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# Projects: Dogleg Upgrade

Friday 17th July 2015

Andrew Kimber

# Project overview

- AIPDG1 – Engineering and management oversight
- AIPDG2 – Magnet removal, modification, test and reinstall ✓
- AIPDG3
  - Upgrade 9 power supplies [1] [2]
  - Upgrade facilities AC power distribution panel (complete),
  - AC supply cables(pulled, awaiting termination) and
  - DC output cabling between service building and tunnel (cables pulled and terminated at the magnet, needs terminating at supply)
  - Install Shunt Resistors for Doglegs 3-9, if required [3]

**To be installed and tested by the Fall 2015 run**

[1] RAR report from C. Tennant. PDF can be found in the dogleg project "Supporting documents" folder
[2] Dogleg specifications from M. Tiefenback can be found in the dogleg project "Supporting documents“ folder
[3] Present plan is to software limit dogleg shunts to 10A. No shunt resistors required.

# Specification

| | Dog 1 | Dog 2 | Dog 3 | Dog 4 | Dog 5 | Dog 6 | Dog 7 | Dog 8 | Dog 9 |
|---|---|---|---|---|---|---|---|---|---|
| Long Term Current Stability - 8Hrs | Unchanged from 6GeV era | 500 ppm | | | | | | | |
| Long Term Current Stability - 24Hrs | | 500 ppm | | | | | | | |
| Max Ripple Current, Peak to Peak , 0-1kHZ | | 5 ppm | | | | | | | |
| Max Ripple Current, Peak to Peak, 1-10kHZ | | 100 ppm | | | | | | | |
| Max Ripple Current, Peak to Peak, ->10kHZ | | 500 ppm | | | | | | | |
| Min. Set Current Resolution | | 50 mA | | | | | | | |
| Absolute Current Accuracy | | 500 ppm | | | | | | | |
| Current Repeatability | | 500 ppm | | | | | | | |
| Maximum Operating Current, A | | 318 | 430 | 378 | 366 | 390 | 414 | 396 | 413 |
| Desired Current overhead | | 10% | | | | | | | |
| Hysteresis | | No hysteresis cycle required | | | | | | | |

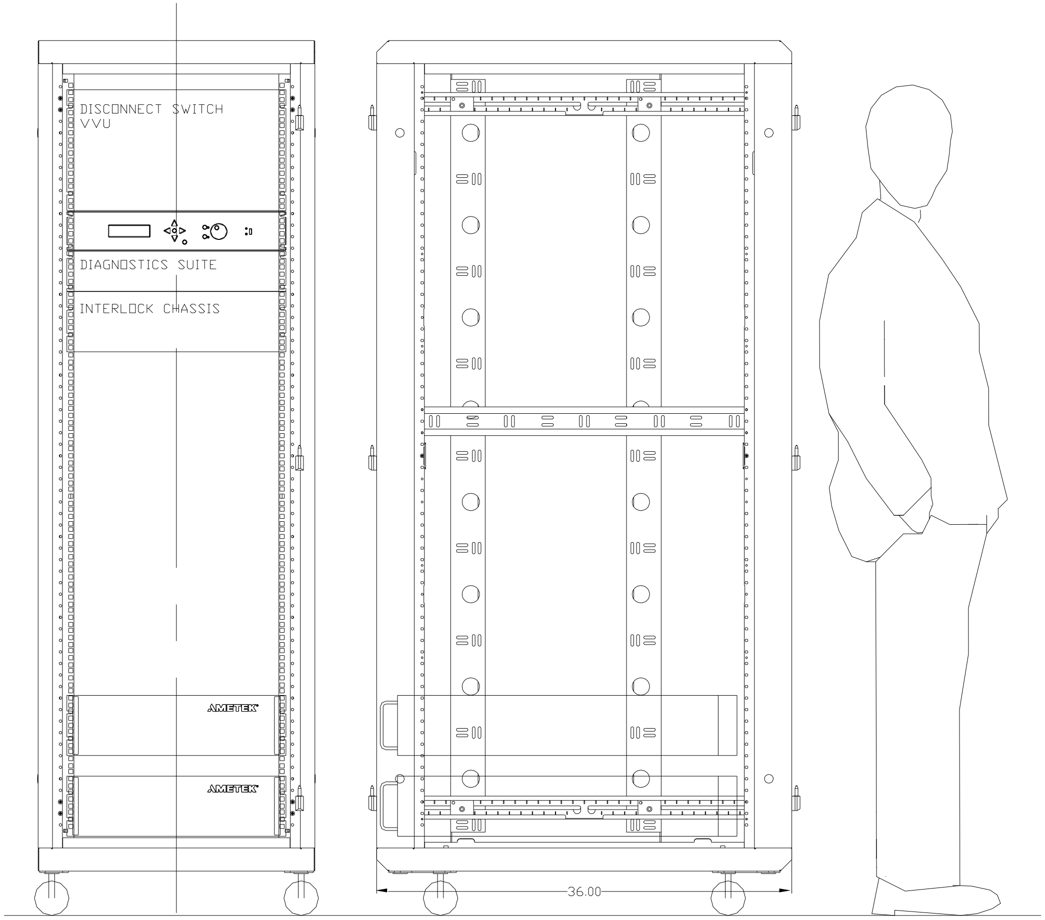
- 80V, 500 Amps
- Low ripple field below 10kHz
- High Efficiency
  - Water requirement unchanged
  - Footprint for buildings are unchanged
  - Minimal impact on breaker and input AC currents

# Timeline highlights

- Design phase started in earnest early this year
- All bulk supplies in house
- Detailed design and manufacture of boards, AC and DC plates, chassis and firmware nearing completion
- FA testing early August 2015 into resistive load
- Excellent progress made on subsequent units (50% complete)
- August and September will see testing of remaining units
- FA test into magnets late August
- Installation of units in W2 and NLSB in Sep/Oct
- Ready for Fall 2015 run

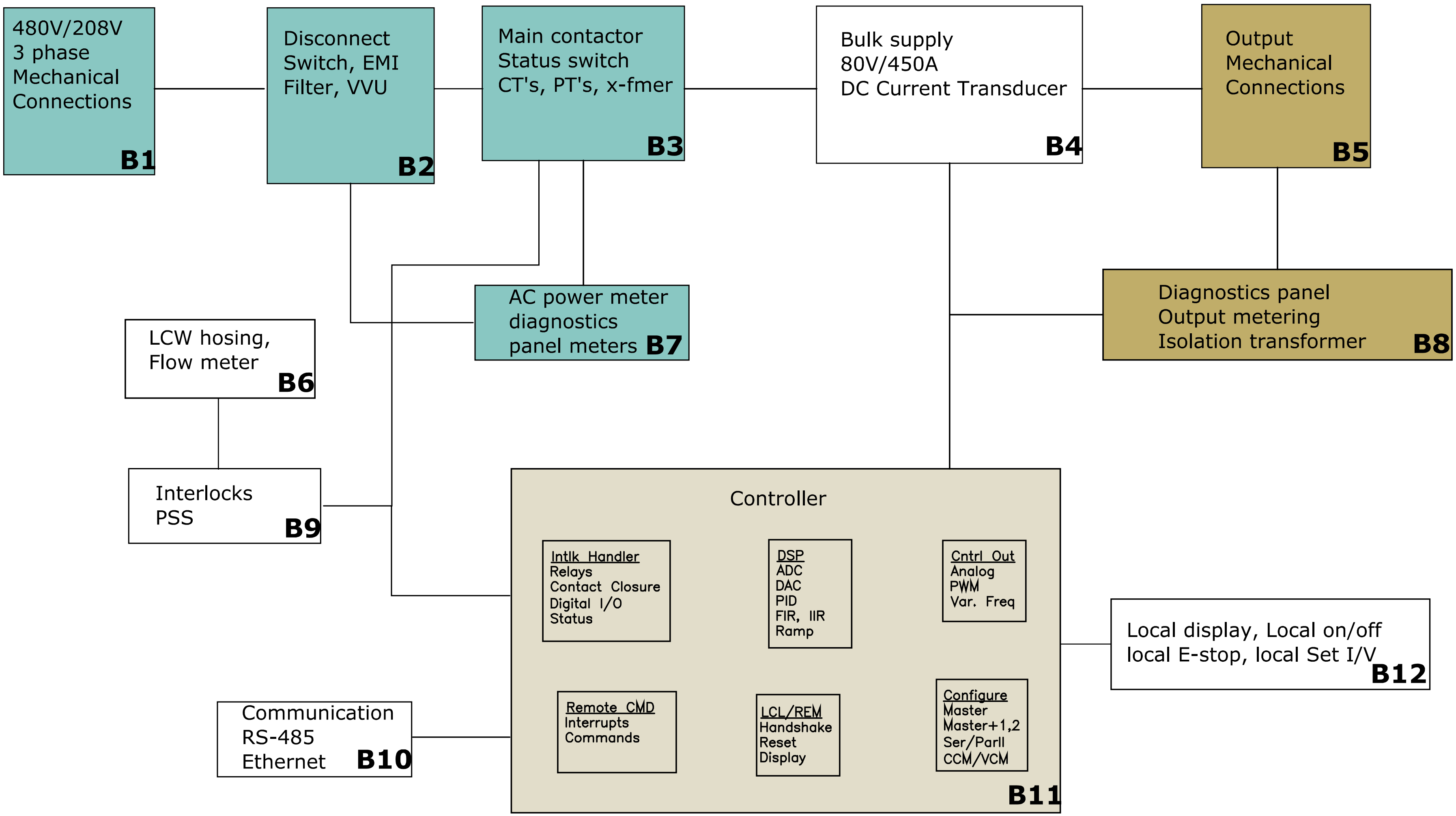
# Design philosophy/concept

- Modular in-house design
- Use existing designs where appropriate
- Use existing components where appropriate (minimize spares)
- Keep it simple
- Improve on the designs of vendors
- Design so that it can be used for future projects
- Use UL approved products where possible
- Use best engineering practice (national codes, IEC standards)

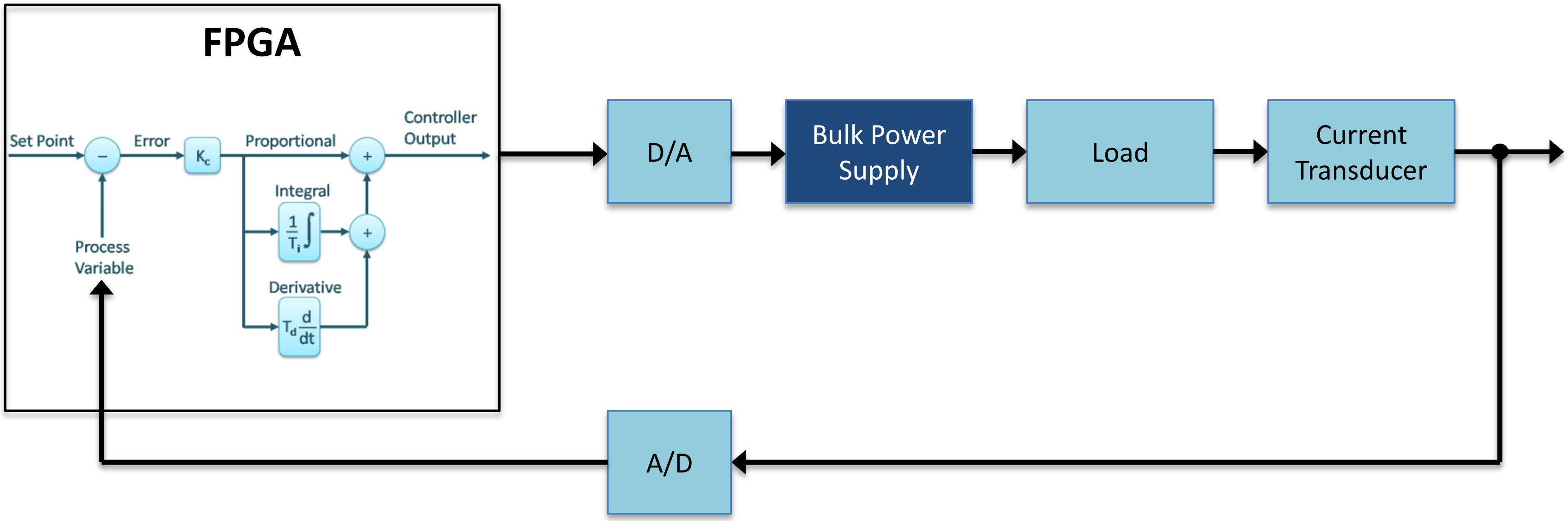



Early concept of general layout

# Modular design



# Closing the loop




Design utilizes an off the shelf commercial bulk supply with an in-house digital control scheme, effectively ‘closing the loop’ around the bulk supply.

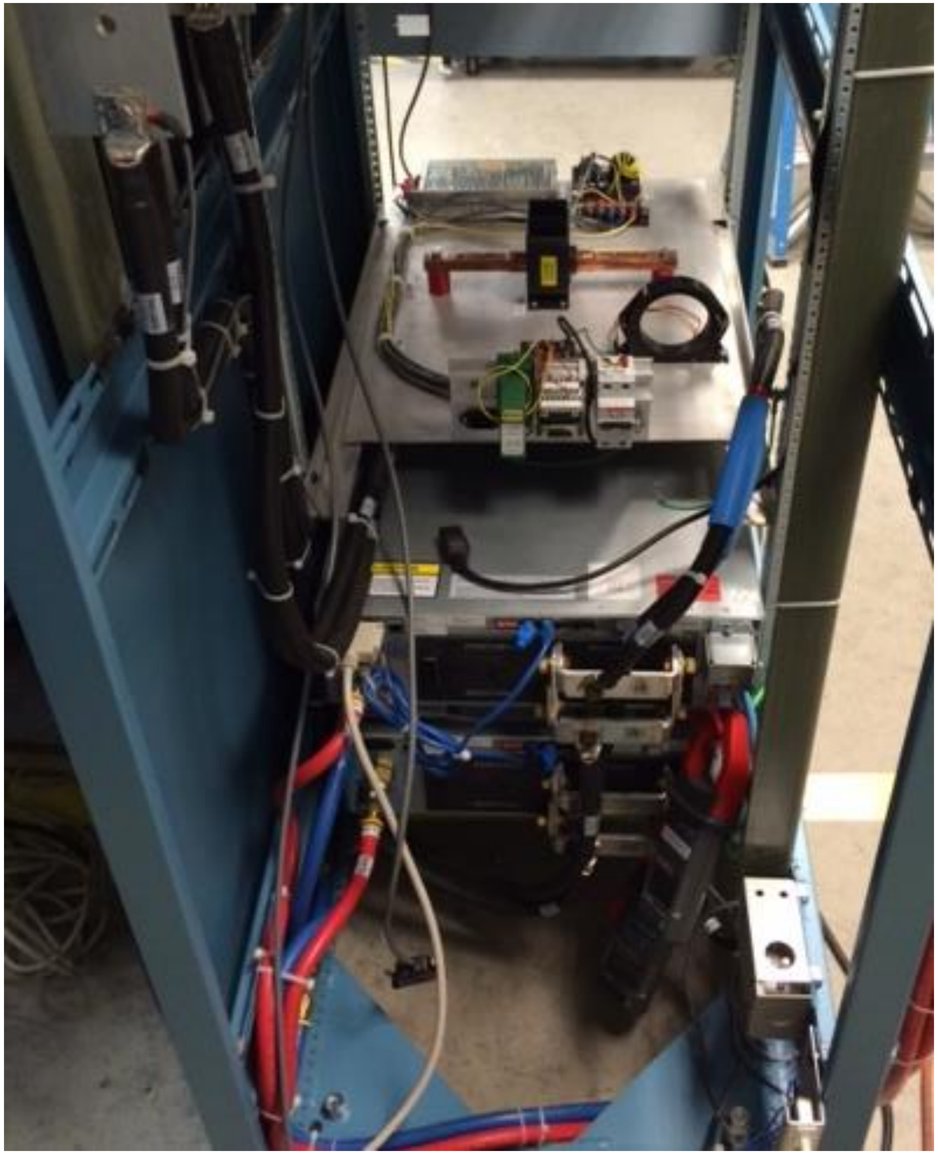
Why Digital ?

- Flexibility
- Easily reconfigured for different systems
- Adaptive (temperature compensation, etc…)
- Ability to implement modern control methods (State Space, etc…)

# Bulk supply contract

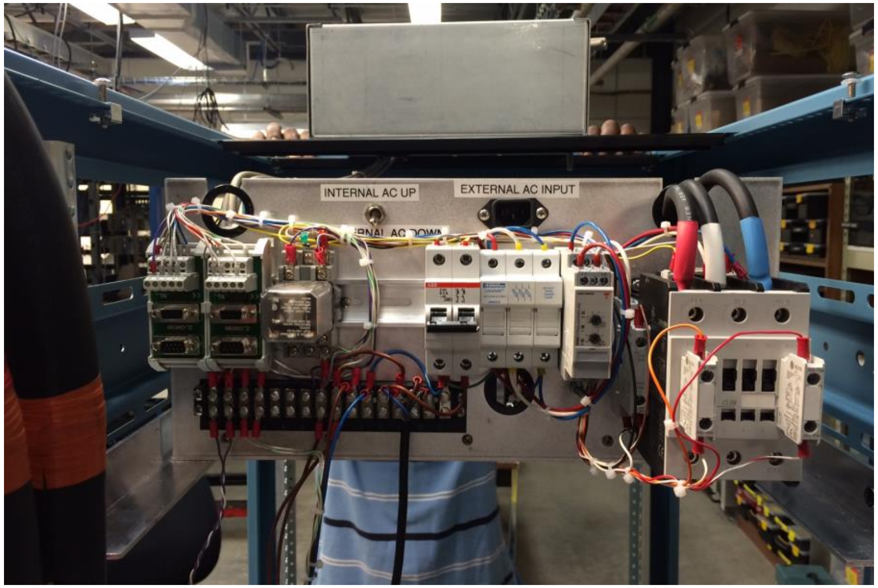
- Tender was placed for a bulk power supply capable of 80V and 450A (36kW) with a regulation of 0.1% in September 2014.
- Bulk supply contract: $256,753 for 10 units (under $280k budget) was awarded to Ametek in January 2015.
- FA ‘unit’ arrived at JLab on May 7th and successful testing completed (with a couple of minor issues). A ‘unit’ is actually 2x250A units in parallel in master/slave configuration.
- Production units were all delivered in June.

# Prototype/First Article

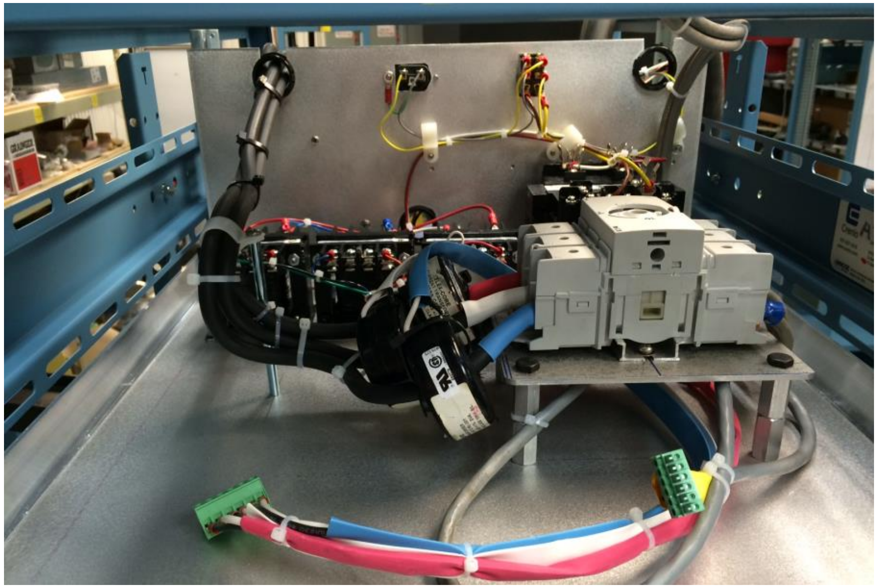



# Rack progress

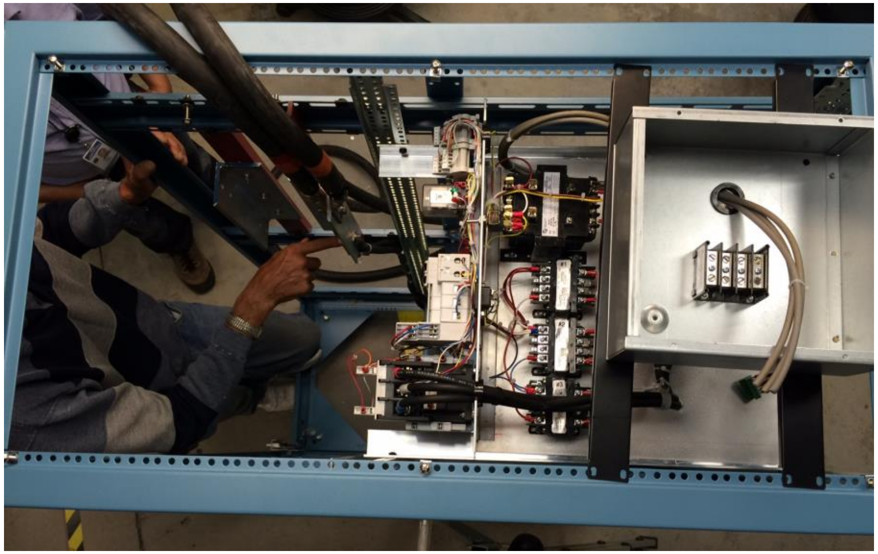

# AC Plate




Back view

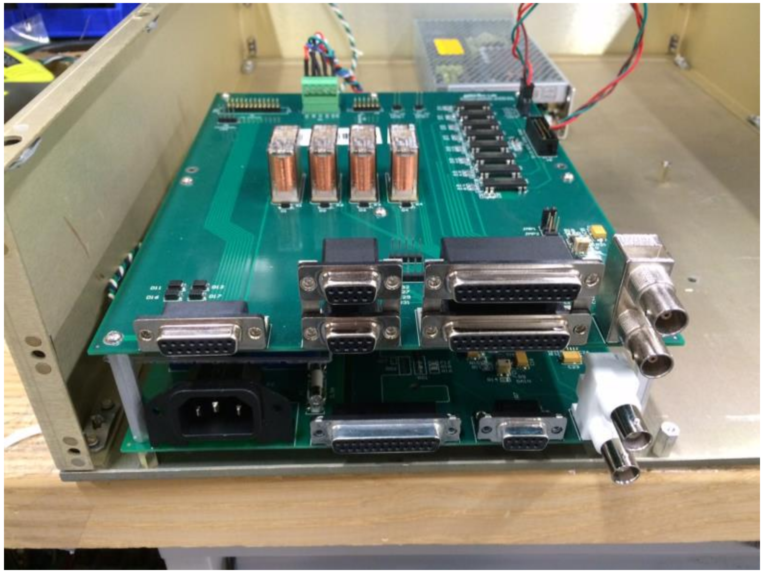


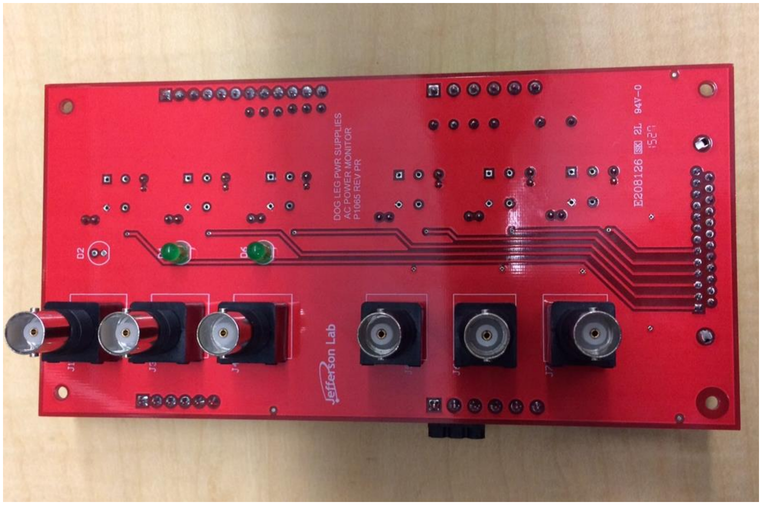
Front view

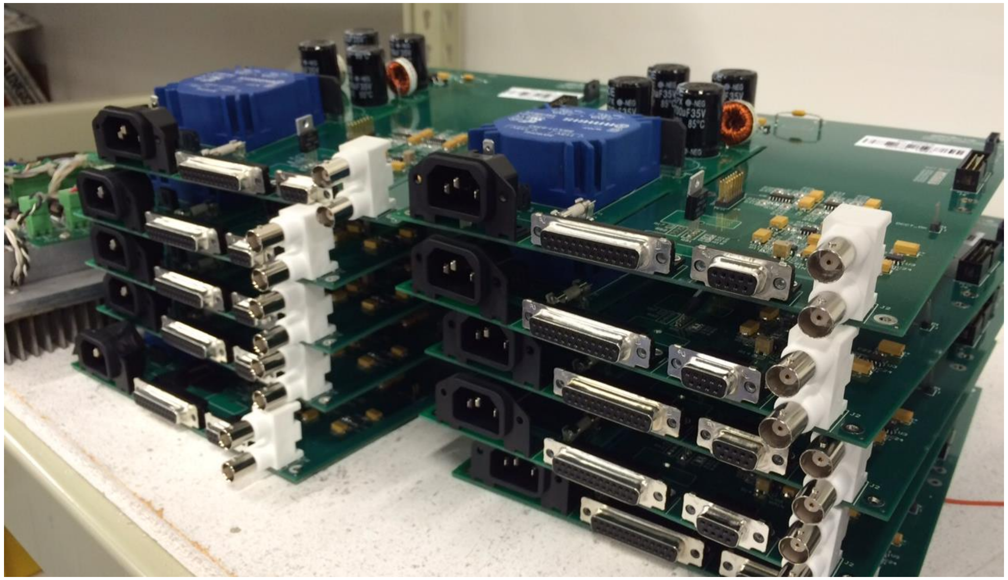


Top view

# Interface boards/chassis

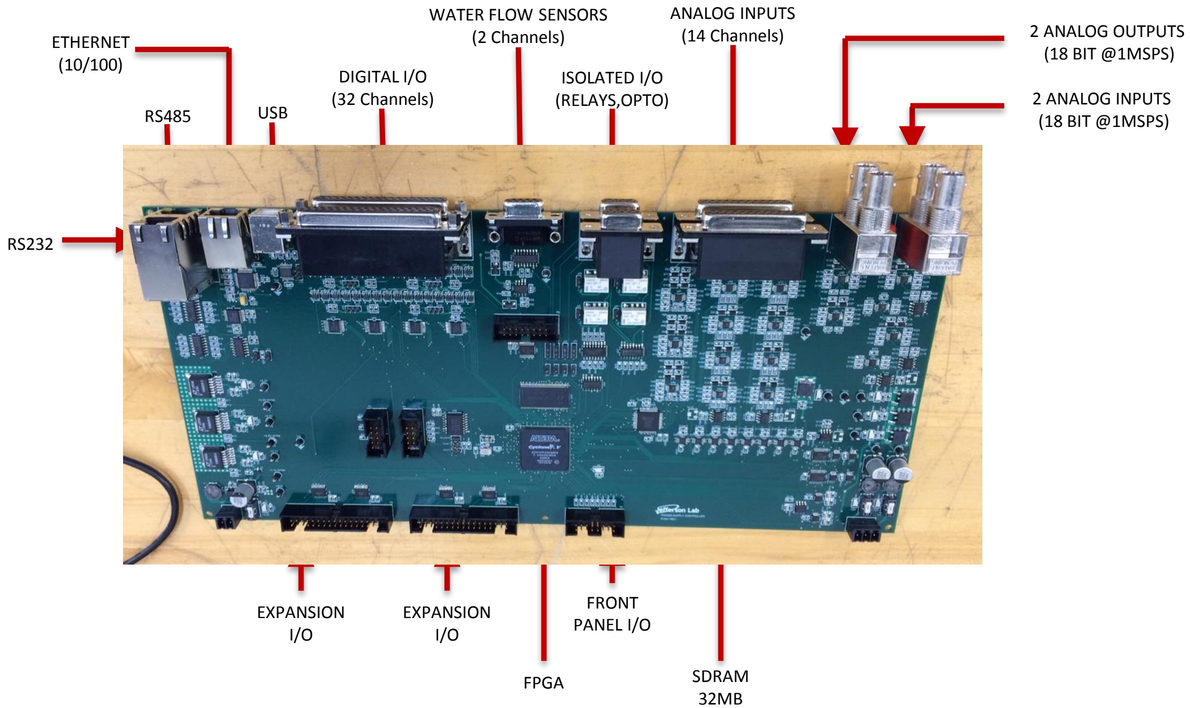


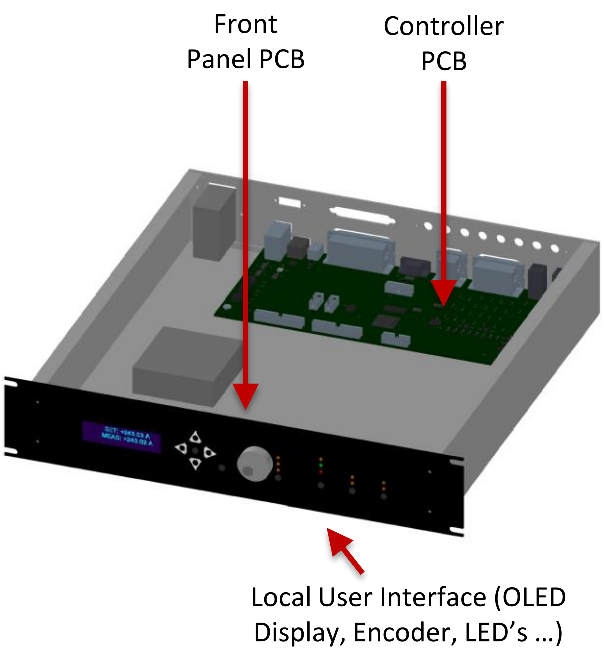



# Controller Design

- Provides system control and instrumentation
- Implements feedback control loop
- Handles remote communication
- Provides local controls
- Implements fault logic (LCW, Overtemp, Overload, …)



# Why build in house?

*We could have purchased 9 power supplies from vendor X*

- Pros for designing/building in house:
  - Complete control over design decisions and layout
  - IP retained within JLab
  - Spares (especially PCB boards) will be significantly cheaper
  - Modular design, expandable (or reducible) as needed for future projects
  - Upgrade path, especially controls firmware
  - On the job training for technicians, easier to troubleshoot (because they helped build it)
  - Ownership of system
  - Interest for engineers
  - Dogleg PSU project was manageable in quantity, power (I&V), and can be delivered quickly
  - Potential cost savings
  - Build within timeline. Most vendors could not deliver full units before January 2016
- Cons:
  - No-one to blame but ourselves!!
  - Move risk from specification writing (Hall B power supplies not detailing dump circuit) to rest of design/manufacture/testing process – higher risk?
  - Labor intensive, prevents other projects making progress
  - Documentation problems (designer throughput, limited technical writing skill base)
  - Do not have years of power supply <u>manufacture</u> behind us
  - No 'standard' products to base designs on

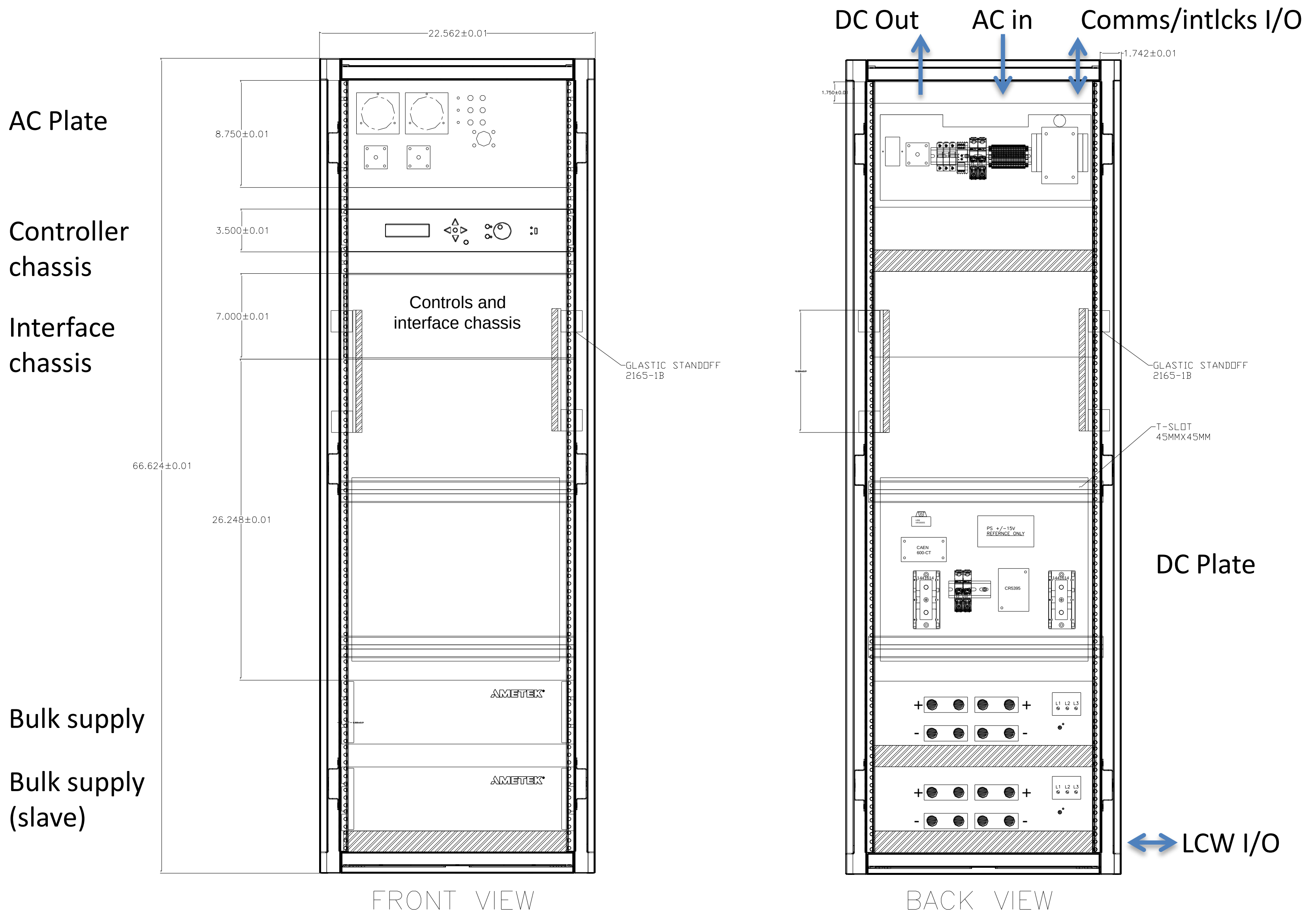
# Summary

- Overall the project is planned to complete, with float, by the fall run 2015
- Procurement costs should come in below budget, although labor costs look to be higher than what is currently in the AWP
- Bulk supply contract complete
- Other procurements nearing completion, testing of FA unit planned in ~two weeks.

**This will be a major achievement for the DC Power group. It will give us units specifically designed for CEBAF operations and will give us flexibility and options for future projects**

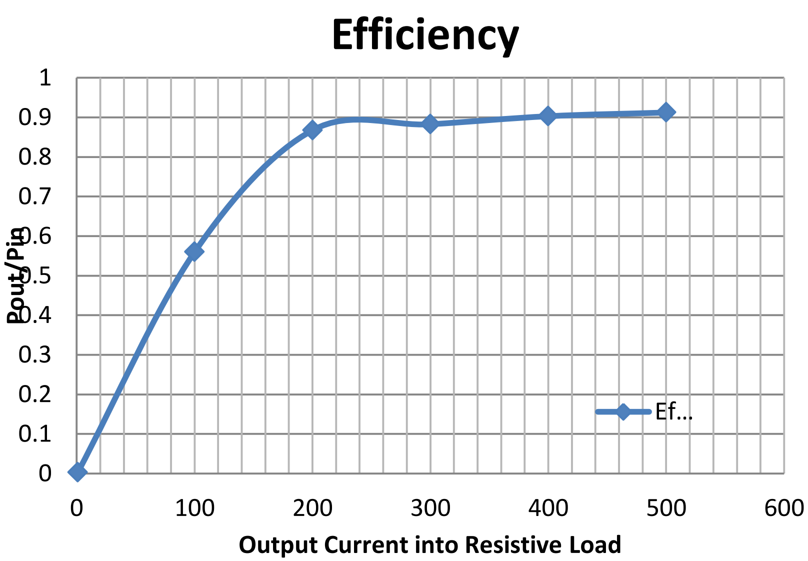
# Backup slides

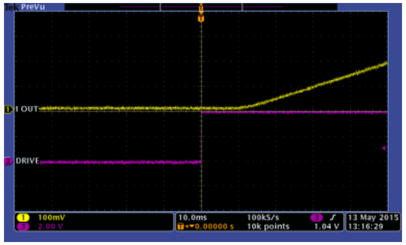
# Overall mechanical design

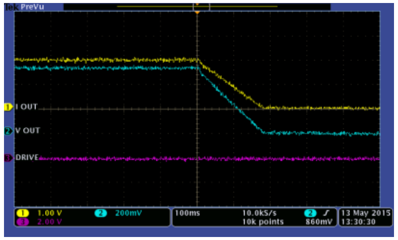


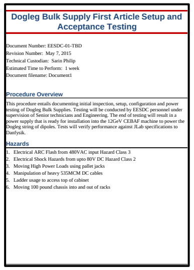
# Testing

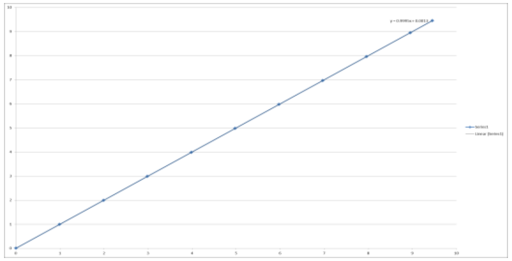
| PS Location | Dogleg First Article | Load Value | 0.16 ohm | Date: | 12-May-15 | | Names: | M.Augustine, M.Todd, K.Banks, S.Philip | | | Master SN: 1513A01842<br>Slave SN: 1513A01843 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ratio | 0 Amps | 50 Amps | 100 Amps | 150 Amps | 200 Amps | 250 Amps | 300 Amps | 350 Amps | 400 Amps | 450 Amps | 500 Amps | 500 Amps | 500 Amps |
| | | | | | | | | | | | | 15:00 | 15:20 | 15:30 |
| Drive | 1.0000 | | 1.0000 | | 3.0030 | 4.0005 | 5.0004 | 6.0003 | 6.9990 | 7.9990 | 9.0009 | 10.0001 | 10.0001 | 10.0000 |
| I Transducer | 100.0000 | 72.0000 | 0.0000 | 93.3000 | 0.0000 | 199.1000 | 0.0000 | 298.6000 | 0.0000 | 398.0000 | 0.0000 | 497.2000 | 0.0000 | 0.0000 |
| I out VDC (monitor) | 50.0000 | 0.0000 | 0.0000 | 99.8500 | 0.0000 | 199.9000 | 0.0000 | 300.0000 | 0.0000 | 400.0000 | 0.0000 | 500.0000 | 0.0000 | 0.0000 |
| V out VDC (monitor) | 8.0000 | 0.0000 | 0.0000 | 13.5520 | 0.0000 | 27.2800 | 0.0000 | 41.4400 | 0.0000 | 56.1600 | 0.0000 | 71.7600 | 0.0000 | 0.0000 |
| V out VDC (at load) | 1.0000 | 0.0190 | 0.0000 | 13.5800 | 0.0000 | 28.7270 | 0.0000 | 41.4000 | 0.0000 | 56.0000 | 0.0000 | 71.6000 | 0.0000 | 0.0000 |
| V L1 (VAC) | 1.0000 | 476.0000 | 0.0000 | 476.0000 | 0.0000 | 473.0000 | 0.0000 | 472.0000 | 0.0000 | 474.0000 | 0.0000 | 473.0000 | 0.0000 | 0.0000 |
| V L2 (VAC) | 1.0000 | 478.0000 | 0.0000 | 478.0000 | 0.0000 | 473.0000 | 0.0000 | 472.0000 | 0.0000 | 474.0000 | 0.0000 | 473.0000 | 0.0000 | 0.0000 |
| V L3 (VAC) | 1.0000 | 476.0000 | 0.0000 | 476.0000 | 0.0000 | 475.0000 | 0.0000 | 474.0000 | 0.0000 | 476.0000 | 0.0000 | 474.0000 | 0.0000 | 0.0000 |
| I L1 (AAC) | 1.0000 | 7.2000 | 0.0000 | 5.3900 | 0.0000 | 12.0000 | 0.0000 | 22.1000 | 0.0000 | 33.5000 | 0.0000 | 51.1000 | 0.0000 | 0.0000 |
| I L2 (AAC) | 1.0000 | 7.2600 | 0.0000 | 5.0000 | 0.0000 | 10.8000 | 0.0000 | 21.4000 | 0.0000 | 34.5000 | 0.0000 | 51.9000 | 0.0000 | 0.0000 |
| I L3 (AAC) | 1.0000 | 8.4000 | 0.0000 | 5.9300 | 0.0000 | 12.5000 | 0.0000 | 23.5000 | 0.0000 | 36.6000 | 0.0000 | 54.6000 | 0.0000 | 0.0000 |
| Power Factor (VAR) | 1.0000 | 0.0700 | 0.0000 | 0.5040 | 0.0000 | 0.6830 | 0.0000 | 0.7660 | 0.0000 | 0.8610 | 0.0000 | 0.9060 | 0.0000 | 0.0000 |
| Real Power In (KW) | 1000.0 | 470.0 | 0.0 | 2270.0 | 0.0 | 6630.0 | 0.0 | 14050.0 | 0.0 | 24750.0 | 0.0 | 39100.0 | 0.0 | 0.0 |
| LCW Flow Master | 1.0000 | | | | | | | 1.4000 | | | | | | |
| LCW Flow Slave | 1.0000 | | | | | | | 1.4000 | | | | | | |
| Temp (In) M | 1.0000 | 0.0 | 0.0 | 85.0 | 0.0 | 86.0 | 0.0 | 86.0 | 0.0 | 86.0 | 0.0 | 86.0 | 0.0 | 0.0 |
| Temp (Out) M | 1.0000 | 0.0 | 0.0 | 88.3 | 0.0 | 88.6 | 0.0 | 89.9 | 0.0 | 91.6 | 0.0 | 93.9 | 0.0 | 0.0 |
| Temp (In) S | 1.0000 | 0.0 | 0.0 | 84.8 | 0.0 | 85.0 | 0.0 | 85.0 | 0.0 | 85.3 | 0.0 | 85.7 | 0.0 | 0.0 |
| Temp (Out) S | 1.0000 | 0.0 | 0.0 | 84.7 | 0.0 | 85.6 | 0.0 | 86.2 | 0.0 | 87.9 | 0.0 | 89.6 | 0.0 | 0.0 |



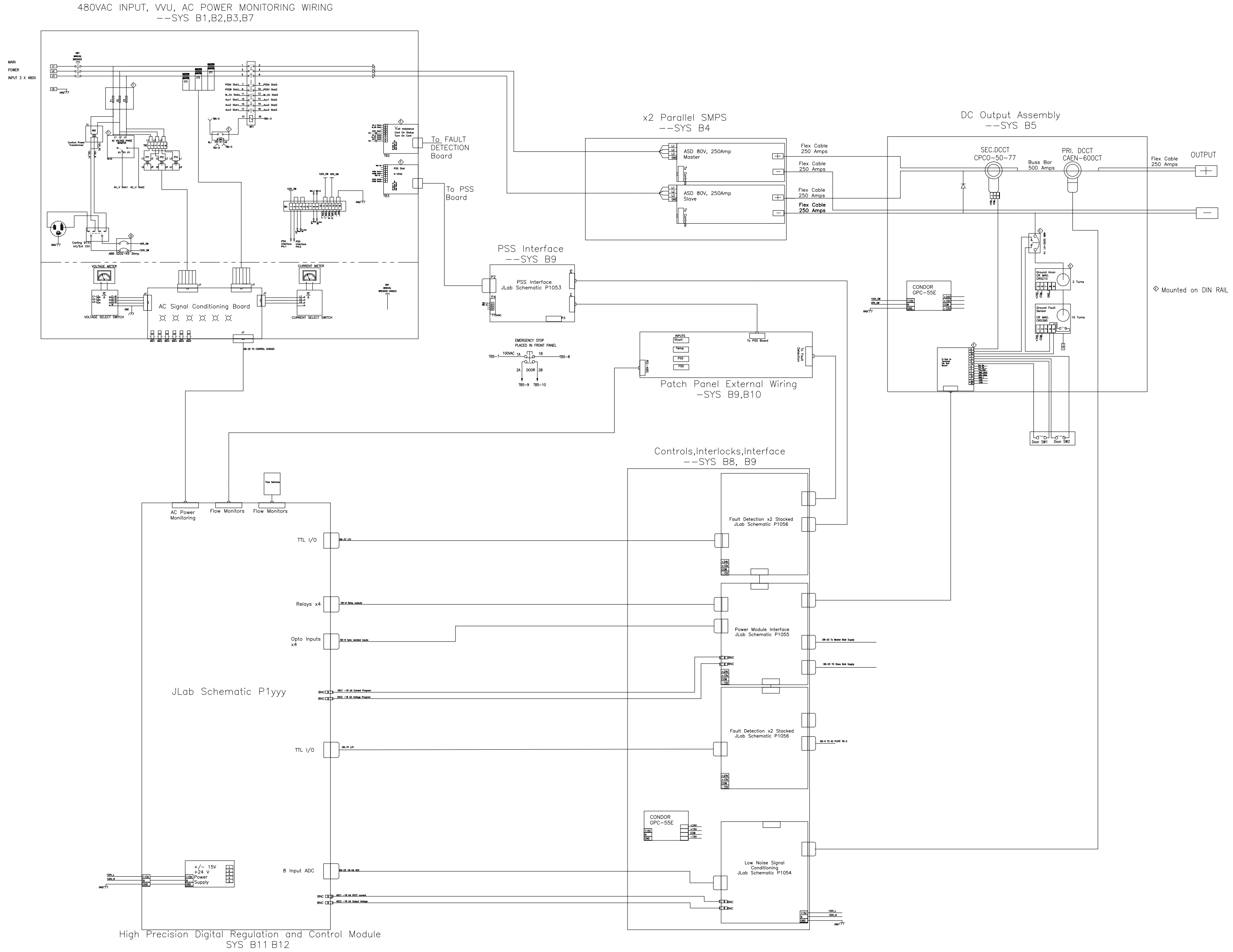



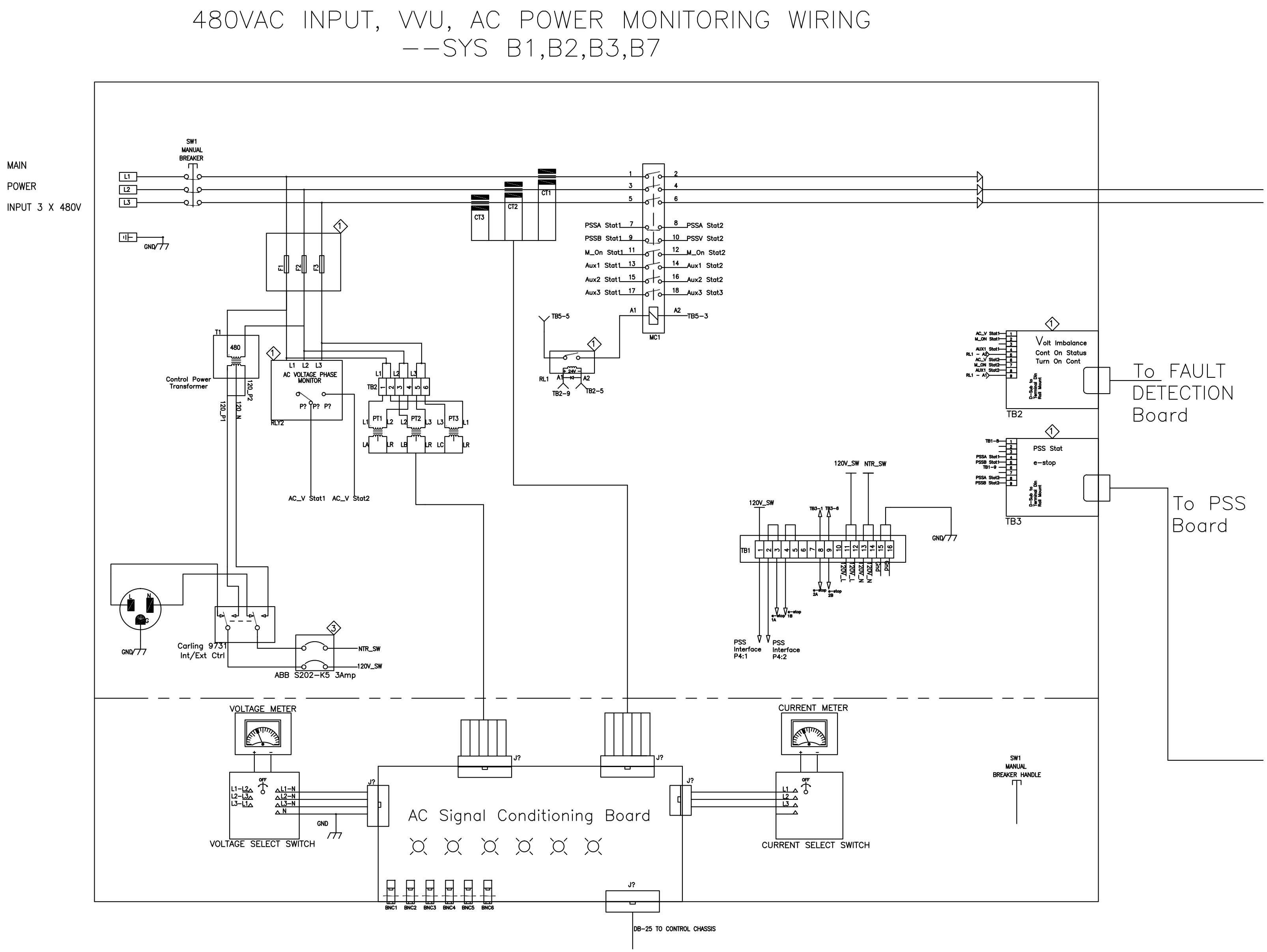
# Risk register

1. Work priority clash with 12GeV (Hall B?)
   - Designer time for schematics and layouts
   - Fab shop time for stuffing boards in house
   - Turnkey if needed?
2. Re-spin required of Power Supply controller
3. Bulk supply contract fails to deliver production units on time
4. Firmware takes longer than expected

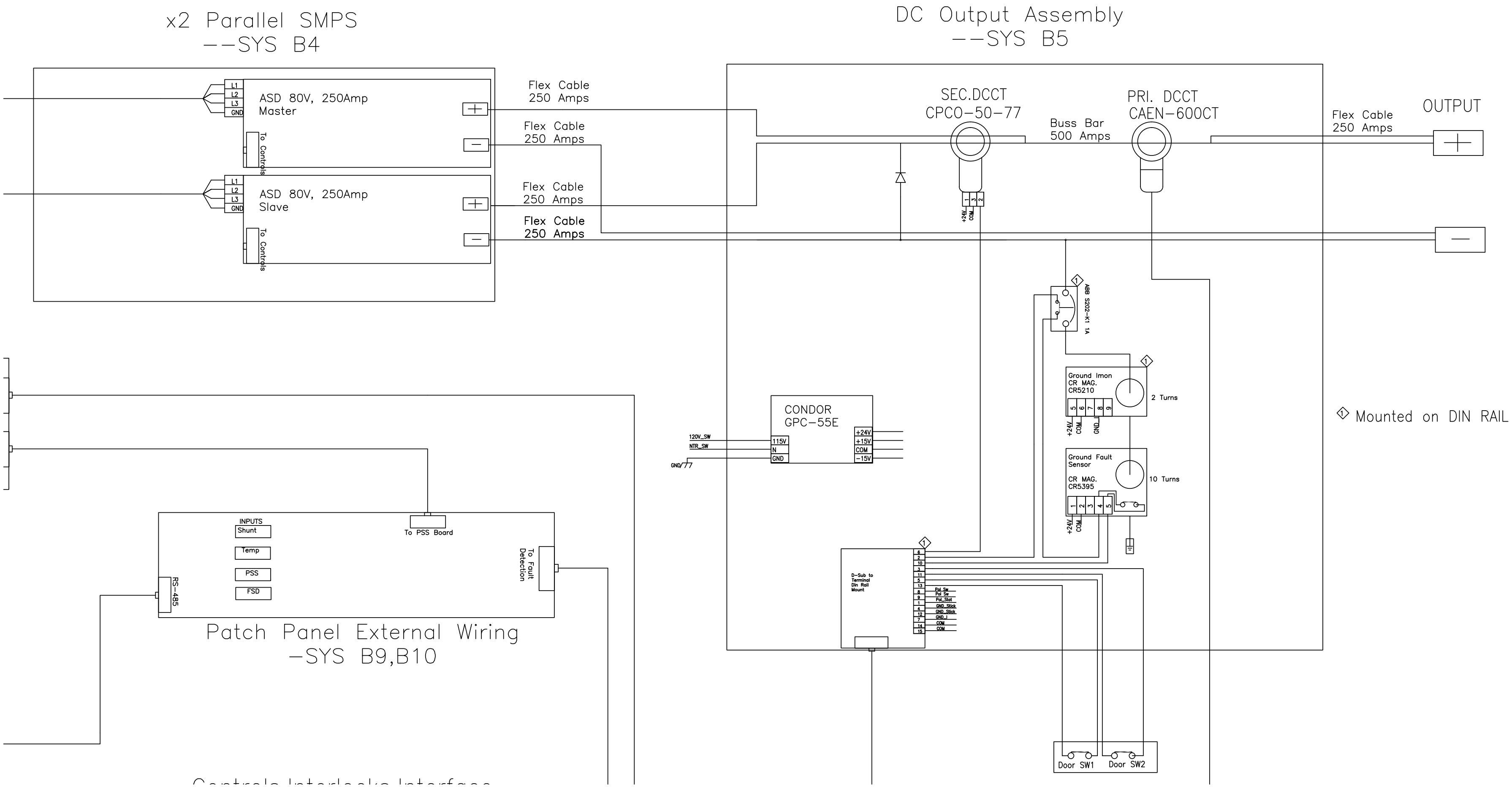
# Overall Electrical Design



# AC Plate electrical



# DC Plate electrical



# Costings

- AWP states:
  - 1.1 FTE's for DC Power (2.3 on plan, worst case)
  - 0.6 FTE's for Fab shop, designer and electricians (0.56 on plan)
  - 0.27 FTE's for Seaton (0.4 on plan)
  - ? FTE's for Croke (0.2 on plan)

  - $518.34K of procurements allocated, $300.21K YTD spent/committed
    - $256,753 for bulk supplies (10 units)
    - $38,626K spent in FY15 on
      - Racks for **all** units (~$22K)
      - DCCT's for **all** units (~$7K)
      - Misc. parts for prototype unit (~$10K)

  - Closest comparison is LAM1C (500A/80V) for $61.4K (part of a larger contract and 2012 dollars) + install/test labor
  - We estimate each dogleg will be ~$40-45K per power supply (+ labor)
  - Additional costs for remaining items (Electricians) and infrastructure, prototyping

Under on procurements, over on labor