

Real-Time Expansion of Software Programmable Logic Controllers

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1. Introduction

Fuji Electric is providing “SPS” as a software PLC (programmable controller) for the “MICREX-SX” series of integrated controllers. The SPS is a PLC operated on Windows NT*¹, a general-purpose OS (operating system) for the PC (personal computer), and is well received because it shares the same programming language and development environment as the hardware PLC for the MICREX-SX. Realization of the PLC function on personal computers allows the development of applications utilizing the rich resources of personal computers and the merging of information technology (internet, intranet) with control technology, a recent trend.

OSs widely used in personal computers are primarily intended for office use. The SPS, whose processing speed is sometimes inadequate for direct machine control, is mainly used in a management system one layer above.

This paper introduces trends of software technology aimed at achieving an adequate processing speed for machine control and utilizing many of the rich and useful resources in personal computers and general-purpose OSs.

2. Real-Time Processing

Personal computer hardware is constructed as a system around a microprocessor and can be applied to every field including high-speed control.

On the other hand, OSs such as the Windows*² series contain functions to perform applications such as word processing and spreadsheets, where importance is placed on the human-computer interface, allowing comfortable operation. In other words, an OS places special emphasis on the batch processing of a large amount of information and on the response of human-computer interface processing. As a result,

*1 Windows NT: A registered trademark of Microsoft Corp., USA

*2 Windows: A registered trademark of Microsoft Corp., USA

these OSs are not necessarily most suitable for the processing of events such as machine control within a specified period of time.

The control performance required of machine control is the ability to monitor the conditions of machinery, and in response to their changes, to compute and output data within a given period of time, generally 1 to 10ms. In addition, response to a given change must be consistent from the viewpoint of accurate repetition of control.

OS functions that respond to and process external events are classified into soft real-time and hard real-time processing functions. In soft real-time processing, the output of results after the receipt of changes (interruptions) of an external event is not necessary performed within a certain period of time, but is used for clerical work. Soft real-time processing is used with an OS such as Windows. In hard real-time processing, it must be guaranteed that the output of results after the receipt of changes (interruptions) of an external event be performed within a certain period of time. In most case machine control requires hard real-time processing.

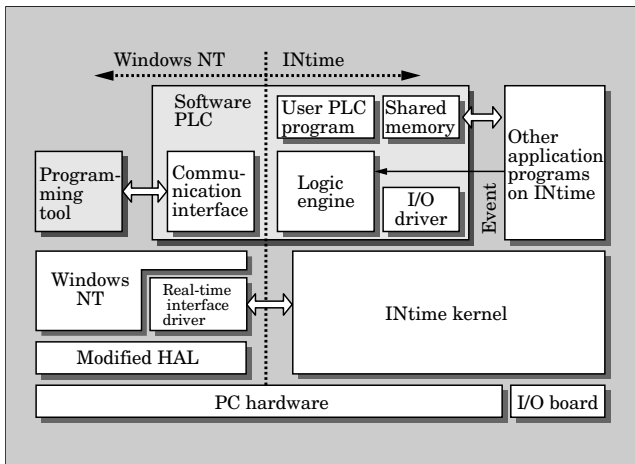
Software PLC with additional hard real-time performance is described below.

3. Software PLC by Real-Time Expansion of Windows NT

3.1 Real-time expansion of Windows NT

Since being released in 1994, Windows NT has steadily come into widespread use as an enterprise key system with its increased functions due to upgrades and improved stability. However, because Windows NT is based on a TSS (time-sharing system), it has been said that it is inferior to conventional real time OSs with regard to real-time characteristics and reliability when applied to an embedded system. To solve this problem, it has been proposed to develop a system that gives Windows NT the same real-time characteristics as that of a specific-OS and the reliability to continue real-time operation in the event of blue screen crash by expanding Windows NT with third parties. RTX of VenturCom Co. and INtime of Radisys

Fig.1 Software construction (software PLC on Windows NT real-time expansion)



Co. are well known as such systems. Here, Fuji Electric implemented a software PLC on INtime2.0, and the construction and main features are described below.

3.2 Software PLC construction on INtime

INtime incorporates the iRMX kernel, an OS developed by Intel, into Windows NT4.0 to realize real-time characteristics. Specifically, Windows NT is positioned as the lowest priority task and is controlled by the INtime kernel, where all Windows NT tasks run. Such construction guarantees real-time characteristics of INtime real-time programs and continuous operation in the event of a Windows NT crash.

Figure 1 shows the software construction of the software PLC that was installed. The PC hardware is a CPU board for PC/AT*3 compatible personal computers or embedded PC boards. A modified HAL (hardware abstraction layer) expands the time-base and interruption management in the HAL that depends on the PC hardware, and upgrades real-time characteristics of INtime applications. A real-time interface driver supports communications between Windows NT and INtime applications. Software PLC runs on this Windows NT real-time expansion. Software PLC consists of two modules and runs on Windows NT and INtime. Running on the INtime side are a control engine to perform sequence control and a field bus I/O driver; user programs are also executed. On the Windows NT side there exists a communication interface for programming tools, which initializes programs on the INtime side. As a result, support is available from programming tools installed on the same PC or other PCs.

3.3 Linking with external application programs

To establish a link with applications on either

*3 PC/AT: A trademark of International business Machines, Corp., USA

Table 1 Main specifications (software PLC on WindowsNT/ real-time expansion)

Item	Specification
Operating environment	OS: Windows NT4.0 SP3 INtime2.01 CPU: Pentium 75 MHz or more Main memory: 48MB or more Hard disk: 1GB or more Extension bus: PCI
Cyclic task	1 (minimum period: 2ms)
Periodic task Event task	16 priorities, 32 tasks
I/O control method	Task synchronization
Programming language	IL, ST, LD, FBD, SFC (conforming to IEC61131-3)
Program capacity/POU	ca. 5k steps/POU

<Note> Pentium: A trademark of Intel Corp., USA

INtime or Windows NT, software PLC is provided with the following.

(1) Event task start

PLC event tasks can be started by applications on another INtime, permitting the synchronous execution of external applications and PLC tasks.

(2) Shared memory

Software PLC can share the same area of memory with other applications. The shared memory can be directly accessed by a PLC user program and used for data exchange with other applications.

(3) Function block for file operation

Software PLC is provided with a function block to allow access of file systems on Windows NT from PLC user programs and to permit the setting and storing of machine control parameters from a file.

(4) Function block for message data exchange

Software PLC is provided with a message function block to perform message data exchange with other applications and to permit alarm and status notification from user programs.

3.4 Main features and specifications

The use of a real-time expansion OS on Windows NT allows the software PLC to achieve excellent real-time characteristics, robustness and linkage with the rich software assets of Windows NT. Table 1 shows the main specifications of the system.

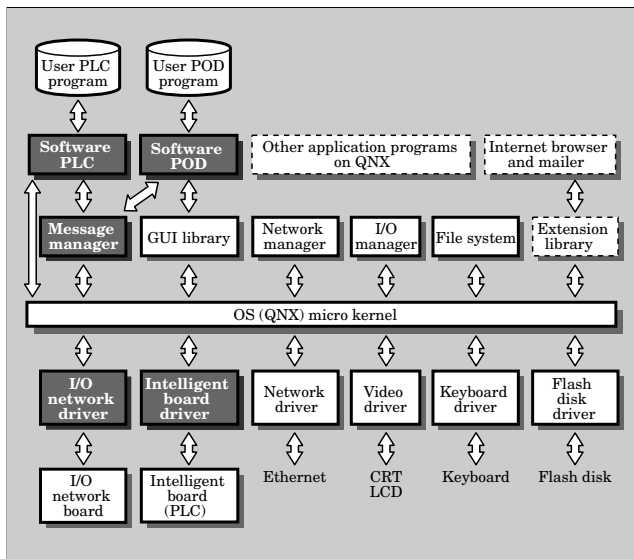
4. Software PLC Using a Real-Time OS

In systems embedding in machines, cost-effective development within a short time period is increasingly required. Based on the requirements of embedded systems, Fuji Electric has developed a software PLC using a real-time OS. This chapter introduces the software PLC based on the platform of a general-purpose real-time OS.

4.1 Features of a real-time OS

The Windows OS generally requires a large auxil-

Fig.2 Software construction (software PLC on a real-time OS)



ary storage device and prescribed procedures for turning power on and off to the system.

In most cases, controllers for machines are installed in environments that are severer with regard to vibration and temperature, than those of office use. Power is turned on and off at random, different from office use. They also require easy maintenance. In other words, a system is required that can be executed with a silicon disk device of small storage capacity having no moving elements, and for which boot-up and shutdown processes are not necessary. In addition, to facilitate maintenance, moving elements of limited serviceable life, such as a fan, must be reduced.

To meet these requirements, a software PLC was installed on a general-purpose real-time OS.

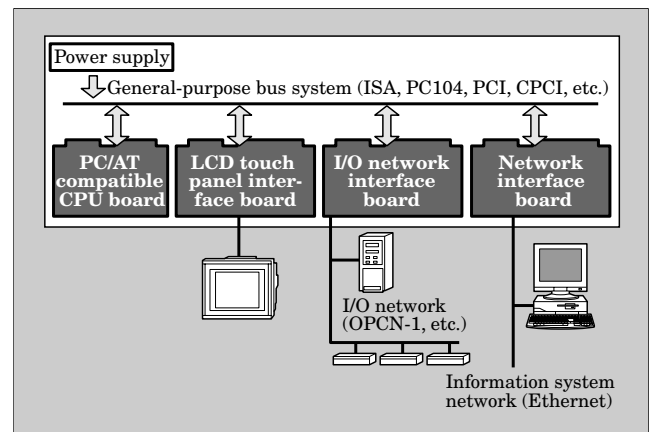
4.2 Software construction

Figure 2 shows the software construction. QNX*4 was utilized as the real-time OS. Centered around the OS is a PLC system and an interface for performing I/O operations with the outside. A HMI (human-machine-interface) is connected to a POD (programmable operation display) through a GUI (graphical user interface) library, permitting the construction of the HMI in the same environment as that of Fuji Electric's hardware POD.

Interfacing with the outside is performed by I/O networks and intelligent boards. Connected to the I/O network are various Fuji Electric networks for I/O devices such as an SX bus and T-link, and an interface board for open networks such as OPCN-1 and DE VICENET. Data exchange between the boards and the interior is performed by device drivers. The software PLC and POD are connected to outside devices through

*4 QNX: A registered trademark of QNX Software Systems Ltd., Canada

Fig.3 Example hardware configuration (software PLC on a real-time OS)



a message manager, and perform upload/download operations of user programs using a general-purpose network (such as an Ethernet*5) as well as read/write operations of external information.

The OS performs task management of these programs. Various other general-purpose libraries can be added to the OS, and an internet- and intranet-capable browser and mailer can be installed on the OS, establishing a system with high expandability.

Figure 3 shows an example of the hardware configuration, where various boards are connected by a general-purpose bus.

HMI operation is performed through LCD keypad panel interface boards and the HMI exchanges information with external actuators and sensors through I/O network interface boards. In addition, network interface boards are connected to an information management system through general-purpose interface boards such as an Ethernet.

4.3 Main features and specifications

Using a low-end OS allows the system as a whole to be made compact in size. Personal computer software for clerical work cannot be used for machine control because the OSs are different. Various open networks can be used for embedded applications, enabling cost-effective development within a short time period and man-hour reduction, compared with the development of a dedicated controller.

Control performance of the newly developed controller is equivalent to that of a dedicated hardware microcomputer, and in most cases realizes satisfactory performance without using a state-of-the-art CPU. Consequently, a cooling fan necessary for a high-speed CPU can be eliminated, leading to cost reduction and easy maintenance.

Table 2 lists the main system specifications.

*5 Ethernet: A registered trademark of Xerox Corp., USA

Table 2 Main specifications (software PLC for real-time OS)

Item	Specification	Remarks
Operating environment	OS : QNX CPU : Intel386 or later version Main memory : 8MB or more File memory : 8MB or more Extension bus:ISA, PC104, PCI, CPCI	CPU and main memory disk differ according to the system size. Extension buses require their corresponding device drivers.
Cyclic task	1 (default task)	Min.: 1ms
Periodic task	4	N times of 1ms
I/O control method	Task synchronization	
Programming language	IL, ST, LD, FBD, SFC	Conforming to IEC61131-3
Processing speed (Sequence-/data-instruction)	200 ns/200 ns (Pentium 75MHz)	Data instruction : ADD
Program capacity /POU	Ca. 5k steps/POU	
Memory capacity	Max.: 256k words	
I/O points	Max.: 8,192	
Number of programs	Max.: 128	
Amount of FB registration	Max.: 512	

<Note> The system is intended for embedded use. The system configuration must meet the performance requirements.

5. Future Trends

With the lower prices and higher performance that result from the proliferation of personal computers, controllers for industrial use which are based on the personal computer platform are expected to increase significantly in the future. Where open architecture is demanded, it has become important to realize machine control using a general-purpose OS. Merits of using a general-purpose OS are as follows.

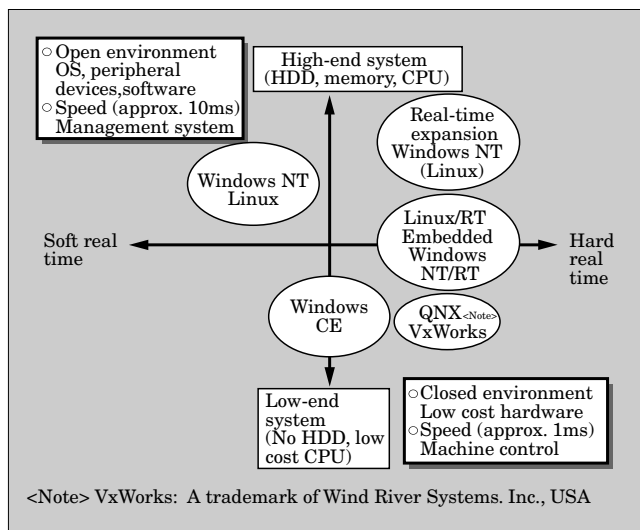
- (1) Can use various network protocols installed previously without conducting new development
- (2) General-purpose OSs have been installed in various machines and most have few bugs and high reliability
- (3) Complete GUI tools and library are available for constructing HMI
- (4) Can run third party software

General-purpose business-use OSs are produced primarily to satisfy requirements for the overwhelming number of household appliances and business machines. Those requirements are not necessarily appropriate for industrial use. To realize the merit mentioned in (4) above, it is useful to employ a business-use OS in the manner introduced in chapter 3, and to realize the merits mentioned in the above (1) to (3) in the manner introduced in chapter 4. Figure 4 shows various OSs and their compatibility.

○ Windows NT

Windows NT has a predominantly large market

Fig.4 Various OSs and their compatibility



share and an abundance of application programs. Many OS manufacturers offer real-time expansion.

○ Linux*⁶

Linux is a UNIX*⁷ OS which recently has received much attention. Its source code is public and is beginning to be used for embedded applications.

○ Windows CE*⁸

Windows CE is used for handheld personal computers. Reportedly, its real-time characteristics will be improved in the next and subsequent versions. Application to FA fields is expected.

○ Real-time OSs such as QNX

These real-time OSs are specific to embedded applications and superior to other OSs with regard to size and processing speed. OS manufacturers deliver network-capable open OSs.

For the time being, it is believed that an OS appropriate for each device will be used and it takes a long time before OSs for industrial use are unified.

In the future, a software PLC compatible with various platforms will be required. PLC based on real-time Java*⁹ will be realized in the future.

6. Conclusion

This paper introduced real-time expansion of the software PLC for the purpose of application to machine control. Keeping abreast of the rapid advances of PC-based controller systems, Fuji Electric will continue to develop and deliver optimum control systems to meet the needs of the time.

*6 Linux: PC UNIX created by Linus Torvalds

*7 UNIX: A registered trademark in USA and other countries licensed by X/Open Co. Ltd.

*8 Windows CE: A registered trademark of Microsoft Corp., USA

*9 Java: A trademark of Sun Microsystems, Inc., USA



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