A DISTRIBUTED AUTOMATION SYSTEM FOR ELECTROPHYSICAL INSTALLATIONS

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ABSTRACT
There was designed a set of devices for automation systems of physical installations. On this basis there was developed a distributed control system. The paper covers problems and possible solutions on the way. Typical applications are discussed. There are presented subsystems with developed devices and structural solutions in different projects. A short description of developed devices is included. The paper shows advantages of used approach.

KEY WORDS
Automation, systems, applications, CANBUS, embedded, controller.

1. Introduction

Budker Institute of Nuclear Physics (BINP) is building a few installations (VEPP-5, FEL, FEL-KAERI) and upgrading an existing colliders (VEPP-2000, VEPP-4). In 70^{th}-90^{th} 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.
First experiments [1] on introduction of new devices and structures confirmed a correctness of main solutions. They allowed to extend a new approach to most our creating installations and experimental stands and to upgrading accelerators. There were stated requirements to developing a unified device set allowing automation of typical application with minimal expenses. These devices were developed and successfully used in control systems of a few our physical installations. The paper describes main principles used during forming requirements and developing the device set. There are described the typical applications of developed devices and briefly characterised these devices.

2. Requirements to device set for physical installation automation

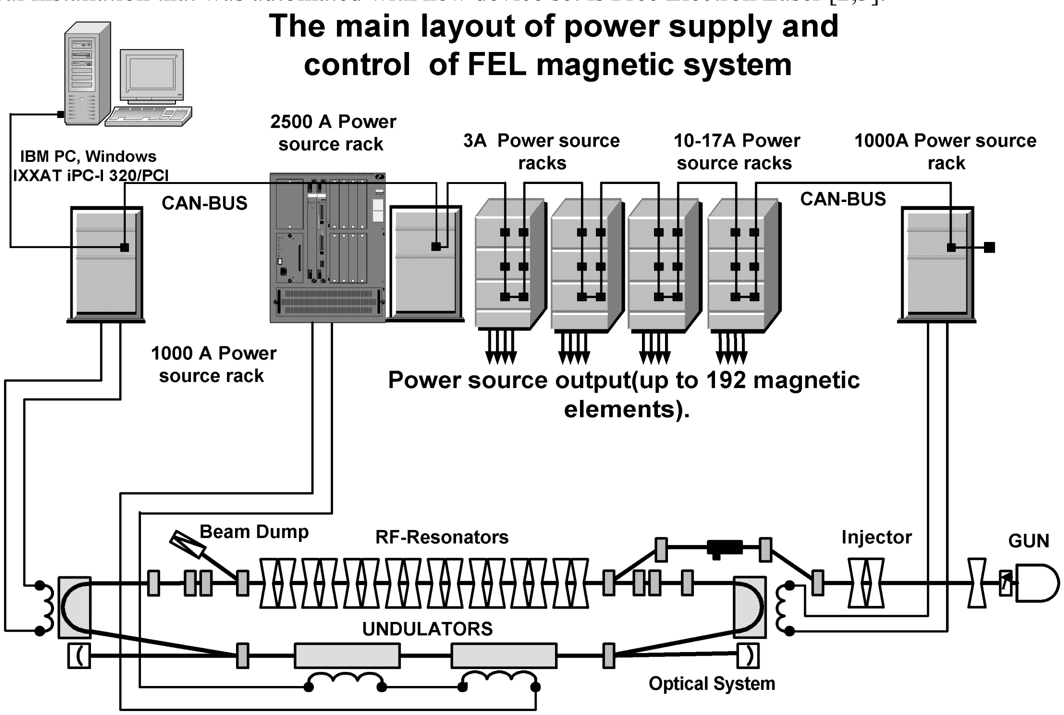
One of the biggest disadvantages of previous automation systems is a great number of signal cables with intermediate connectors and distributing panels between terminal equipment and control devices implemented in CAMAC standard. For avoiding this problem there was decided to implement new devices as embedded devices into end equipment. We assumed to use some inexpensive mono-channel for connection with control computer. After analysis of existing buses we choose CANBUS as low level network.
Recent achievements of semiconductor industry greatly extend opportunities for designers in choosing device functions. This progress allows incorporating in device a lot of quite different functions with low expenses. It gives opportunity to use the device in very different applications. In this case we can reduce a variety of devices. Reducing device set allows us to cut down expenses for development both hardware and software.
Complex functions might be implemented with micro-controller using only. An onboard micro-controller helps to implement complex functions, to add or to change new functions and to simplify interaction between device and control software. It allows perform a complex job without control computer, for example to make temperature stabilisation of cavity or to correct accuracy of controlled power supply. CANBUS as low level network provides a new quality for system- devices are able interact each with other without invoking control computer. It opens a very interesting opportunities in future system improvements.
There are 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.
So, for new control device set we can declare the following requirements:

- 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.

3. Typical application of developed devices

The first physical installation that was automated with new device set is Free Electron Laser [2,3].

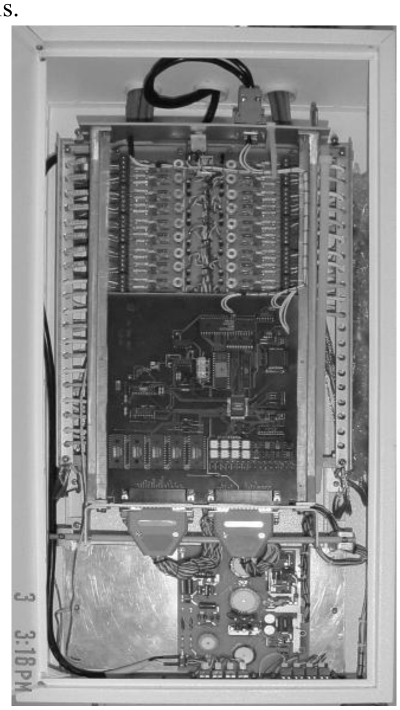


Here is presented a layout of FEL magnetic system control. It includes 192 low power sources for lenses and correctors and 3 high power sources for bending magnets and undulators. Power supplies control is based on CANDAC16 and CANADC40 (in multi-channels racks) and on CDAC20 (in precise high power supplies). All devices are connected with control computer by CANBUS line. This system was put into operation in 2002 and is working with good quality and reliability.

First design of magnetic system automation (2000 year) was based on CAMAC devices. Each 48-channels power supply rack was accompanied by CAMAC crate. They were connected by 288 cables with analogue signals (from DAC. to power supplies and from power supplies to ADCs). Advantages of real system based on embedded devices were so clear and distinct that in next project [4] we didn't discuss alternative approaches. Moreover, besides building new magnetic system of KAERI accelerator based on embedded devices we reconstruct existing injector automation with using new control devices. That system was put into operation in 2003.

Unification of new devices and their multi-functionality allows us to implement temperature control system based on CANADC40 - 40-channels ADC.

Below is shown photo of 40-channels temperature measuring system. A standard device CANADC40 is supplemented by current source board and it is able to work with semiconductor or resistive temperature sensors. It is possible using thermocouples. In this case no need the additional board. A similar system of temperature registration was used in FEL [3,5]. It measures 160 channels.



In conclusion we can add that CANBUS devices are used in some other systems mentioned installations- HF-systems, technological diagnostics and other.

4. Device set for automation systems of physical installations

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 for 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.

It was designed a set of devices to satisfy most of requirements. The device set includes:

- CANDAC16- 16-channel digital-to-analog converter;
- CANADC40- 40-channel analog-to-digital converter;
- CDAC20- precise DAC and 5-channels ADC;
- CAC208- 8-channel DAC and 20 channel ADC.

All devices include 8-bits input and output registers with optical isolation. First pair of devices is intended for using in multichannel systems with low (0,1%÷0,03%) requirements to accuracy. CDAC20 is intended for incorporating into high power precise power supplies. CAC208 is more universal device. It may be used both in cheap multichannel systems and in systems with high requirements. It contains a few additional functions greatly extending possible applications. A table below describes parameters devices briefly.

Parameter	CAN DAC16	CAN ADC40	CDAC 20	CAC208
DAC resolution	16 bit	No	21 bit	16 bit
DAC accuracy	0,05%	No	0,005%	0,03%
DAC channels number	16	No	1	8
ADC noise resolution (20 mS)	No	16,9 bit	18,9 bit	18,9 bit
ADC noise resolution (1 mS)	No	7,6 bit	16 bit	16 bit
ADC accuracy	No	0,03%	0,003%	0,003%
ADC channels number	No	40	5	20
Range (input/ output)	±10 V	±10 V	±10 V	±10 V
Input register channel number	8	8	8	8
Output register channel number	8	8	8	8
EEPROM on-board	No	No	No	16 KB
Thermosensor on-board	No	No	No	Yes

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.

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

During designing devices a special attention was paid to hardware and software compatibility and self-diagnostics. For example, a single control program may work with all ADCs of set. Every device try to interpret incorrect messages and to response maximally adequate way. If control program for CANADC40, for example, requests the CDAC20 to make measurements with gain 100, the device (it hasn't input amplifier but has higher resolution) would make measurement and in output message with measured data it shows that gain was 1. Anyway, the measurements remain correct.

5. 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[2], KAERI[4]) allowed us to introduce both new devices and new architecture to most installations which we build today (VEPP-5, VEPP-2000, wiggler stands, coolers [6]).

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