NOvA Power Distribution System Preliminary Design Review
Review Notes and Concerns

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During the last several days, I have reviewed the NOvA DC power distribution document along with prototypes of power distribution modules that will populate the FEB power distribution boxes. The areas of concern during this effort involved:

1. Module mechanics, especially the connector mechanics.
2. DC current capacity of the modules' traces and connector contacts.
3. Personnel protection and lethal shock hazard mitigation from the 450 VDC power.
4. Operational issues with respect to PCB layout and PCB components.

Module and Connector Mechanics

1. There is too much vertical play between the rear edge card connector's vertical card insert dimension and the vertical dimension of the PCB's edge card connector area. This play can cause the contact area to diminish which de-rates the contact-to-tab area's current capacity. Also, the card's play is large enough to almost allow adjacent tabs to come in contact with the wrong connector contact.

2. Some edge card tabs are overlaid with a trace that is wider than the tab. This further aggravates the edge card to connector play described above.

3. The 3.3 VDC power trace is too close to the PC board's bottom edge. It runs directly into the card guide area.

Once the card is inserted in a crate, this play may diminish. However, the Euro-Card crate's card guides are not known (depending on the manufacturer) for being very exact with regards to card guide slop.

DC Current Capacity

1. The trace coming from the 3.3V edge card tab, on the PDB FEB card, is not wide to handle the full rated output current of 8 amps. An 8-amp trace requires a 0.125 inch width minimum.

2. On the PDB front panel LED card, the 3.3 VDC and the 24 VDC traces from the edge card tabs to the fuse are too long and narrow. Mitigate the potential for trace failure by enlarging the trace width and moving the fuse as close to the edge card connector as possible.

3. As a recommendation, I would put a power input "main" fuse on the card's 3.3 VDC and the 24 VDC power input in addition to the output fuses. There is a relatively large area in the rear of the card (the FEB output card) with intermixed power and power return traces that present a fault hazard that will take the full current supplied by the distribution box's backplane in the event of a short.

450 VDC Lethal Shock Hazard

Since each power distribution box supplies 450 VDC and this power comes from a Caen power supply output channel that can supply up to 15 mA of current, this situation is a high-voltage condition and it also presents a lethal shock hazard (over 5 mA). Even with currents as low as 1 mA, there can be non-lethal shock hazards such as reflex actions. To supply 64, 0.040 mA output current loads, the Caen module would need to supply a minimum of 2.56 mA to the distribution box's backplane. The Caen A1520P HV output module has current limiting features. So, during normal operation, the lethal shock hazard can be mitigated by implementing these current limiting features. However, additional personnel protective measures should be implemented to cover accidental or non-normal power-ON conditions.

1. I would recommend placing a series resistor to limit the output current to less than 1 mA in the event someone comes in contact with a 450 VDC energized lead or PC board area. Some quick calculations suggest using a 449K, 1/2 watt resistor located downstream of the filter capacitor. This would allow, under normal operating conditions (40 uA of load current), a drop of only about 15-17 VDC and would limit the output current in the event of a person touching an energized area to about 1 mA.

2. Reverse the output connector's pin assignment so that the powered pin is on the "inside" row. So, if someone does touch the connector, during extracting a card for example, the outside pin, which provides the larges area of contact, would be at GND potential.

3. Also, keying the edge card connector to prevent the wrong card insertion orientation would add to the module's over-voltage protection. I know the edge card connector is offset in the vertical dimension during insertion into a box or crate but there is no protection for prototyping/testing situations.

4. Are front panels to be used on all of these cards? If so, these would limit significantly the hazard of someone touching any powered 450 VDC pin or contact. In the event a card will not populate a slot, I would strongly recommend the use of blank front panels.

Operational Issues

1. The description within the document indicates that the front end modules are used to amplify very low levels of light. With all the LEDs on these boards, is there going to be a problem of light noise or interference? Does this require an LED shutoff mechanism?

2. On the PC board layout of the FEB power output card, the power and return traces for the 450 VDC are such that they form a fairly large loop area. The power and return traces for the 3.3 VDC and 24

VDC are located inside of this 450 VDC loop area. This is a classical magnetic noise coupling situation. How much concern is there for noise?

3. The connection traces, between the power return lands (for the FEB power output card) for the 3.3 VDC and the 24 VDC, are connected to the output connector pins by very narrow trace sections. In the event of a hard short, this narrow trace segment(s) may fail prior to the fuse failing. I would suggest increasing the land contact area to these output pins.

4. On the LED monitor board schematic, the resistors that drive the indicator LEDs for the 3.3 and 24 VDC are of a large value that limits the LED's current to 0.5 mA (assuming a diode drop across the LED as a typical 1.9 V). This seems to be an insufficient current to drive the LEDs. The schematic does not specify the LED type or part number.

5. The current edge card connector's contact assignment places the power and its return across the connector horizontally. Usually (but not always), with multi-contact connections (for high current), the power and return potentials are separated using the vertical dimension. This makes it harder to short out the connector contacts by accident or improper card insertion. However, vertical potential separation is not as ideal for EMC considerations. Keep in mind that 64 amps are available across the contact area over three connector sections with the present arrangement. A short across this open space can seriously damage the connector. A revision of the connector's contact assignment may be warranted here.

6. On page 3 of the distribution document, it states that 3 kW will be dissipated by the 18-AWG wire pairs. When running and grouping these wires, it may be a good idea to limit the size of the bundles and limit running these bundles in enclosed spaces. This can cause heat build-up in these confined spaces and further increase the wattage dissipation of these wire pairs.

Closing Remarks

Some of the remarks and suggestions are open to discussion. In addition, the complete distribution system has not been reviewed yet. These remarks resulted from a first-time examination of the materials at hand. I would be more than willing to discuss these issues if some seem unreasonable.