DIGITAL CONTROL INTERFACE FOR BIPOLAR CORRECTOR POWER SUPPLIES FOR LCLS

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Abstract

We detail the development, testing and commissioning of a single-board digital interface for modular bipolar corrector magnet power supplies to be installed at the Linac Coherent Light Source (LCLS) at the Stanford Linear Accelerator (SLAC). The sixteen-channel VME-form-factor board replaces the passive control-interface board in the MCOR (Magnet Corrector) Chassis. The board is a self-contained system with both serial and Ethernet connectivity intended for use with an EPICS accelerator control system IOC, however, the ASCII protocol allows generic computer control. The interface card contains 16 independent ADC and DAC channels, each with 16 bits of resolution. Additionally, the interlock, fault, reset and digital control lines are remotely controllable via either the serial or Ethernet connections. The design has been planned so that a mini-IOC can be included on board for direct Channel Access connectivity.

INTRODUCTION

The MCOR (Magnet Corrector) Series is a multi-channel corrector magnet driver system, capable of providing precision bi-polar output currents with minimal zero-crossover distortion. The MCOR design employs a modular architecture, consisting of a rack-mounted crate, with standardized slots for removable power modules, crate controller and diagnostics. A single, unregulated bulk power supply provides the main DC power for the entire crate. The MCOR power module is responsible for converting the unregulated DC bulk power into a precision bi-polar current source suitable for driving corrector magnets and beam line devices. The power modules are controlled using +10 to –10V FS analog command signals sent over the backplane from the control system. There are two types of available MCOR power modules: The MCOR12 (12A FS) and the MCOR30 (30A FS). [1]

The MCOR30 uses a custom H-bridge configuration, operating in an overlapping volt-seconds feedback mode instead of a straight voltage mode to achieve a higher control bandwidth. The transfer function of input command voltage to output current is determined by resistor values on the programming (PGM) card. Each power module provides two independent measurements of its output current; one that closes the regulation loop, and another that returns an independent monitoring signal to the control system. Both of these independent current measurements are available to the control card for diagnostic purposes. [1]

The MCOR12 uses a commercial switch mode servo driver (The AMC 30A8) operating in a voltage feedback mode to regulate the output current. The MCOR 12 system as the name suggests is a 16-channel precision magnet driver, capable of providing bipolar output currents in the range from –12A to +12A. The output current can be adjusted smoothly through zero. [1]

The MCOR 12 employs a modular architecture, so that any individual channel is serviceable without disturbing the operation of adjacent channels in the same crate. This feature significantly improves the overall availability of the accelerator, since in most cases the beam lattice can tolerate the loss of a single corrector and continue to operate, but could not handle the loss of an entire crate of correctors during the repair effort. [1]

Figure 1: MCOR-12 module.

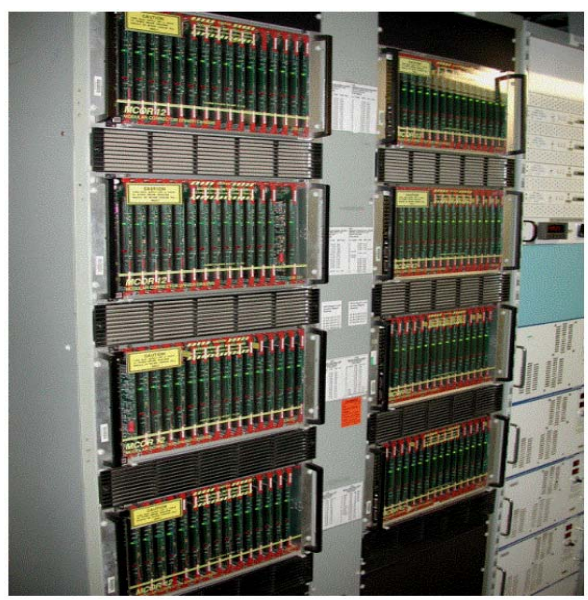

Figure 2: A typical MCOR installation

SYSTEM REQUIREMENT

The present MCOR 12 and 30 corrector chassis must interface with two fundamentally different types of control systems DAC/SAM and Bitbus. This implies using an additional VME based chassis with DAC and VSAMs *(VME Smart Analog Monitor)* for the control and monitor of the MCOR 12 and 30 cards. This scheme takes a lot of real estate and is very expensive. We propose to replace this scheme, by replacing the passive interface card inside the current MCOR chassis with a digital interface card with Ethernet and RS232 connectivity.

The set point and the monitoring requirements for the MCOR corrector system are as follows:

Required data update frequency 4 kHz [2]

Analog Setpoint Requirements
Full scale voltage range ± 10 V
Bandwidth DC - 2 kHz
Accuracy ± 10 mV
Stability (24 hours, ± 3.5 °C) ± 500 μV [2]

Analog Readback Requirements
Full scale voltage range ± 10 V
Bandwidth DC - 2 kHz
Signal to Noise Ratio integrated over 1 Hz - 200 Hz
101 dB or 16.6 ENOB
Accuracy ± 1 mV [2]

Based on the above requirements the MCOR Digital Interface will have the following elements.

1) Ethernet connectivity using Lantronix XPort / RS-232 connectivity
2) 8 bit Microcontroller running at 20Mhz
3) 16 independent channels of 16 Bit Bipolar DACs with Readback to control the MCOR cards
4) 16 channels of 16 Bit 100ksps Differential Bipolar ADCs to monitor the current.
5) Interlocks reset and GND fault lines which can be monitored and controlled.
6) Power Management circuitry.
7) Control and Monitor software written in Labview from National Instruments.

SYSTEM ARCHITECTURE

The MCOR Digital Interface has an embedded Ethernet device server on board to provide Ethernet connectivity. It is a compact RJ45 package with a DSTni-EX 186 controller from Lantronix. It also has 512 kb of flash memory, 10/100 Ethernet transceiver and a high speed serial port. To enable access to a local network or the internet, the XPort integrates a fully developed TCP/IP network and OS inside it. The XPort also includes an embedded web server used to remotely configure, monitor or troubleshoot the attached device. It uses 256kB of RAM to store the web pages and firmware and can easily be password protected, to give limited accessibility to the operators.

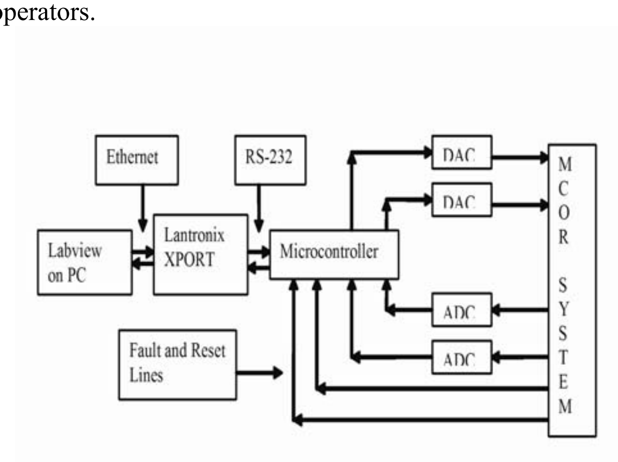

Figure 3: MCOR Digital Interface Block Diagram

The boards also have a CMOS FLASH-based 8-bit microcontroller chip from Microchip™ running at 20 MHz which acts as a slave, and assists in controlling and monitoring the feedback voltage that is proportional to the output current. The microcontroller features 256 bytes of EEPROM data memory, self programming, a Universal Asynchronous Receiver Transmitter (USART) and a synchronous serial port which can be configured as either 3-wire Serial Peripheral Interface (SPI™) or the 2-wire Inter-Integrated Circuit (I^2C™) bus. The microcontroller can be interfaced to the DAC and ADC's using SPI bus protocol. The DACs are used to set the analog reference voltage from -10V to +10V range, whereas the ADC reads back a voltage proportional to the input current. The DAC used on this board is from Linear Technology and is a 16 bit bipolar chip with 1 LSB INL and DNL over the operating temperature range of 0 degrees C to 70 degrees C. The output drive current is about 5mA which is enough to drive the first stage of the MCOR board without any loading effects. The board also features a separate precision voltage reference for the DAC.

The ADC from Linear Technology has eight channels with sampling rate of 100ksps. They can be configured to be either single ended or differential in nature with 16 bits of resolution. The inputs to the ADCs are over voltage protected to +/- 25V. Since the input impedance is 31K ohms, it is driven by a low impedance source. Any wideband noise coupling is minimized by placing a 3000pF capacitor at the input of the ADC. Special care has been taken while laying out the PCB to minimize any noise coupling on the input channels. The microcontroller also has a large number of generic I/O channels, which can be used for monitoring system interlocks, ground fault detection and other fault conditions within the system.

The digital interface card will occupy the left most slot in the MCOR system crate and is powered by the crate power supply.

The board can be controlled using either generic Rs-232 commands or over the Ethernet as the user desires. This makes the board compatible to the EPICS IOC as an EPICS IOC can be embedded on a Motorola Freescale Cold Fire processor which runs at 64Mhz. and supports 10/100 Mb/s Ethernet and 3 serial ports.

To control the interface cards, LabVIEW from National Instruments™ was chosen because of its easy to understand graphical interface controls. LabVIEW also provides a deterministic, real time performance along with LabVIEW Real Time for data acquisition and control. LabVIEW can be readily deployed and the cards can easily be controlled and monitored over Ethernet. LabVIEW can also have the added advantage that it can be interfaced to EPICS using the concept of Shared Memory interface. Data acquired and processed by LabVIEW is available to the IOC to communicate to an EPICS based control system. LabVIEW and the IOC can also send interrupt/signals to notify each other that data is available. The channel access client for LabView supports the use of LabVIEW as a display environment. [3]

APPLICATIONS

The MCOR system can be used in a variety of applications like the Particle Accelerator beams for high energy physics experiments, industrial robotics, medical applications and other motor control systems. The Digital interface card based on Ethernet connectivity allows the operation of these large power supplies to be possible from anywhere in the world.

REFERENCES

[1] G.E. Leyh, et. al. .A Multi-Channel Corrector Magnet Controller,. PAC 95 and IUPAP, Dallas, Texas, 1-5 May 1995

[2] Evgeny Medvedko, Jeff Olsen, Greg Leyh, Stephen Smith, Robert Hettel, Clemens Wermelskirchen, Till Straumann. High resolution Analog/Digital Power Supply Controller, Proceedings of the 2003 Particle Accelerator Conference.

[3] Active Media: http://neutrons.ornl.gov/diagnostics/documents/epics/LabVIEW/SNS_LabVIEWEPICS.html