CONTROL SYSTEM FOR ELECTROMAGNET POWER SUPPLIES

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Abstract

A set of power supplies (PS) with output power rated from 100W to 10KW for electromagnets were developed. These PS have an operating range of 60-80 db with high accuracy (error should be less than 0.01%). Some types of power supplies have bipolar output current. This report will describe a set of unified embedded devices for the control and measurement of PS incorporated into distributed control systems. These embedded devices include DACs and ADCs with multiplexers and status input/output registers. The devices include a microprocessor, and allow work with minimal host involvement. This capability decreases traffic, provides synchronous tuning of all electromagnet elements of the particle accelerator and increases the reliability of the entire system.

1 INTRODUCTION

Budker Institute of Nuclear Physics (BINP) is building a new installation (VEPP-5, FEL) and upgrading an existing collider (VEPP-2000, VEPP-4 [1]). These installations include hundreds of magnet elements (lenses, correctors etc) which are powered by power supply controllers designed and produced by BINP. All power supplies are computer controlled via digital-to-analog converters. Current and voltage in these elements are measured with analog-to-digital converters.

We developed a set of embedded devices for control of power supplies. They have a unified implementation, using similar connectors and software protocols. Integration with the control system is provided by a popular network- CANBUS.

2 TECHNICAL REQUIREMENTS

Magnet elements and their corresponding power supplies, may be divided into two different groups. The first group includes bending magnets and lenses. The second includes low current correctors. Elements of the first group require high stability and accuracy of their power supplies. Typical accuracy requirements for these power supplies are from 0.01% to 0.001%. For corrector power supplies these requirements are lower, approximately 0.1%.

This wide gap in required accuracy made us design two different types of controller. The first is a precise controller for bending magnet and lens power supplies. The second is an inexpensive multi-channel device for multi-channel corrector power supplies.

The precise controller should provide one DAC channel with resolution of approximately 0.001% and accuracy at least 0.01%. It should also provide 4-5 channels of ADC with similar accuracy and resolution for measurement of the output current and voltage, and be able to measure some additional voltages inside the PS. It is very useful to check logical status of some points of power supplies (protection circuitry status, presence of water flow etc) and ON/OFF control for different purposes. For such tasks the controller should provide a few channels for input/output registers with optocouplers.

The inexpensive multi-channel controller should provide multiple-channel DAC (we have chosen 16 channels per controller) with accuracy at least 0.1% and multi-channel ADC (we have chosen 40 channels per controller) with the same accuracy. For digital IN/OUT it should include a few channels of input/output registers with optocouplers.

For connection of the controllers with control computers we have chosen CANBUS. It provides:

- high reliability
- determined delivery time for high priority packets
- wide support by chip and board manufacturers
- opportunity of galvanic isolation between controller and media
- growing popularity in world physics centers.

There are a number of CAN application level protocols. A structure and resources of chosen microprocessor don't prevent to implement one of them in our devices. But the use of many CAN-devices requires us to reduce traffic as much as possible. This leads us to the possible use of CAN message objects later.

3 STRUCTURE OF CONTROLLERS

The multi-channel controller has been implemented in two physically independent devices. One of them contains multi-channel DAC, the second includes

multi-channel ADC. The other properties of these devices are identical.

A block-diagram of all the described devices is presented below in Fig.1. All of them include a few identical parts (microprocessor, CAN controller, DC-DC converter, input/output register) and specific analog parts, which are different for both devices.
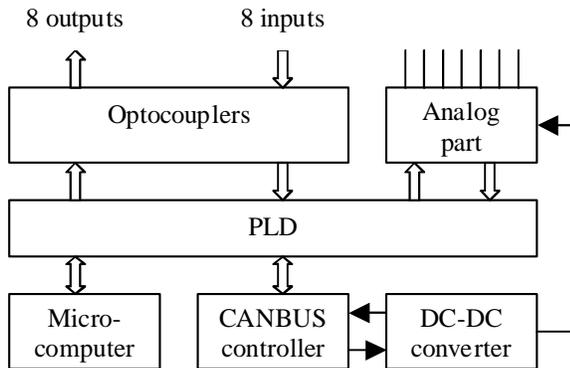

Figure 1: Block-diagram of embedded controller.

4 DESIGN OF CONTROLLERS

The analog part of the precise controller (CDAC20) incorporates one channel of DAC and a multi-channel ADC. The structure of the analog part is shown in Fig.2.
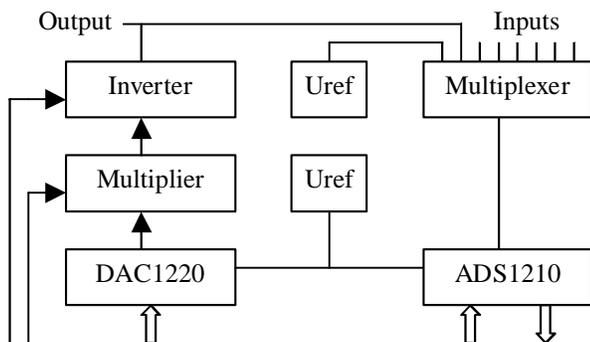

Fig.2. Analog part of precise controller.

The design was based on Burr-Brown delta-sigma converters. The design of the ADC is quite standard. Input signals connected with the ADS1210 through a multiplexer with incorporated over-voltage protection (Burr-Brown MPC507). 5 two-wired channels are intended for external signal measurements. One channel is connected with the DAC output inside the board. This feature gives us the opportunity to control the DAC and to correct it via the microprocessor. One channel of the multiplexer is connected with "ground" and another with the reference voltage. This feature

allows using "system calibration" of the ADC chip and to reduce most sources of inaccuracy.

The design of the DAC had some specific requirements. The chosen chip (DAC1220) provides output signals from 0 to +5V. Most of our power supplies require a range up to 10V. So, the DAC1220 voltage is doubled by circuitry with "flying capacity", which then may be inverted by similar circuitry.

The analog part of the precise controller is galvanically isolated from digital part of the device. It is provided with a DC-DC converter and optocouplers. Galvanic isolation allows us to improve the quality of signal transfer between the controller and power supply.

The analog part of multi-channel DAC (CANDAC16) is based on a single DAC chip (AD669, Analog Devices) and 16 sample-and-hold devices (see Fig.3).
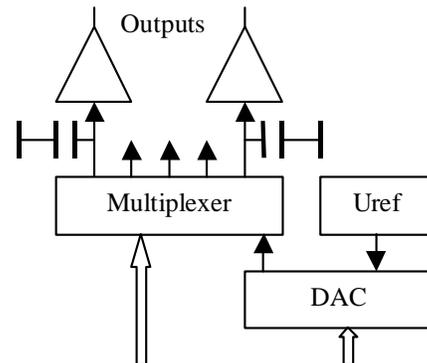

Fig.3. Analog part of multi-channel DAC.

The microprocessor loads a code into a DAC chip, whose output is to a chosen capacitor to update charge. After some time microprocessor repeats this sequence for the next channel. This approach allows us to build a multi-channel DAC with low cost per channel. We use external reference sources to improve stability and accuracy of the device. There is no galvanic isolation between analog and digital areas, which makes for a cheaper design.

The analog part of the multi-channel ADC (CANADC40) is based on a sigma-delta ADC chip (ADS1210, Burr-Brown) (see fig.4).

This circuitry contains a 40-channel multiplexer based on an MPC507 (multiplexer with incorporated over-voltage protection), programmable gain amplifier (PGA), delta-sigma ADC (ADS1210, Burr-Brown) and a reference source. A PGA chip is used to allow automatic changing of the input range of the meter. There is no galvanic isolation between ADC analog and digital areas.
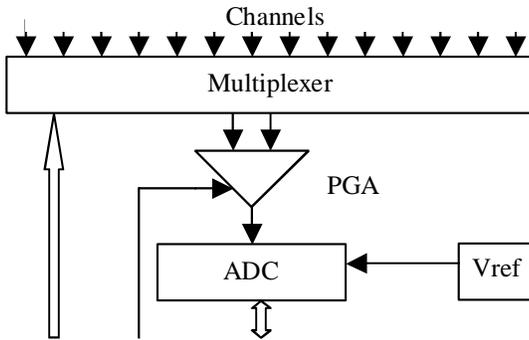
Fig.4 Analog part of multi-channel ADC.

5 EMBEDDED SOFTWARE

The embedded software for all devices was written in assembler to ensure deterministic execution time for critical sections of code. All devices use very similar or identical messages.

Controllers with a DAC on board have an additional feature; they can load a few lines from file, which describe changing the output voltage in time. The host computer can request to process these files by single, group or all devices in the network. This feature allows us to synchronously reconfigure the whole magnet system, or part of it, in the accelerator. The file contains a set of points, and embedded software calculates the intermediate points by linear interpolation when processing the file.

6 PARAMETERS

Table 1: Parameters of the Designed Devices, CDAC20 – precise controller

DAC accuracy	0,005%
DAC resolution	21 bits
DAC channels number	1
ADC accuracy	0,003%
ADC resolution	24 bits
ADC channels number	5+3
ADC and DAC range	±10V
Channels of output register	8
Channels of input register	8

Table 2: CANDAC16- multi-channel DAC

DAC accuracy	0,05%
DAC resolution	16 bits
DAC channels number	16
DAC range	±10V
Channels of output register	8
Channels o input register	8

Table 3: CANADC40- multi-channel ADC

ADC accuracy	0,03%
ADC resolution	24 bits
ADC channels number	40
ADC range	±10V
Channels of output register	8
Channels of input register	8

CONCLUSION

A set of embedded controllers for power supplies was designed and tested. A number of these controllers were used in the power supply system of VEPP-5, FEL. Using embedded controllers has minimized interconnection, simplified maintenance and reduced commissioning time. We suppose to extend this approach to other large installations of this institute.

REFERENCES

[1] VEPP-4 Control System Upgrade, A. Aleshaev, S.Karnaev, B.Levichev, I.Protopopov, S.Tararyshkin, ICALEPCS'97, Beijing, China.