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Precis

Mitsubishi Electric aims to become the world's leading FA supplier through craftsmanship, customer satisfaction, and comprehensive FA solutions based on leading technology and quality. This paper describes e-F@ctory products that help reduce corporate TCO and increase corporate value through the visualization of production information, energy, and safety, and also key related products.

Overview



Author: *Hideyuki Okubo**

The global market of factory automation (FA) is continuously expanding in developing nations such as China. Manufacturing sites in these countries urgently require products that can be easily used even by local workers who are unfamiliar with FA products, and thus Mitsubishi Electric developing all its FA products from the viewpoint of "ease of use."

We have developed the concept of "e-F@ctory," which optimizes the overall factory, using the latest control and network technologies, to make visible a wide range of production information including production quantity, quality data and facility information. In addition, we collaborate with the upper-level manufacturing execution system, reflect the results in the production plan, and utilize them in quality traceability, in order to improve productivity.

Meanwhile, prompted by the Great East Japan Earthquake, energy management aimed at energy conservation in factories has become more significant. By using measurement technology centered on equipment to help conserve energy, it is possible to display the usage of electric power. As a result, waste and irregularities in power consumption can be eliminated, thus saving energy.

This production and energy management uses a C language controller based on the highly versatile Linux OS. This frees the user from troublesome OS maintenance and also improves reliability, thus reducing total cost of ownership (TCO).

CC-Link IE Field Slave Device Expansion Development

Authors: Keisuke Shiotani* and Hironori Kameoka*

1. Introduction

The CC-Link IE Field Network is a new type of network that supports sophisticated intelligent manufacturing systems in which the control data and diagnostic data coexist. It also facilitates setting work, and has improved wiring ability and diagnostic functions, resulting in a network that is easy for the customer to use.

To make the CC-Link IE Field Network even easier to use, and also to enable further equipment expansion, we have developed three new remote units: an e-CON type remote I/O module that facilitates connection of sensors; an MIL connector type remote I/O module that facilitates connection to a relay terminal and terminal block conversion unit; and a temperature control module that can quickly and accurately control temperature (Fig. 1).



Fig. 1 Upcoming line of CC-Link IE Field Network block-type remote modules

2. Features of the Block Type Remote I/O Module

We have newly released a lineup consisting of e-CON type and MIL connector type I/O modules, as block type remote I/O modules that support the CC-Link IE Field Network, thus enabling customers to use this network more easily.

Note that the newly developed products also include the extension functions and fast logic functions found in the existing screw terminal block type module.

2.1 Connection to a one-touch cascade connection power line (e-CON type, MIL connector type)

Both the e-CON type and MIL connector type modules are designed so that the IN side and OUT side can be wired separately, enabling cascade wiring for the power supply and thus eliminating the relay terminal block, saving space (Fig. 2). Also, because each module can be installed using a one-touch operation, wiring is easier, wiring labor is reduced, and incorrect wiring can be eliminated.

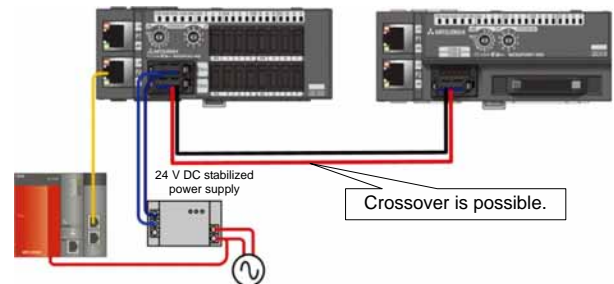


Fig. 2 Cascade connection of a power supply by a power clamp connector

2.2 Easy sensor connection (e-CON type)

The e-CON type unit does not require screw tightening work. Both 2-wire and 3-wire type sensors can be connected directly to the unit. Also, the sensors can be replaced by simply unplugging the connectors. As a result, wiring is easier and maintenance is faster. Also, because this module can be connected directly without using a relay terminal block, for example, the cost and necessary space are can be reduced.

2.3 Ease of connection to a relay terminal or a terminal block conversion unit (MIL connector type)

Since an MIL connector is used in the I/O interface section, it is easy to connect the module directly to a relay terminal, terminal block conversion unit, or a solenoid valve. By combining the module with a terminal made by Mitsubishi Electric Engineering Company Limited, it can be easily used for a wide range of applications such as relay output and AC input. Also, because screw tightening is unnecessary, the module can be replaced by simply unplugging the connector, thus reducing the time required for wiring and maintenance.

2.4 Technology for common use of communication boards

These recently developed e-CON type and MIL connector type units differ from the existing screw terminal block type unit in terms of the wiring method used for the power supply section and the I/O section. However, in order to enable the Ethernet connector to be used for all three products including existing ones, we made the communication boards common.

To do this for the three kinds of products, we had to take into account the larger mounting area of the e-CON type unit compared to that of a screw terminal block, which meant either reducing the number of input/output points or increasing the size of the product.

In order to use the same number of input/output points as that on the existing product, we modified the board configuration and the method of connecting the boards to each other to acquire a sufficient e-CON mounting area. In addition, we considered using different component layouts such as by mounting the e-CON, the power clamp connector, and the rotary switch on the same board (Fig. 3), and thus enabled common use of the communication boards and made them the same size, while offering the same number of input/output points as on the existing product.

3. Features of the Temperature Regulating Unit

The newly developed CC-Link IE Field Network temperature control module was released as a lineup of remote modules for the dispersion of a reduced number of input/output points, thus reducing the amount of external wiring.

3.1 Performance

Table 1 shows the performance of the two kinds of temperature control modules. These products have the same functions as the MELSEC-Q series or MELSEC-L series temperature control modules, and both offer high-speed and highly accurate temperature control.

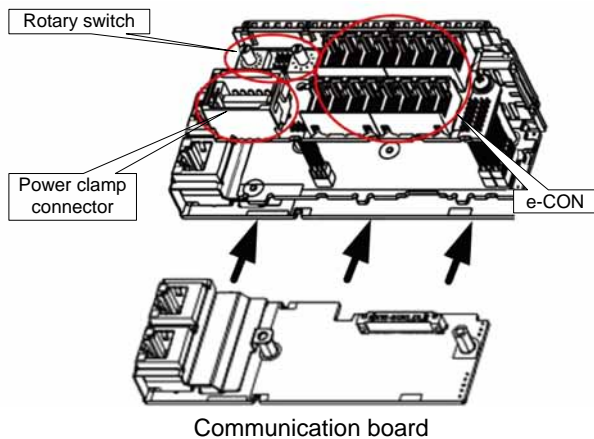


Fig. 3 Component block plan of e-CON type unit

Table 1 Performance of the product developed this time

Type No.	NZ2GF2B-60TCTT4	NZ2GF2B-60TCRT4
Control output	Transistor output	
Number of temperature input points	4 channels	
Usable sensors	Thermocouple	Resistance thermometer
Sampling period	250 ms/4 channels 500 ms/4 channels	
Functions	Heating/cooling control, peak current suppression function, simultaneous temperature rise function, loop disconnection detection function, auto-tuning function	

3.2 Heating-cooling control

Among the features of the CC-Link IE Field Network temperature control module, the heating-cooling control and underlying technology for this control are outlined below.

(1) Outline

The heating-cooling control is a temperature control method consisting of a combination of heating using a heater, for example, and also cooling by means of cooling water, for example. This function delivers better response control than a standard control method consisting of either heating or cooling alone.

(2) Technology for heating-cooling control

For the PID (proportional, integral, and derivative) calculation in the heating-cooling control, a calculation algorithm was added to control the output from two systems, so combined heating and cooling control can be achieved using a single unit.

Heating control output: The operation amount (MVh) when the temperature measurement value (PV) is lower than the target value (SV)

Cooling control output: The operation amount (MVc) when the temperature measurement value (PV) is higher than the target value (SV)

As a result, in the case of an injection molding apparatus (Fig. 4) that uses a mold to make specially shaped plastic products such as vehicle-mounted plastic parts, plastic cases, or rubber products such as rubber packing, combined cooling and heating control

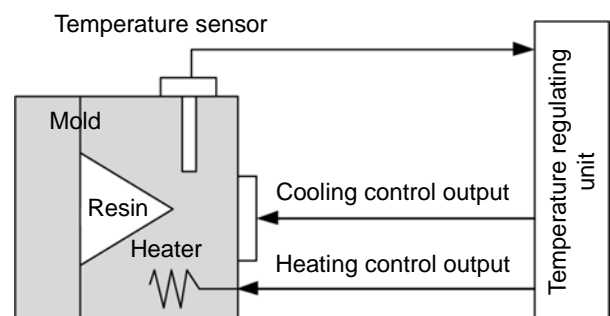


Fig. 4 Heating-cooling control for mold

can maintain a constant temperature inside the mold even when high-temperature resin is injected into the mold.

Previously, however, when heating-cooling control was used, if self-heating of the control object was balanced against natural cooling in the system, a large change in the measured temperature would sometimes occur due to a very small heating or cooling control output, resulting in a greater control output than necessary. To overcome this issue, the point at which the cooling control output starts was shifted, and a temperature zone was provided in which the operation amount for both heating and cooling became 0% (Fig. 5). As a result, for a system with a small temperature change, heating and cooling processing is no longer greater than necessary, thus saving energy.

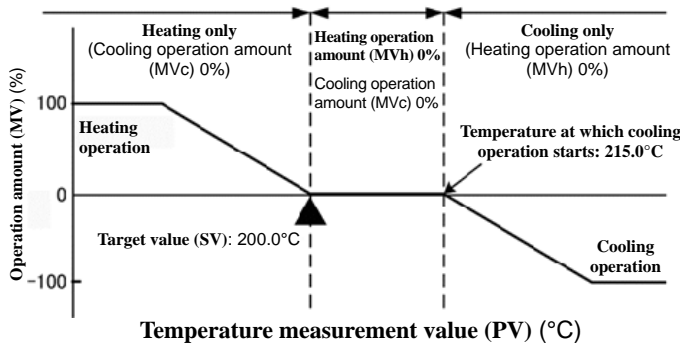


Fig. 5 Temperature area of manipulated value is 0% (200 to 215°C)

4. Conclusion

We have recently developed three kinds of block type remote modules (e-CON type I/O module, MIL connector type I/O module, and temperature control module) in order to expand our range of products.

We shall continue to develop products, extend the product range and provide attractive product groups that can be easily used by our customers.

Reference

Takahiro Yagi/Kengo Kato: CC-Link IE Field Network Block Type Remote Modules, Mitsubishi Denki Giho, 87, No. 3, 157–160 (2013)

OS-Independent Model C Controller “Q24DHCCPU-LS” Supporting Linux

Authors: *Takashi Kusuhara** and *Shiro Inoue***

In recent years, not only sequencers but also devices such as PCs and microprocessor boards are being used in various control units and data processing units on production lines. Unfortunately, this has resulted in issues such as increased management costs for PCs and microprocessor board components due to production interruptions.

The C Controller, which enables various kinds of processing using C programming on the real-time VxWorks¹ OS, aims to solve issues related to the PC or microprocessor board environment. However, in order to replace an existing system that uses a PC or a microprocessor board, it is necessary to transfer the previously developed programs to VxWorks, making it harder to use the C Controller.

This problem has been solved by developing the OS-independent model C Controller “Q24DHCCPU-LS” as an addition to the conventional models, and utilizing Lineo uLinux as the supported OS for the first stage.

This paper describes the newly developed OS-independent model C Controller “Q24DHCCPU-LS,” which has the following features:

- (1) General-purpose architecture that does not depend on the type of OS
- (2) More powerful display functions, and expandability due to the use of USB and a global bus
- (3) Lineo uLinux support (100% pure open-source configuration)
- (4) GUI development environment due to the use of an open source and partner products
- (5) Use of a general-purpose display and USB peripheral devices
- (6) Use of an open source and partner products

1. Introduction

In recent years, equipment manufacturers and end users have been developing products that offer high performance, sophisticated functions, and cost competitiveness, thus boosting the demand for controllers. In addition, not only sequencers, but also devices such as PCs and microprocessor boards are being used in various control units and data processing units on production lines. However, this has resulted in issues such as increased management costs for PCs

and microprocessor board parts due to discontinued production.

The C Controller, which enables various processing using C programming, aims to overcome issues related to the PC or microprocessor board environment, and a model installed with VxWorks has been developed. However, in order to replace the existing system, which uses a PC, it has not been easy to transfer the programs that were previously developed based on a PC, to VxWorks.

To solve this issue, we developed the OS-independent model C Controller “Q24DHCCPU-LS” as an addition to the models installed with VxWorks, and enabled the installation of Lineo uLinux as the first stage. As a result, the OS compatibility of the newly developed C Controller is superior to that of the previous models, which could only support VxWorks, which improves support for customer production sites and also productivity.

This paper describes the present issues and introduces the OS-independent model C Controller “Q24DHCCPU-LS,” which was newly developed to overcome these issues.

2. Features of the C Controller Product

2.1 Robust MELSEC-Q series hardware

The C Controller conforms to the same environmental resistance standard as the other units in the MELSEC-Q series. Also, its RAS function is equivalent to that of the sequencer CPU, which means that compared to a system that uses a PC or a microprocessor, this is a platform for creating highly reliable and robust systems.

2.2 Abundant assets of the MELSEC-Q series

The C Controller is the CPU unit of the MELSEC-Q series. It enables system construction utilizing the numerous units in the MELSEC-Q series. Also, it is a multi-CPU consisting of a sequencer CPU and a motion CPU, which are linked to each other by a high-speed bus, thus seamlessly realizing precision control and also high-speed communication from the data system to the production site by means of CC-Link IE network.

¹ VxWorks is a registered trademark of Wind River Systems, Inc.

2.3 Using C program assets

The C Controller has a dedicated library for accessing each unit of the MELSEC-Q series, in addition to the widely used C standard library. Consequently, it is easy to change over to the C Controller by using C programs developed to date.

3. Issues Related to the C Controller

For large-scale applications and optimum real-time performance, the high-end C Controller “Q24DHCCPU-V” was released in 2012. This controller uses the Intel ATOM² processor, which is a high-specification CPU, for high performance. It was commercialized as a C Controller having the equivalent performance to a PC. However, the following issues must be overcome to replace from PC to C Controller.

3.1 Support for a variety of OSs

As the standard conventional C Controller comes with VxWorks, in order to use the customer’s existing programs, it is necessary to transfer those programs to VxWorks, thus hindering the adoption of the C Controller. Therefore, the controller must support a variety of OSs.

3.2 Support for image display functions

For systems that use a PC, the user often check the manufacturing status on display connected to the

system, and so an image display system that enables GUI to be customized is needed.

3.3 Greater USB interface support

A PC on a manufacturing line uses a variety of USB peripheral devices including a printer and a keyboard, so the C Controller must provide various support for USB devices.

Accordingly, we developed the OS-independent model C Controller “Q24DHCCPU-LS” shown in Fig. 1. Section 4 describes the features of the controller and how the issues were resolved.

4. Features of the OS-Independent Model C Controller

4.1 General-purpose OS-independent architecture

The C Controller has 2MPUs, one is for controlling the system that controls MELSEC products, and the other is for enabling installation of the OS selected by the customer for program execution. Consequently, by selecting the same OS as that of the PC in use, the customer can use the existing programs, thus reducing engineering costs associated with system changeover and construction.

4.2 Enhanced display functions

The controller has an analog RGB (Red, Green,

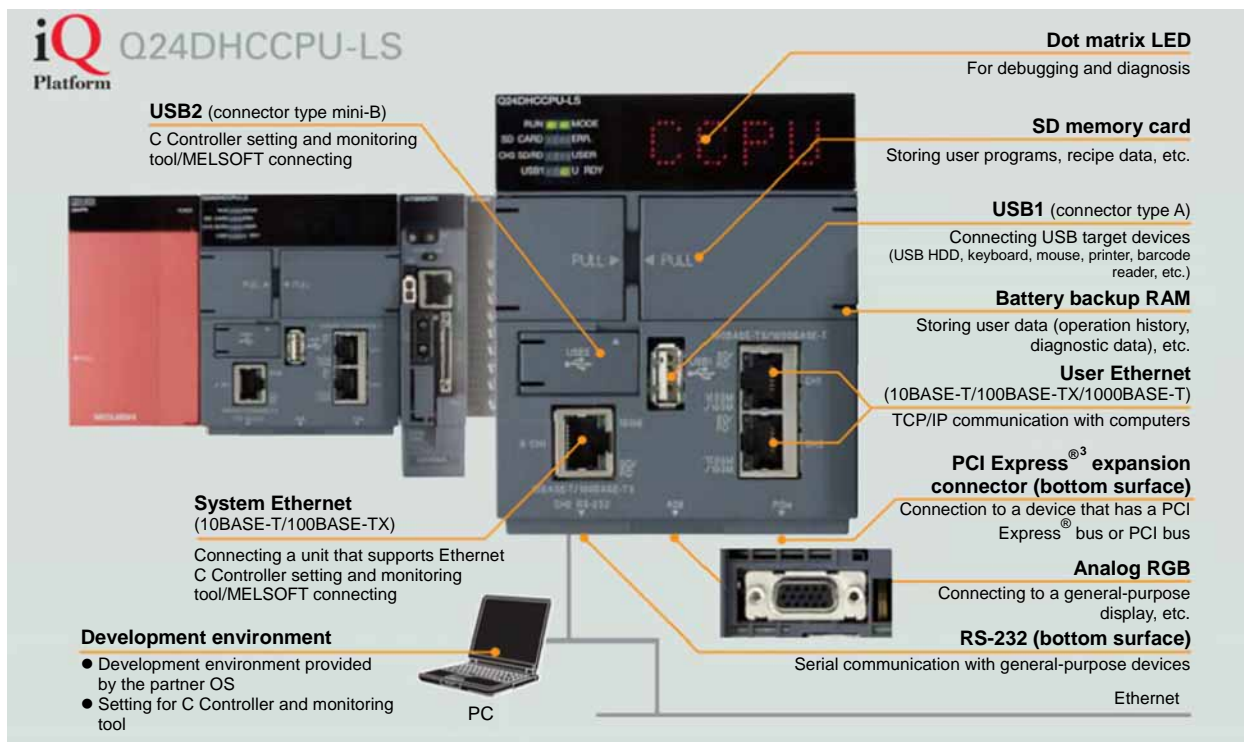


Fig. 1 Appearance of OS-independent model C Controller

² Intel ATOM is a registered trademark or a trademark of Intel Corp.

³ PCI/PCI Express are registered trademarks or trademarks of PCI-SIG.

and Blue) output port. By connecting it to a general-purpose display such as one used with a PC, debugging performance is improved, and also a GUI for monitoring the operation condition of the units can be freely created to match the customer's needs.

4.3 High expandability due to USB

While the ability to connect USB devices depends upon the partner OS, the controller can be connected to various USB devices including a printer and a keyboard with supporting drivers.

These features enable the customer to easily change over from a PC to the C Controller and then configure the system (Fig. 2).

5. OS-Independent Model C Controller Supporting Linux

5.1 Lineo uLinux (partner OS)

For a more open environment, Linux is often adopted. However, since these customers are concerned about support, we selected the "Lineo uLinux" version of Linux which provides enhanced support for this product. Lineo uLinux is intended specifically for embedded systems. It has been customized to enable widespread use in various products such as personal digital assistants, mobile phones, and network products. Also, it is configured with a 100% pure open source, and a runtime license does not need to be activated.

5.2 Qt/Embedded, and GUI Development Environment by GENWARE3

The Qt/Embedded⁴ open-source GUI framework is provided as standard for Lineo uLinux, and is used to develop GUI applications equivalent to those developed using a commercial OS.

It is also possible to use GENWARE⁵ (created by International Laboratory Corporation) separately as a partner product. GENWARE3 is a GUI integrated development environment for units with embedded systems. It uses many functions such as automatic creation of C programs from drawing data, greatly reducing the number of man-hours required for GUI development.

5.3 Utilizing open source and partner products

The standard Lineo uLinux comes with at least 90 open-source packages including script languages (Perl/PHP/Python/Ruby), network file sharing (Samba), and printing system (CUPS). It also enables customization and use of open-source packages throughout the world.

We are also working to increase our lineup of partner products, to assist the development of products with high added value and also reduce engineering costs (Table 1).

5.4 Support setup based on cooperative work

During the development of the OS-independent model C Controller, we collaborated with Lineo Solutions, Inc. and customized Lineo uLinux so that it

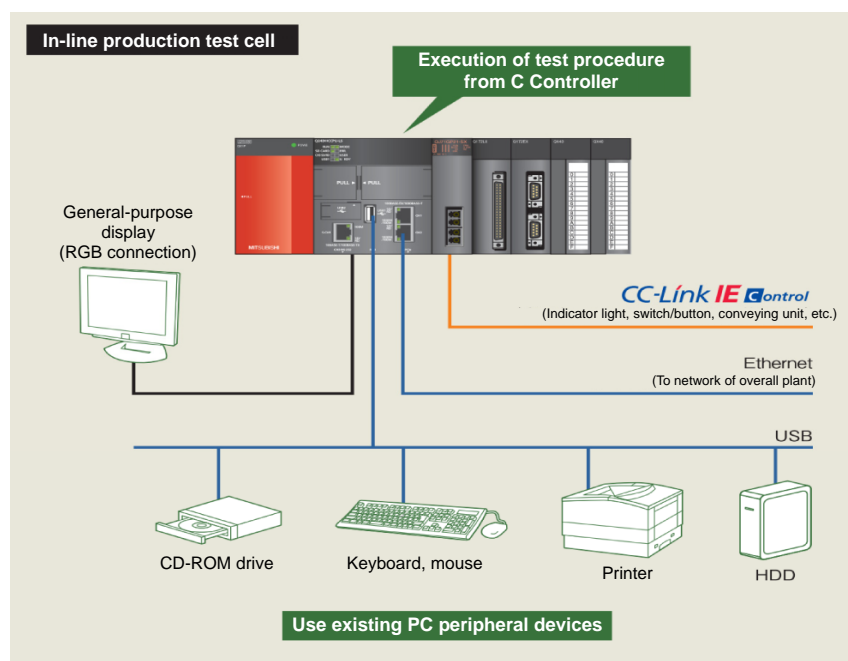


Fig. 2 System construction example with C Controller

⁴ Qt is a registered trademark of Digia Finland Ltd.

⁵ GENWARE is a registered trademark of International Laboratory Corporation.

could be used with the OS-independent model C Controller. In addition, the Linux-related support provided by Lineo Solutions, Inc. enables our customers to use the OS-independent model C Controller with a complete support setup.

Table 1 Partner Product

Product name	Company name
Mimer SQL Embedded Lightweight, high-speed database	Lineo Solutions, Inc.
SmartU2 Remote update system	
Vzet Tool for displaying the trace log	
GENWARE3 Embedded GUI integrated development environment	
	International Laboratory Corporation

6. Conclusion

In this paper, we described the issues associated with using the conventional C Controller and how they are resolved by the OS-independent model C Controller. With this C Controller, we are currently creating an environment that will allow any system to be replaced from a PC to the C Controller, even for systems that have an OS other than a VxWorks real-time OS.

Starting with Lineo uLinux as the first OS supported by the OS-independent model C Controller, we will continue developing the controller to support various OSs based on the needs of our customers. We will also increase the number of partner products of Lineo uLinux (partner OS) to expand our solutions, thereby creating a groundbreaking open-platform C Controller that supports a wide range of systems.

C Controller/Personal Computer Embedded Type Servo System Controller

Author: Kimiyuki Takahashi*

We have newly created a series comprising our C Controller-embedded type and also PC-embedded type servo system controllers, which are compatible with C language programming and PC control. The “C Controller Interface Module Q173SCCF” and the “Position Board MR-MC200” series products realize high-speed and fast-response positioning control.

1. Background of Development

A high percentage of users of PCs or microcomputer boards incorporating a pulse board employ C language as the development language. Some users demand higher productivity by means of high-speed and high-frequency operation, while others want to use a PC to handle large quantities of data or to perform large-scale calculations. In order to meet these needs, we developed the “C Controller Interface Module Q173SCCF” and the “Position Board MR-MC200” series.

2. Outline of the Q173SCCF/MR-MC200 Series

2.1 Product specifications

The newly developed Q173SCCF/MR-MC200 series are servo system controllers that are connected to general-purpose buses (PCI Express/PCI buses) which are now widely used in the PC field. An outline of the specifications is shown in Table 1. Direct coupling with PCs and our C Controllers via a general-purpose bus allows for rapid access from the PCs/C Controllers

to the dual-port memory inside the servo system controller, and also allows the interrupt signal output from the controller to be received on the PC/C Controller side (Fig. 1).

Table 1 Q173SCCF/MR-MC200 series specifications

Item	Specifications		
	Q173SCCF	MR-MC210 MR-MC240	MR-MC211 MR-MC241
Host controller (OS)	C Controller Q24DHCCPU-V (VxWorks ¹ 6.8.1)	PC (Windows ² 7, etc.)	
Connection bus	PCI Express (x1)	MR-MC21n: PCI bus MR-MC24n: PCI Express (x1)	
Servo network SSCNET III/H(150 Mbps)	1 system		2 systems
Control period	0.22 ms	Max 8 axes	
	0.44 ms	Max 16 axes	
	0.88 ms	Max 20 axes	Max 32 axes
Main positioning functions	JOG operation, incremental feed operation, automatic operation, linear interpolation operation, tandem drive, other axis startup function, interface mode function (sequential position command system), etc.		
Software development environment	CW Workbench/ Wind River Workbench	Microsoft Visual Studio ²	
Utility software (test tools, API library)	Q173SCCF Utility SW1DNC-QSCCF-B	Position board Utility MRZJW3-MC2-UTL	

¹ VxWorks is a registered trademark of Wind River Systems, Inc. in the US.

² Microsoft, Windows, and Visual Studio are registered trademarks or trademarks of Microsoft Corporation in the US and other countries.

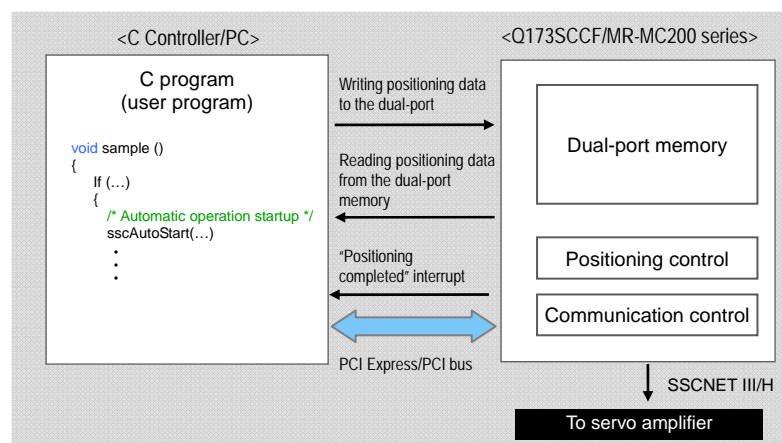


Fig. 1 173SCCF/MR-MC200 series control configuration

2.1.1 Outline of the Q173SCCF

By directly connecting the Q173SCCF to our C Controller Q24DHCCPU-V via the PCI Express bus, it is possible to configure a flexible system using the MELSEC series unit, while utilizing the versatility of the C Controller. The C Controller uses VxWorks, which is a real-time OS (operating system), and can realize control with excellent stability and response. By adding the positioning control API library for VxWorks, which belongs to the Q173SCCF utility, to the development environment of the C Controller, servo control using C language becomes easier to perform. Using the MELSEC series to construct a system eliminates issues related to the microcomputer board/PC environment such as concerns regarding a stable supply of products and increased maintenance costs. The system configuration is shown in Fig. 2.

2.1.2 Outline of the MR-MC200 series

The MR-MC24n is a servo system controller

connected to a PCI Express bus of a PC, and the MR-MC21n is a PCI bus-connected type. The positioning functions of this series, while being equivalent to that of Q173SCCF, are intended to enable one PC to control up to four (max. 128 axes), in order to meet the demands for multi-axis processing utilizing the high-speed processing performance of a PC. By adding the positioning control API library for Windows, which belongs to the position board utility, to the development environment such as Visual C++, servo control using C language can be performed. The system configuration is shown in Fig. 3.

3. Main Features

This product lineup reduces the tact time of the user's equipment in order to meet the high-speed and fast-response positioning needs from the field where priority is placed on PC-based control, particularly for semiconductor manufacturing equipment, thereby expanding the functions that can be linked directly to

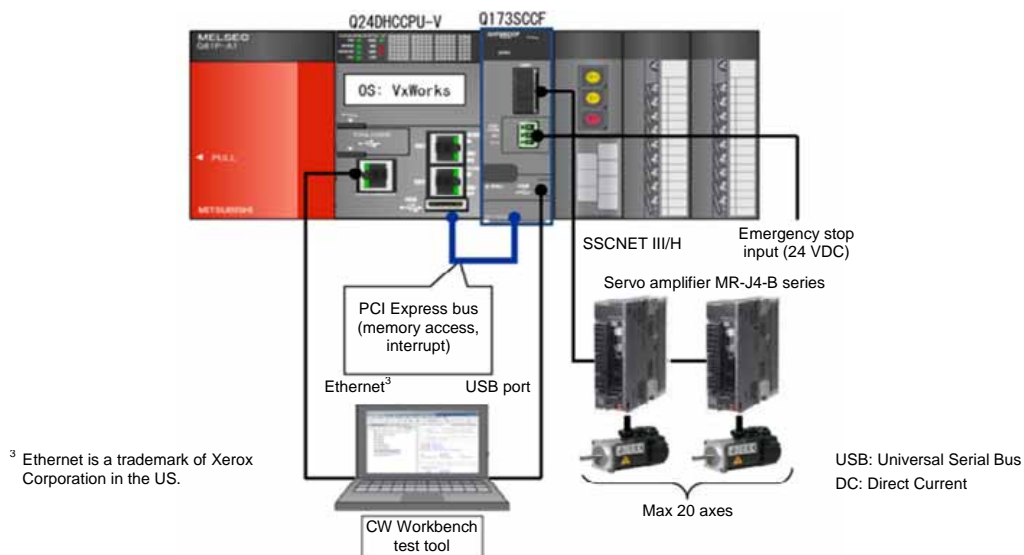


Fig. 2 Q173SCCF system configuration

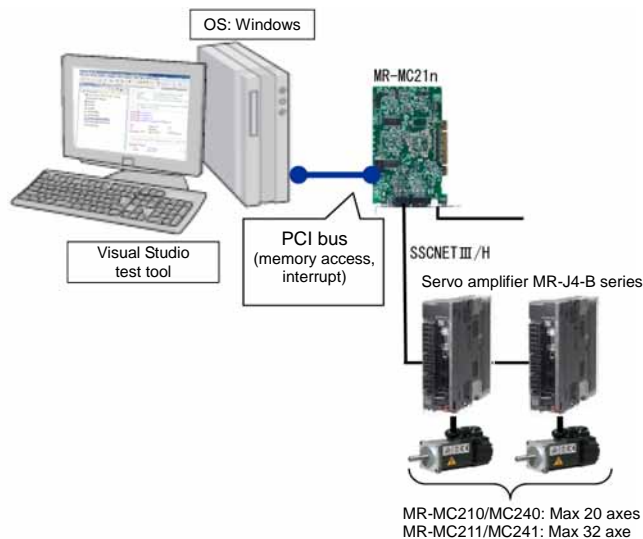


Fig. 3 MR-MC200 series system configuration

improved production. The features of these functions are described below. (The following description covers the features of the Q173SCCF, but the MR-MC200 series also has the same functions.)

3.1 High-speed multi-axis control

In the Q173SCCF, the microcomputer is used exclusively for PTP (point-to-point) control among the positioning functions, thus reducing the operation load on the microcomputer. In addition, it is combined with the increased speed of the servo network with the use of the SSCNET III/H, thus enabling up to 8-axis control when the control period is 0.22 ms. By reducing the control period, more accurate and responsive control can be realized. As a result, the time from when the "operation startup" command is output until the time that the motor starts is reduced, which also reduces the tact time.

3.2 Interrupt function

The Q173SCCF can output an interrupt due to at least 25 factors such as the completion of positioning, the issuance of an alarm, and transit through a specified position. This allows the user to create an event-driven program that uses interrupts, and eliminates the necessity of monitoring by polling. Consequently, it reduces the load on the user program and also enables highly responsive event processing.

3.3 Startup of other axes

In order to reduce the operation time, a method of overlapping different operation motion patterns is often used (Fig. 4). In this case, a user program monitors the operation startup conditions (feedback position, etc.), and operation starts. However, monitoring the operation startup conditions at short intervals increases the load on the user program side, making it difficult to start operation at the target timing.

To overcome this issue, we developed "startup of other axes" whereby the operation startup conditions for the monitoring process that had been performed by the user program were taken into the Q173SCCF, enabling operation to be started by internal processing in the Q173SCCF.

The Q173SCCF monitors the startup conditions of the other axes, and fulfillment of the conditions allows the operation startup of the other specified axes according to the contents of the startup motion of the other axes, and also allows the control to turn the output signal ON or OFF.

Monitoring of the startup conditions of the other axes takes place by internal processing in the Q173SCCF, thus eliminating the necessity for handshaking between the Q173SCCF and the user program. As a result, there is zero response lag at the startup of operation.

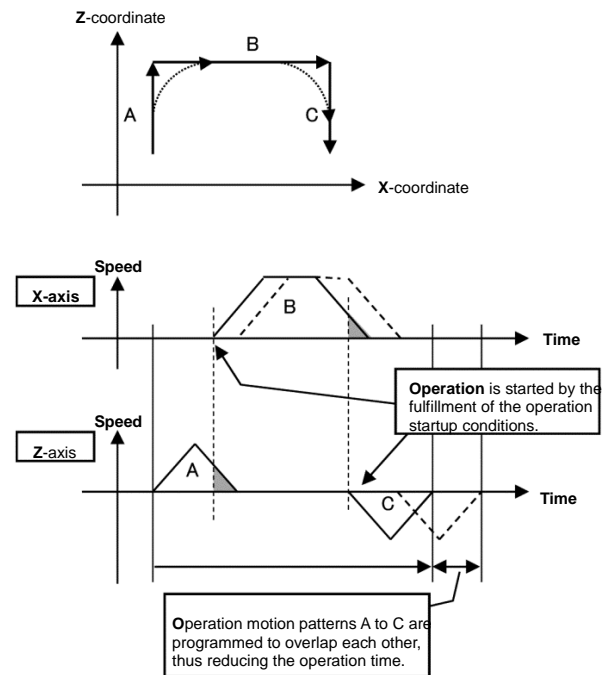


Fig. 4 Overlap of driving operation

4. Conclusion

We have developed the C Controller Interface Module Q173SCCF and the Position Board MR-MC200 series, which constitute a new series of servo system controllers that are optimum for the environment of a C Controller and a PC, and permit high-speed, multi-axis control. We intend to continue developing servo system controller products that optimally meet the market needs at all times, thus widening the fields of application.

The Sensorless Servo “FR-E720EX & MM-GKR Series”

Authors: *Daisuke Nishijima** and *Toshio Morohoshi**

The globalization of industry in recent years is accompanied by the demand for increased value-added drive systems for factory equipment. In response, we have developed the “Mitsubishi Sensorless Servo,” which allows simplified positioning without an incorporated sensor and differs from existing inverters/AC servo motors.

1. Background of Development

Inverters are used mainly for speed control, while AC servo motors are supported by the demand for precision positioning applications, which are increasing in scope in each field of industry.

We have newly developed the “Mitsubishi Sensorless Servo,” which allows us to propose a selection of new drive systems for customers and the market (Fig. 1).

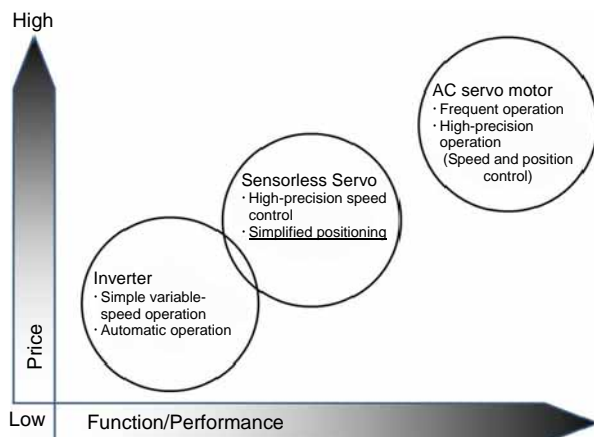


Fig. 1 Positioning of Sensorless Servo Products

2. Features and Value Enhancement of the Sensorless Servo

2.1 Increased added value due to simplified sensorless positioning

The Sensorless Servo has realized simplified positioning without a sensor (positioning accuracy $\pm 1.8^\circ$), which is not possible with the conventional drive system.

2.2 Reduced cost of the drive system

We newly developed both the drive unit and servo motor based on the standard models already released, and the resulting sharing of parts reduced costs. In

addition, the wiring of the motor is simpler as no sensor cable is necessary, reducing cost further.

2.3 Increased added value of the sensorless servo motor

2.3.1 Miniaturization of the motor

Since a sensor is not required, the overall length of the motor can be shortened and the equipment made smaller.

2.3.2 Highly efficient and lightweight newly developed reduction gear

We have newly developed a highly efficient (efficiency of reduction gear at least 80%), lightweight and small reduction gear, contributing to miniaturization and energy saving of equipment.

3. Development of the Sensorless Servo

Simplified positioning can be performed by means of the newly developed drive unit (FR-E720EX) and servo motor (MM-GKR).

3.1 Development of the FR-E720EX series

PM sensorless vector control employs a motor model inside the drive unit. Also, a magnetic field observer, which accurately calculates or estimates the magnetic flux based on the voltage and current, estimates speed and position, thus realizing highly accurate control.

However, the magnetic field observer utilizes the induced voltage of the motor. Consequently, in the low-speed zone where the induced voltage becomes small, the servo may be affected by voltage errors that prevent it from correctly estimating the position and speed. To overcome this, in the low-speed zone, high-frequency superposition assist control was performed for magnetic flux estimation using the saliency of the motor inductance.

The saliency of a motor is a characteristic whereby the difference between the d-axis inductance and the q-axis inductance varies according to the magnetic pole position. Since the magnitude of the current varies due to this difference in inductance, it is possible to estimate the magnetic pole position (Fig. 2).

The current used in this estimation is of a high frequency different from that of the output current. With

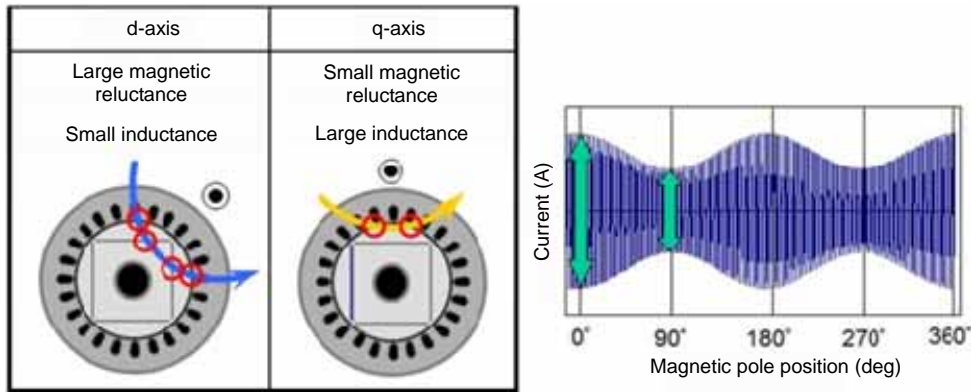


Fig. 2 The inductance difference by the magnetic pole position and current change

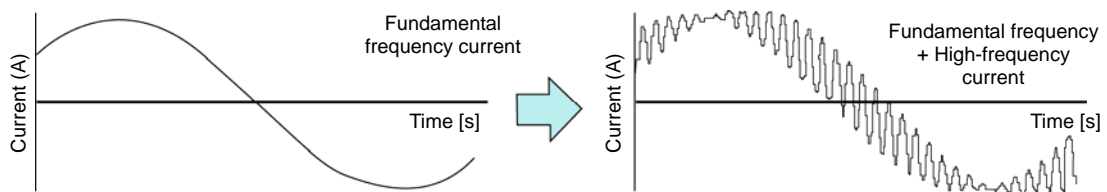


Fig. 3 High frequency applied output current waveform

this current applied to the fundamental frequency, the magnetic pole position can be estimated without any effect on the rotational speed (Fig. 3).

As a result, the magnetic field observer can detect the motor magnetic pole position throughout the entire speed range, thus enabling position control without a sensor.

3.2 Development of the MM-GKR series

3.2.1 Construction and saliency of the rotor

As there is low magnetic permeability in the magnetic path of the flux linkage caused by the d-axis current of an IPMSM (interior permanent magnet synchronous motor), the d-axis magnetic reluctance increases and the inductance decreases. On the other hand, as there is a silicon steel plate of high magnetic permeability in the magnetic path of the flux linkage caused by the q-axis current, the magnetic reluctance of the q-axis decreases, and the inductance increases. In other words, the d-axis inductance becomes less than the q-axis inductance, making it possible to acquire saliency (Fig. 2).

The motor construction employs an IPMSM in consideration of saliency due to the rotor construction. However, this has a drawback in that the effective magnetic flux of the magnets decreases inside the rotor of the IPMSM where the magnets are placed.

3.2.2 Development based on an AC servo motor

As described in 3.2.1, the IPMSM has the drawback of a decrease in effective magnetic flux of the magnets.

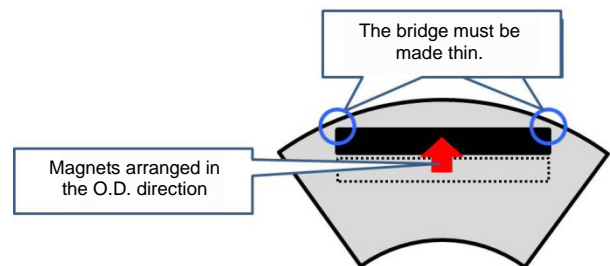


Fig. 4 Limitation in the production of IPMSM

Generally, this is overcome by arranging the magnets in the outer diameter (O.D.) direction of the rotor in order to increase the effective magnetic flux. However, when the magnets are arranged in this manner, the bridge formed between the magnetic insertion part and the O.D. of the rotor is thin-walled, making it difficult to fabricate (Fig. 4).

In this development, a thin bridge was realized, making it possible to arrange the magnets in the O.D. direction closer to the rotor outer periphery than in the conventional case. As a result, we realized an IPMSM based on a standard model of small AC servo motor.

4. Conclusion

We received the R&D 100 Award for the newly developed sensorless servo, which has been highly acclaimed in the market (Fig. 5).

In the future, we will increase the application range of the new servo not only in the inverter market and AC servo motor market, but also in markets with products/services yet to become motor-driven.



Fig. 5 R&D 100 Award

Reference

- (1) Masato Ito, et al: Direct Rotor-Position Estimation Method for Salient Pole PM Motor by Using High-Frequency Voltage, IEEJ Transactions on Industry Applications, Vol. 131 (2011), No. 6, 785–792

High Performance and Energy Saving Induction Motor “Superline Premium Series SF-PR”

Authors: Hiroyuki Hasegawa* and Takuro Isogai*

Awareness of energy conservation has been steadily increasing throughout the world. Against this background, the implementation of regulations is accelerating in order to popularize high-efficiency motors worldwide. To meet such requirements, we developed a high-performance, energy-saving series of motors called the Superline Premium Series SF-PR (hereafter called “premium efficiency motors”).

1. Regulations

Three-phase motors are categorized by efficiency class as defined by IEC (International Electrotechnical Commission) 60034-30, which was enacted in October 2008. In the United States, which has been taking the lead in enforcing motor efficiency rules, the regulation of motors under efficiency class IE3 was started in December 2010, and in Japan as well, motors were regulated in FY2015 in accordance with the Top Runner Standard (equivalent to IE3) under the *Act Concerning the Rational Use of Energy*.

2. High-Efficiency Technology

2.1 Loss

The three-phase motor converts electrical energy (input) into mechanical energy (output). During the energy conversion, part of the energy is consumed inside the three-phase motor as energy loss.

The ratio of the output to the input is expressed as the efficiency η of the three-phase motor. The smaller the loss, the higher the efficiency η , with the potential for realizing a high-efficiency motor. Loss in a three-phase motor is divided into copper loss, iron loss, and so on.

(1) Copper loss

Copper loss occurs when electrical energy is converted into heat energy by the electrical resistance of the conductors. As primary copper loss depends particularly upon winding resistance, expansion of the slot area is an effective means for reducing primary copper loss; however, this results in a reduction of the magnetic path. Thus, it is necessary to improve the lamination factor using a limited slot area. Accordingly,

we improved the production technology, and realized an increase in the cross-section area of the winding conductor. Secondary copper loss, which occurs due to the electrical resistance of the rotor conductors, can be reduced by enlarging the rotor groove, but this raises concerns about an increase in starting current and a decrease in sliding performance. For this reason, we determined the optimum rotor groove profile in order to suppress the increase in starting current and decrease in sliding performance, and thus reduced the secondary copper loss.

(2) Iron loss

Iron loss, which comprises hysteresis loss and eddy current loss, occurs as a result of a change in the magnetic field in the iron core. Hysteresis loss is the reduction of hysteresis of the magnetic body, depending upon the frequency and the magnetic flux density; and eddy current loss is energy loss that occurs due to eddy currents generated during electromagnetic induction in the iron core of a three-phase motor. Iron loss can be reduced by using low-loss material for the iron core or by using the optimum slot profile. However, low-loss iron core material has a low saturation magnetic flux density. For this reason, we optimized the iron core material and the slot profile in order to obtain a balanced condition throughout the entire motor, and thus reduced the iron loss.

3. Product Features

3.1 Realization of efficiency class IE3 under four rated conditions

The energy loss of the SF-PR type premium efficiency motor is an average of 39% less than that of the SF-JR standard efficiency motor, and we have realized an efficiency that is higher than the IE3 efficiency standard value (Figs. 1 and 2).

As shown in the figures above, the newly developed motor conforms to a total of four ratings, consisting of three standard ratings corresponding to the Japanese Top Runner Standard for motors, and one rating that conforms to the U.S. EISA (*Energy Independence and Security Act*). Here, the number of

ratings means the number of combinations of motor power source voltage and frequency. An example of the nameplate for the SF-PR type premium efficiency motor is indicated in Fig. 3.

3.2 Compatibility of mounting dimensions

We have conventionally used a steel frame for all models up to frame No. 225S, as the exterior structural members (frame) of three-phase motors (Fig. 4).

Generally, the torque of a three-phase motor is proportional to the square of the outer diameter of the cylindrical rotor, and is also proportional to the length of the laminated core of the rotor. The steel sheets are superior to aluminum in terms of strength, and are also superior to castings from the viewpoint of fabrication, allowing for a thin frame. As a result, it is possible to increase the outer diameter of the rotor and reduce the necessary length of the laminated iron core, making the motor more compact. By adopting steel material, the frame can be used as a magnetic path, thus raising efficiency. As a result of these efforts, we realized a motor total length that is one of the shortest in the industry, for our motor products including the SF-PR type premium efficiency motor.

3.3 Compatibility between protective devices

Generally, the starting current of a three-phase motor tends to increase as the efficiency is increased. For this reason, it is sometimes necessary to change the protective devices when changing over from a standard to premium efficiency motor. In the case of the SF-PR type premium efficiency motor, the profile of the rotor groove is selected in order to restrain the starting current, which allows the premium efficiency motor to use the same protective device capacity as the previous standard efficiency motor by combining the protection coordinate part of the protective device with our breaker. In this way, we are able to change over from the existing SF-JR type standard efficiency motor to the SF-PR type premium efficiency motor without needing to change the protective devices.

3.4 Expansion of the continuous operating range of a motor when inverter driven at a constant torque

When running a three-phase motor at low speed using an inverter, as the air flow from the cooling fan also drops, the continuous operating range of the SF-JR type conventional efficiency motor when driven at a constant torque is 1:10 (6–60 Hz). In the case of the SF-PR type premium efficiency motor, the temperature rise is restrained. Combined with the advanced magnetic flux vector control of our inverter, this results in a continuous operating range at constant torque of 1:120 (0.5–60 Hz), thus realizing wide-range variable-speed operation (Fig. 5).

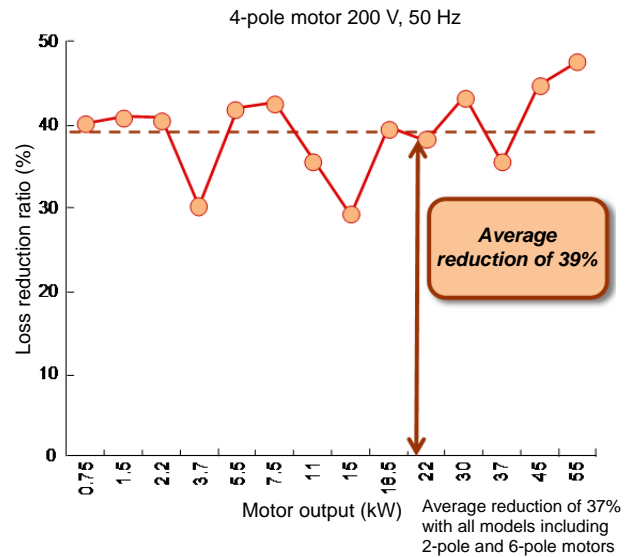


Fig. 1 Loss reduction rate (“SF-JR” → “SF-PR”)

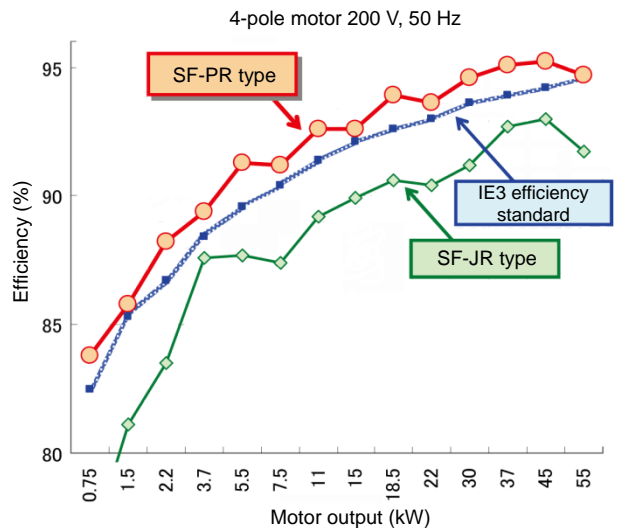


Fig. 2 Efficiency comparison (“SF-PR”, “SF-JR” and Efficiency class IE3)

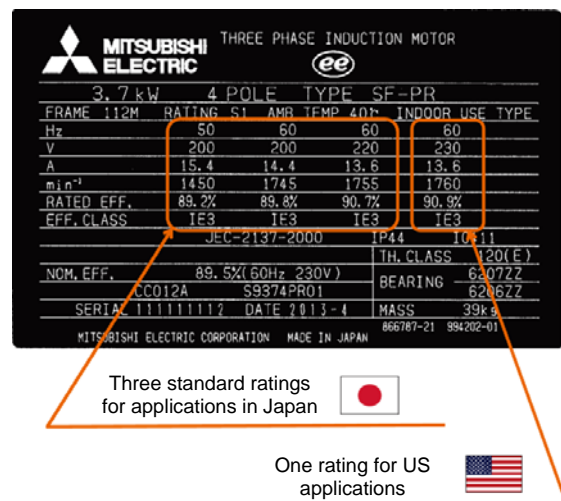


Fig. 3 Nameplate of the “SF-PR” (Example)

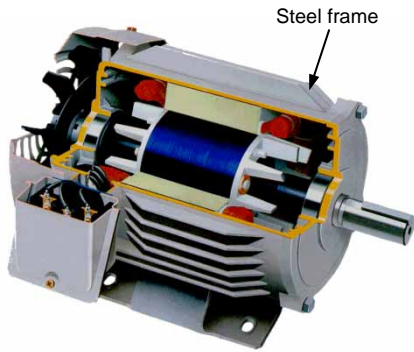


Fig. 4 Structure of the three-phase motor

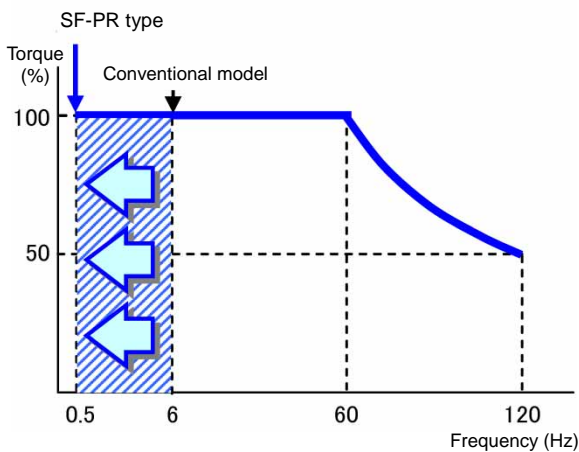


Fig. 5 Expansion of constant torque continuous operation range

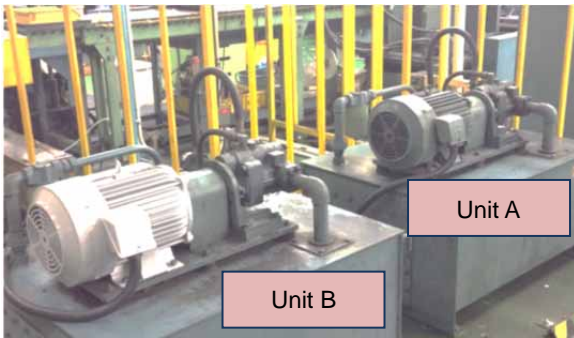


Fig. 6 Hydraulic unit equipment

4. Example of Adoption

As an example application of our newly developed motor at the Shinshiro Factory of Nagoya Works, Fig. 6 shows the hydraulic unit equipment that is used on the three-phase motor winding fabrication line. This equipment originally contained two of our SF-JR type standard efficiency motors. We replaced one of them with the SF-PR type premium efficiency motor, and validated the effects. The three-phase motor installed in unit A is our SF-JR type standard efficiency motor, and the one installed in unit B is our SF-PR type premium efficiency motor. The load specifications for both units A and B are the same.

The reduction of electric power consumed in one day when the SF-JR type standard efficiency motor was replaced by the SF-PR premium efficiency motor is designed to be 10% (13.73→12.37 kWh), and the actual reduction measured was 12% (14.14→12.43 kWh), which is roughly the same. The reduction of CO₂ emission found when ten of the same equipment units were changed over was 2.4 t/year, which is a significant energy saving (Table 1).

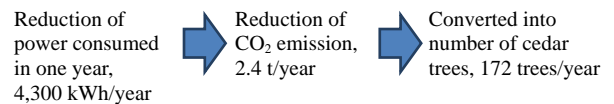
Table 1 Specification comparison of the hydraulic unit equipment

		Unit A	Unit B
Series		Standard efficiency	Premium efficiency
Model name		SF-JR	SF-PR
Output, number of poles, voltage		5.5 kW 4P 200V	
Frequency		60 Hz (powered by a commercial power source)	
Heavy load operation (0.5 h/day)	Power consumption (design)	1.96 kWh	1.84 kWh
	Power consumption (measured)	2.00 kWh	1.87 kWh
Light load operation (8.75 h/day)	Power consumption (design)	11.78 kWh	10.53 kWh
	Power consumption (measured)	12.14 kWh	10.56 kWh
Power consumed in one day (design)		13.73 kWh	12.37 kWh
Power consumed in one day (measured)		14.14 kWh	12.43 kWh

- Number of operating days: 250 days/year
- CO₂ emission: 0.555 kg/kWh
- Cedar trees: 14 kg/year



<When ten of these units were changed over>



5. Conclusion

Due to the increasing environmental awareness globally, motors are required to be highly energy efficient. Particularly, regarding the enactment of regulations for three-phase motors, Japan, Europe, South Korea, and China are following the US, and other countries are likely to enact regulations in the future. We shall continue playing a significant role in responding to the ongoing global demands for high-efficiency, energy-saving motors.

Energy Measuring Unit “EcoMonitorLight”

Author: Yasunori Matsuoka*

The recent amendment to the *Act Concerning the Rational Use of Energy* has promoted a shift in corporate energy management towards further conservation efforts at production sites. Also, the rising price of electricity due to the high cost of fuel for thermal power generation caused by the shutdown of nuclear power stations makes it necessary to reduce consumption by switching off the power during peak demand times, and also to monitor the power consumption. Furthermore, measurement control points are becoming increasingly segmentalized away from the distribution switchboard toward the controlling board of the production line, and on to the production facility level.

To meet the customer demand for a simple means of grasping the electric power consumption, we developed the EcoMonitorLight energy measuring unit with an integrated display that enables the visualization of energy consumption, easily and at low cost.

1. Outline of the EcoMonitorLight

1.1 EcoMonitorLight product concept

(1) Easy and low-cost measurement

The built-in LCD display makes it possible to specify the necessary settings for energy measurement, perform measurement, and display the results, using a single unit. Two models are available: standard and high performance, to suit different applications.

(2) MODBUS¹ RTU (Remote Terminal Unit) (RS-485) with a communication fitted as standard

The built-in MODBUS RTU communication facilitates energy management by providing a connection between the energy measuring unit and a sequencer or a display (GOT). The sequencer performs integrated control of energy data and production information, etc., thus making it possible for the unit to measure the energy consumed by each production facility, carry out preventive maintenance of facilities by real-time measurement, and create a quality control index linked to production information.

(3) Expansion of measurement applications by means of an optional unit

With the optional EMU4-LM logging unit added to the energy measuring unit, energy data can be stored on an SD memory card.

Also, the EMU4-CM-C communication unit that is added to the energy measuring unit allows for CC-Link communication. This enables the visualization of energy consumption by our energy conservation data collection server EcoWebServer III system (Fig. 1), making it possible to easily analyze the measurement data.

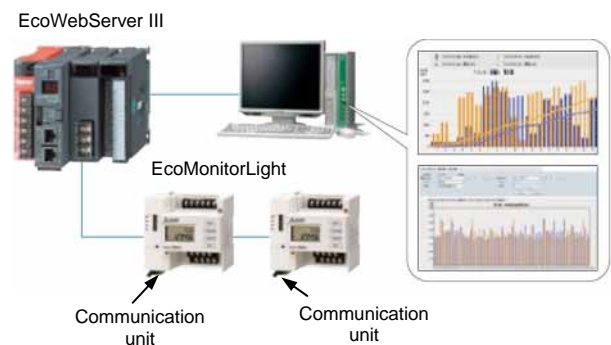


Fig. 1 Visualization of energy by EcoWebServer III

1.2 Product specifications

Table 1 shows the main specifications of the EcoMonitorLight energy measuring unit, which is available in two models. The standard model is intended for customers who wish to start measurement easily and at low cost, and the high-performance model is for customers who wish to measure harmonics, monitor alarms, monitor the upper and lower limits, output alarms, and input/output pulses. Also the optional units are the optional logging unit and CC-Link communication unit.

2. Technology for Commercialization

2.1 Logging unit (option)

We have developed the EMU4-LM logging unit that can store energy data on an SD memory card in order to meet the user demand for easy data storage.

(1) Specifications of the logging unit

Table 2 shows the specifications of the EMU4-LM logging unit, which has two operation modes. In the “automatic updating” mode, the logging operation starts immediately after the completion of setting work, and in the “date and time specification” mode, the logging operation starts at the set starting time.

¹ MODBUS is a registered trademark of AEG Schneider Automation Inc.

Table 1 Specifications of Energy Measuring Unit “EcoMonitorLight”

Item		Specifications		
Type No.		EMU4-BD1-MB (standard model)	EMU4-HD1-MB (high-performance model)	
Phase wire system		Single-phase 2-wire type, single-phase 3-wire type, three-phase 3-wire type (toggled settings)	Single phase 2-wire type, single-phase 3-wire type, three-phase 3-wire type, three-phase 4-wire type (toggled settings)	
Instrument ratings	Voltage circuit	Single-phase 2-wire type, three-phase 3-wire type	110 V AC, 220 V AC common	110 V AC, 220 V AC, 440 V AC common
		Single-phase 3-wire type	110 V AC (between wires 1 and 2 and wires 2 and 3), 220 V AC (between wires 1 and 3)	
	Three-phase 4-wire type	–	Min 63.5 V AC/110 V AC, Max 277 V AC/480 V AC	
	Current circuit	5 A AC, 50 A AC, 100 A AC, 250 A AC, 400 A AC, 600 A AC (Uses dedicated split type current sensors. In all cases the value of the current on the primary side of the current sensor is shown. The 5 A AC current sensor is used in a 2-stage configuration in combination with a current transformer (CT), and the primary side current value can be set to a maximum of 6,000 A.)		
Frequency		50 Hz/60 Hz (automatic frequency discrimination)		
Auxiliary power source ratings		100 V - 240 V AC (+10%, -15%) 50 Hz/60 Hz		
Number of measurement circuits		One circuit		
Main body allowable tolerance		Current, voltage, power, reactive power, apparent power, frequency: ±1.0% (relative to the rated input) Power factor: ±3.0% Electric energy: ±2.0% (over the range of 5 to 100% of rating, power factor = 1) Reactive energy: ±2.5% (over the range of 10 to 100% of rating, power factor = 0) Harmonic current, harmonic voltage: ±2.5%		
Data updating period		250 ms The electric energy and the reactive energy is normally accumulated (follows the short-cycle load fluctuations as well).		
External input		–	Pulse input/contact input 1 point	
External output		–	Pulse output/contact output 1 point	
Communication format		RS-485 (MODBUS RTU communication)		
Power stoppage compensation	Memorized items	Set value, electric energy (power consumption, regeneration), reactive energy, electric energy within a certain period, pulse count value, operation time (backup provided by a nonvolatile memory.)		
External dimensions (Unit mm)		75 (W) × 90 (H) × 75 (D) (excluding protrusions; max dimensions including protrusions: 79 (W) × 90 (H) × 75 (D))		

Table 2 Logging specifications of Logging Unit

Item		Specifications
Logging mode	Automatic updating	Automatic overwrite update
	Date and time specification	Start of operation by starting time setting
Type of logging data	Detailed data	Measurement data is stored at the set detailed data logging period (1 s/1 min/5 min/10 min/15 min/30 min).
	1-hour data	Measurement data is stored at a 1-hour period.
Number of logging elements	Detailed data	1-second period: Max 4 elements Other than a 1-second period: Max 10 elements
	1-hour data	Max 10 elements
Internal memory logging period	Detailed data	1-second period: 20 hours, 1-minute period: 20 days 5-minute period: 100 days, 10-minute period: 200 days 15-minute period: 300 days, 30-minute period: 600 days
	1-hour data	620 days
SD memory card (2GB) logging period		Detailed data 1-second period: 10 months Detailed data other than that acquired over a 1-second period: 10 years or more 1-hour data: 10 years or more
System logging data		3,600 records
Data output format		CSV format (ASCII code)

(2) Logging operation

Measurement data (energy data) saved directly to an SD memory card poses an issue in that the logging data is corrupted when the SD memory card is replaced (uninstalled). In addition, some users avoid leaving the SD memory card installed to maintain the security of external memory media. To overcome this issue, we determined the specifications of the logging unit so that the data acquired from the energy measuring unit is temporarily stored in the internal memory of the logging unit (Fig. 2) in two forms, namely detailed data (selected at intervals of between 1 second and 30 minutes) and 1-hour data, and when the SD memory card is installed, the logging data is output.

Since the logging data output to the SD memory card is used during data analysis or preparation of a ledger sheet, the data must be easy to edit, so the specifications enable the logging data to be output in CSV file format to the SD memory card. The logging data output is shown in Fig. 3. The logging data and the system log data stored in the internal memory of the logging unit are converted to the logging data file (as detailed data/1-hour data/1-day data file) and the system log data file in the CPU (with the SD memory

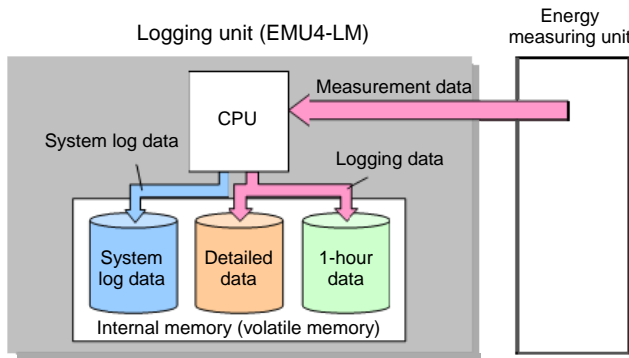


Fig. 2 Logging operation

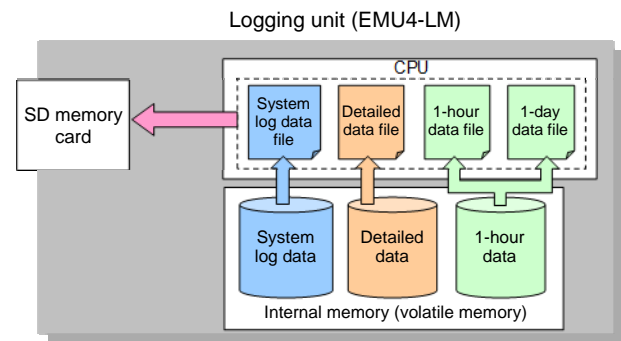


Fig. 3 Logging data output

card driver and the file system installed). The CPU in the logging unit outputs the logging data file and the system log data file to the SD memory card in the CSV file format.

(3) Simplifying the logging unit setting operation

(i) To meet the customer demand for simplified settings for saving measurement data such as electric energy, we selected specifications that enable the basic elements (electric energy, current, voltage, power, etc.) to be logged by setting only the current time. The unit settings made at the factory prior to shipment are:

- Logging mode: Automatic update
- Detailed data: 1-minute cycles

(ii) Some customers who were concerned about the security of external memory media requested us not to install an SD memory card in the logging unit, but instead use a single SD memory card to collect data from multiple logging units during the periodic patrol inspection. Accordingly, we have assigned an ID to each logging unit (an ID assigned at each energy measuring unit side), which allows for specifications in which an ID folder is created for each logging unit ID (between 1 and 255), enabling logging data to be collected from multiple units (Fig. 4) using a single SD memory card.

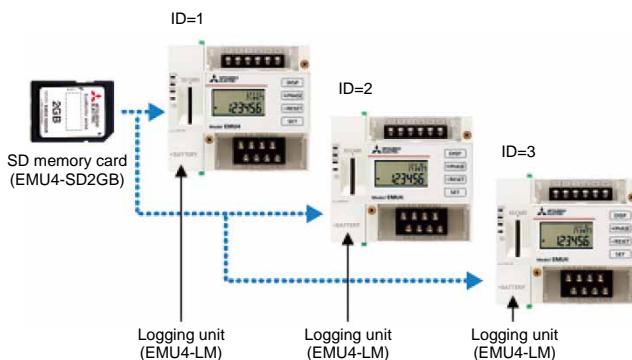


Fig. 4 Logging data collection by SD memory card

2.2 Application to production facilities

(1) Operation time measurement

To be able to use the energy measuring unit for

diagnosing the life of the production facilities or performing preventive maintenance, a function integrates the electric current measurement (at least 0.4% of the rated current) time in 250 ms units, and displays the time unit (h) as the operation time of the facilities (Fig. 5). The operation time (h) can also be output to a higher-level system by MODBUS RTU communication.

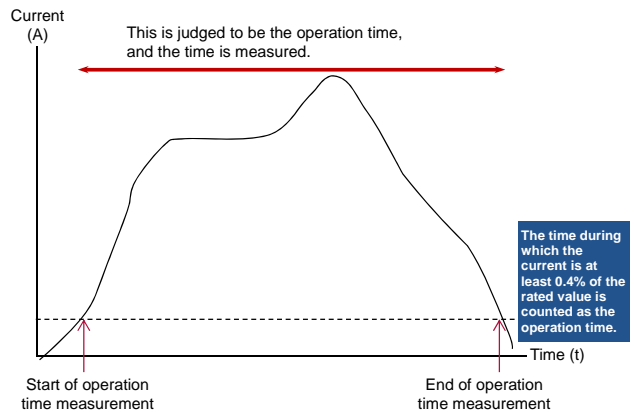


Fig. 5 Operating time measurement

Also, to measure the operation time during which the machinery or manufacturing equipment is actually operating, a function enables the contact inputs to the energy measuring unit (the high-performance model only) to be set to the operation time start and end triggers, thus making it possible to measure the actual operation time.

(2) High-precision measurement

As electric power for spot welding and brazing is used only for short periods of time, omissions could occur unless measurement is performed continuously under short-cycle loads. With the energy measuring unit, which performs continuous measurement of electric energy at a sampling period of approximately 250 μs, there are no omissions even under a short-cycle load, thus realizing highly accurate measurement (the updating cycle of the measurement value data: 250 ms).

(3) Compliance with overseas standards

To satisfy the demand for standards-compliant

products for overseas customers or for use in overseas machinery assembling, we designed the energy measuring unit to comply with overseas standards, and acquired the right to use the CE mark as well as the UL and KC marks.

2.3 Engineering environment preparation

(1) Data collection using dedicated software

Energy data can be collected online from a remote location by using the EcoWebServer III system; however, this is expensive for users who want a simple and low-cost system for only a few collection items. Consequently, we developed the EMU4-SW1 data collecting software, which supports MODBUS RTU communication and can be downloaded free of charge from our website. The features of this software (Fig. 6) are as follows:

- (i) Enables up to 124 measurement data items to be collected from the energy measurement unit, which are displayed as the current values.
- (ii) Measurement data can be logged at a specified period (1 minute or 1 hour).
- (iii) Logging data is output in the CSV file format.
- (iv) The basic settings (phase wire system, primary current, primary voltage, etc.) of the connected energy measuring unit can be specified.

The EMU4-SW1 data collecting software supports both Japanese and English, and allows other languages and models to be supported by adding a model definition file, which includes language information, without needing to change the source code.

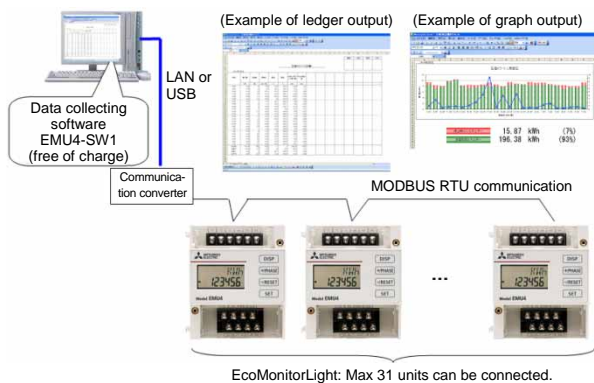


Fig. 6 Data collection by exclusive software

(2) Visualization of data by means of a display

To visualize the energy used at a manufacturing site, or to control the correlation between productivity and energy consumption, we incorporated a MODBUS RTU communication in the energy measurement unit, which allows direct connection to a GOT. Also, for users who are unfamiliar with the GOT, we prepared a sample screen (Fig. 7) exclusively for an energy measuring unit for our GOT1000 series (GT14**-Q, GT1030), which

can be downloaded free of charge from our website.

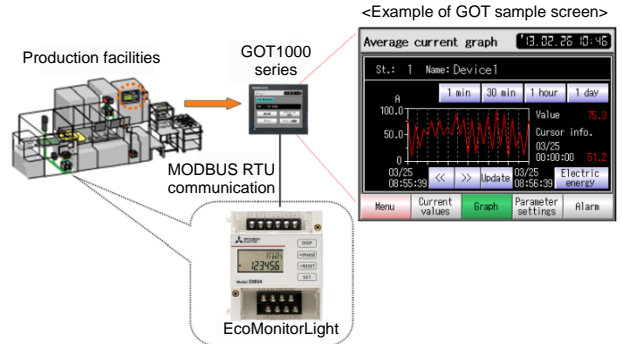


Fig. 7 Visualization of data by display device "GOT"

3. Conclusion

This paper described the EcoMonitorLight energy measuring unit with integrated display that enables the visualization of energy consumption, easily and at low cost.

We will continue to develop various energy measuring units with enhanced functions to help our customers conserve energy.

