Cornell Laboratory for
Accelerator-based Sciences and Education (CLASSE)

TFPX Service Cylinder Connectors and Wiring

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EPIX / FPIX Workshop
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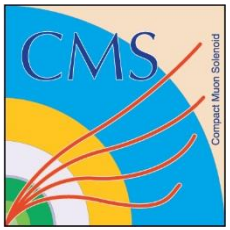

Outline

- TFPX Cartridge
- Specifications
- Serial Power
- High Voltage
- LpGBT Portcard
- Wire Selection
- Backup

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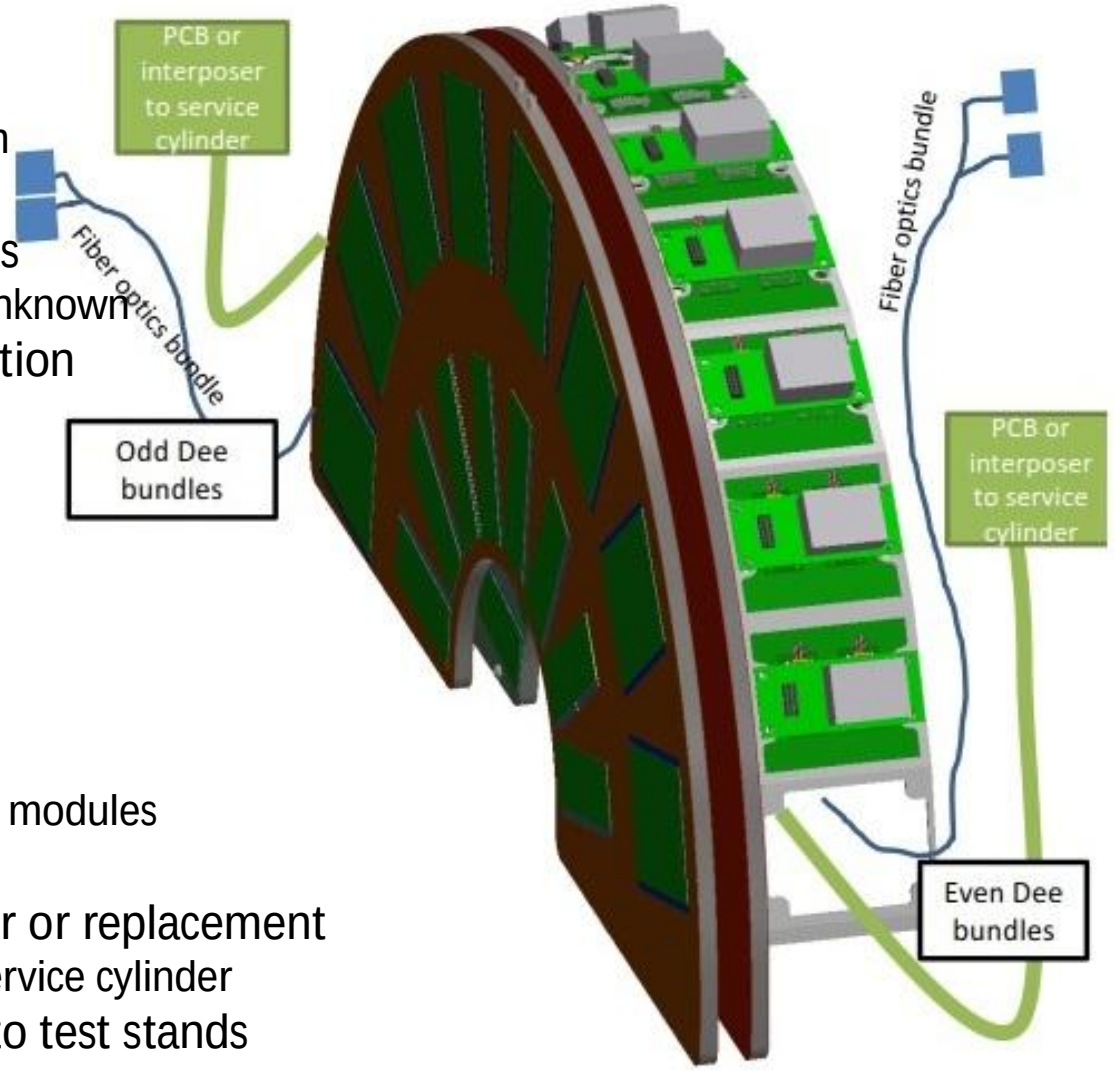
TFPX Cartridge

TFPX Cartridge Assembly

- 8 cartridges per service cylinder
  - 1 service cylinder = ¼ whole system
- 32 cartridges total
- Short “pigtails” to mating connectors
  - Characteristics of the pigtails are unknown
- All are identical, regardless of Z position
  - Eliminates need for “service loops”



Each consists of 3 sub-assemblies

- Odd-Dee (rings 1 and 3)
- Even-Dee (rings 2 and 4)
- Portcard Frame
  - holds 10 portcards
  - Each has 2 LpGBT and 2 VersaLink+ modules

- Cartridges can be removed for repair or replacement
  - No disturbance to other stuff on service cylinder
- Cartridges can easily be connected to test stands

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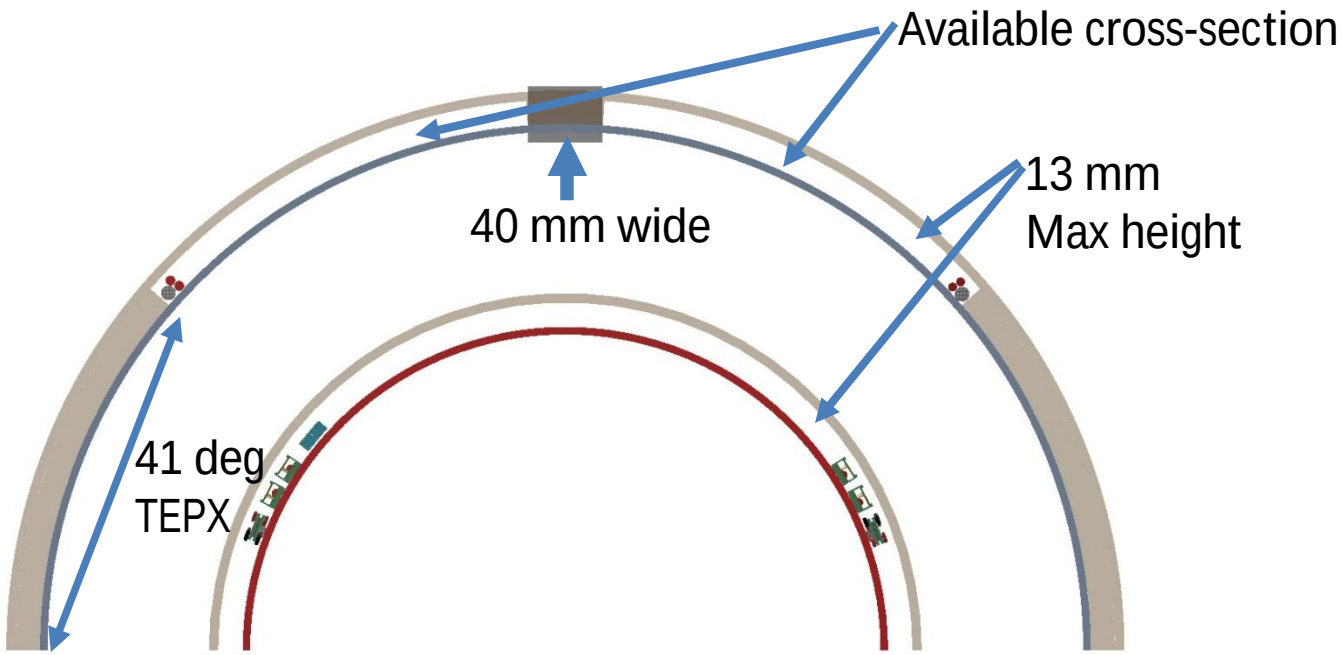
Specifications

- SP connector (1 for odd-dee, 1 for even-dee)
  - Serial Power - 2 pair for 8-amp circuits
  - Serial Power - 2 pair for 4-amp circuits
  - HV returns – 4 wires @ 1 per SP circuit
  - Temperature – 2 pairs @ 2 2-wire RTDs per Dee
- HV connector (1 for odd-dee, 1 for even-dee)
  - Voltage up to 1 kV
  - Planning for 1 HV wire per module
  - 22 wires for odd-dee, 32 wires for even-dee
  - Hoping for 1 HV wire per SP chain, would reduce to 4 HV wires per dee
- Portcard power connector
  - DC-DC converter input power – 10 pairs
  - 0.25 amp per portcard
  - There are a few individual portcard frames for TBPX needs
    - TBPX e-links are also on the service cylinder

Specifications

- Limited height
  - < 12 mm height if 1 mm reserved for cover
- Limited cross section in TEPX region
  - Area shared with wires and cooling tubes for TBPX and TFPX



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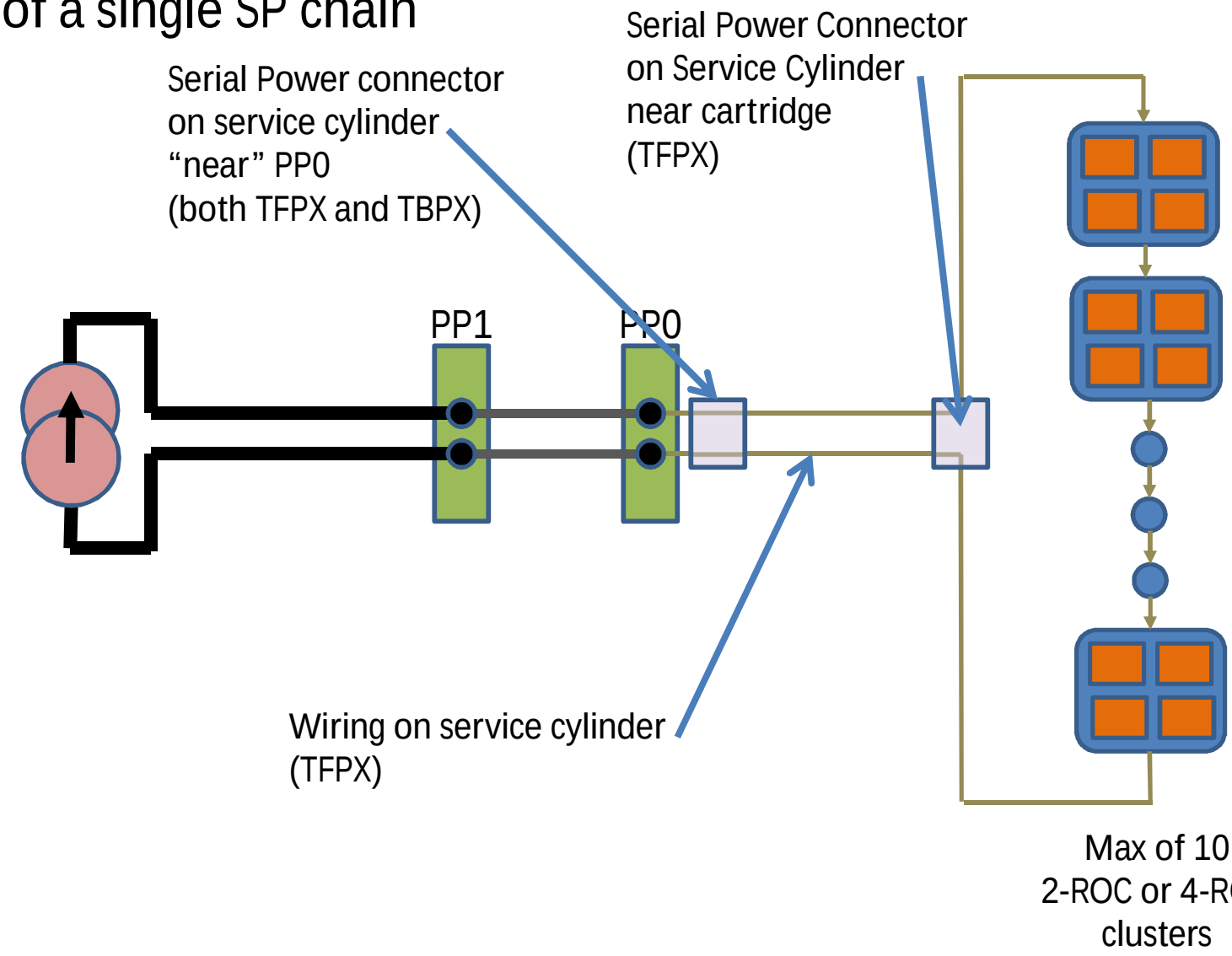
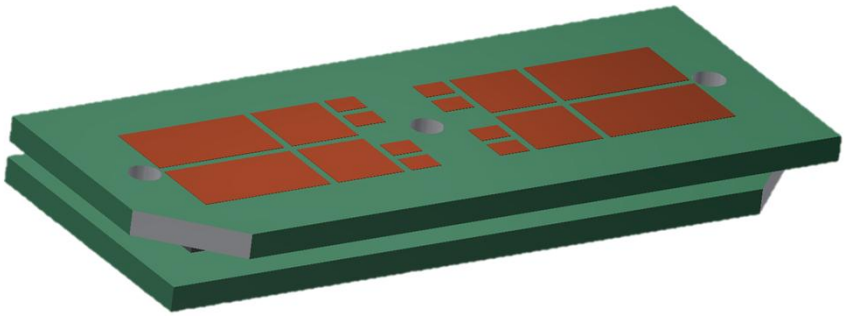
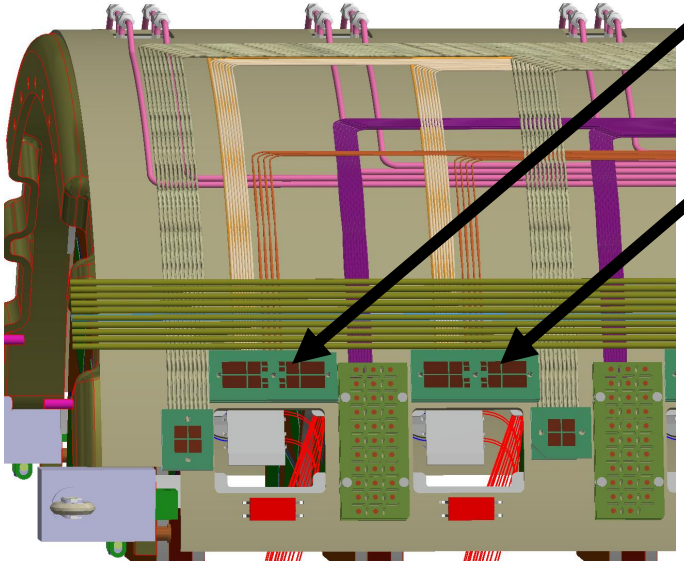
SP Connector

Wiring of a single SP chain



SP Connector



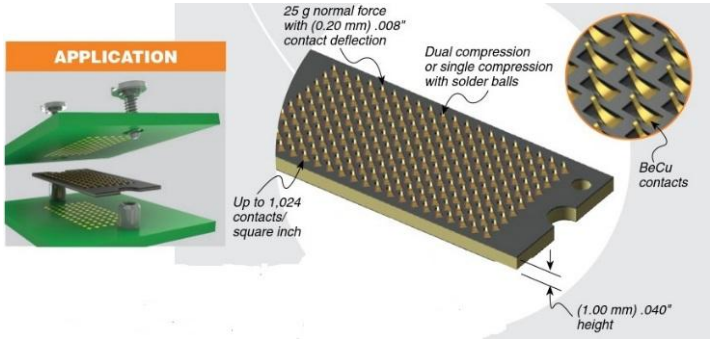


- For TFPX, 300 pin interposer connector to be used; one per dee (2 per cartridge).
- The interposer will wire
  - 4 8-amp SP conductors
  - 4 4-amp SP conductors
  - 4 HV return conductors
  - 4 Temperature conductors
- For TFPX, a second interposer connector will be used “near” PP0
  - Provides matching to PP0 cable
- For TBPX, maybe only the connector near PP0 will be used
  - TBPX will have long pigtails

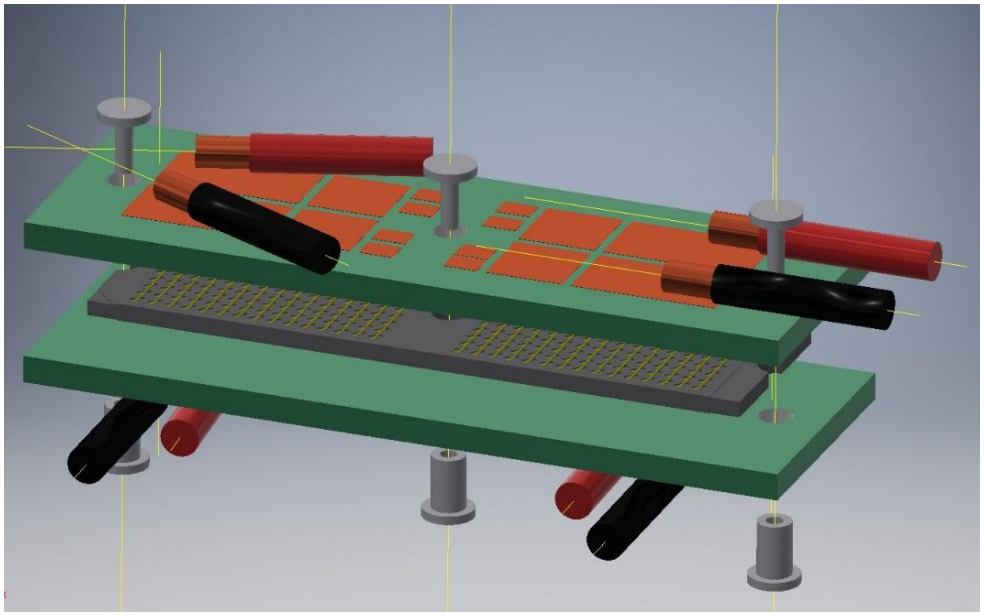
SP Connector - Concept

- Interposer Board Plan
  - 1mm pitch array
  - 300 pins
    - 45 for each 8-amp circuit (178 ma. each pin) [222 ma. per pin @ 10 amps]
    - 25 for each 4-amp circuit (160 ma. each pin) [200 ma. Per pin @ 5 amps]
    - 2 for each of 6 temperature wires
    - 2 for each of 4 HV return wires
  - Strain relief needs to be considered

Note: Test board had 28 pins for each 4-amp circuit

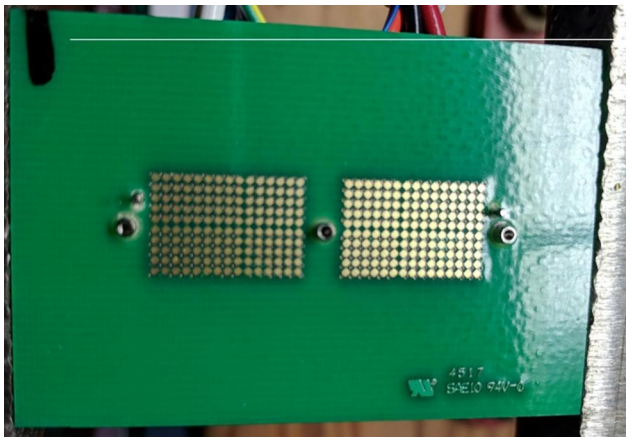


Interposer for stacking PCBs

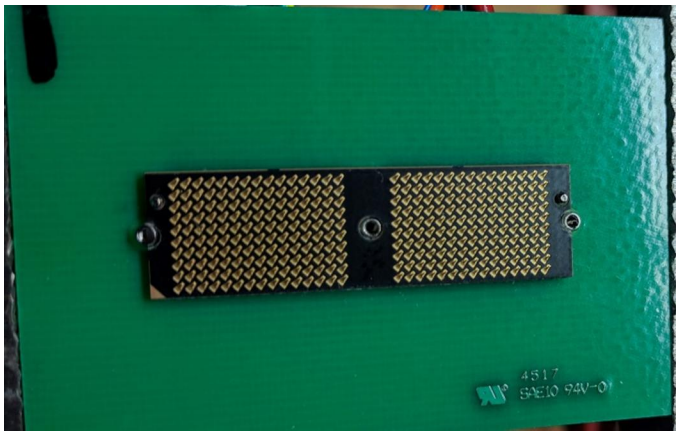


Inventor Model

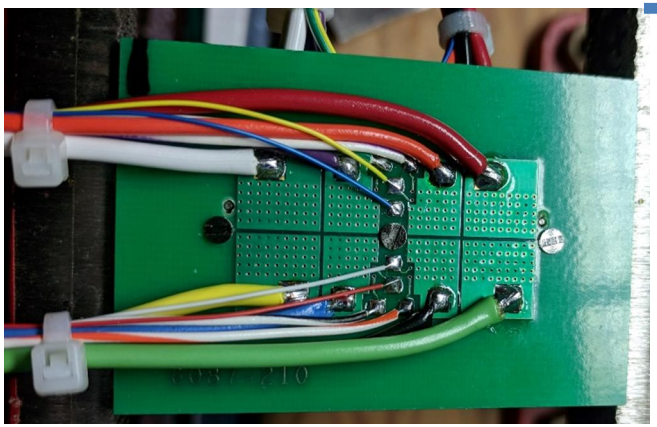
SP Connector - Demo



Bottom PCB



Interposer in place

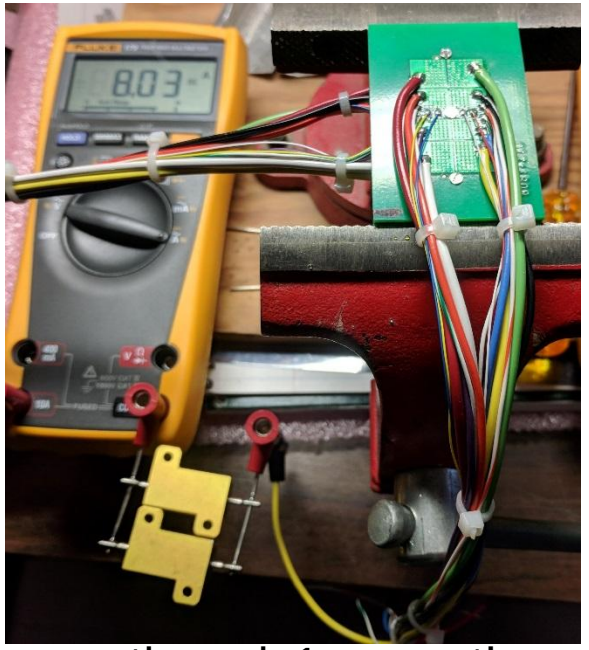


Top PCB attached

Thickness = 8.6 mm

2.2 mm wire
1.6 mm PCB
1.0 mm Interposer
1.6 mm PCB
2.2 mm Wire

A) Newly proposed wire type is thinner (1.53 mm)
B) Could reduce interposer to 0.5 mm thick



8 amps through 1 connection

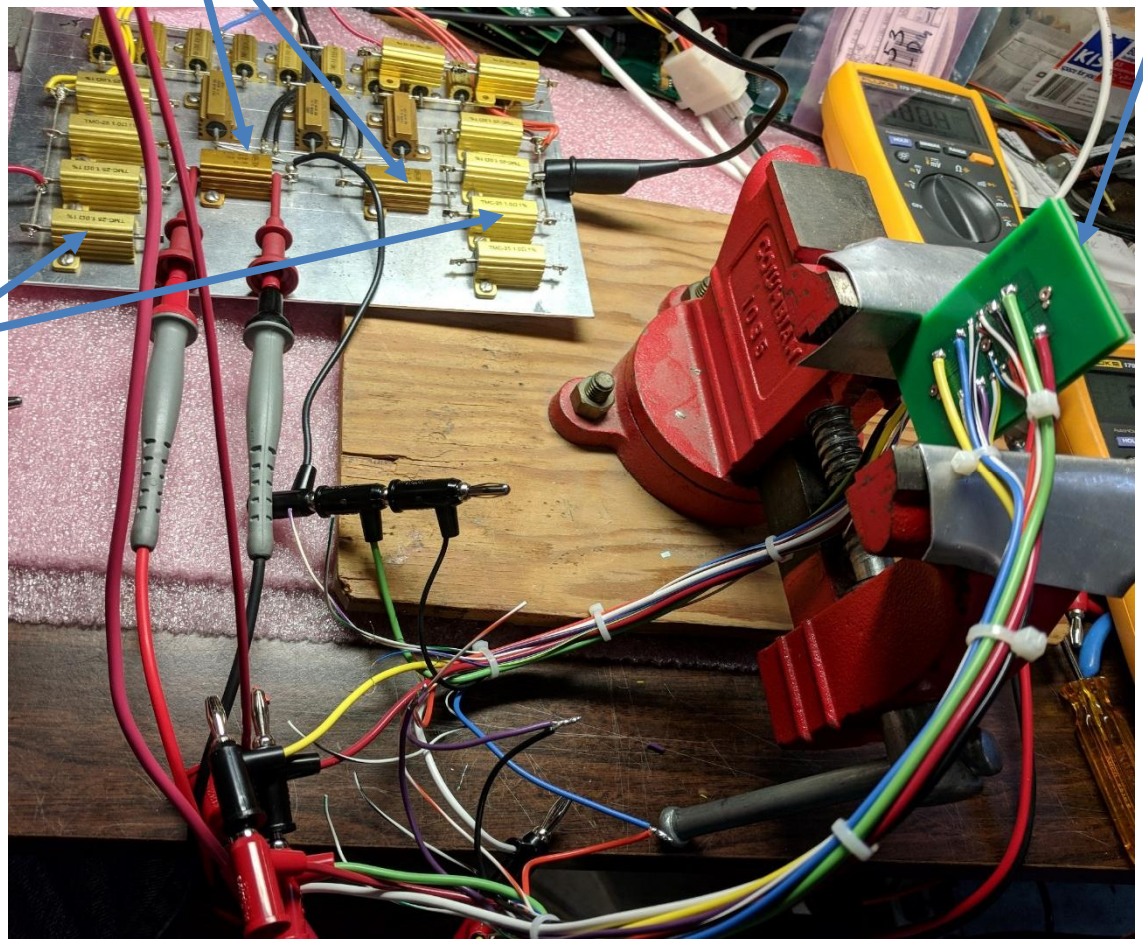
SP Connector – Demo Testing

Full current test setup

Current sense resistors

2 PCBs plus Interposer

Load resistors



SP Connector - Initial Testing Results

A) Wire the 4 8-amp connections in series and apply 10 amps
B) Wire the 4 4-amp connections in series and apply 5 amps

60 amps flowing through the connector

Measure voltage drop across each connection

Did not have access to a micro-volt meter

- 8-amp connections with 10 amp current
  - All 4 between 7.9 mV and 8.3 mV
  - R = E/I = 8.3 mV / 10 A = 0.83 mOhm = 37 mOhm per pin
- 4-amp connections with 5 amp current
  - All 4 between 5.8 mV and 6.0 mV
  - R = E/I = 6 mV / 5 A = 1.2 mOhm = 34 mOhm per pin

Resistance includes 2 PCB planes, 2 vias, 2 via-to-pad connections, plus interposer

Measure temperature on surface (scrape away soldermask)

- 24.2 C before power
- 39.6 C after 20 minutes at full power
  - 15.4 C rise
  - Total Power Loss ~ 0.44 watts

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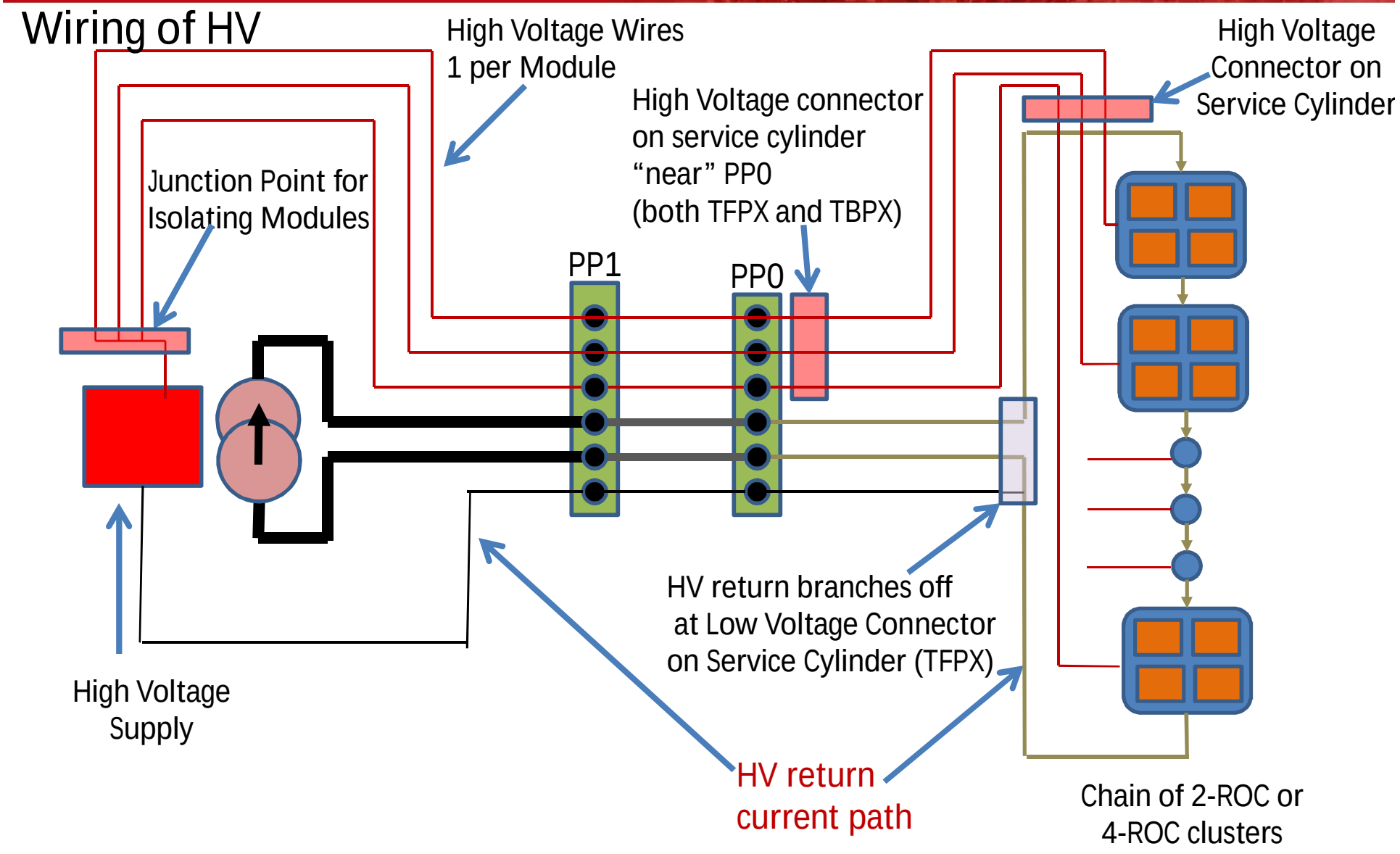
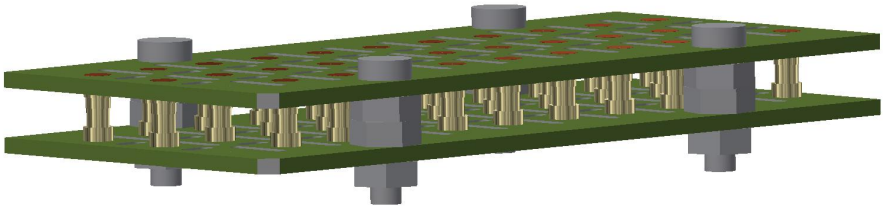
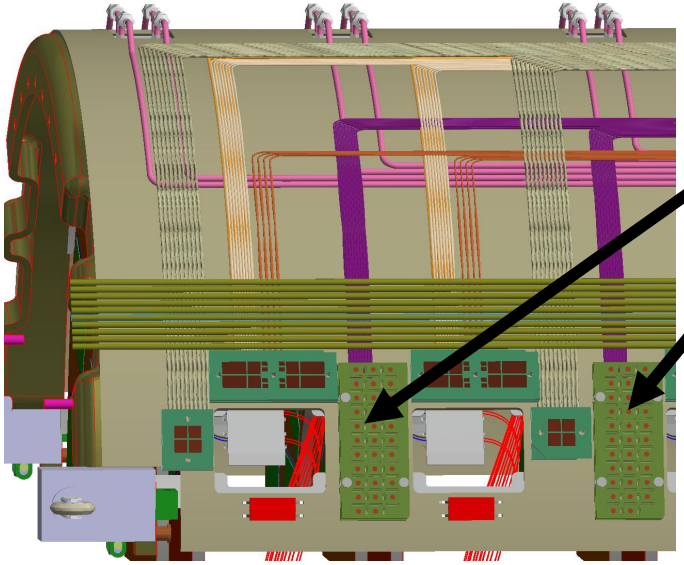
Serial Power Chain with High Voltage



HV connectors for TBPX and TFPX





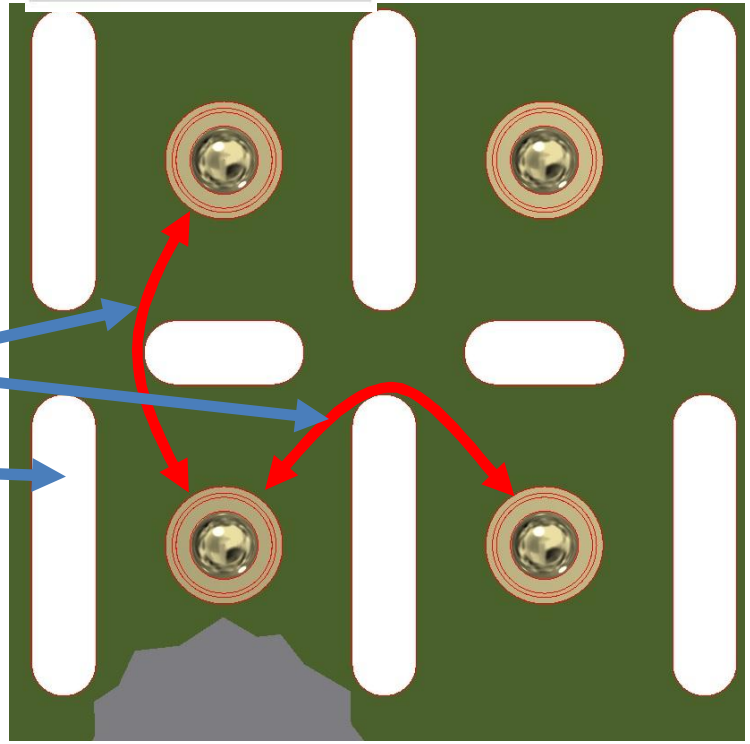
- PCB uses electrical standard spacing needed for 1 kV HV connections; however this takes up a lot of space
- 32 pin connector to accommodate for even dee. Same connector can be used for TBPX and TFPX to reduce number of parts at this stage
- 16 total HV-in pcb boards for TFPX
- For TFPX, a second connector will be used “near” PP0
  - Provides matching to PP0 cable
- For TBPX, maybe only the connector near PP0 will be used
  - TBPX will have long pigtails

HV spring terminal PCB

Initial Rules

- Spacing – shortest air distance
  - At least 1 mm spacing
  - Air breakdown = 3 kV/mm
- Creepage – shortest surface distance
  - Use slots to increase creepage distance
  - 5 mm from IPC-2221 calculator
  - This dimension drives the design
- Isolation – material breakdown
  - PCB material FR4 = 20 kV/mm thickness
  - Expected board thickness ~ 1 mm

Voltage (DC or AC peak)	1000	
Calculate		
SPACING	**mm**	**inches**
IPC-2221B:		
external	5	0.1969
internal	1.5	0.059
coated	2.33	0.0917
IPC9592	5.6	0.2205
Reset		



HV spring terminal PCB

Spring terminals

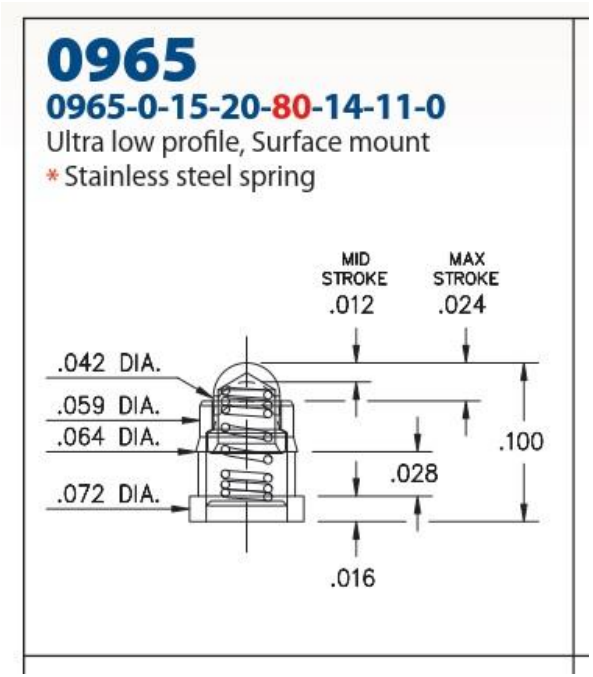
Mill-Max 0965-0-15-20-80-14-11-0 (DigiKey ED1649)

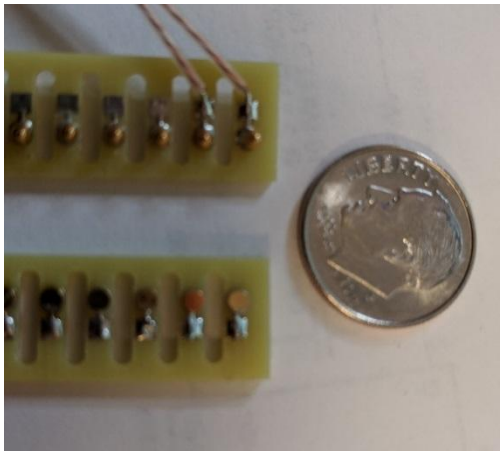
1.8 mm dia, 2.2 +/- 0.3 mm high

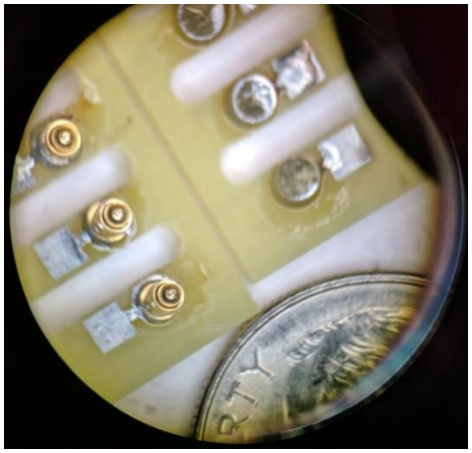
Targets

Mill-Max 1578-1-57-15-00-00-03-0 (DigiKey ED10763)

2 mm dia, 0.89 mm high







First prototype

Wires were on the same side as the pins

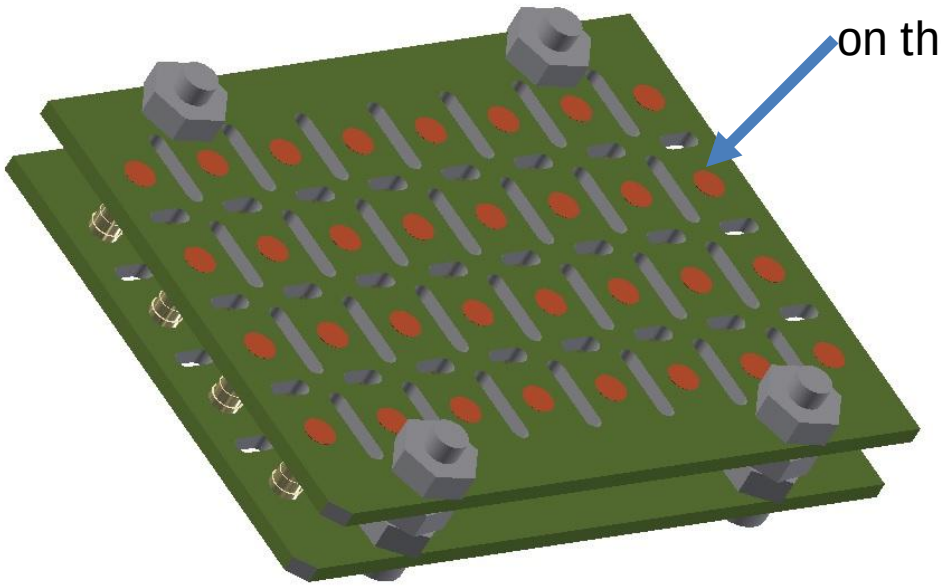
Single row of 16 pins

HV spring terminal PCB

32-pin assembly
29 mm wide and 40 mm long
Screws are 8 mm long (material = PEEK)
Slots are 1 mm wide and boards are 1 mm thick.

Initial design has been changed to 11 x 3 instead of 8 x 4

HV wires are soldered to pads on the back-side of the boards.



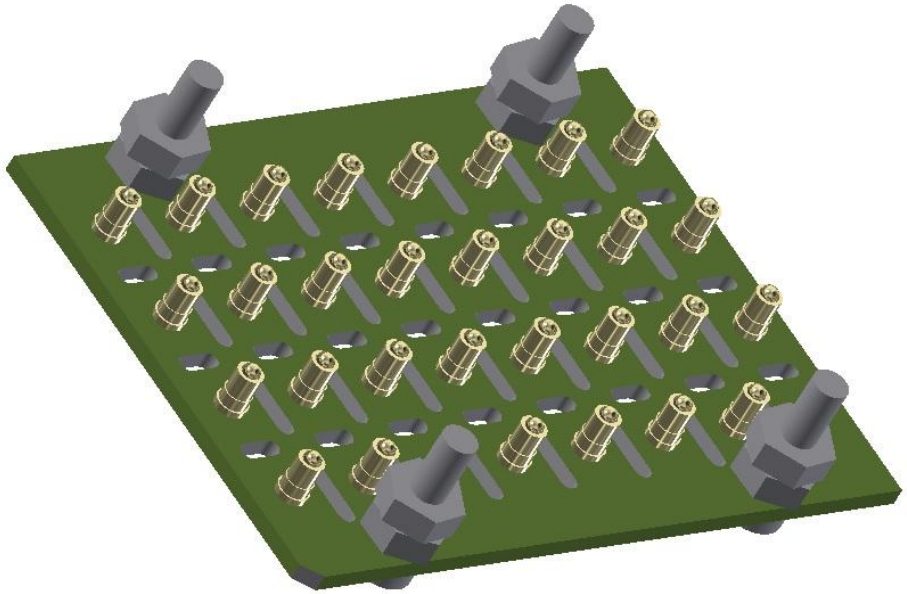


Figure out:
1) Mounting to service cylinder
2) Strain relief

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- **LpGBT Portcard**
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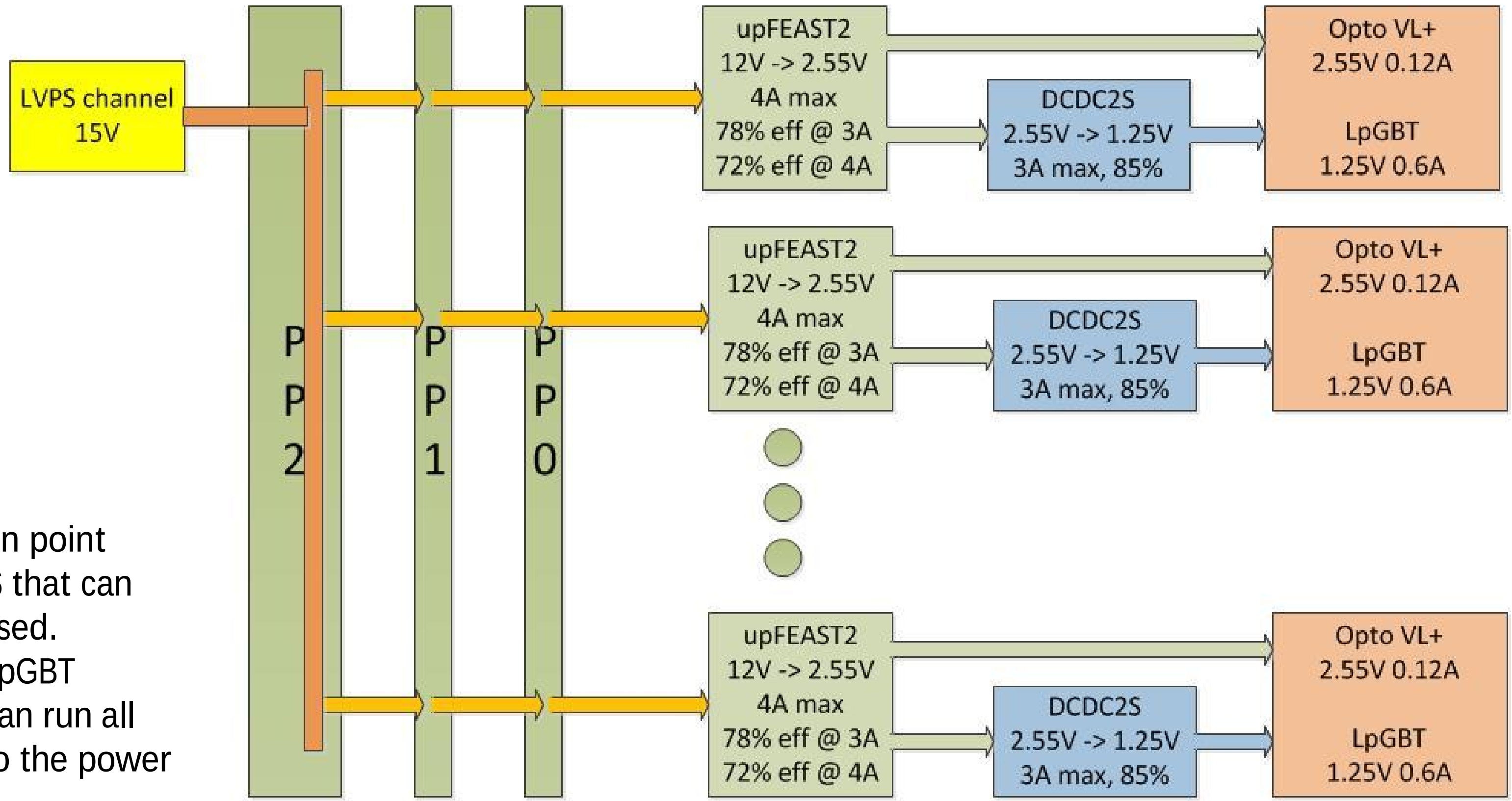
LpGBT power

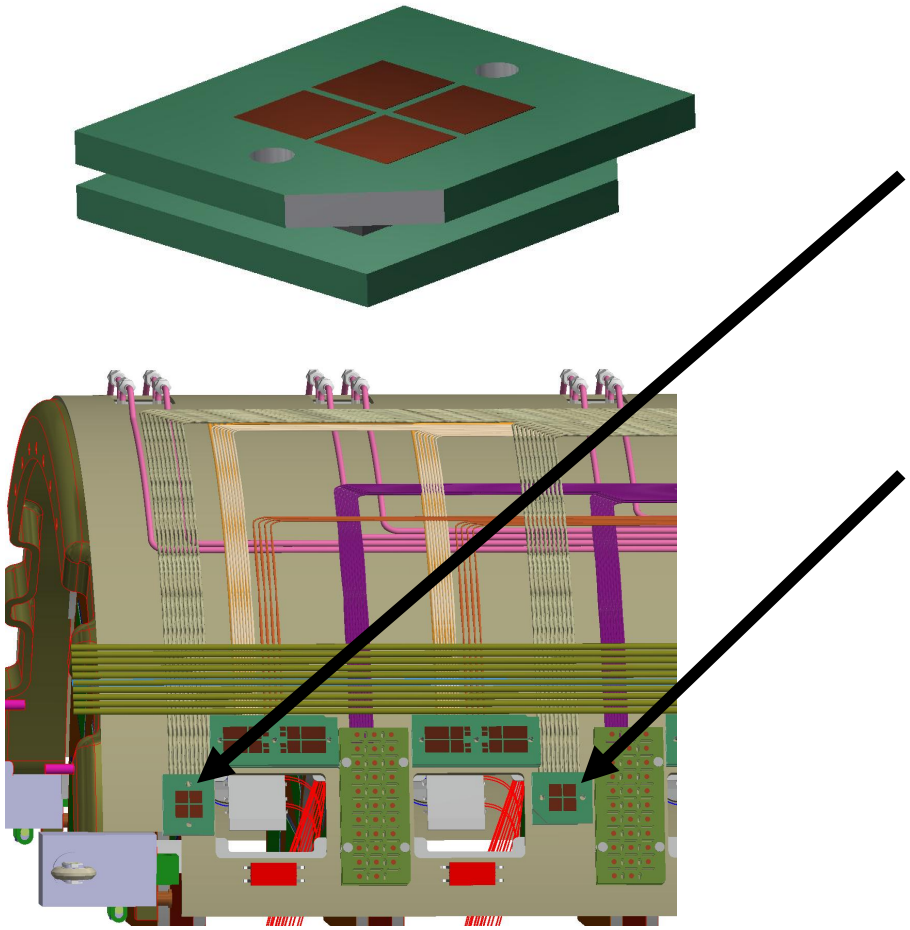
Want to run many portcards from the same power supply, and be able to disconnect any failed portcard

PP2 is a junction point outside of CMS that can be easily accessed. Alternatively, LpGBT power cables can run all the way back to the power supply racks.



LpGBT Power using upFEAST2 and DCDC2S

100 pin portcard mechanism power for TBPX and TFPX



- For each portcard mechanism the power will be provided for all 10 port cards with a 100 pin interposer
- For both TBPX and TFPX, a second interposer connector will be used “near” PP0
  - Provides matching to PP0 cable

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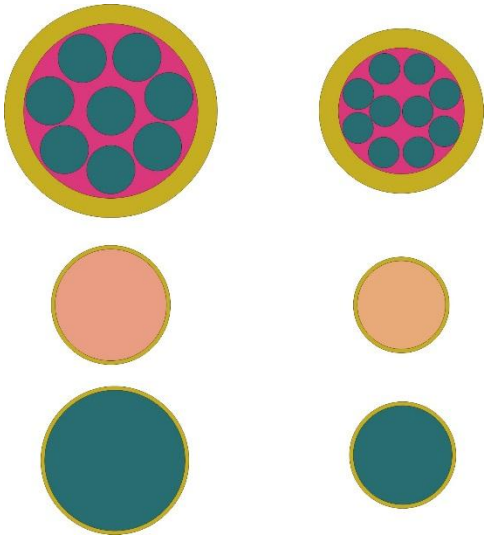
SP Wiring

Scaled drawing, standard AWG, all have same or less resistance per meter

8 Amp

4 Amp

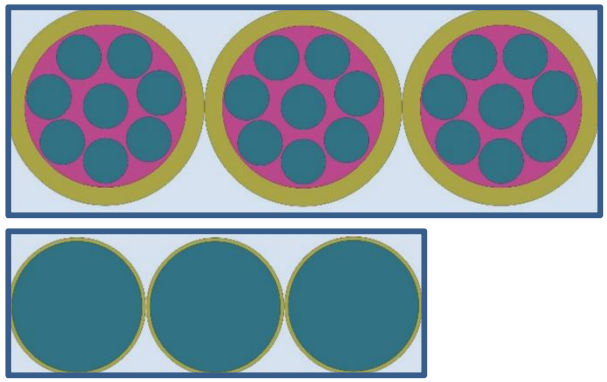


CCA, stranded, from IT Services V1.4
OD = 2.2 / 1.7 mm
A = 3.80 / 2.27 mm^2

Copper, solid round, AWG = #17 / #19
OD = 1.23 / 0.99 mm
A = 1.19 / 0.77 mm^2

CCA, solid round, AWG = #15 / #18
OD = 1.53 / 1.10 mm
A = 1.84 / 0.96 mm^2

8 Amp Wire Packing



CCA, stranded, from IT Services V1.4
A = 14.5 mm^2 = 100%

CCA, solid round
A = 7.04 mm^2 = 49%

CCA = Copper Clad Aluminum

CCA Wire Table

Solid wires from MWS Wire Industries
http://mwswire.com/
CCA = Copper-clad Aluminum

Insulation = Polyimide ML (Kapton),
For SP: Single Buildup (0.2 mm thick, 3000 V)
For HV: Quad Buildup (0.76 mm thick, 10,000 V)

Use 10% or 15%?

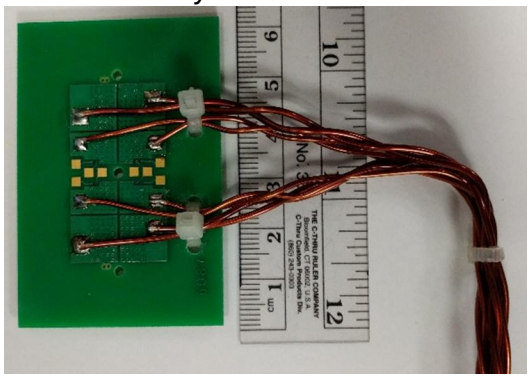
#15 for 8 Amp

#18 for 4 Amp

May be able to use #16 & #19

Maybe #24 for Portcard?

Maybe #26 for HV?



SP wires only

Clad metals are two distinct metals or alloys that are metallurgically bonded together so that the optimum combination of functional properties is achieved. Copper Clad Aluminum (CCA) is an electrical conductor with a sleeve of copper bonded to a solid aluminum core. The composite wire is uniquely suited to electrical applications where weight to conductivity issues are critical. The copper makes up either 10% or 15% of the cross sectional area of the wire and assures excellent solderability. AC conductivity at frequencies greater than 5 MHz is equal to solid copper. CCA is manufactured in accordance with the requirements of ASTM B-566. Film insulations are available on CCA wire. For insulation data, see pages 2 and 3.

Typical Physical Properties

	10%CCA	15%CCA
DC Conductivity	62.9% min IACS	64.4% min IACS
% Copper by volume	8-12%	13-17%
% Copper by weight	27% nom	34% nom
Density	.120 lb/cu in	.131 lb/cu in
Tensile strength, annealed	20-25 kPSI	20-25 kPSI
Tensile strength, hard drawn	16-30 kPSI	16-30 kPSI
Elongation, annealed	5-15% min	5-15% min
Elongation, hard drawn	1% min	1% min

(Tensile and elongation values are size dependent)

SIZE (AWG)	DIAMETER (INCHES)	AREA (CIR. MILS)	FEET PER POUND		POUNDS PER 1000 FT.		OHMS PER 1000 FT. AT 20□C		SIZE (AWG)
			10% CCA	15% CCA	10% CCA	15% CCA	10% CCA	15% CCA	
14	.0641	4109	215	197	4.64	5.06	3.91	3.79	14
15	.0571	3260	270	247	3.69	4.03	4.93	4.78	15
16	.0508	2581	342	314	2.92	3.19	6.23	6.05	16
17	.0453	2052	430	394	2.32	2.53	7.83	7.60	17
18	.0403	1624	542	497	1.84	2.01	9.90	9.61	18
19	.0359	1289	684	627	1.46	1.59	12.5	12.1	19
20	.0320	1024	862	791	1.16	1.26	15.7	15.2	20
21	.0285	812.3	1087	997	.920	1.00	19.8	19.2	21
22	.0253	640.1	1378	1264	.726	.792	25.1	24.4	22
23	.0226	510.8	1728	1585	.580	.632	31.5	30.5	23
24	.0201	404.0	2184	2004	.456	.498	39.8	38.6	24
25	.0179	320.4	2750	2524	.363	.396	50.2	48.7	25
26	.0159	252.8	3498	3210	.286	.312	63.6	61.7	26
27	.0142	201.6	4378	4018	.228	.249	79.7	77.3	27
28	.0126	158.8	5554	5096	.180	.196	101	98.2	28
29	.0113	127.7	6915	6346	.145	.158	126	122	29
30	.0100	100.0	8811	8085	.113	.124	161	156	30
31	.0089	79.21	11134	10216	.0896	.0979	203	197	31
32	.0080	64.00	13777	12642	.0726	.0792	251	244	32
33	.0071	50.41	17488	16048	.0572	.0624	319	310	33
34	.0063	39.69	22214	20384	.0449	.0490	405	390	34
35	.0056	31.36	28035	25725	.0355	.0387	513	498	35
36	.0050	25.00	35244	32340	.0283	.0309	643	624	36
37	.0045	20.25	43521	39935	.0229	.0250	794	770	37
38	.0040	16.00	55002	50470	.0181	.0196	1000	975	38
39	.0035	12.25	72090	66150	.0139	.0151	1310	1280	39
40	.0031	9.610	91848	84280	.0109	.0119	1670	1620	40

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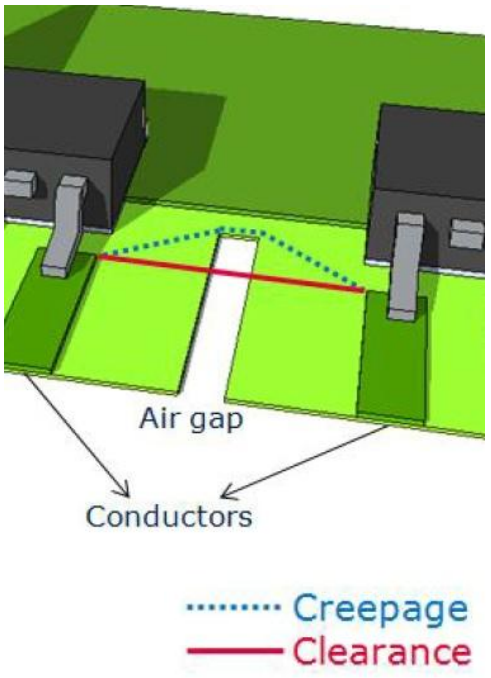
HV Design Considerations

- Clearance
  - the shortest distance through air between two conductors
- Creepage
  - the shortest distance along the surface of the insulation material
- Isolation
  - electrical breakdown through an insulating material
- Pollution degree
  - The detector environment will be clean and dry, with nitrogen flow
  - Test stands in labs may be worse
    - Pollution degree 2: Normally only nonconductive pollution occurs. Occasionally a temporary conductivity caused by condensation must be expected (example: product used in typical office environment); Typical usage: office and household environment

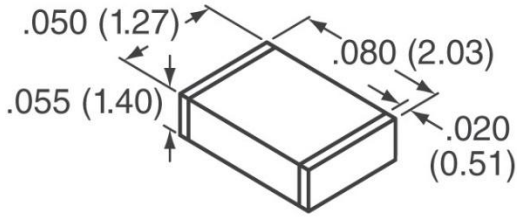


A good introduction to HV design considerations:

www.infineon.com/dgdl/Infineon-ApplicationNote_MOSFET_CoolMOS_Electrical_safety_and_Isolation-AN-v01_00-EN.pdf?fileId=db3a30433d1d0bbe013d20e0cbf017fe

HV Design Considerations

- CERN specific standards
  - References to CERN specific standards are welcome
- Current Projects
  - What are the clearance/creepage design rules for the modules?
- Previous Projects
  - Pointers to previously accepted and installed designs are useful
- Industrial Trends
  - High voltage semiconductors and passives have small dimensions
  - However, potting/encapsulating/coating are often used
- Commercial Standards
  - IPC-2221
  - IEC-60950-1
  - Regulatory approval for commercial sales



Ceramic capacitor
0805 package
1 kV DC

Are there “design review” requirements?

LpGBT Portcard Power

- Power needs for portcards
  - LpGBT
    - 1.25 v, 0.6 A, 0.75W
  - Optics (Versatile Link+)
    - 2.5 v, 0.12 A, 0.3 W
- Number of portcards
  - About 520 for TBPX plus TEPX
- Baseline option
  - Two LpGBT/VL+ per DC-DC (1 portcard)
  - Portcard powered with 11 volt input
    - Power in = 2.6 W @ 80% efficiency
    - Current in = 0.25 amp
  - Power for each portcard is brought from “PP2”
    - Where is this located for convenient access?
  - Multiple portcards are bussed together at “PP2”
    - How Many? A 500 watt supply that is half-loaded could run about 100
    - Method for disconnecting individual DC-DC