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Implementation of Control for Peripheral Machine Equipment Based on the External Soft PLC Integrated with CNC

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***Abstract*—This article discusses the general structure of the CNC control system with the Soft PLC module which was implemented as an external unit. The advantages of reducing the EtherCAT cycle, increasing control system reliability and disadvantages associated with the additional cost of the proposed solution were investigated. The proposed solution also uses the external Soft PLC instead of the safety controller and reduces hardware requirements to CNC. This ultimately leads to an overall reduction in the cost of the distributed control system. Hardware solutions analysis was conducted to select a single-board microcomputer for Soft PLC. A solution was offered for communication between the CNC and the external Soft PLC.**

Keywords—interface NC-PLC; architecture of distributed control system; software-implemented controller; single-board microcomputer; automation of software installation

I. Introduction

The list of technological problems to solving with modern control systems is growing steadily. Traditional materials processing technologies are constantly extended by solutions of consumers with their own know-how, advanced features of automation, control of groups of production facilities, etc. [1, 2]. Solutions from leading manufacturers has already appeared at a market, which are allow integrating additional functions and algorithms directly into the control core of the system. As example, Bosch Rexroth the company provides a set of software libraries (Open Core Interface Library) to provide access to the control functions from user applications [3,4].

On the other hand, maintained a trend of building control systems for decentralized manufacturing equipment. Moreover, solutions with provision of access to the core functions of CNC naturally pushed towards open architecture. When the kernel provides open, well-specified and standardized interfaces for implementing peripheral devices for various purposes. For example, if you need to install on machine the scanner of QR-codes for the store instruments, the changer control problem will require the implementation of additional data processing functions for instruments.

Based on the decomposition of the core functions of the CNC control system, traditionally identified two complex tasks: geometric and logical. The logical problem is implementing as auxiliary functions and functions to ensure the technological process, as well as a binding the control system to a specific of machine equipment. The interaction with such technological environment based on design and technological features of the machine is realized with the usage of PLC.

II. The Structure of the Control System with Peripheral Modules Based on Soft PLC

Implementation PLC tasks (Soft PLC) and NC as a single software process executing on a single computing device hardware (CPU), [5] has some disadvantages. When a critical error occurs in the NC, the task of electroautomatics process control also will be interrupted. This will lead to unpredictable consequences in the actuator devices and units. The tasks of the CNC and PLC on separate processors ensures the correct operation of the PLC even if a failure occurs in the CPU, performing the tasks of the CNC.

The interaction interface of CNC (geometrical task) with Soft PLC (logical task) is a description of rules for interaction between motion control system with the peripheral machinery equipment. Because in surrounded of this equipment the movement is realized. It peripheral machining equipment determines when it is possible and when it is impossible make the movement of the actuator units. For example, the hydraulic clamps can block rotary or vertical movement of the machine axes to increase rigidity of the structure and to achieve greater accuracy. Those. if the axis is locked hydraulically, the external PLC of hydraulic power station should be able to inform the kernel of the CNC system [6]. The more functionality defines NC-Soft PLC interface, the more flexible and versatile CNC system is when it is installed on a given machine equipment.

General structure of CNC system AxiOMA Control with usage of single-board computers for Soft PLC functions is shown in Fig. 1.

CNC kernel implements the control of the machine axes. Tasks of logic control (Soft PLC) for peripherals are implementing on a separate single-board computer. For interaction with field I/O devices and servo-drives in real time the high-speed network is using EtherCAT protocol.

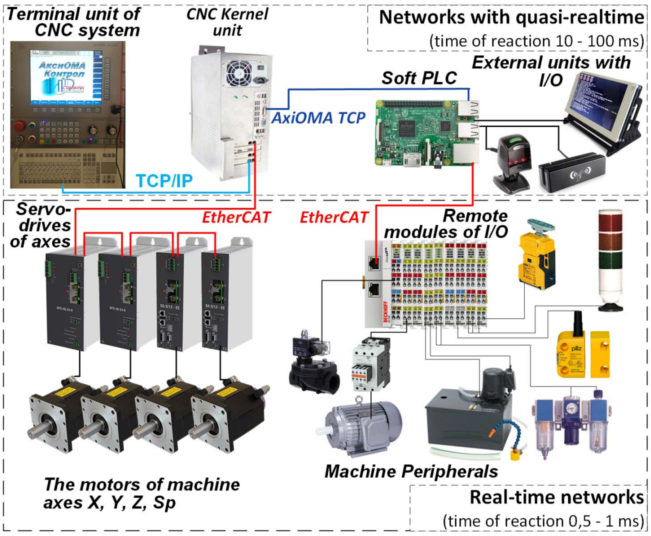

Fig. 1. Generalized structure of CNC system with usage of single-board computers for Soft PLC and additional I/O devices.

The implementation of tasks CNC and logic control on different processors should also divide the high-speed network on two sub-networks. This will reducing time of the EtherCAT cycle, increase speed of operations with devices in subnets and improving common reliability of the solution. In case of an error, for example, in the servo control subnet the work of I/O modules will be saved.

The usage of external Soft PLC controller leads to increasing of cost, because of additional device in structure. However, such external controller can also implement safety functions in relation to the CNC part. And external safety control reduces hardware requirements for Kernel CNC, which ultimately leads to an overall reduction in the cost of system [7].

As it shown on Fig.1, external PLC module solves the problem of integration of additional peripheral equipment for task of logic control. For example, the set of control operation for machine equipment can be implemented on separate touch panel. In addition, QR code of selected tool with additional measurements info can be obtained through external device.

The use of single-board computers in the structure of the distributed control system offers the following advantages:

- distribution of the computational load of control tasks on multiple processors;
- increasing the reliability and survivability of the system by distributing the management and control of activity of hardware modules;
- variability in the selection of models for single-board computers, depending on the complexity and responsibilities of the control tasks;
- distribution of diagnostic and monitoring functions of the control process;
- implementation of a safety subsystem in the structure of the control system on a separate controller (Soft PLC) [8];
- empowerment of local integration of additional I/O data devises.

Depending on the desired functionality on the PLC subsystem for implementing a specific machine control task can be selected single board computer. The main characteristics for this choice are:

- The presence of ports for connecting peripheral I/O devices and memory modules (Ethernet, USB, SPI, SD card, mini-SATA and etc.);
- The total computing performance of microcomputer;
- The support or availability of versions of software packages (operating system, drivers) for the integration of Soft PLC kernel system;
- The characteristics of hardware modules on board microcomputer (chip Ethernet, processor, RAM controller, a graphics co-processor, etc.).

III. Selection of Solutions for the Implementation of Soft PLC Task

The experiments showed, that the computing power of single board computer Raspberry Pi B + is sufficient to run the kernel of AxiOMA Control CNC system and to work on simple machines (the two-axis turning and three-axis milling) [9]. On the other hand, the performance of single board computers will be sufficient to perform the Soft-PLC tasks.

However, solutions like Raspberry Pi have a significant disadvantage - their designers and manufacturing are located abroad from Russia. This leads to the following problems:

- the delivery time significantly increased;
- the possibility of removing from the manufacturing of single-board computer, which will require recycling of development of hardware and software components.

If development and production will take place in domestic enterprises (or abroad, commissioned by the domestic enterprise), it is possible to place an order for the supply of single-board computers of a certain configuration.

Consider the solutions offered by following domestic developers: "Electronic Equipment Factory" Ltd., "Fastwel Group" LLC, “T-Platforms” Ltd., STARTERKIT.RU (Izhevsk) (see Table 1).

For comparison, Table 1 shows the characteristics of Raspberry Pi B +. In addition, for the Baikal-T1 shows the characteristics of the CPU based on which it is possible to build a system.

TABLE I. COMPARISON OF CHARACTERISTICS OF SINGLE-BOARD COMPUTERS OF DOMESTIC PRODUCTION

System	Characteristics				
	Manufa-cturer	***Processor***	***RAM***	***Periph. interfaces***	***OS***
Raspber-ry Pi B+	Raspberry Pi Foundation	ARM1176 JZ-F, (700 MHz)	512 MB	GPIO, USB, Ethernet	Linux
Tion-Pro 28	"Electronic Equipment Factory" Ltd.	Freescale IMX287 (454 MHz ARM9)	128 MB	GPIO, USB, Ethernet, UART	Linux
Fastwel CPB905	"Fastwel Group" LLC	AMD Geode LX800 (500 MHz)	256 MB	Ethernet, UART, USB, FBUS, PCI, ISA	Linux, QNX, Windows XP Embedded/CE
Fastwel CPB909	"Fastwel Group" LLC	Intel Atom E38xx (1.33 -1.91 GHz)	Up to 4 GB	GPIO, Ethernet, PCI, PCI-e	Linux, QNX, Windows XP Embedded/CE
HolaDuo -PC	STARTERK IT.RU	Dual ARM Cortex-A9 (1 GHz)	1 GB	SPI, USB, Ethernet, UART, mini PCI-e	Linux
Baikal T1	"T-Platforms" Ltd.	2 core P5600 MIPS 32 r5 (1,2 GHz)	At least 1 GB	GPIO, USB, UART, SPI, Ethernet, PCI-e	Linux

IV. THE TASK OF INTERACTION OF THE CNC AND PERIPHERAL COMPUTING MODULES

Communication of CNC kernel machines and microcomputers Soft PLC implemented by means of protocol AxiOMA TCP that is based on Ethernet network (Fig. 2) [10]. The problem of communication network and ensure its fault-tolerance is implemented as separate subsystem that implements following:

- communication interface between software modules of the system through an intermediate level of network protocol;
- the level of the network protocol with system driver's transport protocols (eg, TCP / IP for Ethernet) at both the CNC tasks and Soft PLC;
- diagnosis and monitoring of the network connection to the modules of the control system.

For developers of PLC machine programs component elements of CNC- Soft PLC interface are present as following:

- Components of Soft PLC, which implementing access to the input/output signals [11];
- function block library, which describes the interaction of interface signals CNC- Soft PLC and how do they work;
- configuration data set tools for information exchange between the CNC and the Soft PLC;
- diagnostic tools providing opportunities for interaction between NC data and Soft PLC [12].

A set of data to be exchanged between CNC and Soft PLC tasks is formed in the core of the control system (Fig. 2 block "data model CNC- Soft PLC») based on the configuration of machine parameters of machine equipment. Machine parameters describe the number of channels, the axes of spindles, tool changer stores etc., to be used on the machine. According to the configuration parameters of the machine, the set of object data is formed for communication with Soft PLC in a special region "common memory of data" (of NC-PLC interface). Thus access to the data can be obtained by the local implementation of Soft PLC (executed with NC tasks on a single processor), as well by implementation of remote (via network protocol).

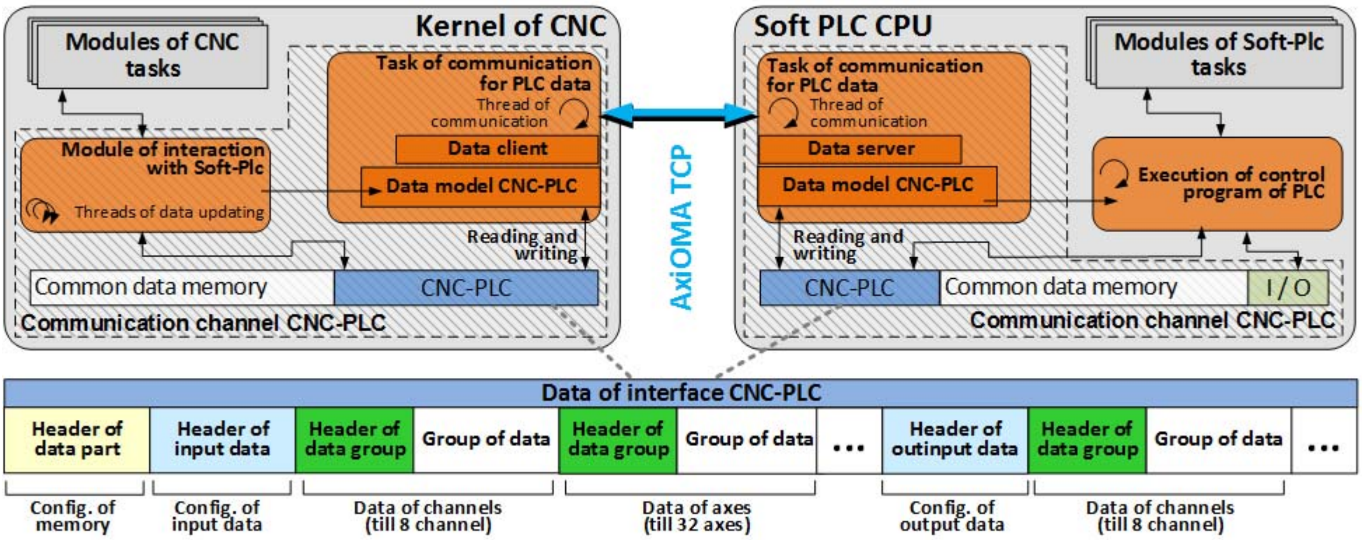

Fig. 2. Interaction of CNC and Soft PLC tasks by protocol AxiOMA TCP

Description of CNC-Soft PLC interface data structures is transferred to the Soft PLC in the form of a header area of memory distribution (metadata) during initialization of the network connection. As a result, the data of cyclic network exchange are arranged in the same sequence in memory of the device (or several devices) of Soft PLC. This ensures access to the data from the PLC program which provides a library of functional blocks operating in accordance with the received structure.

V. Conclusion

Geometrical and logical control tasks can be implemented on different hardware modules of control system. When performing a number of conditions related to the availability of the control modules in the network communications, potentially increases the reliability of the control system. The usage of microcomputers as a platform to perform tasks Soft-PLC allows the integration of additional I/O devices such as scanners of QR codes for tool magazine, readers of magnetic access control keys, monitors of visualization functions and parameters of PLC devices, etc.

The comparison of characteristics of single-board computers for foreign and domestic production has shown the possibility of usage of them to create distributed modules of Soft PLC. Their hardware supports Linux operating system family and has a rich set of interfaces for connecting peripheral devices for control.

In AxiOMA Control system, the interaction between PLC and CNC kernel functions is implemented through a special data set for interface CNC-Soft PLC. The configuration of such data is generating based on the current machine parameters of the control system: the number of channels, the axes, tool stores etc. Functional blocks of CNC-Soft PLC interface implement data access based on the configuration received from side of CNC.

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