THE DC-MAGNET POWER SUPPLIES FOR THE LCLS INJECTOR*

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Abstract

The injector section of the LCLS machine at SLAC [1] requires 100+ dc-magnet power supply systems for operation. Intermediate rack-mounted power supplies provide dipole, quadrupole and solenoid magnet power up to 20 kW at 375 A. A SLAC-developed Ethernet power supply controller interfaces to these commercially available power supplies. Smaller bipolar units rated 6A, 12A, and 30A provide power for small magnets such as correctors, dipoles, and quadrupoles. DACs and ADCs housed in VME crates control these power supplies. For all systems, stability requirements are better than 1000 ppm and EPICS is the controls interface. This paper describes the main hardware characteristics of the power supply systems.

INTRODUCTION

The Power Conversion Department (PCD) [2] at SLAC, in close cooperation with the LCLS Controls group [3], was responsible for defining the major characteristics of the power supply (PS) systems for the LCLS injector: their concept, specification, procurement, installation, and commissioning.

PCD conducted regular reviews throughout the design, fabrication, and installation phases to account for the performance, integration, and safety aspects of each power system.

Successful commissioning of the dc-magnet power supplies occurred in early 2007 [4].

INTERMEDIATE POWER SUPPLIES

Figure 1 shows the power supply's system architecture and Table 1 presents the basic performance requirements.

A 1U, 19-inch rack-mounted Ethernet-based power supply controller (EPSC) provides the precision regulation of magnet current via a closed external current loop. It also monitors power supply's current, voltage, and ground current. It manages the external interlocks, and communicates abnormal conditions to the LCLS control system.

The EPSC provides better then 1-ppm current setting resolution and 50-ppm stability over a 40 °C environment change. It employs a standard analog power supply interface to control standard commercial power supplies of many ratings, types and from different manufacturers.

The control loop of each power supply was adjusted to yield an overall output current regulation bandwidth of 10 Hz. Procedures to adjust this bandwidth are described in [5].

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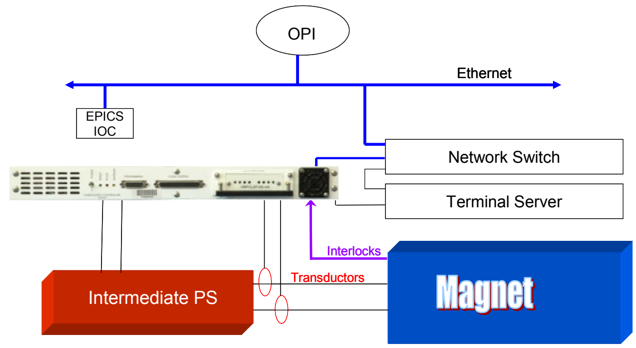

Figure 1: The Intermediate PS Architecture

Table 1: Intermediate PS - Performance Requirements

Output V, I and P	Up to 200 V and 375 A, 10 kW/15 kW rack-mounted PS
Stability versus temp	≤ 2 ppm / °C – 10 to 100%
Short/Long term stability	100 ppm RMS, 1 s / 10 s
BW as V/I source	dc to – 3 dB ≥ 1 kHz / 10Hz
Conducted EMC	FCC, Part 15, Class A
Life / MTBF	≥ 20 years / ≥ 100,000 hrs
Load	0.05 H ≤ L ≤ 1.0 H 0.1 s ≤ L/R ≤ 1.0 s

THE ETHERNET POWER SUPPLY CONTROLLER (EPSC)

The EPSC is a replacement for the PEP II Bitbus PS controller. It is interchangeable with the PEP II chassis, but uses an Ethernet instead of Bitbus protocol [6]. It provides greatly enhanced performance and diagnostics for approximately US$2500 / unit. Table 2 presents the main performance characteristics of the EPSC, and figure 3 its internal structure.

The main features of the EPSC are:

- Daughter boards for magnet dependant configuration
- Support for redundant transductor
- Hardware protection, latching and reporting of all system faults by FPGA
- Ramping of power supply output current

Table 2: EPSC Performance Characteristics

Parameter	
DAC resolution	24 bits
DAC noise (0.1 to 10 Hz)	2 μVrms
DAC Linearity 0-10V	2 ppm max
ADC effective # of bits	20 bits
ADC readings per second	60
ADC noise (0.1 to 10 Hz)	3 μVrms
ADC temp stability max	0.25 ppm / °C max

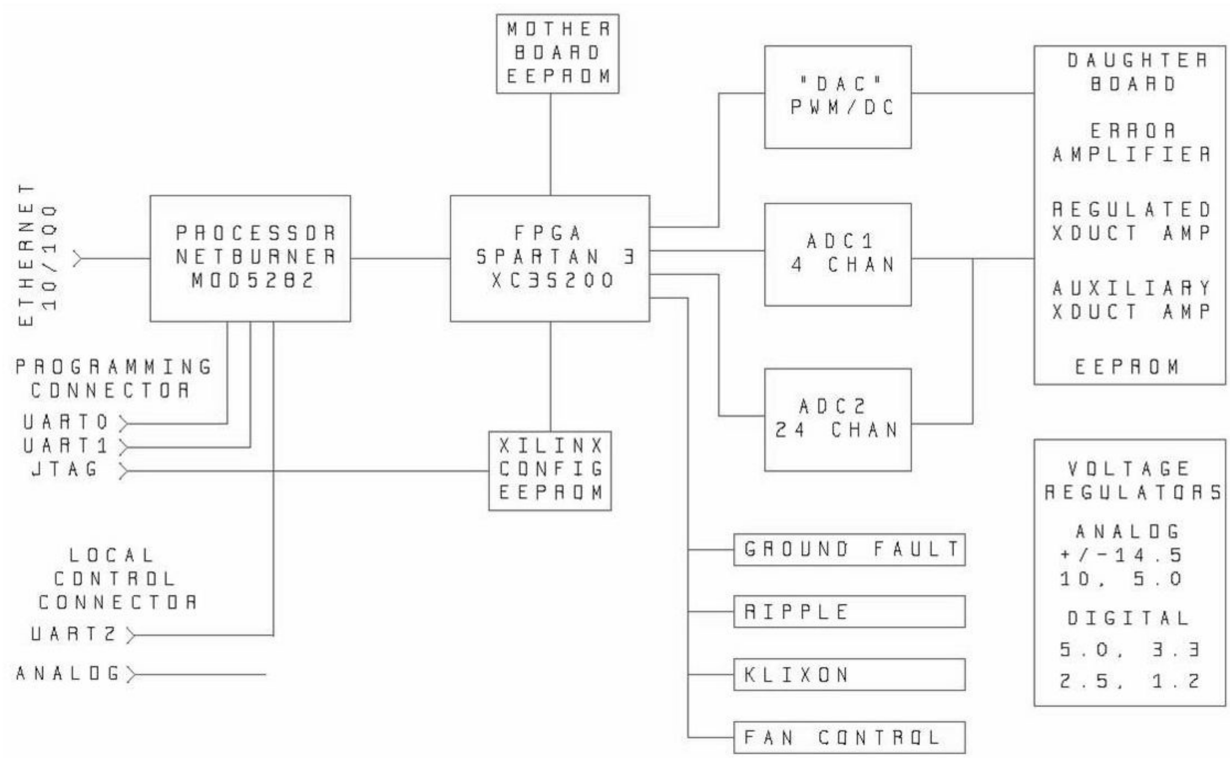

Figure 2: internal structure of the EPSC

CORRECTOR POWER SUPPLIES

Figure 3 shows the general power system configuration for the smaller bipolar systems and Table 3 shows the performance requirements.

A programmable logic controller (PLC) controls and monitors the operation of the bulk power supplies. The PLC is EPICS-compatible. It provides remote turn-on and turn-off capability, and monitors the output voltages and currents of the three bulk power supplies. It also detects ground current flow.

A single Eurocard crate accommodates up to 16 bipolar power modules (MCOR) of different ratings [7]. A single bulk PS rated 60V and 165A provides regulated voltage to two crates.

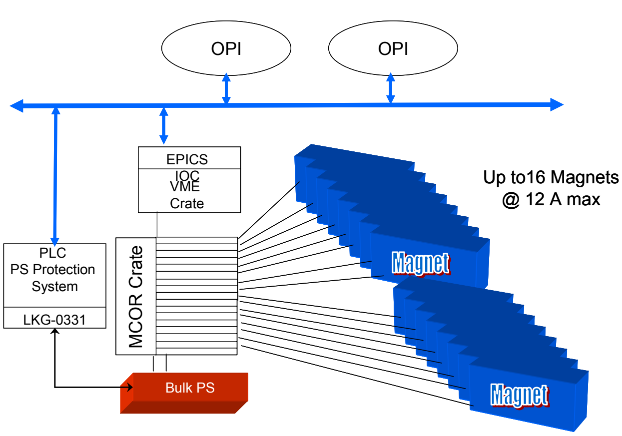

Figure 3: Bulk PS System Architecture - Magnets < 30A

Table 3: Corrector PS uses and requirements

Ratings	40V, 6A or 40V, 12A or 40V, 30A
Uses	Power 6 A, 12 A, and 30 A correctors, small quadrupoles, and trim magnets that require unipolar or bipolar current
Stability versus temp	≤ 13 ppm / °C, 10 to 100%
Short term stability	30 ppm RMS, 1 s
Long term stability	400 ppm RMS, 10 s at 30 °C
Ambient	4 °C to 45 °C
Bandwidth as I source	dc to – 3dB ≥ 10Hz
Load	$0.05\ H \leq L \leq 1.0\ H$ $0.1\ s \leq L/R \leq 1.0\ s$

SAFETY

The Power Conversion Department held regular safety and project review meetings throughout the program. An Electrical Equipment Inspection Program (EEIP) at SLAC maximized the use of nationally recognized testing laboratory (NRTL) listed components and ensured the equipment satisfies the NEC and OSHA safety codes [8].

Power supply to magnet power cables are flexible stranding, low smoke, zero halogen, construction suitable for cable tray and accelerator housing use. Cable ampacities conform to the 2005 NEC, Tables 310-16 and 310-17. Cable tray fill conforms to NEC Article 392.

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