Factory Automation & Mechatronics Revolution

Applicable to High-speed and Advanced Control Systems

The control and drive systems required for leading-edge factory automation systems can be configured from advanced devices such as programmable controllers suitable for high-speed control and servo systems capable to suppress mechanical variation.

Supports Global and Open Network Communication Standards

The device line-up including programmable controllers conform to IEC standards as well as other devices compliant with overseas standards is provided. Ethernet, DeviceNet and other various open networks are also supported.

Provides an Integrated Programming Environment

The programming environment for the programmable controller supporting full IEC languages such as Ladder Diagram and Structured Text can cover broad control applications. Moreover, various function block library for motion control, instrumentation control and so on can be used to organize application programs easily up to large-scale systems.

Fuji Electric Control & Drive Systems
Providing the Highest Level Systems & Components for FA & Mechatronics Applications

Fuji Electric FA Components & Systems Co., Ltd.
http://www.fujielectric.co.jp/fcs/eng/
For today’s industry automation, environment-friendly control devices and automation systems which do not contain hazardous substances are required, harmonizing with energy saving and production optimization.

Fuji Electric’s main system control devices, such as the MICREX-SX series of programmable controllers, the MONITOUCH series of programmable operation displays, the FRENIC series of general-purpose inverters and the ALPHA5 series of servo systems, are expanding their range of applications through the performance enhancement and product series expansion, furthermore, these are evolving toward by utilizing open networks and standardized software technology. These devices are also advancing their compliance with the RoHS directive.

The cover photo shows an image depicting these devices organized by a network to operate automobile production line optimally.

CONTENTS

Inverter and Servo Systems

Present Status and Future Prospects for Drive Control Equipment 2
FRENIC-MEGA Series of High-performance Multi-function Inverters 7
Expanding Application of FRENIC-Lift Series for Elevators 12
High-performance Servo System ALPHA5 Series 16
Application Examples of Motion Control System 22

Programmable Control Devices and Systems

Present Status and Future Prospects for Programmable Control Devices 26
New Redundant System of MICREX-SX Series of Integrated Controllers 31
Board-type General-purpose PLC 35
New MONITOUCH V8 Series of Programmable Operation Displays 39
Present Status and Future Prospects for Drive Control Equipment

1. Introduction

Drive control equipment such as general-purpose inverters and servo systems have contributed to the automation and energy saving of machines and equipment. The applications of drive control equipment have increased, their functions and performance have been enhanced, and the drive control equipment itself has been made smaller in size and lower in cost.

Recently, product development has been advanced to support new requirements such as the elimination of the use of hazardous substances in compliance with the RoHS*1 directive and such, the support of environmental preservation through expanded green procurement, and adoption of measures to prevent sulfidizing gas from corroding electronic components in certain fields.

This paper discusses the technical trends and Fuji Electric’s product lineup of inverters and servo systems that meet these requirements.

2. Technical Trends of Drive Control Equipment

2.1 Technical trends of inverters

(1) Low-noise technology

Since the 1990s, the use of IGBTs (insulated gate bipolar transistors) as switching devices in inverters has contributed to a reduction of acoustic noise in motors, and lower loss and smaller size of the inverters. On the other hand, electromagnetic noise has increased due to the high switching speeds. Measures to counter this electromagnetic noise have until now been implemented in the periphery of the inverter, but in recent years, there has been an increase in inverters equipped with a built-in EMC (electromagnetic compatibility) filter. Moreover, inverters equipped with a built-in DC reactor for suppressing the harmonic current of a power supply are also being introduced.

Previously, an EMC filter and DC reactor were available as separate options. As a result, the ensuring of installation space was troublesome and the wiring connections became complicated. To optimize these constant factors, the EMC filter and DC reactor were reduced in size and built into the inverter which has the same installed area as conventional one.

(2) Control technology

The higher performance of microprocessors that control inverters has enabled even low-cost inverters to be provided with high-level control such as vector control.

Vector control with a speed sensor provides improved torque control accuracy and frequency response. Additionally, sensorless vector control has improved its performance and is currently being used in practical applications. V/f control is not simple constant V/f control, but rather is typified by dynamic torque vector control, the mainstream implementation thereof computes and outputs the optimal voltage and frequency according to changes in the operating conditions such as fluctuation of the load. Moreover, products equipped with vector control, sensorless vector control and V/f control are available, and the appropriate control method is selected according to the application.

(3) Ease of use

With the improvements in control performance, the number of installed functions has increased dramatically. For this reason, the ability for the drive control equipment to be used easily by the user is requested, and requests for an automatic adjusting function and simple setup are also important. These types of operating functions can be realized with loader software that runs on a PC. The inverter is equipped with a USB (universal serial bus) as a standard feature, and can easily be connected to a PC.

With the FRENIC-MEGA series, for example, the keypad panel is provided with a USB port so that the keypad panel can be detached from the inverter, transported to an office and connected to a PC, so that operation data and the like from the inverter can be checked at an office location.

Moreover, in an increasing number of cases, the host controller and inverter are connected by an open network, for which many types of communication cards are available as an option.

---

*1: RoHS is restriction of the use of certain hazardous substances in electrical and electronic equipment.
In attempting to realize the above-described ease of use with a general-purpose inverter, the installed functions were constrained, and the functions were ineffective in some applications. Thus, as with the FRENIC-Lift series for elevator applications and the FRENIC-Eco series for fan and pump applications, Fuji Electric created a product series from custom inverters specialized for a particular application.

In addition, synchronous motor driving that supports the recent trends toward smaller sizes and reduced energy consumption is expected to become more widespread.

2.2 Technical trends of servo systems

(1) Control performance

Servo systems have achieved dramatic improvements in control performance over the past 10 years. Speed response, which is a barometer of the servo system’s basic characteristics, has improved by a factor of 4 and the encoder resolution has improved by a factor of 16. As a result, shorter tact times and highly accurate position control are possible.

(2) Ease of use

Support tools running on a PC have become commonplace and such tools simplify the work necessary to initiate various functions and the response in times of trouble. Additionally, servo systems are evolving beyond the device concept of a motor drive and toward the concept of a becoming a system device that realizes “optimal motion control for the machine.” For this purpose, a function for analyzing mechanical characteristics and a vibration suppressing control for suppressing low-frequency mechanical resonance by servo control are provided as standard features to realize simple and robust control for the mechanical resonance point. Moreover, as a notch filter that suppresses only the vibration components and does not degrade the overall response, an automatic notch filter is also provided and functions to monitor the torque vibration constantly, and to automatically compute and suppress the vibration frequency. By providing these functions and performance and by reducing the size of the motors and amplifiers, the machinery is becoming more compact in size.

Since the introduction of the FALDIC-α series, Fuji Electric has advanced to respond dynamically to these types of leading-edge requests. In particular, the ALPHA5 series, which was launched in 2006, features the industry’s top class of performance, has a small size and supports the use of a USB loader, was developed based on the concept of “a next generation servo system for evolving machines.” A general-purpose interface such as for a pulse train and a high-speed serial bus (SX bus) enable flexible system construction.

In this manner, technology will continue to advance toward the concept of “optimal motion control for the machine” and system support via the bus system will continue to advance.

2.3 Design techniques

Inverters and servo amplifiers are designed to output an arbitrary AC voltage and achieve improved control performance by using an IGBT to perform high-speed switching. However, since the switching is performed at high-speed, if the IGBTs are connected and used in a parallel configuration, unbalance current must be suppressed during the switching. Also, IGBT technology has advanced to achieve smaller sized semiconductor chips by reducing loss, but as packages are made smaller, heat spots have become a serious problem.

Based upon electromagnetic analysis, unbalance current during a parallel connection is suppressed by equalizing the inductance of a copper bar in the periphery of the IGBT.

In consideration of the cooling of an IGBT module, the IGBT is positioned in an optimal location and the shape of the cooling fins is optimized based on thermofluid simulation. Also, the fin shape obtained thusly is a complex die-cast aluminum heat sink, and in order to ensure stable product quality, a flow and solidification simulation is performed and the casting plan is also optimized at the same time.

2.4 Environmentally friendly technology

In response to environmental regulations enacted in Europe and elsewhere and to the increase in green procurement, drive control equipment is becoming RoHS compliant, and is being designed from the product development stage so as to be free of hazardous substances. Moreover, products are being provided with longer useful service lives, and the limited-life components of electrolytic capacitors and cooling fans are achieving service lives of 10 years in the latest models.

On the other hand, corrosive gas as typified by sulfidizing gas is being used in a wider range of applications than in the past, and equipment used in a corrosive gas atmosphere tends to fail. Copper and silver corrode easily, and in drive control equipment, the chip resistors, the copper bar and the like on a printed circuit board are susceptible to corrosion. Having researched the capacity for tolerance in such an environment and studied countermeasures, Fuji Electric is formulating criteria for strengthening the environmental durability of its products.

3. Drive Control Equipment Product Series

Fuji Electric’s product series of drive control equipment encompass a wide range from simple variable speed inverters to servo systems capable of highly responsive and highly accurate positioning, and is suitable for a wide range of industrial applications.
### 3.1 Inverter product series

Table 1 lists Fuji Electric’s inverter product series. General-purpose inverters include the FRENIC-Mini series of compact inverters, the FRENIC-Multi series of high performance compact inverters, the FRENIC-Eco series of fan and pump inverters and the FRENIC-MEGA series of high performance multi-functional inverters that has been newly commercialized. As a result, the changeover from the prior generation models of the FVR-C11S series, FVR-E11S series, FRENIC5000P11S series and the FRENIC5000G11S series is complete.

With the new series, pet name has been unified as the expression of “FRENIC-XX”, and the product image has been refurbished. The external appearance is shown in Fig. 1.

As the top level models of general-purpose inverters, the FRENIC-MEGA series is newly provided with sensorless vector control. Moreover, the built-in type EMC (electromagnetic compatibility) filter and DC reactor are provided with the same installation dimensions.

<table>
<thead>
<tr>
<th>Model type</th>
<th>Series</th>
<th>Supply voltage</th>
<th>Capacity range (kW)</th>
<th>Frequency control range (Hz)</th>
<th>Main specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>General-purpose inverter</td>
<td>FRENIC -Mini</td>
<td>Single-phase 100 V</td>
<td>0.1</td>
<td>00</td>
<td>Compact inverter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Single-phase 200 V</td>
<td>0.1</td>
<td>00</td>
<td>400 Hz max. output freq.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3-phase 200 V</td>
<td>0.1</td>
<td>00</td>
<td>Side-by-side mountable</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3-phase 400 V</td>
<td>0.1</td>
<td>00</td>
<td>Supports global standards (400 V input)</td>
</tr>
<tr>
<td></td>
<td>FRENIC -Multi</td>
<td>Single-phase 200 V</td>
<td>0.1</td>
<td>00</td>
<td>High-performance compact inverter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3-phase 200 V</td>
<td>0.4</td>
<td>00</td>
<td>Overload capability : 200%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3-phase 400 V</td>
<td>0.4</td>
<td>00</td>
<td>Optional card supports</td>
</tr>
<tr>
<td></td>
<td>FRENIC -Eco</td>
<td>3-phase 200 V</td>
<td>0.1</td>
<td>00</td>
<td>Inverter for fan and pump applications</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3-phase 400 V</td>
<td>0.1</td>
<td>00</td>
<td>Energy-saving operation</td>
</tr>
<tr>
<td></td>
<td>FRENIC-MEGA</td>
<td>3-phase 200 V</td>
<td>0.1</td>
<td>00</td>
<td>High-performance, multi-functional inverter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3-phase 400 V</td>
<td>0.1</td>
<td>00</td>
<td>Vector control with PG, sensorless vector control, torque vector control, V/F control</td>
</tr>
<tr>
<td></td>
<td>FRENIC 5000G11S</td>
<td>3-phase 200 V</td>
<td>0.7</td>
<td>120</td>
<td>High-performance, multi-functional inverter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3-phase 400 V</td>
<td>0.7</td>
<td>120</td>
<td>Starting torque : 200%</td>
</tr>
<tr>
<td></td>
<td>FRENIC 5000P11S</td>
<td>3-phase 200 V</td>
<td>0.5</td>
<td>100</td>
<td>PID control &amp; RS-485 provided as standard</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3-phase 400 V</td>
<td>0.5</td>
<td>100</td>
<td>Optional card supports vector control</td>
</tr>
<tr>
<td></td>
<td>FRENIC -Lift</td>
<td>3-phase 400 V</td>
<td>0.5</td>
<td>120</td>
<td>Inverter for variable torque loads</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PID control &amp; RS-485 provided as standard</td>
</tr>
<tr>
<td></td>
<td>High-frequency inverter</td>
<td>FRENIC 5000H11S</td>
<td>3-phase 200 V</td>
<td>0.7</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Automatic energy-saving function enables highly effective driving</td>
</tr>
<tr>
<td></td>
<td>High-performance vector-control inverter</td>
<td>FRENIC 5000VG7S</td>
<td>3-phase 200 V</td>
<td>0.7</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Special functions and control for elevators</td>
</tr>
<tr>
<td></td>
<td>Thin type inverter</td>
<td>FRENIC 5000VG7F</td>
<td>3-phase 200 V</td>
<td>0.5</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>Regenerative PWM converter</td>
<td>RHC-C</td>
<td>3-phase 200 V</td>
<td>7.5</td>
<td>500</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Regeneration with high efficiency</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Reduced harmonic current input</td>
</tr>
</tbody>
</table>
3.2 Servo system product series

Table 2 lists Fuji Electric’s servo system product series and Fig. 2 shows the external appearance of this series.

As a core product line, the high performance and multi-functional FALDIC-α series supports multiple motors and motion systems that use the SX-bus. The FALDIC-β series targets semiconductor manufacturing equipment and robotic machinery, and is uniquely

Fig. 1 External appearance of inverters

Table 2  Fuji Electric’s servo system product lines

<table>
<thead>
<tr>
<th>Series</th>
<th>Applicable motor</th>
<th>Capacity range (kW)</th>
<th>Rated/max. speed (r/min)</th>
<th>Main specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALPHA5</td>
<td>GYS motor (low inertia : slim)</td>
<td>0.05</td>
<td>100</td>
<td>3,000/5,000 (6,000)</td>
</tr>
<tr>
<td></td>
<td>GYC motor (low inertia : cubic)</td>
<td>0.1</td>
<td>2</td>
<td>3,000/5,000 (6,000)</td>
</tr>
<tr>
<td></td>
<td>GYG motor (medium inertia)</td>
<td>0.5</td>
<td>15</td>
<td>2,000/2,000 (2,000)</td>
</tr>
<tr>
<td>FALDIC-α</td>
<td>GYS motor (low inertia : slim)</td>
<td>0.05</td>
<td>100</td>
<td>3,000/5,000 (6,000)</td>
</tr>
<tr>
<td></td>
<td>GYC motor (low inertia : cubic)</td>
<td>0.1</td>
<td>2</td>
<td>3,000/5,000 (6,000)</td>
</tr>
<tr>
<td></td>
<td>GYM motor (medium inertia)</td>
<td>2.9</td>
<td>15</td>
<td>1,500/3,000 (2,000)</td>
</tr>
<tr>
<td>FALDIC-β</td>
<td>GYS motor (low inertia : slim)</td>
<td>0.05</td>
<td>75</td>
<td>3,000/5,000 (6,000)</td>
</tr>
<tr>
<td></td>
<td>GYC motor (low inertia : cubic)</td>
<td>0.1</td>
<td>75</td>
<td>3,000/5,000 (6,000)</td>
</tr>
<tr>
<td>FALDIC-W</td>
<td>GYS motor (low inertia : slim)</td>
<td>0.05</td>
<td>75</td>
<td>3,000/5,000 (6,000)</td>
</tr>
<tr>
<td></td>
<td>GYG motor (medium inertia)</td>
<td>0.5</td>
<td>2</td>
<td>2,000/2,000 (2,000)</td>
</tr>
<tr>
<td>Digital ES</td>
<td>GRK motor (High inertia)</td>
<td>0.05</td>
<td>3.7</td>
<td>2,000/3,000 (6,000)</td>
</tr>
</tbody>
</table>

(1) Frequency response : 1,500 Hz
(2) 20-bit encoder as standard
(3) Max. speed ; 6,000 r/min
(4) Online auto notch filter function
(5) Vibration suppressing control function
(6) Size reduction of servomotor and servo amplifier
(7) USB connector for PC loader
(8) Many varieties of motors
(9) High-speed serial bus (SX bus) and support of various other buses
(10) Option of built-in positioning function
positioned as an extremely small amplifier that is easy to use and provides high performance. The FALDIC-W series is well suited for application to machine tools and general-industrial applications with medium inertia motors.

As the successor to the FALDIC-α series, the ALPHA5 series achieves higher performance and multi-functionality, and can be used in a wide range of industrial applications.

### 4. Postscript

This paper has described the recent trends and has introduced Fuji Electric’s product series of inverters and servo systems. Fuji Electric intends to continue to strive to improve functionality and performance, and also to satisfy new requests for improved ease of use and environmental durability.
FRENIC-MEGA Series of High-performance Multi-function Inverters

1. Introduction

In recent years, the performance and functionality of general-purpose inverters have evolved dramatically, and the range of applications has expanded from simple variable-speed driving systems to machine tools and vertical and horizontal conveyance machinery.

Fuji Electric, which has been supplying the FRENIC 5000G11S series for these types of applications, and has developed also the FRENIC-MEGA*1 series to support this expanded range of applications. This series of inverters provides dramatically improved control performance, equipment compatibility, and environmental suitability.

This paper will introduce the features of the FRENIC-MEGA series.

2. Configuration of the FRENIC-MEGA Series Models

2.1 Many model variations

Figure 1 shows the external appearance of the FRENIC-MEGA series and Table 1 lists the available model variations.

The FRENIC-MEGA series lineup includes a basic model that is suitable for replacing the conventional model of the FRENIC 5000G11S series, along with the new additions of a model equipped with a built-in EMC filter for reduced noise generation and a model equipped with a built-in DC reactor for suppressing the harmonic current of a power supply.

Furthermore, so that the FRENIC-MEGA series can support larger damping load applications such as vertical conveyance machinery, the standard capacity of the model equipped with a built-in brake circuit has been increased to 22 kW. Additionally, the lineup of models equipped with a built-in brake circuit has been expanded by build-to-order production to include 200 V (30 to 55 kW) and 400 V (30 to 110 kW) models.

2.2 Utilization of dual ratings (HD/LD specifications)

The FRENIC-MEGA series supports two types of output ratings, HD (high duty) specifications and LD (low duty) specifications, in a single unit so as to match the type of load application. The HD specifications provide overload tolerances of 150% for one minute and 200% for three seconds for general-purpose applications, while the LD specifications provide an overload tolerance of 120% for one minute for applications having relatively light overload requirements such as fans, pumps, and centrifugal separators. Moreover, the LD specifications enable operation of a motor that is one class higher than that which could be operated with an ordinary inverter.

![External appearance of FRENIC-MEGA series](image)

*1: MEGA is Maximum Engineering for Global Advantage.

![Table 1 FRENIC-MEGA series model varieties](image)
3. Performance and Functionality

3.1 Dynamic torque vector control

The FRENIC-MEGA series is equipped with Fuji Electric’s proprietary dynamic torque vector control technology, which has been well received in the marketplace. Using an equation for the voltage of an induction motor, and based on a motor constant and the current, this control method computes the optimal voltage and frequency according to changes in the operating conditions such as load fluctuations. This method maintains the speed of an induction motor at a specified value, and generates stable torque. In a conveyor or centrifugal separator, for example, it is desired that the torque ripple is small and that the fluctuation in the rotating speed is also small, even if the load torque fluctuates. Therefore, with the FRENIC-MEGA series, voltage error compensation is used to reduce the torque ripple, and magnetic flux compensation that utilizes a magnetic flux observer and highly accurate motor constant tuning are used to realize a dramatic improvement in speed control performance. Figure 2 shows the comparative results of speed ripple caused by torque ripple. The speed ripple at the time of the lowest speed has been reduced to approximately 50% that of the conventional series, and thus speed stability has increased in the low speed region. Figure 3 shows the comparative results of speed vs. torque characteristics. Magnetic flux compensation and highly accurate tuning of the motor constant achieve lower speed fluctuation due to load torque fluctuation than in the conventional series. In particular, the accuracy of speed control has been greatly increased on both the 1-to-10 Hz driving side and on the 5-to-10 Hz damping side.

3.2 Sensorless vector control

In order to support applications requiring highly accurate torque limiting and torque response, without using a speed sensor, the FRENIC-MEGA series is equipped with new sensorless vector control in addition to the dynamic torque vector control and vector control with a speed sensor which have been provided with the

Fig.2 Speed ripple

![Fig.2 Speed ripple](image)

(a) FRENIC-MEGA (400 V, 0.4 kW) 0.5 Hz

(b) Conventional series FRENIC 5000G11S (400 V, 0.4 kW) 0.5 Hz

Fig.3 Speed vs. torque characteristics

![Fig.3 Speed vs. torque characteristics](image)

(a) FRENIC-MEGA (200 V, 3.7 kW)

(b) Conventional series FRENIC 5000G11S (200 V, 3.7 kW)

Fig.4 Block diagram of sensorless vector control

![Fig.4 Block diagram of sensorless vector control](image)

Fig.5 Torque limiting characteristics (sensorless vector control)

![Fig.5 Torque limiting characteristics (sensorless vector control)](image)
Figure 4 shows a block diagram of the sensorless vector control. Figure 5 shows the torque limiting characteristics. In Fig. 5, it can be seen that the torque limiting accuracy is within ±10% on the drive side. Additionally, Fig. 6 shows the current response characteristics. From this figure, it can be seen that the current response is 600 Hz and that a high torque response is realized. Thus, the FRENIC-MEGA series, without a speed sensor, can be used with press machinery and other applications requiring highly accurate torque limiting and high responsiveness.

### 3.3 Vector control with speed sensor

The FRENIC-MEGA series, similar to the conventional FRENIC 5000G11S series, is provided with an established vector control function (with speed sensor) utilizing pulse generator (PG) feedback so as to support applications requiring highly accurate torque limiting and high torque response. The FRENIC-MEGA series achieves improved speed response by means of high-speed control computations based on a method having proven successful with the conventional model series, and improved torque limiting accuracy by utilizing a temperature sensor (NTC thermistor).

Figure 7 shows the torque limiting characteristics and Fig. 8 shows the speed response characteristics. Focusing on the torque limiting characteristics at 100% driving torque in Fig. 7, in the case of the conventional model series, axle torque varied in the range of 85% to 100% according to the speed, but with the FRENIC-MEGA series, axle torque can be controlled to be nearly constant at 110%. Moreover, from Fig. 8 it can be seen that the speed response has been improved from the 60 Hz of the conventional model series to 100 Hz for the FRENIC-MEGA series. These performance characteristics additionally improve the performance in lifter and other vertical conveyer applications, wire drawing machines, printing presses and so on.

### 3.4 USB port provided as a standard feature on the keypad panel

Personal computers of recent years have been equipped with USB (universal serial bus) ports as a standard feature. So that these types of personal computers can be utilized as loaders, the FRENIC-MEGA series is provided with a USB port in the inverter keypad panel as a standard feature (Fig. 9). The keypad panel memory can be used to temporarily store...
the inverter’s internal data (function code data and maintenance information), thus enabling workers to perform maintenance tasks at safe locations such as at an office (Fig. 10).

3.5 Pulse train input provided as a standard feature in the inverter unit

A pulse train input function, which was formerly an optional feature, is provided as a standard feature in the FRENIC-MEGA series.

Accordingly, frequency commands by means of a pulse train input (single-phase pulse + polarity signal) from a PLC or other pulse train generator are possible (maximum pulse input: 100 kpps) as a standard feature with the FRENIC-MEGA series. Pulse train input is advantageous because there is no associated conversion error when an analog quantity such as voltage and current is converted into a digital quantity. Pulse train input is used in applications requiring highly accurate speed control such as injection molding machines, winding machines and the like.

4. Environmental Performance

4.1 Conformance with the RoHS directive

With the enactment of the WEEE*2 and RoHS*3 directives in the EU (European Union), environmental responsiveness is becoming a standard feature in the inverter industry.

The FRENIC-MEGA series controls the content of the six hazardous substances*4 restricted by the RoHS directive to levels below their specified maximum allowable content.

4.2 Longer-life components

The DC link bus capacitor and cooling fan are components that have a limited service life, and require replacement as part of regular maintenance. For these components, the FRENIC-MEGA series uses longer-life components than in the conventional series, designed to have a service life of 10 years. This service life rating assumes the usage conditions of an ambient temperature of 40°C, and load factors of 100% (HD specification) and 80% (LD specification).

Additionally, as shown in Fig. 11, the cooling fan can be replaced in 22 kW and lower models with a one-touch operation, and replacement in 30 kW and above models can be carried out simply by removing two screws, without removing the front cover.

4.3 Improved environmental durability

Inverter specifications presume a usage environment that is free from dust and corrosive gas, but actual usage conditions do not always satisfy those conditions. To increase durability under actual usage conditions, the following processing has been performed on standard models of the FRENIC-MEGA series.

(1) Plating of the copper bar

Conventionally, the copper bar inside an inverter had not been plated, but since copper corrodes in a sulfidizing gaseous atmosphere, a plating process is

---

*2: WEEE is Waste Electrical and Electronic Equipment Directive.
*3: RoHS is restriction of the use of certain Hazardous Substances in electrical and electronic equipment.
*4: Six hazardous substances are lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE).
implemented on this copper bar in the FRENIC-MEGA series.

(2) Coating of the cooling fan

The cooling fan is exposed to dust, which in addition to being a source of trouble with the bearings, also causes the printed circuit board inside the fan to be susceptible to failure. With the FRENIC-MEGA series, the printed circuit board is coated and lead lines are sealed to prevent such failure.

5. Utilization of Simulation Technology

Simulation technology was utilized in the development of the FRENIC-MEGA series to find quick solutions for ways to increase the overload tolerance and to embed the EMC filter and DC reactor. The main findings from the simulations are described below.

5.1 Heating and cooling analysis

In the thermal cooling design of the cooling fins, there exists a tradeoff between cost and design parameters, such as the number, thickness and height of the fins. Optimization of the fin shape is a crucial factor in improving the cooling performance at a minimum cost.

Therefore, we built several types of analysis models having fin shapes thought to be representative of the design parameters, and compared the test results thereof to those of thermofluid simulation results. We assessed the simulation accuracy and then optimized each design parameter. As a result, the FRENIC-MEGA series achieves a 49% reduction in mass compared to the die-cast fins of conventional models.

Moreover, the method of arranging cooling fins for the IGBT (insulated gate bipolar transistor) module and diode module, which are heat generating sources, can create a large differential in the temperature distribution on the base surface of the module. The arrangement of modules is extremely crucial for module cooling, and the prototyping and evaluation of large-capacity inverters to determine the optimal arrangement is particularly costly and time consuming. Therefore, we utilized thermofluid simulation to improve the development efficiency.

5.2 Casting simulation of die-cast fins

Previously, the manufacture of the metal mold for die-cast fins and the selection of a proposed casting method were performed by trial and error based on the intuition and experience of an experienced specialist. In order to quantify these processes, we performed a casting simulation. From the results of the simulation, we determined the shape of the metal mold and the casting conditions to realize more efficient development and stable manufacturing.

6. Postscript

This paper has presented the features of high-performance and multi-function FRENIC-MEGA series. The FRENIC-MEGA series is provided greater compatibility with equipment and is capable of supporting a wider range of applications than conventional general-purpose inverters. Fuji Electric intends to continue to develop general-purpose inverter products in response to market needs.

Reference

Expanding Application of FRENIC-Lift Series for Elevators

Tetsuya Nomura
Hiroyuki Yonezawa

1. Introduction

In recent years the elevator industry has been transitioning from geared elevators that use standard induction motors (IM) to gearless elevators that use permanent magnet synchronous motors (PMSM). This transition is being implemented in order to reduce machine room size, conserve energy, and improve the ease maintenance. Meanwhile, in Europe, where elevators were first popularized, there is an exceedingly brisk business in modernizing aging elevators to inverter-based control. In cases where an existing motor and gears are to be reused, operation without a speed sensor is often required. Responding to this demand, “FRENIC-Lift series” is equipped with a new type of torque vector control that enables operation without a speed sensor, in addition to the vector control with speed sensor used previously.

This paper introduces the expanding application of FRENIC-Lift series of inverters for elevators.

2. Control Method of FRENIC-Lift Series

Control method of the inverter for elevator-use is shown in Table 1. Approaches for each control method in FRENIC-Lift series are described below.

2.1 Permanent magnetic synchronous motor drive

Gearless elevators that use a PMSM have good overall torque transmission efficiency, and the current control performance of the inverter has a greater effect on elevator car vibration than geared elevators. The FRENIC-Lift series uses a high-speed RISC (reduced instruction set computer) microprocessor to realize a current response which is five times that of the FRENIC 5000G11UD series of inverters for elevators.

Figure 1 shows the current response characteristics. We can find out that the cutoff frequency at which the gain falls by −3 dB is 500 Hz. Close attention to the variation in sensing by the current sensor and to the reduction in unbalanced output voltage enabled an improvement in overall current control performance. As a result, elevator driving with reduced car vibration is possible.

In a PMSM, the rated voltage of the motor is determined according to the electromotive force that is determined by the rotating speed. Since there are various rated voltages for motors, the rated current is not uniform, even for the same motor output. The overload rating of the FRENIC-Lift series has been increased to 200% (for an allowable time of 10 s) compared to conventional models, so that even a motor having a low rated voltage and a high rated current can be driven without increasing the inverter capacity.

2.2 Induction motor drive

(1) Vector control with a speed sensor

A geared elevator that uses an IM is a drive system often generally used. The FRENIC-Lift series is standardly equipped with a feedback pulse detection circuit of a complementary output encoder. As a result, in the case where the encoder is of the complementary output type, the motor can be driven without adding any extra options.

In a geared elevator, a worm gear is generally

<table>
<thead>
<tr>
<th>Motor type</th>
<th>Control method</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMSM</td>
<td>Vector control with speed sensor</td>
</tr>
<tr>
<td>IM</td>
<td>Vector control with speed sensor</td>
</tr>
<tr>
<td></td>
<td>Torque vector control (without speed sensor)</td>
</tr>
</tbody>
</table>

Table 1 Control method of the inverter for elevator-use
used, and various such gears exist, from those having low mechanical efficiency to high efficiency ones. The FRENIC-Lift series provides convenient functions such as a soft-start function (two types) and ASR (automatic speed regulator) gain switching capable of smoothly starting even a traction machine having large static friction.

(2) Torque vector control (V/f control without a speed sensor)

In a geared elevator, when converting old equipment to inverter control, in some cases a speed sensor cannot be used. In such a case, the inverter utilizes torque vector control (V/f control without a speed sensor).

The torque vector control of the FRENIC-Lift series provides that reduced speed ripple, improved speed control accuracy and improved current response to enable smoother startup than in conventional models.

Figure 2 shows various waveforms in the case where an elevator is driven by torque vector control. The upper plot shows the reference speed, the middle plot shows the motor current and the lower plot shows the estimated motor torque value. This data was measured under no-load and rising operation (in the regenerative operation). From the estimated motor torque value during constant speed, we can find out that the traction machine has good mechanical efficiency. When the mechanical brake is released and the motor starts to move, the desired torque is generated quickly. It can be seen that torque ripple is suppressed to a low value, and even in the case of a highly efficient traction machine, the torque vector control of the FRENIC-Lift series is able to realize smooth control.

2.3 Wide variety of encoder interfaces

The FRENIC-Lift series is standardly equipped with an interface supporting 12 V and 15 V complementary output encoders as a speed sensor attached to the motor. Moreover, the various encoders listed in Table 2 can also be supported with the addition of an optional card. In PMSM driving, there exist several different methods having different rotor position detection methods. Thus, the FRENIC-Lift series provides a full lineup of optional cards to support nearly all encoders used in elevator applications.

3. Functions

The FRENIC-Lift series is provided with functions for improving the quality of the elevator system. Some characteristic functions are described below.

3.1 Unbalanced load compensation

The elevator control generally uses a load sensor to reduce the vibration felt inside the car when the mechanical brake is released. The load sensor must be maintained regularly in order to be able to handle weak signals.

Figure 3 is a control block diagram of the FRENIC-Lift series. The automatic speed regulator is the function of causing the motor speed to follow the output of the ramp controller. In the control of the FRENIC-Lift series, the automatic speed regulator is compensated by an unbalanced load compensator. To verify the effect of the unbalanced load compensation, Fig. 4 shows the results of measured vibration in the elevator car. The motor is a PMSM, the elevator specifications are a rated speed of 1.75 m/s and a rated load of 1,000 kg, and no load sensor is used. If the unbalanced load compensator is not used, an extremely large amount of vibration will be generated when the mechanical brake is released. In contrast, if the unbalanced load compensator is used, no vibration is generated. By using this function, not only can the load sensor be omitted,
but regular maintenance of the load sensor becomes unnecessary.

3.2 Automatic reset function

When a power failure occurs while an elevator is moving, the inverter detects the power failure and enters an alarm state. Furthermore, if highly-loaded operation is continued in a high temperature environment, the inverter itself will reach a high temperature and may enter an alarm state for protection. Usually, when the inverter enters an alarm state, the elevator controller will release the inverter alarm state after verifying that there is no danger. If the power supply and equipment conditions are good, there is only a very slight possibility that the inverter would enter an alarm state due to these causes. However, power failure occurs frequently in some countries and an inverter may be installed in a high temperature area, and so it is necessary to consider these cases at the initial step of designing.

In the case of an inverter alarm due to a power failure or high temperature, the inverter itself will ascertain the cause. Additionally, the present inverter status is also ascertained, and thus the FRENIC-Lift series is equipped with a function that automatically releases the alarm state without requiring the input of a reset signal. This function is used particularly often in Europe and Asia.

3.3 Expanded functions during battery operation

An emergency stop made by an elevator due to a power failure may cause a passenger to become trapped in the elevator car. Consequently, recent elevators are commonly equipped with an emergency operation function that automatically switches over to battery power during a power failure and travels to the nearest floor. This function in the FRENIC-Lift series that switches over to battery power is called “battery operation.” Since a battery power source drives the elevator during battery powered operation, the elevator is generally operated at a low speed in order to reduce power consumption and to reduce the required battery capacity. Moreover, to move the elevator to the nearest floor more reliably, the elevator moves in the regenerative direction (direction in which the elevator would naturally fall). If the elevator were to move in the opposite direction (driving direction) and that the battery capacity was insufficient, the battery voltage would drop and operation would become impossible. Once the battery voltage drops, charging is required and the rescue of passengers would not be possible during an emergency. Thus, the elevator controller must somehow be aware of the running direction, which forms the regenerative direction.

The FRENIC-Lift series is equipped with new functions that output “recommended running direction for battery operation (RRD function)” prescribing the regenerative direction and “torque limitation for battery operation (TL function)” even if the elevator operates in the driving direction, the maximum torque is limited and a drop in battery voltage is suppressed. By using RRD function, the elevator controller can operate the elevator in the regenerative direction easily. By using
3.4 Elevator system using a CAN

A CAN (controller area network) is a high-speed highly reliable network that has been used successfully in many applications mainly in the automotive industry. In elevator systems primarily in Europe, there are examples of the elevator controller and various switches, sensors, displays, and the like being connected with a CAN. Thus, it is relatively common for an elevator controller to be equipped with a CAN. The FRENIC-Lift series was designed to support CANopen, a type of open network by using CAN.

Table 3 shows the main CANopen specifications of the FRENIC-Lift. The maximum transmission rate of 250 kbit/s is extremely fast compared to serial communication using a protocol such as RS-485, moreover, bus arbitration is performed with CSMA/NBA (carrier sense multiple access with non-destructive bitwise arbitration) to enable highly efficient communication. For example, in the case that speed command are received from the elevator controller at a fixed cycle and the inverter state data are transmitted at a different cycle, even if the data collide with each other, arbitration will be performed automatically and the speed command can be prioritized. Also, the use of the CANopen function enables the elevator controller and the inverter to monitor the status of each other’s operation, and to configure an even more reliable network.

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication protocol</td>
<td>CANopen</td>
<td>Based on ISO11898 (high-speed CAN)</td>
</tr>
<tr>
<td>Transmission method</td>
<td>Half-duplex transmission</td>
<td></td>
</tr>
<tr>
<td>Network topology</td>
<td>Bus topology (multi-master)</td>
<td></td>
</tr>
<tr>
<td>Bus arbitration</td>
<td>Carrier Sense Multiple Access with Nondestructive Bitwise Arbitration (CSMA/NBA)</td>
<td>When the transmission data collides, the object with higher priority is transmitted</td>
</tr>
<tr>
<td>Synchronization</td>
<td>Asynchronous transmission and phase correction</td>
<td></td>
</tr>
<tr>
<td>Data length</td>
<td>8 byte (max.)</td>
<td></td>
</tr>
<tr>
<td>Error detection</td>
<td>Cyclic redundancy check sequence</td>
<td></td>
</tr>
<tr>
<td>Channel coding</td>
<td>Non-return-to-zero sequence and bit stuffing</td>
<td>When there are 5 consecutive bits at the same level on the bus, a reversing bit level is added</td>
</tr>
<tr>
<td>Maximum transmission rate</td>
<td>250 kbit/s</td>
<td>Transmission time of one frame is about 0.5 ms</td>
</tr>
<tr>
<td>Function</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heartbeat consumer</td>
<td>1 s</td>
<td>Operation of the elevator controller can be monitored</td>
</tr>
<tr>
<td>Heartbeat producer</td>
<td>1 s</td>
<td>Elevator controller can monitor the operation of the inverter</td>
</tr>
<tr>
<td>Event timer</td>
<td>20 ms</td>
<td>State data for the inverter is transmitted at a fixed cycle</td>
</tr>
</tbody>
</table>

TL function and presetting the torque limiting value according to the battery capacity, driving operation in a range in which battery voltage does not drop is easily realized.

4. Postscript

This paper has presented an overview of the FRENIC-Lift series of inverters for elevators. Fuji Electric intends to continue to develop new functions and to improve performance in response to market needs.
1. Introduction

The application of servo systems to general industrial machinery such as semiconductor and LCD manufacturing equipment and electronic parts manufacturing systems has expanded in recent years. For such applications, there is an increasing need for faster speed, higher accuracy, shorter time required for adjustment at system startup, smaller size, and easier maintenance.

The ALPHA5 series is a series of servo systems that meet these needs. In addition to providing higher speed and higher accuracy which improve the basic control performance, and smaller size, the ALPHA5 series is also equipped with a command pulse smoothing function, an automatic notch filter, and a new vibration suppressing control to realize a significant reduction in the time required for adjustment at system startup. Additionally, the PC software support tool (PC loader) has been redesigned, and ease of use has been improved.

The specifications and characteristics of the ALPHA5 servo series are introduced below.

2. Basic Specifications

Figure 1 shows the external appearance of the ALPHA5 series.

Both the servo amplifier and the servo motor are smaller in size than previous models. The servo amplifier requires 25 to 30% less installation space than Fuji

Fig.1 Appearance of the ALPHA5 series

<table>
<thead>
<tr>
<th>Item</th>
<th>Model</th>
<th>GYS (ultra-low inertia series)</th>
<th>GYC (low inertia series)</th>
<th>GYG (medium inertia series)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated output (kW)</td>
<td></td>
<td>0.05 to 0.75</td>
<td>1.0 to 5.0</td>
<td>0.1 to 0.75</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 types</td>
<td>6 types</td>
<td>4 types</td>
</tr>
<tr>
<td>Rated speed (r/min)</td>
<td></td>
<td>3,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. speed (r/min)</td>
<td></td>
<td>6,000</td>
<td>5,000</td>
<td>6,000</td>
</tr>
<tr>
<td>Max./Rated torque ratio</td>
<td></td>
<td></td>
<td>300%</td>
<td>20-bit serial encoder (incremental)</td>
</tr>
<tr>
<td>Encoder</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protective ventilation</td>
<td></td>
<td>Totally enclosed, self-cooling (IP67)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mounting method</td>
<td></td>
<td>Flange IMB5 (L51), IMV1 (L52), IMV3 (L53)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Installation location, altitude</td>
<td></td>
<td>Indoors, 1,000 m or less</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ambient temperature and humidity</td>
<td></td>
<td>−10 to +40 °C, 90%RH or less (no condensation)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applicable standards</td>
<td></td>
<td>In accordance with UL/cUL (UL1004), CE marking<em>1 (EN60034-1, EN60034-5), RoHS directive</em>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*1: CE marking is marking indicating conformity with European product safety standards.
*2: RoHS is restriction of the use of certain Hazardous Substances in electrical and electronic equipment.
Electric’s previous models and the servo amplifier can be installed side-by-side without a gap as with previous models, thus enabling an even further reduction in size of the equipment.

The specifications and characteristics of this servo series are introduced below.

### 2.1 Servo motor basic specifications

The basic specifications of ALPHA5 series servo motors are listed in Table 1. The servo motors are classified as three types, GYS, GYC and GYG, according to their inertia. The models are further classified according to their rated output, rated speed, and existence of a brake, to comprise a total of 52 types. ALPHA5 series motors use a new small-size and high resolution 20-bit incremental encoder and 18-bit absolute encoder. As a result, more accurate positioning can be realized and their total length can be reduced by approximately 15% compared to Fuji Electric’s previous models. For models of 750 W and below, the increase in maximum speed from 5,000 r/min to 6,000 r/min contributes to a shorter tact time for the machinery. The motor construction provides high environmental durability, and as in Fuji’s previous models, all motor models have an enclosure rating of IP67.

### 2.2 Servo amplifier basic specifications

The basic specifications of ALPHA5 series servo amplifiers are listed in Table 2. There are three types of amplifiers and they are equipped with a general interface, the original high-speed serial bus (SX bus) or a built-in linear positioning function SX bus. A product lineup has been prepared for the general interface type, having the most commonly used pulse train and analog

<table>
<thead>
<tr>
<th>Item</th>
<th>VV type</th>
<th>VS type</th>
<th>LS type (linear positioning system)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Command interface</td>
<td>General interface (pulse train, analog voltage input)</td>
<td>High speed serial bus (SX bus)</td>
<td></td>
</tr>
<tr>
<td>Control type</td>
<td>Position control, speed control, torque control</td>
<td>Position control</td>
<td></td>
</tr>
<tr>
<td>Application motor series</td>
<td>GYS motor, GYC motor, GYG motor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Application motor output</td>
<td>0.05 to 5.0 kW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power supply</td>
<td>Main power</td>
<td>Single-phase or 3-phase, 200 to 240 V AC (3-phase : greater than 1.0 kW)</td>
<td></td>
</tr>
<tr>
<td>Control power</td>
<td>Single-phase, 200 to 240 V AC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feedback</td>
<td>Control</td>
<td>IGBT PWM sine wave operation</td>
<td></td>
</tr>
<tr>
<td>Overload resistance</td>
<td>20-bit serial encoder (incremental, resolution/rev. 1,048,576)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>18-bit serial encoder (absolute/incremental, resolution/rev. 262,144)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency response</td>
<td>300%/3 s</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,500 Hz (motor inertia = load inertia)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communication interface</td>
<td>RS485</td>
<td>SX bus</td>
<td></td>
</tr>
<tr>
<td>Sequence input</td>
<td>8 lines</td>
<td>5 lines</td>
<td></td>
</tr>
<tr>
<td>Sequence output</td>
<td>5 lines</td>
<td>2 lines</td>
<td></td>
</tr>
<tr>
<td>Input pulse train</td>
<td>Differential input ; Maximum input frequency 1.0 MHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Open collector input ; Maximum input frequency 200 kHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pulse string type is selected with the following 3 parameters :</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>◦ Command pulse/command direction</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>◦ Forward rotation pulse/reverse rotation pulse</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>◦ 90° phase difference, 2 signals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output pulse train</td>
<td>Different output; Maximum output frequency 1.0 MHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pulse string type; 2 signals of 90° phase difference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analog voltage input</td>
<td>Speed command</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Input range : −10 to +10 V</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Resolution : 15 bits/full scale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Torque command</td>
<td>Input range : −10 to +10 V</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Resolution : 14 bits/full scale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analog monitor voltage output</td>
<td>Output range : −10 to 10 V, Resolution : 14 bits/full scale</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Type is selected with a parameter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Installation</td>
<td>Indoors, altitude of 1,000 m or less, in a location free of dust, corrosive gas and direct sunlight</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Compatibility with European standard : Pollution degree : 2, over voltage category : II</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environment</td>
<td>Ambient temperature and humidity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>−10 to 55 °C/10 to 90%RH (no condensation)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Resistance to vibration and impact</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.9 m/s², 19.6 m/s²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applicable standards</td>
<td>In accordance with UL/cUL (ul508C), CE marking (low voltage directive IEC61800-5-1), RoHS directive</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
voltage commands, and the high-speed serial bus interface type, which is expected to become the main type in the future.

In the internal circuitry of the amplifier, limited lifespan components of aluminum electrolytic capacitors and cooling fan have an extended service life. Also, a USB (universal serial bus) is provided as a standard feature, and since connection to a PC loader is possible via a commercially available cable, the ease of use has been improved.

3. Higher Functionality

3.1 High-speed and highly accurate positioning

To improve productivity, shorter tact times are increasingly being requested. Moreover, with the miniaturization of electronic components and so on, requests for more accurate machine processing have increased as well.

With the ALPHA5, in addition to deploying a newly developed high-speed processing circuit comprised of a CPU and custom LSI chip, the control algorithm that had been developed in conjunction with conventional servos has been improved further to realize a frequency response of 1,500 Hz and high-speed positioning capability. Moreover, a 20-bit, high resolution, highly accurate encoder was utilized to enable smooth and precise positioning operation.

Figure 2 shows an example waveform of the positioning operation for a 10 mm ball screw. Positioning at 1μm and below is realized with a command delay (settling time) of 1.5 ms. Application of the ALPHA5 to semiconductor manufacturing equipment and the like, wherein high tact and high accuracy are required, enables an improvement in mechanical performance.

3.2 Control functions that have evolved for ease-of-use

(1) Automatic tuning

The application of the aforementioned high-speed processing circuit and the high-resolution encoder has enabled more accurate estimation of the load inertia. Additionally, the use of an automatic notch filter, an automatic vibration suppressing control and a pulse smoothing function (to be described below) in a belt drive or other mechanism having low rigidity, or in a mechanism that uses coarse command pulses, enables automatic tuning to be implemented easily and with high responsiveness.

(2) Automatic notch filter

A notch filter is a filter that attenuates only specified frequency components. In a servo system, setting the notch filter to attenuate the mechanical resonance frequency enables suppression of the vibration component only, without impairing the overall response.

The ALPHA5 is newly equipped with an automatic notch filter that constantly monitors the torque vibration and automatically sets the vibration frequency. Analysis of the mechanical system and manual setting of the resonant frequency had previously been required, but with the ALPHA5, such tasks are now unnecessary, enabling a reduction in the adjustment time at startup. Moreover, even in cases where the resonant frequency changes due to the complexity or time degradation of the mechanical system, the ALPHA5 is always able to set an appropriate resonant frequency automatically.

Figure 3 shows example waveforms in the cases where the automatic notch filter has been enabled and has been disabled. When the automatic notch filter is disabled, the vibrations continue, but when the automatic notch filter is enabled, torque and speed vibrations are suppressed instantaneously when vibrations are detected.

3.3 New vibration suppressing control

The vibration suppressing control is a function that suppresses vibration at the tip of a robot arm or the like after a positioning operation, and enables a reduction in tact time in machines having low rigidity. In the past, it had been necessary to perform desktop calculations or a frequency analysis in order to obtain the frequency of vibration at the tip of an arm, and then to set that frequency manually. The ALPHA5, however, is equipped with an online learning function and is provided with an automatic vibration suppressing control that functions to set the vibration frequency automatically, thereby achieving a reduction in adjustment time compared to the previous method of manual setting.

Fig.3 Automatic notch filter

![Fig.3 Automatic notch filter](image-url)
Additionally, with the ALPHA5, the inertia (workpiece inertia) of the tip portion of a robot arm is set as a parameter, enabling better vibration suppressing performance than in the past. Figure 4 shows example waveforms of the operation when measuring arm tip vibration with a laser displacement meter in the case where duration of the positioning operation is 125 ms. With the conventional vibration suppressing control, the vibrations are shown to continue with a cycle time of approximately 83 ms. Suppression of this type of a vibration cycle time, which is nearly the time of the positioning operation, had been previously been difficult to accomplish, but such control has been realized with the new vibration suppressing control.

(4) Pulse smoothing function

In cases such as where a stepping motor is replaced with a servo motor, the coarseness of the command pulse resolution has caused torque vibration and mechanical vibration, and a loud operating sound to be generated. The ALPHA5 is provided with a pulse smoothing function to handle such cases. Figure 5 shows example waveforms when the pulse smoothing function is disabled and enabled. This function smoothes the torque and speed to enable smooth high-speed positioning.

4. Improved Ease of Use (PC Loader Function)

4.1 Improved monitor function

Accompanying the higher levels of performance and functionality of servo amplifiers, there has also been an increase in the number of parameters. Moreover, the ability to transfer larger amounts of data at higher speeds has become necessary for the waveform monitor used to verify servo operation during the adjustment of those parameters. However, with conventional general communications, the transfer of data takes a considerable amount of time, and the repeated setting and verifying of data during the adjustment at startup results in extremely poor work efficiency.

The ALPHA5 series, which supports USB communication and is capable of high-speed data transfers, is a stress-free, easy-to-use loader for users.

Table 3 compares the basic specifications of the waveform monitor function (trace function) of a conventional servo system and the ALPHA5 series. With the ALPHA5 series, in order to observe data more accurately, the sample period was shortened, and the number of sampling points were increased significantly. Also, the measurement cursor was improved and a waveform comparison function, a frequency analysis (FFT) function and other functions were added to aid the adjustment at startup.

The waveform comparison function is capable of overlaying and displaying two sets of waveform data. As a result, operating differences based on parameter differences can be assessed easily, and this leads to a reduction in the adjustment time at startup. Moreover, comparisons are also possible to historical waveform data that has been saved, and as shown in the example historical trace comparison screen of Fig. 6, the effect of time degradation on the mechanical system can be observed by comparing waveforms of the adjustment at machine startup and recent waveforms. This function can also be used to verify variances among machines of the same model.

With the frequency analysis (FFT) function, waveform data frequencies can be analyzed, the frequency of torque vibration and the like can be measured, and parameters relating to the notch filter and vibration...
suppressing control can be set easily.

4.2 Simple setup

(1) Easy tuning and profile operation
Previously, in order to set operation-related parameters, adjust the control gain to a suitable level for the machine, verify the load ratio during operation and perform other adjustments at startup of a servo system, the servo motor had to be attached to the mechanical system and be controlled by operating commands from a host controller.

Ever since the “FALDIC-W series,” Fuji Electric servo systems have been equipped with a profile operation function, which operates according to a pattern set by the servo amplifier, and an easy tuning function, which automatically adjusts the control gain during a profile operation, even in cases such as that shown in Fig. 7 where there is no host controller. The ALPHA5 series inherits these functions, and since the servo system can startup even before a host controller is provided, the adjustment at startup of the entire system can be implemented in a shorter amount of time.

Furthermore, the combination of these functions with an automatic notch filter enables many types of mechanical systems to realize sufficient response using the easy tuning function only.

(2) Sequence test
Previously, in order to debug a host controller program, the servo motor had to be attached to the mechanical system, and that mechanical system had to be in an operable state.

The ALPHA5 series, as shown in Fig. 8, is newly provided with a sequence test mode capable of debug-

Fig.6 Example of historical trace comparison screen

Fig.7 System configuration of easy tuning and profile operation

Fig.8 System configuration of sequence test mode

Fig.9 Alarm history monitor screen

Fig.10 Warning monitor screen

ging the host controller with a servo amplifier only, even when there is no mechanical system or servo motor. According to commands from the host controller, the servo amplifier generates signals and monitor data as if the servo motor attached to the mechanical system was running, and outputs them to the host controller.

With this function, since the host controller’s program is executed and debugged by the servo amplifier itself before the mechanical system is completed, the time required for adjustment at startup of the overall system can be reduced.

4.3 Enhanced maintenance functions

(1) Alarm-associated data
In order to investigate the cause of an alarm that has been generated, the operating state at the time when that alarm was generated must be known.
With the ALPHA5 series, the alarm history have been enriched with those data, which are thought to be useful in investigating the cause of the alarm, such as speed, torque and cumulative conduction time and so on at the time when the alarm was generated. Figure 9 shows the alarm history monitor screen. With this associated data, the cause of the alarm can easily be analyzed, and the amount of time required for such an investigation can be reduced.

(2) Warning monitor

The servo amplifier contains consumable parts such as a cooling fan, main circuit capacitors, and a battery for absolute position data backup, and their replacement timings depend on the cumulative operating time of the servo amplifier. The ALPHA5 series is provided with a warning monitor to notify the user of these replacement times. Figure 10 shows the warning monitor screen. This screen displays not only warning signals, but also displays the elapsed time and remaining time until replacement will be needed, and so on, and helps to improve the ease of maintenance.

5. Postscript

Specifications and features of the ALPHA5 series have been introduced above. The ALPHA5 servo systems realize the industry’s top level of performance and ease of use.

Fuji Electric intends to continue to work toward increasing the capacity of its product series, broadening the motor lineup, expanding functionally by increasing support for Modbus-RTU*1 communications and full-closed control, and supporting the replacement of existing products.

Reference


*1: Modbus is a registered trademark of Gould Modicon.
1. Introduction

Motion control systems used for controlling machines are comprised of a controller and an actuator. The controller determines the machine operation and the timing and pattern of the machine motion, while the actuator drives the machine according to commands from the controller.

The controller consists of a dedicated controller for motion, a programmable logic controller (PLC) based-, or a PC based-controller, and each type of controller competes in the marketplace based on its own strengths and advantages.

Recent motion control systems exhibit the following technological advances.

(1) Increased number of control axes
(2) Higher speed and higher accuracy
(3) Network connectivity (reduced wiring)

Fuji Electric was early to adopt a method of network connection in time with the release of its MICREX-SX series of controllers and FALDIC-D series of servo systems. These components, in combination with motion software technology, provide various types of machine control. Applying the high-performance servo system ALPHA5 series, the accuracy of the control and also the work efficiency have been improved significantly. Figure 1 shows the basic configuration of Fuji Electric’s motion control system.

This paper introduces the features and example applications of Fuji Electric’s motion control system.

2. Features

2.1 Increased use of software in motion control

(1) Lower cost

The embedding of software for motion control in a CPU module capable of high-speed processing eliminates the need for an expensive custom motion module. Figure 2 illustrates the difference in configuration.

(2) Enhanced motion control software programs

Motion function blocks (motion FBs) form the core of the motion control programs, and various types of FBs are available in a product lineup ranging from basic point-to-point (PTP) positioning control, linear interpolation control and circular interpolation control, to the synchronous operating system such as synchronous control and electronic cam control. By utilizing these motion FBs, users will be able to focus on creating application software for their company’s own machines.

The motion FBs are registered and managed as a software library, and they support horizontal deployment and reuse.

(3) Improved affinity for user programs

Motion FBs are connectable via a ladder diagram language so that users can create programs as if they were operating the machine. A programming example is shown in Fig. 3.

(4) Additional control axes by block copy command

In the case where more than one axis has the same functions, the second and subsequent axes can be added by block-copying the program of the first axis, so that the program can be created more efficiently.

Fig.1 Basic configuration of Fuji Electric’s motion control systems
Figure 4 shows an example where a control axis is added by using the block copy command.

(5) Freely combinable motion functions

Users are able to assign motion FBs freely to each axis. There are no restrictions from the functions of other axes included in the program. The PTP positioning FB and synchronous control FB can also be combined freely.

2.2 Adjustment of the servo system without using a loader

Since the MICREX-SX is provided with a servo parameter editing FB and the human machine interface (POD) is provided with a servo parameter adjustment screen, servo parameters can be edited from the POD screen. Figure 5 shows an example of the system configuration and editing screen required for servo parameter editing. There is no need to prepare adjustment equipment when the manufacturer’s personnel works at the end user’s factory, as adjustments can be made while in the onsite configuration. Moreover, the POD is also provided with a motion waveform display function so that the operating waveform of the motor can also be verified.

3. Application Examples

3.1 Example application to an X-Y table

An example application of the new ALPHA5 AC servo system model is presented in which a handwritten-based teaching function is applied to an X-Y table that uses two axes. The system configuration is shown in Fig. 6 and the control blocks are shown in Fig. 7. A finger is used to trace the operating trajectory of the motor on the POD’s analog keypad panel. The POD captures the trajectory as coordinate data in individual single dot unit, and the MICREX-SX converts that data into teaching data, and performs interpolation to operate two ALPHA5 units. In this application example, PTP positioning control, linear interpolation control and circular interpolation control are supported. Details of the control are described below.

(1) Data is sampled in cycles of 50 ms, and a maximum of 2,000 points can be sampled (within 100
seconds).
(2) The coordinate data captured by the POD is scaled from the screen size into the actual X-Y table size.
(3) The radius and circumferential speed are set for the portion to be circularly interpolated.
(4) Position data between two points that have been sampled and stored is circularly interpolated, and circular interpolation is performed continuously to reproduce on the X-Y table the motion of the trajectory, which had been traced onto the POD screen.

In this example, there is no need to use a PC to generate trajectory data for the motion, and the end user is able to generate the trajectory data onsite and with extreme ease. Moreover, since the motion control unit uses a system of function blocks (FBs), there are cost benefits as a custom motion module is unnecessary.

3.2 Example application to a bottling system

Features of a bottling system application that uses the MICREX-SX and the ALPHA5 are described below.

A bottling system is a machine that fills liquid in a bottle. Previously, the entire bottling system had been driven with a single motor, and various mechanical parts were intricately synchronized with a mechanical cam. However, as there was increased demand for the ability to support multi-product production and for improved productivity, an electronic flexible system was sought.

Fuji Electric resolved this issue by providing electronic cam control in a high-speed and highly accurate system based on the MICREX-SX and the ALPHA5. Figure 8 shows the configuration of the motion control system for the bottling system. The three axes of the servo system provide accurate synchronous control with the electronic cam, and the remaining two axes provide speed synchronous control. This system has the following features.

Fig.8 Configuration of electronic cam control system for bottling system

(1) Highly accurate synchronous control

Master axis processing that forms the control reference is provided inside the MICREX-SX, and the ALPHA5 units which drive the various mechanisms of the machine are synchronized to the master axis processing. With this method, a reference position is calculated with the master axis processing at a predetermined operation cycle, and the target positions for all ALPHA5 units are computed from the reference position. By issuing commands via an SX bus connected to all ALPHA5 units, precise synchronous accuracy can be ensured.

(2) Highly accurate electronic cam control

Electronic cam control connects four patterns continuously as the cam pattern to extend the motion of one cycle from 360° to 360° × 4 = 1,440°.

As a result, the trajectory pattern of the machine is set with 4-times higher resolution, and accuracy is improved. Figure 9 shows the entire waveform of the cam pattern.

(3) Performance improvement of auto tuning

In the past, servo systems had the problem of requiring a considerable amount of time for tuning in order to match the machine characteristics.

The newly utilized ALPHA5 has an improved auto tuning function and has achieved a significant reduction in tuning time. With a conventional model, tuning required an average of 30 minutes per unit, but with the ALPHA5, the tuning time has been reduced to 10 minutes per unit and the entire setup, which includes trial operation of the controller and the machine, can be completed in half a day.

(4) Higher rotational speed of the motor

With the ALPHA5, the maximum rotational speed of the motor has been increased to 6,000 r/min from the 5,000 r/min speed of the conventional model, thereby enabling higher speed operation and contributing to increased production capability of the machine.

As a result of these features, in contrast to the conventional mechanical cam control, electronic cam control is successful in streamlining the machine, increasing production capability, and supporting the manufacture of products of various sizes.

Fig.9 Continuous cam pattern waveform
3.3 Printed circuit board inspection system

Examples illustrating the improved performance of Fuji Electric’s motion control system are described below.

This printed circuit board inspection system is a control system that combines a PC and the board-type CPU of the MICREX-SX to perform imaging inspections of printed circuit boards, and then to transport inspected printed circuit boards at high-speed to the next process. Two servo system units are provided for the purpose of positioning and transporting the printed circuit boards. Figure 10 shows the system configuration of a motion control system. For approximately the past four years, Fuji Electric’s FALDIC-α series has been used as the servo system, but requests have recently increased for shorter inspection times, improved circuit board inspection capability and so on, and the reduction of settling time remained a problem.

To resolve this problem, Fuji Electric’s high-speed and highly accurate ALPHA5 series of servo systems has replaced the FALDIC-α series. Features of the ALPHA5 series are described below.

1. Compatibility with the FALDIC-α series
   Connection to the MICREX-SX series is fully upward compatible with the FALDIC-α series, so that the ALPHA5 series can replace the FALDIC-α series without requiring changes to the existing system or software programs. Additional functions that supplement the increased performance of the ALPHA5 series can be supported by adding ALPHA5 function blocks to the software programs.

2. Shorter settling time due to improved responsiveness
   By increasing the speed response to 1,500 Hz (2.5 times higher than that of the FALDIC-α series), tracking in response to a positioning command is improved dramatically, and the settling time is reduced.

3. Highly accurate positioning due to improved encoder resolution
   The positioning accuracy was improved dramatically by using a 20-bit encoder with approximately 1 million pulses per revolution (the FALDIC-α series used a 16-bit encoder with approximately 60,000 pulses per revolution) for position detection.

Application of the ALPHA5 series, having the above-described features, to an inspection system enables an approximate 30% reduction in settling time and improvement in positioning accuracy from 2μ to sub-micron levels.

4. Postscript

The FALDIC-α series is used in most of Fuji Electric’s servo systems at present, but a transition to the ALPHA5 series is planned as capacity is enhanced. Moreover, the FRENIC5000VG7S (vector control inverter) already supports usage of an SX bus, and the FRENIC-MEGA (general-purpose inverter) is slated to be equipped with an SX bus interface. In this way, a broader variety of actuators are being provided with the capability of connecting to an SX bus, extending the uses for motion control systems based on the MICREX-SX.

In the future, Fuji Electric intends to continue to improve competitiveness in response to customer requests for higher speeds and to advance the next generation of controllers and motion networks.
1. Introduction

Automation systems are evolving as they are supported by product technology for a wide variety of control devices, such as programmable controllers (PLCs), programmable operation displays (PODs), inverters, servo systems and various sensors. Since these control devices have increased their network connection capabilities in recent years, automation systems are now able to construct up to large-scale distributed systems using general-purpose control devices. Meanwhile, with the performance improvement of these individual devices, their application is being developed to different fields than in the past.

Under these circumstances, improved reliability, improved development efficiency, shorter development time span, multi-functionality and lower cost are also being sought for the development of automation system devices.

This paper describes the latest product technologies of programmable control equipment fields, as well as the technological trends and application.

2. Technical Trends of Automation Systems

2.1 PLC technical trends

(1) Efforts toward achieving high-reliability systems

Higher reliability is requested of the PLCs used in automation systems so that even if a partial system failure occurs, system control will be maintained and continued to keep ensuring the system operation from shutting down.

Ever since its debut, the MICREX-SX series of integrated controllers has been provided with redundant power supply modules and CPU modules to realize high-reliability systems. Table 1 lists the MICREX-SX CPU series lineup.

The SPH2000-256H of CPU module has been newly released as the latest model of the SPH2000 series enabling the realization of a system handling large amounts of data. The characteristic feature of this model is stronger redundant functionality through

<table>
<thead>
<tr>
<th>Series name</th>
<th>Type of shape</th>
<th>CPU series name</th>
<th>Features</th>
<th>Corresponding program capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>MICREX-SX</td>
<td>Building block</td>
<td>SPH200</td>
<td>Low price products</td>
<td>2 k, 4 k, 8 k, 16 k, 32 k, 48 k, 74 k, 117 k, 245 k, 256 k</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SPH300</td>
<td>Highest CPU performance</td>
<td>2 k, 4 k, 8 k, 16 k, 32 k, 48 k, 74 k, 117 k, 245 k, 256 k</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SPH300EX</td>
<td>Equipped with 2 high-performance CPUs</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>SPH2000</td>
<td>Equipped with Ethernet in standard</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Board</td>
<td>FBC-2000</td>
<td>Onboard SPH2000 functions and performance</td>
<td></td>
</tr>
<tr>
<td>SPB</td>
<td>Block</td>
<td>20 I/O basic unit</td>
<td>Compact integration with CPU, I/O &amp; power supply</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>30 I/O basic unit</td>
<td>Compact integration with CPU, I/O &amp; power supply</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>40 I/O basic unit</td>
<td>Compact integration with CPU, I/O &amp; power supply</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>60 I/O basic unit</td>
<td>Compact integration with CPU, I/O &amp; power supply</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Board</td>
<td>FBC-SPB</td>
<td>SPB CPU board equipped with RS-485 communication capability in standard</td>
<td></td>
</tr>
</tbody>
</table>

*The SPB program capacity is the value in SX mode (IEC language) operation.
larger capacity of equalized data among CPUs and high-speed data equalization. By using Ethernet as a dedicated equalization bus, which is a standard feature of the CPU module, an equalization data capacity of 320 kwords, which is 40 times larger than before, and an equalization data transfer speed that is 4 to 26 times faster than before are realized. This high-speed and large capacity equalization bus enables compact flash (CF) card data equalization and function block (FB) instance equalization, which have not been realized in the past. Therefore automation systems can be constructed with even higher reliability.

The features are listed below:

- A maximum of 320 kwords can be equalized
- FB instance equalization and CF equalization are possible
- The CPU can be replaced during the operation with hot-plug base board.

*1: Ethernet is a registered trademark of Fuji Xerox Co., Ltd. in Japan.

Table 2 Comparison of SPH redundancy capabilities

<table>
<thead>
<tr>
<th></th>
<th>SPH2000-256H Redundant CPU</th>
<th>SPH300 Redundant CPU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum equalization capacity</td>
<td>320 kwords</td>
<td>8 kwords</td>
</tr>
<tr>
<td>Equalization performance</td>
<td>8 kwords/20 ms</td>
<td>8 kwords/200 ms</td>
</tr>
<tr>
<td></td>
<td>320 kwords/250 ms</td>
<td></td>
</tr>
<tr>
<td>Equalization bus</td>
<td>Ethernet (dedicated)</td>
<td>SX bus</td>
</tr>
<tr>
<td></td>
<td>100 Mbit/s</td>
<td>25 Mbit/s</td>
</tr>
</tbody>
</table>

Fig.1 Network connectivity requested for automation system

Fig.2 Protocol stack structure for industry Ethernet

- Multi-CPU redundancy (up to 4 CPUs) is supported
- Standard modules such as power supply, base board, PI/O, and so on, are also used for redundant system.

Table 2 shows the comparison of SPH redundancy capabilities.

(2) Network technology

The network connectivity of a PLC is requested in all hierarchical levels, i.e., the plant level, controller level and device level. (See Fig. 1.)

Under these circumstances, Ethernet and Ethernet-based network technology applications to automation systems are rapidly being advanced. A characteristic feature of such applications is implementation of a protocol suitable for both the data processing and automation control applications on an Ethernet, which is realization of industry use of an Ethernet. (See Fig. 2.)

The MICREX-SX series supports an Ethernet and other various open networks with dedicated communication modules. So that the systems ranging from small-scale process control systems to large-scale hierarchical distributed systems can be constructed.

Adapting to such the network trends as above, the SPH2000 series is equipped with an Ethernet port as a standard feature. Furthermore, various network functions shown in Figs. 3 to 5 were released in 2007.

(3) Deployment of PLC technology to built-in control devices

In recent years, applications of PLC-based automation systems have been increasing toward built-in applications for machines and process equipment.

Previously, it was commonplace for a built-in controller to be developed with a dedicated control board and a custom built-in software. Such a method was in the mainstream because, under these conditions, the controller had to utilize the available hardware resources (processing capability, memory capacity and the like) to the maximum extent in order to satisfy the specific requirement for control devices. Moreover, C language was commonly used in the development of the software, and assembly language was also used in products that sought even higher performance.

Meanwhile, as development constraint for electronic devices, various electronic parts are being discontinued at an accelerating pace in order to increase performance and environmental friendliness of the materials used. As a result, conditions are occurring that compel the redevelopment of hardware and software controllers for built-in control devices. As electronic parts are expected to be discontinued at increasingly shorter cycle times in the future, countermeasures will be needed in order to ensure a future stable supply of electronic devices which ensure the same specifications as existing one.

In response to such change of constraint, in some fields where custom built-in controllers had been developed, a trend has emerged in recent years that general-
purpose PLCs which have been improved their computing capability are replacing such custom controller.

A major reason for this trend is to have guaranteed more than 10 years for the supply period of the product in the case of a PLC. Even if electronic components are discontinued during this time, hardware with same specifications should be guaranteed by the PLC supplier, and therefore, the OEMs of a built-in controller do not take on any hardware procurement risk.

Another reason for this trend is the maintainability of the software. The PLC software development environment is adequate as long as dedicated programming software can run on a PC and a communication cable linking the PC and PLC are available. Comparing with the custom controller, there is no need to prepare custom development software corresponding to each installed microprocessor or custom type debugging equipment such as an ICE (in circuit emulator). Moreover, since the PLC development equipment is lightweight, software debugging and revising at the on-site location where the controller is installed, software analysis and revision in the case of malfunction, and so on can be performed easily. For the following reasons, the PLC programming language presents a low barrier for the developer of custom controller software to migrate towards the use of a PLC.

- A conventional ladder diagram language
- Structured programming of Data and program conforming to the international standard IEC language
- ST (structured text) language suitable for control programming than C language can be used

In response to these requests, board-type controllers that are smaller and thinner than a PLC but that still maintain the functions, performance and ease of use of PLCs based on the MICREX-SX series are also being developed in Fuji Electric’s PLC product line.

The FBC (Fuji-board controller)-SPB based on the MICREX SX series and the FBC-2000 based on the SPH2000 of the MICREX-SX SPH series are available as board type controllers. As well as the module type SPH2000 series, the FBC-2000 is also equipped with an Ethernet port and a compact flash memory slot. Moreover, since the FBC-2000 board is equipped with a standard SX bus, various MICREX-SX series modules, inverters, servo systems, PODs and the like equipped with an SX bus can be connected as needed, so that they enable a flexible and expandable system construction.

(4) Deployment in the motion control field

Accompanying the recently increasing CPU performance of PLCs and the improved data communication performance of servo amplifiers and other control devices, the conventional implementation of motion control by a custom controller is being replaced by PLC-based systems in an increasing number of instances. In particular, in the case where a multi-axis control device is applied to a large printing press or the like that had previously been synchronized mechanically, synchronous control can be implemented in the same manner as before by electronic multi-axis control provided by servo motors networked with a PLC which are directly coupled to the control axis. This method has many characteristic features: mechanical adjustments are unnecessary, structural machine changes are easily implemented, machine operation specification changes can be realized by the software only, and the machine cost can be reduced. Controllers capable of supporting this multi-axis motion control require even greater capability, such as multi-axis synchronization, high-speed computation, high-speed data exchange performance, and the like.

For this type of multi-axis motion control, Fuji Electric provides the SPH300EX as a CPU module of the MICREX-SX series. The SPH300EX module contains two processing cores of the SPH300 series’ CPU module, which have the highest computing capacity in
the series, and thus the computing capacity and I/O area increased by a factor of two. These enable the efficient system construction that meets the demands of the motion control field.

(5) Packaged machine controller products

Fuji Electric provides a multi-axis motion control system consisting of the MICREX-SX series equipped with a built-in motion control program and the POD equipped with a built-in custom numeric control (NC) program editing screen. This multi-axis motion control system is known as “Simple NC.” By packaging the hardware and software required for NC into these products, machine set OEMs can easily realize NC-based motion control by installing the Simple NC (Fig. 6). A functional aspect of this system is that instead of NC programming using the standard G-code for the NC system, the programming can be implemented graphically by operations on the POD screen. These products enable machine set OEMs and end users to perform flexible machine control and machine operations.

We expect to expand PLCs as well as the application of these products to the motion control field in the future.

(6) New functions for development support

In recent automation systems, sophisticated control systems are often constructed using an Ethernet network. In these cases, there is demand for functions that enable program development and device maintenance via the network from the remote network-connected devices.

In response to this demand, a transparent communication function have been newly provided for the CPU module SPH300 series and the SPH2000 series of the MICREX-SX series.

In the case of the MICREX-SX series, control devices such as an inverter, servo amplifier, POD and the like can be connected to the SX bus which is the main bus. Although the tasks of setting and adjusting numerous control parameters as well as programming are necessary for these control devices, custom support tools for each device were individually connected to perform such tasks in the past.

With the newly developed transparent communication function, however, the CPU module of the MICREX-SX series serves as a relay router for the SX bus to communication interface modules (RS-422, USB and Ethernet) or Ethernet port of CPU module. Thus, the control devices connected to the SX bus can be operated remotely, thereby enabling significant improvements in development efficiency and maintainability.

On the foundation of this transparent communication function, an integrated support environment was realized for the control devices, including the MICREX-SX series. As a next step, Fuji Electric is working to integrate the support tools for the various control devices, and to develop integrated support tools for realizing more efficient and higher quality development for the entire control system.

2.2 Technical trends of PODs

The POD in an automation system is an essential device for interfacing with the operator. With recent advances in peripheral device technology, the display expressiveness, data processing capability, network connectivity and so on of PODs have been strengthened considerably.

Under these circumstances, the MONITOUCH V8 series has been added to the main MONITOUCH series. Table 3 lists the product lineup of the MONITOUCH V8 series.

With the MONITOUCH V8 series, communication and network performance have been improved with an 8-way communication function, drawing performance has been improved significantly, and external interface functions have been extended. The product lineup contains many models having different screen sizes, drawing capacities and external interface functions in order to support various user needs.

Moreover, in recent years PLCs have increasingly been applied to such instrumentation systems for instance plant control systems which have conventionally been realized by distributed control systems (DCS). An instrumentation system requires a POD to display the monitoring data. However, in order to display many

Table 3 MONITOUCH V8 series lineup

<table>
<thead>
<tr>
<th>Model</th>
<th>Type</th>
<th>6-inch (screen size)</th>
<th>8-inch</th>
<th>10-inch</th>
<th>12-inch</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>STN monochrome</td>
<td>STN color</td>
<td>TFT color</td>
<td>TFT color</td>
<td>TFT color</td>
</tr>
<tr>
<td>High</td>
<td>Full spec</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>V808iS</td>
</tr>
<tr>
<td>performance</td>
<td>Basic</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>V808iS</td>
</tr>
<tr>
<td>Standard</td>
<td>Full spec</td>
<td>V806iMD</td>
<td>V806iCD</td>
<td>V806iTD</td>
<td>V808iC</td>
</tr>
<tr>
<td></td>
<td>Basic</td>
<td>V806MD</td>
<td>V806CD</td>
<td>V806TD</td>
<td>V808C</td>
</tr>
</tbody>
</table>
types of data monitored on a POD screen by a PLC, a large effort is required to develop PLC software and to create the POD screen linked to them.

To resolve this problem, Fuji Electric has recently released an “SX instrumentation package” that combines the CPU module of the MICREX-SX SPH2000 series for the PLC, and a UG30 (MONITOUCH V7) series for the POD. A feature of this product is that the POD display screen corresponding to the FB will be generated automatically by simply using the instrumentation FB of the “Expert” development support tool to specify the data to be displayed on the POD, and then activating a data linking tool. The automatically generated POD screen is known as a face plate (FP), and the FPs are provided as well as instrumentation FBs in a library format.

This function not only makes the development of PLC control software and the POD screen more efficient but also simplifies the user task of debugging the POD screen and PLC control software. Therefore it enables a significant reduction in the time required for system development.

3. Postscript

The latest technology used in Fuji Electric’s automation system devices and the target application fields have been discussed above. The application fields are expected to expand as the performance and multifunctionality of individual devices continue to improve in the future. In particular, since the evolution of network technology is predicted to accelerate in the future, even higher technical development capabilities will be needed.

As a comprehensive manufacturer of automation system devices, Fuji Electric intends to continue to provide latest-technology products in order to meet the needs of our customers.
New Redundant System of MICREX-SX Series of Integrated Controllers

1. Introduction

The MICREX-SX series of integrated controllers have a maximum program capacity of 256 ksteps, a maximum data memory capacity of 2 Mwords and a maximum of 65,536 points at 1/O terminals. They can configure the optimal control systems scalable from small-scale to large-scale.

In a control system for a petrochemical or water processing plant or the like where a large loss is feared to be generated if the control system is halted due to device failure, it is vital to improve system reliability by providing the devices with standby redundancy in control functional units.

Since its introduction, the MICREX-SX series has supported 1-to-1 warm standby redundancy for CPU modules and has contributed to proliferation of highly versatile, reliable and safe systems in seeking to ensure both of system reliability and cost reduce.

This paper introduces a system equipped with a new redundant function based on the SPH2000 series of CPU modules which have been improved significantly for monitoring and data functions. Figure 1 shows the external appearance of the SPH2000 series.

2. Configuration of SPH2000 Redundant System

The SPH2000 series supports CPU module redundancy and redundancy of the basic system consisting of the power supply, base, CPU and network.

2.1 Module redundancy

The previous SPH300 series supports redundant CPU functions with 1-to-1 warm standby, 1-to-1 cold standby, and N-to-1 cold standby.

The SPH2000 series supports redundancy of the CPU module (module duplexing) with 1-to-1 warm standby and 1-to-1 cold standby redundancy, for which there are many application examples with SPH300 series redundant systems. Figure 2 shows the redundant module configuration.

In a duplexed CPU module configuration, the redundant pair of a working CPU and a standby CPU are mounted on the same SX bus, and the working CPU is connected to the standby CPU via a bus for equalizing the application control data. In a multi-CPU configuration, CPU redundancy is also possible, and a system having a maximum of four pairs of multi-CPUs can be configured. Because the working CPU and the standby CPU must have the same application program, a support tool can be used for performing a batch download to both the working and standby CPUs.

With duplexed CPU modules, the operating states of the working CPU is monitored by the standby CPU, and if the working CPU fails, control changes over to the standby CPU and operation can be continued. In addition to the CPU module, the power supply module and the LE-net network module can also be duplexed.

Since standard modules can be used except for the redundant SPH2000 series of CPU module, an existing...
system not yet made redundant can be easily switched to a redundant system that make the most of resource efficiency with low system cost.

2.2 System redundancy

An entire basic system, including the power supply, baseboard, CPU module and LE-net module, is duplexed in case of system redundant configuration. The basic system and the I/O system are connected with a loop-structure LE-net. The working CPU and standby CPU are connected with an equalized bus. Figure 3 shows the system duplexing configuration. As in the case of module redundancy, both the working and standby CPUs store the same application program.

The redundancy changeover operates as follows. The CPU module and LE-net module of the working system monitor each other, and if an abnormal condition is detected, control transfers to the standby system. The CPU of the standby system monitors the working CPU which is its redundant pair, and makes shift to the working system after detecting the failure or the transfer to the standby state of its pair CPU.

In the case where a failure occurs in any of the power supply, baseboard, CPU module or LE-net module, in order to continue the changeover operation to the standby system, this system redundancy can realize a system having higher reliability than provided by module redundancy.

Moreover, the use of a loop-structure LE-net enables other communication means to be maintained even if the LE-net module fails or is halted, and therefore, the system operating state can be maintained by replacement in units of the failed basic system. As in the case of module redundancy, system cost can be reduced since standard modules can also be used in addition to the SPH2000 series modules.

3. Features of a SPH2000 Redundant System

Table 1 compares the redundancy specifications of

<table>
<thead>
<tr>
<th>Item</th>
<th>SPH300 series specifications</th>
<th>SPH2000 series specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program memory</td>
<td>32/74/117/245 ksteps</td>
<td>256 ksteps</td>
</tr>
<tr>
<td>Data memory</td>
<td>32/128/256/512 kwords</td>
<td>2 Mwords</td>
</tr>
<tr>
<td>Max. number of I/O points</td>
<td>8,192 points</td>
<td>8,192 points (standard)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>65,536 points (for extended I/O)</td>
</tr>
<tr>
<td>Module duplexing / system duplexing</td>
<td>Module duplexing</td>
<td>Module duplexing, system duplexing</td>
</tr>
<tr>
<td>Standby method</td>
<td>1-to-1 warm standby</td>
<td>1-to-1 warm standby</td>
</tr>
<tr>
<td></td>
<td>1-to-1 cold standby</td>
<td>1-to-1 cold standby</td>
</tr>
<tr>
<td></td>
<td>N-to-1 cold standby</td>
<td></td>
</tr>
<tr>
<td>Multi-CPU</td>
<td>4 units (1-to-1 warm standby)</td>
<td>4 units (1-to-1 warm standby)</td>
</tr>
<tr>
<td></td>
<td>1-to-1 cold standby</td>
<td>1-to-1 cold standby</td>
</tr>
<tr>
<td></td>
<td>7 units (N-to-1 cold standby)</td>
<td></td>
</tr>
<tr>
<td>Range of equalized memory</td>
<td>I/O memory</td>
<td>I/O memory</td>
</tr>
<tr>
<td></td>
<td>Edge detection, timer, counter</td>
<td>Edge detection, timer, counter</td>
</tr>
<tr>
<td></td>
<td>Retain memory of the user FB instance</td>
<td>Specified user FB instance memory</td>
</tr>
<tr>
<td></td>
<td>Specified general memory, specified retain memory</td>
<td>Specified general memory, specified retain memory</td>
</tr>
<tr>
<td>Equalized task</td>
<td>Default task only</td>
<td>Equalization can be specified for all tasks</td>
</tr>
<tr>
<td>Writing to CF cards of both systems</td>
<td>Not supported</td>
<td>Supported with module duplexing only</td>
</tr>
<tr>
<td>Duplexing range</td>
<td>Power supply, network (LE-net)</td>
<td>Power supply, network (LE-net) : during module duplexing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Power supply, base, network (LE-net) : during system redundancy</td>
</tr>
<tr>
<td>Changeover time</td>
<td>130 ms (module duplexing)</td>
<td>130 ms (module duplexing)</td>
</tr>
<tr>
<td></td>
<td>780 ms (system duplexing)</td>
<td>780 ms (system duplexing)</td>
</tr>
<tr>
<td>Equalization time</td>
<td>512 words/1.5 ms to 512 words/10 ms</td>
<td>320 kwords/250 ms</td>
</tr>
<tr>
<td>Equalization size</td>
<td>Max. 8 kwords</td>
<td>Max. 320 kwords</td>
</tr>
<tr>
<td>Equalized bus</td>
<td>SX bus</td>
<td>Ethernet</td>
</tr>
<tr>
<td>Equalized cable</td>
<td>SX bus cable</td>
<td>Shielded category 5 LAN cross cable</td>
</tr>
<tr>
<td>Bit rate</td>
<td>25 Mbit/s</td>
<td>100 Mbit/s</td>
</tr>
</tbody>
</table>
3.1 High-speed large-capacity equalization

The MICREX-SX series supports a warm standby method in which the standby CPU inherits the data of the working CPU during a redundancy changeover. This inherited data is known as equalized data, and in the SPH300 series, the equalized data is transmitted via the SX bus. Because the SX bus is a system bus on which the updating of I/O data, system monitoring and message-based communication is also performed, the transmission of equalized data is limited to a maximum of 512 words per tact, causing a bottleneck in the transmission performance of equalized data.

With the SPH2000 series, an Ethernet*1 port provided as a standard feature is used exclusively as an equalized bus during redundant operation and realizes an equalized data transmission performance of 13.3 kwords/10 ms for a maximum equalized data capacity of 320 kwords. Compared to the SPH300 series, this is a 40-times improvement in equalized data capacity and a 4- to 26-times improvement in equalized data transmission performance.

If the control data of the application program uses 320 kwords or less, all control data can be equalized. The application program can be created without having to consider the equalized data capacity.

3.2 Setting of equalization execution task

The MICREX-SX series allows a maximum of five tasks to be set, one default task and a combined total of four fixed-cycle tasks and event tasks. With the SPH300 series, the transmission processing of equalized data is performed on completion of the default task. In contrast, the SPH2000 series, which allows the setting of multiple tasks that carry out the transmission processing of equalized data, provides flexible support of redundancy, even for sophisticated multi-task application programs. Figure 4 shows the view of equalized data setting.

3.3 Setting the equalized data

With the SPH300 series, data specified for equalization in the general memory (non-retain memory) and in the retain memory, previously inputted edge detection values, and the current values and previously inputted values of the timer and counter, and data for which the retain memory of the user function block (FB) instance are equalized as such data which must be inherited in the control state.

With the SPH2000 series, equalization can be specified for all memory of a user FB instance. Equalization is specified with the variable name of the data and the user FB instance name. The name of the variable specified for equalization can be changed.

Moreover, with the increase in equalization data capacity, equalization can be specified for all areas other than general memory (non-retain memory), and therefore only the size of the equalization data can be set for the general memory for which equalization capacity limitations still remain, and all areas can be set at once, without setting equalization for each variable. Figure 5 shows the equalized data range setting of the support tool.

3.4 Writing to CF cards of both systems

The SPH2000 series and the SPH300 series are both capable of using a compact flash (CF) card as user ROM. The user ROM stores the application program and user data files, and the user ROM can be read from or written to by the application program. Moreover, the user ROM can also be used as a large capacity memory that only stores user data files without the application program. CF cards of up to 2 GB maximum can be utilized.

For redundancy, an FB has been added to the SPH2000 series that writes in a batch process to the CF cards of the working and standby CPUs. This FB enables duplexing of the parameters and recipe data necessary for operation, and can perform CF card data equalization at such times as when parameters are changed during adjustment of the machine.

3.5 Extended I/O function

The extended I/O function connects remote I/O via a maximum of eight system networks, enabling
I/O control for a maximum of 4,096 words (65,536 points) in a single configuration. The higher speed and larger capacity that accompanies the redundancy of the SPH2000 series supports an extended I/O function that was not supported with the SPH300 series.

The extended I/O performs an I/O refresh for a single remote master per tact cycle and performs an I/O refresh for all eight remote master units in eight tact cycles. In the extended I/O operation, the application task and I/O refreshing are not synchronized, and therefore the I/O refresh is restarted at the redundancy changeover timing. Figure 6 shows the redundancy changeover timing using extended I/O.

### 3.6 LE-net module redundancy

LE-net is a field-level network that connects processors. It was developed by Fuji Electric to lower costs and to streamline system construction. The network is available in two varieties, a bus structure and a loop structure. Table 2 lists the specifications of the loop structure LE-net.

The redundancy when the SPH2000 series and the SPH300 series are combined is described below.

In the case where the SPH2000 series modules are duplexed and the LE-net module is made redundant with the SPH300 series, duplexed maintenance FBs form a mechanism that enables the application program to control redundancy changeover so that the load on the system software is reduced.

With the system duplexing of the SPH2000 series, the working and standby LE-net modules are not mounted on the same system, and therefore duplexed maintenance FBs are not used in the redundancy changeover.

With system duplexing, the system software operates via the equalized bus to monitor between CPUs and to monitor the status of the LE-net module on the same system, and performs a redundancy changeover when an abnormal condition is detected in the working system.

Moreover, the LE-net module monitors the operating state of the CPU module in the same system, and adds a mechanism for transitioning to the standby system if the CPU module fails. Consequently, with system duplexing, the LE-net can be made redundant simply by implementing the redundancy settings of the LE-net module.

### 4. Postscript

An overview of the redundancy and features of the SPH2000 series has been presented.

In the instrumentation plant control field which requires a distributed control system (DCS), where the redundant system is one of the characteristics, there has been an increase in the applications of general-purpose PLCs for realizing a good balance between higher system reliability and lower total cost, and we believe that the new redundancy functions introduced herein will provide strong support for such purposes.

Fuji Electric intends to continue to develop distinctive technology that leverages the versatility and flexibility of the SPH2000 series.

### Table 2 Loop-structure LE-net specifications

<table>
<thead>
<tr>
<th>Item</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of connectable nodes</td>
<td>Max. 64 nodes</td>
</tr>
<tr>
<td>Node No. setting range</td>
<td>0 to 63</td>
</tr>
<tr>
<td>Connection distance</td>
<td>Total length : 500 m</td>
</tr>
<tr>
<td></td>
<td>Distance between nodes : 100 m</td>
</tr>
<tr>
<td>Transmission media</td>
<td>Shielded category 5 cross cable</td>
</tr>
<tr>
<td>Topology</td>
<td>Single-loop duplex wiring</td>
</tr>
<tr>
<td>Communication method</td>
<td>Half-duplex, double-system transmission and first-come first-received method</td>
</tr>
<tr>
<td>Communication protocol</td>
<td>1-to-N broadcast communication</td>
</tr>
<tr>
<td></td>
<td>1-to-1 Message communication</td>
</tr>
<tr>
<td>Transmission signal method</td>
<td>RS-485 differential signal</td>
</tr>
<tr>
<td>Transmission rate</td>
<td>5 Mbit/s fixed</td>
</tr>
<tr>
<td>Error check</td>
<td>CRC 16-bit</td>
</tr>
<tr>
<td>Encoding method</td>
<td>4B5B NRZI</td>
</tr>
</tbody>
</table>
1. Introduction

The application fields for programmable controllers (PLCs) have continued to adopt open standards and become multi-functional and more diverse in recent years. Accompanying these trends, such marketplace demands are persistent as more flexible system architecture, lower cost, larger scale system construction and more efficient program development that support more sophisticated, easier maintenance and better network connectivity system.

Based on the concept of a “global system component,” Fuji Electric’s MICREX-SX series of integrated controllers has, since their introduction, extended functionality and extended the product series in order to support the above demands accurately.

This paper describes a board-type controller that applies the MICREX-SX series technology.

2. Board-type Controller, “FBC-SPB”

The FBC-SPB is a board controller that is based on the SPB, a small block PLC of the MICREX-SX series. Control systems for medium- and small-scale systems can be constructed by connecting an expansion I/O board and optional boards having communication functions and the like to the CPU board. Figure 1 shows the external appearance of the FBC-SPB.

2.1 FBC-SPB features

Table 1 lists the basic features of the FBC-SPB.

The FBC-SPB product lineup consists of three types of 8 k, 16 k and 32 k steps of program memory capacities. Also, the CPU board contains the standard functions of an RS-485 interface as well as a high-speed counter, a pulse catch input, and an interrupt input.

2.2 Connection to an inverter

A RS-485 interface is provided with, not only a general-purpose communication interface, but also a connection interface for Fuji Electric’s FRENIC-Multi series, FRENIC-Eco series and FRENIC-Mini series of inverters. Figure 2 shows the inverter interface.

(1) Inverter loader interface

The inverter loader interface enables the inverter to be supported directly via the RS-485 interface of the CPU board.

(2) Easy application interface to inverter function

The function code of the inverter can be read and written directly from an application running on the board-type controller. In this case, there is no need for a communication program and the like.

2.3 Flexible system configuration

A maximum of three units of expanded I/O board and a maximum of two units of optional board can be connected to FBC-SPB. Moreover, the connection structure can be configured flexibly in the stack, side-by-side, or other connection. Figure 3 shows some system configuration examples of the FBC-SPB.

2.4 Programming support tool

The same programming support tool for the MICREX-SX series can be used and various optimal control programs can be created easily and efficiently by combining function blocks (FBs) prepared for their function and type of control.

Figure 4 shows the FB programming for an elevator control system example.

The FBC-2000 is a board controller based on the CPU module SPH2000 of the MICREX-SX series. Figure 5 shows the external appearance of the FBC-2000.

3.1 FBC-2000 features

The FBC-2000 is configured from the combination of a CPU board with various types of boards such as I/O and communication boards. The FBC-2000 is provided with the same large capacity memory and various types of interfaces as the SPH2000 series to realize equivalent functionality and performance. Moreover it has a small low-profile shape, and has a communication function and combinational structure for facilitat-
ing various configurations.

### 3.2 Optimization of system configuration

The CPU board is provided with an SX bus connector for expansion-use, a loader port and a 1-channel Ethernet\(^1\) interface, thus enabling connection with various SX bus products and Ethernet connection. Therefore it is achieving an overall cost reduction for the system and enabling the construction of an even more optimal system configuration. Figure 6 shows an example of a system configuration using the FBC-2000.

\(^1\): Ethernet is a registered trademark of Fuji Xerox Co., Ltd. in Japan

---

**Fig.5** Board-type controller, “FBC-2000”

**Fig.6** Example system configuration using FBC-2000

**Fig.7** Example of proposed controller box

---

### 3.3 Product development for diverse markets and uses

The FBC-2000, with its smaller and thinner structure, has a very different installation method than a general-purpose PLC, and is applicable to markets and uses which were difficult for the general-purpose PLC to support. Moreover, further advanced products based on the FBC-2000 board shape can also be proposed.

Examples of product application that fully utilize these features are listed below.

1. **Controller box**

   Figure 7 is an example of a proposed product wherein only a CPU board is arranged inside the product case. This product can be mounted in the limited space inside the control panel. By installing an application program for the use, the customer solution can be provided with a customized controller rather than a PLC.

2. **POD with controller**

---

**Fig.8** POD with controller

**Fig.9** Functional evolution of SPH2000
Figure 8 shows a “POD with controller” in which an FBC-2000 CPU board is mounted on the rear of a POD. A simple and space-saving system configuration is possible, and features not available with a PLC can be provided, such as the ability to perform various settings or a fault diagnosis from the POD screen.

3.4 Inheritance of the SPH2000 series’ functional evolution

Since the FBC-2000 has the same FA platform as the SPH2000 series, it preserves application program compatibility.

Additional functions of the SPH2000 series, i.e., the FTP client server, C language interface and mail client, are also provided to the FBC-2000. (See Fig. 9.)

4. Postscript

To meet the needs of various markets in the future, various functions and a product lineup are requested for PLCs and board-type general-purpose PLCs as their applications. The inherited global architecture of the MICREX-SX series of integrated controllers and the product technology of the MICREX-SX series will be used to develop a product lineup. Moreover, flexible application in various fields is thought to be possible by combining product groups and support tools, which support the five types of programming languages conforming to IEC standards. Fuji Electric intends to continue to provide products and systems in which PLC technology is applied increasingly.
New MONITOUCH V8 Series of Programmable Operation Displays

1. Introduction

Programmable operation displays (PODs) are playing an increasingly important role in the FA field, and this market has been growing steadily year-by-year. Fuji Electric’s UG30 (MONITOUCH V7) series of PODs boasts a wide variety of models with the industry’s greatest number of connection types, and has responded to user requests ahead of other companies by supporting color displays of 32,768 colors, supporting the exchange of data using compact flash (CF) cards, and so on.

With the higher functionality and complexity of machinery and equipment in recent years, users are also requesting more diverse and higher levels of performance to PODs. In a control system, for example, such requests call for a diversification of the connection topology, an increased number of connectable units and the capability to handle a larger quantity of communication data. As an information system, PODs are requested to be able to replace a system realized with a conventional panel computer and to provide greater compatibility with PCs. As a human-machine interface, PODs must provide improved expandability and higher levels of display and communication performance, which are the original functions of the POD.

Moreover, as the scale of a system becomes larger, shorter development times are requested, and the betterment of use and convenience for the user including ease of constructing the screen and ease of maintenance is also considered important for the display device.

This paper introduces Fuji Electric’s new MONITOUCH V8 series of PODs that satisfy the latest user needs.

2. Overview of the MONITOUCH V8 Series

2.1 Development concept

The new POD MONITOUCH V8 series was de-

<table>
<thead>
<tr>
<th>Model</th>
<th>6-inch</th>
<th>8-inch</th>
<th>10-inch</th>
<th>12-inch</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>STN monochrome</td>
<td>STN color</td>
<td>TFT color</td>
<td>STN color</td>
</tr>
<tr>
<td>6-inch</td>
<td>320 × 240</td>
<td>640 × 480</td>
<td>800 × 600</td>
<td>800 × 600</td>
</tr>
<tr>
<td>8-inch</td>
<td>320 × 240</td>
<td>640 × 480</td>
<td>800 × 600</td>
<td>800 × 600</td>
</tr>
<tr>
<td>10-inch</td>
<td>640 × 480</td>
<td>800 × 600</td>
<td>800 × 600</td>
<td></td>
</tr>
<tr>
<td>12-inch</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1 MONITOUCH V8 series lineup

<table>
<thead>
<tr>
<th>Standard</th>
<th>V806iMD</th>
<th>V806iCD</th>
<th>V806iTD</th>
<th>V808iC</th>
<th>V810iC</th>
</tr>
</thead>
<tbody>
<tr>
<td>65,536-color, 256-color, 16-tone</td>
<td>USB-A, USB-B</td>
<td>Communication interface unit : OK</td>
<td>CF card interface</td>
<td>Screen data : 12 Mbytes, SRAM 512 kbytes</td>
<td>LAN interface</td>
</tr>
<tr>
<td>256-color</td>
<td>USB-A, USB-B</td>
<td>Communication interface unit : OK</td>
<td>CF card interface</td>
<td>Screen data : 12 Mbytes, SRAM 512 kbytes</td>
<td>LAN interface</td>
</tr>
<tr>
<td>65,536-color, 256-color, 16-tone</td>
<td>USB-A, USB-B</td>
<td>Communication interface unit : OK</td>
<td>CF card interface</td>
<td>Screen data : 12 Mbytes, SRAM 512 kbytes</td>
<td>LAN interface</td>
</tr>
<tr>
<td>256-color</td>
<td>USB-A, USB-B</td>
<td>Communication interface unit : OK</td>
<td>CF card interface</td>
<td>Screen data : 5 Mbytes, SRAM 128 kbytes</td>
<td>LAN interface</td>
</tr>
<tr>
<td>65,536-color</td>
<td>USB-A, USB-B</td>
<td>Communication interface unit : OK</td>
<td>CF card interface</td>
<td>Screen data : 1.5 Mbytes, SRAM 128 kbytes</td>
<td>LAN interface</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>High performance</th>
<th>V808iS</th>
<th>V810iT</th>
<th>V810iS</th>
<th>V812iS</th>
</tr>
</thead>
<tbody>
<tr>
<td>65,536-color</td>
<td>USB-A, USB-B</td>
<td>Communication interface unit : OK</td>
<td>CF card interface</td>
<td>Screen data : 12 Mbytes, SRAM 512 kbytes</td>
</tr>
<tr>
<td>256-color</td>
<td>USB-A, USB-B</td>
<td>Communication interface unit : OK</td>
<td>CF card interface</td>
<td>Screen data : 12 Mbytes, SRAM 512 kbytes</td>
</tr>
<tr>
<td>65,536-color</td>
<td>USB-A, USB-B</td>
<td>Communication interface unit : OK</td>
<td>CF card interface</td>
<td>Screen data : 12 Mbytes, SRAM 512 kbytes</td>
</tr>
<tr>
<td>256-color</td>
<td>USB-A, USB-B</td>
<td>Communication interface unit : OK</td>
<td>CF card interface</td>
<td>Screen data : 12 Mbytes, SRAM 512 kbytes</td>
</tr>
<tr>
<td>65,536-color</td>
<td>USB-A, USB-B</td>
<td>Communication interface unit : OK</td>
<td>CF card interface</td>
<td>Screen data : 12 Mbytes, SRAM 512 kbytes</td>
</tr>
<tr>
<td>256-color</td>
<td>USB-A, USB-B</td>
<td>Communication interface unit : OK</td>
<td>CF card interface</td>
<td>Screen data : 12 Mbytes, SRAM 512 kbytes</td>
</tr>
</tbody>
</table>

The new POD MONITOUCH V8 series was de-
veloped based on the concept of achieving an intrinsic ease-of-use. Seeking a high level of usability by increasing the performance level and providing realistic display capability, as well as enhanced connectivity and expandability, the MONITOUCH V8 series aims to achieve production innovation and to unite the job site and remote office further.

2.2 Elegance and ease of use

The MONITOUCH V8 series high-performance models are equipped with a high-speed accelerator and utilize a high-speed algorithm to perform drawing process at high-speed with both hardware and software. The use of TFT liquid crystal technology in the 6- to 12-inch displays improves visibility and makes it easier for the operator to assess the process situations.

2.3 Display device that is easy for anyone to use

In addition to the user interface which is trending toward componentization, various switch functions that do not require macro programs or ladder programs are included as a standard feature. Moreover, the requirement for a large capacity user memory is also satisfied.

2.4 Realization of flexible system operation

An Ethernet*1 interface is provided as a standard feature in all 6- to 12-inch model sizes. High-speed communication that combines three serial communications channels and an Ethernet enables connection of a maximum of eight models of external devices, and realizes 8-way communication.

2.5 MONITOUCH V8 series lineup

Table 1 lists the MONITOUCH V8 series lineup, which consists of a high-performance model and a standard model, and is based on the UG30 (MONITOUCH V7) series, with all models being provided with a USB (universal serial bus)-A/B interface, and both model types being available with or without an Ethernet interface.

3. MONITOUCH V8 Series Features

3.1 Display performance

(1) 65,536 display colors

With a high-resolution display of 65,536 colors in the case of no blinking and 32,768 colors in the case of blinking, JPEG and BMP images are clearly visible, and photos, illustrations, 3-D parts and so on can be displayed realistically. As a result, visibility is improved and the operator is able to assess the process situations with greater ease.

(2) 30 frames-per-second video display with 16.77 million colors

The use of the latest high-performance graphic accelerator chip has resulted in a dramatic improvement in video display performance. With 30 frames-per-second high-speed video, there is no time lag in the display, even for applications having a short tact time.

(3) 256-tone monochrome display

The monochrome images commonly used in image processing by semiconductor equipment can be displayed more clearly, and graduation reproducibility and a convexo-concave sense have been improved significantly.

3.2 Operation performance

(1) Analog switch

A conventional analog film resistor is used as the touch panel switch. Since the switch layout has a high degree of freedom, the designing work is easy and an intuitive operation screen can be realized.

(2) High-speed response

Previously, in cases where there was a large quantity of communications data or where a connected device had a slow communications speed, the switch processing waited until completion of the communication, and as a result the response decreased.

In order to solve this problem, we conducted a review of the communication efficiency of each connected device in order to realize high-speed communication. Additionally, we conducted a review of the internal task configuration and increased efficiency to realize a higher speed switching response.

3.3 Communication connectivity

(1) 8-way communication

With a conventional POD, a maximum of only two types of devices could be connected simultaneously. With 8-way communication, however, combining an Ethernet interface (8 protocols) and a serial communication interface (3 protocols), a maximum of 8 types of programmable logic controllers (PLCs) of different models and having been made by different manufacturers, and their peripheral devices, can be connected with a single POD. Moreover, a D-sub connector or a modular connector can be freely selected for the connection port, allowing flexible support of the user’s work environment.

(2) Connection configuration 1: Serial connection (3 ports)

Up to a maximum of three types of serial-communicating PLCs and peripheral devices can be connected. As a result, even in cases that could not be realized in the past, such as where multiple types of temperature controllers and inverters are being used, all the connections can be implemented with a single POD. Figure 1 shows a configuration of the expanded serial connectivity.

(3) Connection configuration 2: Serial + Ethernet mixed configuration

In addition to the conventional 2-way communication with a temperature controller and PLC, the new

---

*1: Ethernet is a registered trademark of Fuji Xerox Co., Ltd. in Japan.
MONITOUCH V8 PODs can also add Ethernet communication capability. Figure 2 shows a configuration of a serial and Ethernet mixed connection.

(4) Connection configuration 3: Ethernet connection

With a single POD, a maximum of 8 types of PLCs and Ethernet connections are possible. Even PLCs of differing types or from different manufacturers, having been installed in an existing system, can be connected, enabling the flexible support of various systems. Additionally, by attaching an optional unit, the Ethernet interface can be expanded to 2 ports, and used as a gateway. For example, even if different networks, such as between a job site and an office, are connected with a POD, data can be delivered without placing additional load on the network itself.

Figure 3 shows a configuration of an Ethernet connection.

3.4 Expanded function (USB master/slave)

The provision of two types of USB interfaces (master/slave) on all models as a standard feature enables various USB functions to be utilized.

(1) High-speed transmission of screen data

Figure 4 shows the configuration for a transmission of USB screen data. A large quantity of screen data generated with screen creation software (V-SFT-5) can be transmitted (downloaded/uploaded) at high speed.

(2) Support of the PictBridge standard

The PictBridge common standard for connecting a digital camera and printer via a USB and for printing photographs is supported. Figure 5 shows a configuration that supports PictBridge. A PictBridge-compliant printer can easily print such documents as daily or monthly reports.

(3) Connection of CF card reader/writer

In addition to an internal CF card interface, a
USB-connectable CF card reader/writer is also supported, so that two CF card drives can be used simultaneously. Figure 6 shows a configuration supporting the use of two CF card drives. Files can be copied between the two CF cards, and this feature can be used in various ways depending on the application. For example, if a CF card is used as an internal drive, the data of that internal drive can be copied via the USB to another CF card, enabling sampling data, recipe data and the like to be backed up efficiently without disturbing the CF card in the slot.

(4) Mouse and keyboard connections
Support of an externally attached USB mouse and USB keyboard is planned.

4. V-SFT-5 Screen Creation Software

The functionality of the screen creation software supported by the MONITOUCH V8 series has also been improved significantly.

The V-SFT-5 (Editor Ver. 5) inherits the easy-to-use user interface that was well received with Editor Ver. 4, and also adds functions for reducing the work needed to create screens.

4.1 Component parts function

The components parts are the single modules that multiple functional parts are combined into. Being extremely easy to use, component parts preset with the necessary functions or macros are selected from a list and can be used with simple drag and drop operations. Figure 7 shows the component parts operating screen. This powerful tool eliminates the need for tedious programming and enables even an inexperienced operator to generate diverse functions freely and intuitively.

Figure 8 shows a comparison of screen creation settings for an alarm function. In the case where an alarm function was used with the conventional screen creation method, the alarm parts, buffering area setting, and message setting had to be set individually. With the component parts function, however, the necessary settings are provided as a single package which can be implemented in a single operation.

4.2 Multifunction switch

Various switch functions are provided to support a diverse range of user needs.

(1) Multi-output memory function
Bit output to a maximum of 16 locations is possible with a single operation. Thus a switch, similar to a radio button, which turns on only one location at the same time can be generated easily.

(2) On delay function
The execution timing of the switch can be set freely in such an output operation will not begin unless the switch is pressed and held down for a certain amount of time.

(3) Off delay function

This setting enables the output to be maintained for a fixed amount of time after the switch is released.

5. Postscript

An overview of the new POD MONITOUCH V8 series and a description of its features have been presented. With the increasing applications of touch panels, POD use is expected to continue to increase not only in the FA field, but also in the food service and building management fields and elsewhere.

Fuji Electric intends to develop and provide leading-edge touch panel products that can be used flexibly to meet this type of increasingly diverse user needs.