Power Supply Control for the Spallation Neutron Source*

R.F. Lambiase, B. Oerter, J. Smith, BNL, Upton, NY

Abstract

Brookhaven National Laboratory is currently constructing an accumulator ring as part of a six laboratory collaboration to build the Spallation Neutron Source (SNS) that will be located in Oak Ridge, Tennessee. Control of the power supplies will be implemented using a simple integrated system that provides all functions (setpoint, readback, control and status) with a single board at the power converter. Communication between the power supply interface and the VME control card is through a pair of fibers that also provides electrical isolation. This paper describes the power supply control system and it's impact on the SNS.

1 THE BASIC SYSTEM

In simplest terms, the power supply control scheme consists of two boxes separated by a pair of optical fibers.

On the power supply side, the box is called the Power Supply Interface (PSI). Each power supply has it's own PSI. This single box provides all the analog and digital data paths that the supply requires.

On the control side, the box is called the Power Supply Controller (PSC). The PSC can control up to six PSIs. It resides in the VME control crate, where it communicates to the controls computer and event timer.

2 REQUIREMENTS AND FEATURES

2.1 Project Requirements

While a low cost, easy to use power supply interface is always a design goal, the project requirements of SNS made this even important.

Power conversion equipment will be specified at BNL, built at a vendor's facility, and shipped directly to the SNS site at ORNL, where their technical staff will install it. This installation and commissioning must be done easily, and with minimum oversight by BNL staff.

2.2 System Features

Power supply control for SNS was conceived with design features in three categories – performance, vendor integration, and system integration.

This interface provides all the performance features required for both operations and diagnostics.

- Timed readings and setpoints – While the power supplies are set to a DC level, noise, ripple, and line disturbances are not DC. It is important to know what the value of the current is during the time the beam is present in the magnetic field.
- Burst mode – Data is normally sampled at a 60 Hz rate. But, to discern higher frequencies, this can be increased to as much as 10KHz.
- Circular buffer – Each channel will have a circular buffer, that provides historical information leading up to a fault event.
- Independent operation for testing – Total remote control is possible, even if the global control system is down.

Keeping the interface simple for the vendor to integrate reduces the cost of the power supplies, and can yield more responses to request for proposals. The vendor interface features are:

- No isolation circuitry required - The fibers and the PSI power supplies provide all the isolation that is required. That eliminates the need for the vendors to build in circuitry with both digital isolation and analog isolation.
- No need to provide external power – When packaged in the 1U chassis, the PSI has it's own power.
- All the equipment needed to test the system interface will be provided by BNL.

System integration is a combination of installation and commissioning. The features that make system integration simpler are:

- There are no compatibility surprises – The supply is integrated with the control system before the unit is shipped from the vendor. Even wiring mistakes will be eliminated.
- Installation is very simple – The unit is plugged into an AC outlet, a single cable connects it to the

*Work performed under DOE contract DE-AC02-98C10886

power supply, and a pair of fibers connect it to the PSC.

- Software conflicts and version mismatches between PLC software, software drivers, and other control software are eliminated.
- The unit does not require the control system to be available to test the power supply remotely.

3 SYSTEM HARDWARE

3.1 The Power Supply Controller

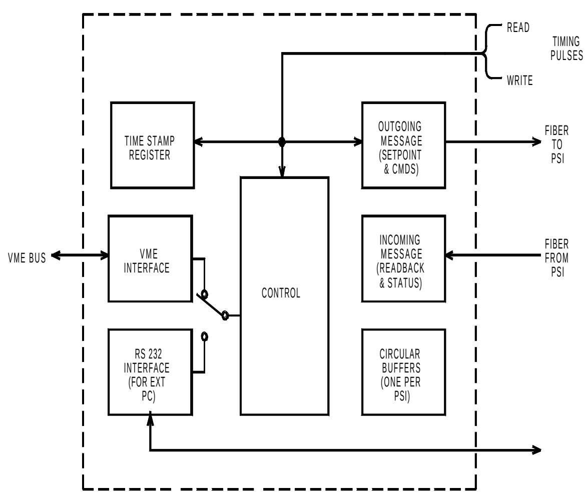

Figure 1: The Power Supply Controller (PSC)

A block diagram of the Power Supply Controller is shown in Figure 1. Each PSC can control up to six Power Supply Interface units.

This board will normally reside in a VME crate along with the front end computer and other control elements. Data and commands are sent over the VME bus. But, the PSC can be switched to accept data and commands from a front panel RS-232 connector. Other than the source of such information, the VME and RS-232 interfaces have identical functionality.

An outgoing message can be initiated either by the VME bus or by the external read or write pulses. For SNS, the external pulses are used, and they are generated from event decoders. The outgoing message is a single data frame.

There are two major modes of operation of the PSC. In the normal mode, each timing pulse from the event link initiates one data gathering cycle: sending data out to the PSI and getting data back into the PSC. This will typically be done at a 60Hz rate, and be synchronous with the beam.

A second mode, called the burst mode, is used to gather data with finer time resolution. Here, a single pulse from the event timer triggers a burst of data gathering cycles. The number and frequency of these cycles would be programmable by the front end computer (FEC).

The burst mode can reveal synchronous information that happens at a rate faster than the 60 Hz beam rate. It can show the ripple of power supply. A twelve pulse converter, for example, would have a fundamental frequency of 720 Hz.

3.2 The Power Supply Interface

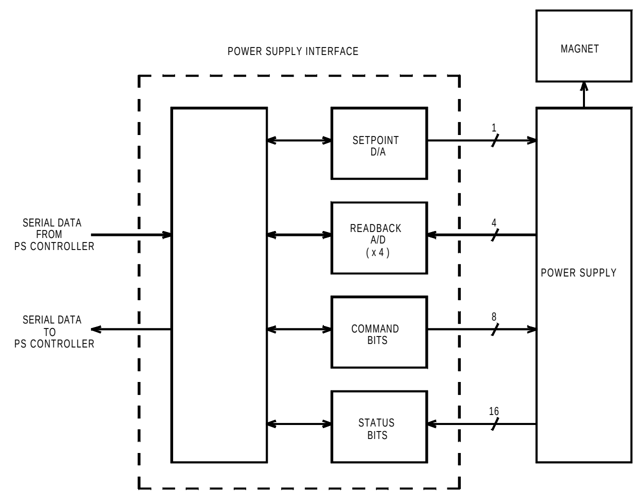

Figure 2: The Power Supply Interface (PSI)

A block diagram of the Power Supply Interface is shown in Figure 2. A single PSI only controls a single power supply. This allows the electronic signals to be at the power supply potential, with all isolation being provided by the fibers. This eliminates opto-isolators and isolation amplifiers.

The PSI has one 16-bit D/A converter, which is used to establish the current setpoint, and four A/D converters:

- Setpoint wrap-around
- Measured current
- Measured voltage
- Amplified (x 50) current loop error

Four separate A/D converters are used in place of one A/D and a multiplexing switch for two reasons. First, it eliminates switching transients, and second, it increases the time available to perform the conversions. This allows for economical 16-bit conversions with an overall maximum speed of 10KHz for the PSI data rate.

Up to eight digital command bits can be sent to the power supply, although typical units will not require that many. Up to sixteen digital status bits can be received from the power supply.

3.3 Fiber Optics

Communications between the PSC and PSI are via 62.5 micron multimode fiber, operating at 1300nm, and terminated with duplex SC connectors.

The data is encoded on a 5 MHz carrier using a self clocking bi-phase mark encoding scheme. The carrier is continuous.

4 MESSAGE TYPES

Messages between the PSI and PSC consist of one or more frames. Each frame has a start bit, ID, Data, CRC and end bits.

4.1 Messages from PSC to PSI

Messages from the PSC to the PSI will be one frame. There are three types of messages that can be sent from the PSC to the PCI.

- A write command that sends a setpoint.
- A write command that sends command bits.
- A read request.

Each message has an ID field which identifies the message type.

4.2 Messages from the PSI to the PSC

The PSI sends a reply to the PSC after it receives a message from the PSC. In response to a command read request, the PSI returns three frames:

- An echo of the received data.
- Digital Setpoint (prior to the DAC)
- Digital Command

In response to a status/ADC reading, the PSI will return six frames:

- An echo of the received data
- Digital Status
- ADC 1 (Typically, analog setpoint)
- ADC 2 (Typically, analog measured current)
- ADC 3 (Typically, analog measured voltage)
- ADC 4 (Typically, analog measured voltage)

In response to a write request, only one frame is returned – the echo of the received data.

Each frame contains a 16 bit word plus an 8-bit identifier. Each frame above has a unique ID value.

5 CONFIGURATIONS

The PSCs and PSIs can be mechanically configured to optimise cost or permit “stand-alone” operation.

5.1 Normal Configuration

For normal operations, the PSC resides in the control VME card cage.

The PSC is packaged into a 19” rack mounted box that is 1U (1.75”) high. Small power supplies are included to power the board locally.

5.2 Test Configuration

In this configuration, the PSC is packaged into a single slot VME enclosure. The enclosure is only used to provide DC power for the card, and physical protection. In this configuration, data will be provided by the RS-232 port on the face of the PSC.

The PSI is not changed from its normal configuration for test. A typical scenario will have the a laptop computer communicating with the PSC in this “Mini-VME” enclosure and a pair of fibers going to the PSI of the power supply being tested.

5.3 Multiple Regulator Configuration

In some applications, small regulators, which share a common bulk power source, are packaged in card cages. One application would be to have each of these regulators in a 6U by 10HP (2.0”) card. It would be economical for the PSI to be in a 6U VME style card as well.

To this end, the card used in the normal 19” rack configuration is mechanically designed be usable as a 6U by 4HP (0.8”) card. Six pairs (regulator and PSI) would fit in a standard 84HP wide rack, and could be controlled by a single PSC, in either of it’s configurations.

REFERENCES

[1] R. Lambiase, B. Oerter, J. Smith, “Description of the Power Supply Control Scheme for the Spallation Neutron Source”, BNL/SNS Technical Note No. 071, February 4, 2000.