



# ATF2 High Availability DC Magnet Power Supplies

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# Topics

- Power System Overview
  - Power Supply Requirements
  - Power Supply Controller
  - Power Supply Topology
  - Power System Diagrams
- Vendor Proposals
- Awarded Vendor
- Schedule
- Responsibilities



# Power Supply Requirements

Magnet Power System Data			Cable Data					Power Supply Data									
Magnet - Values Based on Standardizing			Cable - Based on Standardizing I +10%					DC Rating and Other Data									
Name (Element)	Type (Keyword)	Area	Normal Operating Volts	Single Maximum Volts (40C)	Normal Operating Amps	Maximum Amps	Single Magnet Resistance (ohms)	NEC Type or Other Data	1/C, 2/C or 3/C	1/C R (75C) (Ohm/ft)	Round Trip Length(ft)	Voltage Drop (V)	Cable Loss (kW)	Rated Volts	Rated Amps	Rated kW	Power Supply Loss (kW)
Quadrupole 1	IHEP	Extraction	14.99	16.53	136.0	150.0	0.11	#4.0	2/C	0.06260	600	6	0.8	30	150	4.5	0.6
Quadrupole 2	IHEP	Extraction	14.99	16.53	136.0	150.0	0.11	#4.0	2/C	0.06260	600	6	0.8	30	150	4.5	0.6
Quadrupole 3	IHEP	Extraction	14.99	16.53	136.0	150.0	0.11	#4.0	2/C	0.06260	600	6	0.8	30	150	4.5	0.6
Quadrupole 4	IHEP	Extraction	14.99	16.53	136.0	150.0	0.11	#4.0	2/C	0.06260	600	6	0.8	30	150	4.5	0.6
Quadrupole 5	IHEP	Extraction	14.99	16.53	136.0	150.0	0.11	#4.0	2/C	0.06260	600	6	0.8	30	150	4.5	0.6
Quadrupole 6	IHEP	Extraction	14.99	16.53	136.0	150.0	0.11	#4.0	2/C	0.06260	600	6	0.8	30	150	4.5	0.6
Quadrupole 7	IHEP	Extraction	14.99	16.53	136.0	150.0	0.11	#4.0	2/C	0.06260	600	6	0.8	30	150	4.5	0.6
Quadrupole 8	IHEP	Extraction	14.99	16.53	136.0	150.0	0.11	#4.0	2/C	0.06260	600	6	0.8	30	150	4.5	0.6
QM16	IHEP	Matching	14.99	16.53	136.0	150.0	0.11	#4.0	2/C	0.06260	600	6	0.8	30	150	4.5	0.6
QM15	IHEP	Matching	14.99	16.53	136.0	150.0	0.11	#4.0	2/C	0.06260	600	6	0.8	30	150	4.5	0.6
QM14	IHEP	Matching	14.99	16.53	136.0	150.0	0.11	#4.0	2/C	0.06260	600	6	0.8	30	150	4.5	0.6
QM13	IHEP	Matching	14.99	16.53	136.0	150.0	0.11	#4.0	2/C	0.06260	600	6	0.8	30	150	4.5	0.6
QM12	IHEP	Matching	14.99	16.53	136.0	150.0	0.11	#4.0	2/C	0.06260	600	6	0.8	30	150	4.5	0.6
QM11	IHEP	Matching	14.99	16.53	136.0	150.0	0.11	#4.0	2/C	0.06260	600	6	0.8	30	150	4.5	0.6
QD10	IHEP	Final Focus	5.01	5.51	45.5	50.0	0.11	#2	2/C	0.20100	600	6	0.3	30	50	1.5	0.1
QD10"	IHEP	Final Focus	5.01	5.51	45.5	50.0	0.11	#2	2/C	0.20100	600	6	0.3	30	50	1.5	0.1
QF9X	IHEP	Final Focus	5.01	5.51	45.5	50.0	0.11	#2	2/C	0.20100	600	6	0.3	30	50	1.5	0.1
QF9'	IHEP	Final Focus	5.01	5.51	45.5	50.0	0.11	#2	2/C	0.20100	600	6	0.3	30	50	1.5	0.1
QD8	IHEP	Final Focus	5.01	5.51	45.5	50.0	0.11	#2	2/C	0.20100	600	6	0.3	30	50	1.5	0.1
QF7	IHEP	Final Focus	5.01	5.51	45.5	50.0	0.11	#2	2/C	0.20100	600	6	0.3	30	50	1.5	0.1
QD6	IHEP	Final Focus	5.01	5.51	45.5	50.0	0.11	#2	2/C	0.20100	600	6	0.3	30	50	1.5	0.1
QF5	IHEP	Final Focus	5.01	5.51	45.5	50.0	0.11	#2	2/C	0.20100	600	6	0.3	30	50	1.5	0.1
QF5'	IHEP	Final Focus	5.01	5.51	45.5	50.0	0.11	#2	2/C	0.20100	600	6	0.3	30	50	1.5	0.1
QD4X	IHEP	Final Focus	5.01	5.51	45.5	50.0	0.11	#2	2/C	0.20100	600	6	0.3	30	50	1.5	0.1
QD4'	IHEP	Final Focus	5.01	5.51	45.5	50.0	0.11	#2	2/C	0.20100	600	6	0.3	30	50	1.5	0.1
QD2B	IHEP	Final Focus	5.01	5.51	45.5	50.0	0.11	#2	2/C	0.20100	600	6	0.3	30	50	1.5	0.1
QF3	IHEP	Final Focus	5.01	5.51	45.5	50.0	0.11	#2	2/C	0.20100	600	6	0.3	30	50	1.5	0.1
QD2A	IHEP	Final Focus	5.01	5.51	45.5	50.0	0.11	#2	2/C	0.20100	600	6	0.3	30	50	1.5	0.1
QF1	FFTB	Final Focus	4.88	5.60	69.8	80.0	0.07	#4.0	2/C	0.06260	600	3	0.2	30	100	3.0	0.1
QD0	FFTB	Final Focus	8.95	9.80	127.9	140.0	0.07	#4.0	2/C	0.06260	600	5	0.7	30	150	4.5	0.4
B5	PEPII	Final Focus	5.80	6.38	160	176.0	0.04	#4.0	2/C	0.06260	600	7	1.2	30	200	6.0	0.4
B2	PEPII	Final Focus	5.80	6.38	160	176.0	0.04	#4.0	2/C	0.06260	600	7	1.2	30	200	6.0	0.4
B1	PEPII	Final Focus	5.80	6.38	160	176.0	0.04	#4.0	2/C	0.06260	600	7	1.2	30	200	6.0	0.4
SF6	SLAC	Final Focus	10.00	11.50	40	46.0	0.25	#2	2/C	0.20100	600	6	0.3	30	50	1.5	0.1
SF5	SLAC	Final Focus	10.00	11.50	40	46.0	0.25	#2	2/C	0.20100	600	6	0.3	30	50	1.5	0.1
SD4	SLAC	Final Focus	10.00	11.50	40	46.0	0.25	#2	2/C	0.20100	600	6	0.3	30	50	1.5	0.1
SF1	SLAC	Final Focus	10.00	11.50	40	46.0	0.25	#2	2/C	0.20100	600	6	0.3	30	50	1.5	0.1
SD0	SLAC	Final Focus	10.00	11.50	40	46.0	0.25	#2	2/C	0.20100	600	6	0.3	30	50	1.5	0.1



# Power Supply Requirements

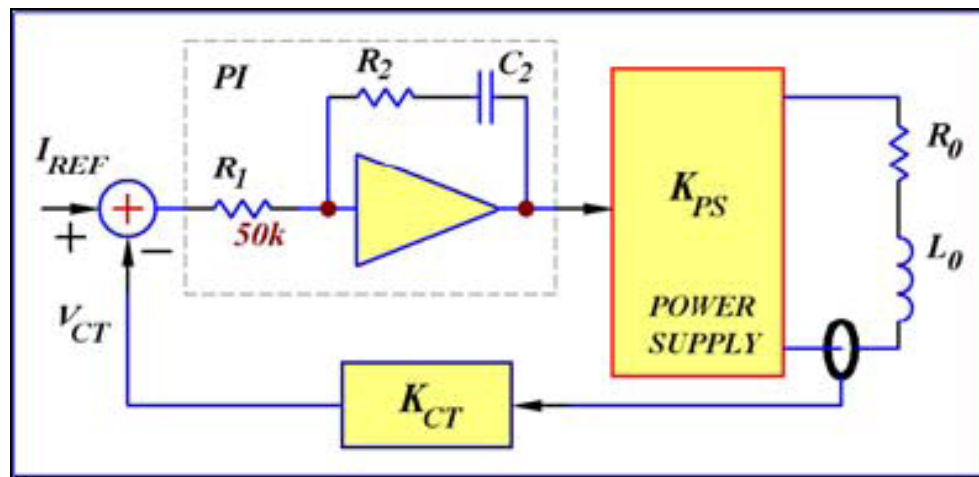
- Generally, ATF2 Magnets require:
  - up to 30 V
  - 50 to 200 A
  - Up to 10 ppm stability



# Power Supply Controller

- SLAC Ethernet Power Supply Controller
  - Provides precision current regulation using a precision current transducer and an external analog current feedback loop
  - 20-bit effective resolution for analog reference voltage (1 ppm accuracy measured)
  - 2 ppm/°C current stability
  - Continuous calibration
  - Interlocks for magnet protection
  - Analog readbacks

# Power Supply Controller



- Control Loop
  - Classic PI controller
  - Size  $R_2$  and  $C_2$  for a critically damped system and bandwidth  $f_c$

$$R_2 C_2 = \frac{L_0}{R_0}$$

$$G = \frac{K}{s} \quad K = \frac{K_{CT} K_{PS}}{R_0 R_1 C_2} \quad \text{open loop gain}$$

$$\frac{V_{CT}}{I_{REF}} = \frac{1}{\frac{s}{K} + 1} \quad K = 2\pi f_c \quad \text{closed loop transfer function}$$

$$C_2 = \frac{K_{CT} K_{PS}}{2\pi f_c R_0 R_1} \quad R_2 = \frac{L_0}{R_0 C_2}$$



# Power Supply Controller

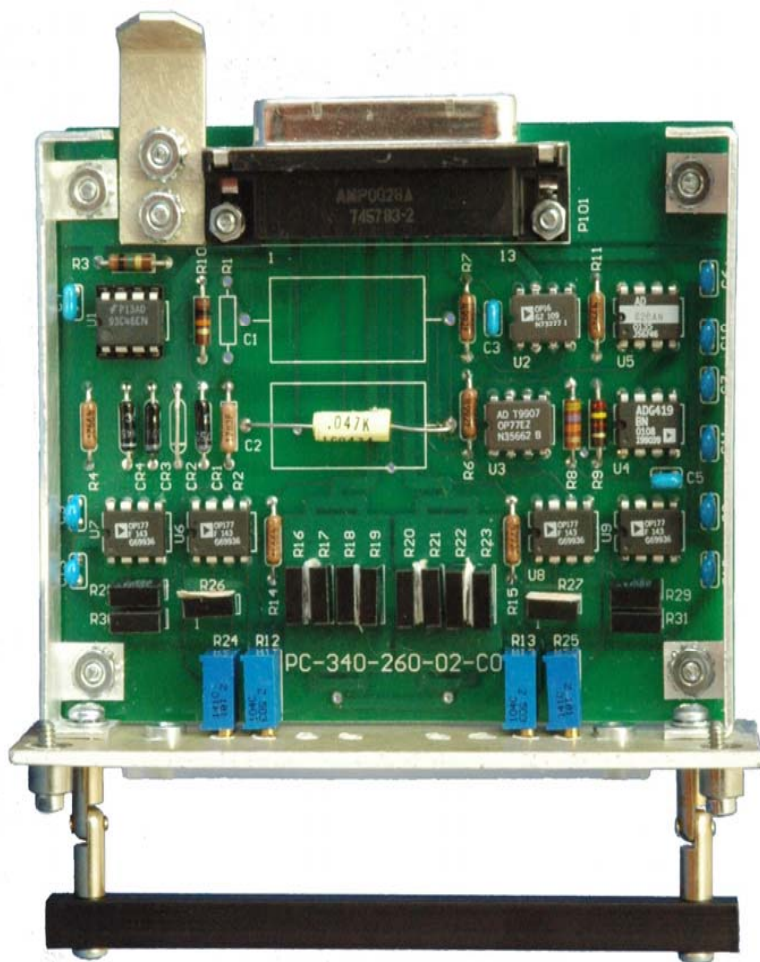


Front View



Rear View

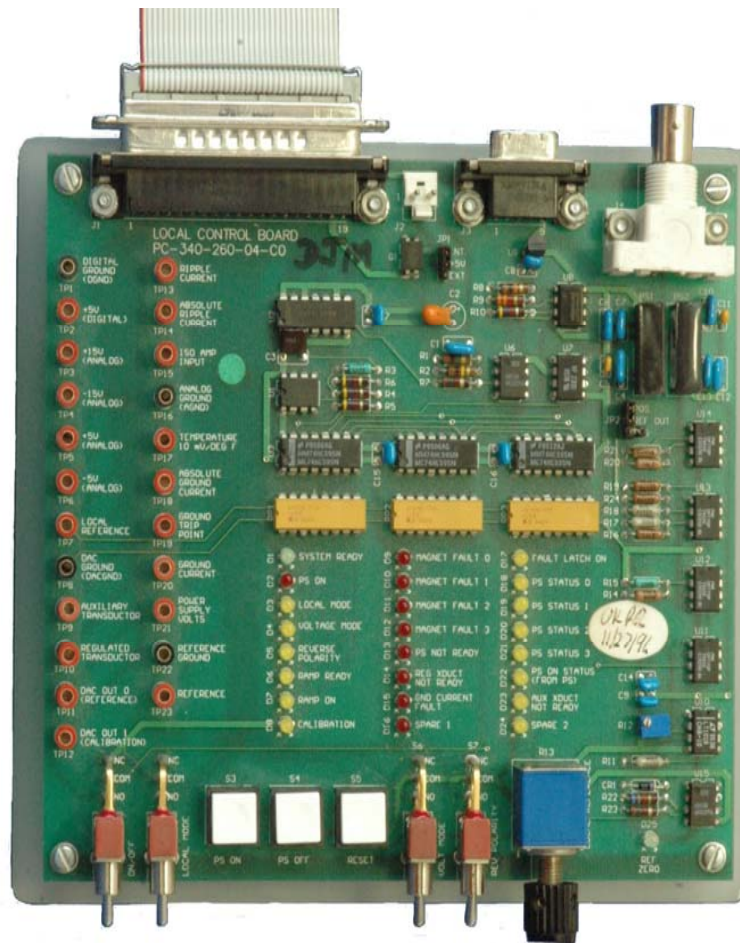
# Power Supply Controller



- Daughter Board
  - Removable
  - Contains Magnet-specific components
    - PI controller circuit
    - Burden resistors for DCCT
    - EEprom to store IP address and conversion constants

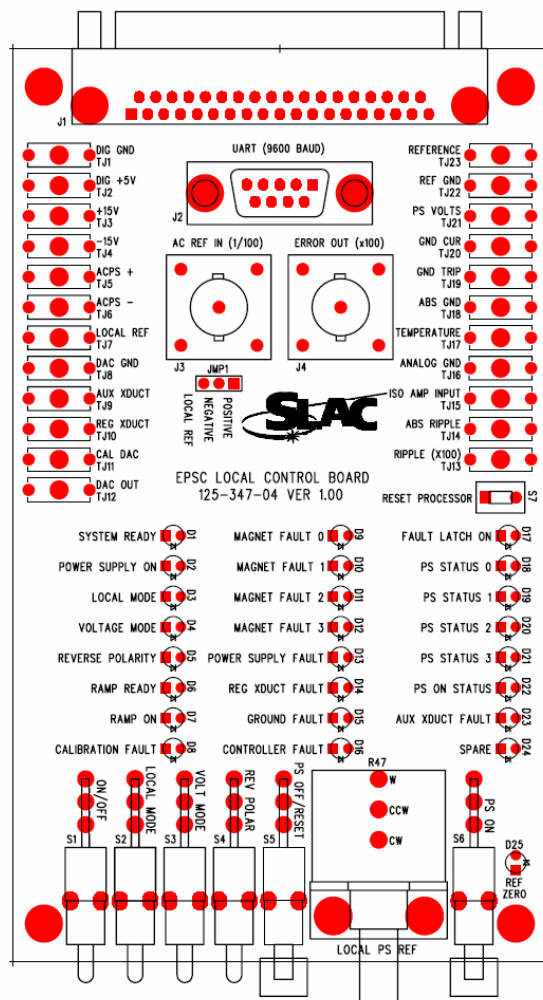


# Power Supply Controller



- Local Control Board
  - Operate the power supply locally
  - Access to diagnostic information
  - A new Local Control Board is under development

# Power Supply Controller



- New Control Board
  - Half the size
  - More robust
  - All the same controls
- Under Development
  - May be ready for ATF2



# Power Supply Topology

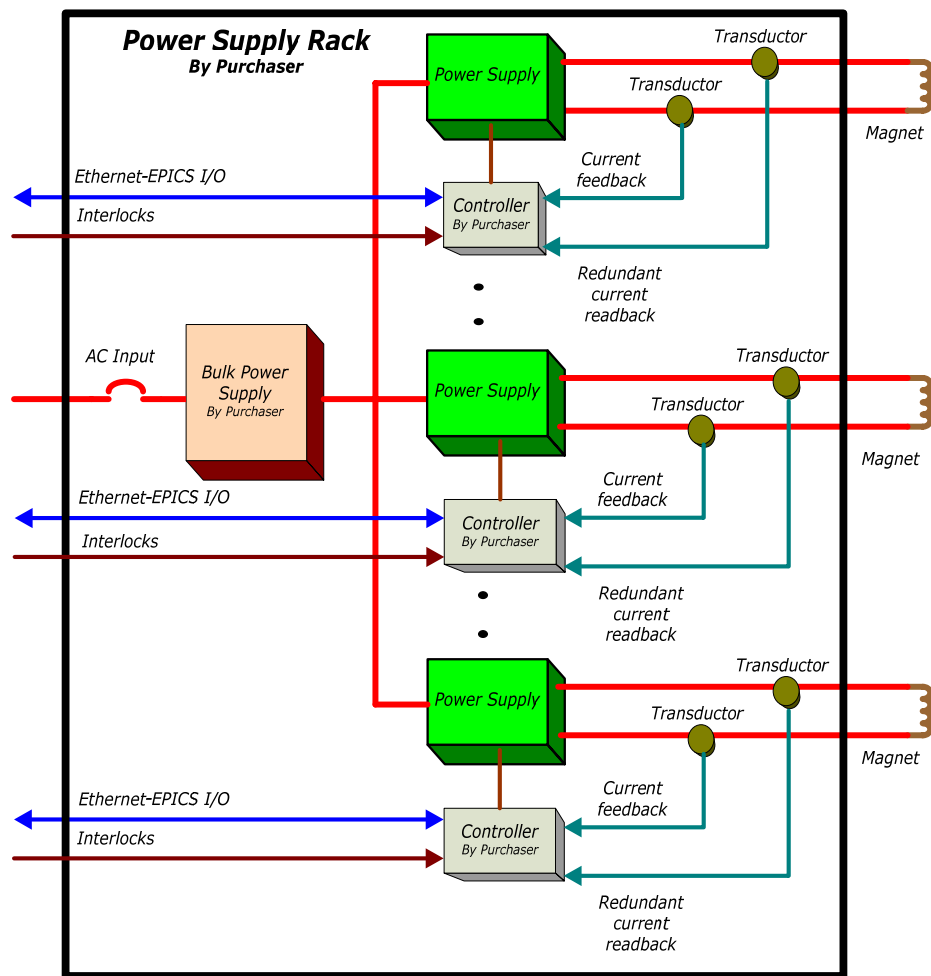
- Power Module Blocks
  - Use 30V, 50A blocks to construct power supplies
  - Simple Buck Regulator Topology
  - Add one extra power module for N+1 redundancy to increase availability
  - High Availability is an absolute requirement for success in the ILC
- Bulk Power Supply
  - Use off-the-shelf power supplies
  - Provide 40V regulated DC to Power Modules
  - One Bulk for several Power Supplies



# Power Supply Topology

- Power Supply Specifications
  - 30V, 50A Power Modules (Buck Regulators)
  - Common Crate for different configurations
  - Common Interface board to Controller
  - Analog and Digital readbacks/controls
  - N+1 redundancy
  - Automatic Current Sharing
  - Air-cooled rated for 50°C
  - Ground Current Detection

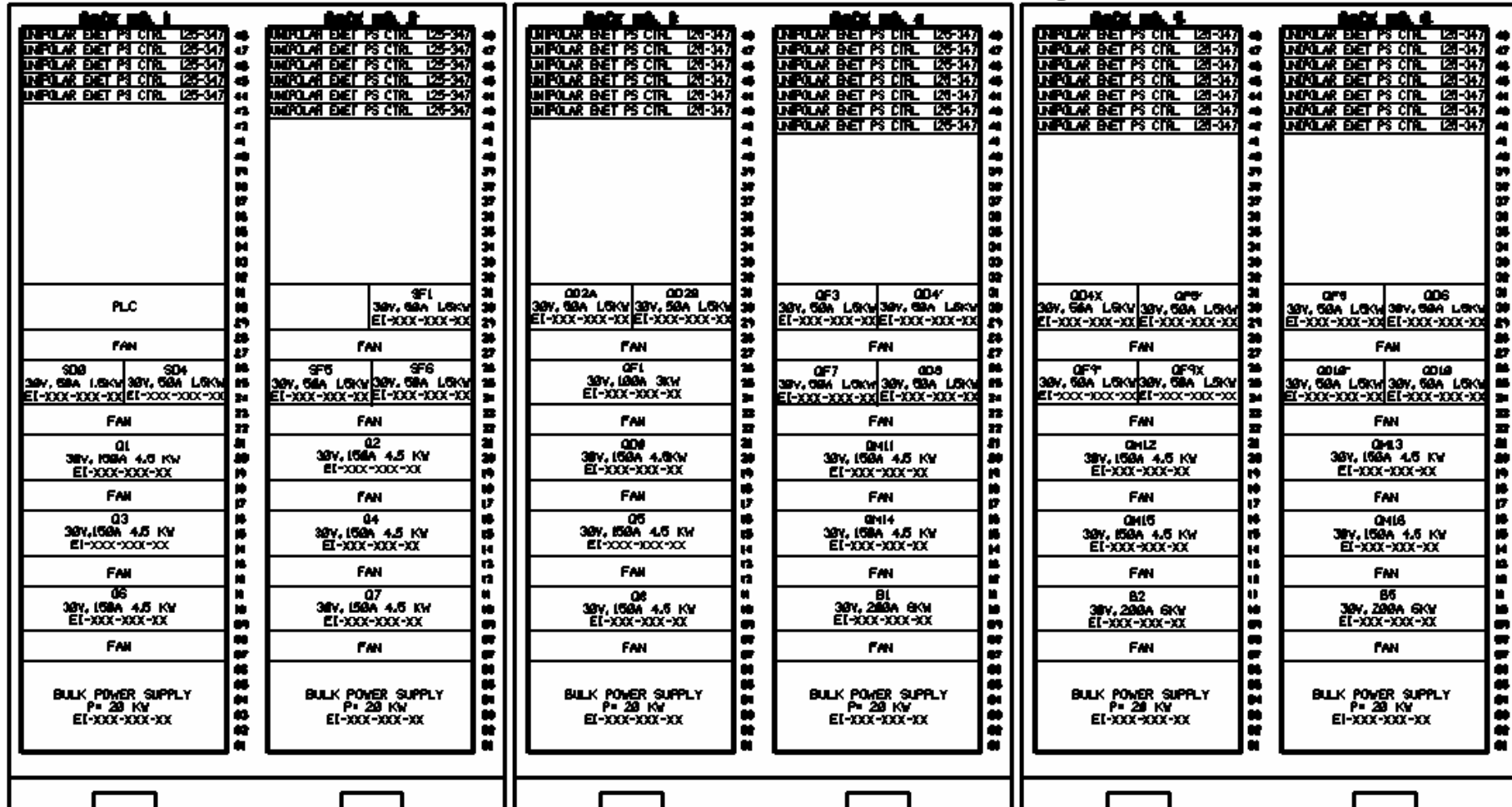
# Power System Diagram



- One Bulk Power Supply per rack
- Multiple Power Supplies per bulk power supply
- One Controller per Power Supply



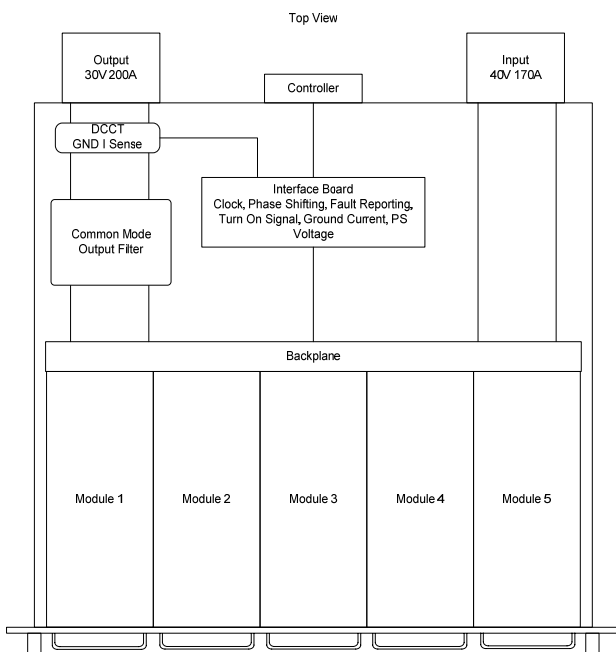
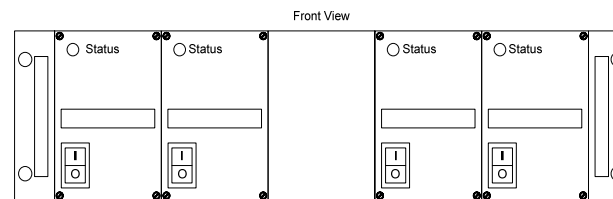
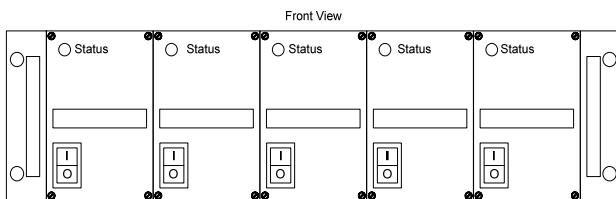
# Power System Diagram



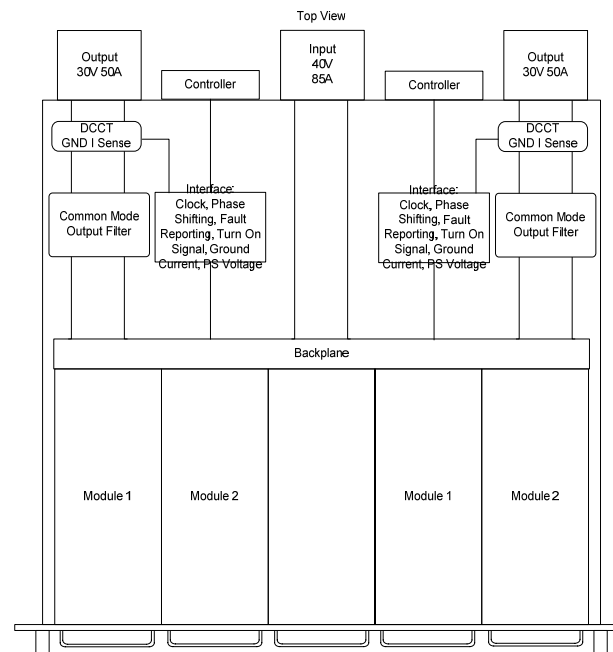
## Rack Profile

3<sup>rd</sup> ATF2 Meeting, KEK  
ATF2 Power Supplies

# Power System Diagrams



Crate with 5 Modules



Crate with 2 Modules



# Vendor Proposals

- OCEM (Italy):
  - Current mode control loop
  - Cost:
- IEPower (Canada):
  - Voltage mode control loop
  - Cost:
- Vektrex (USA)
  - DSP voltage control loop with 24-bit ADCs
  - Cost:

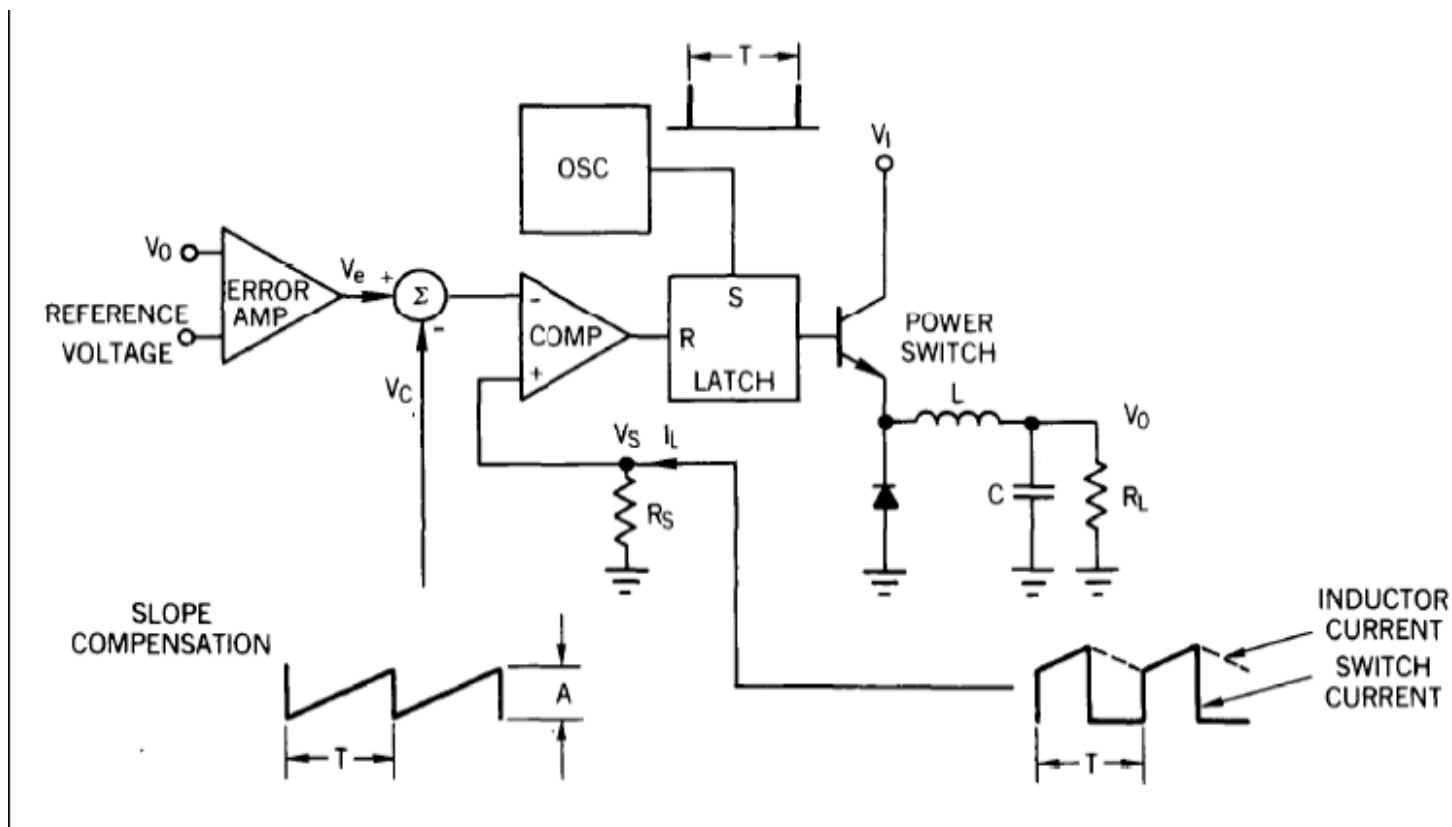




# Awarded Vendor

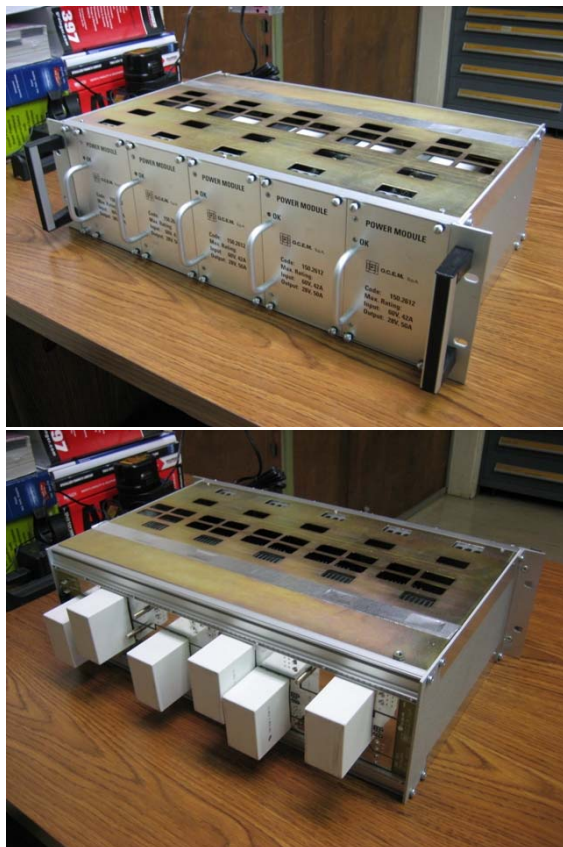
- OCEM
- Prices per power supply
  - Dual 50A:
  - 150A:
  - 200A:
- Prices per spare part
  - Power Module:
  - Crate (Single 100-200A):
  - Crate (Dual 50A):
  - (Crate includes interface board)

# OCEM Proposal

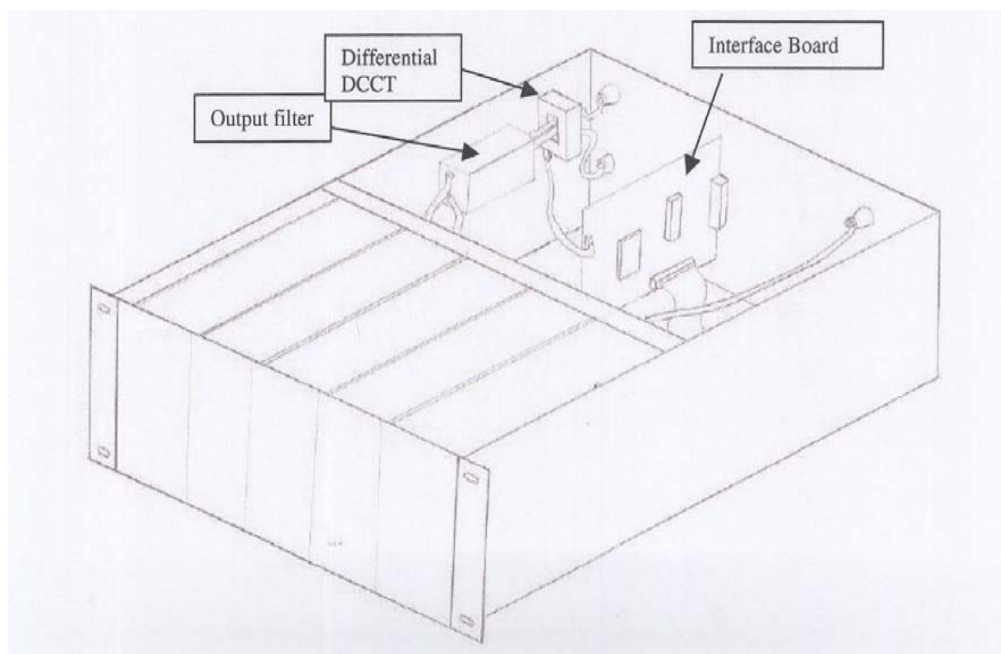


Current Mode Controlled Buck Regulator  
with Slope Compensation

# OCEM Proposal

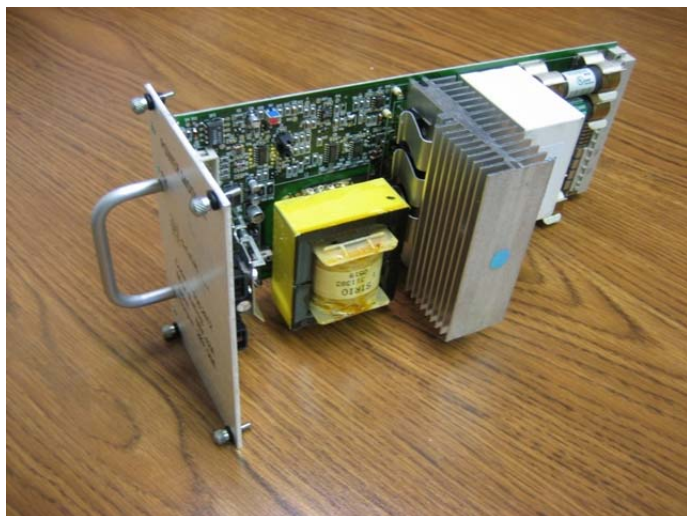


Power Supplies used at Diamond

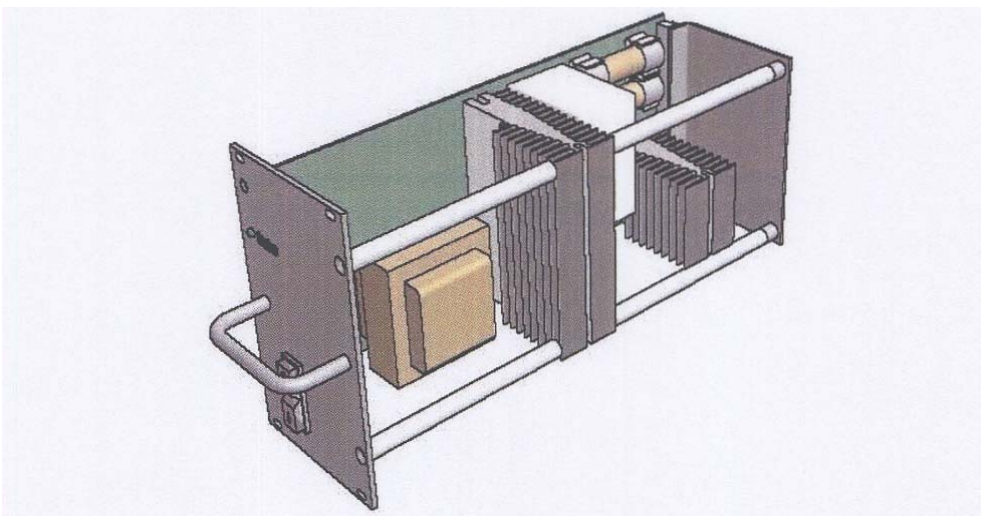


Power Supplies proposed for ATF2  
(from OCEM's proposal)

# OCEM Proposal

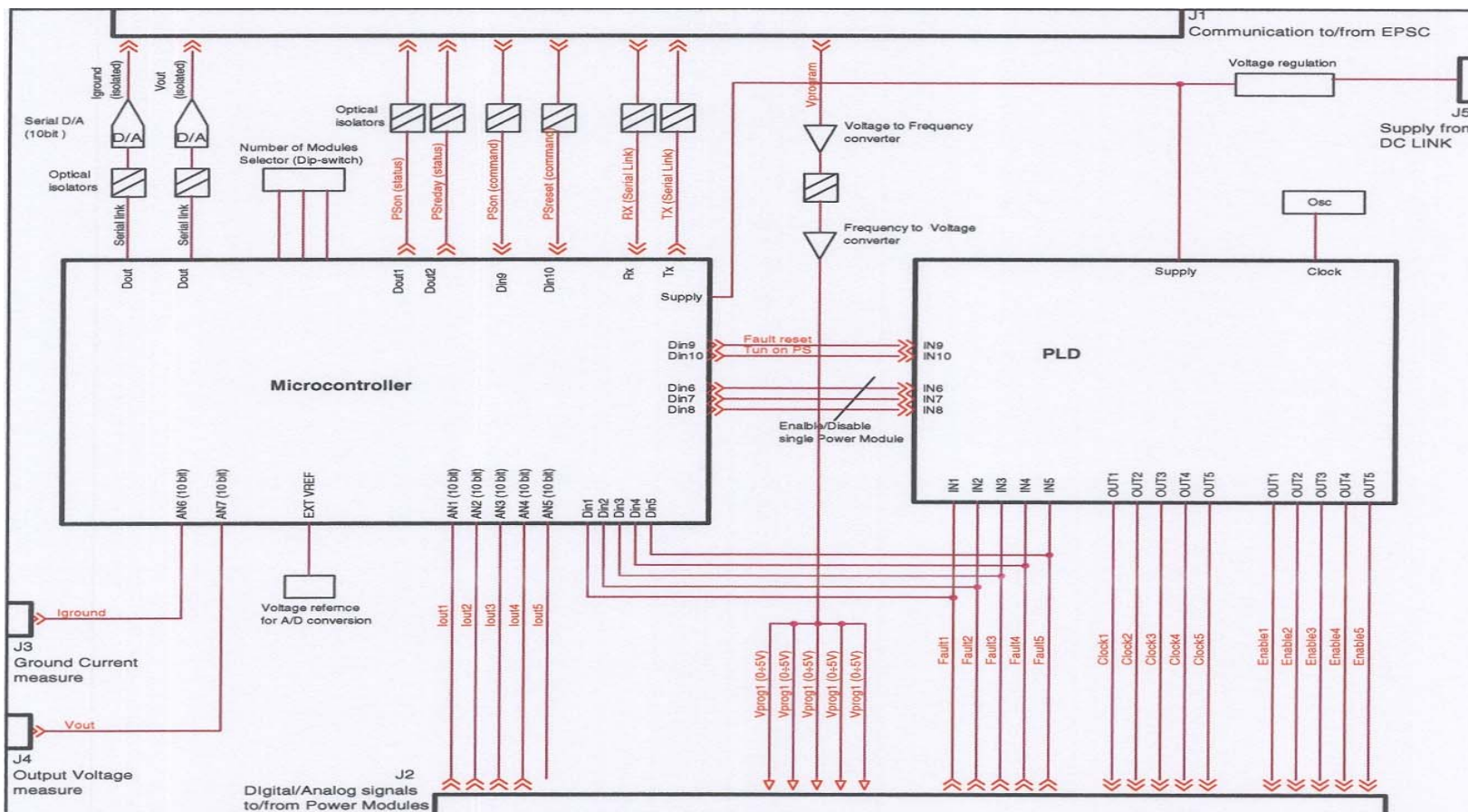


Power Module used in  
Diamond Power Supplies



Power Module proposed for ATF2  
(from OCEM's proposal)

# OCEM Proposal

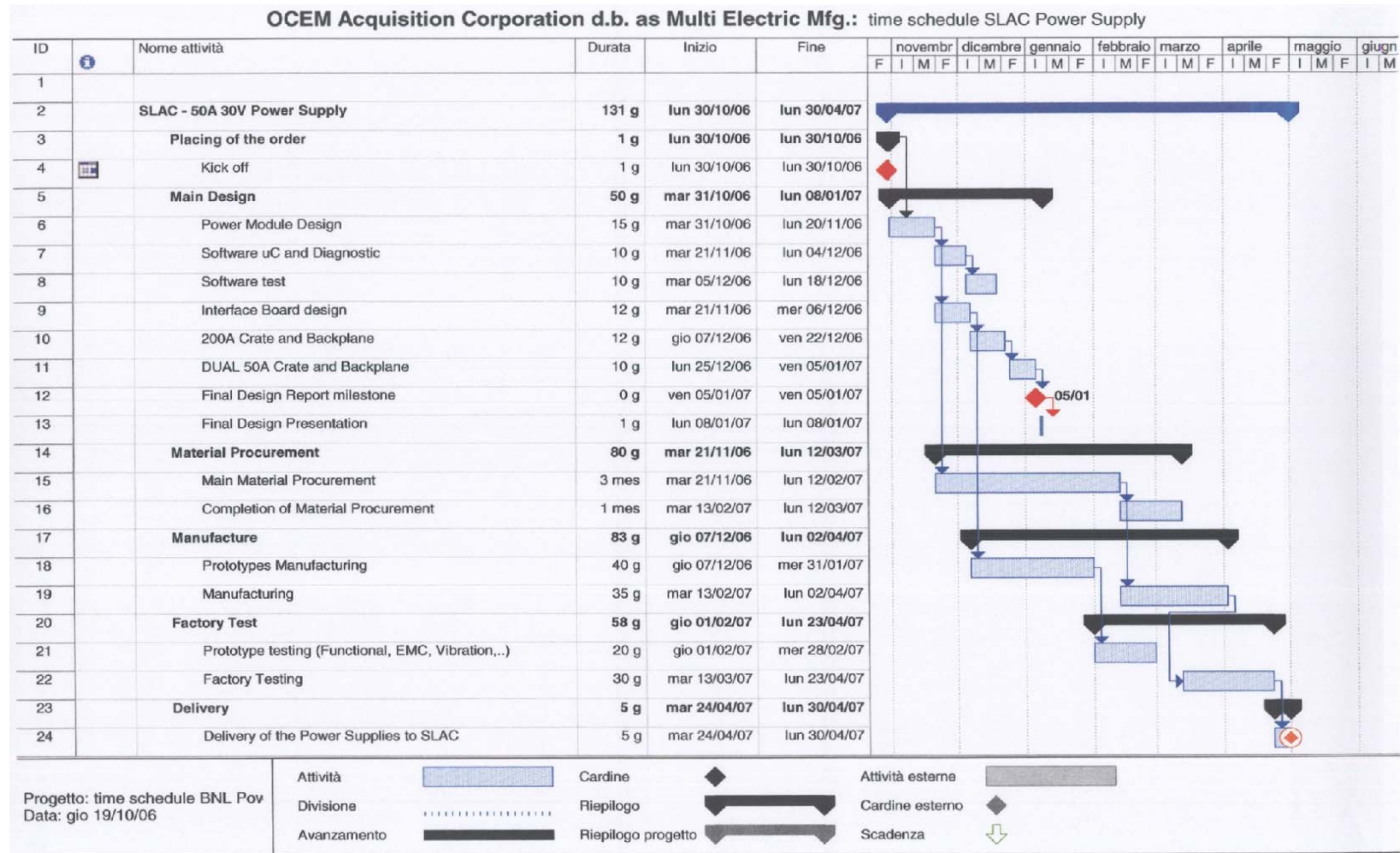


Interface board

3<sup>rd</sup> ATF2 Meeting, KEK  
ATF2 Power Supplies

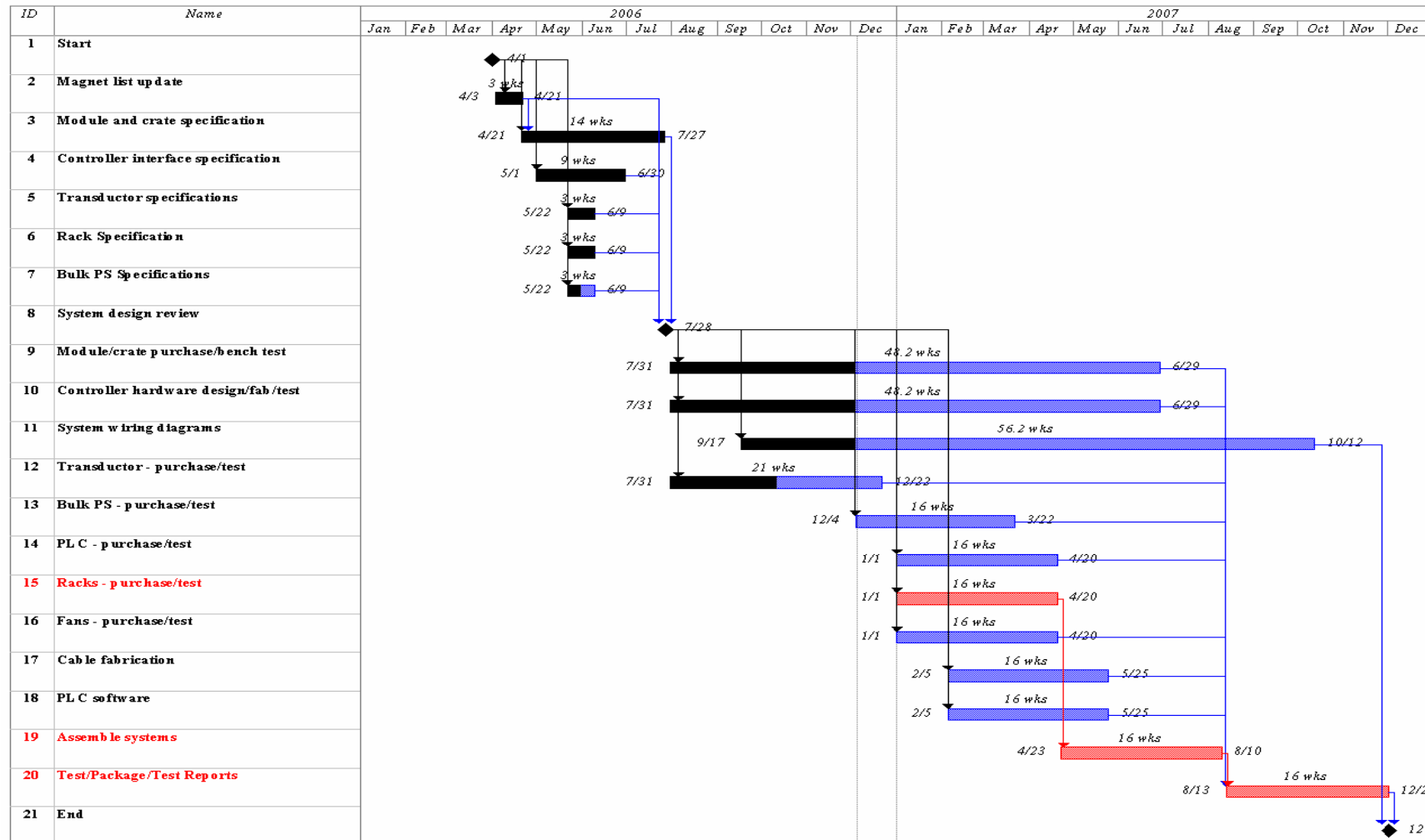


# Vendor Schedule



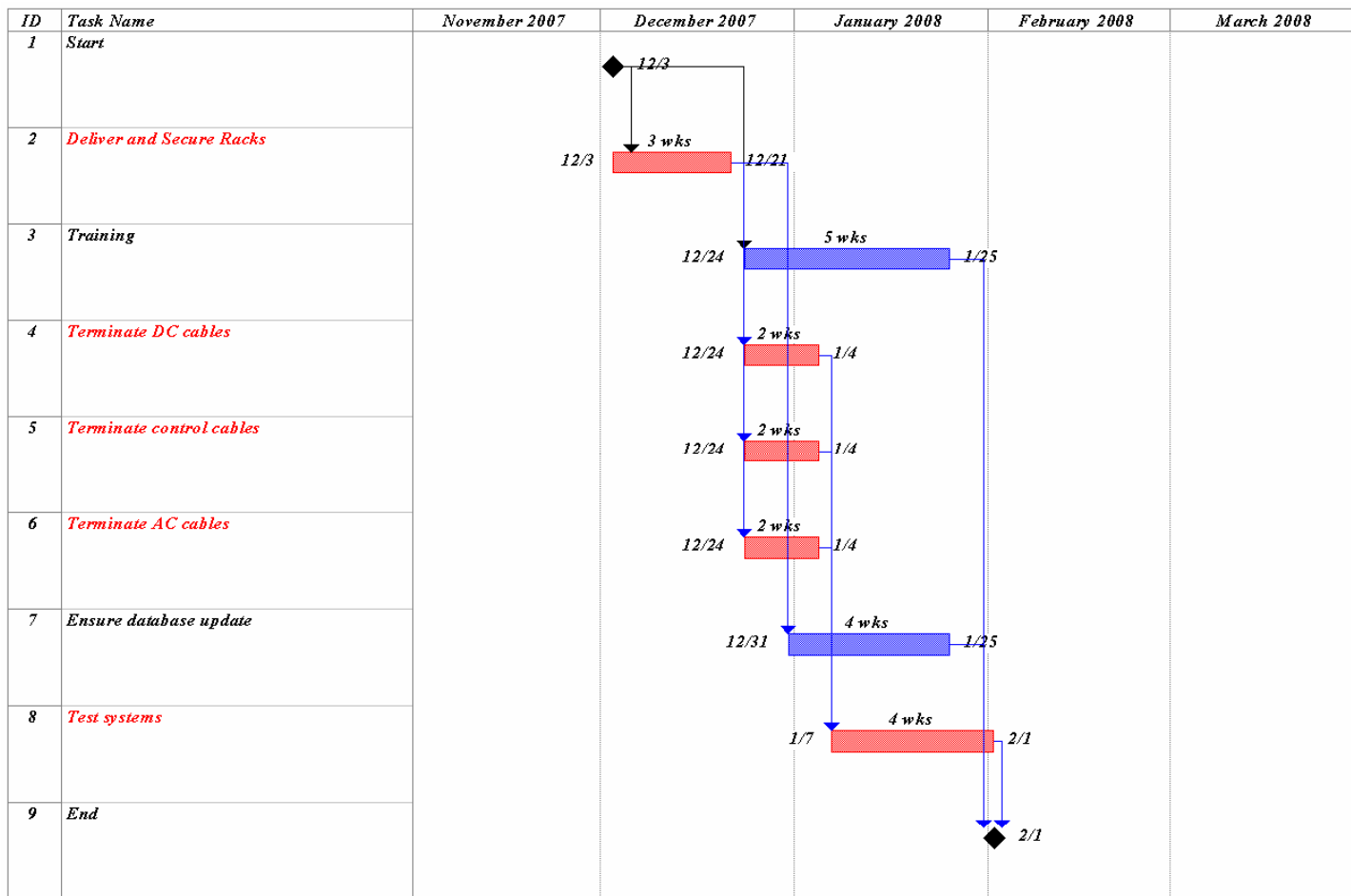


# SLAC Schedule – Delivery





# Schedule - Commissioning







# Schedule

- Immediate tasks:
  - Purchase:
    - Bulk Power Supplies
    - Racks
    - PLC
  - Drawings:
    - Electrical Interconnects within Racks
    - Rack Layout



# Schedule

- Information for KEK Tasks:
  - DC Cable sizes:
    - 2 AWG for 50A Power Supply (~40 mm<sup>2</sup>)
    - 4/0 AWG for all others (~140 mm<sup>2</sup>)
    - Cables are oversized to reduce cable loss and bulk power supply size
  - AC Service
    - 400 VAC, 3 Phase, 100A, 6 total
    - 100 VAC, 1 Phase, 20A, 9 total
- Items Needed from KEK:
  - ATF2 Commissioning Schedule
    - Magnets; AC, DC, and control cables
  - Best time to commission Power Supplies



# Responsibilities

Power supply system	Responsibility
Controllers	SLAC
Bulk Power Supplies	SLAC
Power Supplies (Power Modules)	SLAC
Cooling Fans	SLAC
Racks	SLAC
Intrrack cables	SLAC
Controller Software	SLAC
System Software	KEK
Performance Test	SLAC
Cables	
Input AC cables	KEK
DC cables to magnets	KEK
DC cable raceway system	KEK
Ethernet Cables to Controllers	KEK
Magnet Interlock Cables to Controllers	KEK
Installation	
Wiring and Layout Diagrams	SLAC
Training	SLAC
Cable Termination	SLAC
Testing System	SLAC



# Conclusion

- Ethernet Power Supply Controller
- N+1 High Availability Power Supplies
- Awarded Vendor: OCCEM
- Ready to deliver by: Dec 2007
- Ready to commission by: Feb 2008
- Responsibilities
- Comments or Questions?