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CM Testing Equipment: Quench Protection, DAQ, Splice Resistance

Darryl Orris/Mike Tartaglia

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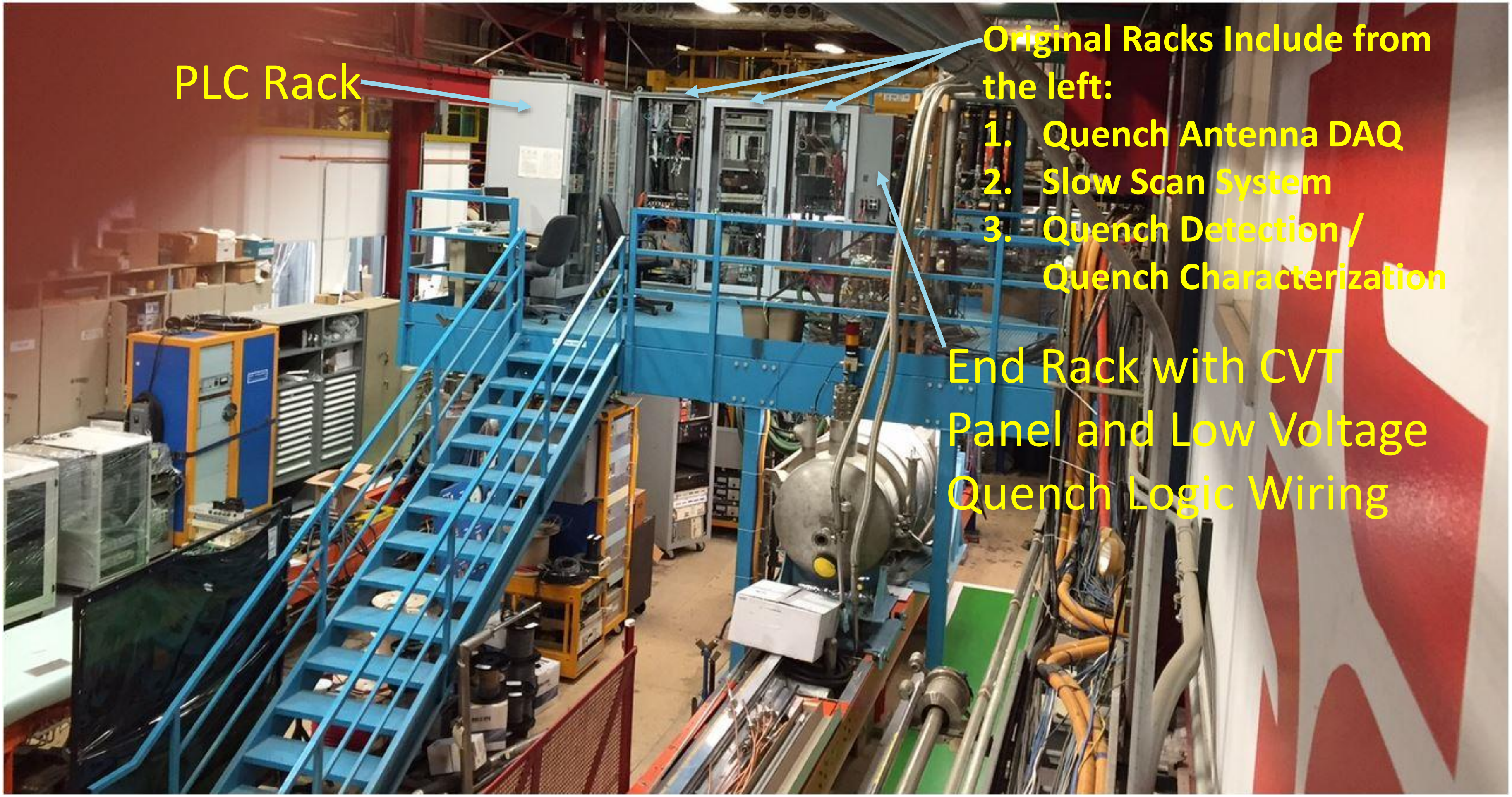
LMQXF Cold Mass Requirements and Conceptual Design Review

Overview

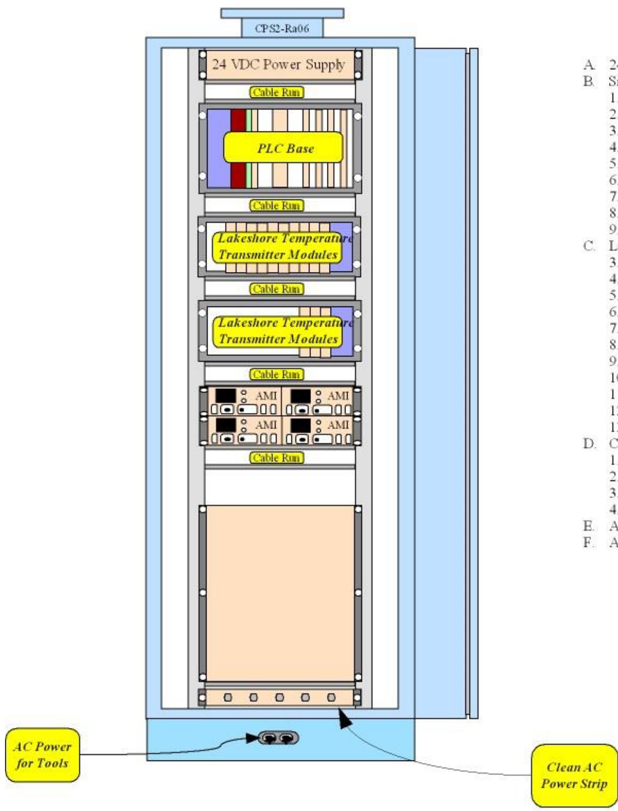
- Test Stand Controls –
  - Existing Siemens PLC will be upgraded to Allen-Bradley
- DAQ monitoring –
  - Existing VME/VxWorks front end, Sun/Unix are obsolete
  - New system will integrate with PLCs
    - Basis is design being developed for Mu2e experiment which is in final/detailed state
- Quench Detection and Characterization –
  - Existing VME/VxWorks/Sun/Unix system is obsolete
  - New FPGA-based system (3rd generation)
    - Basis is design being developed for Mu2e experiment
  - New Isoamp design already deployed in other test areas
- Splice Resistance Measurement –
  - New Design based upon Mu2e Test Stand system (nano-Vmeter)

Test Stand 4 / DAQ Platform



Test Stand 4 / DAQ Original Process Control and Quench Protection /Characterization Rack Layout

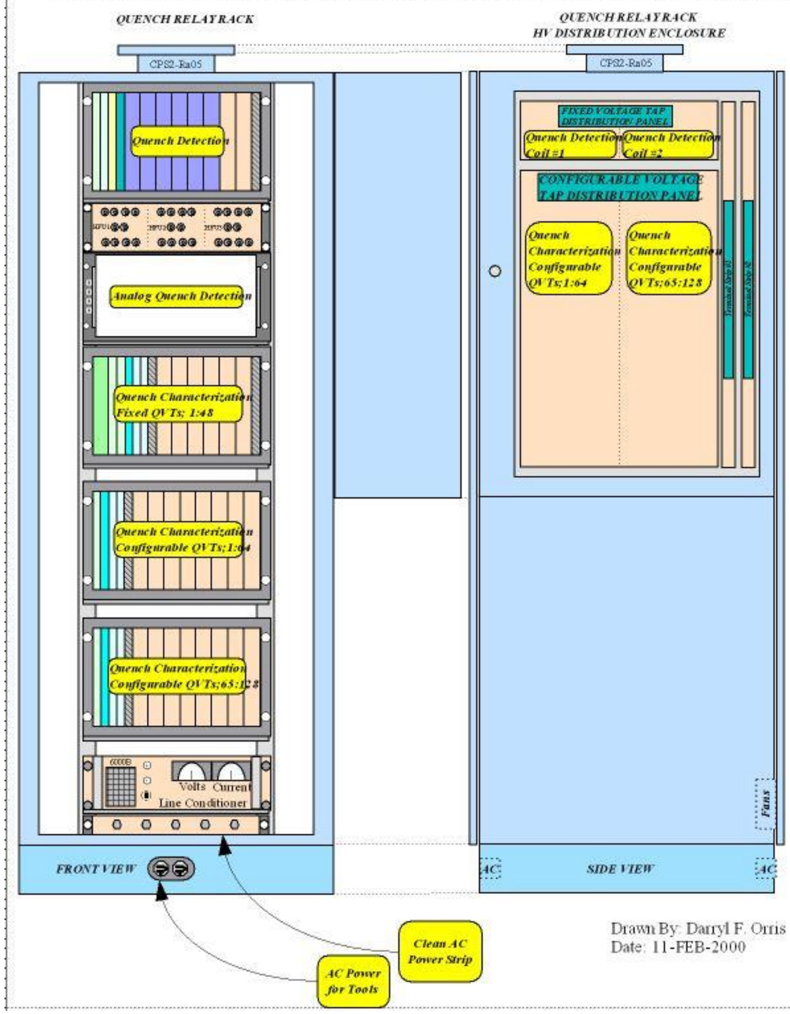
CPS2-H4 PROCESS CONTROL INSTRUMENTATION RACK



A. 24 VDC Power Supply (Acopian)
B. Siemens 505 Series PLC Base
  1. Power Supply 505-6660.
  2. PLC 545-1106
  3. Ethernet TCP/IP 505-2572
  4. 32-Pt 24 VDC Input 505-4332
  5. 32-Pt Relay Output 505-4932A
  6. 16-Pt Diff. Analog Input 505-2555
  7. 8AI/4AO 505-7012
  8. 8AI/4AO 505-7012
  9. 8-Ch Analog Output 6208B
C. Lakeshore Temperature Transmitter Crate
  3. Cernox TT - Model 234
  4. Cernox TT - Model 234
  5. Cernox TT - Model 234
  6. Cernox TT - Model 234
  7. Cernox TT - Model 234
  8. Cernox TT - Model 234
  9. Cernox TT - Model 234
  10. Cernox TT - Model 234
  11. Cernox TT - Model 234
  12. Cernox TT - Model 234
  13. Power Supply
D. C. Lakeshore Temperature Transmitter Crate
  1. Platinum TT - Model 231
  2. Platinum TT - Model 231
  3. Platinum TT - Model 231
  4. Power Supply
E. AMI Liquid Level Box Model 135 (2)
F. AMI Liquid Level Box Model 135 (2)

Drawn By: Ruben Carcagno
Date: 15-October-1999

CPS2-H4: LHC QUENCH SIGNAL INSTRUMENTATION RACK



Drawn By: Darryl F. Orris
Date: 11-FEB-2000

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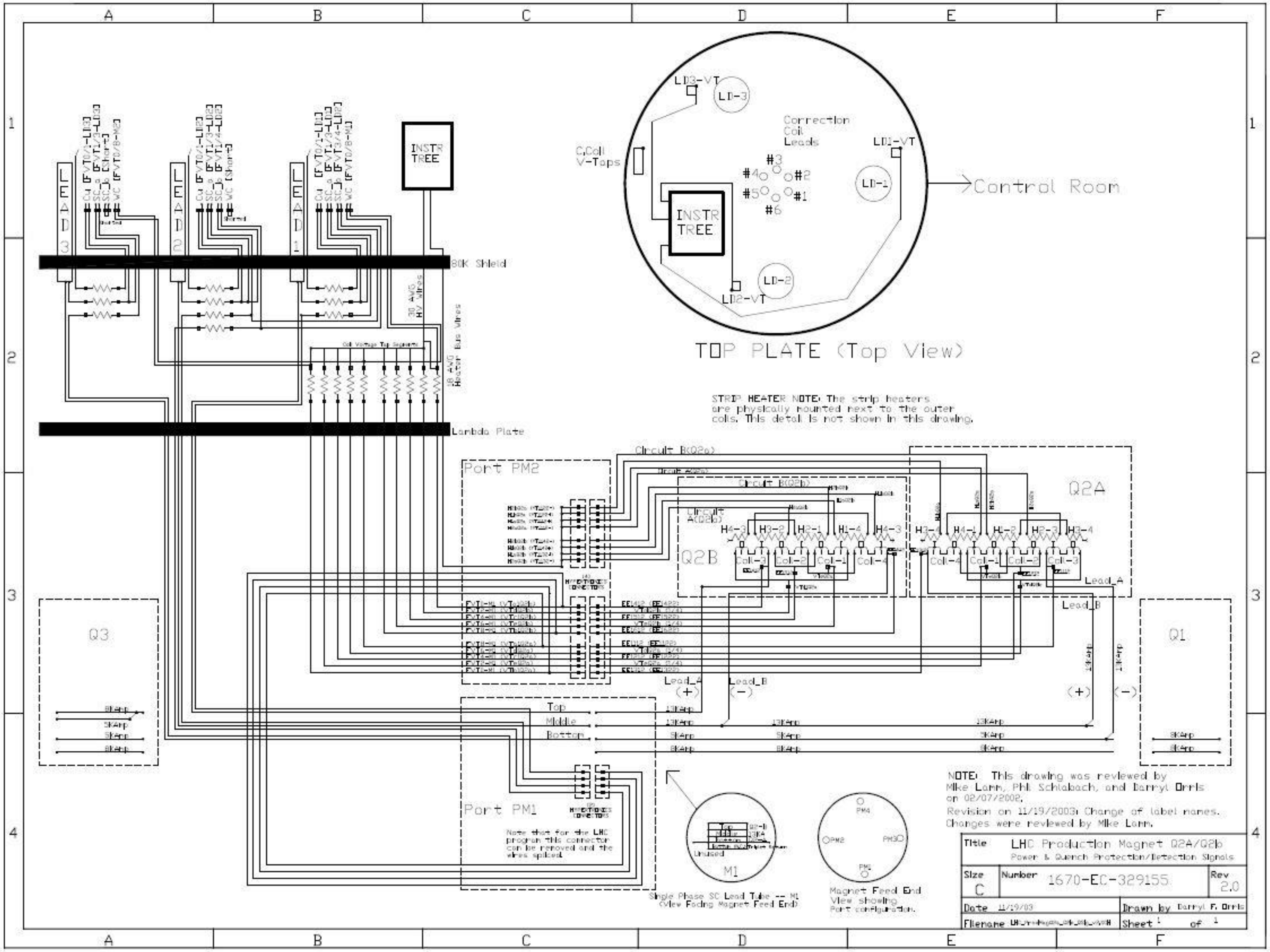
Test Stand 4 Existing Q2A/Q2B Power Bus / Quench Protection Wiring



The Test Stand power bus and Quench Protection Wiring is Still in Place.

Proposed Upgrades

- Replace two 15kA vapor cooled copper leads with two 20kA vapor cooled copper leads
  - Keep the third 15kA lead?
- Use the existing DAQ racks, cabling, and wiring
- Much of the existing Quench Protection End Rack wiring can probably be used
  - The CVT panel will probably be used as is
- Depending on the number or protection heaters that are externally cabled, a new distribution panel made be needed
  - A copy of the VMTF heater distribution panel could be made
- Implement a splice measurement system controlled by the PLC
- Upgrade the Quench Protection system
- All internal HV wiring will have to be tested to meet the new hipot requirements

Quench Protection Design

Quench Protection Design –

- Implement complete redundancy from the connection to the magnet voltage tap wires through to the power supply and dump circuit – no single point failure modes
- Implement a three tier quench protection system
  - Tier 1 – Digital Quench Detection (FPGA) will be used for the Primary QP
  - Tier 2 – Analog Quench Detection will be used for the Reductant QP
  - Tier 3 – System Monitor, Logic Analyzer with First Fault Detection, Fast Logger, etc.
- Standard quench signals include: Whole Coil, Whole Coil – IDot, Bucked Half Coils, Cu Leads , SC Leads, and Ground Fault
  - The two magnet whole coils will be treated as half coils for bucking
  - The SC thru bus will have to be protected – Summed with SC Leads

Quench Detection Signals

– Digital and Analog Quench Detection hardware will be in separate chassis powered by independent UPS's

Implement one 24-Ch IsoAmp Box with 16 IsoAmps				Implement one 24-Ch IsoAmp Box with 16 IsoAmps		
DQD Sig	I-AMP #	FPGA Q-Sigs.		AQD Sig	I-AMP #	AQD Q-Sigs.
WC Sum	1	1		WC Sum	1	1
WC-1	2	2		WC-1	2	2
WC-2	3	3		WC-2	3	3
SC Lead 1 (+)	4	4		SC Lead 1 (+)	4	4
SC Lead 2 (-)	5	5		SC Lead 2 (-)	5	5
SC Thru Bus	6	6		SC Thru Bus	6	6
SC Lead 3 -- NC				SC Lead 3 -- NC		
Cu Lead 1 (20kA)	7	7		Cu Lead 1 (20kA)	7	7
Cu Lead 2 (20kA)	8	8		Cu Lead 2 (20kA)	8	8
Cu Lead 3 (15kA) -- NC	9			Cu Lead 3 (15kA) -- NC	9	

– Each isolation amplifier chassis can be expanded to accommodate the third lead if needed in the future

Quench Characterization Signals

Implement one 32-Ch IA Box with 32 IsoAmps						
QC Sig	IsoAMPs	Loggers		QC Sig	IsoAMPs	Loggers
WC-1	1	1		Strip Heater 1	21	21
+HC-1	2	2		Strip Heater 2	22	22
-HC-2	3	3		Strip Heater 3	23	23
WC-1	4	4		Strip Heater 4	24	24
+HC-1	5	5		Strip Heater 5	25	25
-HC-2	6	6		Strip Heater 6	26	26
Thru Bus	7	7		Strip Heater 7	27	27
SC Lead 1 (+)	8	8		Strip Heater 8	28	28
SC Lead 2 (-)	9	9		Spare?	29	
SC Thru Bus	10	10		Spare?	30	
SC Lead 3 -- NC	11	11		Spare?	31	
Cu Lead 1 (20kA)	12	12		Spare?	32	
Cu Lead 2 (20kA)	13	13		Heater PS-1 Cur	N/A	29
Cu Lead 3 (15kA) -- NC	14	14		Heater PS-1 V	N/A	30
CLIQ Lead 1	15	15		Heater PS-2 Cur	N/A	31
CLIQ Lead 2	16	16		Heater PS-2 V	N/A	32
CLIQ Lead 3	17	17		Heater PS-3 Cur	N/A	33
CLIQ Bus 1	18	18		Heater PS-3 V	N/A	34
CLIQ Bus 2	19	19		Heater PS-4 Cur	N/A	35
CLIQ Bus 3	20	20		Heater PS-4 V	N/A	36
				Magnet Current	N/A	37
				Magnet Idot	N/A	38

Quench Protection System Estimate Assumptions

Quench Protection Assumptions –

– DQD [WC, WC-Idot, HC's, Cu Leads-I, SC Leads, GF]

- Iso amp: 12 ch (24-Ch. Chassis) – includes 4 spares
- Analog inputs: 16 ch (1 mod) + 16 ch (1 spare mod)
- 8-slot cRIO FPGA chassis with controller (1 spare)
- 24 V digital inputs: 16 ch (1 mod) + 16 ch (1 spare mod)
- 24 V digital outputs: 16 ch (1 mod) + 16 ch (1 spare mod)
- TTL digital i0: 32 ch (1 mod) + 32 ch (1 spare mod)

– AQD DQD [WC, WC-Idot, HC's, Cu Leads-I, SC Leads, GF]

- Iso Amp: 12 ch (24-Ch. Chassis) includes 4 spares
- AQD boards: 10 (includes 2 spares)

Quench Protection System Estimate Assumptions

Quench Characterization and QD Monitor Assumptions

–

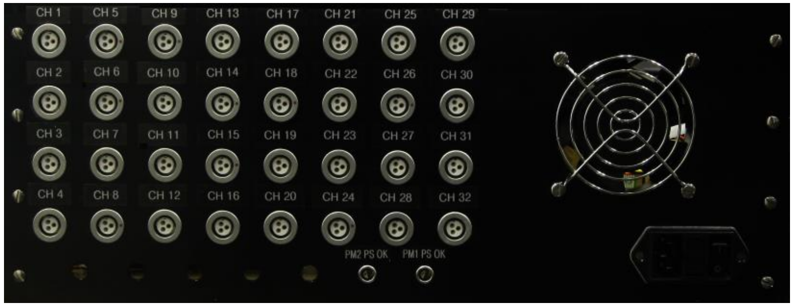
- QC
  - Iso amp: 32 ch (1 box)
  - 8-slot PXI chassis (1 Spare)
  - PXI controller (1 Spare)
  - Analog inputs 32 ch (4 mod) + 16 ch (2 spare mod)
- QD monitor
  - 24 bit analog inputs: 4 ch (1 mod) + 4 ch (1 mod spare)
  - 8-slot cRIO FPGA chassis with controller
  - 24 V digital inputs: 16 ch
  - 24 V digital outputs: 16 ch
  - TTL digital i0: 32 ch

Quench Detection Estimate Assumptions

Custom Versus Commercial –

– Custom hardware solutions will only be used when necessary

- The isolation amplifiers are a custom design but will be outsourced for commercial fabrication
- 32 Channel Isolation Amplifier Box: Uses AD215 IA isolation amplifiers
- Fisher HV connectors will be used for the inputs, which will match the existing test stand 4 HV quench cables



Slow Logging Estimate

Cryo Montioring –

– All thermometry, liquid level, pressure, and flow will be scanned by a PLC

– RTDs can be readout via a new Lakeshore 240 Series, 8-ch cards -- $2,019 / 8-ch card

Coming soon

240 Series Input Modules

240 Series Features

- Two or eight cryogenic temperature sensor inputs
- Supports industry-leading Lake Shore Cernox, platinum, and other RTDs, plus DT-670 diodes
- Precision measurement circuitry with on-board conversion to calibrated temperature units
- Monitor temperatures down to 1 K and up to 800 K
- Current reversal to minimize thermoelectric offsets
- Front-mounted OLED screen for temperature and status reporting
- Fully configurable through direct USB connection
- PROFIBUS-DP communication integrates with distributed PLC-based control architectures
- Easy DIN rail mounting with integrated rear connections for shared power and network

Slow Logging Estimate

Spice Measurements –

- Hardwired for production measurements
- Use high precession voltage measurement hardware including a multiplexor

– **The two-channel Model 2182A Nanovoltmeter** is optimized for making stable, low noise voltage measurements and for characterizing low resistance materials and devices reliably and repeatability. It provides higher measurement speed and significantly better noise performance than alternative low voltage measurement solutions. It offers a simplified delta mode for making resistance measurements in combination with a reversing current source, such as the Model 6220 or 6221.

Slow Logging Estimate

Spice Measurements –

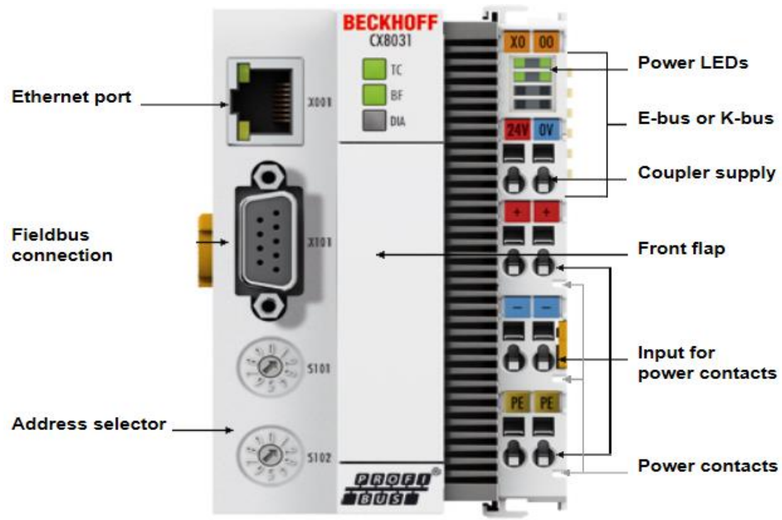
Keithley Model 7168
Nanovolt Scanner Card 8-channel, 2-pole

Keithley Model 7001
Switch/Control Mainframe 80-channel

Slow Logging Estimate

Spice Measurements –

EL6002, EL6022 | 2-channel serial interfaces RS232/RS422/RS485, D-sub connection



CX8031 | Embedded PC for PROFIBUS

GPIB-to-RS232 Converter

Splice Measurement Estimate

Spice Measurements – Total cost is $14.6

Description	System	QTY	Unit Price ($k)	Total Price ($k)
8 channels, Splice measurements	Keithley Model 2182A Nanovoltmeter	1	$3.5	$3.5
	Keithley Model 7168 8-Ch Nanovolt Scanner Card	1	$3.5	$3.5
	Keithley Model 7001 Switch Mainframe	1	$2.6	$2.6
	Ni GPIB to RS232 Converter	1	0.6	$0.6
			total =	$12.6
PLC with profibuss	Beckhoff CX8031 Embedded PC for PROFIBUS	1	$3.0	$3.0
	Beckhoff EL6002	1	$0.4	$0.4
			total =	$3.4
Cables, Connectors	Cabling	1	$1.0	$1.0
			Total=	$14.6

Wire Routing Change

CERN may require different routing of voltage tap and sensor wires –

- Existing stand instrumentation interface utilizes Hypertronics connectors in the helium interconnects
- An alternative would route wires to a connector flange in helium tubing, with connections to a vacuum flange on the cryostat
  - Implementing this feedthrough close to the feed can (interface box?) should be considered in order to keep the signal distance as short as possible

Vacuum Feedthrough Cabling Cost Estimates

Vacuum Feed though Cabling –

- Magnet Voltage Taps – Assuming all coil taps are brought out through a vacuum feedthough then new HV cabling will have to be installed
  - Assumption – 1 WC and 2 HCs for two magnets
    - Will require 1 4-pair HV cable for each magnet plus 1 spare cable
      - M&S = $600.00
      - Labor = 8 hours
- Protection heater power cables and voltage tap cables
  - Assumption #1 – Assume only 4 heater circuits are powered (4 SHs internally wired in parallel in each circuit)
    - Will require 2 power cables and 1 4-pair HV voltage tap cable
      - M&S = $1k
      - Labor = 6 hours
  - Assumption #2 – Assume 16 independent heater circuits are powered
    - Will require 8 power cables and 4 4-pair HV voltage tap cable
      - M&S = $9k
      - Labor = 54 hours
    - Will require a VMTF style protection heater distribution panel
      - M&S = $3.5k
      - Labor = 80 hours

Total M&S Cost Estimate

M&S Estimates –

- Quench Protection / Characterization -- $93,245
- Splice Measurements – $14,600
- RTD readout of16 channels = $4038

Vacuum Feed though Cabling –

- Add $1.6k for vacuum feed through cabling with protection heater assumption #1
- Add $13.1k for vacuum feed through cabling with protection heater assumption #2

Labor Cost Estimate

- Estimate of Labor for Quench System Upgrades –

	Engineering Physicist	*Electrical Design Engineer*	*Electrical Technician*	*Applications Development & Systems Analyst*
Produce Detailed Design	180	180	60	180
System Validation and Design Reviews	120	120		120
Develop and Test Quench Protection Software	180	180	40	200
Fabricate, Assemble, & Perform Acceptance Tests of Electronic Components	120	120	320	120
Stage, Assemble, and Test Quench Protection and Slow Logging System	180	180	200	180
Generate User Documentation	100	100	40	100
Perform Quench Protection and Slow Logging Integration Tests	140	140	140	140
Totals =	1020	1020	800	1040
2.2 FTEs (1768 hrs/FTE) =	0.58	0.58	0.45	0.59

- Add 14 hours tech labor for vacuum feedthrough cabling with PH assumption #1
- Add 142 hours tech labor for vacuum feedthrough cabling with PH assumption #2

Schedule

Assuming commissioning in June 2019, this project should probably start a year in advance in order to support concurrent projects

Work on the Mu2e Quench Protection and Monitoring system will use the same resources; however, that work will ramp up significantly in 2017, ahead of the LARP test stand upgrade

Summary

- The upgrades to the test stand 4 quench protection and monitoring systems will use the existing racks and cabling
- Test stand high voltage signals will have to be tested and possibly modified to meet the new hipot requirements
- The quench design configuration will be based on the latest design for Mu2e. The same engineering/technical resources will be supporting both systems so this is expected to be a more efficient use of labor
- The cryo scan controls will all be PLC based, including the splice measurements
- Commercial hardware solutions will be used whenever possible
  - The few in-house designs will be commercially fabricated