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The NOνA Power Distribution System

History

Version 1: October 12, 2010, describes system built for NDOS.
Version 2: September 9, 2011, describes system built for FD.

Contents

1 Introduction

The NOνA Power Distribution System (PDS) supplies power to four different electronic components used in the readout: front-end boards (FEBs), avalanche photodiodes (APDs), thermoelectric coolers (TECs), and data concentrator modules (DCMs) It does *not* provide power to the timing distribution units (TDUs). The Power Distribution System consists of: (1) the power supplies and their racks, (2) the Power Distribution Boxes that fan out the power to the FEBs, APDs, TECs, and DCMs, and (3) the power cables and their cable trays. Two similar systems are needed: one for the Near Detector and one for the Far Detector. The number of each component is given in Table 1.

Table 1: NOνA electronics channel counts.

Module	Near Detector	Far Detector
FEB	497	11,520
TEC	497	11,520
APD	497	11,520
DCM	11	180
TDU	2	15

The parameters of the Power Distribution System, including specifications of each component, their prices, and manufactures, is given in a document on the NOνA document database: see Ref. [1]. Details of the system are posted on the Virginia web site in Ref. [2].

In the design of the Power Distribution System we have adhered to the electrical design standards outlined in *Electrical Design Standards for Electronics to be used in Experiment Apparatus at Fermilab, April 15, 1999* [3] and the Fermilab ES&H Manual 5050: Electrical Safety [4].

2 Requirements

The large number of channels and the extent of the detectors demand that the Power Distribution System must be remotely controllable. The system must also be robust and safe. The required lifetime is ten years. The voltage, current, and power requirements for the five components are given in Table 2. Turn-on currents have not been measured. The front-end electronics must detect and amplify very low light levels; hence low-noise power supplies are required.

At the time the system wasa designed the actual noise and ripple requirements were not specified. Estimates of the currents needed for the FEB, TEc, DCM, and APDs were 0.5 A, 0.15 A, 1.25 A, and 40 μA, respectively. The system was designed to handle twice those currents. The channel count also changed, in particular the number of channels required per Power Distribution Box. That number has now converged to 64 for the Far Detector and between 12 and 64 for the Near Detector.

Table 2: Power requirements for the detector electronics.

Module	Voltage	Max. Current	Power Distribution Box Channels	Total current	Power
FEB	3.3 V	1.0 A	64	64 A	211 W
TEC	24 V	0.30 A	64	20 A	480 W
APD	350–450 V	40 μA	64	2.6 mA	2 W
DCM	24 V	1.5 A	1	1.5 A	30 W

3 System Layout

A schematic of the Power Distribution System is shown in Fig. 1 and the layout for a diblock is given in Fig. 15. An electrical schematic is shown in Fig. 2. All power to the front-end electronics is supplied by low voltage and high voltage power supplies that lie off the detector. The power is distributed by Power Distribution Boxes (PDBs) which are situated on the detector. An isometric view of a custom Power Distribution Box is shown in Fig. 5. A single 6-conductor, 18AWG cable from each PDB output carries the high voltage needed by the APDs, the 24V needed by the TE coolers, as well as the 3.3V needed by the FEBs, and their return currents. All the electronic components and the power supplies float: ground reference is at the PDBs. A maximum of 66 FEBs and 1 DCM are served by each PDB.

4 Power Supplies

High Voltage Power Supplies

The HV to the PDBs is provided by two Wiener MPOD HV-EX high voltage power supplies System mainframes using 15 ISEG EHS F6 05xi_156-F floating 16-channel cards. Each of the 16 channels of the ISEG is individually programmable from 0–500V, and provides a maximum of 15mA of current. A custum-made (REDEL SAG.H51+SRG.H51) cable harness takes the 16 HV channels from each ISEG card to a nearby breakout box fabricated at UVa, and shielded tri-axial RG-58A/U cables with triaxial 3-lug BNC connectors go from the patch panel to the PDBs. Each Wiener HV channel feeds a single PDB.

Low Voltage Power Supplies

The required power, including cable losses is shown in Fig. 3. The low voltages (3.3V and 24V) needed by the FEBs, DCMs, and TE coolers, are provided by the Wiener PL506 LX Power Supply System. Each Wiener PL506 chassis has six floating individually programmable power supply modules: three 2–5.8V channels, each rated to 115A and 550W, and three 12–30V channels, each rated to 23A and 550W. (NOte: the standard low voltage module has a range of 2–7V. Because the Front-End Boards have a voltage regulator that

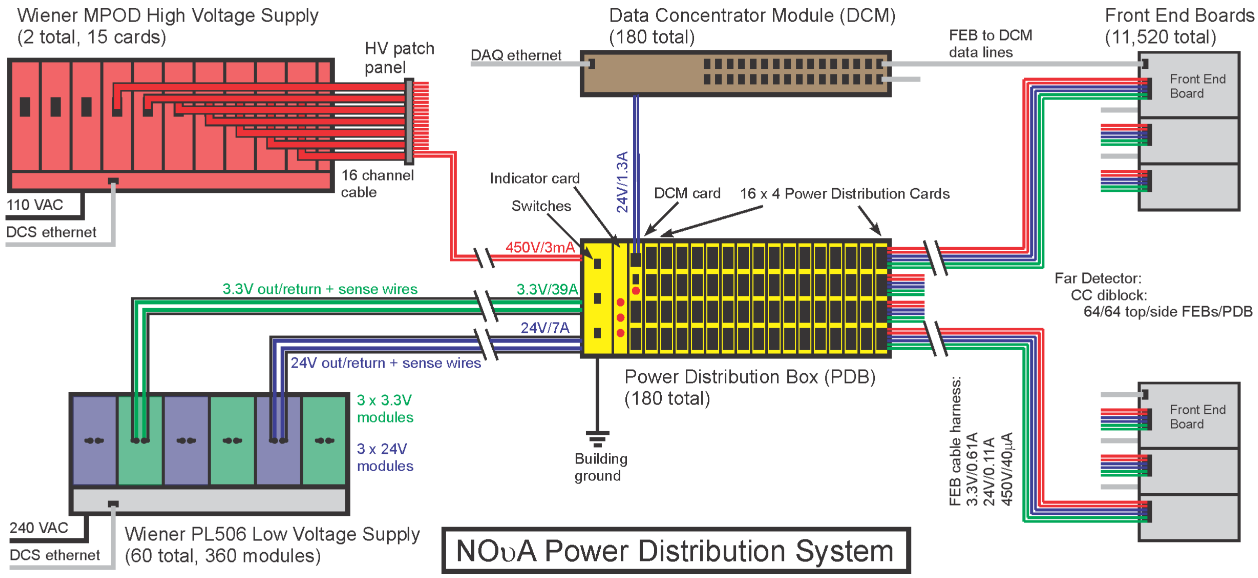

Figure 1: Layout of the Power Distribution System. Each Power Distribution Box feeds 3.3V, 24V, and 350–450V via a single cable to a maximum of 66 front-end boards, and 24V via a single cable to the nearby data concentrator module. The APD voltage to the Power Distribution Boxes is provided by Wiener MPOD cards situated in a Wiener MPOD mainframe. The FEB, TE cooler, and DCM power are provided by Wiener PL506 power supplies. The channel counts are for the NOνA Far Detector only.

only goes up to 6.0V, the modules we have procured from Wiener were modified to only go to 5.8V. As of this writing the 7 low voltage supplies purchased for NDOS do not yet have this modification.) Hence each PL506 crate feeds power to three adjacent PDBs: the 3.3V via 2AWG cables and the 24V via 6AWG cables. The cables can safely carry the maximum rated current of the Wiener supplies without the need for fuses; nevertheless they will be fused at the power supply. The Wiener low voltage supplies have a remote sensing feature which allows the voltages at the PDBs to be set to their desired values. This feature is needed because the different cable lengths from the Wieners to the PDBs produce non-negligible differences in the voltage drops. The longest cable runs are about 16 m, corresponding to one-way voltage drops of 0.51V and 0.56 V, respectively for the 3.3V and 24V lines. Voltage drops on the 18AWG cables running from the PDBs to the FEBs are much smaller, resulting in a voltage range at the FEBs between 3.41–3.30V, well within the allowed range of the FEB voltage regulators, which protect the FEBs from inadvertent application of the highest voltage (7V) the Wiener supplies can provide. A total of 122 kW of power is consumed by the FEBs, DCMs, and TE coolers (the APDs consume no appreciable power); 19 kW is lost in the cables and 3 kW is lost in the PDBs to heat. To provide the power the Wiener supplies, which have an average efficiency of 72

Both of the Wiener power supplies are remotely controllable with Ethernet interfaces. They have programmable trip levels and their noise and ripple specifications meet the re-

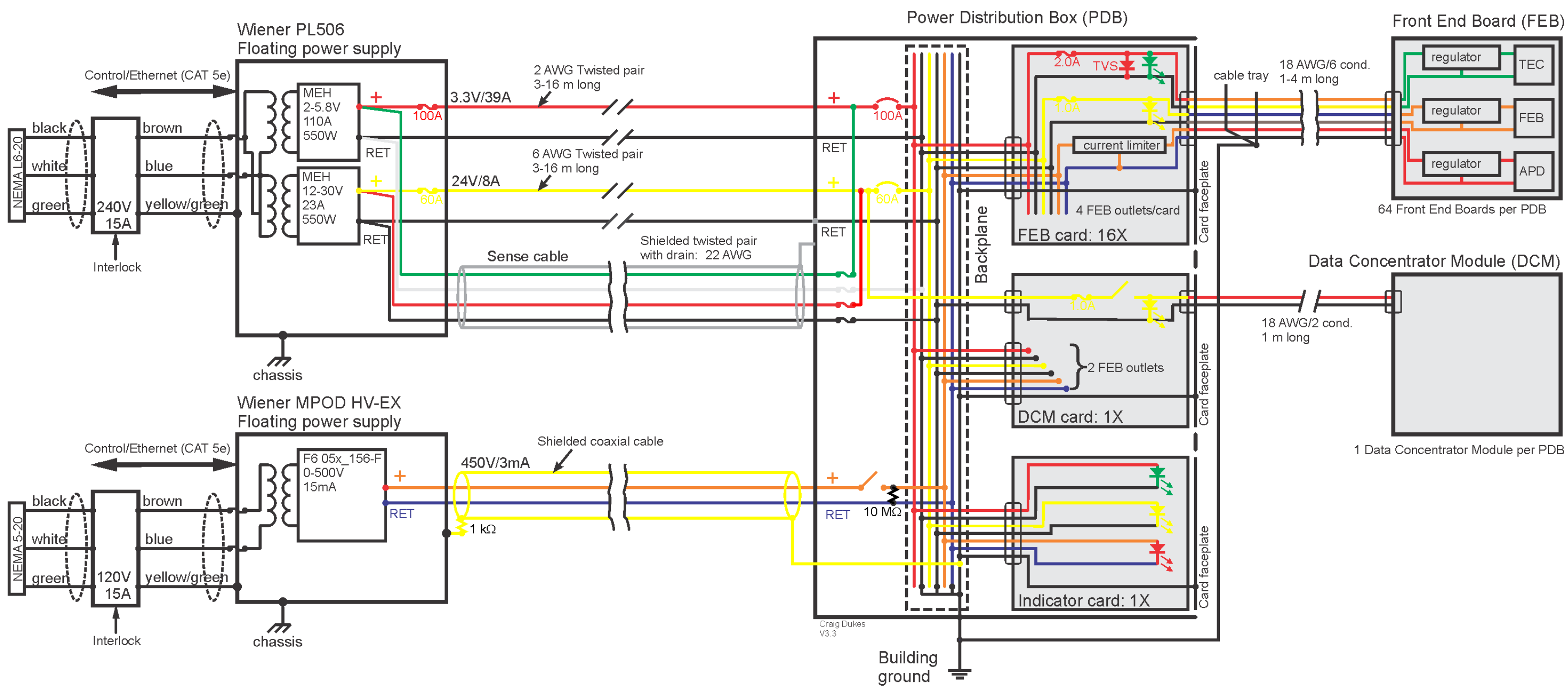

Figure 2: Schematic of the Power Distribution System.

Table 3: Power supplies parameters.

Item	Low Voltage	High Voltage
Manufacturer	Wiener	Wiener
Mainframe type	PL506	MPOD HV-EX
Size	3U	8U
Weight	21.7 kg + 5.6 kg = 27.3 kg	24 kg
Power	3840 W (240 VAC, 16A)	3000 W
	550 W per pod	
Input Power	100 – 264 VAC, 16A	100 – 240 VAC, 50/60 Hz, 16A
Pods per mainframe	6	10
Pod type	MEH	ISEG EHS F6 05x_156-F
Channels per pod	1	16
Voltage range	2 – 5.8 V[a]	0 – 500 V
	12 – 30 V	
Maximum current	115A	15mA
	23A	
Voltage resolution		100 mV
Ripple	< 3 mV pp	< 30 mV pp
Regulation	< 25 mV @ ±100% load	
Remote sense	Fast < 10 m run	
	Slow < 100 m run	
Float	±10V	200V

[a]Modified from standard 2 – 7 V

quirements of the FEBs, APDs, and TE coolers.

The 24V, 1A power to the Time Distribution Units (TDUs) is provided by an on-board AC to DC adapter and runs off of 110 VAC.

5 Power Distribution Boxes

5.1 Overview

A total of 180 far detector and 10 near detector Power Distribution Boxes (PDBs) are needed (not including spares). To fit within the tight space constraints of both detectors the Power Distribution Boxes employ a standard DIN 3U subrack with a custom backplane that feeds 3.3V, 24V, and HV (350–450V) to 18 cards: 16 FEB cards that feed 3.3V, 24V, and HV power to the front-end boards (FEBs), 1 DCM card that feeds 24V power to a data concentrator module, and 1 Indicator card that has LED lamps that indicate of the on/off status.

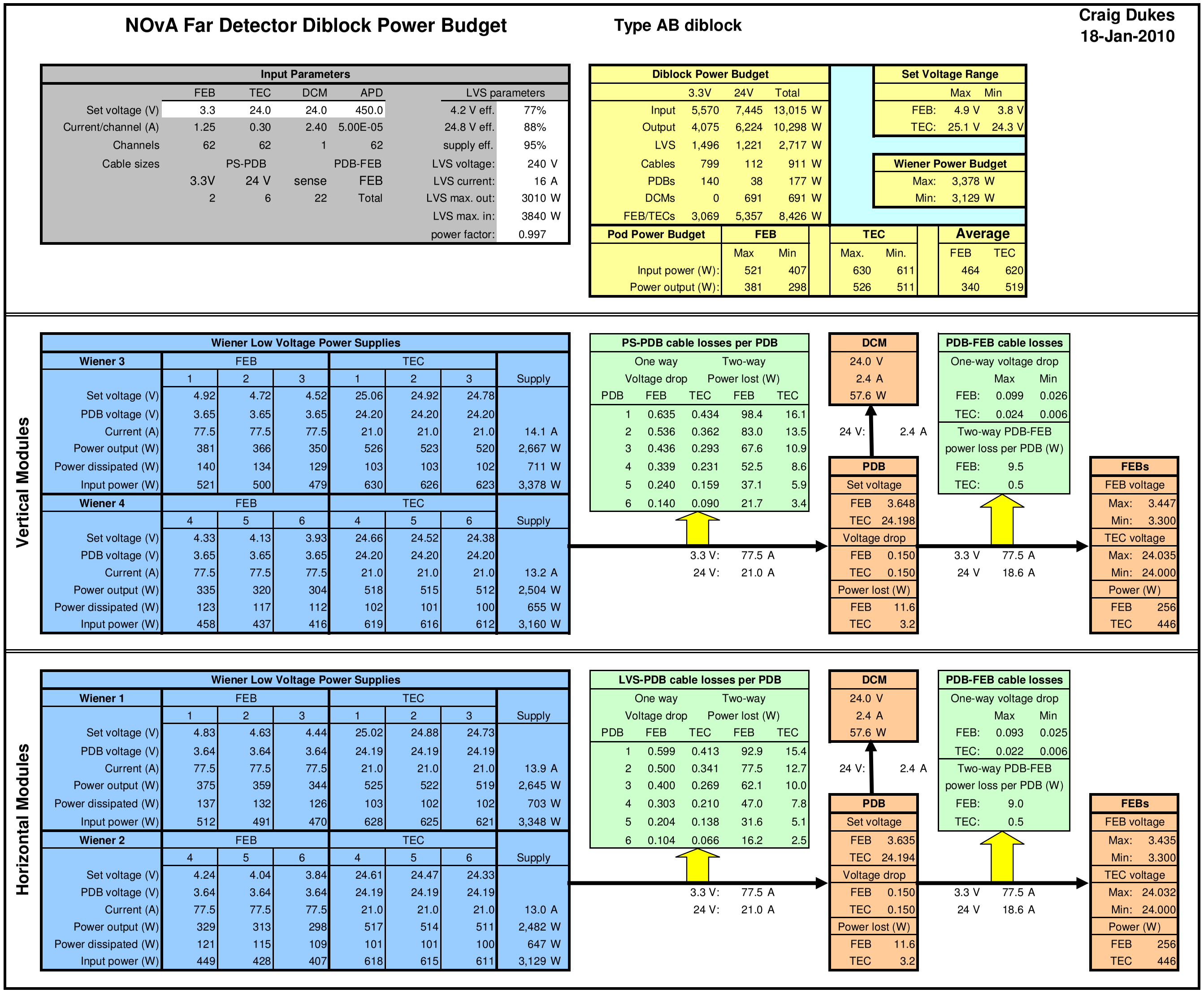

Figure 3: Power budget of the Power Distribution System. The power budget of a type AB diblock is shown, including the power supply losses, cable losses, and losses in the Power Distribution Boxes. The required set voltages to produce a nominal 3.3 V and 24 V at the FEBs is also given.

The low-voltage power is input through connectors on the side of the PDB. It then goes to front-panel circuit breakers rated at 100A and 40A respectively for the 3.3V and 24V lines, which can also be used to locally power off the PDB, although the operating procedure will be to always power off the crate at the supply before handling it or its cards. The high-voltage power goes to a front-panel switch rather than a breaker.

The box has been designed to provide the currents given in Table 4, all of which are roughly a factor of two greater than the expected currents. The individual cards, decribed below, are fused at $1/0.75 = 1.33$ the maximum rating. The trace widths are set to handle currents 1.4 times the fused value.

Table 4: Power Distribution Box current design capacity.

Item	24V	3.3V	HV
backplane	72A	132A	NA
FEB card 1 channel	1.0A	2.0A	300μA
FEB card 4 channels	4.0A	8.0A	1.2mA
DCM card output to DCM	6.0A	NA	NA

The PDBs were designed from the outset to have no intelligence; rather to be simple distribution boxes to fan out the power to the FEB boards. There was some thought to provide higher voltage DC power to a distribution box using DC-to-DC converters to provide the 3.3V and 24V power. Although such as system would have been in principle less expensive, sparse engineering design resources would have had to been used, and the cost, including design, would have been essentially the same. Also, since it was known that the power had to be clean, the advantages of using the very clean power that is provided by supplies that Wiener produces compelled us to the solution described here.

Photographs of the FEB, DCM, and indicator cards (Version 3) are given respectively in Fig. 10, Fig. 11, and Fig. 12. The schematics for the three cards and the backplane are given in Appendix A. The circuit board layouts for the three cards and backplane are being produced as of this writing, and will be given in Appendix C when completed.

5.2 History

The first prototype of the Power Distribution Box was designed by Yoshihiro Masui, a UVa electrical engineering graduate student, with help from Craig Dukes and Andrew Norman, completed in early summer of 2007 and tested. Design of a second prototype, which corrected and few mistakes, and incorporated a few design changes, was underway in the fall of 2007, but was halted when NOνA funding was cut off in December 2007. The Version 2 PDB was never built. In the spring of 2009 a preliminary safety review was done by Steven Chappa of Fermilab [6]. The major design change was the incorporation of a current limiter circuit for the high voltage power. Two current limiters were designed and tested (see Ref. [7]) and a new prototype of the Power Distribution Box, Version 3, was designed. The card-edge connector used in the Version 1 and Version 2 prototypes was replaced by a pinned connector. Besides addressing the Chappa's recommendations, the Version 3 prototype incorporated increases in both the 3.3V and 24V currents, which had escalated from early estimates. In particular, the 24V current capability was increased to 1.0A to accommodate the possibility of a large increase in power needed by the passive TEC cooling option. Designing the system to fit in the small 3U format proved to be a challenge.

A total of 15 PDBs of Version 3.2 were built at UVa in the summer of 2010 for the Near Detector prototype (NDOS), of which 12 were shipped to Fermilab and installed. (Note that only 10 PDBs were needed for the NDOS, and indeed were planned: 9 for the normal blocks and 1 for the muon ranger. However, because the timing system was designed to have equal length Cat-5 cables two more PDBs were added to the muon ranger, which only has a total of 33 FEbs. Hence the PDBs serving the muon ranger are largely empty.) We found that the PDBs worked well with the exception of a few problems. These include: poor crimping of the sense cables and fuses on the sense cables blowing when the breakers at the power supply breaker boxes were switched off with the power on. It was decided to redesign the breaker boxes, replacing them with fuse boxes, with only the hot outputs fused, attached to the power supply enclosures for this reason and also to make the supplies easier to install. We also found that twice several cards had their fuses blown. In at least one case this was due to people measuring hot voltages on the FEBs (not FEB cards), and clearly shorting power lines.

For the Far Detector a number of minor changes were made to the PDB, which is designated Version 3.3. These include:

- The boxes were manufactured by 3W Electronics, Inc. in Charlottesville, Virginia, which all parts except the card components supplied by UVa.
- The busbar designs were changed to: have all busbars their nominal sizes (i.e., smaller); to have tabs for the braid to the ground busbar; to have separate tapped holes for the sense cable connections on the busbars; to have separate DCM and sense cable lugs; to have all screw holes sized #10; to increase the length on the marine connector side; and to shave off a bit of length on the opposite side.
- Move the marine connectors back 2 cm to make the cabling easier.
- Use non-perforated panels to keep material from getting in to the PDBs and to facilitate putting on decals.
- Use a lower value of the high voltage bleed resistor.
- Use different fuse holders for the sense cable fuses. These allow the fuses to be replace without having to open up the PDBs.
- Use a custom made ground braid, cut to size and insulated.
- Add stand-offs to the upper and lower busbars.

- Use lugs rather than swivel-nuts to connect to the marine connectors. (Several problems were related to the swivel-nuts either being screwed on too tightly on too loosely.)
- Cable tie the power cables going along the rear so they will not chafe on the busbar edges.
- Have Schroff fabricate all enclosure parts with the exception of the faceplates.
- Have all the faceplates fabricated by EMachineShop.
- Have 3W fabricate the boxes.

5.3 Numbering Scheme

The numbering scheme for the headers of the FEB card and DCM card are given respectively in Fig. 6 and Fig. 5.4. The Power Distribution Box channel numbering scheme is given in Fig. 4.

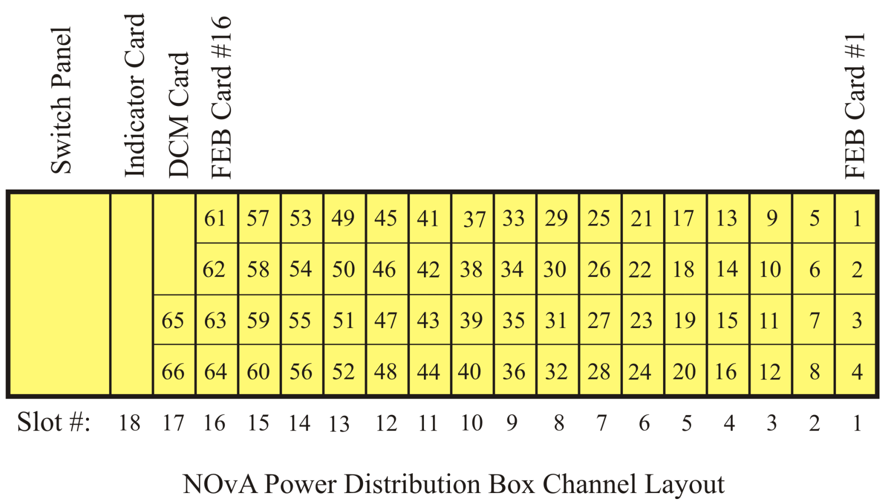

Figure 4: Numbering scheme for the Power Distribution Box.

5.4 Backplane

The backplane feeds the power to the all of the cards. Schematics for the backplane are given in Figs. 33 and 34 of Appendix A. The 3.3V, 24V, and ground feeds are all done using copper bus bars that are soldered to the pc board. The 3.3V RET and 24V RET lines are connected to the ground bus bar, although if it were decided to float the PDB, those connections can easily be severed. To reduce the possiblity of a short, the RET bus bars are on the outside. The bus bar cross sectional area has been set to limit the current to be below the 1000A/in^2 specification given in Ref. [3]. The actual sizes of the busbars is given in Table 5. Note that this capacity exceeds the maximum output capacity of the power supplies. The actual size of the busbars used for the ND PDBs is quite a bit larger in some cases than that needed to carry the design current. This was done in order to ease manufacturing and reduce costs. The larger quantities needed for the FD allow us to make the appropriately sized busbars for each voltage.

Table 5: Power Distribution Box busbars.

Item	Design Current	Required Area	Size Minimum	Size Actual (ND)	Size Actual (FD)
3.3V	132A	0.132 in.^{2}	1/8″× 1.056″	1/8″× 1.125″	1/8″× 1.125″
3.3V RET	132A	0.132 in.^{2}	1/8″× 1.056″	1/8″× 1.625″	1/8″× 1.125″
24V	72A	0.072 in.^{2}	1/8″× 0.576″	1/8″× 1.125″	1/8″× 0.625″
24V RET	72A	0.072 in.^{2}	1/8″× 0.576″	1/8″× 1.625″	1/8″× 0.625″
Ground	202A	0.202 in.^{2}	1/8″× 1.616″	1/8″× 1.625″	1/8″× 1.625″

5.5 FEB Card

Each FEB card provides power to 4 FEBs, allowing a maximum of 64 FEBs to be powered through one PDB by the 16 FEB cards. (Two more FEBs can be powered extra channels in another card called the DCM card.) Schematics for the FEB are given in Figs. 35 – 39 of Appendix A. Each 3.3V and 24V output is individually fused and has LED indicators. There is no LED indicator for the HV outputs. Transient voltage suppressors on the 3.3V lines protect the FEBs from over voltage due to an out of regulation power supply.

A current limiter for the HV lines was added to the design in Version 3 of the FEB card, and whose schematic can be seen in Fig. 36. This was added as a safety feature under the recommendation of Steve Chappa, and it limits the current to below 1 mA. It has the added feature that a short in one front-end board, rather than tripping the Wiener, and putting all of the HV channels served by the PDB down, only kills the channel in question. However, the limiter does produced a current-dependent drop in the output voltage. Because of this, and because we wanted channel-by-channel voltage control for individual APDs, a shunt regulator voltage control circuit was added to the front-end board design. As mentioned above, two current limiters were designed and tested; the results are given in Ref. [7]. A fault analysis of the current limiter circuit was done by John Oliver, the NOνA Project Electrical Engineer [8], and was approved by Steve Chappa in October 2009.

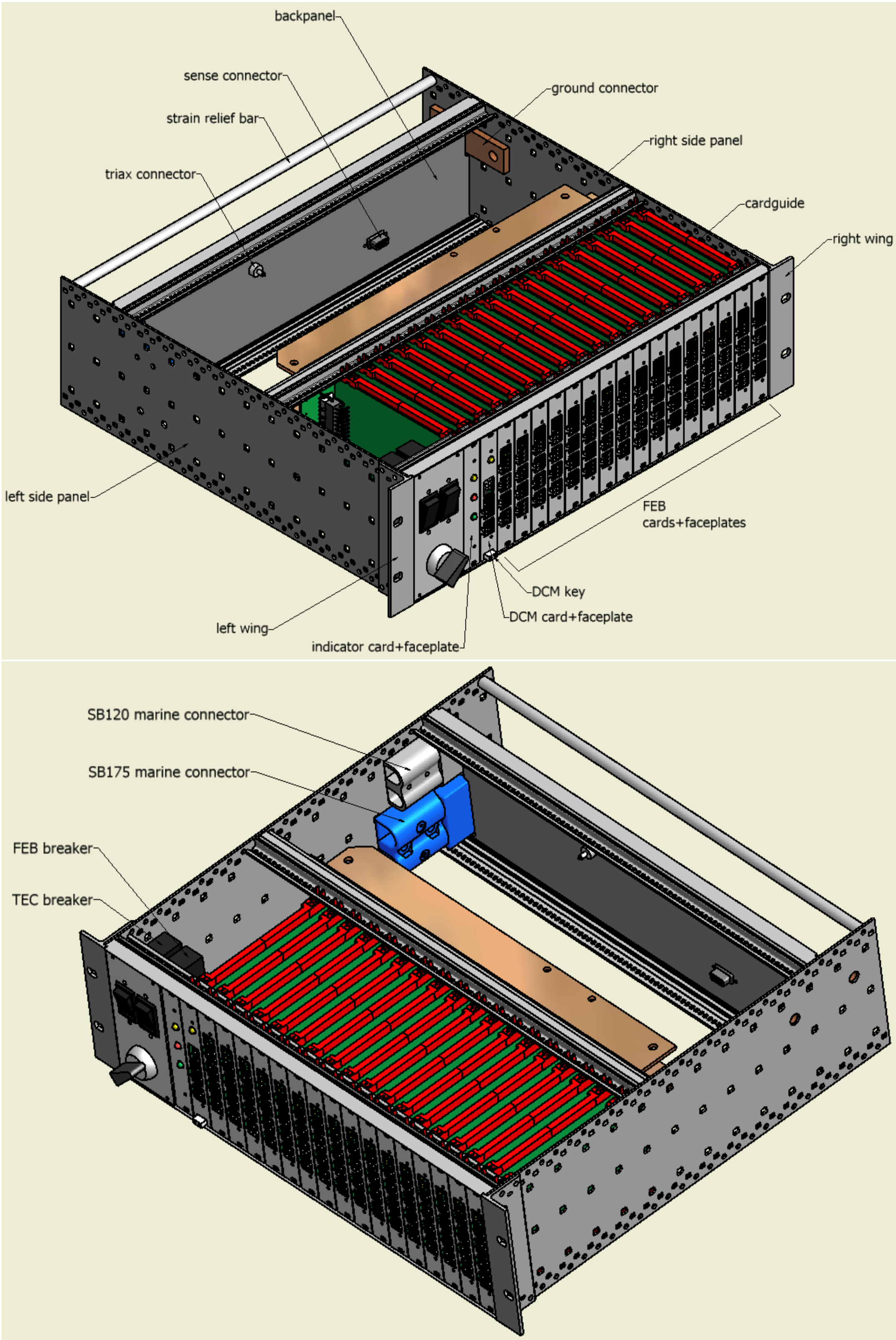

Figure 5: Isometric view of a Power Distribution Box.

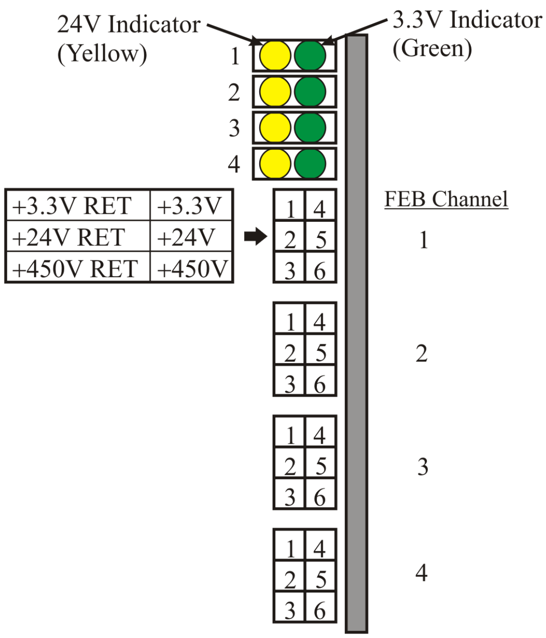

Figure 6: Front panel layout of PDB FEB card.

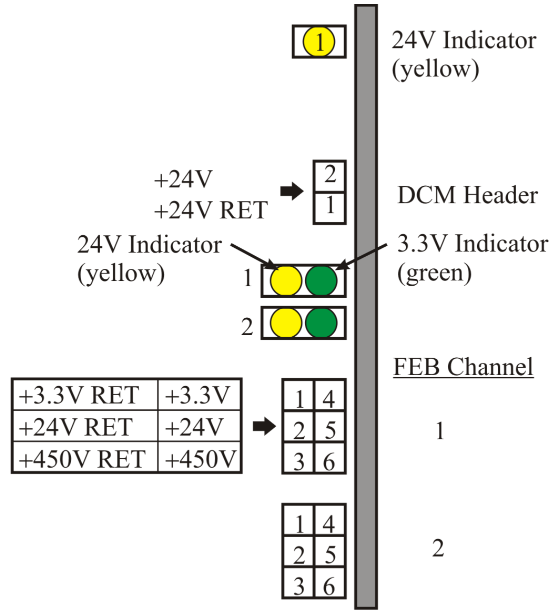

Figure 7: Front panel layout of PDB FEB card.

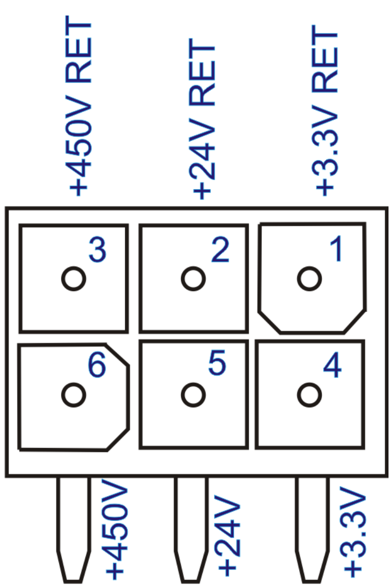

Figure 8: Header pinout for the FEB power.

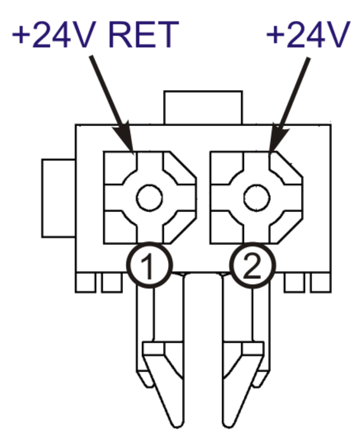

Figure 9: Header pinout for the DCM power.

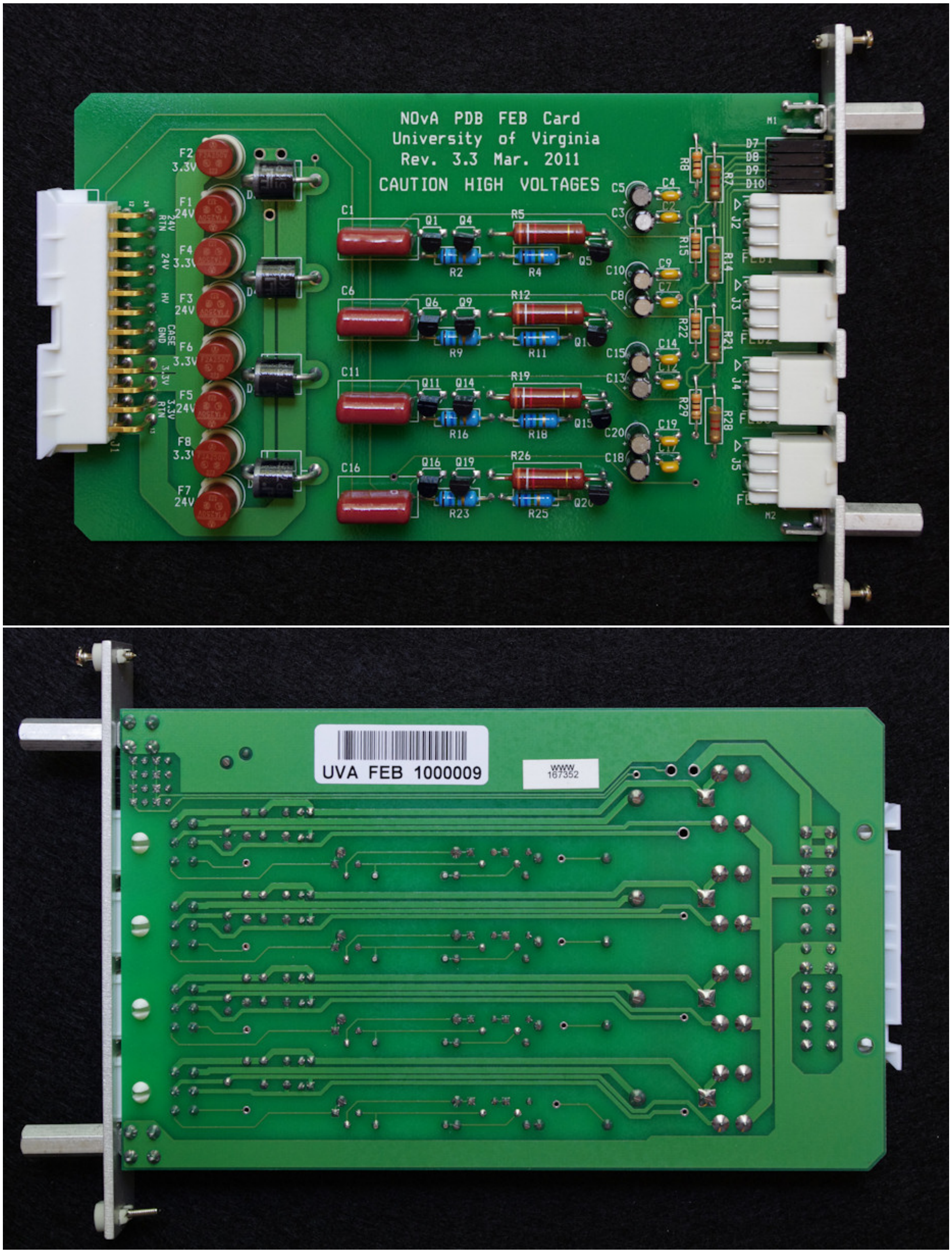

Figure 10: Version 3.3 of the PDB card that powers four FEBs.

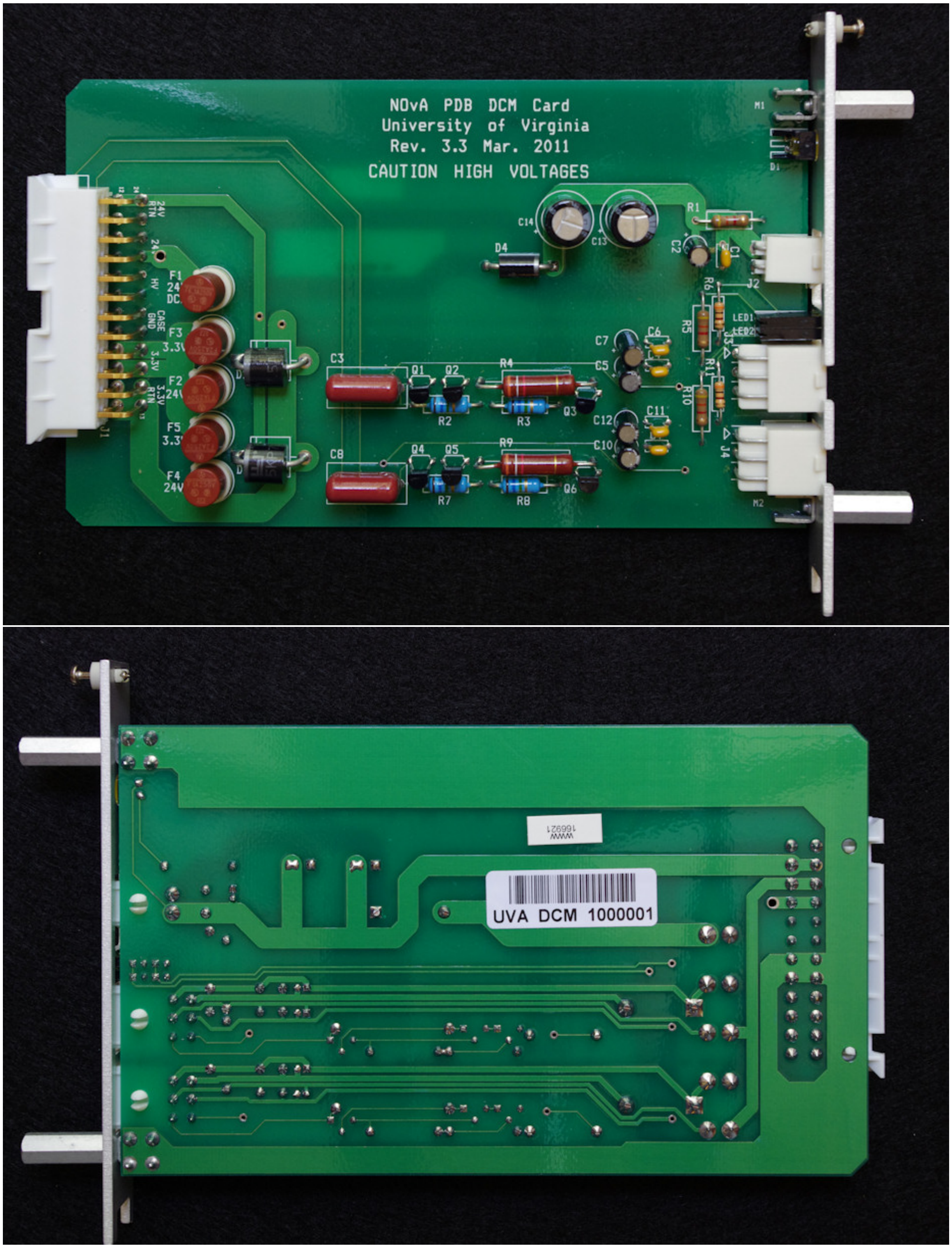

Figure 11: Version 3.3 of the PDB card that powers a DCM (as well as has two spare FEB power channels.

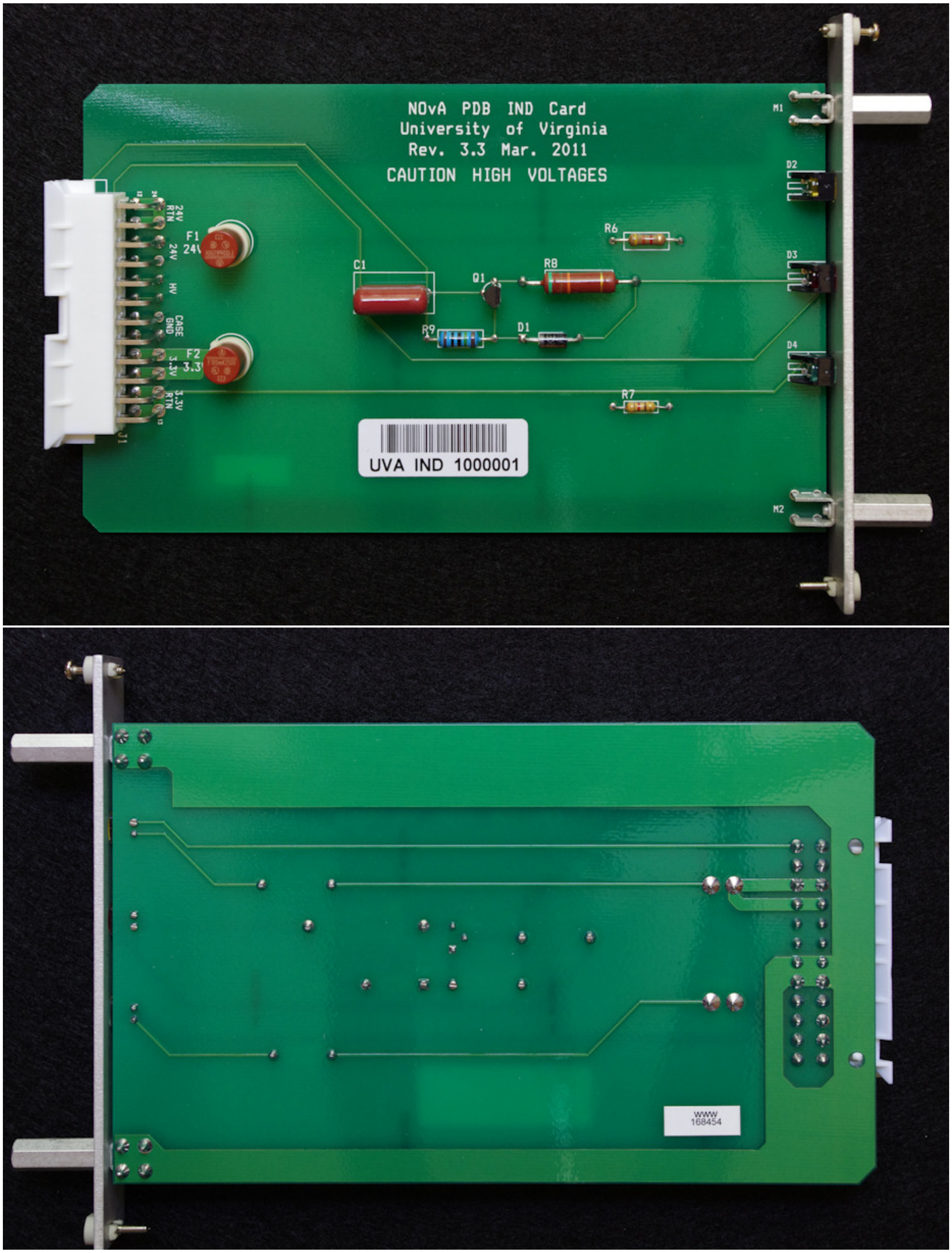

Figure 12: Version 3.3 of the PDB card with indicator lamps.

5.6 DCM Card

A special card, called the DCM card, feeds 24V power to the associated DCM, and has two spare FEB power outlets. The power to the DCM is tapped off before the 24V breaker, allowing the DCM to be powered on while the 24V to the TE coolers is off. An LED lamp indicates that the power is on.

In the orginal design a switch allowed the power to be turned off. A small enough switch could not be found that handles the increased current rating, and we decided to abandon the switch altogether.

5.7 Indicator Card

A third card, called the Indicator Card, has LEDs that show which voltages are on: 3.3V, 24V, and HV.

6 Power Distribution Box Layout

The fundamental unit for the Power Distribution System for the far detector is the 62-plane di-block. Far detector planes have 12 modules for a total of 384 cells and alternate between horizontal and vertical orientation except at the bounds between superblocks. Near detector horizontal (vertical) planes have 3 (2) modules for a total of 96 (64) cells. The INPD planes are identical to the near detector. The channel counts for the far detector super-blocks, di-blocks, blocks and planes are given in Fig. 13 for the far detector, and Fig. 14 for the near detector.

The far detector consists of are 16 di-blocks, which come in two varieties: 13 consist of AB block pairs, and have 31 horizontal and 31 vertical planes. These AB di-blocks are serviced by PDBs which provide power to 62 FEBs each. The second type of di-block, which spans the boundary between superblocks, consists of AA block pairs, and has 32 vertical planes and 30 horizontal planes. These AA di-blocks are serviced by PDBs which each provide power to 64 FEBs on the top (vertical modules) and 60 FEBs on the side (horizontal modules). At the rear of the detector is a partial di-block consisting of 6 vertical and 5 horizontal planes; each PDB feeds 24 (20) top (side) FEBs.

The layout of a far detector di-block is shown in Fig. 15. In a normal di-block there are 12 x 31 = 372 vertical modules, requiring 6 PDBs, each feeding power to 62 FEBs, and 372 horizontal modules, requiring 6 PDBs, each feeding power to 62 FEBs. For each PDB there is one DCM. The Wiener power supplies are mounted on relay racks on the upper catwalk: one Wiener for every three PDBs for a total of four for each di-block. Two Wiener mainframes are needed for the entire detector: it is situated at the detector midpoint. Since each Wiener output channel supplies power to one PDB, 12 HV channels are needed to supply the 12 PDBs in a di-block.

For the complete far detector, 180 PDBs are needed, 2 Wiener mainframes with a total of 15 1511B boards, and 60 Wiener PL506 crates (Table 6).

NOvA Far Detector Electronics Layout

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8-Jul-11

15 kT Detector

Modules/Plane	
Vert	Hor
12	12

Blocks:	30
Planes:	960
Modules:	11,520
Cells/module:	32
Cells:	368,640

"A" block:	v	v
"B" block:	h	h
"C" block:	h	v

Diblock	Block	Plane orientation First	Last	Planes Vert	Hor	Total	Diblock planes Vert	Hor	FEBs per PDB Vert	Hor	FEBs per diblock Vert	Hor	PDBs per diblock Vert	Hor
1	1	h	v	16	16	32	32	32	64	64	384	384	6	6
	2	h	v	16	16	32								
2	3	h	v	16	16	32	32	32	64	64	384	384	6	6
	4	h	v	16	16	32								
3	5	h	v	16	16	32	32	32	64	64	384	384	6	6
	6	h	v	16	16	32								
4	7	h	v	16	16	32	32	32	64	64	384	384	6	6
	8	h	v	16	16	32								
5	9	h	v	16	16	32	32	32	64	64	384	384	6	6
	10	h	v	16	16	32								
6	11	h	v	16	16	32	32	32	64	64	384	384	6	6
	12	h	v	16	16	32								
7	13	h	v	16	16	32	32	32	64	64	384	384	6	6
	14	h	v	16	16	32								
8	15	h	v	16	16	32	32	32	64	64	384	384	6	6
	16	h	v	16	16	32								
9	17	h	v	16	16	32	32	32	64	64	384	384	6	6
	18	h	v	16	16	32								
10	19	h	v	16	16	32	32	32	64	64	384	384	6	6
	20	h	v	16	16	32								
11	21	h	v	16	16	32	32	32	64	64	384	384	6	6
	22	h	v	16	16	32								
12	23	h	v	16	16	32	32	32	64	64	384	384	6	6
	24	h	v	16	16	32								
13	25	h	v	16	16	32	32	32	64	64	384	384	6	6
	26	h	v	16	16	32								
14	27	h	v	16	16	32	32	32	64	64	384	384	6	6
	28	h	v	16	16	32								
15	29	h	v	16	16	32	32	32	64	64	384	384	6	6
	30	h	v	16	16	32								
		Total planes:		480	480	960								
		Planes/superblock:		80	80	160								

	Vert	Hor	Total
PDBs	90	90	180
FEBs	5,760	5,760	11,520
Cells:	184,320	184,320	368,640

Figure 13: Channel counts for the far detector super-blocks, di-blocks, and blocks. The Power Distribution System is laid out on a di-block by di-block basis. All di-blocks consist of a CC block pair, having 32 vertical and 32 horizontal planes.

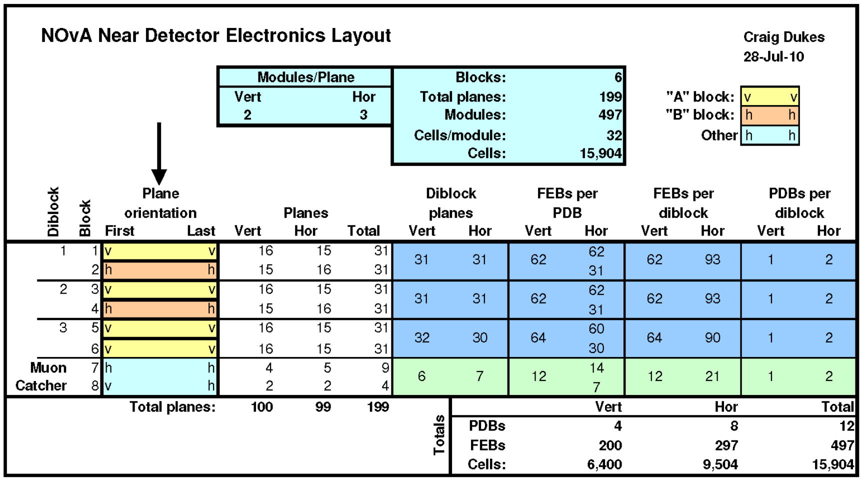


Figure 14: Channel counts for the near detector. There are only 2 (3) vertical (horizontal) modules per plane, as opposed to the 12 for the far detector. Hence the PDBs mounted on the side of the detector serve few FEBs. The first two di-blocks are normal type AB; the last di-block is a AA type. Finally, there is a Muon Catcher system near the end that consists of 13 planes and is served by a single PDB.

Table 6: Power distribution system components

Item	FD	ND
Front-end Boards	11,160	497
Power distribution boxes	180	10
Wiener ISEG modules	12	1
Wiener MPOD mainframes	2	1
Wiener PL506 crates	60	4
Relay racks	17	2
Total wall power	199 kW	9 kW
3.3V, 1-conductor, 2 AWG cable, Wiener to PDBs	3,350 m	223 m
24V, 2-conductor, 6 AWG cable, Wiener to PDBs	1,657 m	110 m
HV, RG-58A/U triaxial cable: MPOD patch panel to PDBs	2,723 m	tbd
Building ground cable, size tbd	tbd	tbd
4-conductor, 24 AWG sense cable: PDBs to Wieners	3,332 m	110 m
6-conductor, 18 AWG cable: PDBs to FEBs	25,498 m	1,700 m
1-1/4″conduit	1,744 m	tbd
4″×2″ cable tray	1,506 m	tbd
8″×4″ cable tray	63 m	tbd

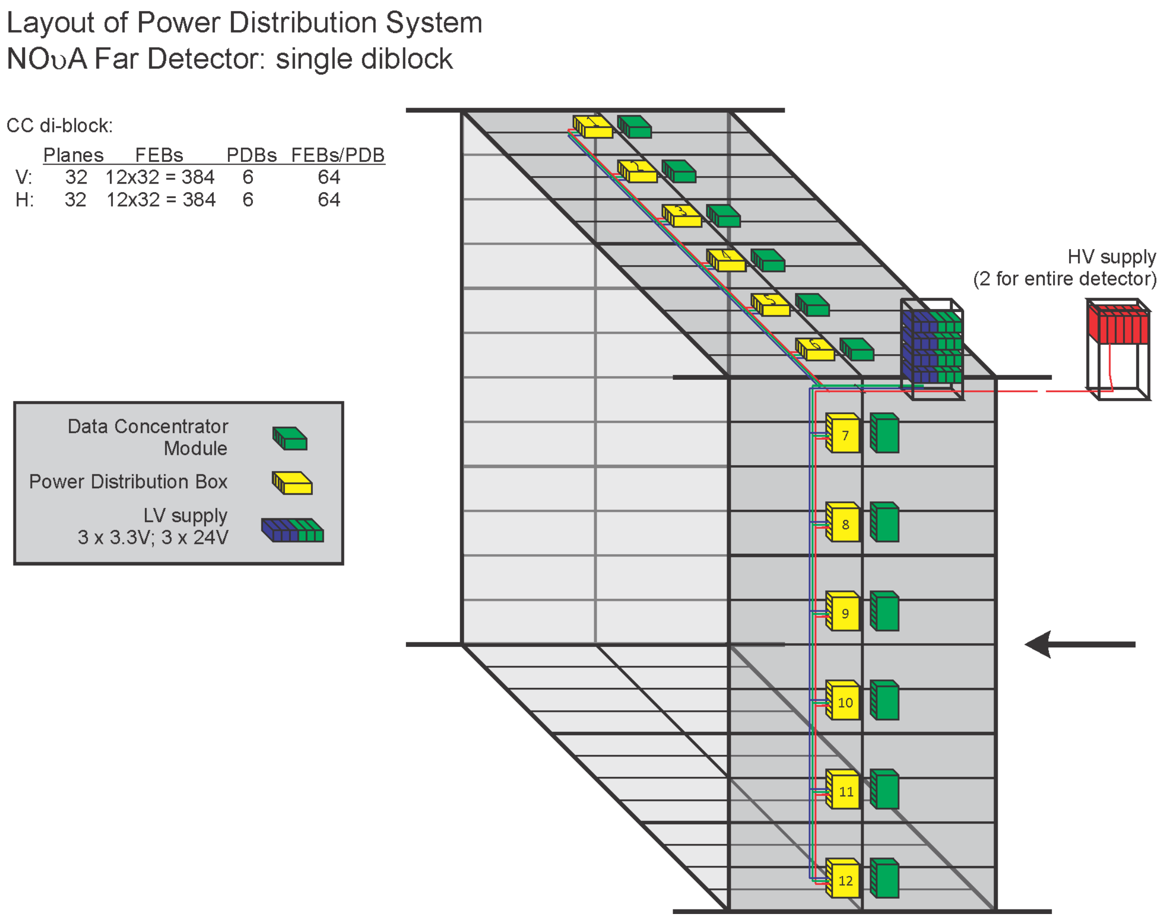


Figure 15: Layout of the Power Distribution System for a far detector di-block. Each PDB powers all of the FEBs in a 2 longitudinal block by two module wide area.

The detailed layout of the PDBs, cable trays, and cables (as well as the DCMs and cooling manifolds) for the far detector has been drawn using AutoCAD. The PDBs serving the vertical modules will be set on the flat part of the module manifolds, as can be seen in Fig. 16. The DCMs are adjacent to them. The restriction in the maximum height of the PDBs (and DCMs) to 3U (5.25″) is in order to allow the rolling access bridge to be as close as possible to the vertical module manifolds and electronic boxes for installation and repair. Figure 17 shows a blowup of the rather busy top west corner of the far detector. The PDBs (and DCMs) serving the horizontal modules are mounted sideways on the west side of the detector using a commercial framing system such as Unistrut.

The layout for the Power Distribution System for the near detector is shown in Fig. 18. The FEBs are on the top and on one side of the detector. Each side PDB feeds power to 45 (48) horizontal modules for type A (B) blocks and each top PDB feeds 64 (62) vertical modules for type A (B) blocks. An additional PDB feeds the 13 planes of the muon ranger at the rear of the spectrometer. A total of 10 PDBs, 4 Wiener supplies, and one Wiener MPOD mainframe with one ISEG HV card are needed for the entire near detector. Unlike the far detector, where each HV channel serves two PDBs, each PDB crate in the near detector has its own HV channel.

7 Mounting

The PDBs are mounted directly on the top and sides of the NOνA modules, as shown schematically in Fig. 1. The top PDBs are fixed to a tray, shared by the DCMs, with feet that rest on the horizontal modules, between the vertical manifolds, as shown in Fig. 19 for a Type AA diblock and Fig. 20 for a Type AB diblock.

The side PDBs are mounted on Unistrut scafolding used to mount the PDBs, DCMs, and cable trays. The 'wings' of the PDBs are used to mount to a Delrin fixture which is then attached to a Unistrut channel as shown if Fig. 21.

8 Cabling

The NOνA cables are listed in Table 7 below. There are three power cables to run from the power supplies in the catwalk to the PDBs along side the detector: 3.3V, 24V, and HV (350–450V). One sense cable runs from the PDBs to the power supplies and is used for remote sensing of the voltage at the PDBs. The 3.3V, 24V, and HV power from the PBBs to the FEBs is carried by a single six-conductor cable, as is the 24V power from the PDBs to the DCMs. The ground braid to the PDBs has not yet been specified. Note that the CAT5e cable taking the data from the FEBs to the DCMs is not part of the Power Distribution System, but uses the same cable trays as the power cables.

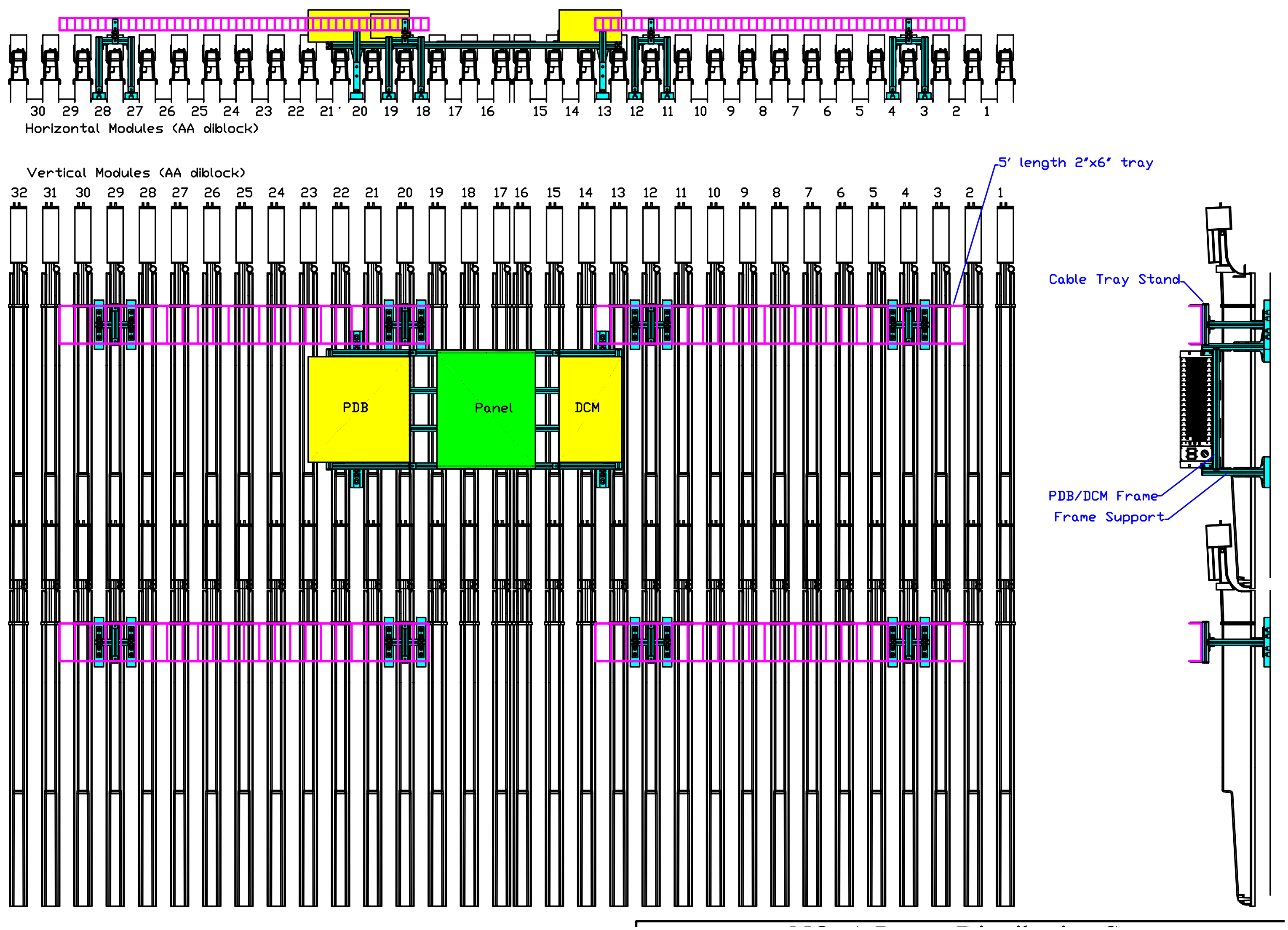


Figure 16: Front, side, and top views of the top of a near detector AA di-block, showing the PDB, DCM, support tray, cable trays and their supports.

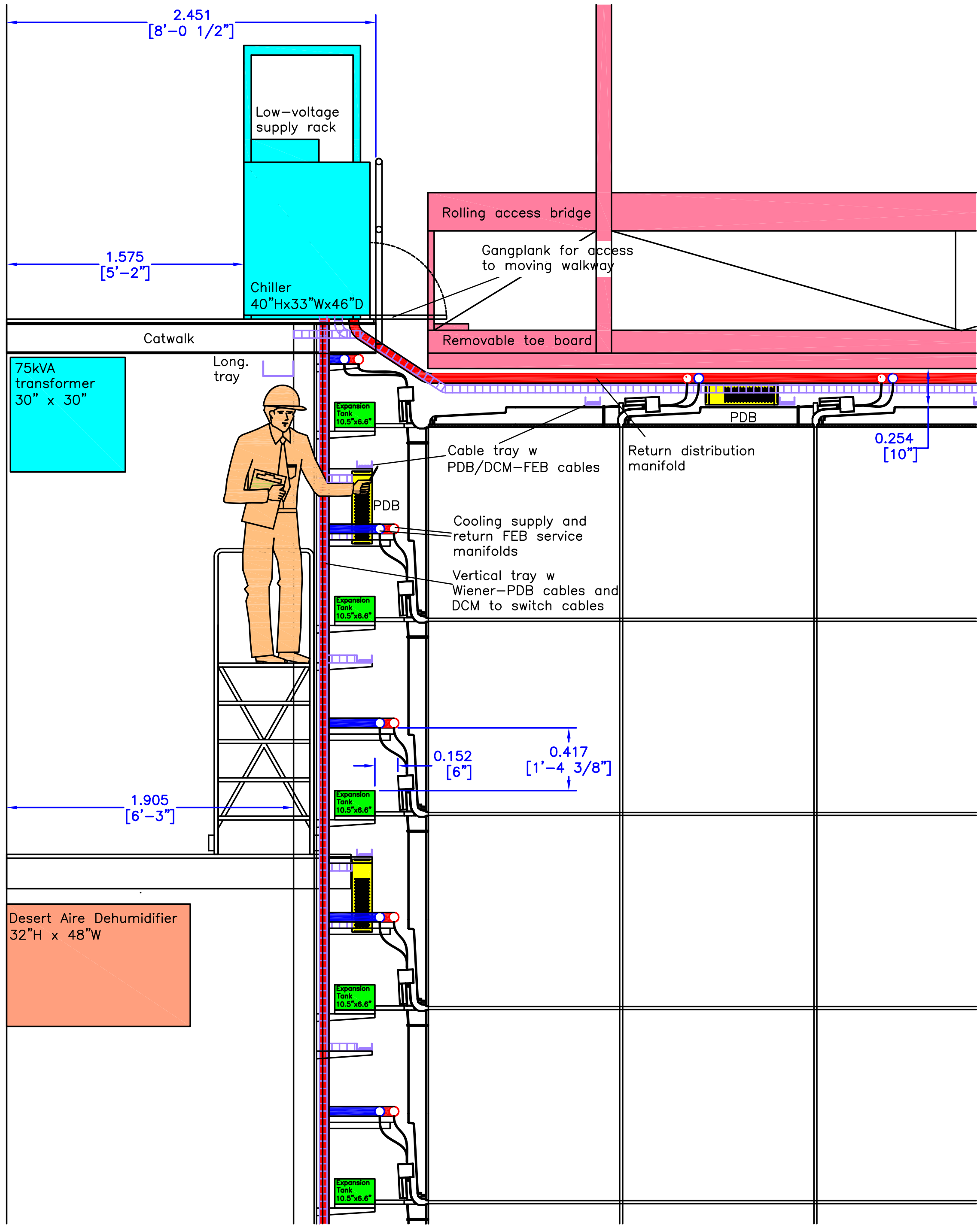


Figure 17: Front view of the top west corner of a far detector di-block. The PDBs fit between the module manifolds and the rolling walkway on the top, and between the manifolds and the catwalk support columns on the side. Cable trays and cooling water manifolds are shown. Not shown are the DCMs, which are behind the PDBs, and the power and signal cables.

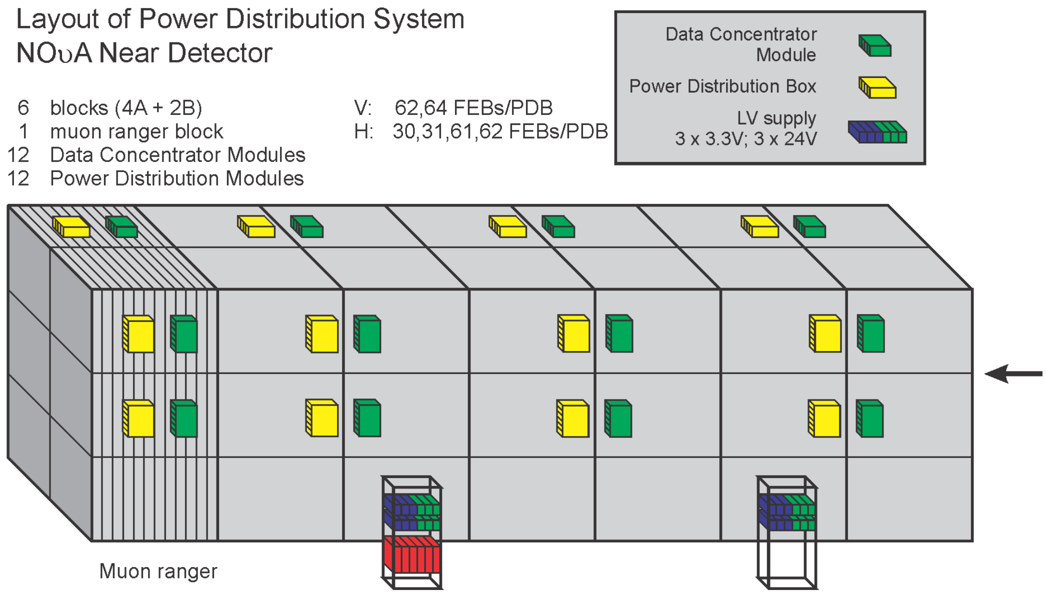


Figure 18: Layout of the Power Distribution System for the near detector. The top PDBs feed power to FEBs to two modules of two blocks. The side PDBs feed FEBs in three modules for a single block. A single PDB feeds the muon ranger.

8.1 Low Voltage Power Supply to PDB Cabling

For each Far Detector diblock, the power cables supplying 3.3V and 24V to the PDBs go from the Weiner low voltage power supplies on the upper catwalk to 6 PDBs on the top of the detector and 6 PDBs on the side of the detector. The cable lengths, voltage drops, and power dissipation are given in Fig. 22. The power cables are routed to the Power Distribution Boxes via 1.25″ grounded liquid-tight flexible metal conduits.[1] There will be three conduits placed in each trench between vertical modules. The conduits will also carry the high voltage

[1] Cable trays cannot be used for cables of size ?. Cable trays would also could not be placed in between modules. Hence the use of conduit.

Table 7: NOνA cable types.

Item	Cond.	AWG	Type	Manufacturer / SN
PS-PDB 3.3V	1	2	Tray cable	
PS-PDB 24V	2	6	Tray cable	
PS-patch panel HV	12	24	DB37 Male/Female	Black Box/EDN37J-0025-MF
Patch panel-PDB HV	2	22	RG-58A/U shielded triaxial cable	
Sense	4	22	2 pairs with shield and drain	Belden/6543FE
PDB-FEB	6	18	Tray cable	Belden/27600A
PDB-DCM	2	18	Tray cable	
ground	?	?	braid	

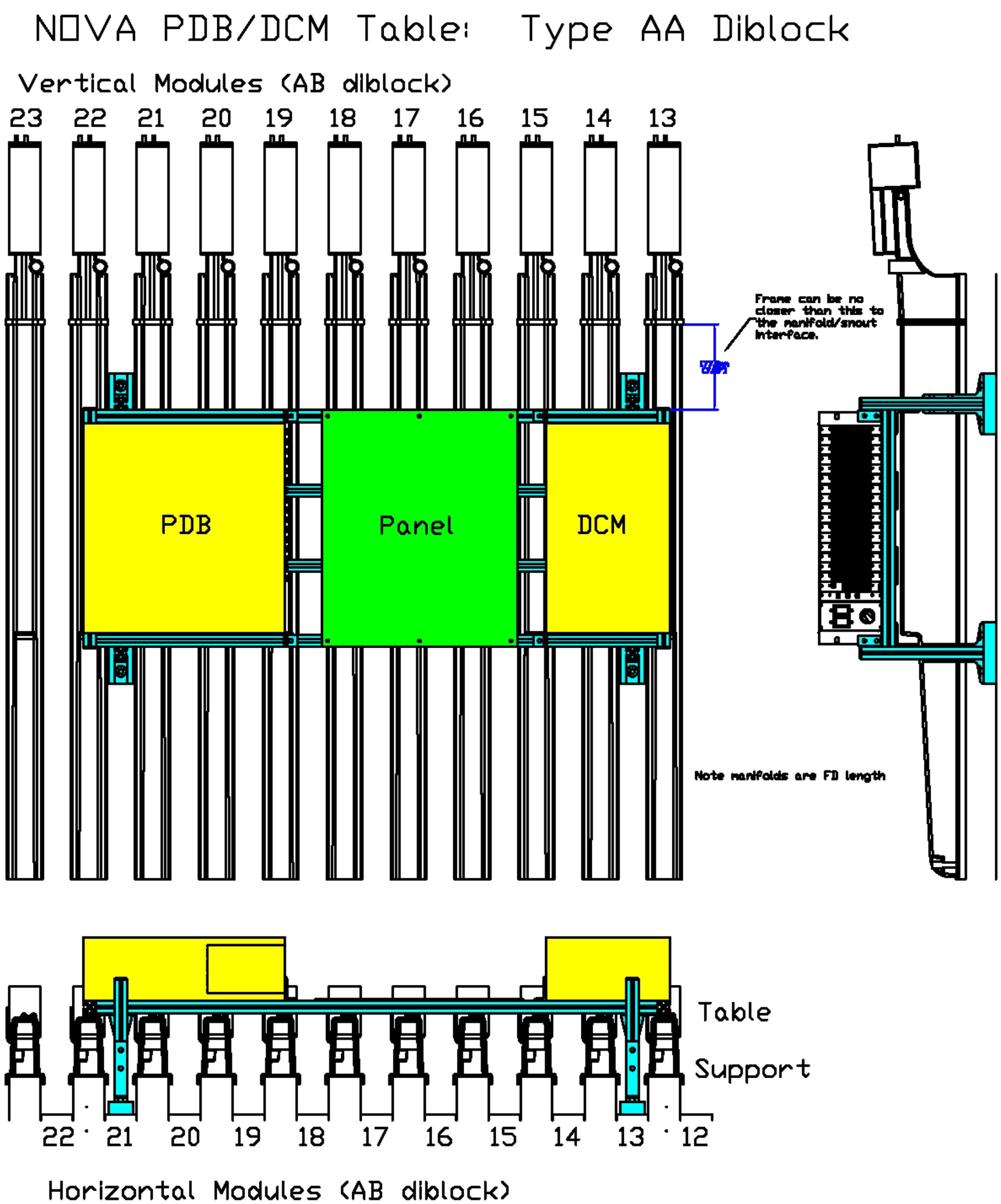


Figure 19: Top PDB support for a Type AA diblock. The DCM is also supported by the same tray.

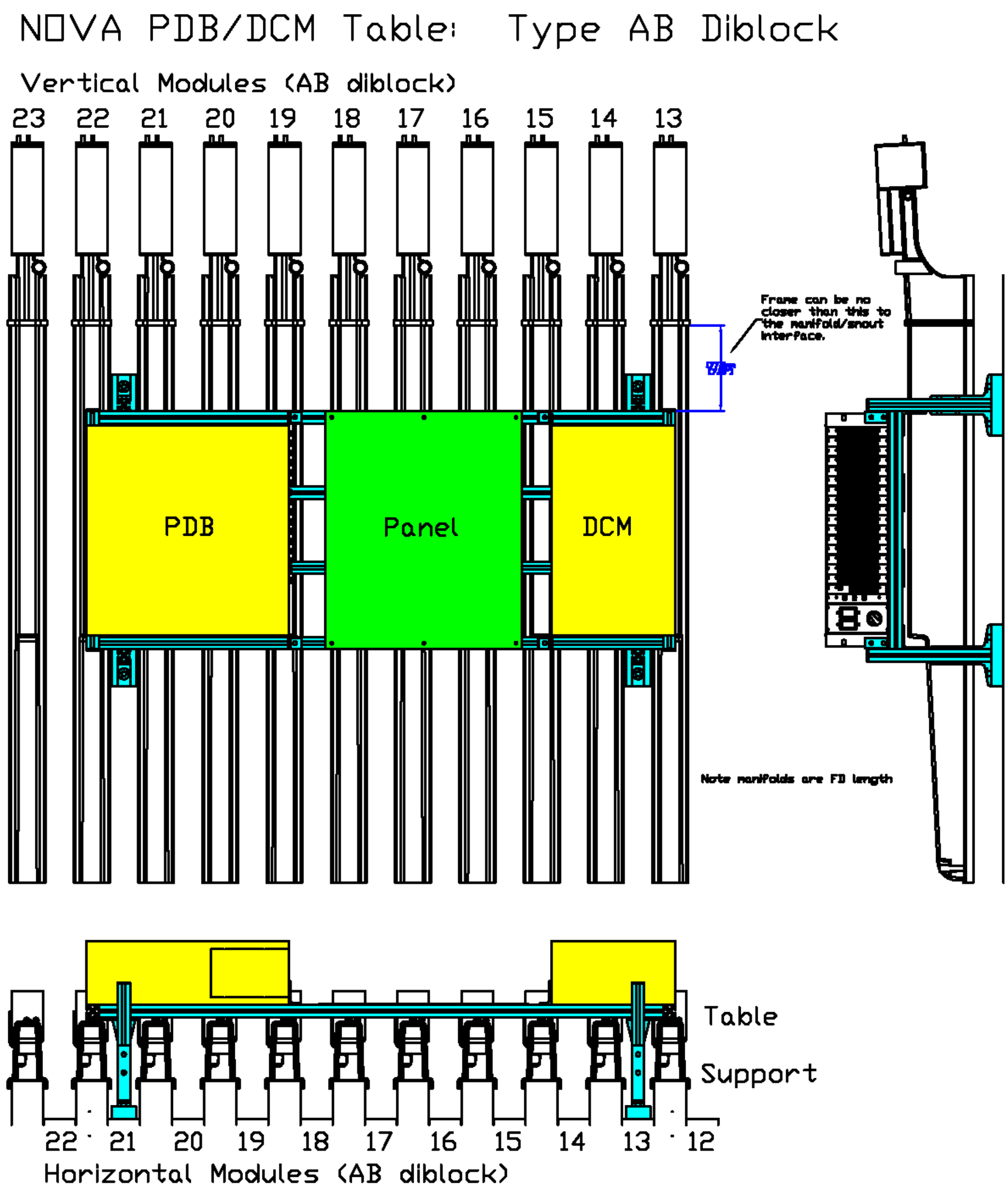


Figure 20: Top PDB support for a Type AB diblock. The DCM is also supported by the same tray.

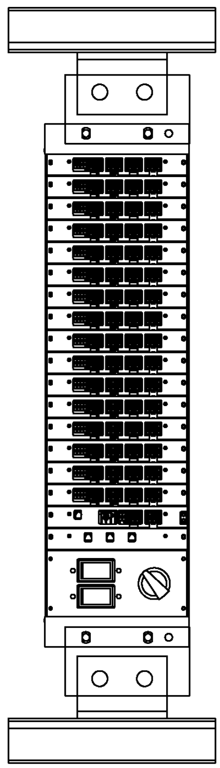


Figure 21: Side PDB support. The DCM is also supported in this way.

Table 8: NOνA cable color scheme.

Power Supply to Power Distribution Box						
FEB (3.3V)	SRC	RET				
	Red	Black				
TEC (24V)	SRC	RET				
	Yellow	Black				
APD (HV)	Yellow jacket					
	SRC	RET				
	Orange	Blue				
Sense	Jacket: gray					
	FEB (3.3V)		TEC (24V)			
	SRC	RET	SRC	RET		
	Green	White	Red	Black		
Power Distribution Box to FEB/DCM						
PDB-DCM	Jacket: White					
	SRC	RET				
	Red	Black				
PDB-FEB	Jacket: Black					
	FEB (3.3V)		TEC (24V)		APD (HV)	
	SRC	RET	SRC	RET	SRC	RET
	Orange	Yellow	Blue	Brown	Red	Black

cables and the sense cables. The grounded end is at the power supply. All the low voltage power supply cables will have inline fuses at the power supply.

8.2 Low Voltage Power Supply Sense Cables

Sense cables run from the low voltage power supplies to the Power Distribution Boxes. The cables consist of two individually shielded, twisted pairs. The sense lines are terminated on the supply end in the manufacturer's pluggable terminal strips. At the Power Distribution Box they are terminated in a D-sub style DB-9 connector with insulated housing. The sense lines are attached to the back of the Power Distribution Box in a corresponding DB-9 receptacle. The pinout of the DB-9 is shown in Fig. 23.

The sense lines are fused at 0.25A to prevent damage to the lines. The fusing is implemented as inline fusing on the cables at the Power Distribution Box side of the sense lines.

8.3 High Voltage Power Supply to PDB Cabling

The power cables from the Wiener MPOD high voltage power supplies will be routed to a patch panel on the same relay racks. The cables running from the patch panel to the PDBs are triaxial coax. They will be routed in the same conduit as the other cables.

LV Supply to PDB Cable Lengths and Voltage Drops

Craig Dukes
24-Nov-09

Normal AB di-block

Input Parameters					
	Cable type		Current		Conductors
3.3V	2	AWG	77.5	A	2
3.3V sense	22	AWG			2
24V	6	AWG	21.0	A	2
24V sense	22	AWG			2

Voltage Drops (one way)				
	Top		Side	
	Max	Min	Max	Min
3.3V:	0.635	0.140	0.599	0.104
24V:	0.434	0.090	0.413	0.066

Cable Lengths (m)				
	Top		Side	
	Max	Min	Max	Min
3.3V:	15.98	3.53	15.08	2.63
24V:	15.93	3.32	15.17	2.44

Di-block power dissipation (total)			
	3.3V	24V	Total
Total:	688	126	814 W

One Way Di-block Cable Lengths			
	Total	Max	Min
3.3V	111.7 m	16.0 m	2.6 m
	366.3 ft	52.4 ft	8.6 ft
24V	110.5 m	15.9 m	2.4 m
	362.4 ft	52.3 ft	8.0 ft

Lengths from drawing 1377-v4 (Dukes). They are all one-way lengths.

Top PDBs: Cable Lengths, Voltage Drops, and Power Consumption								
Length (one way)	**PDB 6**	**PDB 5**	**PDB 4**	**PDB 3**	**PDB 2**	**PDB 1**	**Sum**	
3.3V: (m)	3.53	6.03	8.53	10.98	13.48	15.98	58.53 m	
(ft)	11.58	19.78	27.99	36.02	44.23	52.43	192.03 ft	
24V: (m)	3.32	5.84	8.48	10.77	13.29	15.93	57.63 m	
(ft)	10.89	19.16	27.82	35.33	43.60	52.26	189 ft	
Voltage drop (one way) (V)								
3.3V:	0.140	0.240	0.339	0.436	0.536	0.635		
24V:	0.090	0.159	0.231	0.293	0.362	0.434		
Power lost (two way) (W)							**Total**	**per meter**
3.3V:	22	37	53	68	83	98	360 W	3.1 W/m
24V:	4	7	10	12	15	18	66 W	0.6 W/m
Total:	26	44	62	80	98	117	426 W	1.8 W/m

East

1, 2, 3 ⇐, 4, 5, 6

West

Side PDBs: Cable Lengths, Voltage Drops, and Power Consumption								
Length (one way)	**PDB 7**	**PDB 8**	**PDB 9**	**PDB 10**	**PDB1**	**PDB 12**	**Sum**	
3.3V: (m)	2.63	5.13	7.63	10.08	12.58	15.08	53.13 m	
(ft)	8.63	16.83	25.03	33.07	41.27	49.48	174 ft	
24V: (m)	2.44	5.08	7.72	9.88	12.53	15.17	52.82 m	
(ft)	8.01	16.67	25.33	32.41	41.11	49.77	173 ft	
Voltage drop (one way) (V)								
3.3V:	0.104	0.204	0.303	0.400	0.500	0.599		
24V:	0.066	0.138	0.210	0.269	0.341	0.413		
Power lost (two way) (W)							**Total**	**per meter**
3.3V:	16	32	47	62	77	93	327 W	3.1 W/m
24V:	3	6	9	11	14	17	60 W	0.6 W/m
Total:	19	37	56	73	92	110	388 W	1.8 W/m

Top

7, 8, 9 ⇐, 10, 11, 12

Bottom

Figure 22: Low voltage power supply to PDB cable lengths and voltage drops.

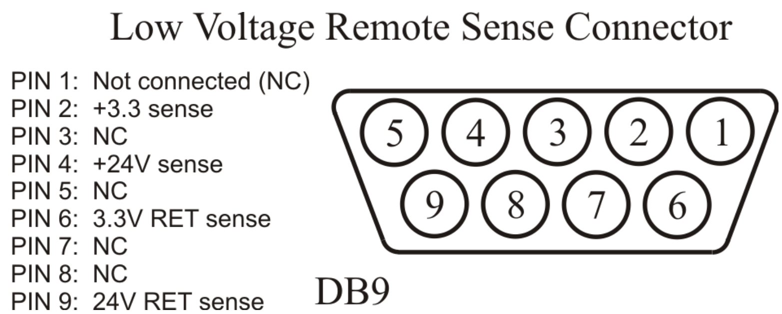


Figure 23: The pinout for the Power Distribution Box remote sense connector.

8.4 PDB to FEB cables

The power cables going from the PDBs to the FEBs are 6-conductor, 18AWG, non-paired, tray cable, with a PVC jacket (Belden 27600A). They are placed in wire basket cable trays of $6\times2\,\text{in}^2$ size. The layout of the cable trays for part of a top far detector AB di-block is shown in Fig. 25. The layout of the side cable trays is similar. The top lateral cable trays (and cooling manifolds) are set between the vertical modules in order to allow access to the electronics boxes and the FEBs. Cable tray and cable lengths are given in Table 6. A total of 11,160 6-conductor, 18 AWG, cables are needed to carry the power from the PDBs to the FEBs for the far detector. A total of 495 cables carry the power from the high and lov voltage supplies to the PDBs.

The PDB-FEB cables are grouped into four cable harnesses, each with 15 or 16 cables, depending on the diblock type and whether the PDB is mounted on the top or the side of the detector (see Fig. 24). The cable harnesses serving quadrants Q1 and Q2 are shorter in length than those serving quadrants Q3 and Q4, resulting in four different types of harnesses that are used. A total of 720 (30) cable harnesses are needed for the far (near) detector (where we have excluded the near detector muon catcher from the total).

Table 9: Total number of cable harnesses of each type needed for the far detector.

	Short	Long
15 cable	180	180
16 cable	180	180

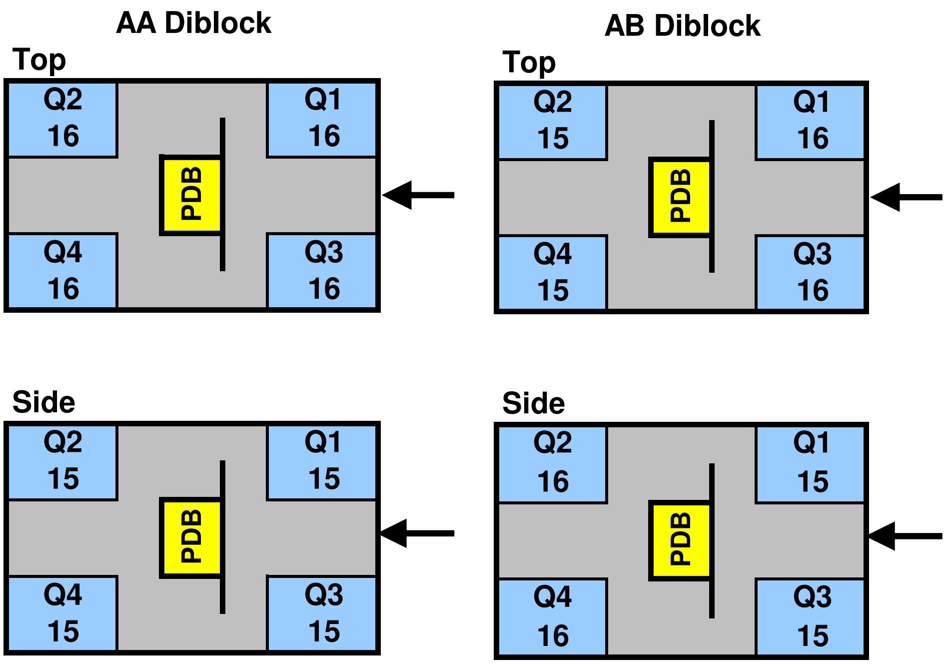


Figure 24: Number of cables per PDB–FEB cable harness. Each PDB has four cable harnesses feeding between 15 and 16 Front End Boards. The number of cables is each harness is shown for top and side PDBs for AA and AB diblocks.

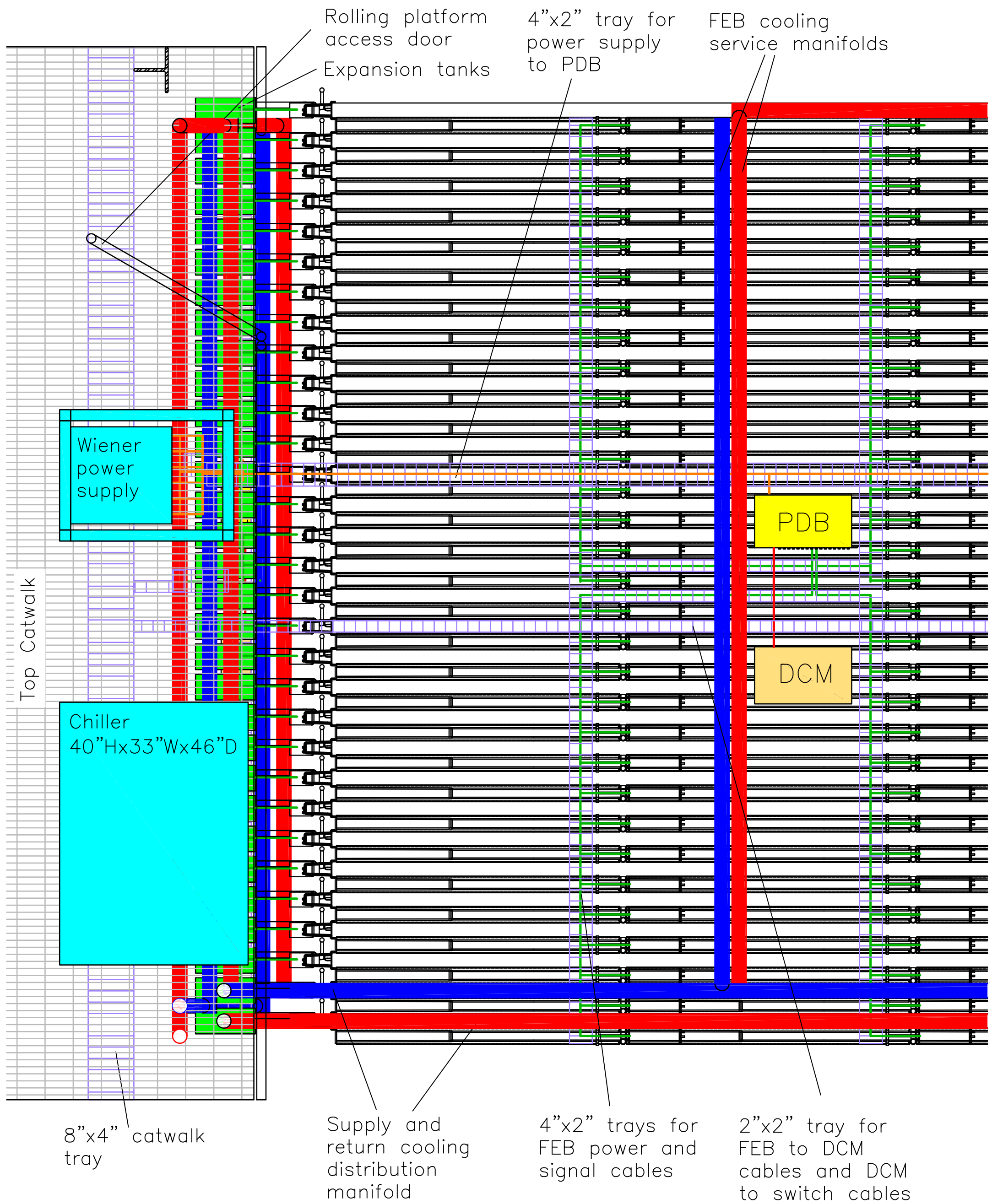


Figure 25: Top view of the west side of a Far Detector AB di-block, showing the locations of the PDBs and the DCMs, as well as the cable trays, power cables, and cooling manifolds. Note that the cable trays going from the power supplies to the PDBs have been replaced by conduit.

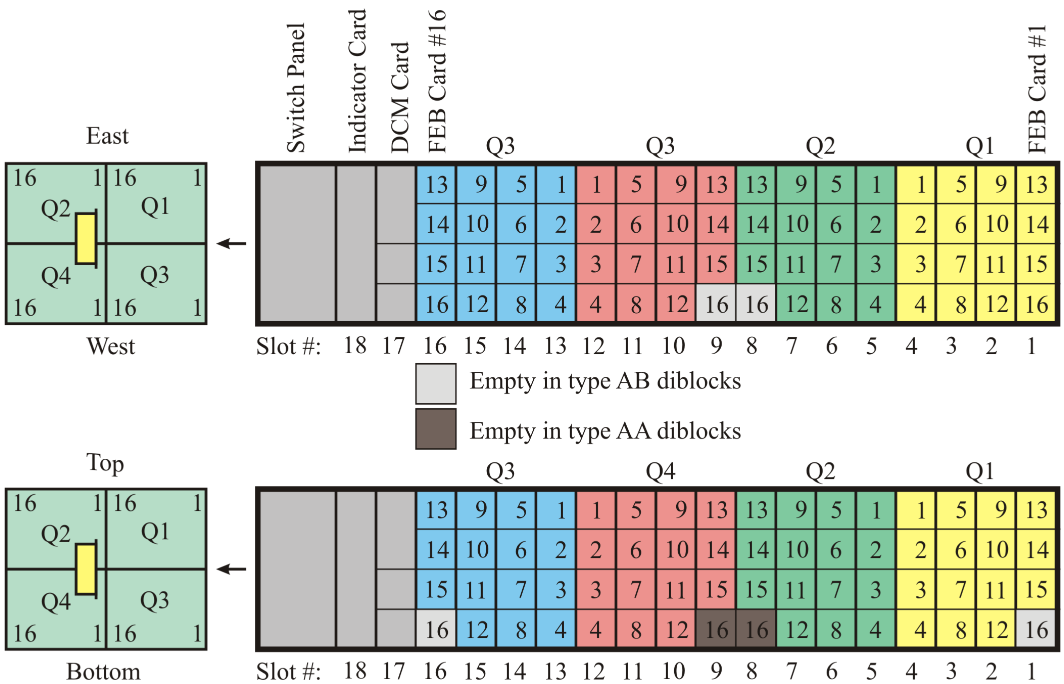


Figure 26: Cable map of the PDB channels for top PDBs (top) and side PDBs (bottom). The figures at left show the cable numbering scheme.

PDB to FEB Cable Lengths and Voltage Drops: Top AB Di-block

Craig Dukes
24-Nov-09

Lengths from drawing 1377-v4 (Dukes). They are all one-way lengths.

Input Parameters

Currents				
3.3V	24V	450V	Wire gauge (AWG):	18
1.25	0.30	0.00005	Top FEB pitch:	0.1350
			Conductors:	6

PDB-FEB Distance

Total	Ave	Max	Min	Entire di-block
146 m	2.4 m	3.8 m	0.98 m	875 m
478 ft	7.7 ft	12.4 ft	3.2 ft	2,871 ft

Cable Mass

Quadrant:	1	2	3	4	Total
Power	10.5 lb	9.6 lb	7.5 lb	6.8 lb	34.5 lb
Cat 5	5.8 lb	5.3 lb	4.1 lb	3.7 lb	18.9 lb
Total:	16.26	14.90	11.63	10.56	53.4 lb

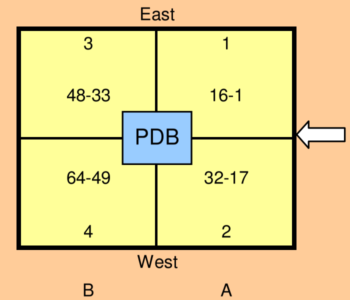
Voltage Drops (one way)

	Max	Min	Diff
3.3V	0.099	0.026	0.074 V
24V	0.024	0.006	0.018 V

Total Dissipated Power (W)

	3.3V	24V	Total
PDB	10	1	10 W
Diblock	57	3	61 W

Number of cables:	62
Total power/length:	0.069 W/m
Max. power/length:	1.108 W/m



FEB:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Total (m):	3.000	2.865	2.730	2.595	2.460	2.325	2.190	2.055	1.920	1.785	1.650	1.515	1.380	1.245	1.110	0.975	31.80 m
Resistance (ohm):	0.063	0.060	0.057	0.054	0.052	0.049	0.046	0.043	0.040	0.037	0.035	0.032	0.029	0.026	0.023	0.020	0.67 Ohm
Voltage drop (3.3V):	0.079	0.075	0.071	0.068	0.064	0.061	0.057	0.054	0.050	0.047	0.043	0.040	0.036	0.033	0.029	0.026	
Voltage drop (24V):	0.019	0.018	0.017	0.016	0.015	0.015	0.014	0.013	0.012	0.011	0.010	0.010	0.009	0.008	0.007	0.006	

FEB:	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Total
Length (m):	3.790	3.655	3.520	3.385	3.250	3.115	2.980	2.845	2.710	2.575	2.440	2.305	2.170	2.035	1.900	1.765	44.44 m
Resistance (ohm):	0.079	0.077	0.074	0.071	0.068	0.065	0.062	0.060	0.057	0.054	0.051	0.048	0.045	0.043	0.040	0.037	0.93 Ohm
Voltage drop (3.3V):	0.099	0.096	0.092	0.089	0.085	0.082	0.078	0.074	0.071	0.067	0.064	0.060	0.057	0.053	0.050	0.046	
Voltage drop (24V):	0.024	0.023	0.022	0.021	0.020	0.020	0.019	0.018	0.017	0.016	0.015	0.014	0.014	0.013	0.012	0.011	

FEB:	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	Total
Total (m):	0.980	1.115	1.250	1.385	1.520	1.655	1.790	1.925	2.060	2.195	2.330	2.465	2.600	2.735	2.870	28.88 m
Resistance (ohm):	0.021	0.023	0.026	0.029	0.032	0.035	0.037	0.040	0.043	0.046	0.049	0.052	0.054	0.057	0.060	0.60 Ohm
Voltage drop (3.3V):	0.026	0.029	0.033	0.036	0.040	0.043	0.047	0.050	0.054	0.057	0.061	0.065	0.068	0.072	0.075	
Voltage drop (24V):	0.006	0.007	0.008	0.009	0.010	0.010	0.011	0.012	0.013	0.014	0.015	0.015	0.016	0.017	0.018	

FEB:	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	Total
Total (m):	1.770	1.905	2.040	2.175	2.310	2.445	2.580	2.715	2.850	2.985	3.120	3.255	3.390	3.525	3.660	40.73 m
Resistance (ohm):	0.037	0.040	0.043	0.046	0.048	0.051	0.054	0.057	0.060	0.063	0.065	0.068	0.071	0.074	0.077	0.85 Ohm
Voltage drop (3.3V):	0.046	0.050	0.053	0.057	0.060	0.064	0.068	0.071	0.075	0.078	0.082	0.085	0.089	0.092	0.096	
Voltage drop (24V):	0.011	0.012	0.013	0.014	0.015	0.015	0.016	0.017	0.018	0.019	0.020	0.020	0.021	0.022	0.023	

Figure 27: Cable lengths, voltage drops, and power dissipation for top PDB to FEB cables for a type AB diblock.

PDB to FEB Cable Lengths and Voltage Drops: Side AB Di-block

Craig Dukes
24-Nov-09

Lengths from drawing 1377-v4 (Dukes). They are all one-way lengths.

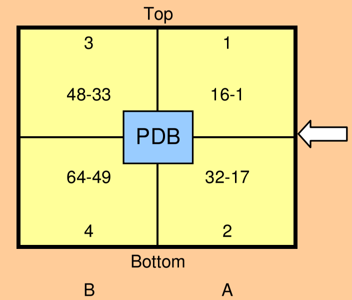
Input Parameters				
Currents			Wire gauge (AWG):	18
3.3V	24V	450V	Top FEB pitch:	0.1350
1.25	0.30	5.00E-05	Conductors:	6

PDB-FEB Distance				
Total	Ave	Max	Min	Entire di-block
137	2.22	3.54	0.96 m	825 m
451	7.3	11.6	3.1 ft	2,706 ft

Voltage Drops (one way)	Max	Min	Diff
3.3V	0.093	0.025	0.068 V
24V	0.022	0.006	0.016 V

Total Dissipated Power (W)	3.3V	24V	Total
PDB	9	1	10 W
Diblock	54	3	57 W

Number of cables:	62
Total power/length:	0.069 W/m
Max. power/length:	1.108 W/m



FEB:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Length (m):	2.980	2.845	2.710	2.575	2.440	2.305	2.170	2.035	1.900	1.765	1.630	1.495	1.360	1.225	1.090	0.955	31.48 m
Resistance (ohm):	0.062	0.060	0.057	0.054	0.051	0.048	0.045	0.043	0.040	0.037	0.034	0.031	0.028	0.026	0.023	0.020	0.66 Ohm
Voltage drop (3.3V):	0.078	0.074	0.071	0.067	0.064	0.060	0.057	0.053	0.050	0.046	0.043	0.039	0.036	0.032	0.029	0.025	
Voltage drop (24V):	0.019	0.018	0.017	0.016	0.015	0.014	0.014	0.013	0.012	0.011	0.010	0.009	0.009	0.008	0.007	0.006	

FEB:	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	Total
Total (m):	3.540	3.405	3.270	3.135	3.000	2.865	2.730	2.595	2.460	2.325	2.190	2.055	1.920	1.785	1.650	1.515	40.44 m
Resistance (ohm):	0.074	0.071	0.068	0.066	0.063	0.060	0.057	0.054	0.052	0.049	0.046	0.043	0.040	0.037	0.035	0.032	0.85 Ohm
Voltage drop (3.3V):	0.093	0.089	0.086	0.082	0.079	0.075	0.071	0.068	0.064	0.061	0.057	0.054	0.050	0.047	0.043	0.040	
Voltage drop (24V):	0.022	0.021	0.021	0.020	0.019	0.018	0.017	0.016	0.015	0.015	0.014	0.013	0.012	0.011	0.010	0.010	

FEB:	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	Total
Total (m):	0.960	1.095	1.230	1.365	1.500	1.635	1.770	1.905	2.040	2.175	2.310	2.445	2.580	2.715	2.850	28.58 m
Resistance (ohm):	0.020	0.023	0.026	0.029	0.031	0.034	0.037	0.040	0.043	0.046	0.048	0.051	0.054	0.057	0.060	0.60 Ohm
Voltage drop (3.3V):	0.025	0.029	0.032	0.036	0.039	0.043	0.046	0.050	0.053	0.057	0.060	0.064	0.068	0.071	0.075	
Voltage drop (24V):	0.006	0.007	0.008	0.009	0.009	0.010	0.011	0.012	0.013	0.014	0.015	0.015	0.016	0.017	0.018	

FEB:	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	Total
Total (m):	1.520	1.655	1.790	1.925	2.060	2.195	2.330	2.465	2.600	2.735	2.870	3.005	3.140	3.275	3.410	36.98 m
Resistance (ohm):	0.032	0.035	0.037	0.040	0.043	0.046	0.049	0.052	0.054	0.057	0.060	0.063	0.066	0.069	0.071	0.77 Ohm
Voltage drop (3.3V):	0.040	0.043	0.047	0.050	0.054	0.057	0.061	0.065	0.068	0.072	0.075	0.079	0.082	0.086	0.089	
Voltage drop (24V):	0.010	0.010	0.011	0.012	0.013	0.014	0.015	0.015	0.016	0.017	0.018	0.019	0.020	0.021	0.021	

Figure 28: Cable lengths, voltage drops, and power dissipation for side PDB to FEB cables for a type AB diblock.

9 Relay Racks

The power supplies are situated in 44U relay racks situated on the upper catwalks in the far detector and in an alcove for the near detector. There is one relay rack per diblock for the far detector low voltage supplies and two relay racks for the high voltage supplies. For the near detector there are two relay racks, each with two low voltage power supplies, and one with the sole high-voltage power supply. Figure 17 shows the position of a relay rack in the far detector, and Fig. 31 (Fig. 32) show the rack population for the near detector low-voltage (high-voltage) relay rack, and Fig. 29 (Fig. 30) show the rack population for the far detector low-voltage (high-voltage) relay rack.

The Wiener PL506 low voltage supplies consume quite a bit of power. Their air intakes are located below the units, with exhaust above. A set of internal fans cool the units. A test was made with a single supply run at full power and outfited with temperature sensors [9]. The maximum temperature was found to be 48 C, which is within the specified operation range of 0–70 C for the Wieners. To improve the cooling a nine-fan packs was used, and the maximum temperature was found to be 28 C. One fan pack will be placed at the bottom of the relay racks and one above each PL506 for exhaust, giving a total of five (three) fan packs for the far (near) detector relay racks.

The relay racks have a power interruption system designed for the DØ experiment installed in the case of smoke detection: the DØ Rack Monitor Interface (RMI) [10]. This disables AC power to the equipment in the rack when smoke is detected, with the exception of the rack monitor itself and the field point monitoring system. Test results of the system can be found in Ref. [11].

NOνA Far Detector Low Voltage Relay Rack

Position	Front: Equipment	Voltage	Power	Back: Equipment
U-45				
U-44				
U-43	Rack Protection			Rack Protection
U-42				
U-41	Cable Run Gap			Cable Run Gap
U-40				
U-39	DAQ Switch	110-240	70 W	*Empty*
U-38				*Empty*
U-37	DCS Switch	110-240	70 W	*Empty*
U-36				*Empty*
U-35	*Empty*			*Empty*
U-34	*Empty*			*Empty*
U-33	*Empty*			Air Gap
U-32	*Empty*			24V Power supplies
U-31				(Fieldpoint)
U-30	Field Point	24VDC	120 W	Power Distribution Block
U-29				(Fieldpoint)
U-28	Air Gap			Air Gap
U-27	Air Gap			Air Gap
U-26	Fan Tray (9 Fan)	115	120 W	Fan Tray (9 Fan)
U-25				*Rear Access*
U-24	Wiener PL506 #4	240	2,038 W	
U-23				
U-22	Air Gap			LV Breaker Panel
U-21	Air Gap			
U-20	Fan Tray (9 Fan)	115	120 W	Fan Tray (9 Fan)
U-19				*Rear Access*
U-18	Wiener PL506 #3	240	2,167 W	
U-17				
U-16	Air Gap			LV Breaker Panel
U-15	Air Gap			
U-14	Fan Tray (9 Fan)	115	120 W	Fan Tray (9 Fan)
U-13				*Rear Access*
U-12	Wiener PL506 #2	240	2,019 W	
U-11				
U-10	Air Gap			LV Breaker Panel
U-9	Air Gap			
U-8	Fan Tray (9 Fan)	115	120 W	Fan Tray (9 Fan)
U-7				*Rear Access*
U-6	Wiener PL506 #1	240	2,149 W	
U-5				
U-4	Air Gap			LV Breaker Panel
U-3	Air Gap			
U-2	Fan Tray (9 Fan)	115	120 W	Fan Tray (9 Fan)
U-1	*Empty*			*Empty*
		Total:	9,233 W	

Figure 29: Far detector low-voltage relay rack population.

NOνA Far Detector High Voltage Relay Rack

Position	Front Equipment	Voltage	Power	Position	Back Equipment
U-45	*Empty*			U-45	*Empty*
U-44				U-44	
U-43	Rack Protection			U-43	Rack Protection
U-42				U-42	
U-41	Cable Run Gap			U-41	Cable Run Gap
U-40				U-40	
U-39	*Empty*			U-39	*Empty*
U-38	*Empty*			U-38	*Empty*
U-37	*Empty*			U-37	*Empty*
U-36	*Empty*			U-36	*Empty*
U-35	*Empty*			U-35	*Empty*
U-34	*Empty*			U-34	*Empty*
U-33	*Empty*			U-33	*Empty*
U-32	*Empty*			U-32	*Empty*
U-31	*Empty*			U-31	*Empty*
U-30	*Empty*			U-30	*Empty*
U-29	*Empty*			U-29	*Empty*
U-28	*Empty*			U-28	*Empty*
U-27	*Empty*			U-27	*Empty*
U-26	*Empty*			U-26	*Empty*
U-25	*Empty*			U-25	*Empty*
U-24	*Empty*			U-24	*Empty*
U-23	*Empty*			U-23	*Empty*
U-22	*Empty*			U-22	*Empty*
U-21	HV Patch Pannel (32 Channel)			U-21	HV Patch Pannel Back
U-20				U-20	
U-19	HV Patch Pannel (32 Channel)			U-19	HV Patch Pannel Back
U-18				U-18	
U-17	HV Patch Pannel (32 Channel)			U-17	HV Patch Pannel Back
U-16				U-16	
U-15	Air Gap			U-15	Air Gap
U-14	Air Gap			U-14	Air Gap
U-13	Fan Tray (9 Fan)	110-240	117 W	U-13	Fan Tray (9 Fan)
U-12				U-12	*Empty*
U-11				U-11	*Empty*
U-10				U-10	*Empty*
U-9	Wiener MPOD	110-240	600 W	U-9	*Empty*
U-8	ISEG HV			U-8	*Empty*
U-7	(9U)			U-7	*Empty*
U-6				U-6	*Empty*
U-5				U-5	*Empty*
U-4				U-4	*Empty*
U-3	*Empty*			U-3	*Empty*
U-2	*Empty*			U-2	*Empty*
U-1	*Empty*			U-1	*Empty*
		Total:	717 W		

Figure 30: Far detector high-voltage relay rack population.

NOνA Near Detector Low Voltage Relay Rack

Front

Position	Equipment	Voltage	Power
U-44			
U-43	Rack Protection		
U-42			
U-41	Cable Run Gap		
U-40			
U-39	DAQ Switch	110-240	70 W
U-38			
U-37	DCS Switch	110-240	70 W
U-36			
U-35	DCS Computer	110-240	300 W
U-34	*Empty*		
U-33	*Empty*		
U-32	*Empty*		
U-31	*Empty*		
U-30		110-240	40 W
U-29	Controls Terminal		
U-28	(LCD Screen)		
U-27			
U-26			
U-25			
U-24			
U-23	Air Gap		
U-22	Keyboard	USB	W
U-21	Air Gap		
U-20	Air Gap		
U-19			
U-18	Field Point	24VDC	120 W
U-17			
U-16	Air Gap		
U-15	Air Gap		
U-14	Fan Tray (9 Fan)	110-240	117 W
U-13			
U-12	Wiener PL506	240	2,520 W
U-11			
U-10	Air Gap		
U-9	Air Gap		
U-8	Fan Tray (9 Fan)	110-240	117 W
U-7			
U-6	Wiener PL506	240	2,520 W
U-5			
U-4	Air Gap		
U-3	Air Gap		
U-2	Fan Tray (9 Fan)	110-240	117 W
U-1	*Empty*		
		Total:	5,991 W

Back

Position	Equipment
U-44	
U-43	Rack Protection
U-42	
U-41	Cable Run Gap
U-40	
U-39	*Empty*
U-38	*Empty*
U-37	*Empty*
U-36	*Empty*
U-35	DCS Computer Back
U-34	*Empty*
U-33	*Empty*
U-32	*Empty*
U-31	*Empty*
U-30	*Empty*
U-29	*Empty*
U-28	*Empty*
U-27	Aux. Terminal Block
U-26	DIN mounted
U-25	(DB37 Cable routing)
U-24	*Empty*
U-23	Air Gap
U-22	*Empty*
U-21	Air Gap
U-20	24V Power supplies
U-19	(Fieldpoint)
U-18	Power Distribution Block
U-17	(Fieldpoint)
U-16	Air Gap
U-15	Air Gap
U-14	Fan Tray (9 Fan)
U-13	*Rear Access*
U-12	
U-11	
U-10	LV Breaker Panel
U-9	
U-8	Fan Tray (9 Fan)
U-7	*Rear Access*
U-6	
U-5	
U-4	LV Breaker Panel
U-3	
U-2	Fan Tray (9 Fan)
U-1	*Empty*

Figure 31: Near detector low-voltage relay rack population.

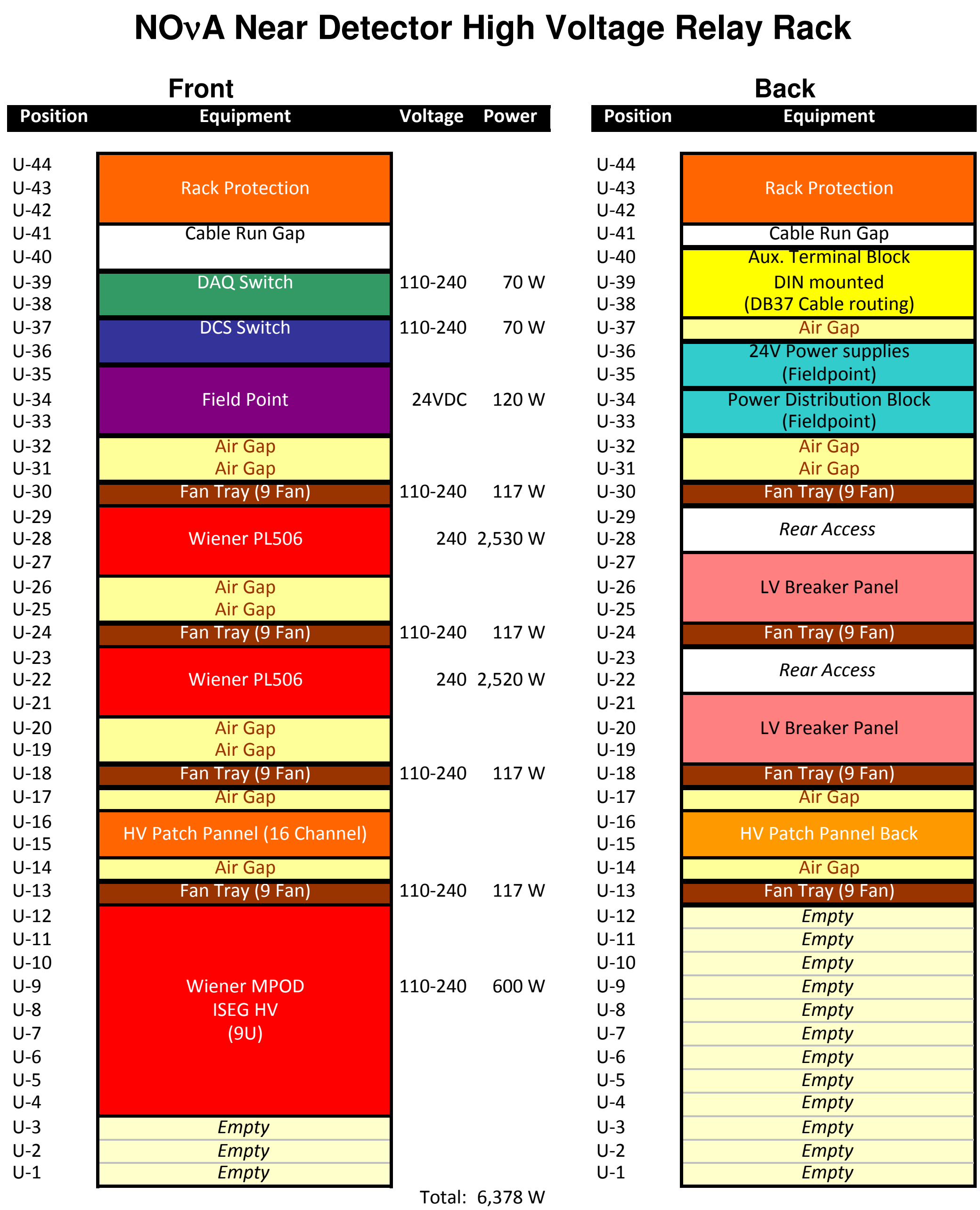


Figure 32: Near detector high-voltage relay rack population.

10 Appendix A: PDB Circuit Board Schematics

In the following pages are the Version 3.2 schematics for Power Distribution Box boards, including: (1) the backplane, (2) the FEB card, (3) the DCM card, and (4) the indicator card. The latest version of the schematics can be found at Ref. [5].

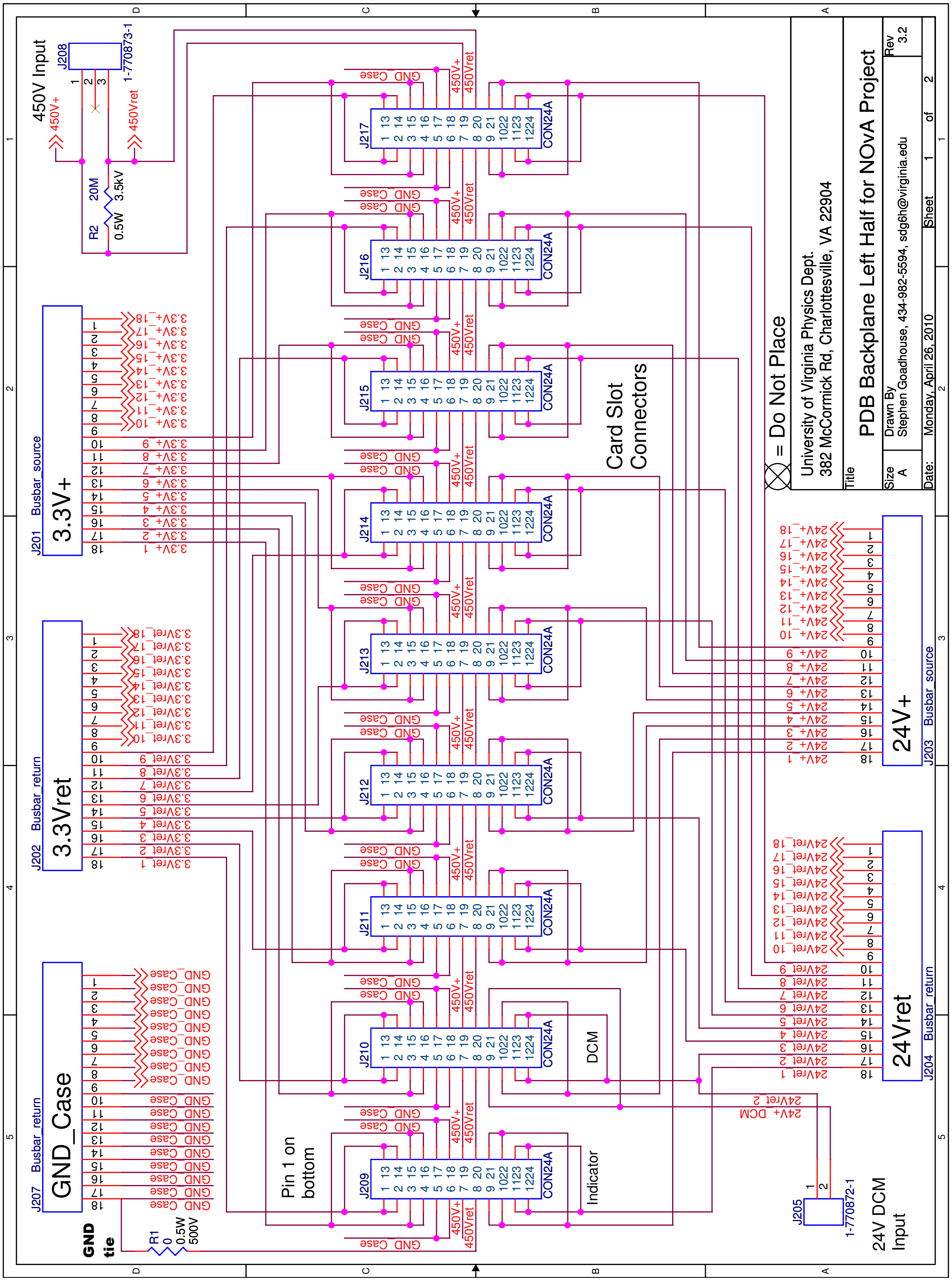


Figure 33: Schematic: Backplane v3.2 (Sheet 1)

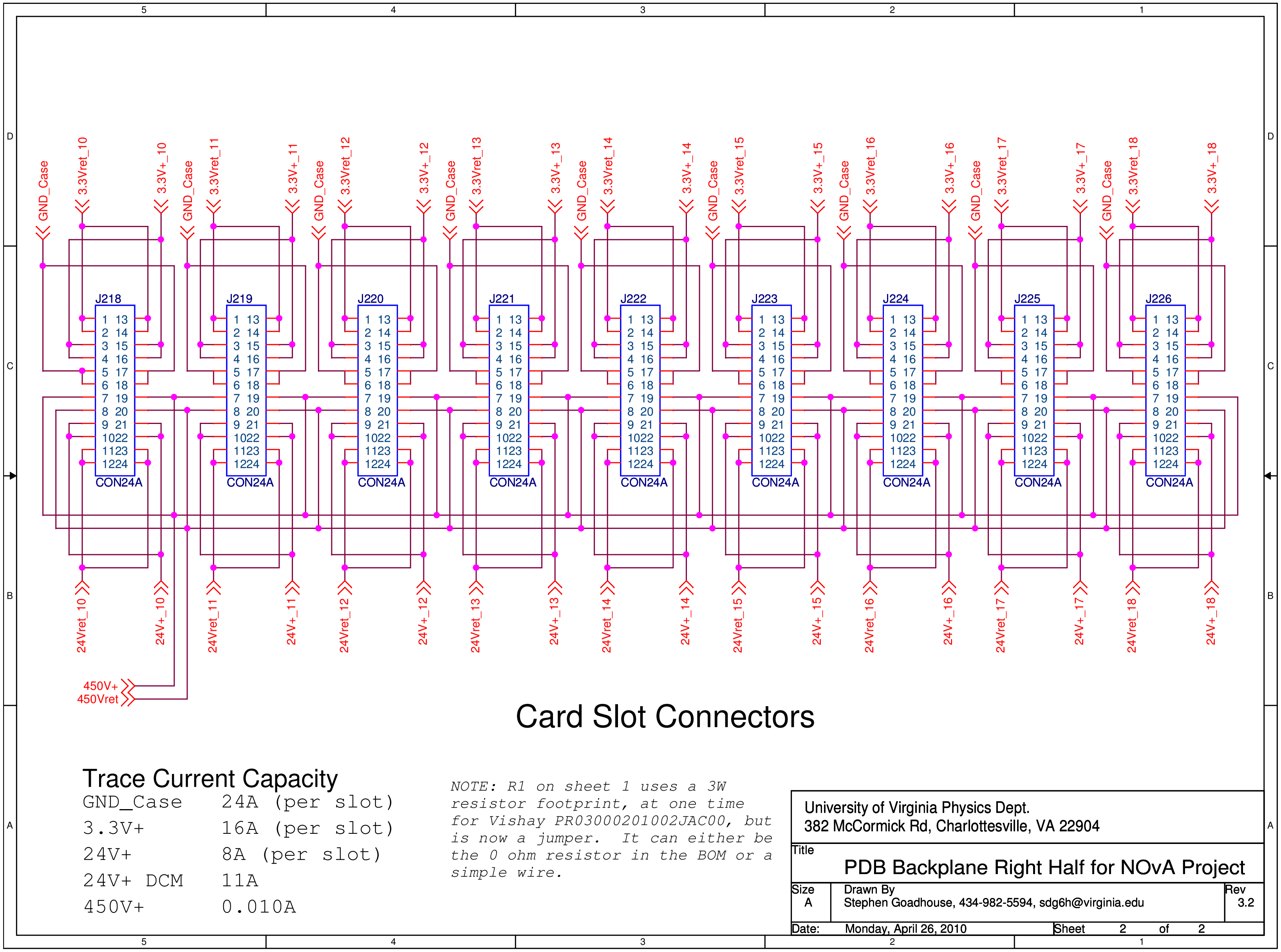


Figure 34: Schematic: Backplane v3.2 (Sheet 2)

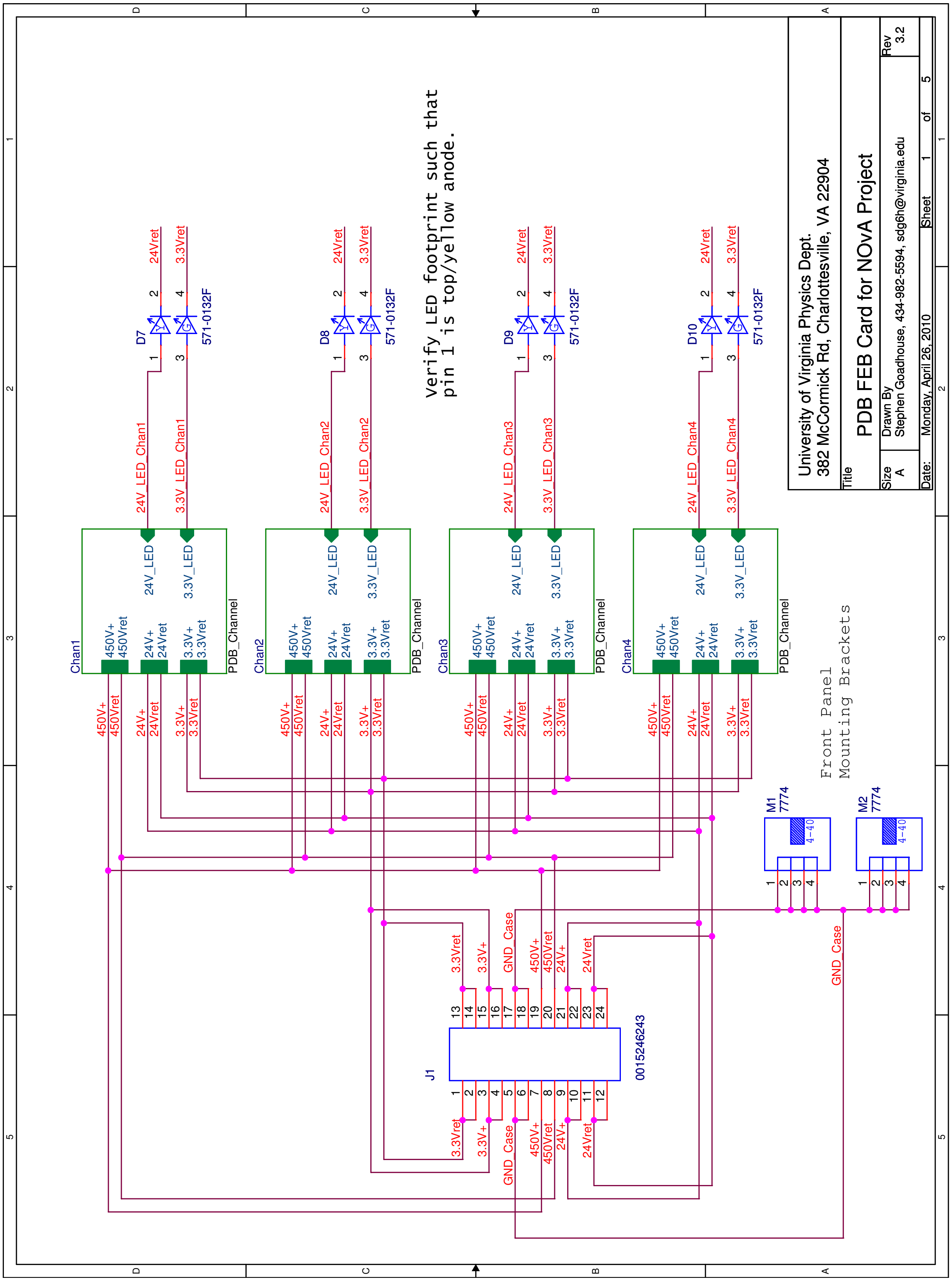


Figure 35: Schematic: FEB Card v3.2 (Sheet 1)

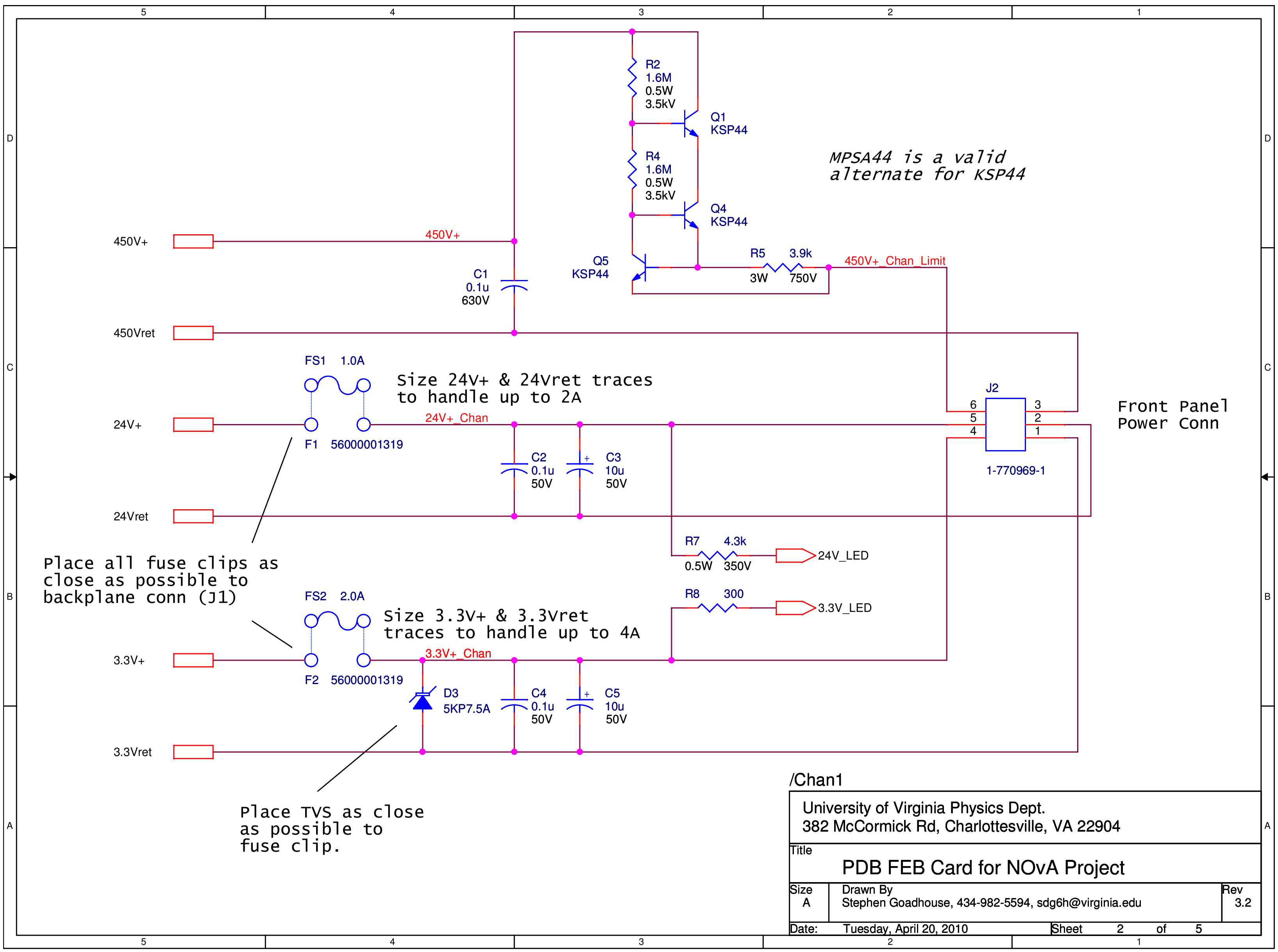


Figure 36: Schematic: FEB Card v3.2 (Sheet 2)

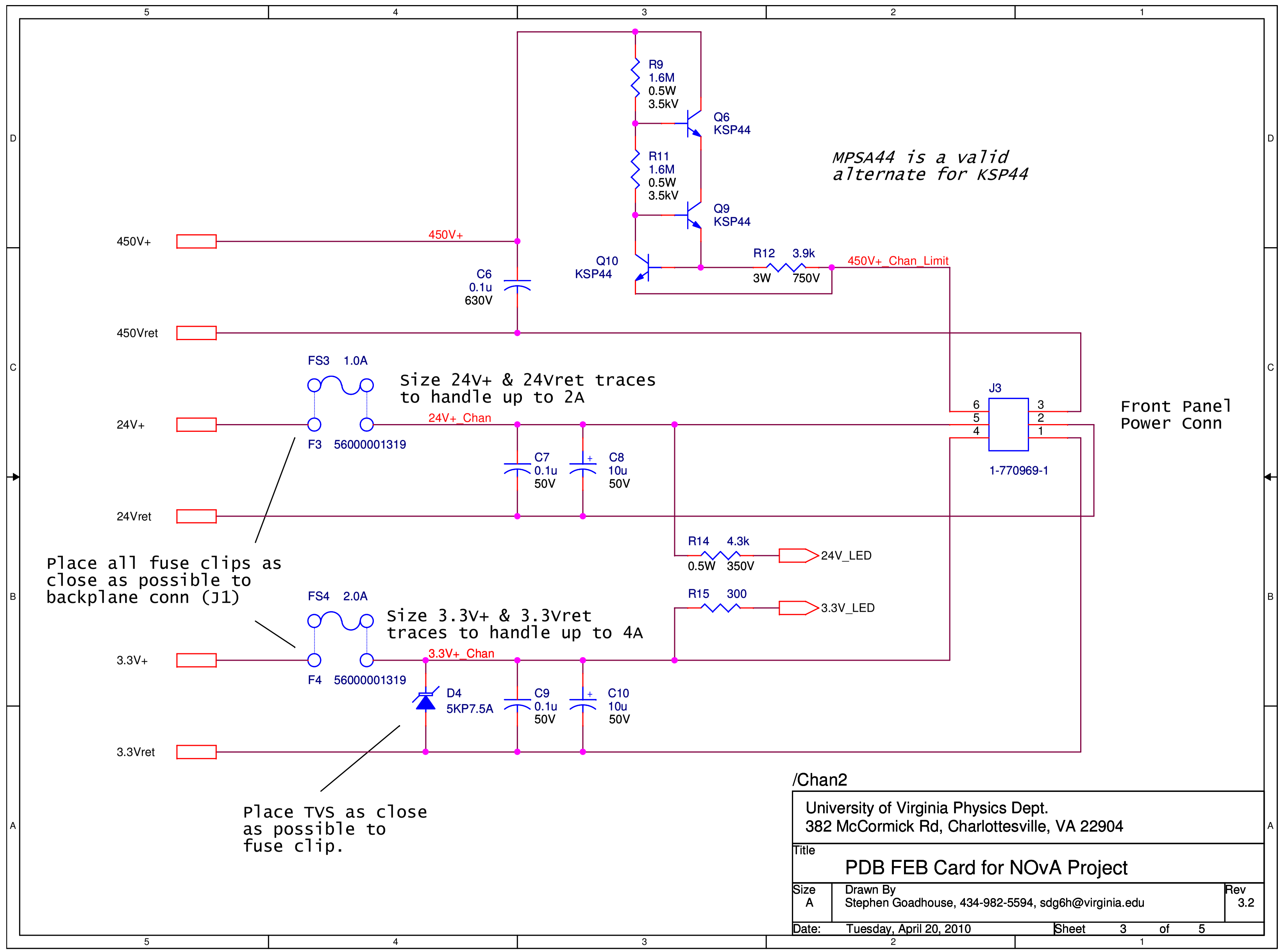


Figure 37: Schematic: FEB Card v3.2 (Sheet 3)

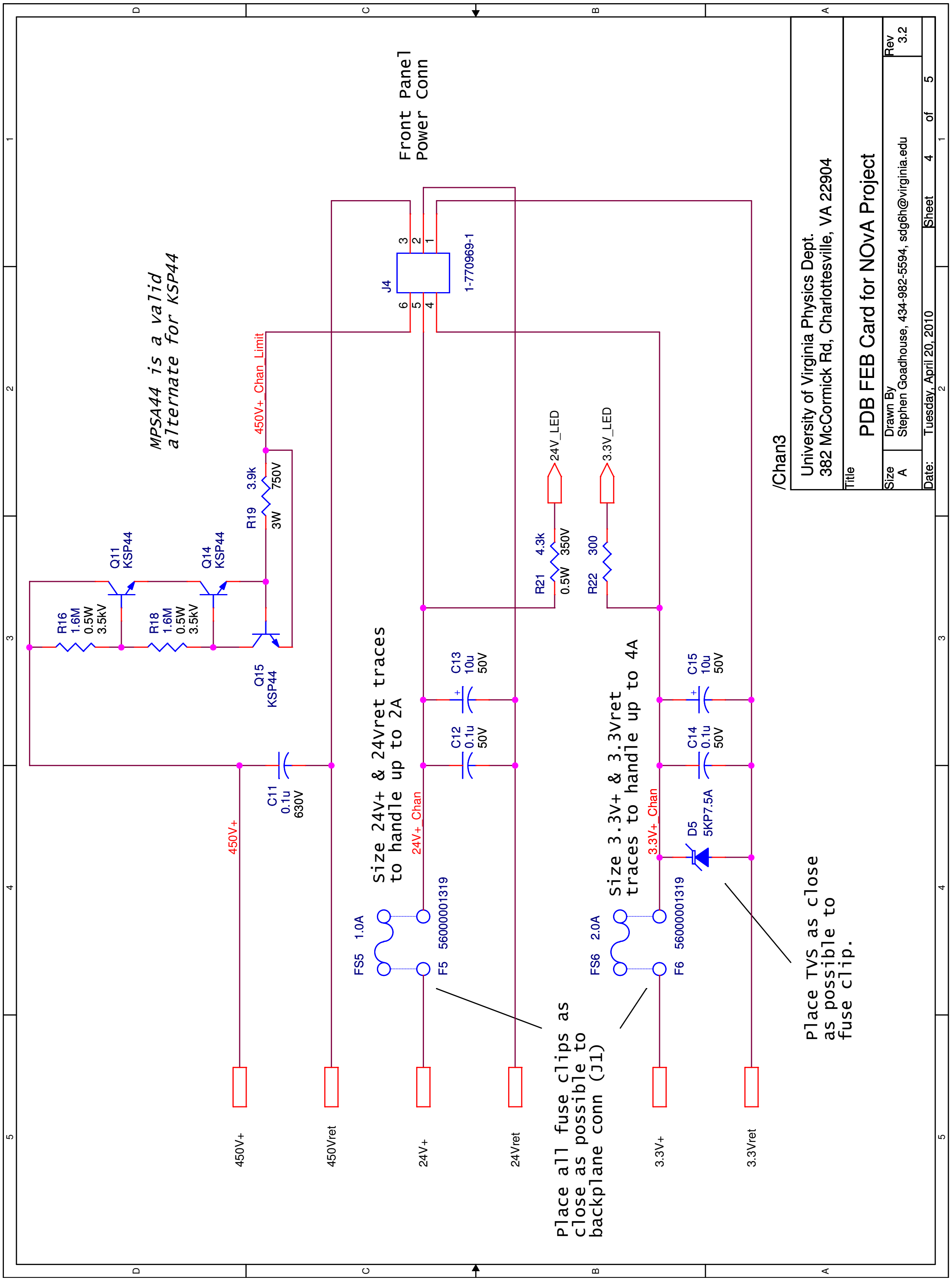


Figure 38: Schematic: FEB Card v3.2 (Sheet 4)

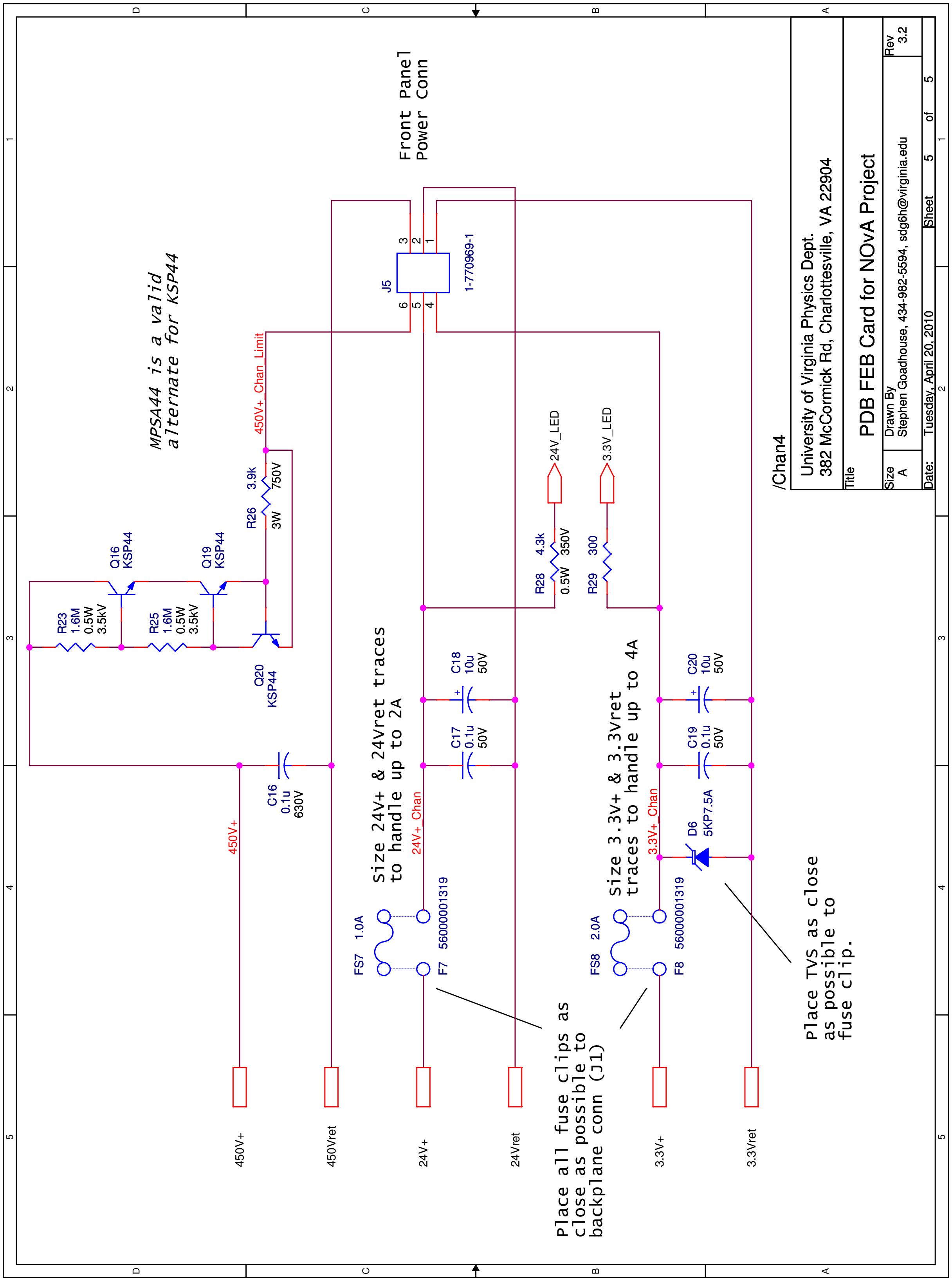


Figure 39: Schematic: FEB Card v3.2 (Sheet 5)

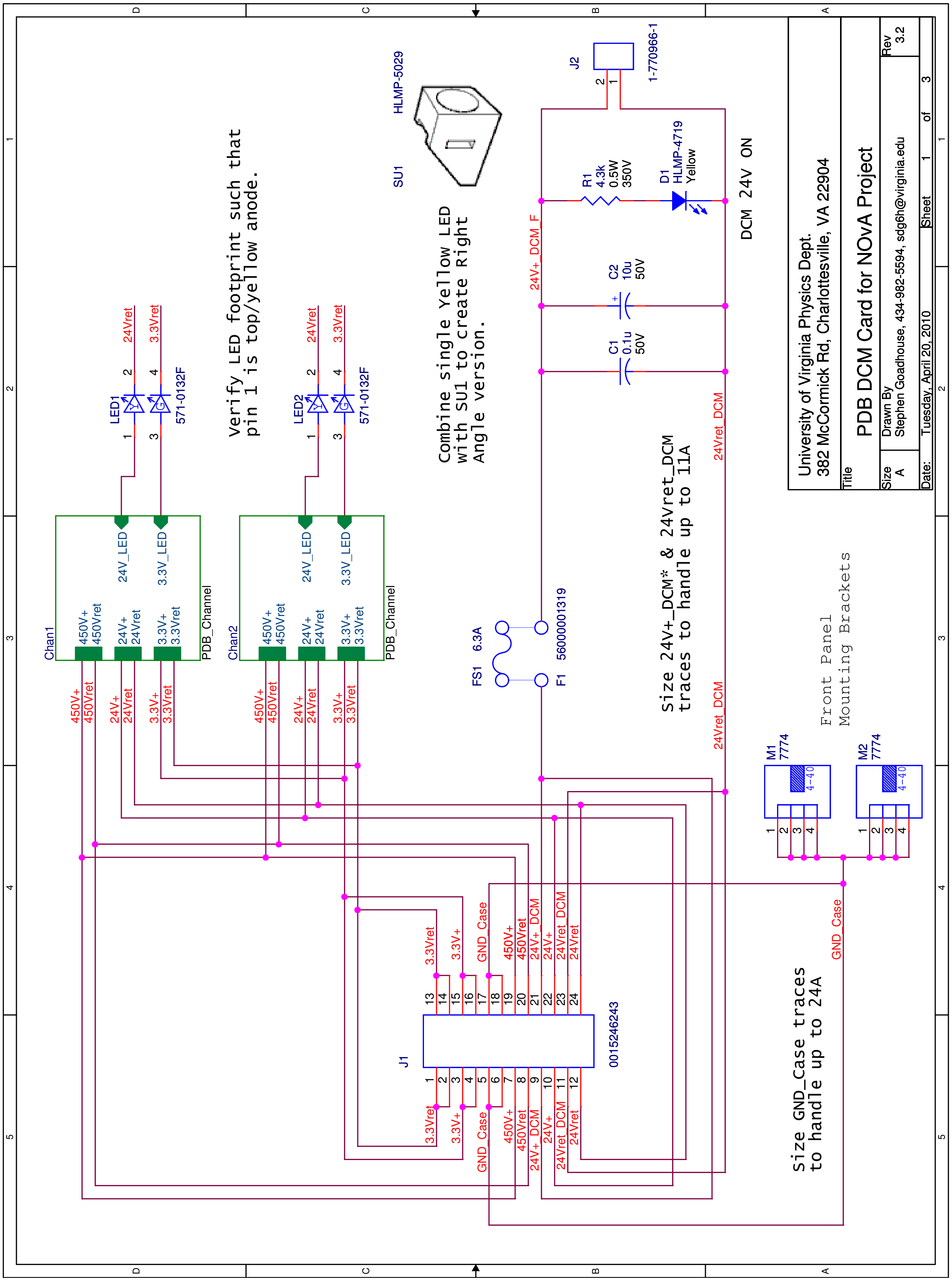


Figure 40: Schematic: DCM Card v3.2 (Sheet 1)

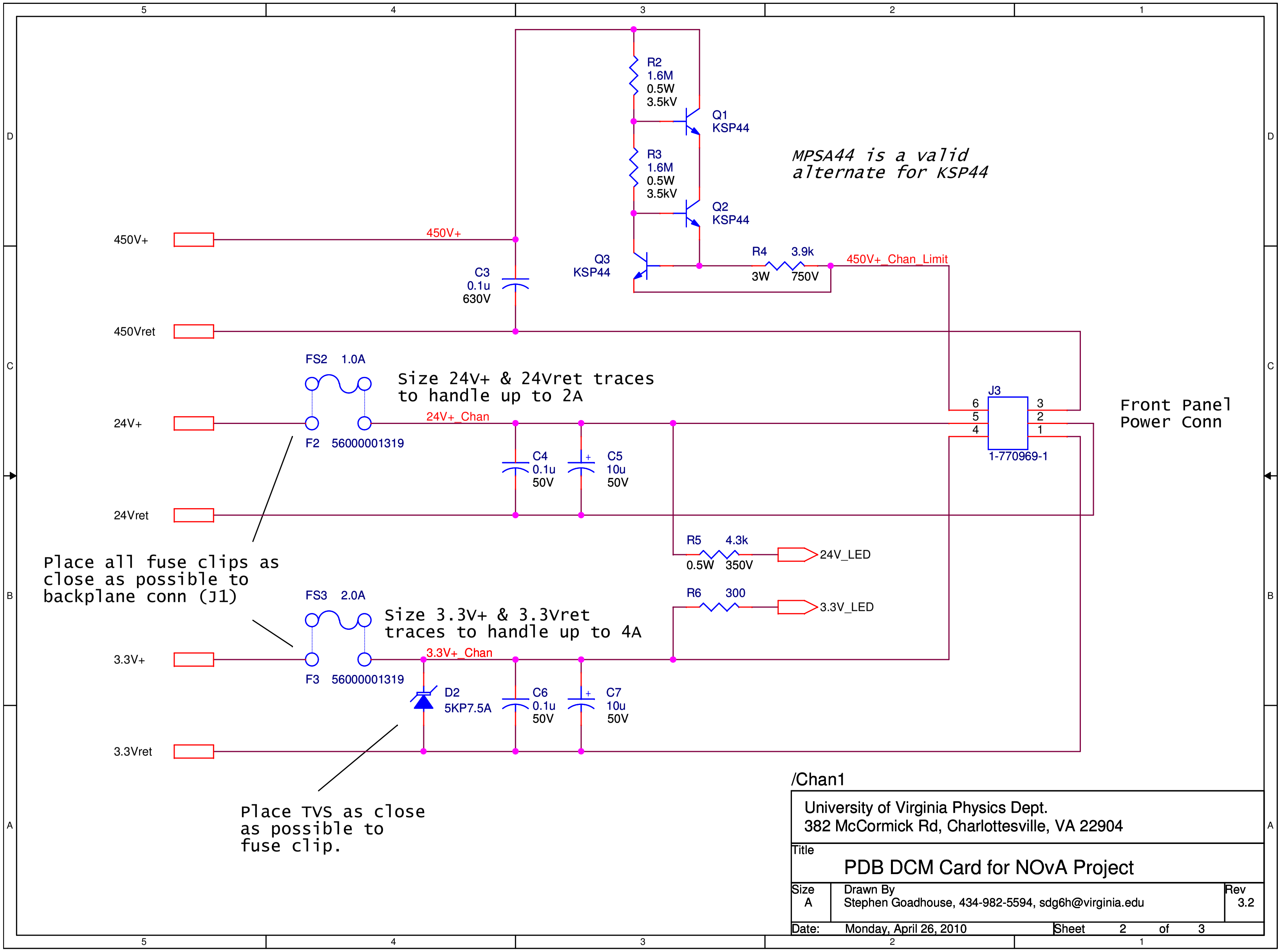


Figure 41: Schematic: DCM Card v3.2 (Sheet 2)

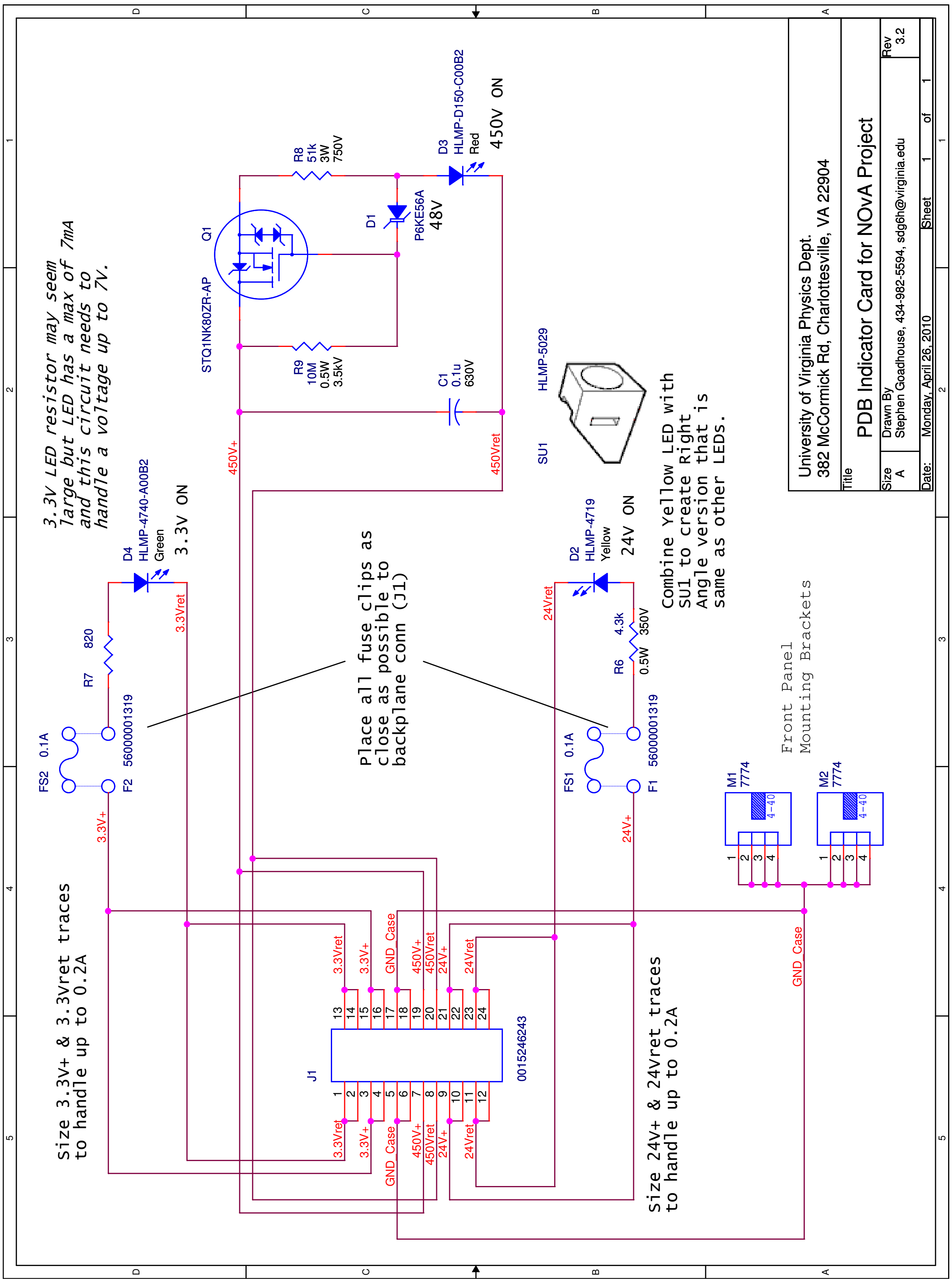


Figure 42: Schematic: Indicator Card

11 Appendix C: Near Detector on Surface Ground Scheme

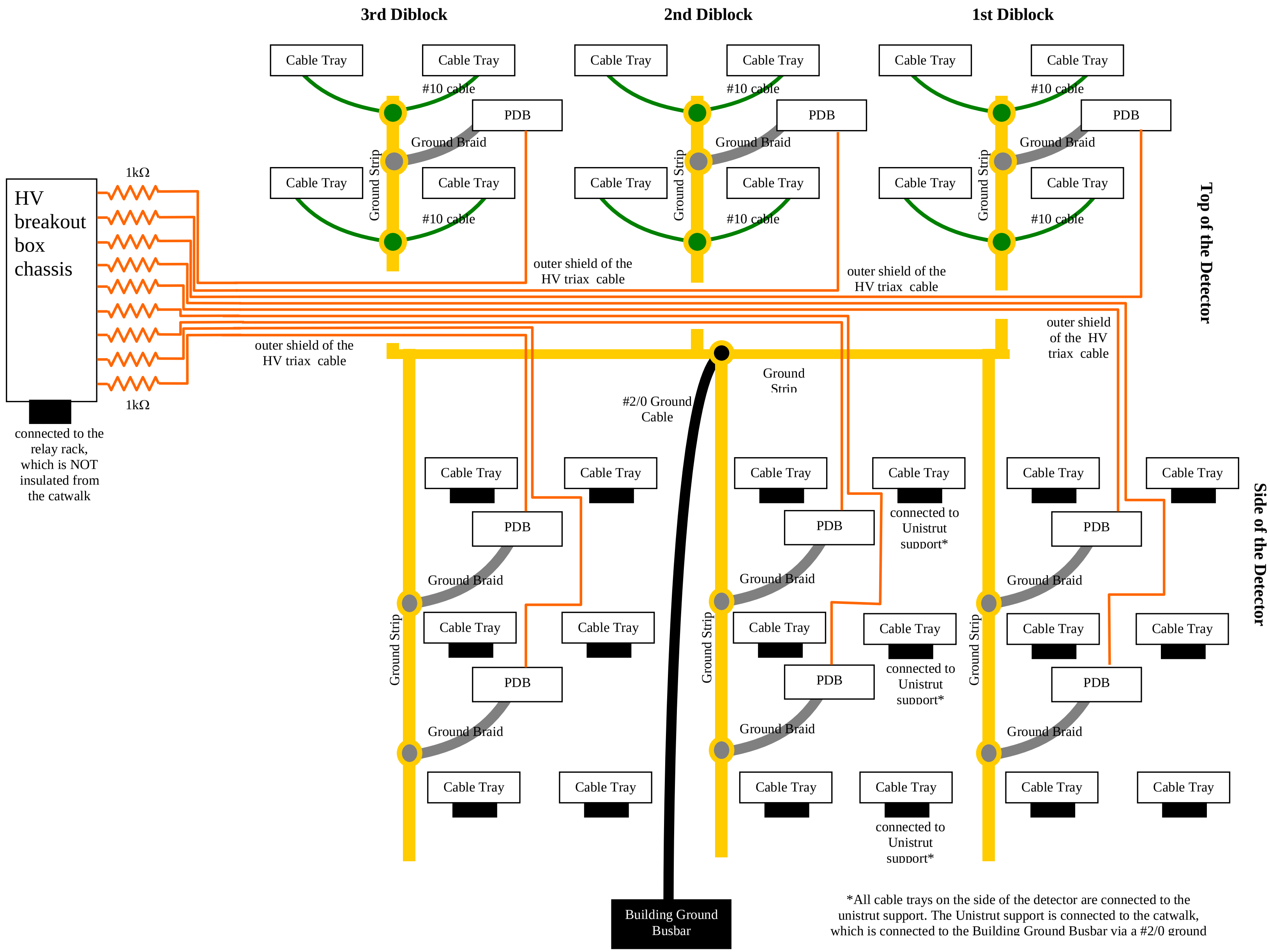


Figure 43: Near detector on surface ground scheme

References

[1] *BoE Power Distribution System*, E. Craig Dukes, 2 February 2010, NOνA internal document, DocDB-2239-v4.

[2] http://galileo.phys.virginia.edu/research/groups/hep/aag/nova/nova_local.html

[3] *Electrical Design Standards for Electronics to be used in Experiment Apparatus at Fermilab*, April 15, 1999 (unpublished).

[4] http://www-esh.fnal.gov/pls/default/esh_home_page.page?this_page=5040

[5] *Power Distribution Box Schematics*, NOνA internal document, DocDB-1967-v2.

[6] *NOνA Power Distribution System Preliminary Design Review Review Notes and Concerns*, Steve Chappa, 6 April 2009, NOνA internal document, DocDB-3689-v1.

[7] *NOνA Power Distribution Box High Voltage Current Limiter Evaluation*, Hunter Tammaro, E. Craig Dukes, and Larry St. John, 14 August, 2009, NOνA internal document, DocDB-4154-v1.

[8] *Fault Analysis: Single Point Failures for the 3-Transistor Current Limiter*, John Oliver, 15 October, 2009, NOνA internal document, DocDB-4526-v1.

[9] *Wiener PL506 Heat Rise Tests*, A. Norman, NOνA internal document, DocDB-4532-v2.

[10] *Smoke Detection and AC Power Distribution/Interruption for NOνA Near Detector Surface Building Electronics Racks*, Michael S. Matulik, 1 June 2010, Technical Note: IG_20100001.

[11] *Test of the Smoke Detection and AC Power Interruption System for NOνA Near Detector Surface Building Electronics Racks*, Michael S. Matulik, 17 June 2010, Technical Note: IG_20100002.