Computer Science Journal of Moldova, vol.7, no.2(20), 1999

The main principles of small systems development for manufacturing and research automation

O. Nicolaiciuc, E. Guţuleac, V. Cheibaş

Abstract

Major factors are described that determine the development of small automation systems of manufacturing and research for use in small production companies and research centers. The requirements towards stations and networks are emphasized and their properties are outlined along with the main systems development trends.

1 Introduction

Key factors that impact the development of small automation systems of manufacturing and research are:

- Falling prices of personal computers combined with significant advancement of their computing power and reliability;
- Appearance of powerful and cheap **MCS-51** and **AVR** family of microcontrollers by Atmel Corp. and **PIC** family of microcontrollers by Microchip Corp. These are characterized by high productivity comparable with that of i386 computers, low power consumption (< 6mA) combined with relatively high loading power (up to 20mA);
- These microcontrollers have a built-in electrically programmable flash program memory and non-volatile data memory, serial high-speed ports, several timers and an advanced interrupts system.

©1999 by O.Nicolaiciuc, E.Guţuleac, V.Cheibaş

Some microcontrollers include: $10 - 16$ bit analog-to-digital and digital-to-analog converters, analog comparators and an advanced sleep-protection system **WDT** [1, 2];

- Global trend to re-structure large industrial and scientific establishments and break them down into smaller production and research enterprises;
- Severe decline or full disappearance of centralized funding for manufacturing and research automation in many countries;
- Moral obsolescence of expensive modular systems such as **CAMAC**, **MULTIBUS-II**, **VME-BUS**, etc., decline of their production, and stronger trend for developing bus-modular systems [3].

The listed characteristics of modern microcontrollers, their low cost, sinking prices on personal computers (**PC**) determine the replacement in development of research and production automation of obsolete and expensive modular systems **CAMAC**, **MULTIBUS-II** by modern small distributed Multi-Microprocessor Systems [4, 5] with up to 20 independent units. These systems are designed for use in small industrial and research enterprises.

2 General systems trends

Practically in all works devoted to architecture of modern small systems of automation of manufacturing and research the following general trends are observed: **decentralization, minimal cost, simplicity of installation and use, high efficiency**:

- The modern concept of **decentralization** of systems also assumes territorial dispersion of the computing system, and separation of system's function (measurements, primary processing and management) into a series of weakly-related functions, and allocation of these functions between several decentralized processors

[6]. Therefore, modern **Decentralized** Systems are **Systems with Multiply Instruction and Multiply Data – MIMD**. Territorially dispersed decentralized systems are commonly referred to as **Local Area Networks – LAN**, and separate independent elements of a **LAN** as **Stations**. On the other hand, each **Station** also can perform a few weakly related functions simultaneously and consists of several weakly related processors, i.e. a **Multi-Microprocessor (MMP)** Station;

- Development of **decentralized** automation systems of manufacturing and research in a small business environment takes **minimal cost** as one of the basic requirements;
- Systems designed for operation in these conditions should satisfy the requirement of **simplicity of installation and use**, and allow easy modification;
- The concept of **maximum efficiency** is based on the ratio of productivity and price. However, presently this concept also includes **minimal redundancy** of the system. By redundancy is meant hardware redundancy (unutilized units of equipment or excessive control signals), and temporal redundancy (for example, transmission of excessive data through networks).

3 Development Principles of Stations Architecture

In the works devoted to architecture of modern concentrated **MIMD** systems for manufacturing and research automation (**Stations**), the following key features and tendencies are to be noted:

- **Modularity** is a property of a system with territorially concentrated elements (**Stations**) that enables a constructive performance of all units as a set of the functionally complete and independent modules with an interface identical to that of the **System Bus**;

- **Flexibility** – a property of **Modular Systems** that allows easy change of structure using various module combinations. In addition **flexibility** implies a facility of system modernization by independent modernization of each of its modules. The development of new systems is simplified and the term of their moral obsolescence is extended through implementation of a combination of new and already existing modules. This improves structural regularity and as a consequence the system's **control- diagnostic qualities**. This also ensures that it is easy to reorganize the system to control a different management or research object;

- **Modularity** also allows easy replacement of failed modules, i.e. system's **maintainability** increases;

- The concept of **Modularity** is closely connected to the concept of **System Bus**, i.e. it is expected that all modules have identical sockets with contacts connected in parallel (**System Bus**). There are more than 250 various Bus-Modular Systems created to date, the most known of which are **EUROBUS, VME-BUS, FASTBUS, MULTIBUS-I/II, P-896, CAMAC**. However, most of them are morally obsolete by now. Many other appear to be redundant and too expensive. In addition these standards are lowly compatible with the "de-facto" industrial standard of **MCS-51** family microcontrollers and with the hardware compatible **AVR** family. Besides that, the former are lowly compatible with frequently used **MCS-86/88** and **MCS-80/85** microprocessors. As a rule, modernized **P-896** and **MULTIBUS-II** interfaces are widely used in modern systems;

- **Upgradability** – capability that allows modifying the number of modules in a station or the number of stations in a network;

- **Multifunctionality** – property of stations having no rigid specialization or attachment to the specific object of management or research, thus capable of carrying out various functions;

- **"Intellectuality" (Intelligence)** – the property of most modules determined by the presence of programmable microcontrollers or microprocessors that use individual programs. By updating the software one can easily change intelligence levels;

- **Constructive uniformity** – constructively uniform execution of all modules in a station. The dominant standard today is **EUROCARD** (IEC48D, 1980), that allows the creation of card sets as a combination of the optional sizes of (160 and 220mm) wide and (100 and $233,53$mm) high. Most widely used are **E2** cards sized $220 \times 233,53$mm (**MULTIBUS-II**) and **E4** sized 100×220mm (**EUROBUS, ESONE**);

- **Multi-Bus Systems** – simultaneous use in one station of several various **Buses**. Such a technical solution is widely used in modern **PCs** and in many **Bus Modular Systems**. Most widely accepted are the **Two-Bus Systems**, each bus having several localized weakly-connected microprocessors and microcontrollers of various capacity and word length. **The buses** are interconnected through a general **Two Ways Resource**, most frequently – **Data Memory** [6, 7, 8];

- **Sufficient productivity** – indispensable principle for development of the problem-oriented systems. The achievement of necessary productivity is achieved, as a rule, by creating multiprocessor systems in one station capable of parallel execution of several independent tasks or of several parts of one task. In addition higher reliability is obtained by the **Gradual Degradation** property of the system that is achieved by task re-distribution between various processors in case of failure of one or some of them. This also means higher flexibility of the system;

- **Program Compatibility** – requirement for all microprocessors and controllers in the system – allowing the use of a rich arsenal of previously created software applications. Presently, when one system contains several computing elements based on various families of processors (**Pentium-II, MCS-86/88, MCS-80/85, MCS-51, AVR** etc.) this requirement is fulfilled by coding the software using a high level programming language (as a rule – "C");

- The development of **Bus-Modular Systems** requires **Maximal Universality** where every added module ensures the widest possible number of applications;
- **Non-synchronization and Minimum Number of Control signals** simplifies the protocol of exchange between modules, increases reliability of communication and transmission speed;
- When developing small size distributed systems that measure and process large amounts of data it is often necessary to provide **Local Visualization** of the operative information on the stations, which greatly simplifies system usage.

4 Principles of network architecture development

The requirements for architecture, organization, environment of networks and transfer protocols are also determined by the current technical and economic situation:

- Falling prices on personal computers combined with dramatic growth of their computing power and reliability, the fact that peripheral devices remain the most expensive part of a PC, and **minimal cost** requirement of a network, all these determine another important feature of modern small systems of production and research automation – **information-command principle** of **LAN** architecture. According to this principle the single **PC** included in a LAN, plays a role of a task generator and data receiver. It carries out secondary processing, ordering, saving and visualization of the data. **Peripheral Stations** measure analog and discrete information from various gauges and carry out its preliminary processing. They also operate with various external objects, self-test, and transfer the obtained information to the **PC**;

- In order to minimize system's cost and maintain interchangeability, standard-configuration **PCs** are used, while communication is carried out using the **RS232C** hardware;
- One more requirement for a modern **LAN** operating in conditions of strong electromagnetic and electrostatic fields is **Optical Isolation** of at least 500V of all peripheral stations;
- In order to minimize the size of network transmission frame and decrease the loading on **RS232C** hardware, the developers resort to limiting the number of **Peripheral Stations** in a network and the number of commands for one station to that of 16. This enables them to combine in one byte both the command and the address (similar to register commands in microprocessors);
- The most expensive and labor-intensive element of a modern **LAN** is the **Transmission Medium** (cable). Therefore, in systems undergoing frequent modernization, it is desirable to use standard cables and connectors;
- The length of a **Transmission Medium** for the **RS232C** interface influences the transmission speed. Therefore it is desirable to limit its length to a minimum;
- When developing a small **LAN** the most economic topology is a **Bus Topology** with separated transmission lines from the **PC** to the **Stations** and from the **Stations** to the **PC**. The transmission from **PC to Stations** is a broad-cast, while from **Stations to PC – Multiple Access LAN with Collision Detection** is used;
- Use of the **RS232C** interface means that the basic strip of frequencies is used – **Baseband LAN**;
- The **Information-Command Principle** of **LAN** development assumes the following basic modes of data exchange:

– Reception of tasks by one or several **Peripheral Stations** from the **PC**;
– Reception by the **PC** of measurement results sent by any **Station** on **PC** request;
– Self-testing by any **Station** on the **PC** request with transfer of testing results back to the **PC**;
– Hardware reset of all **Stations** initiated by the **PC**;
– Reception by the **PC** of emergency information initiated by any **Station**.

5 Conclusions

To summarize, general trends for developing modern **small systems of manufacturing and research automation in small product companies and research centers** are outlined. Described are their common requirements and basic features:

1. In modern systems a clear trend is observed of creating **Specialized LANs** and **MMP Stations**;

2. The **Stations** of modern systems should satisfy such common requirements, as **Modularity, Bus Organization, Flexibility, Open Organization, Constructive Unity, Continuity and Software Compatibility**;

3. Most economically and technically feasible for modern **Information-Command LAN** is the **Bus Organization** with centralized access, having a minimal cable length, with one coordinating **PC** and several **Peripheral Stations**. All **Stations** should have **Optically Isolated** network environment, **Standard Configuration PCs** and **RS232C** transmission protocol should be used along with **Standard Cables**;

4. The most feasible for use in **Peripheral Stations** are powerful and reliable 8-bits **MCS-51** and **AVR** family **microcontrollers**,

and occasionally **MCS-86/88** and **MCS-80/85 microprocessors**;

5. In systems processing **Large Arrays of Data** it is necessary to integrate **Local Visualization** of the information into **Peripheral Stations**;

6. For the purposes of achieving necessary productivity of **Peripheral Stations** the use of concentrated **MMP** with **Two-Bus Architecture** is recommended.

7. As a development basis for **Peripheral Stations** of a **LAN** it is preferable to use **EUROCARD Constructive Lines**.

References

[1] Atmel Application Specific Standard Products. http://www.atmel.com

[2] Microchip Products. http://www.microchip.com

[3] Nicolaiciuc O.I., Bejan L.S., Vapirov V.V. Development Perspectives of BUS-module systems for automation productions and scientific researches, Materials of subtrade conference "Data Base and COMPUTER knowledge's", 28-30 Sept. 1988, Rostov on Don, p.7.

[4] 17th Conference on local computer networks, Sept.13-16, 1992, Minneapolis (Mn): Proc. -Los Alamitos(Ca) et al: IEEE computer soc.press, 1992, XVI, p.710 IEEE publications, Inst.of electrical and electronics engineers (New York).

[5] International conference on parallel architectures and computation techniques (4;1996;S.L.). Papers of the fourth international conference on parallel architectures and computation techniques Pt.1. 1997, pp.243–338.

[6] Torgow U.I. Use of a few microprocessors in microcomputer, Microprocessors funds and systems. 1985, No 1, pp.70–75.

[7] Nicolaiciuc O.I., Culibaba A.B., Krupski V.F. Multi Microprocessors graphic CAMAC station for production automation, scientific researches, automated designing. VI Symposium "Module information-calculable systems" (Vilnius, 21-23 October 1987): Vilnius: Sciences Academy Lit. SSR, 1987, pp.127–128.

[8] Nicolaiciuc O.I. Specialized Multi Microprocessors Control system. 3-rd Conference of young scientists and specialists on current sources and to transformation of energy and information (Moscow, 1987): Moscow: Sciences Academy USSR, 1987, p.155.

O.Nicolaiciuc, E.Guţuleac, V.Cheibaş,
SEC "Informinstrument SA",
Str.Puşkin,6
MD2012
Phone: +373–2–240–505
e-mail: onic@ch.moldpac.md

Received September 9, 1999