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TECHNICAL TREND OF PROGRAMMABLE CONTROLLERS

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1. FOREWORD

Nearly 20 years ago, the first programmable controllers emerged on the market. Since then programmable controllers have posted remarkable market growth, rising to a scale of about ¥130 billion in 1991. As the demands for programmable controllers expands, users needs also diversify. Users can choose from a broad array of programmable controllers in sizes from large to small, to suit various purposes.

Now manufacturers are making small programmable controllers even more compact. As programmable controller functions improve, the manufacturers devise mounting and extending methods, making these models useful for simple intelligent control.

Applications for large versions expand in range, particularly for models that combine special control and general-use processors to perform controller and computer functions.

Since 1971, Fuji Electric has worked on programmable controllers, the F-MATIC FUJILOG and MICREX series. In 1990 new FLEX-PC series was developed aiming for mechanical control.

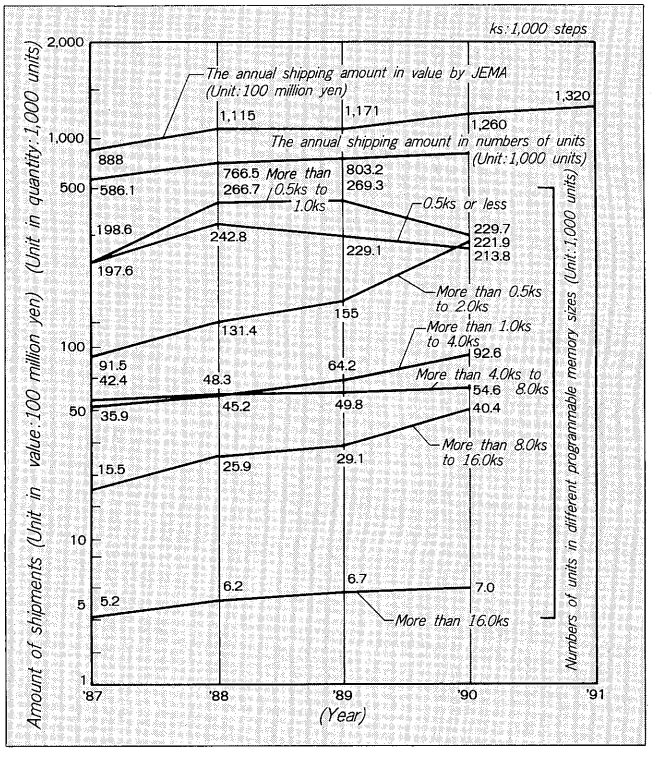
2. MARKET OF PROGRAMMABLE CONTROLLER

In the past, programmable controllers exhibited elevated annual growth rates between 20 and 30 percent. While the industry now cannot duplicate this performance, demand for programmable controllers gains ground steadily. Figure 1 shows shipment statistics of programmable controllers from the Japan Electrical Manufacturers' Association (JEMA).

Programmable memory sizes offer a typical index of programmable controller sizes. Recent statistics point to significant changes in these areas. Growth in shipments of small-capacity programmable controllers, those with 1 k-word or less, is slowing, while shipments of medium-capacity models with 2k to 4k-word memories is growing. This also may reflect the increasing demands for man-machine interface services and data processing control among users of small programmable controllers.

In mechanical control equipment fields, widespread use of customized controllers with microcomputers make this equipment as common as programmable controllers. Trends to use microcomputer-based models may indicate the existing programmable controller's inability to fully satisfy needs for mechanical control.

Fig. 1 Shipment of the general purpose PCs in Japan

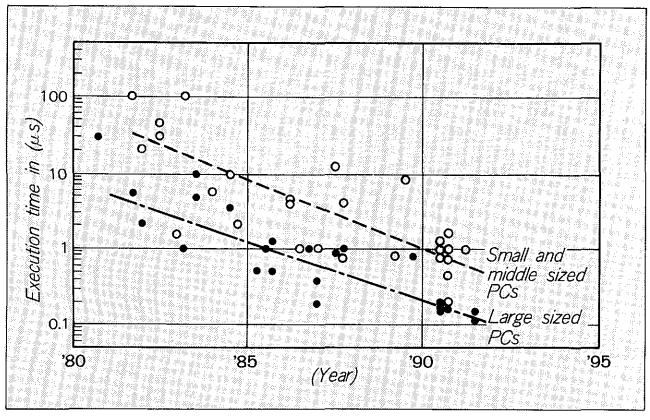


However, microcomputer-based systems face several problems in development costs and time, as well as service. For this reason, users want manufacturers to develop general-use programmable controllers that can respond adequately to most user requirements.

Users today require:

(1) a degree of freedom in input/output configurations and varieties, to suit the controller to each control task.
(2) controllers realize a special specification of each machine, to accommodate tasks such as rapid processing.
(3) Man-machine interfaces should be able to suit machines.

Fig. 2 Trend in basic instruction execution time of PCs



3. TECHNICAL TRENDS

3.1 Functions

Trends today include network systems for factory automation and computer-integrated manufacturing (FA and CIM), systems that process large amounts of data for FA and CIM, the widespread use of various advanced units and enhanced control quality. Such trends raise the capacities of program and data memories and the data processing speeds.

Figure 2 plots the main programmable controllers' speeds for basic instructions during the past 10 years. The latest large machines commonly attain processing speeds of 0.15 μs, while small models generally operate at 1μs or faster. In addition to faster processing speeds for basic instructions, today's machines also work faster than before with functional instruction such as transfer, comparison, arithmetic and the operating system processing time, including input/output processing and fault detecting and recovering processing.

In structural evaluation, the controller system's overall dimensions are as important as those of single controllers. Manufacturers and designers must examine a number of issues to assure flexibility and to provide the configuration that best matches specific machine requirements.

For example, it is necessary to select freely the number of input/output (I/O) points, the kind of I/O and the method to extend the I/O. Additionally units like fast counters and pulse output units and indicators, must conform to standards. And wherever possible, the designers must streamline wiring throughout the system.

3.2 Programming

In factory automation, accelerated processing speeds make it necessary to improve the software development environment. With the growing number of programmable controllers in use and the expandisng memory capacity per controller, users must generate additional programs.

3.2.1 Language

Instruction set in programmable controllers have great significance in the application software's development efficiency. With the extending scope of programmable controllers, developers find it necessary to add many instruction words for numerical arithmetic, code conversion, communication control and other functions. Consequently, programmable controllers today contain more than 300 kinds of instruction sets.

For convenience, users want the ability to select the optimum use for the largest possible number of instruction sets. However, even with programs created for the same processing functions, different operators may use the instructions differently, causing two problems. First, programmers cannot read programs which other programmers create. Secondly, after long periods of operation, maintenance will become difficult. There are two approaches to solve these problems.

In the first approach, designers adopt modular, functional and macro concepts similar to those in computers. Under this approach, it may be advisable to expand the subroutines in programmable controllers to full-scale systems.

In the second approach, designers employ the sequential function chart (SFC), which is a high-order concept of the ladder-like programming in conventional programmable controllers. SFC attracts industry's attention because it is an excellent programming method for sequential control, which is typical in mechanical control.

3.2.2 Tools

As for tools, a number of loaders that use personal computers (except special loaders) now enjoy popularity as programming tools. Items in this category include small maintenance loaders attached to the machine and advanced loaders with build-in floppy disk and ROM writers. These models are the specially designed keyboard loaders.

Although personal computer-based loaders offer slightly lower operability than dedicated loaders, they provide a number of advantages that makes them useful as the main programming tools.

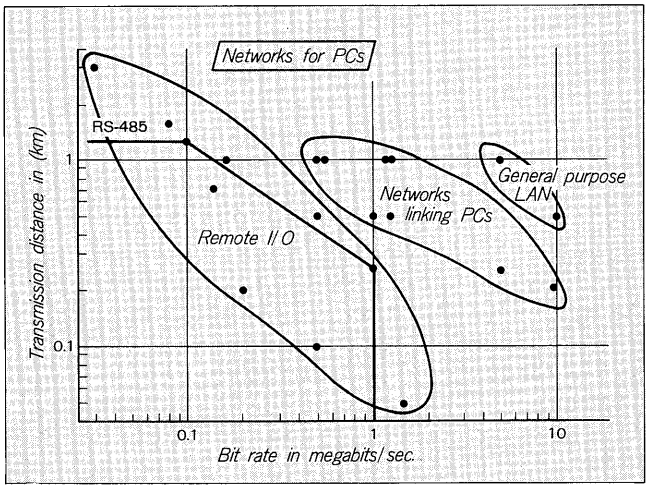
(1) Less expensive than comparable equipment, they are available anywhere.
(2) Improvements in personal computers automatically enhance the hardware performance of these loaders.
(3) At the same time, many engineers know how to use personal computers skillfully.

Many users adopt computer-aided design (CAD) systems to program software. While CAD systems are relatively expensive, their features mean CAD will become one of the main workstation tools for mechanical control. CAD provides a unified, compatible tool for users of programmable controllers from different manufacturers. With CAD, users can create and manage the peripheral circuits and can structure designs in a uniform manner, in programming the programmable controller. CAD also provides excellent documentation capabilities.

3.2.3 Operability

For these tools, users chiefly require operability. Efficient design activity depends on simple operations that do not interfere with the programmer's train of thought.

Fig. 3 Network classifications and their performances



Those tools must offer advantages similar to those of personal computers, for example the ease of using personal computer software or basic items such as attractive screens, simple actions and uniform operating procedures. Other features to enhance operability include HELP functions, free keyboard assignments and macro keys to initiate multiple, continuous operations with a single stroke.

3.3 Network

Programmable controllers have been used as system components for assembly within equipment. However, the items that programmable controllers must process are becoming larger; they range from standalone machines to production lines and overall factories. In this environment, networking functions that allow easy distributed control of a system will become important.

JEMA research on machine manufacturers and switchgear or controlgear manufacturers indicates that 75% of such makers use networks. Programmable controller networks adopt one of three classifications:

(1) full-scale networks, include host computers;
(2) relatively small networks connecting programmable controllers;
(3) networks of low-level programmable controllers, generally called remote I/Os.

Figure 3 shows the plots of transmission distances and speeds in different networks from various manufacturers. Multiplying the transmission distance by the transmission speed provides an indication of network performance.

Full-scale network includes manufacturing automation protocols (MAP), mini-MAP and Ethernet*[1].

Small networks to link programmable controllers also accommodate microcomputers, personal computers, numerical control (NC) machines and robot control equipment. For such networks, manufacturers must offer low hardware and construction costs, plus simple communication. Manufacturers of programmable controllers offer special networks.

*1 Ethernet: Registered trademark of Zerox Corp.

Manufacturers offer dedicated networks for remote I/O systems. These range from the general-use versions with distribution to 32 units, including the I/O and the operational indication unit (programmable operation display and programmable display, POD and PD) within a 1km diameter, to the economical, so-called cable-saving networks with 10 units in a 100 m range. The RS-485 standard transmission line for networks features a relatively small construction cost, as *Figure 3* shows.

Networks serve as the programmable controller's main interface with other machines; in such systems, it is relatively easy to adopt and adhere to specific standards. At the same time, the two overriding considerations are user needs for multiple venders and for cost-effective systems.

3.4 Advanced-Function modules

In many cases, programmable controllers offer intelligent I/O functions, to handle processing that takes place outside the controller. Among the varieties of intelligent I/O functions are user-machine interfaces, actuator connection and intelligent actuator control functions. Such designs add to the value of programmable controllers, while enhancing space efficiency, cost performance and ease of use.

3.4.1 MMI

Programmable controllers now come with timer and counter features. However, operating these functions requires a loader, but machine operators cannot operate these features, so that it is necessary to add hard timers, counters, digital switches and indicators. Now indication setting units replace some of the external functions. Some manufacturers build all the functions including the operation panel, into the programmable operation display (POD).

3.4.2 Intelligent modules

Enhanced microcomputer performance and small electronic devices, such as surface-mounted devices (SMDs) make it possible to house advanced-function control units in cases the size of parallel input/output (PIO) modules. Various practical-use modules now are available, such as the position control unit, the voice composite unit, the magnetic card reader/writer, the ID controller, the fault diagnosis unit and proportional plus integral plus derivative (PID) controllers. Manufacturers will expand their lineups of such modules.

3.5 Maintenance issues

According to JEMA research, there are several faulty points and causes of faults, as *Figure 4* and *5* show. Most of the faults show up at the I/O point and the most common causes include load short-circuiting and defective connections. Now developers study ways to adopt intelligence at I/O points and to use output that contains overcurrent protection.

In addition, many faults arise from unknown causes. The cause of these faults include operating environments

that deteriorate as application scopes expand. One way to solve this problem is to enhance the level of noise and vibration immunity.

Overall, maintenance of programmable controllers should be simpler than it is. As programmable controllers become more complicated and users face growing difficulties in recruiting qualified technicians, it will become necessary to simplify maintenance procedures.

4. PROGRAMMABLE CONTROLLER STANDARDS

JEMA recently conducted research about the trends among users of programmable controllers and discovered that users give favorable ratings to the functions, performance and prices of programmable controllers, but give rather low ratings to compatibility. Unless or until the programmable controller industry adopts standards for programming languages and network interconnection, it will be difficult for users to construct FA and CIM in a multivendors environment.

Therefore, it is necessary to promote standards for programmable controllers and the networks. Today, two movements focus on standards for programmable controllers.

One comes from the Japan Industrial Standards (JIS) organization. Draft standards from the International Electrotechnical Commission (IEC) for "The Terms of the Programmable Controller" (JIS B3500) now are in place. Other drafts for JIS consideration include "Functional Characteristics of Programmable Controller", "Programmable Controller Language", "Test Methods For Programmable Controllers" and "Programmable Controller Communication". With these standards in place, programmable controllers with adopt common expressions and specifications.

The second movement for standards addresses international MAPs and lower networks such as mini-MAPs, interconnection plans for local area networks (LAN) compatible with multi-vendor programs. Some Manufacturers produce specific interfaces for programmable controllers in these environments, but the cost limits use of the interface to test situations. Eventually, the cost will drop, making the interface a standard for industrial LANs.

ME-NET operate as an inter-programmable controller network. While no one has proposed this system as a standard, its widespread adoption make it a de facto industrial standard.

At the low end field buses are under IEC consideration as programmable controller network standards, although it will take time to establish such a network. In Japan, JEMA promotes the adoption of the JEMA-NET specifications and decisions on this proposal are forthcoming.

5. CONCLUSION

In the past, considerations of programmable controllers focused on functions, performance and cost. More recently, ease of use has become the focal interest. According to JEMA's research on trends in programmable controller users, there is great demand for compatibility, simple instructions, common programming tools and a comprehensible manual. All of these requirements add up to a demand for ease of use.

As the industry settles issues of standards, manufacturers will find ways to satisfy additional user needs. To make programmable controllers easy to use, manufacturers will pursue ways to unify equipment as general controllers or machine controllers and to employ programmable controllers as the system core by incorporating user-machine interfaces and positioning functions within the system.