EMBEDDED DEVICE SET FOR CONTROL SYSTEMS. IMPLEMENTATION AND APPLICATIONS.

V. Kozak, BINP, Novosibirsk, Russia.

Abstract

Creating new installation [1] and upgrading existing facilities [2] require a great amount of control devices. There was designed an unified device set for new control systems. All devices implemented as embedded controllers for incorporating into controlled equipment like power supplies, RF-stations and so on. First applications [3] show a lot of advantages embedded controllers over classical modular devices. Now these devices are widely used in control systems both in BINP and in other scientific institutions. Here is presented the developed device set, described implementation and discussed typical applications.

INTRODUCTION

Budker Institute of Nuclear Physics (BINP) is building a few new installations (VEPP-5, FEL [1], FEL-KAERI) and upgrading an existing colliders (VEPP-2000 [2], VEPP-4). In 70th-90th control systems of the large installations was based on CAMAC devices. Growing requirements to functions, parameters and reliability of automation components initialize creating a new generation of automation devices. An activity on creating new automation components, new structural and architectural decisions was begun in 2000 year.

EMBEDDED DEVICE SET

One of the biggest disadvantages of previous automation systems is a great number of signal cables with intermediate connectors and distributing panels between terminal equipment and control devices implemented in CAMAC standard. For avoiding this problem there was decided to implement new devices as embedded devices into end equipment. All devices should be based on micro-controller and be connected with control computers by inexpensive mono-channel. We have chosen CANBUS as low level network.

There were a few factors that should be taken in account. All devices must be unified as much as possible both in hardware and in software. A unified command set can greatly reduce expenses on developing and building new control systems. We have paid a special attention to hardware and software compatibility of new device generation. All requirements are listed below.

- All devices must be embedded in terminal equipment.
- All devices must be based on micro-controller or microprocessor.
- All devices should use CANBUS for interaction with control computer or with other devices.
- Devices should combine a number typical function (many devices in single).
- Devices should be maximally unified by functions, command set, connectors for external connections.

To reduce design time there was used an unified structure of all devices which shown below.

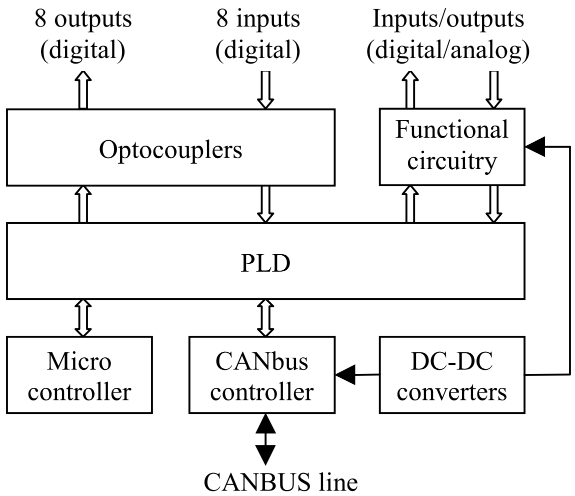

Figure 1: Block diagram of embedded controller.

Core of design is identical for all devices and consists of microcontroller, CANbus controller, DC-DC converters, PLD and digital optocouplers. A functional circuitry defines destination of device. It may contain ADC, DAC, PWM circuitry, delayed pulse generators, digital input/output or combination of these functions. This approach allows to have identical a significant part of devices. It is concerned to schematics, PCB layout, PLD equations and microcontroller software. It greatly saves both efforts and time used for designing and debugging. Most developed devices are listed in table 1.

Table 1: Embedded device set

Designation	Functional description
CANDAC16	16 channel 16 bit DAC
CANADC40	40 channel 24 bit ADC
CDAC20	6 channel 24 bit ADC, 21 bit DAC
CEDAC20	6 channel 24 bit ADC, 21 bit DAC, euromechanics
CAC208	20 channel 24 bit ADC, 8 channel 16 bit DAC
CGVI8	8 channel delayed pulse generator
CPKS8	8 channel pulse-width generator
CURVV	Multiport input/output register
SLIO24	24-bit bi-directional register
CKVCH	Reconfigurable RF multiplexer

IMPLEMENTATION OF DEVICES

Analysis of existing control systems shows that most control devices are analog-to-digital and digital-to-analog converters for slow signals and direct current. These ADCs and DACs usually are accompanied by a number digital channels (switch on/off and check state). There are very different requirement for signal conversion from 1% (temperature measurements and correctors powering) to 0,001% (power supply for bending magnets). There is very different concentration of channels from single channel in 10KA power supply to 48 controlled power supplies in single rack. These converters are used in various systems:

- magnetic system;
- RF-system;
- temperature measurements;
- vacuum system;
- diagnostic system;
- and so on.

There is overview of implementation of these converters. Implementation of functional circuitry is based on unified structures, also. For example, basic structure of analog to digital conversion looks as showed on fig.2.

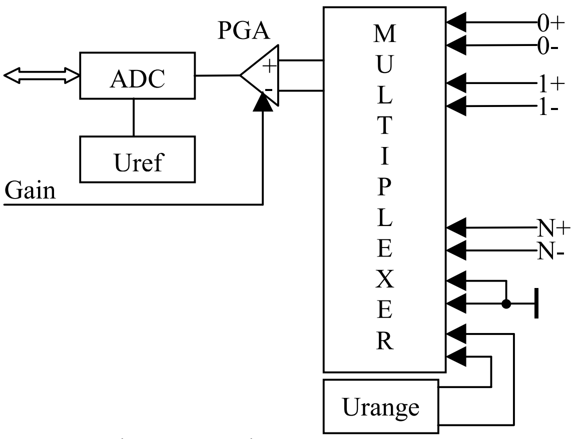

Figure 2: Basic ADC structure.

It consist of:

- Differential multiplexer
- High precision reference
- Programmable gain amplifier or instrumentation amplifier
- ADC chip

Different devices use modification of this basic circuitry. Precise models (CDAC20, CAC208) use a special reference source connected with inputs. It allows to perform a system calibration and to reach high accuracy. Moreover, the system calibration allows providing precision of device which equal precision of reference source. We can improve accuracy of ADC by replacing reference source part. Inexpensive models (CANADC40) have simplified schematics. A few inputs are used for internal needs (to measure a power supply voltage, environment temperature and so on).

Digital-to-analog converters use two different structures. Multichannel converters (CANDAC16, CAC208) use single DAC chip and number sample-and-hold parts as showed below.

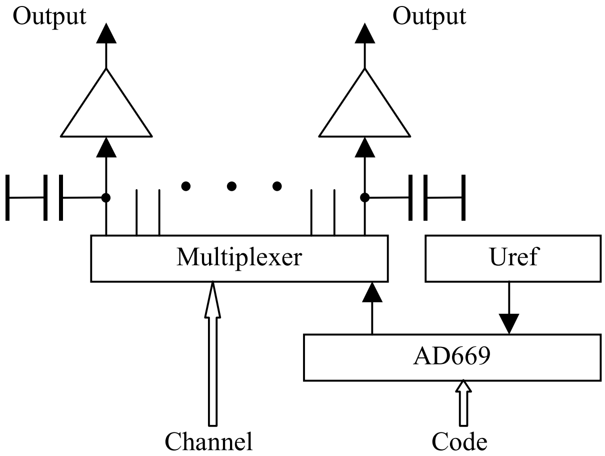

Figure 3: Block diagram of multichannel DAC.

Main parameters of multichannel converter are listed in table 2.

Table 2: Parameters of CAC208

Parameter of CAC208	Value
External ADC inputs	20
ADC bits	24
Range, V	±10
Effective resolution, bits rms	22
Scale drift, ppm/°C	1,5
Accuracy, %	0,003
DAC outputs	8
DAC resolution, bits	16
Range, V	±10
Accuracy, %	0,05
Input digital channels	8
Output digital channels	8

Precise DAC (in CDAC20, CEDAC20) is implemented with delta-sigma converter DAC1220 from Burr-Brown. It allows having an excellent resolution and quite good accuracy (better than 10^{-4}) without any tricks. One input channel of on-board ADC is connected with output of DAC. Microcontroller of device performs measurement of DAC output voltage with some period and corrects code in DAC chip. This "digital correction" allows improving accuracy of DAC.

Precise device (CDAC20) is described by table 3.

Each control system includes a lot of digital devices performing the following functions:

- delayed pulse generation for synchronisation system;
- pulse-width conversion;
- digital input/output.

For this applications there were designed the following devices:

- CGVI8- 8-channel delayed pulse generator. It provides delayed pulses with jitter 10ns and with delay from 100 nS to 214 Sec;
- CPKS8- 8-channel pulse-width converter;

- CURVV- multi-port input/output register;
- CKVCH- reconfigurable multiplexer for high frequency signals;
- SLIO24- multiport bi-directional registers for interfacing old equipment to CANBUS.

Table 3: Parameters of CDAC20

Parameter	Value
External ADC inputs	5
ADC bits	24
Range, V	±10
Effective resolution, bits rms	22
Scale drift, ppm/°C	1
Accuracy, %	0,002
DAC outputs	1
DAC resolution, bits	21
Range, V	±10
Accuracy (digital correction off), %	0,01
Scale drift (digital correction off), ppm/°C	5
Accuracy (digital correction on), %	0,002
Scale drift (digital correction on), ppm/°C	1
Input digital channels	8
Output digital channels	8

Today these devices are using in VEPP2000 control system for replacing old CAMAC modules in different subsystems.

TYPICAL APPLICATIONS

Most AD and DA converters are used with controlled power supplies for magnetic system of accelerators. Here is shown a typical configuration of this application.

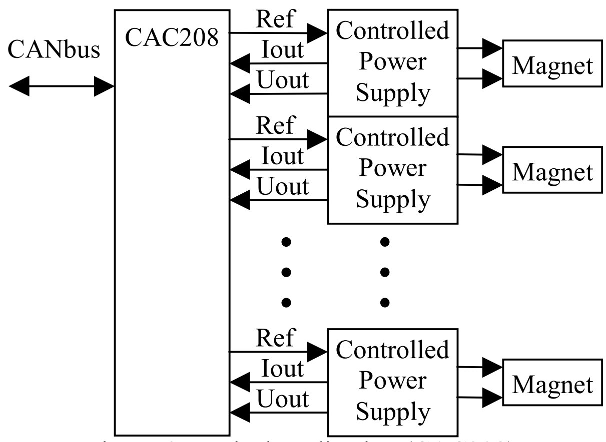

Figure 4: Typical application (CAC208).

Each channel of power supply requires one DAC channel for controlling output current and two ADC channels for measuring real current in magnet and voltage on it. One device CAC208 may work with 8-channel system. In old system were used a pair devices (CANDAC16 and CANADC40) which served 16 controlled power supplies.

A typical magnetic system (FEL [3], VEPP-2000) includes 200÷500 controlled power supplies and 25÷100 CANbus devices.

Another typical application is temperature monitoring system. These systems measures temperature in 200÷500 points of facility (FEL, VEPP-2000). Now they are based on CANADC40. It can work with different sensors (resistive, semiconductor and etc) and have excellent resolution (better than 0,1°C).

Using identical devices in different systems greatly simplified programmer's job and reduces maintenance expenses.

CONCLUSION

It is possible to state that designed device set entirely confirmed correctness of initial assumptions. It allows to implement automation subsystems of physical installations cheaper, to improve reliability of systems, to decrease maintenance expenses. A functional universality has allowed to reduce a list of used base components for automation and to simplify control software in host computer.

A micro-controller on-board allowed implement in devices high-level functions. Each device may interact with other devices without involving host. It gives us opportunities to build really distributed automation systems when we distribute between subsystems not control devices but intelligent functions.

A successful experience building automation system based on the new device set (FEL[3], KAERI[4]) allowed us to introduce both new devices and new architecture to most installations which we build today (VEPP-5, VEPP-2000, coolers [5]).

REFERENCES

[1] Antokhin E.A., Akberdin R.R., et al., “First Lasing at the High Power Free Electron Laser for Siberian Center for Photochemical Research” 25th international free electron laser conference, September 2003, Japan, MO-O-03.

[2] Yu.M. Shatunov et al., “Project of a new electron-positron collider VEPP-2000”, EPAC’2000, p.439.

[3] Y.M. Velikanov, et al., “Free electron laser for the Siberian centre for photochemical research: Control and power supply system for electromagnet elements”, RuPAC’04, October, 2004, Dubna, Russia.

[4] Byung Cheol Lee et al, “Development of a 40-MeV Superconducting Energy-Recovery Linac for Infrared FEL”, APAC’04, Gyeongju, Korea, 2004.

[5] V. Reva et al, “Commissioning of Electron Cooler EC-300”, EPAC’04, Lucerne, 2004.