УДК 004.3

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AUTOMATION OF NON-STANDARD SCIENTIFIC EQUIPMENT

Abstract. Considered the problem of computerization and automation of custom scientific equipment in the terms of time and cost optimization of hardware and software development. A flexible architecture for multipurpose measuring system, which allows quick development of control, monitoring, data collection and analysis systems is proposed. The system allows programming of separate modules logic, as well as end-user interfaces development.

Keywords. Automation, detectors, educational equipment, unique scientific equipment, physical experiment, sensors, user interface.

Introduction

World-wide trends of interactive and telecommunication technologies integration into scientific researches and also deficit of Ukrainian science in modern scientific equipment, dramatically increased popularity of the problem of non-standard instruments upgrade. But every developer faces the problems of new scientific equipment development and upgrade of existing scientific instruments and devices. At least three constraints for this problem can be defined.

1. Separate solution for every unique scientific device is being developed. It leads to inflexible solutions that could not be extended or modified. As result, development takes a long time and requires big investments. In absence of single approach for development of such systems every developer solves considered problem by their own discretion.

2. Single task solution software is closely coupled with hardware of device as well as can be maintained well enough only by it developer. Strong dependence of instrument software developer causes a list of maintenance problems. Firstly, software of device should be maintained and it would be hard task for another developers. Secondly, there is no single standard for development of such systems.

3. As a rule, obsolete equipment is being upgraded by experts with huge experience, but also with constant skills, ideas and list of used technologies. As result, they use obsolete hardware interfaces which require development of artificial drivers and also as result device can’t be used collectively.

For a long time famous companies are being developed systems to solve devices automation problems with elimination of listed constraints [1]. But, massive part of them can’t be used for scientific tasks. For example, various systems developed by Siemens, are intended for automation of power engineering and industrial automation.

The RealLab [2] data collection system is based on modular approach. Modules are connected over industrial interface RS-485. Each module consists of microcontroller with analog switch with 16 inputs, amplifier, ADC, DAC, 3-digital inputs. It can have different types of protection depending of serie. Software as well as protocols of this system is open-source. Shortcomings of RealLab are low-speed communication interface, which causes low speed of signal processing, and poor variety of modules.

The L-Card system [3] consists of various modules. Modules are gathered in special holders. System configurator allows create blocks for signals processing from modules in the holder. This system can be connected to PC via USB or Fast Ethernet interfaces. Weakness of the system: parallel bus between modules requires small distance between them, special cables for connection are required, it uses commercial software that can not be modified or extended, so variety of system usage is limited.

The AFS™ [4] data collection system developed for automation of educational experiments. The system allows to connect all sensors to PC and organize collecting and transmission of experimental data. Further data processing is performed by software, based on progressive visual programming IDE LabVIEW. This system is oriented on school experiments. Weakness of the system: USB connection limits the distance between PC and experimental device, commercial software, low accuracy of signals measurements and limited functionality.

Formulation of a problem

In the scope of our scientific research modern tools for multipurpose automation and computerization of non-standard scientific equipment have been developed. We are talking about flexible computer measuring system (further CMS) for automation and computerization of unique scientific instruments. It is based on hardware-software complex for registration and processing of physical quantities (further HSC). CMS should allow upgrade existing equipment up to date with minimal expenses of time and money.

Main part

HSC is based, first of all, on modular approach. Such approach should allow quick adaptation of HSC for existing equipment and also development of new computerized scientific instruments. Using of standard data transmission protocols should enable development of interactive devices and instruments with remote access.

We are proposing three-layer system architecture, which depicted on figure 1. As shown on the picture, the lowest (peripheral) level is responsible for interaction of the system immediately with physical equipment. This level can consist of single-solution as well as industrial physical values sensors (detectors). These sensors produce data streams. Also along with sensors this level contains of feedback devices, which provide feedback supervision. Further we will call all of them peripheral modules (PM).

The second level contains modules of low-level (LLLM) and high-level (HLLM) logic. LLLM and HLLM devices with their own programmed logic acquire and process data from PM and then transmit data up to the next (higher) level of hierarchy. For this reason LLLM and HLLM have Ethernet controller for organizing of distributed data network among itself and control modules (CM).

The third (the highest level) contains PCs of users and CMs. Every stable PC can be used as CM. Portable PCs also can be used there. For example, well-known Raspberry Pi [5] has enough performance and necessary communication interfaces to control LLLM и HLLM.

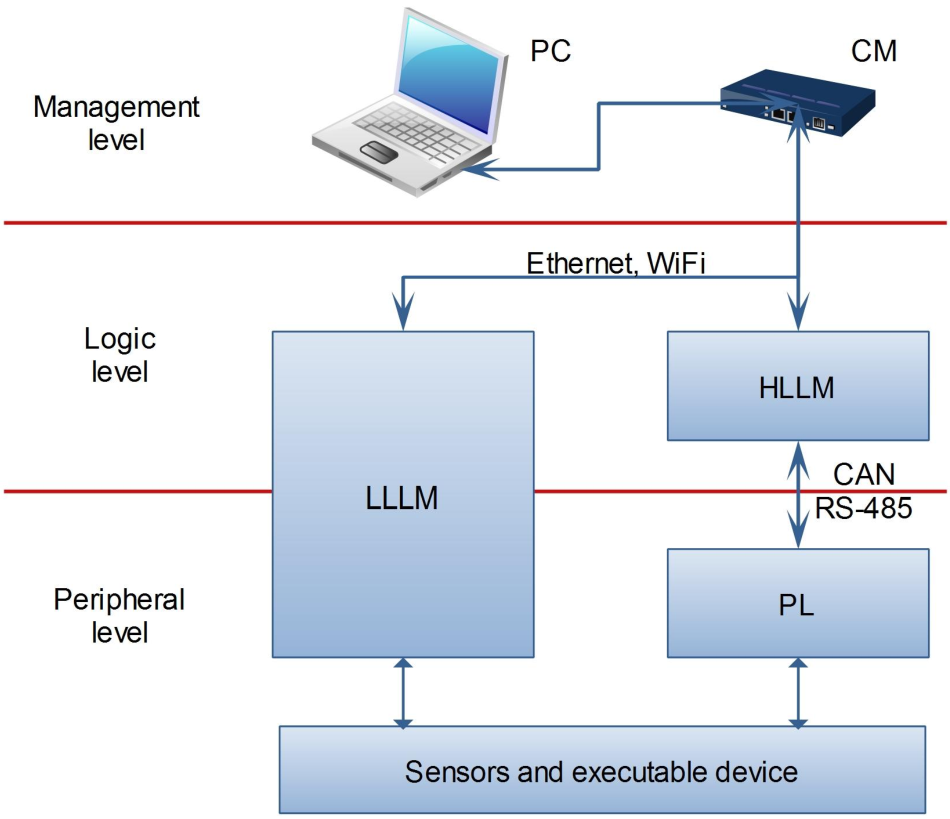

Figure 1 – three-layer architecture of CMS

As shown on figure 2, PM has power supply unit, ADC, analog and/or digital inputs-outputs and controller of high speed bus.

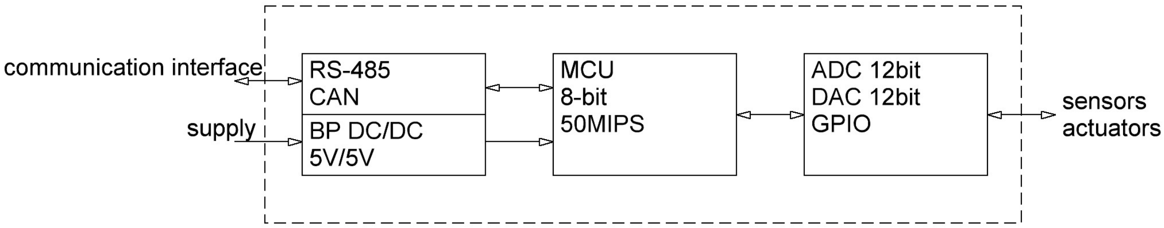

Figure 2 – the scheme of peripheral module

LLLMs (see figure 3) are devices with controller and external analog and digital channels for ADC and DAC. Also LLLMs have Ethernet controller for commutation with control modules. LLLMs contain elementary logic for processing of data from periphery. For example, if LLLM has periphery with analog inputs for measurement of current strength and voltage, then it can process data stream and compute value of power consumption according to it logic. It can pass instantaneous value of power consumption to another module by request or can calculate average value for continuous time period and store it locally, and only after that send data. Thus, LLLM can do high-loaded gathering and primary processing of experimental data.

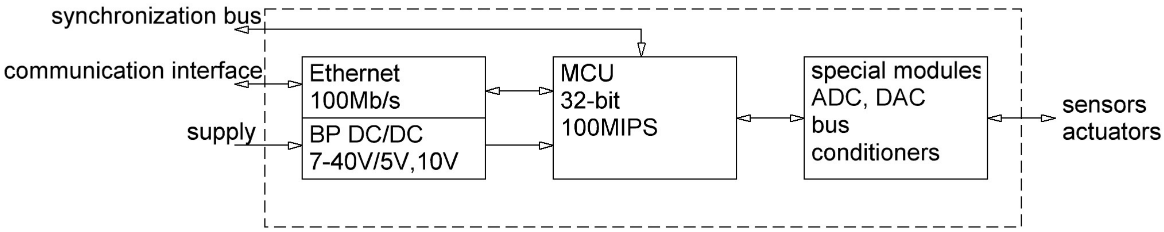

Figure 3 – the scheme of LLLM

Despite of HLLM and LLLM are on the same hierarchy level, the first one is more complex system (see figure 4). HLLM unites a few PMs (quantity depends on data bus) in a single net based on high-speed data bus like CAN or RS-485. HLLM contains programmed logic of work with all PMs, gathers and processes data and then negotiates with CM via Ethernet controller. In fact it encapsulates all the logic of PMs that connected to it and control modules recognize them as a single device.

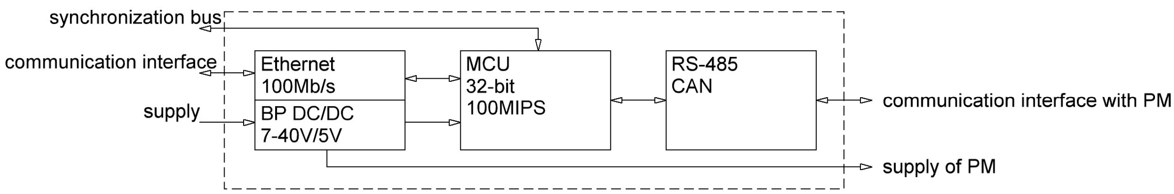

Figure 4 – the scheme of HLLM

 ISSN 1562-9945

Programmable logic speeds up data processing, development of devices with feedback and small response time, decreases load on communication interface and allows parallelize processing of data. Programmable inner logic is based on byte code interpretation. The interpreter is extended by compiled functions library for improvement of data processing performance. Each HLLM and LLLM has it internal library of compiled functions. The library can be loaded by request from CM to PC, so user can develop logic for control. Such approach doesn't require additional documentation for description of devices capabilities, doesn't allow call non-existing function by mistake.

Open data transmission protocol should allow all experts easily develop their software and hardware modules (with programmable logic) and create software for different platforms of clients. Certified data exchange technologies (Ethernet, Wi-Fi etc.), enable a lot of users to access resources of an instrument and process it data real-time.

Also HSC can be used for collective usage of high-cost equipment. In this case collecting of the data and also control of experiment can be done over Internet. It should allow creation of centers for collective usage of equipment.

Conclusion and future work

The following can be summarized:

1. Proposed three-layer architecture of multipurpose measuring system. Such architecture enables quick computerization of non-standard scientific equipment.

2. Developed protocol for transmission of programmable modules logic, interchanging and storing of data between modules of CMS. The protocol is based on well-tested data exchange technologies (Ethernet and Wi-Fi protocols, CAN and 485 buses).

3. Developed mechanism for construction of logic of high-level logical modules (HLLMs). This mechanism allows dispense data processing and decision making load along all the system.

Future work will be dedicated to development of components for CMS, including a wide range of low-level and high-level modules, development of interfaces for designer of logic, processing and visualization of data, feedback and control subsystems.

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 ISSN 1562-9945