The ELETTRA Power Supply Control System

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Abstract

The control of the magnet power supplies is one of the most important tasks within the ELETTRA control system. According to our distributed architecture, the equipment interface units (EIU) have been integrated in the power supply cabinets, providing local and remote control functions: status reading, commands, output current reading and ramp generation. Each EIU consists of a VMEbus based crate containing the digital-to-analog converter (DAC), analog-to-digital converter (ADC), digital input/output modules together with a microprocessor module running the OS-9 real time operating system; a MIL-1553B highway interface supports the communication with the control system environment. Exploiting the same communication interface, we have implemented an integrated development system which has been used for the tests of the embedded EIUs. The detailed EIU hardware and software design is given.

1. INTRODUCTION

A total number of 268 highly stabilized power supplies is needed for the ELETTRA magnet families [1]: 58 for the Transfer Line, 46 for the Storage Ring bending, quadrupoles and sextupoles [2], 164 for the Storage Ring correctors. The power supply cabinets, housing up to 12 units, are spread out over the so called "service area" inside the 260 m Storage Ring circumference.

Following the general scheme of the ELETTRA control system, the EIUs are integrated inside the power supply cabinets and carry out the interface with the power supplies of that cabinet [3]; distinct MIL-1553B field highway [4] branches connect the EIUs with the LPCs, and one ethernet Local Area Network (LAN) the LPCs with the control room workstations. We have grouped the power supply LPCs and the corresponding EIUs with operational criteria: 1 LPC and 6 EIUs for the Transfer Line, 1 LPC and 17 EIUs for the Storage Ring bending, quadrupoles and sextupoles, 1 LPC and 24 EIUs for the Storage Ring correctors.

Each power supply can also be locally set and controlled.

2. THE EIU HARDWARE

In order to easily fit the different power supply cabinet configurations a modular approach as well as a high degree of standardization for both the electronics and mechanics is adopted for the EIU. Each EIU consists of a VME electronic crate containing one CPU board, one MIL-1553B Remote Terminal and input/output (I/O) boards carrying out the hardware interface.

Taking advantage of the system modularity, combinations of a restricted number of I/O board types is used for the control of all the power supplies: one analog output (DAC16), one analog input (ADC16), one digital I/O (DIGIO), one combined analog-digital I/O (ADIO) and one enhanced ADIO board for the correctors (ADIOC). All the boards feature 1 kV peak isolation between the power supply and the Control System VME bus electronics. A 32 pin, DIN 41612 Dtype, 5.08 mm spacing P2 connector is adopted for the I/O signals; the J2 backplane is not used in order to prevent interactions among the boards, like temperature induced common drift. The board type, serial number, revision and VME interface parameters are stored into a 64 byte PROM.

The DAC16 is a single channel board with a 16 bit monotonic Digital-to-Analog Converter (DAC). The DAC16 sets the power supply output current and guarantees the reproducibility of the accelerator optics. A drift of maximum ± 3 parts per million (ppm) of Full Scale Range (FSR) per °C has been measured on the DAC16 output. Isolation is given by opto-couplers on the "digital side" of the DAC and by an on-board DC/DC converter for its supply.

A four digit hexadecimal display on the front panel shows the actual digital input code applied to the DAC. Acting on a toggle switch the value stored into an internal Local Set Register (LSR), which can be read by the CPU board through the VME bus interface, changes; this feature is used to locally set the power supply, as described below. A second four digit hexadecimal display indicates the LSR contents.

One dual-slope 16 bit Analog-to-Digital Converter (ADC) with no missing code equips the ADC16 board. On each power supply an independent output current transducer (DC Current Transducer or shunt), which is not part of any internal regulation loop, provides the analog input signal to the ADC16. The drift induced on the analog input signal by temperature variations is ± 1.5 ppm of FSR/°C. Isolation is obtained by the same technique as the DAC16. A front panel four digit hexadecimal display shows the ADC digital data. For the local operation of the power supply, a continuous conversion mode with 1.5 conversions per second can be selected through the VME bus interface.

Table 1
Power supply DAC and ADC resolution

	DAC bits	ADC bits
Storage Ring Bending, Quadrupoles, Sextupoles. Transfer Line Bending.	16	16
Transfer Line Quadrupoles.	15	14
Storage Ring Hooked Sextupoles. Transfer Line Correctors.	15+sign	14+sign
Storage Ring Correctors.	15+sign	15+sign

The DIGIO is a 16 channel software configurable digital I/O board, which is used to send commands and to read the power supply status. The channels are individually isolated and the board is safely connected to different power supplies.

The ADIO is a combination of the boards described above: it provides one 15+sign bit DAC and one 14+sign bit ADC with ± 10 ppm of FSR/°C drift plus 12 digital I/O channels.

An improved version of the ADIO, called ADIOC, is under design. It features 15+sign bit DAC/ADC together with additional DAC circuitry for harmonic feedback [5] operation.

Table 1 reports the DAC and ADC resolution adopted for the different magnet power supplies.

3. Software Architecture

The power supply control system makes an extensive use of software: whenever possible we have adopted an intelligent and hardware independent control in order to guarantee an easy maintenance and configuration flexibility [6].

The EIU software, based on the OS-9 operating system, essentially consists of the following parts: I/O modules (drivers and descriptors), Command/Response (C/R) server, ramp generation processes and alarm client (figure 1).

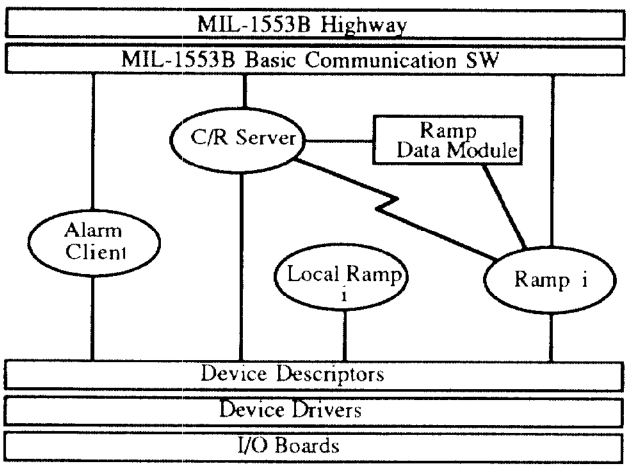

Figure 1. Power supply EIU basic software architecture.

3.1 Drivers and Descriptors

The OS-9 features a versatile unified hardware-independent I/O system, based on the device driver and device descriptor concepts. Exploiting these characteristics, we have assigned a descriptor for each power supply I/O point such as ADC, DAC, digital status and commands, and labelled it according to our naming convention [7]. This implementation enables us to include all the specific I/O point characteristics, like conversion parameters or address offsets, in the corresponding device descriptor without keeping an additional special local data base. The different I/O board drivers are written in the 68000 assembly language.

3.2 Command/Response Server

The C/R server permits the exchange of data and messages between the EIU and the rest of the control system through the MIL-1553B highway communication services [4]. After receiving a LPC request, the server process analyses the incoming message starting from the I/O point logical name. According to our naming convention, its structure contains all the information to access the equipment together with the action to perform, the data direction and the type of data involved. The engineering units conversion is executed by extracting the relevant parameters from the descriptor modules.

There are two operating modes: direct and indirect. In direct mode the action is carried out by the C/R server process itself, while in indirect mode it is processed by a different task. This distinction is necessary because one single C/R server is installed on each EIU and all the upper LPC requests go through it. A slow action like a power supply current ramp, which takes several minutes, would then force all the incoming messages to queue and block the access to the EIU. The indirect mode lightens the C/R server work transferring part of it to other defined processes. Another way to avoid the server bottleneck could be to fork the C/R process every time a message arrives. This solution has the disadvantage of requiring a lot of EIU memory and of reducing the average system response time.

3.3 Ramp Process and Ramp Data Module

This process is the implementation of an indirect action. One ramp process, forked at system power-up, is associated to each power supply. After the initialization it starts sleeping and waits for the magnet current ramp parameters. The communication between this process and the C/R server is provided by a memory data module. The C/R server fills the data module record related to a specific power supply with the received current parameters, sends a wake up signal to the associated ramp process and finally returns to sleep. After waking up, the ramp process extracts the parameters from the data module and finally starts operating.

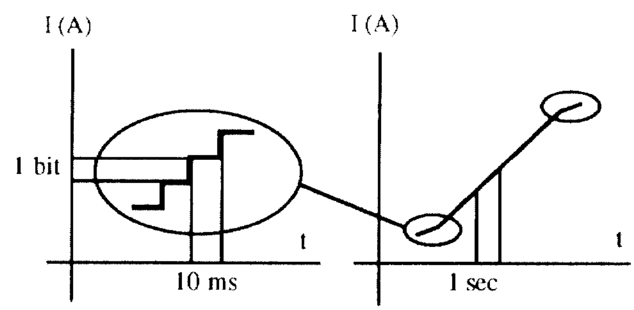

Figure 2. Ramp types.

There are two ramp types: bit-per-bit and polyline (figure 2). The first one allows the power supply user to modify the output current value, through the DAC16 board, on a bit-per-bit basis with a period of ten milliseconds. In this way the power supply linearity and ripple specifications are satisfied. In polyline mode the ramp is split into three segments: the first and last segment are bit-per-bit while the intermediate one can have a different Ampere/second slope.

In case we start a ramp when another one, associated to the same power supply, is already active an error occurs. The ramp process can be stopped at its last value at any time.

After reaching the required set point, the ramp process checks the difference between the power supply DAC and ADC values: if it overcomes a certain tolerance, a warning message is returned to the control room computers but no special action is taken.

3.4 Local Ramp Process

One of the main features provided by the DAC16 boards is to allow a user to locally set the magnet current. A so called local ramp process takes continuously care of the power supply local/remote input signal, polling it every second. In local case, the process disables every remote request, sets the ADC16 continuous conversion mode and finally begins to read the DAC16 LSR value. When this changes, a bit-per-bit ramp starts running after its new content. The actual DAC16 output is generated by the local ramp process and changes with the maximum slope allowed for that power supply. The local set point can be modified at any time and the associated task consequently adjusts the ramp direction. The output current value can be read on the ADC16 display.

Turning back to the remote mode, the local process stops at the last reached value, resets the ADC16 continuous conversion operation and begins to poll again the local/remote signal every second.

3.5 Alarm client

This process continuously checks the power supply status finding out anomalies or fault conditions. If a malfunction occurs, the alarm client immediately sends a message to its connected LPC where the alarm server processes it and eventually takes a consequent action. All the power supply alarms come from digital status signals. The alarm client is a simple task and it does not include any closed-loop control.

4. SOFTWARE DEVELOPMENT SYSTEM

In order to ease the power supply software development we have installed the OS-9/NET package on top of our MIL-1553B layered communication software [4]. Typical LAN utilities, like remote login and homogeneous file access, are then available between a LPC and its EIUs. A disk equipped LPC is used as remote software development system for all the associated diskless EIUs.

5. CONCLUSIONS

The presented hardware and software modular power supply control design provides easy maintenance and upgrade. The early standardization of the control functions has facilitated the development of a uniform user interface for the different power supply types.

Two EIUs running the described logical software architecture have been successfully installed for the control of the ELETTRA pre-injector diagnostic line [8] magnet power supplies.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

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