Motion Controller Contributing to Automation of Factory Equipment

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ABSTRACT

Motion controllers are being increasingly required to increase the speed and precision of industrial machinery and equipment and improve the efficiency of equipment design, debugging, and start-up. To meet these customer needs, we have developed the "MICREX-SX Series" CPU module. By executing sequence control and motion control in parallel, this module can improve application execution performance by a factor of four compared with conventional products. It also supports EtherCAT, which is becoming increasingly popular as an open network, to enable faster and more accurate machines. In addition, it can utilize motion control FBs and logging functions to dramatically improve program development, debugging efficiency, and system reliability.

1. Introduction

Motion controllers are used to control the motion of industrial robots and other industrial machinery and equipment, thereby contributing to the automation of factory equipment. The handling of complex operations and machining, reduced process time, and improved precision are sought in industrial machinery and equipment. As such, motion controllers are required to have a level of performance that allows them to control a greater number of control axes at higher speeds. In addition, there is increasing demand from customers for the ability to select control system components with the best performance and price from among multiple manufacturers, resulting in the rapid popularization of EtherCAT*1 as an open network capable of realizing such system configurations. Furthermore, there is demand for a logging function for obtaining and visualizing control information to improve the efficiency of equipment design, debugging, and start of production; to determine the cause of failures; and to shorten response times.

In response to these market demands, Fuji Electric has developed new CPU modules for the "MICREX-SX Series" of integrated controllers for control, operation and monitoring. One of these is the "SPH5000M," which is compatible with the "E-SX bus," which realizes fast and highly accurate control performance. The other is the "SPH5000EC," which is compatible with EtherCAT and logging functions. This paper describes the SPH5000EC.

2. Features of the "SPH5000EC"

When the EtherCAT-compatible SPH5000EC is used as a motion controller, motion control programs can be executed four times faster than when using the conventional product, the "SPH3000D."

Figure 1 shows an example of a motion control system configuration that uses the SPH5000EC, Fig. 2 shows an example of coordinated high-speed control via an enhanced processor bus, and Table 1 shows the main features of the SPH5000EC. In addition, Fig. 3

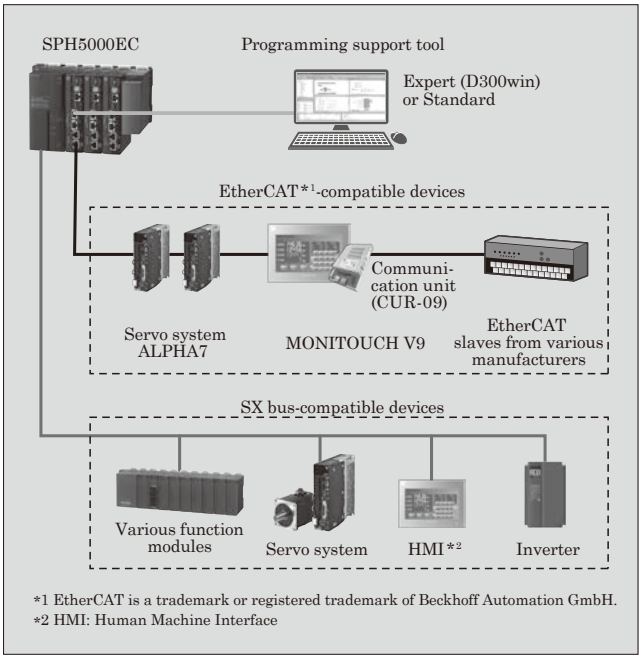

Fig.1 Example of a motion control system configuration that uses the "SPH5000EC"

*1 EtherCAT is a trademark or registered trademark of Beckhoff Automation GmbH

* Power Electronics Industry Business Group, Fuji Electric Co., Ltd.

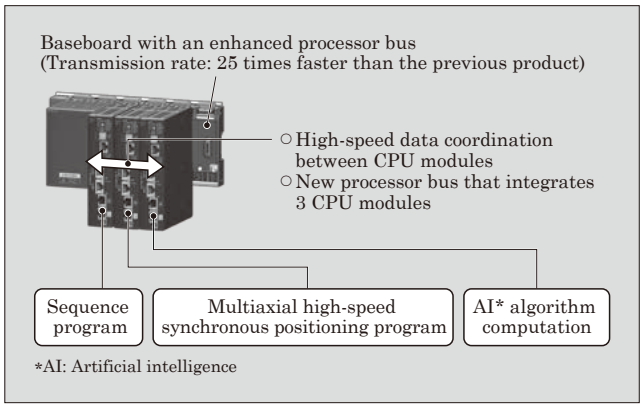

Fig.2 Example of coordinated high-speed control via an enhanced processor bus

Table 1 Main features of the "SPH5000EC"

Feature	Details
Application execution performance	Multi-core microcomputer achieving 4 times the speed of the previous model, the SPH3000D
Large capacity memory	Program memory: 512 Ksteps Data memory: 5,120 Kwords
Data backup	Maintenance-free battery with battery-less data backup method
Information network	Gigabit Ethernet*1 high-speed communications
Motion network	Support for EtherCAT*2
Data transmission between multiple CPUs	Enhanced processor bus achieving 25 times the transmission rate of the previous product Parallel execution of 3 SPH5000EC units for high-speed control
Logging function	Data collected inside the controller without affecting control, stored on an SD card, and displayed and replicated on a PC (Supported formats: NP1PA1C-256E, NP1PA1C-512E)

*1 Ethernet is a trademark or registered trademark of FUJIFILM Business Innovation Corporation
*2 EtherCAT is a trademark or registered trademark of Beckhoff Automation GmbH

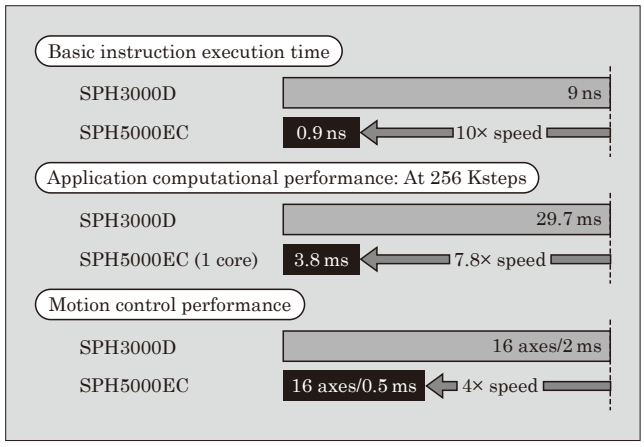

Fig. 3 Application execution performance comparison

compares its application execution performance with that of the SPH3000D.

3. Technology to Support Increased Speed and Reduction of System Construction Cost

3.1 EtherCAT communication technology

With the SPH5000EC, an open network can be configured by installing an EtherCAT communication port with high-speed and real-time performance on the front of the module.

Figure 4 shows the configuration of an EtherCAT system. As an EtherCAT master, the SPH5000EC can connect to various EtherCAT slaves, allowing a flexible system to be constructed by combining up to 238 slave devices to meet customer requirements. Such devices include Fuji Electric's "ALPHA7" servo system and "MONITOUCH V9" programmable display, as well as equipment made by other manufacturers.

In addition, when combined with a baseboard equipped with an enhanced processor bus, up to three SPH5000EC units can operate in synchronization with the control cycle.

For example, multi-axis motion control is possible for a maximum of 48 axes when the control cycle is set to a minimum of 0.5 ms (using three SPH5000EC units with 16 axes per EtherCAT line) and for a maximum of 192 axes (using three SPH5000ECs with 64 axes per EtherCAT line) when the control cycle is set to 2 ms.

In addition, as shown in Fig. 5, the SPH5000EC supports the EtherCAT Hot Connect function and is capable of connecting and disconnecting slaves while operating as the EtherCAT master. Since the configuration can include unconnected slaves at the end or in the middle of the network, the system configuration can be a mixture of required slaves and optionally added slaves.

Accordingly, we have developed an EtherCAT configurator that can be used to efficiently configure a flexible system.

As shown in Fig. 6, the EtherCAT network can be configured by launching the EtherCAT configurator from the "Expert (D300win)" programming support tool. Batch management of EtherCAT master and slave configurations can be performed in tree view by

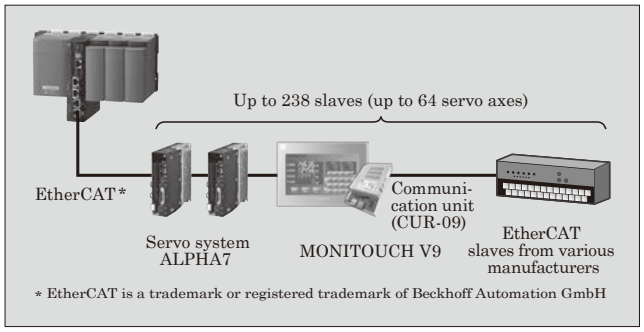

Fig.4 EtherCAT system configuration

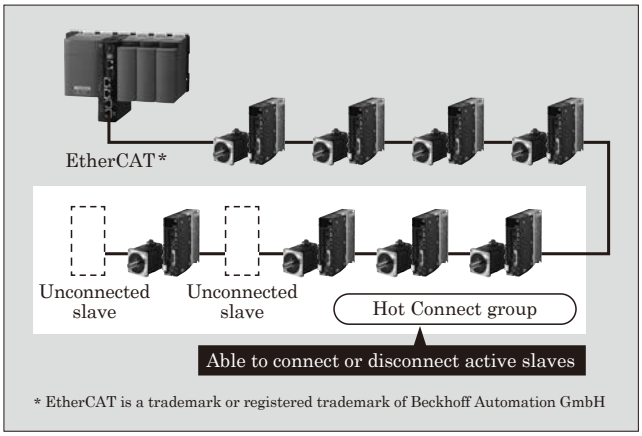

Fig.5 Hot Connect function

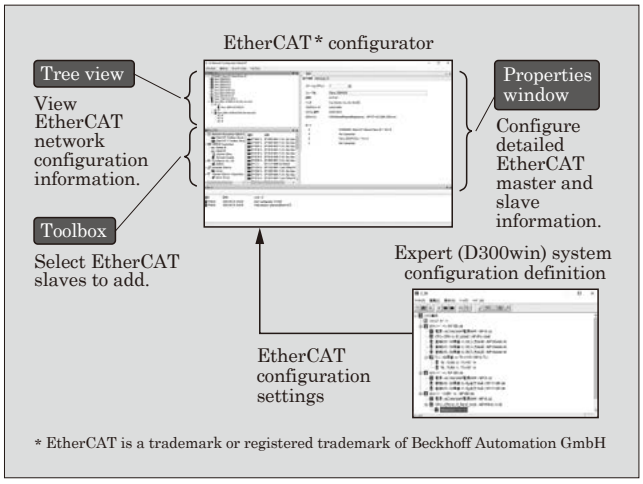

Fig.6 EtherCAT configurator

using simple operations, and the combined use of the Expert (D300win) and the EtherCAT configurator enables the configuration of flexible systems that include original Fuji Electric networks, such as SX bus, E-SX bus and T-Link.

3.2 Various motion control libraries

In addition to Fuji Electric's original motion control function blocks (FBs), we developed motion control FBs that conform to PLCopen*2 specifications as functional software that reduces the system construction cost borne by the user.

With Fuji Electric's original motion control FBs, various motion controls such as point to point (PTP) positioning, linear interpolation, arc interpolation, interrupt positioning, and synchronous operation can be easily realized. Furthermore, the motion control FBs

*2 PLCopen is a third-party organization that promotes the international IEC 61131-3 standard for PLC programming and formulates the specifications of and certifies standardized function blocks independent of vendors. It is also a trademark or registered trademark of the PLCopen association.

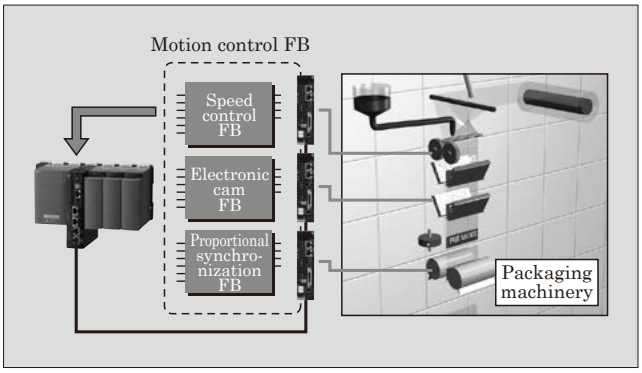

Fig.7 Example application of motion control FBs

that conform to PLCopen specifications enable the reduction of hardware dependency and improve the reusability of user programs. They can also reduce training and support costs.

By combining these various FBs, users can construct motion programs for large-scale systems in a short amount of time and freely configure functions required by the machine for each axis. Figure 7 shows an example of the application of motion control FBs. The reuse of FBs can dramatically improve program development efficiency, debugging efficiency and system reliability.

3.3 User data logging technology

We have equipped the CPU module of the SPH5000EC with a newly developed logging function. By using the logging function, it is possible to store any user data in the CPU module at any time without affecting the scan time of the application.

By using the simultaneously developed user program and waveform display tools, it becomes possible to visualize saved chronological user data on the waveform or program monitor, and use it for user program debugging and analysis of failure causes.

Figure 8 illustrates the collection modes of the user data logging function. SPH5000EC has a trigger mode and a trace mode for logging user data.

In trigger mode, user data before and after a trigger condition specified by the user can be collected for a specified number of samples and stored on the SD card. This mode is useful for understanding the behavior of the application before and after an error terminal of an FB or another component is turned on, or to store the quality information before and after each manufacturing cycle.

On the other hand, in trace mode, user data can be continuously collected at any time specified by the user and stored on the SD card for each fixed size specified by the user. This mode enables the user to learn about the quality characteristics and other characteristics from changes in data that is continuously collected at fixed times.

Figure 9 shows the SX monitor and waveform monitor integration function. All of the application data

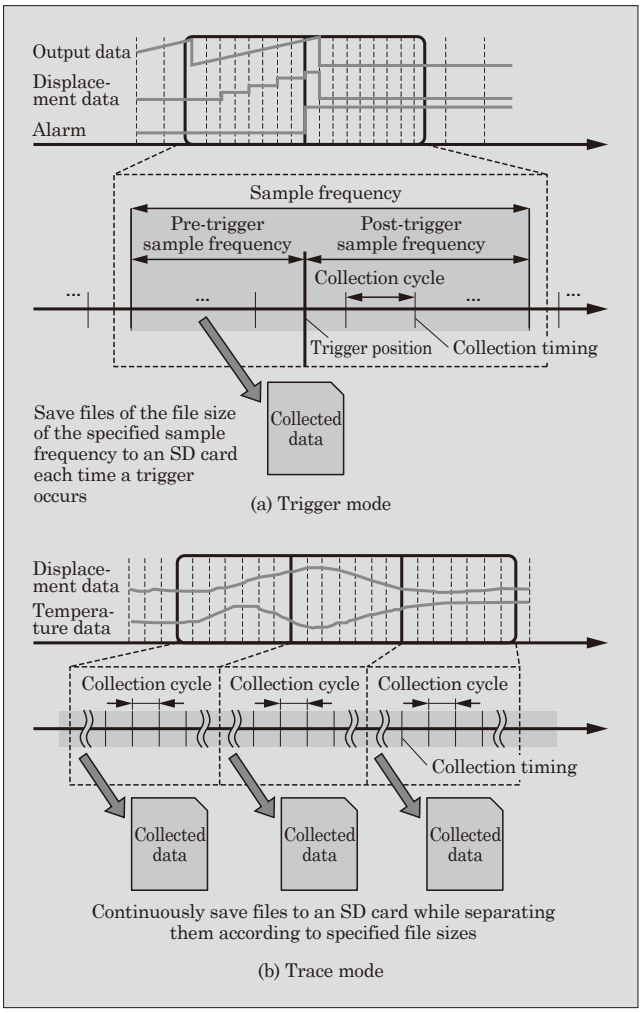

Fig.8 Collection modes of the user data logging function

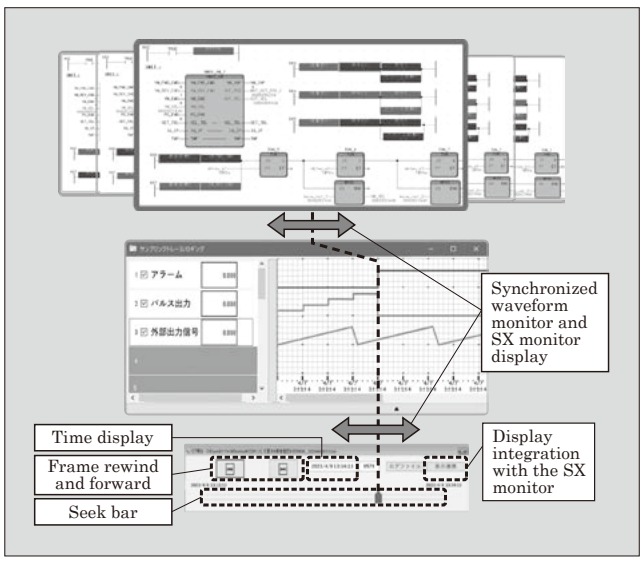

Fig.9 SX monitor and waveform monitor integration function

can be saved at each scan, and the SX and waveform monitors can be used in combination to replicate the behavior of the application from the user's desk. By integrating the display of the SX monitor with that of the waveform monitor, and by making it possible to advance and reverse the frame, the behavior of the application can be debugged at every scan.

In addition, data can be continuously acquired at regular times such as daily, hourly, every minute, or every second, or at regular intervals that are integral multiples of the tact period, and it can be used to collect information on the operating status of the equipment and the production status.

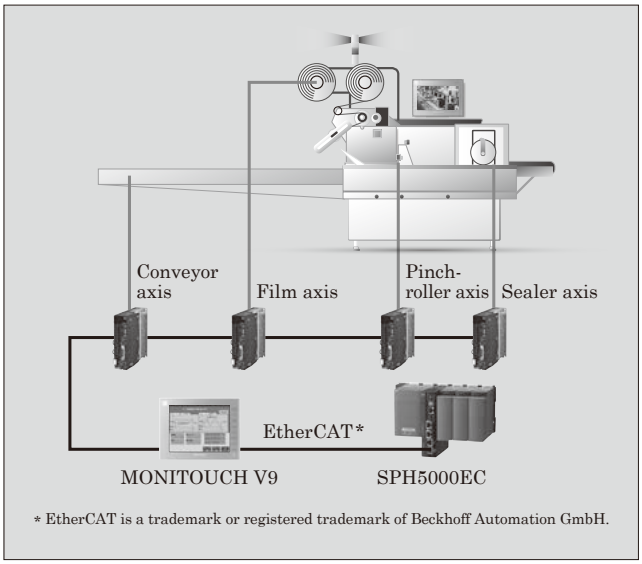

Fig.10 Example of a packaging machinery system that uses the "SPH5000EC"

4. Application Example

This chapter covers a case study of the application of the SPH5000EC to a packaging machinery system.

The packaging machinery system uses multiple sensors and actuators to perform sequence control and motion control. In particular, high-speed and high-precision motion control is required to improve productivity and quality.

In the previous packaging machinery system that used the SPH3000D, sequence control and motion control needed to be performed by one single-core microcomputer, making it difficult to achieve higher speeds.

The SPH5000EC has a system configuration that utilizes a multi-core computation execution engine. Figure 10 shows an example application of a packaging machinery system that uses the SPH5000EC.

This system performs sequence control with one computation execution engine and motion control with the other, thereby achieving integration of the sequence control and motion control functions of the previous configuration.

5. Postscript

This paper has described a motion controller that contributes to the automation of factory equipment.

The use of the "MICREX-SX SPH5000EC" for motion control applications improves the performance of sequence control and multi-axis high-speed synchronous control and further increases the speed and accuracy of machines, thereby improving production efficiency. Furthermore, by incorporating artificial intelligence (AI) algorithms such as multivariate statistical process control (MSPC), this controller can also be used for the diagnosis of defects in FA systems.

Going forward, we intend to expand the application of controllers to solve problems at manufacturing sites.

References

(1) Shimokawa, T. et al. "MICREX-SX SPH5000M" Motion Controller. FUJI ELECTRIC REVIEW. 2020, vol.66, no.1, p.22-27.

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