

AN EMBEDDED POWER SUPPLY CONTROLLER

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Abstract

Several different models of high current power supplies are used to test accelerator magnets at the Fermilab's Development and Test Department (D&TD). Department-wide standardization of current control and monitoring has been achieved by embedding a proprietary intelligent device into each of these power supplies. The device is based on a highly integrated Intel 87C196 microcontroller that is used to control and monitor current, collect status information, issue control signals and communicate with a host computer. The controller interfaces with a power supply via onboard high precision ADC and DAC converters, and digital I/O registers. Some of the advanced features of the system include: downloading and interpreting of complex ramp profiles, built-in parabolic waveform approximation, external triggering, and fiber-optic communication media. Network access is enabled by an extensive set of UNIX tools such as GUI, ramp profile simulator, API library, and shell programming tools.

1 POWER SUPPLIES FOR ACCELERATOR MAGNETIC SYSTEMS

Modern particle accelerators employ a large number of high current power supplies to drive their magneto-optical systems. These supplies are capable of achieving thousands of Amps of current and maintaining it with the accuracy of better than 100 ppm. Accelerator physics as well as the inductive nature of the load dictate sophisticated waveforms of the magnet current. In contrast, most of the supplies, that come from the factory, are equipped with a minimal interface; it is usually comprised of an input for the analog reference signal and a digital I/O to transmit status and to accept control signals. As a result, an external control system is required to make a power supply usable in a fully automated environment.

2 D&TD POWER SYSTEMS

High current power supplies have been always an integral part of the Development and Test Department magnet test facility. They are used for both conventional and superconducting magnet tests.

2.1 Former Systems

In 1994 two different power control systems coexisted at the Fermilab's Development and Test Department. One of them was based on a VAX computer and used the CAMAC interface, whereas the other was a UNIX-based system and used the VXI interface. The VAX-based system was about to become extinct and UNIX system had severe drawbacks:

- The system did not allow users to generate controllable ramps because of the non-deterministic characteristics of the Unix system.
- The system did not provide sufficient means for automatic/remote control of power supply and for logging the current and power supply histories.
- The long analog cable runs deteriorated the signal quality in the industrial environment.
- Multiple analog and digital cables between the power supply and the measurement system created ground loops.
- User interfaces were not adequate.
- The information about a power supply status or cause of exception was not available via computer interface.

2.2 New System Design

The new Fermilab Development and Test Department control system [1] was designed to overcome the above mentioned drawbacks and to provide a uniform interface for every power supply in service. This standardization was achieved via encapsulation of the control functions into an intelligent controller that is embedded into each power supply. The controller is accessed by conventional methods from the host computer through a serial interface. Server software that is running on the host computer, fans out the connection to the multiple local and remote clients.

2.3 Hardware

The controller module consists of several subsystems (Fig.1):

- 87C196KR processor with integrated peripherals, 64 kBytes of external FLASH ROM, 64 kBytes of external SRAM.
- High precision isolated 16 bit DAC used for the ramp profile generation.

Operated by the Universities Research Association under contract with the U.S. Department of Energy

- High precision isolated 24 bit ADC for digitizing the power supply current.
- Digital I/O with 32 input and 16 output lines for status readout and application of the control.
- Input and output external trigger lines for synchronization of the external measurement system with the current profile.
- Fiber-optic interface for communication with the host computer.

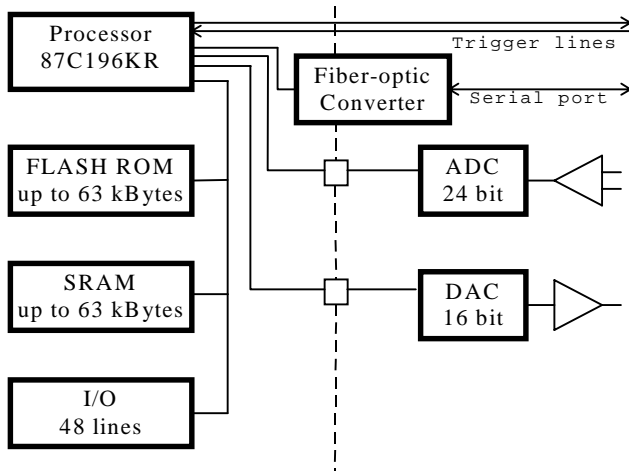


Figure 1 Controller Block-Diagram

The 87C196KR [2] is a 16-bit microcontroller designed especially for the high speed event control. Its primary components include a CPU, several types of memory, six I/O ports, two timers, A/D converter, two serial I/O devices and an event processor array.

Special care was taken to eliminate the possibility of ground loops and to preserve the integrity of the analog signals. This was achieved by taking the following measures: the controller communicates with the external world via a fiber-optic link, the ADC and DAC are isolated by means of separate DC/DC converters and the ADC has a balanced differential input.

Both the DAC and the ADC use external high precision references that exhibit an extremely low temperature drift of only 0.6 ppm/C.

AD7710 ADC [3] employs a sigma-delta conversion technique to realize up to 24 bits of no missing code performance, and an integration time of one power line cycle has been programmed for improved noise rejection. The ADC is used in a background calibration mode that removes both zero scale and full-scale errors while still allowing for 10 samples/s acquisition rate.

2.4 Firmware

Firmware consists of a simple monitor and power supply controller code. The monitor is used primarily for debugging and offers the capability to view/modify

memory locations, and to download user code into SRAM and execute it.

C language and the compiler from BSO Tasking [4] was used to implement the most part of the firmware.

A proprietary serial protocol was developed for the reliable communication with the host computer over a serial line.

The controller recognizes a set of 28 commands including, among others, downloading and executing complicated profile tables and storing and retrieving of up to 1024 ADC readings. A typical profile table consists of a number of segments, where the segment may be one of the following types:

- Parabolic ramp segment described by the destination current, initial ramp rate and acceleration.
- Hold segment which allows the controller to wait for the software or hardware trigger.
- Wait segment (delay).
- Unconditional jump segment for the jumps inside the profile table.
- Repeat segment for organizing the loops.
- Trigger segment used to issue a synchronization signal for the external recipient.

The ADC buffer is set up as a FIFO and may be controlled by the host computer or via the profile table. For example, ramping to a specific current, taking a requested number of measurements and disabling the FIFO for further readout.

In addition, software readable id provides a means of identification of the controller/supply system, which enables the application of the appropriate calibration constants and constraints.

2.5 Software

An extensive set of the software components has been developed to provide a convenient and easy to use interface to the power supply control system. It consists of the following elements:

- A server that may run under the Unix or VxWorks [4] operating system.
- A GUI that provides easy access to all main features of the power supply control system.
- A simulator for developing and debugging profile tables on a Unix workstation without actually running a power supply.
- A simple trace client for archiving ADC data.
- An API comprised of a reach set of functions that give the user application full control over the power supply.
- Shell programming tools that allow the user to write standard Unix scripts and to access the main controller features without the need for C programming.

SUMMARY

The power supply control system has been deployed in all T&DD test stands and has proved to be a reliable and full-featured system with a user-friendly interface. It has been successfully used in our cryogenic and conventional test stands being fully capable of generating precision ramps ranging from a fraction of an Amp/s up to 18000 Amps/s. In addition, adopting a parabolic form of the ramp segments was invaluable for improving of the transient response of the SCR-based high current supplies.

REFERENCES

- [1] 'An Open Distributed Monitoring and Control System', J.M.Nogiec, E.Desavouret, J.Pachnik, S.Sharonov, J.Sim, Proceedings of CHEP'97, April 1997, Berlin
- [2] '8XC196KR Users Manual', Intel Corporation
- [3] '1994 Design-In Reference Manual', Analog Devices, Inc., 1994
- [4] '80C196 C Compiler User's Guide', Boston Systems Office Tasking
- [5] 'VxWorks Programmer's Guide 5.2', Wind River Systems, Inc., 1995