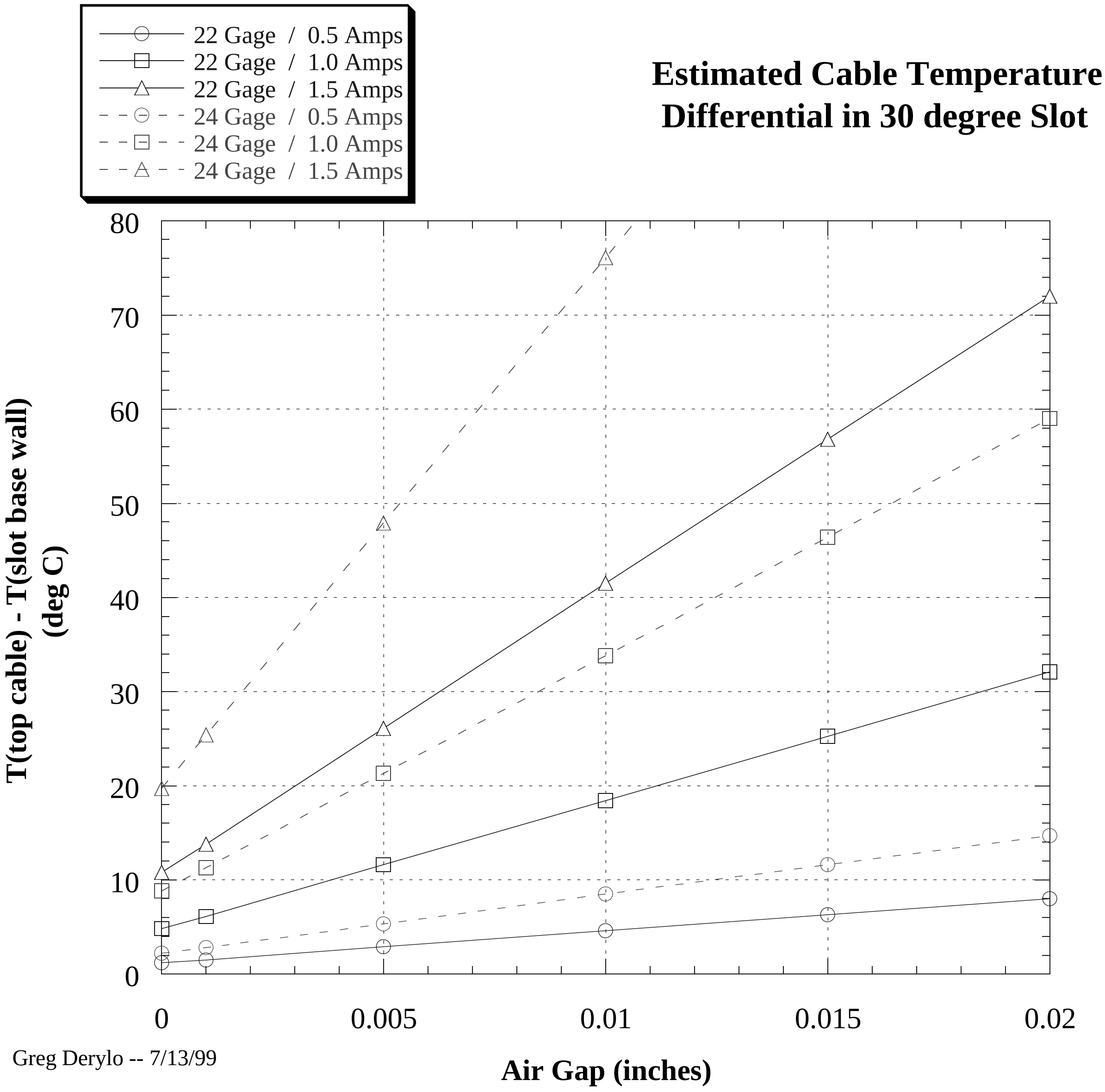

Figure 2: Temperature rise of the topmost cable with respect to the endwall temperature for a 0.5, 1.0, and 2.0 Amps per conductor and for 22 and 24 AWG.

References

[1] Cdfnote-4994 Report on Cabling for CDF Cable Committee

[2] These numbers come from Sergio Zimmerman

[3] The calculations were done by Greg Derylo at SiDet.