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Mitsubishi Electric

ADVANCE

Latest Factory Automation Technologies and Systems

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Latest Factory Automation Technologies and Systems

• **Editorial Inquiries**

Hideyuki Ichiyama
Corporate Productivity Engineering & Logistics Dept.
Fax: +81-3-3218-2465

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Technical Reports

Precis

Mitsubishi Electric Corporation has been working toward becoming a "one & only FA supplier" in contributing to manufacturing around the world and in satisfying customers, by providing its e-F@ctory integrated FA solution with the latest technologies and top quality as a foundation.

This issue introduces the latest FA technologies and systems that make up this foundation for e-F@ctory.

(1) Remote IO-Link units compatible with CC-Link IE field networks; these types of units are compatible with IO-Link as a European international standard for sensor communications.

(2) Mitsubishi CNC E80 series; this easy-to-use, IoT-compatible series with functions for improving the cost performance of machine tools satisfies needs in emerging markets.

(3) New version of the GX series of the Fiber 2D Laser Processing System; this series has realized high processing stability, high reliability, high-speed processing, and complete automation, while reducing running costs and saving labor.

Overview

Author: *Yasushi Umeda**

Requirements for digital production systems in the future

The digitization and networking of production systems has been acknowledged widely. Amid such fast development of information technologies for the cyber layer of cyber physical production systems (CPPSs), at this stage it is crucial to use such technologies efficiently to create new value. However, there is still no clear winning formula anywhere in the world. In particular, it is important to leverage the advantages of the Japanese manufacturing industry in the new framework of CPPSs to make the industry world-leading. The main advantage is "high-quality manufacturing," which includes skilled labor, high-quality products, precise manufacturing without defects, constant improvement of manufacturing processes, and cost reduction. Accordingly, CPPSs involving many cutting-edge IT should focus on supporting individuals, diligently helping operators and engineers at manufacturing sites to make improvements on site, and identify and solve problems. Production system engineers will be increasingly required to use such CPPSs efficiently to develop, design, and operate production systems, solve problems, and make improvements.

**Professor , Research into Artifacts, Center for Engineering,
School of Engineering, the University of Tokyo*

Development of IO-Link Master Module

Author: *Satoshi Namematsu**

1. Introduction

In line with the trend toward Industry 4.0 and IoT, it was recently suggested in Europe to use IO-Link to enhance seamless information-sharing through networks from end-use devices, such as sensors and actuators, to higher-level production management systems. Accordingly, sensor manufacturers in and outside Japan have been developing various devices such as sensors and actuators that are compatible with IO-Link. Mitsubishi Electric Corporation has developed remote IO-Link units that conform to IEC61131-9, which is an international standard for IO-Link.

This paper describes the characteristics of IO-Link and technologies for reducing the cost of remote IO-Link units and simplifying parameter setting.

2. Characteristics of IO-Link

IO-Link is an industrial digital communication standard for sensors and actuators used at manufacturing sites (bi-directional and point-to-point communications) and it was standardized in 2013 by IEC 61131-9. Networking with IO-Link has made it possible to obtain measured values, operation values, and diagnostic data from IO-Link devices in addition to conventional digital signals. IO-Link also makes it easier to set parameters when IO-Link devices are replaced.

This chapter describes the characteristics of IO-Link.

2.1 Improved information collection and accurate management (higher operation efficiency)

Conventionally, sensors transmit only control signals (two levels of OK and NG, analog values). Since IO-Link provides data communications, it is possible to obtain measurement data, identification data, and setting information from IO-Link devices. Moreover, digitization of analog values prevents degradation of measurement data. In addition, since identification data and setting information can be obtained from IO-Link devices, the devices in use at manufacturing sites can be precisely managed and management costs can be reduced (Fig. 1).

2.2 Simple design work (standardized parts and operation)

Previously, it was necessary to prepare control units and cables (e.g., multiple signal wires, shield wires, and power supply wires) that matched the interfaces of sensors. In contrast, for IO-Link, standard IO-Link units are used as control units and standard IO-Link cables (unshielded three-wire cables [signal, power supply, and GND]) are used as cables. Therefore, there is less wiring at actual manufacturing sites and it is relatively simple and standardized, enabling simple equipment to be designed. This reduces the costs for equipment and management (Fig. 2).

2.3 Quick detection of deterioration and failure (preventive maintenance)

Conventional sensors can handle only control signals and so must be periodically maintained, making it time-consuming to identify a faulty section (whether a broken cable or faulty sensor) after a malfunction. With IO-Link, IO-Link devices send deterioration information

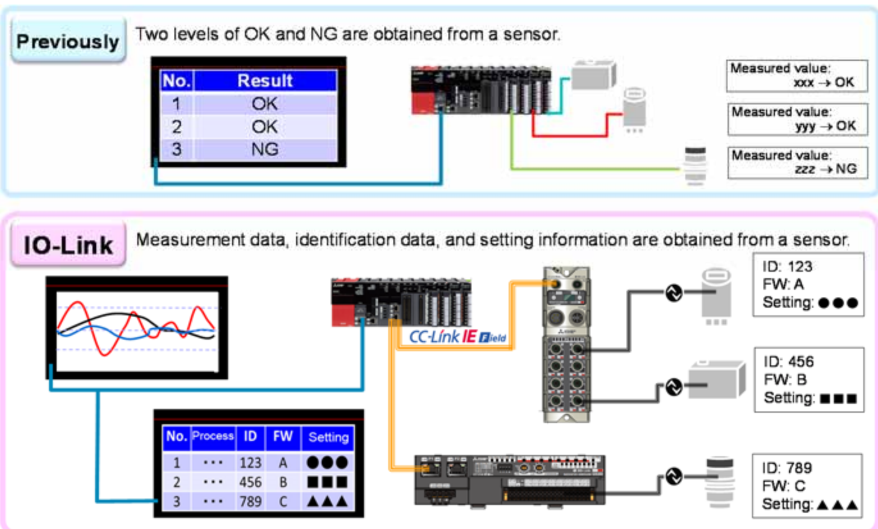

Fig. 1 Example of improvement in operation efficiency

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(diagnostic information) and the sensor status can be monitored remotely from graphic operation terminals (GOTs) and PCs, thus reducing the number of times of maintenance. In addition, IO-Link makes it easier to locate faulty sections and reduces downtime (Fig. 3).

2.4 Automatic parameter setting (improved maintainability)

When replacing a sensor in the past, the parameters, which varied from sensor to sensor, had to be redefined using a special tool, ladder, or other tool, and operators needed to have such skills. Meanwhile, with IO-Link, immediately after an IO-Link device is replaced, the IO-Link unit sends the parameter settings that have been saved in the unit to the new IO-Link device automatically to redefine the parameters. Therefore, operators need to perform replacement only, and do not need to set parameters using special tools, etc., reducing downtime. In addition, the only task to be done is replacement, which prevents the situation where sensors can be replaced only by a certain person and others do not know how to do it (Fig. 4).

3. Technologies Supporting Remote IO-Link Units

The developed remote IO-Link units bridge CC-Link IE field communication and IO-Link communication and function as IO-Link master units that control IO-Link devices.

Table 1 lists the main specifications of remote IO-Link units.

Chapter 2 described the characteristics of IO-Link. To expand the use of IO-Link, the cost of introducing (due to the addition of IO-Link communication functions) IO-Link systems needed to be reduced and technologies for simplifying parameter setting were required.

The next section describes technologies for reducing costs and simplifying parameter setting.

3.1 Cost reduction technologies

IO-Link communication functions have been added to sensors and actuators that used to handle only control

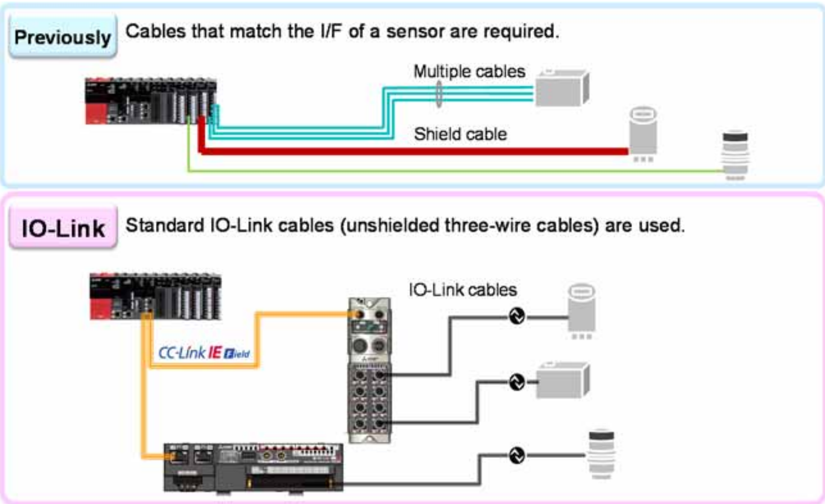

Fig. 2 Example of standardized parts and operations

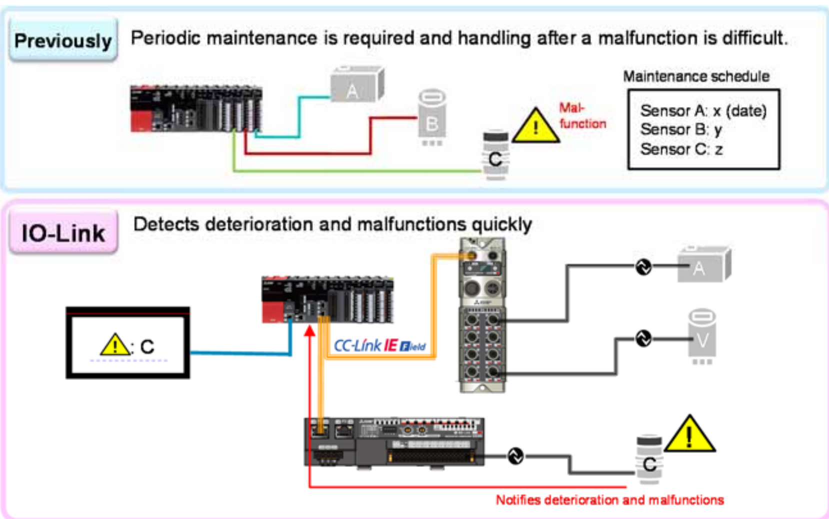

Fig. 3 Example of preventive maintenance

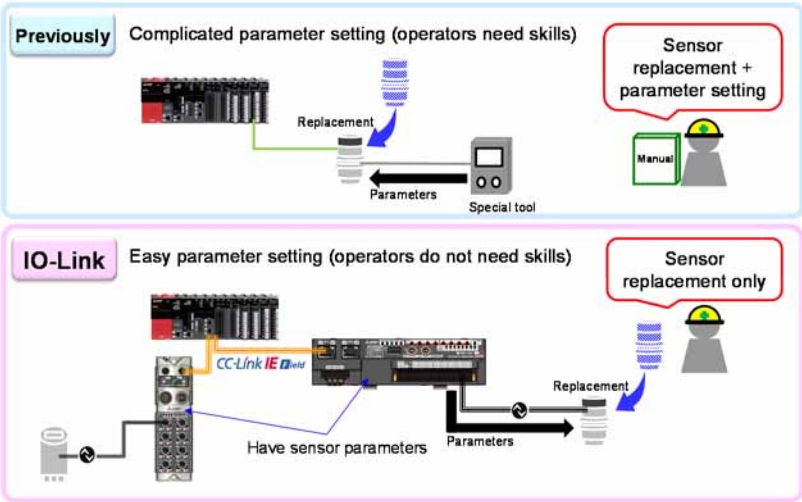

Fig. 4 Example of improved maintainability

Table 1 Main specifications of remote IO-Link units

Item	Description
Interface	· Bi-directional point-to-point communications · Signal (C/Q), power supply (L+), and GND (L-) · IO-Link mode (for IO-Link data communication) · SIO mode (conventional digital signals)
Communication rates	· Transmit mode COM1 (4.8 kbps) · Transmit mode COM2 (38.4 kbps) · Transmit mode COM3 (230.4 kbps)
Communication system	· Start-stop synchronization serial communication (UART communication)
Data type [Cyclic data]	· Process data (0- to 32-B data with higher priority [e.g., measurement data]) · Status (validity or invalidity of process data)
Data type [Acyclic data]	· Device data (parameters, ID data, diagnostic information) · Events (information on errors, warnings, maintenance, and other matters)

signals, which increases the costs. To reduce the initial cost when customers introduce IO-Link systems, it was necessary to reduce the cost of remote IO-Link units.

As shown in Fig. 5, a remote I/O unit that processes control signals can connect to the LSI terminal for communications via the I/O drivers. Meanwhile, a remote IO-Link unit requires IO-Link PHY (physical layer) (ICs for IO-Link communication) and microcomputers that control them. For the conventional IO-Link PHY, the IO-Link communication system was UART communication, which was used between the microcomputers for control and IO-Link PHY. However, there were few microcomputers with eight UART communication channels, and so creating remote IO-Link units with eight channels, such as by using two microcomputers with four UART communication channels, would increase the cost.

Therefore, when selecting IO-Link PHY, the latest one was chosen. One chip of such IO-Link PHY has two IO-Link communication channels and serial peripheral interface (SPI) communication is used between a microcomputer for control and IO-Link PHY as shown in Fig. 6. Each IO-Link PHY has its own address and multiple IO-Link PHY chips can be controlled through one-channel SPI communication. In addition, with IO-Link communication (UART communication), IO-Link data from the microcomputer for control is stored in the first in first out (FIFO) in the IO-Link PHY via the SPI communication and IO-Link communication is realized by the UART generation circuit.

Adoption of the IO-Link PHY reduced the number of necessary parts and realized a remote IO-Link unit with one reasonably-priced general-purpose microcomputer and eight-channel IO-Link communication.

3.2 Technologies for simplifying parameter setting

It used to be impossible to access IO-Link devices from PCs through various network communication protocols (Ethernet → CC-Link IE field → IO-Link). Therefore, as shown in Fig. 7 (1), when an IO-Link device was installed, the customer needed to write a ladder program according to the manual of the IO-Link device manufacturer and to define parameters via a sequencer. However, setting parameters by writing a ladder program requires skills, and customers often made errors. Therefore, as shown in Fig. 7 (2), Mitsubishi Electric Corporation has simplified parameter setting by using a graphical user interface (GUI) on a PC.

The next section describes the technologies for simplifying parameter setting.

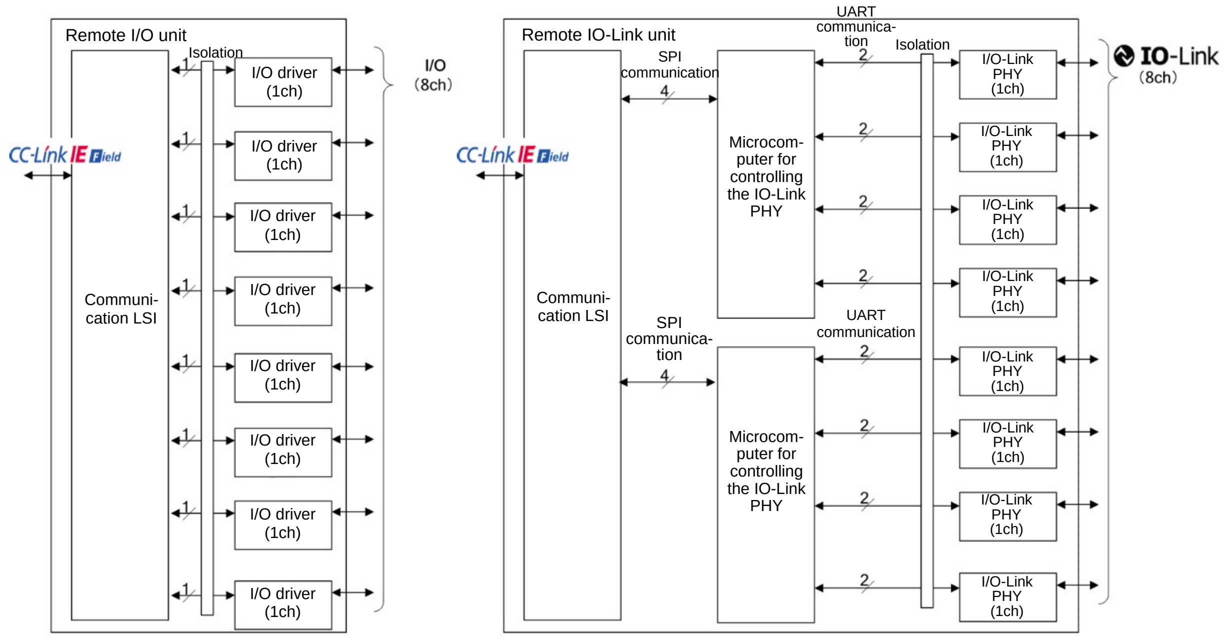

Fig. 5 Comparison of the configuration of remote I/O and remote IO-Link units

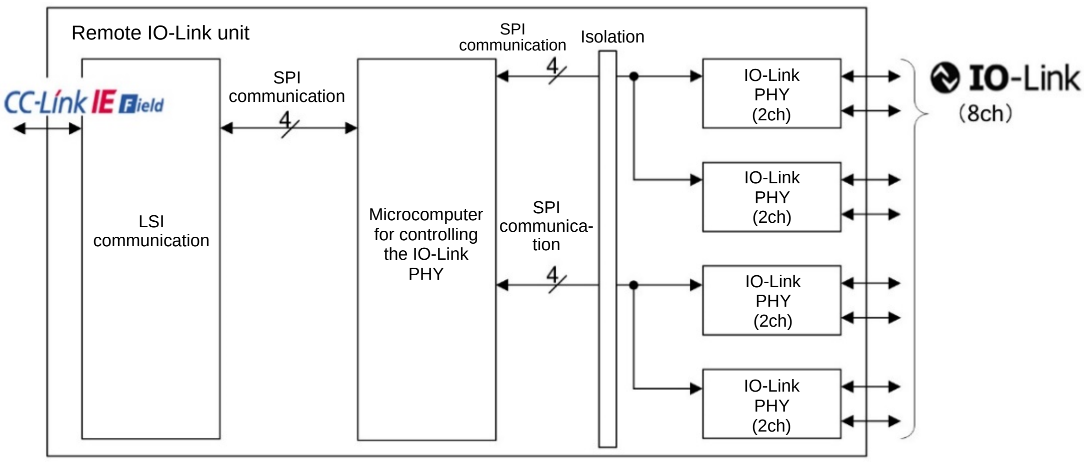

Fig. 6 Configuration of a remote IO-Link unit with the new type of chip

3.2.1 Development of an FDC tool

Mitsubishi Electric Corporation has developed IO-Link device management and configuration software, called MELSOFT Field Device Configurator (FDC), as a tool for setting GUIs on a PC. The FDC is compatible with the open specification of Field Device Tool (FDT) that can start from engineering software GxWorks3.

Customers import an IO Device Description (IODD) file that contains IO-Link device setting information written in Device Description Language into the FDC. In the FDC tool, a Device Type Manager (DTM) (software driver) called an IODD interpreter interprets the imported IODD file successively and acts as DeviceDTM. This DeviceDTM provides a GUI that allows customers to define IO-Link device parameters.

The IO-Link standard requires that IO-Link device manufacturers provide an IODD file for each IO-Link device without exception. Customers only need to import such provided IODD file into the FDC, which makes it possible to set the parameters of IO-Link devices without errors.

3.2.2 SLMP protocol compatible with IO-Link

To set IO-Link device parameters using the FDC tool on a PC (to allow data to reach the devices), Seamless Message Protocol (SLMP)[1] had to be compatible with the IO-Link communication protocol. For this purpose, for SLMP communication frames, the structure of request (read and write) frames that corresponded to the data types (process data, device data, and event data)

[1] Common protocol that links Ethernet and a CC-Link IE field network seamlessly

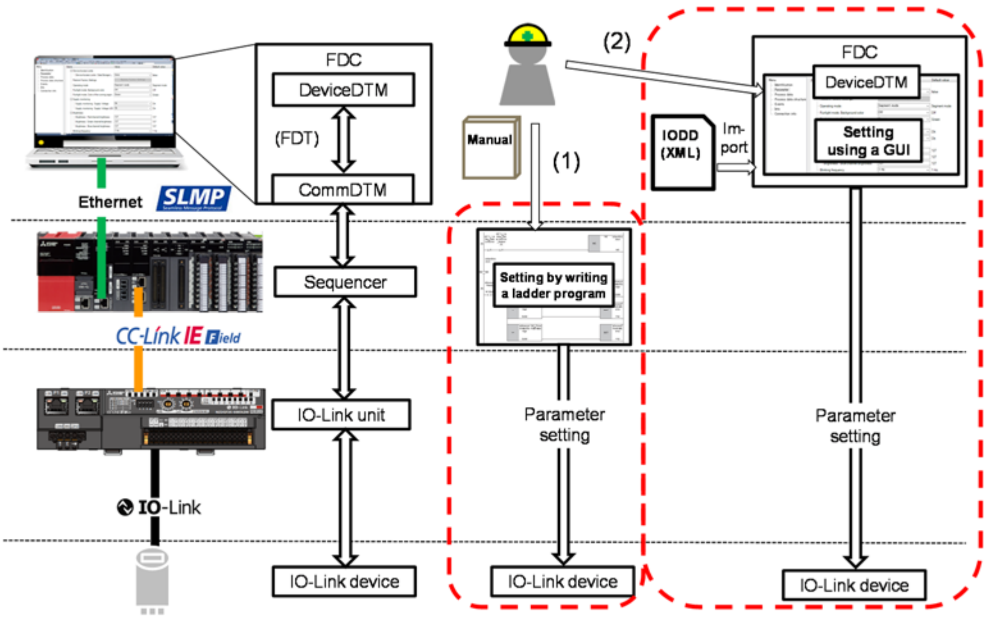

Fig. 7 Comparison of parameter setting of IO-Link devices

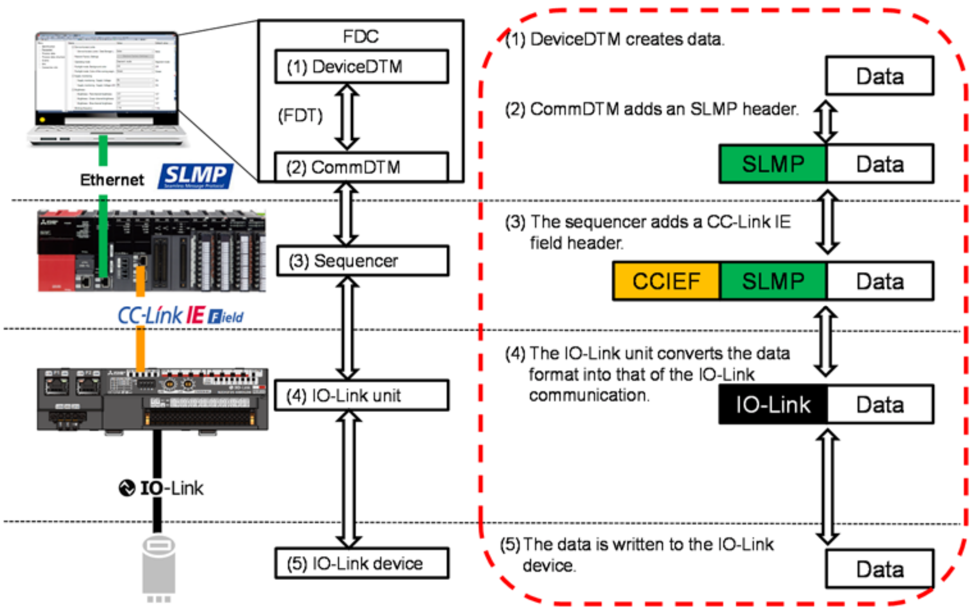

Fig. 8 Communication from a PC to an IO-Link device

of the IO-Link communication listed in Table 1 and corresponding response frame structure were defined.

3.2.3 Development of communication driver CommDTM

The developed SLMP compatible with IO-Link completes a system that can network from Ethernet to IO-Link devices.

We have developed the CommDTM communication driver that receives access requests from DeviceDTM to IO-Link devices based on the FDT specification and converts them into the created SLMP protocol.

The developed FDC tool, IO-Link-compatible SLMP protocol, and developed CommDTM allow customers to define IO-Link device parameters using the FDC tool; the parameters are written to the IO-Link devices via a network of Ethernet, CC-Link IE field, and IO-Link as shown in Fig. 8 (1) to 8 (5).

4. Conclusion

This paper described the characteristics of IO-Link and technologies that support remote IO-Link units developed this time. We will continue to pioneer the sensor and sequencer market.

Mitsubishi CNC "E80 Series" to Meet Needs of Emerging Markets

Author: *Takashi Sueda**

1. Introduction

In recent years, the demand for processing smartphone parts has been increasing in Asia and sales of midpriced machine tools, such as tapping centers and machining centers, have increased. Mitsubishi Electric Corporation's CNC has been well received and its market share has grown. Mitsubishi Electric aims to develop products that match market needs and has been developing CNC machines for high-grade and moderate-priced machine tools as well as mid-priced machine tools.

In 2014, we released the CNC M800/M80 series. For this series, we developed high-value-added functions (e.g., 5-axis machining and combined machining functions) for high-grade machine tools by leveraging its functional expandability. The series is highly reputed by users for processing performance and operability, including in the mid-priced machine market. Meanwhile, in the moderate-priced machine tool market, there is high demand for cost-effective machine tools with a simple configuration. To satisfy such needs, we have developed the CNC E80 series.

This paper describes the functions of the E80 series.

2. E80 Series

2.1 Positioning of the E80 series

Mitsubishi Electric provides various models in the CNC series: high-performance CNC M800 series for 5-axis machines and combined lathes that are used for complicated processing (e.g., processing of aircraft parts) and standard CNC M80 series for machining centers and multi-system lathes that are used to process dies and precision parts. The E80 series is a highly cost-effective CNC that is optimum for machine tools with a simple configuration, such as simple machining centers that process smartphone cases and 2-axis lathes and lathes with milling function that are used to process automotive parts (Fig. 1).

2.2 E80 series system configuration

The E80 series is a control unit with an integrated display and is a successor to the conventional model of the E70 series. As shown in Fig. 2, the E80 series provides high-speed optical communications with Mitsubishi Electric's high-performance drive units as is the case with the M800/M80 series. The E80 unit can also drive a spindle through analog connection to an inverter. In addition, the series features a secure digital (SD) card slot as standard and provides two types of sheet keyboards: one for lathes and one for machining centers (Fig. 3). The thickness of both display and keyboard is just 9.5 mm, which expands the possibility of machine tool design thanks to the flat shape.

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2.3 Performance of the E80 series

The E80 series equipped with a CPU specific for CNC with high-speed processing capability equivalent to that of the M800/M80 series offers the following: high processing capability for processing programs to boost

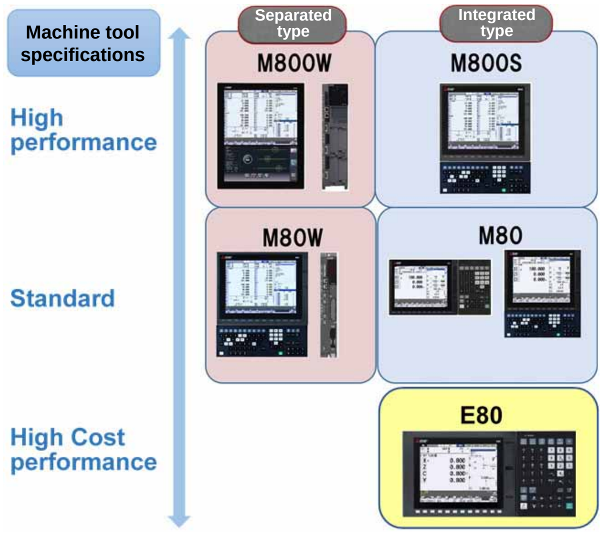

Fig. 1 Positioning of E80 series

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productivity; and programmable logic controller (PLC) processing capability for processing large ladder programs at high speed. These capabilities reduce the cycle time and deliver high-accuracy processing. Compared to the E70 series, the segment processing capability of the E80 series is double that of the E70 series, the PLC processing capability is nine times, and the communication capacity between the NC and drive unit is three times, as shown in Fig. 4.

3. Characteristic Functions of the E80 Series

This section describes the functions that contribute to the high performance of the E80 series: improved

Fig. 2 Example of E80 series connection

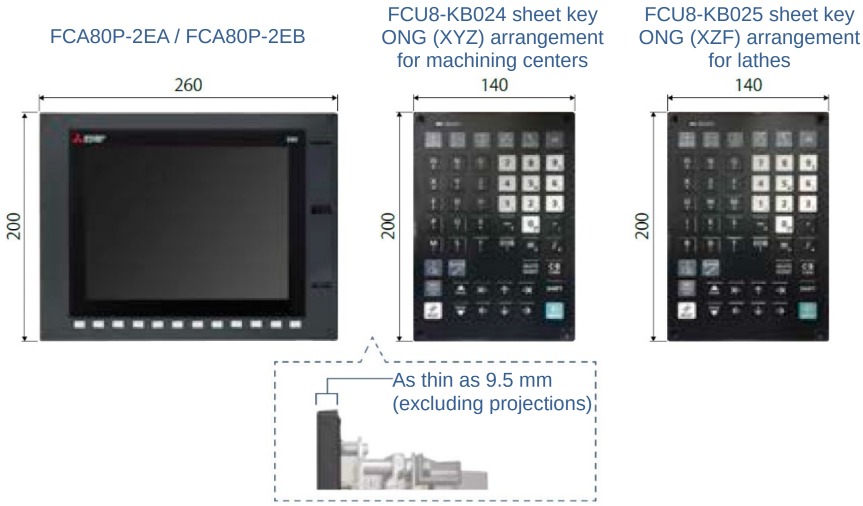


Fig. 3 Display and sheet keyboard size

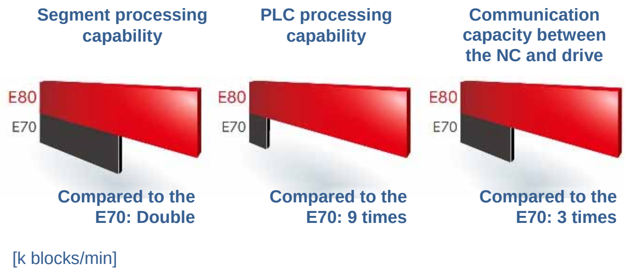


Fig. 4 Performance comparison between E80 series and E70 series

cost-effectiveness of machine tools, ease of use, and IoT compatibility.

3.1 Expanded analog interface spindle function

In the moderate-priced machine tool market, the cost of some machine tools is reduced by installing spindles that are driven by inverters that are connected by analog in place of drive units (Fig. 5). Previously, when this type of machine was used for tapping, the feed axis for driving the drive unit could not be synchronized with the analog interface spindle and so a tool with a special expansion and contraction mechanism was required. The E80 series can perform high-accuracy synchronized tapping even with analog interface spindles thanks to the improved analog output commands. This improvement makes machine tools highly cost-effective.

3.2 Development of a function for multi-head processing machines

Multi-head processing machines are highly cost-effective machine tools that can process multiple works of the same type at the same time (Fig. 6). For the E80 series, a multiple-axis synchronization control function has been developed for multi-head processing machines. Previously, only two feed axes could be controlled in synchronization, whereas this new function enables synchronization control of three axes or more. In addition, the tool length of each axis can be corrected for operation based on the tool length of each Z axis, which makes it possible to process each work highly accurately.

3.3 Functions for various machine specifications

Recently, in the moderate-priced machine tool market, high-quality and high-accuracy processing has been demanded. Such needs are naturally high for simple machining centers and lathes with a milling function. The E80 series has high-accuracy control, Super Smooth Surface (easySSS) control, and tolerance control functions as user-friendly functions for highly accurate processing to ensure excellent ease of use.

The high-accuracy control function prevents a corner from rounding and a circular arc from becoming smaller than the commanded one by reducing differences between a path commanded by a processing program and the actual machining path (Table 1).

The easySSS control is a function that can utilize the SSS control provided on the M800/M80 series by performing simple setting operations. The control judges a processing program globally to reduce vibration due to local changes on the path and moves the tool smoothly, which realizes high-quality processing (Fig. 7).

For the tolerance control, only the tolerance needs to be specified. The tool then moves smoothly within the processing scope. Even if a processing program contains

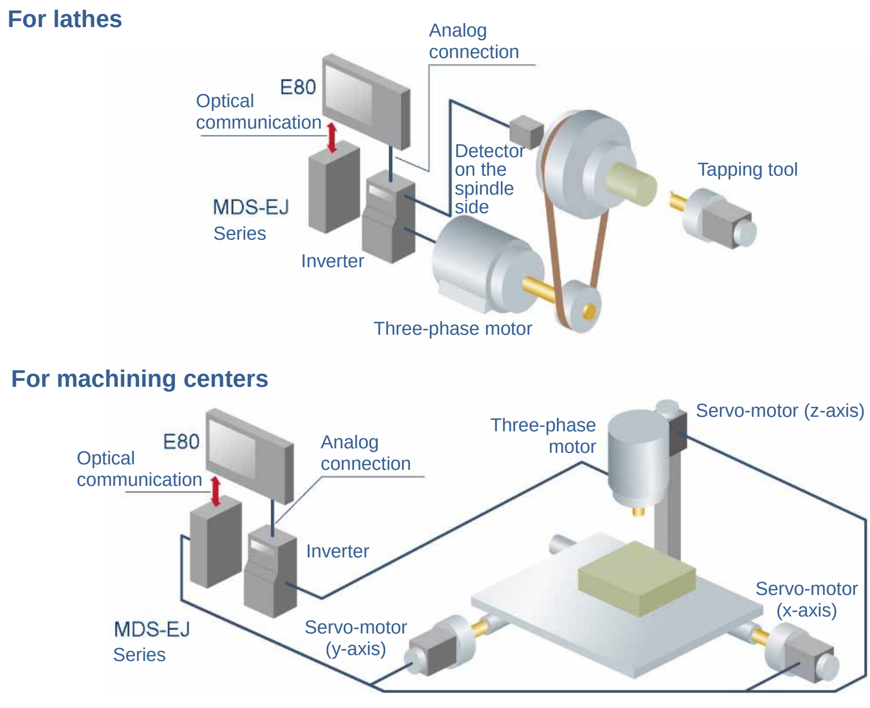


Fig. 5 Inverter drive spindle connection

unnecessary level differences of segments and noise, the control realizes smooth processing (Fig. 8). In addition, since the function moves the tool while removing such unnecessary levels, the cycle time is reduced.

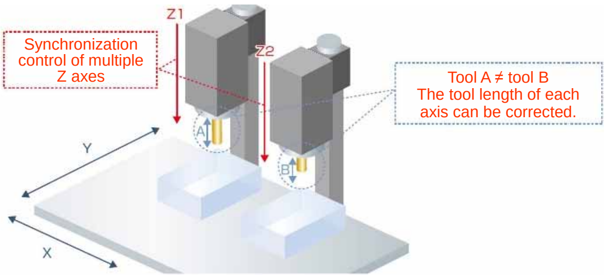
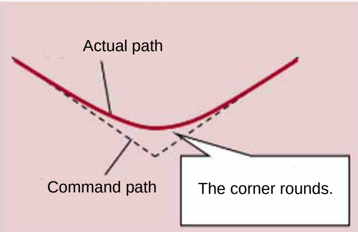
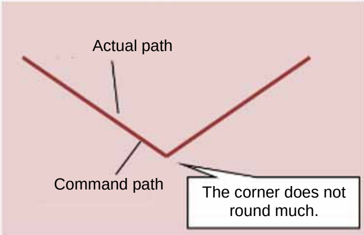
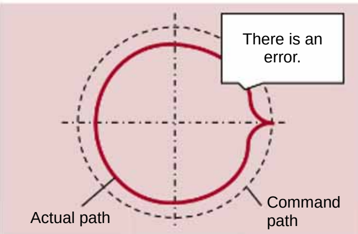
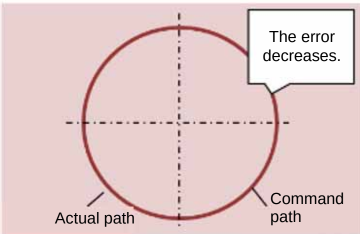


Fig. 6 Same shape processing with multi-head processing machine

3.4 Expansion of program editing and customization functions

The interactive cycle insertion function improves ease of use. This function supports work planning by making the operations as intuitive as possible. Simply specify the processing shape and dimensions on the screen, and the function automatically creates a processing program. This function has many cycles and so can cope with various types of processing. It can also be customized, for example, by adding a cycle insertion screen unique to a machine manufacturer and by hiding unnecessary cycles (Fig. 9). This function makes machine tools easier to use.

Table 1 Command path and machining path when high-precision control is enabled and disabled

	When high-accuracy control is disabled	When high-accuracy control is enabled
Error at a corner		
Error at a circular arc		

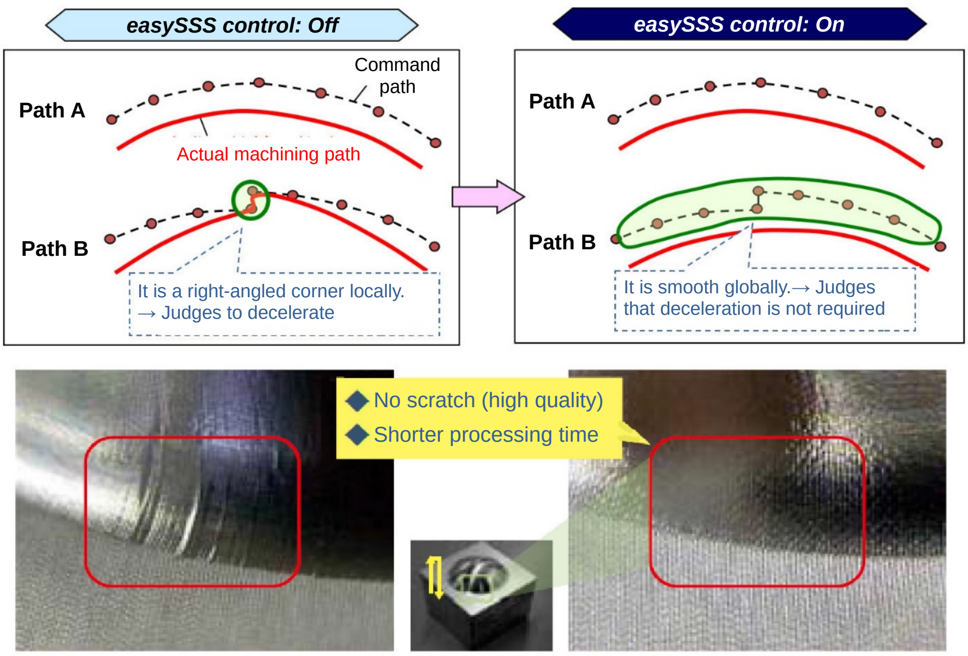


Fig. 7 Processing path and processing result when easy SSS control is enabled and disabled

3.5 Functions that support optimization of manufacturing

FA systems are rapidly becoming IoT-enabled. Mitsubishi Electric has been proposing “e-F@ctory,” which optimizes the entire manufacturing by connecting all equipment and facilities to the IoT and analyzing and using data. The E80 series has many functions that support IoT; this section describes field networks and a function for email notification to operators.

3.5.1 Field networks

CC-Link that can be used for many types of products, from wire-saving to safety equipment, and CC-Link IE that links control systems at high speed and high capacity, have been used at manufacturing sites with e-F@ctory. The E80 series is also compatible with these field networks (Fig. 10). The series is also EtherNet/IP-enabled, and so can be combined with various general-purpose Ethernet devices and CC-Link IE Field that can transmit large volumes of data at high speed.

3.5.2 Function of email notification to operators

The function of email notification to operators emails the operation status of a machine from numerical control

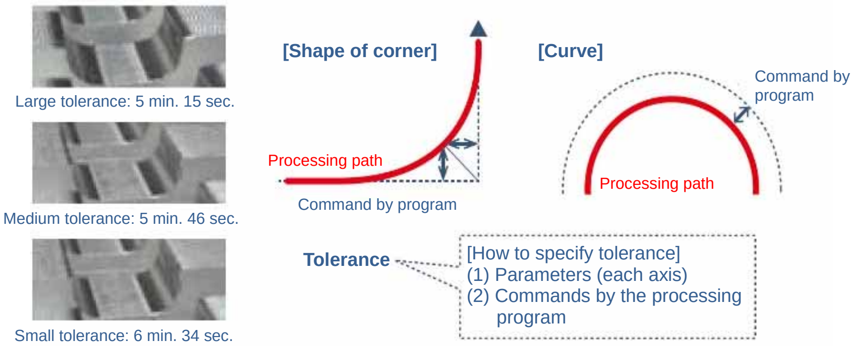


Fig. 8 Processing path and processing time when tolerance control is enabled.

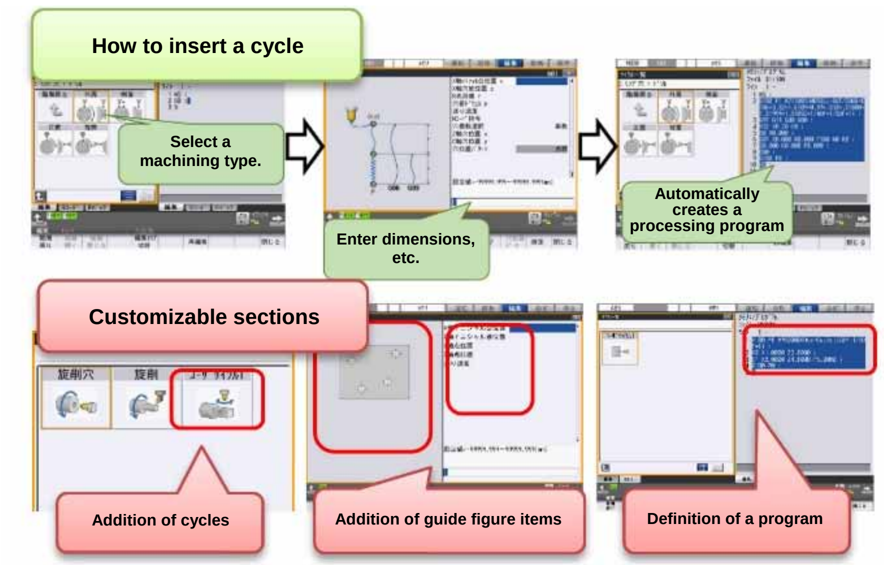


Fig. 9 Interactive cycle insertion and customization.

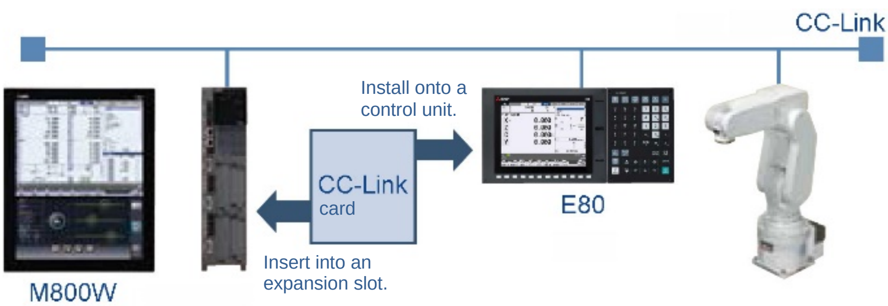


Fig. 10 CC-Link connection

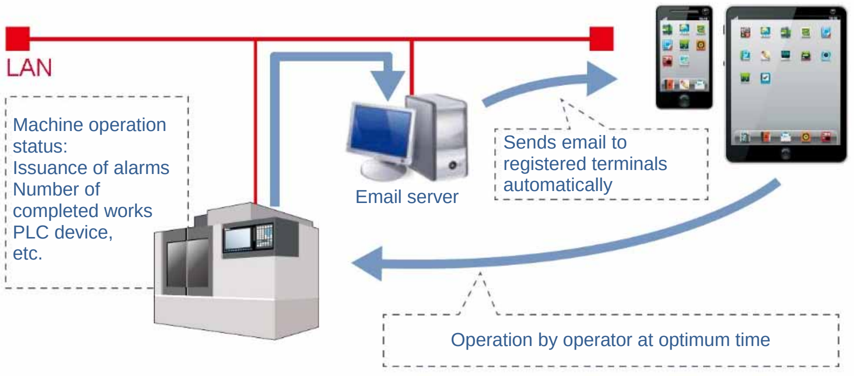


Fig. 11 Email notification to operator

(NC) automatically at the time preset on the NC (Fig. 11). By specifying transmission conditions (e.g., time and alarm), destinations (email addresses) are automatically registered. Therefore, the status can be checked on PCs, smartphones, and various other terminals. Since the function requires only a simple network environment and Simple Mail Transfer Protocol (SMTP) server, environment settings are easy and the machine operation status can be monitored from anywhere, thus reducing downtime in an emergency.

4. Conclusion

This paper described the CNC E80 series. Although the needs for machine tools are continuously evolving, the E80 series satisfies such needs and provides a foundation for manufacturing around the world. We will keep developing products that match market needs in the future.

New Fiber 2D Laser Processing System GX Series

Author: *Hiroki Murasawa**

1. Introduction

2D laser processing systems have established their positions as essential machine tools at manufacturing sites thanks to dramatic technical progress and expansion of the market. In recent years, in the markets of processing systems for cutting metal plates in Japan, China, the U.S., and major powers in Europe, the number of laser processing systems installed each year has significantly exceeded that of turret punch presses. Meanwhile, as the population of workers continues to decrease, the manufacturing industry is being forced to automate processing processes, reduce running costs, and improve productivity. Therefore, fiber laser processing systems with high productivity and lower running costs have been gaining attention.

2. Product Specifications and Concepts

To satisfy such market needs, Mitsubishi Electric Corporation has developed new 2D fiber laser processing system GX series (hereafter, “GX”), a solution for high-dimensional automation (Table 1). This paper describes the concepts of the GX, which include: (1) high processing stability and reliability, (2) high-speed processing and low running cost, and (3) complete automation and labor-saving.

Table 1 Main ML3015GX specifications

Item		ML3015GX
Travel method		Photon scanning
Stroke (mm)	x-axis	3100
	y-axis	1550
	z-axis	120
Fast feed speed (m/min)	x- and y-axes	Combined 170
Positioning accuracy (mm)		0.05/500 (x- and y-axes)
Repeatability (mm)		±0.01 (x- and y-axes)

2.1 High processing stability and reliability

2.1.1 Processing diagnosis function by AI

Laser processing of metal plates is performed while spraying assist gas. Skilled workers can roughly predict whether the processing is proper or defective by listening to the sound of the gas flow during cutting and by observing the flow of molten metal. Accordingly, we considered that it should be possible to judge whether processing is proper or defective by sensing and analyzing the sound and light generated during processing without observing the processed surface.

To realize such a function, we collected a large amount of data during proper processing and various types of improper cutting operations and then made AI learn from it. Based on the learned data, the AI then judges data on sound and light generated during processing to determine the processing status (Fig. 1).

If the AI judges that the processing is defective, the nozzle monitor function, which is described later, is executed to identify what caused the defect. If the processing nozzle has a problem, it is replaced in order to continue the operation; if the nozzle has no problem, the processing conditions are automatically changed to more stable ones to correct the processing defect. If the defect still remains even after the conditions were changed, the system stops due to an error because it may not be possible to automatically eliminate the cause of the defect. Executing these functions can prevent users from wasting raw materials.

2.1.2 Nozzle monitoring function

One cause of processing defects is deformation of the processing nozzle due to heat during processing and collision with the raw material. The shape of the hole of a processing nozzle significantly affects the flow of assist gas, and so deformation of the hole may affect processing adversely. Deformation of small-diameter processing nozzles in particular is known to have a large influence, and even slight deformation of such nozzles affects the processing. In actual working environments, when a processing defect is found, the operator removes the processing nozzle and examines the hole shape visually to check whether it is proper or defective. We decided to use a camera to do this in place of operators.

For this function, we collected a large number of photographs of proper and defective nozzles and made AI learn from them to be able to make judgments, similar to the processing diagnosis function. Even for a processing nozzle for which a defect is hard to identify by visual check as shown in Fig. 2, the function can judge whether it is defective. This function can quickly eliminate processing defects caused by defective processing nozzles.

**Nagoya Works*

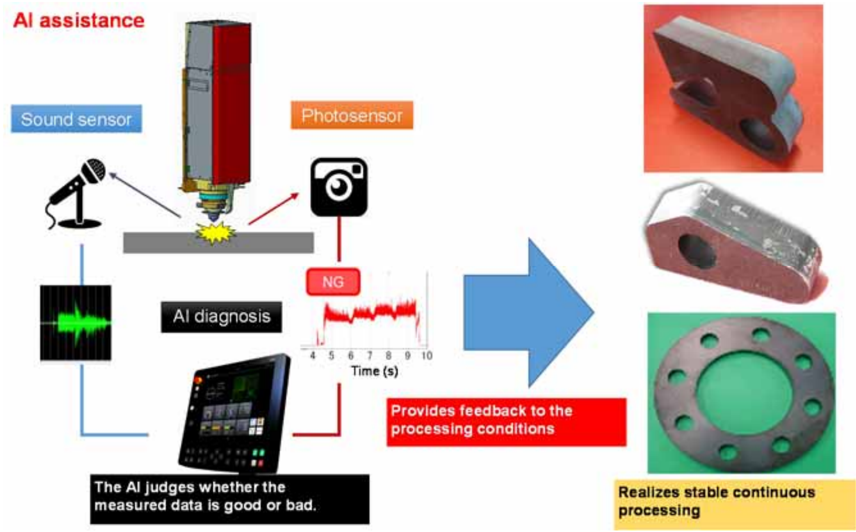
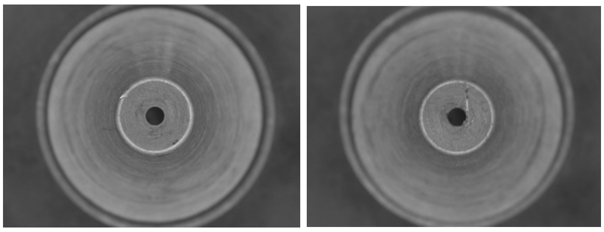


Fig. 1 Processing diagnosis function



Proper nozzle　　Defective nozzle

Fig. 2 Proper and defective processing nozzles

2.2 High-speed processing and low running costs

2.2.1 High-speed high-accuracy processing

Since the wavelength of fiber laser is shorter than that of carbon dioxide gas laser, it is strongly absorbed by metals and also has excellent light-harvesting characteristics. Therefore, fiber laser is optimum for cutting thin plates at high speed. To maximize its performance, Mitsubishi Electric has developed processing systems with higher rigidity and a lighter driving unit, thus increasing the fast feed speed of the x- and y-axes to 1.2 times and the acceleration to 1.3 times. Compared to the conventional processing systems, the new type reduces the takt time for thin benchmark shapes by 10% (Fig. 3) and improves the roundness of small-hole processing by 33% (Fig. 4), achieving high-speed high-accuracy processing.

2.2.2 Low running costs

As the output of fiber laser processing systems has increased, nitrogen has been more frequently used as the processing gas. Compared to the processing method involving chemical reactions (e.g., oxidation combustion reactions), when nitrogen is used, the processing rate is not restricted by such reactions and the productivity may be increased as the output of the oscillator is higher. However, the amount of nitrogen gas consumed during processing tended to increase, making it difficult to improve the productivity while reducing the running cost. For GX, the processing gas flow was visualized (Fig. 5) to clarify processing phenomena and a new AGR-eco technology that reduces the consumption of nitrogen gas was developed; AGR-eco can reduce nitrogen gas consumption for 9-mm mild steel by up to 90% (Fig. 6).

2.3 Complete automation and labor-saving

Faced with labor shortages at production sites and increased use of fiber laser processing systems for production, there is a strong need to boost productivity by laser processing of metal plates through automation, including the manufacturing processes before and after metal plate laser processing. The steps of metal plate laser processing consist of supply of materials, laser cutting, discharge of the cut materials, and taking out and sorting of cut parts from the discharged materials. To reduce the labor required for sorting after laser cutting, global demand for automatic sorters is expected to increase rapidly. To satisfy such market need, we added automatic sorting systems to our lineup (Table 2). These systems completely automate the metal plate laser cutting processes from the supply of materials to the sorting of cut parts, thereby saving labor for such operations.

The four arms of this system automatically select the optimum tool based on the target items to be sorted. This function allows the sorting of parts having various shapes for which the raw material varies. In addition, a technology for controlling the four arms separately has made it possible to sort picked-up parts into any orientation (Fig. 7).

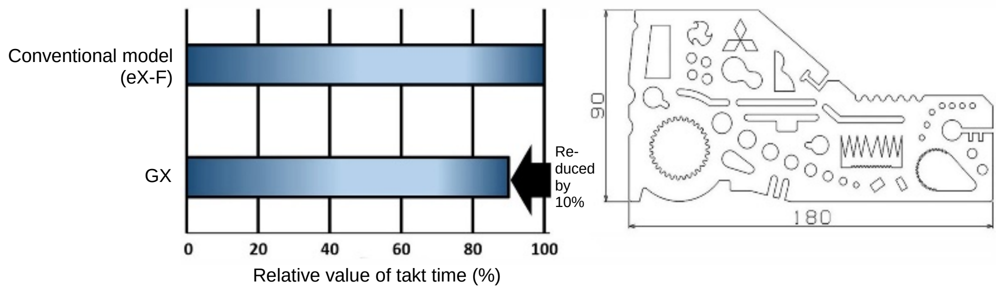


Fig. 3 Reduced takt time

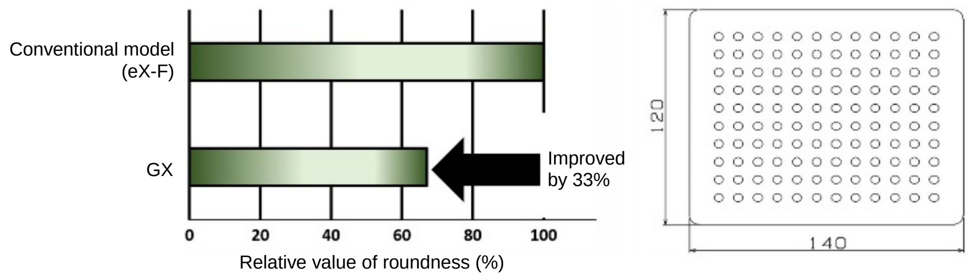


Fig. 4 Improved roundness

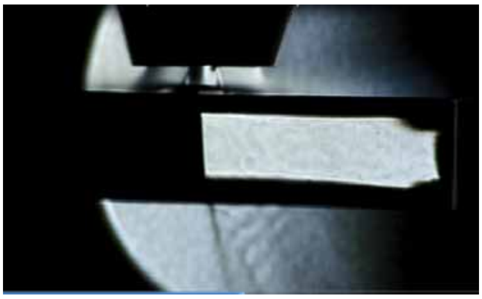


Fig. 5 Technology for visualizing processing gas

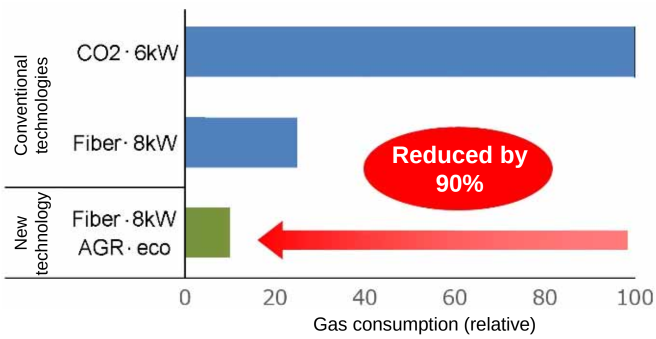


Fig. 6 Reduction of nitrogen gas consumption

Table 2 Specifications of automatic sorting system

Item	Automatic sorting system	
	Standard type	Lightweight type
Method of picking up products	Independent-control arm x 4	
Thickness of target plates	Up to 25 mm	Up to 9 mm
Transportable weight	2,000 kg	1,000 kg
Rotational placement	Possible	
Loading and unloading function	Provided	

Fig. 7 An automatic sorting system picking up products

3. Examples of Latest Processing

When the fiber laser was first put on the market, it was used for high-speed cutting and micromachining of thin plates and processing of highly reflective materials, to leverage its characteristic of high convergence thanks to the wavelength used (Fig. 8). Meanwhile, the recent increases in oscillator output and advances in processing technologies have improved the processing performance for medium-thick to thick plates. Thus, the fiber laser is highly regarded as a processing method also for medium-thick to thick plates. This section introduces such latest processing technologies.

3.1 Increased maximum processible thickness

In laser processing, the optimum diameter of the beam spot and beam profile vary depending on the raw material and thickness of the targets. Generally, such beam characteristics can be changed by replacing the processing lens. However, in the case of lens replacement, the variable ranges of lenses are discrete, making it impossible to select a beam that is optimum for all raw materials and thicknesses. The GX is equipped

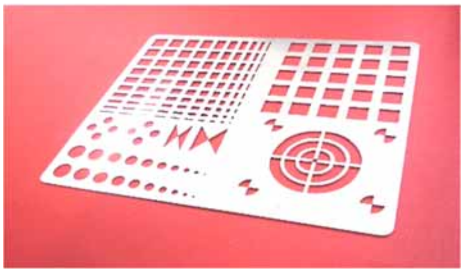


Fig. 8 Example processing by fiber laser

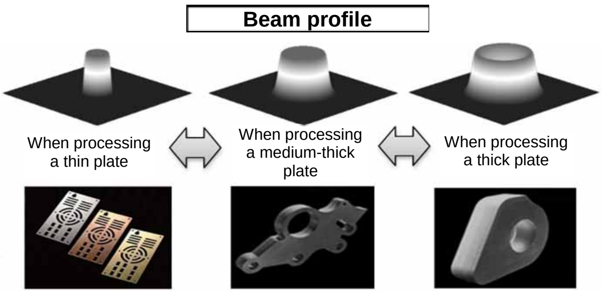


Fig. 9 Example beam profiles for various types of raw materials and thickness

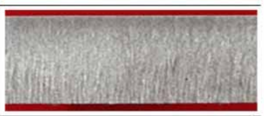
Material	Thick-ness	Processed sample	Cut section
Mild steel SS400	32 mm		
Stainless steel SUS304	30 mm		
Aluminum alloy A5052	30 mm		

Fig. 10 Processing quality at the maximum cuttable thickness

	Conventional technology	New technology
Cut section		
Roughness of the cut section Rz (μm)	240	35

Fig. 11 Example processing by fiber laser

with our unique processing head with a variable optical system. By changing the beam spot diameter and beam profile continuously, it is possible to use the optimum values for each type of raw material and thickness (Fig. 9).

Figure 10 shows example cutting at the maximum cuttable thickness for different raw materials by GX. The maximum thickness that the GX can cut effectively is 32 mm for mild steel, 30 mm for stainless steel, and 30 mm for aluminum alloys.

3.2 Technologies for improving the processing stability for thick mild steel plates

Cutting technologies using fiber laser have been rapidly advancing and the quality and stability of processing have been approaching those of the CO_2 laser. However, when processing thick mild steel plates with the thickness of 16 mm or more with oxygen, variations in material quality may cause abnormal combustion, which may make stable processing impossible. To solve this problem, a new beam oscillation method and new type of nozzle were developed for the GX to reduce the influence of variations in material quality. This development has made it possible to stably process mild steel plates for which the material quality significantly varies. Figure 11 shows examples of processing.

4. Conclusion

This paper described the concepts of the GX series of new fiber 2D laser processing systems and the latest technologies applied to the GX. Processing technologies for fiber laser processing systems have been dramatically advancing and technological innovation will continue. We will steadily improve the performance of our products as a comprehensive laser processing system manufacturer to satisfy increasingly sophisticated and diversifying user needs, in response to various needs at many production sites.

References

(1) Y. Saitoh: Mitsubishi Electric Corporation's Latest Laser Processing Technologies, Proceedings of the 84th Laser Materials Processing Conference (Jan. 2016), 139–144 (2016)
(2) N. Miyamoto, et al.: Cutting-edge Technology with Fiber Laser Processing Machine, Mitsubishi Denki Giho, 89, No. 4, 251–254 (2015)

MELSEC iQ-R Series Energy Measuring Module

Author: *Yuki Nobe**

1. Introduction

The revised Japanese energy saving law requires applicable companies to introduce energy management; accordingly, production sites need to work harder to save energy. Under these circumstances, requirements for measuring instruments have been changing, for example, measurement points need to be fractionalized and management of unit consumption needs to be improved by managing energy data and production data collectively.

In addition, it is increasingly necessary to monitor equipment statuses using measured data at production sites to reduce equipment maintenance costs and downtime.

Mitsubishi Electric Corporation has developed a new model of energy measuring module, the MELSEC iQ-R series, to satisfy such needs.

This paper describes the characteristics of the energy measuring module and its technologies.

2. Outline of the Energy Measuring Module

2.1 Product specifications

The RE81WH energy measuring module was developed as the MELSEC iQ-R series. Table 1 lists its main product specifications.

The module is directly inserted into a slot of a sequencer to reduce the work of laying communication lines and creating ladder programs for communications. In addition, the module can collect data at high speed through communications using the system bus of the MELSEC iQ-R series.

Furthermore, compared to the conventional equivalent model, the QE81WH of the MELSEC Q series, the effective value measurement cycle was shortened to one 25^{th} (1/25) from 250 to 10 ms. This improvement has made it possible to monitor equipment statuses more minutely by analyzing current and voltage values.

Moreover, the new model has functions not found in the conventional MELSEC Q series, including those for measuring instantaneous values (on a cycle of 254 μs) and harmonics. These functions can detect high-speed and minute changes that cannot be detected by measuring effective values, enabling more accurate monitoring of equipment statuses.

2.2 Product concept

(1) Realization of equipment status monitoring by shortening the effective value measurement cycle

Usually, when measured values are used for energy management, the measurement cycle does not need to be short, for example, when checking the trend of the electric energy per hour. Therefore, methods in which values measured on a measurement cycle of several hundred ms are collected every minute through communications are used. However, to use measured values for maintenance, the measurement cycle of several hundred ms may not be enough to detect an equipment malfunction. Therefore, for this module, the effective value measurement cycle has been made shorter (to 10 ms) to enable equipment statuses to be monitored more minutely (Fig. 1).

(2) Improved maintenance work using instantaneous values and harmonics

This module has a function for measuring instantaneous values to detect equipment malfunctions by detecting changes at higher speed that cannot be detected using effective values. By measuring instantaneous values, it is possible to monitor the raw waveforms of actual voltages and currents, and thus monitor equipment statuses more minutely (Fig. 2).

In addition, the harmonic measurement function makes it possible to easily obtain analysis results of fast Fourier transform (FFT) with the power supply frequency (50/60 Hz) as the frequency resolution.

(3) Space saving, wire saving, and easy measurement

Many energy management systems are configured as stand-alone measuring instruments and data is sent to higher-level systems (e.g., sequencers) through communications.

Due to this configuration, even for measurement of equipment with a sequencer, (1) space for installing a measuring instrument is needed, (2) a communication line needs to be laid, and (3) a communication program needs to be created. Therefore, much space is required and the cost tends to be high.

To solve such problems, this module is configured by directly inserting it into a slot of a sequencer (Fig. 3), thus offering the following advantages:

(i) Using an empty slot of a sequencer base saves space.

(ii) Direct connection with the sequencer can collect

*Fukuyama Works

Table 1 Specifications of RE81WH energy measuring module

<table>
<tr><th colspan="4">Item</th><th>Specifications</th></tr>
<tr><td colspan="4">Model</td><td>RE81WH</td></tr>
<tr><td rowspan="10">Measurement specifications</td><td colspan="3">Phase and wire type</td><td>Single-phase 2-wire, single-phase 3-wire, and three-phase 3-wire</td></tr>
<tr><td rowspan="4">Instrument rating</td><td rowspan="2">Voltage circuit</td><td>Single-phase 2-wire
Three-phase 3-wire</td><td>Direct input: 110 and 220 VAC
Combination with a transformer for measuring instruments (VT): 1 to 6,600 V</td></tr>
<tr><td>Single-phase 3-wire</td><td>110 VAC (between the first and second wires and between the second and third wires) and 220 VAC (between the first and third wires)</td></tr>
<tr><td colspan="2">Current circuit</td><td>Direct sensor input: 5, 50, 100, 250, 400, and 600 AAC
Combination with a converter (CT): 1 to 6,000 AAC</td></tr>
<tr><td colspan="2">Frequency</td><td>50/60 Hz (automatic discrimination)</td></tr>
<tr><td colspan="3">Number of measurement circuits</td><td>1</td></tr>
<tr><td rowspan="2">Tolerance of measure-ment items</td><td colspan="2">Effective values</td><td>Current, voltage, electric power, reactive power, and apparent power: ±1.0% (when the rating is 100%)
Frequency: ±1.0% (45 to 65 Hz)
Harmonic current and harmonic voltage: ±2.5% (when the rating is 100%)
Power factor: ±3.0% (when the electrical angle is 90°)
Electric energy: ±2.0% (5 to 100% of the rating, power factor = 1)
Reactive energy: ±2.5% (5 to 100% of the rating, power factor = 0)</td></tr>
<tr><td colspan="2">Instantaneous values</td><td>Current and voltage</td></tr>
<tr><td colspan="3">Data update cycle</td><td>10 to 10,000 ms (can be set at intervals of 10 ms)</td></tr>
<tr><td colspan="3">Response time</td><td>100 ms or less</td></tr>
<tr><td colspan="4">Power interruption backup</td><td>Backup to a nonvolatile memory (Storage items: Set values, maximum and minimum values, electric energy, and reactive energy)</td></tr>
<tr><td colspan="4">Number of occupied I/Os</td><td>32</td></tr>
<tr><td colspan="4">External size</td><td>27.8 (W) × 106 (H) × 107.1 mm (D), excluding protrusions</td></tr>
<tr><td rowspan="6">Functions</td><td colspan="3">Measurement</td><td>Measurement and weighing are performed and the data is successively stored in a buffer memory.</td></tr>
<tr><td colspan="3">Periodic electric energy</td><td>The electric energy only when the input signals are on is measured and it is successively stored in a buffer memory.
(Can be used to determine the electric energy only when equipment is functioning, for example)</td></tr>
<tr><td colspan="3">Maximum and minimum values hold</td><td>Stores the maximum and minimum values of current, voltage, electric power, and power factor along with the times of occurrence</td></tr>
<tr><td colspan="3">Upper and lower limit alarms</td><td>Monitors the upper and lower limits of the measured values and outputs the monitoring results as output signals</td></tr>
<tr><td colspan="3">Testing</td><td>Without current and voltage applied, outputs fixed values to a buffer memory
(Can be used to debug ladder programs, for example)</td></tr>
<tr><td colspan="3">Integrated value set</td><td>Presets the integrated values (electric energy and reactive energy) to any values</td></tr>
</table>

data without communications.

(iii) The data can be easily managed with the sequencer only by FROM and TO commands from the sequencer.

3. Characteristics and Technologies for Commercialization

3.1 Shorter effective value measurement cycle

When computing measured values, current and voltage values are input into measuring instruments and then A/D converted into digital values to compute voltage, current, electric power, and other items.

Mitsubishi Electric's measuring instruments (e.g., QE81WH, equivalent model of the MELSEC Q series) use special computation software to calculate measurement values. For the new module, the digital filter used for the computation software was refined to improve the response characteristics, which has shortened the measurement cycle.

3.2 Instantaneous value measurement function

The volume of data is larger with instantaneous values than effective values, making it more difficult to process such data. To solve this problem, this module provides two data acquisition methods; users can select

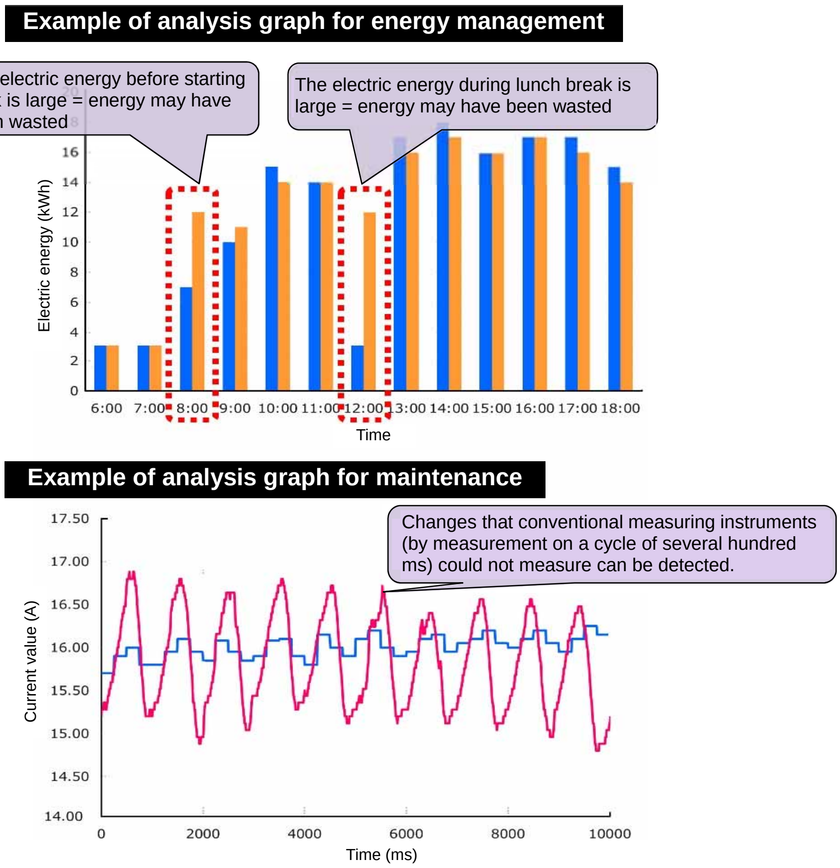


Fig. 1 Examples of graphs for various applications

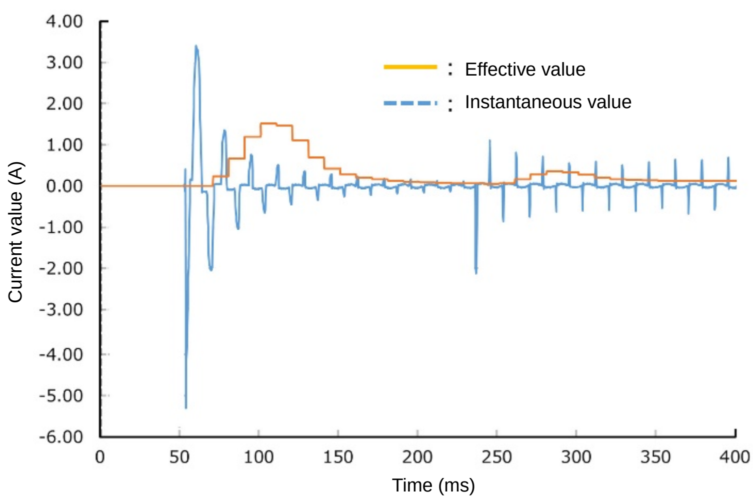


Fig. 2 Example of waveform of instantaneous values

the optimum one based on the length of scanning time and ease of data analysis.

(1) Method of obtaining every data item separately (254 μs)

The energy measuring module stores instantaneous values in one buffer memory on a cycle of 254 μs. Data needs to be obtained faster than the instantaneous value measurement cycle (254 μs) and thereby a shorter scanning time is required for operation, which makes it difficult to coexist with other processing (e.g., control of production equipment). However, when data is converted into CSV, a time stamp can be added to each data item, making it easier to analyze the data on PCs and other devices (Fig. 4a).

(2) Method of obtaining a set of data for a certain period at a time

Data for up to 50 ms is accumulated in the module and once the accumulation is complete, the set of data is stored in multiple buffer memories at a time. Since data is obtained every 50 ms, one time stamp is added per 50 ms (196 data items). Therefore, separate time stamps need to be manually added, which makes analysis complicated. Meanwhile, the scanning time can be longer in operation, which makes it easier to coexist with other processing (e.g., control of production equipment) (Fig. 4b).

3.3 Simple analysis of instantaneous values using harmonics

This module has a harmonic measurement function to monitor equipment statuses based on waveforms (instantaneous values). This function enables the results of FFT analysis to be obtained with the power supply frequency (50/60 Hz) as the frequency resolution as measured values.

Using this function enables monitoring of changes in frequency components in waveforms, making it possible to detect abnormal waveforms.

3.4 Conformance to overseas standards

We have obtained CE marking and UL mark, certifying compliance with overseas standards (requirements), targeting customers overseas and to enable our modules to be installed in systems for overseas markets.

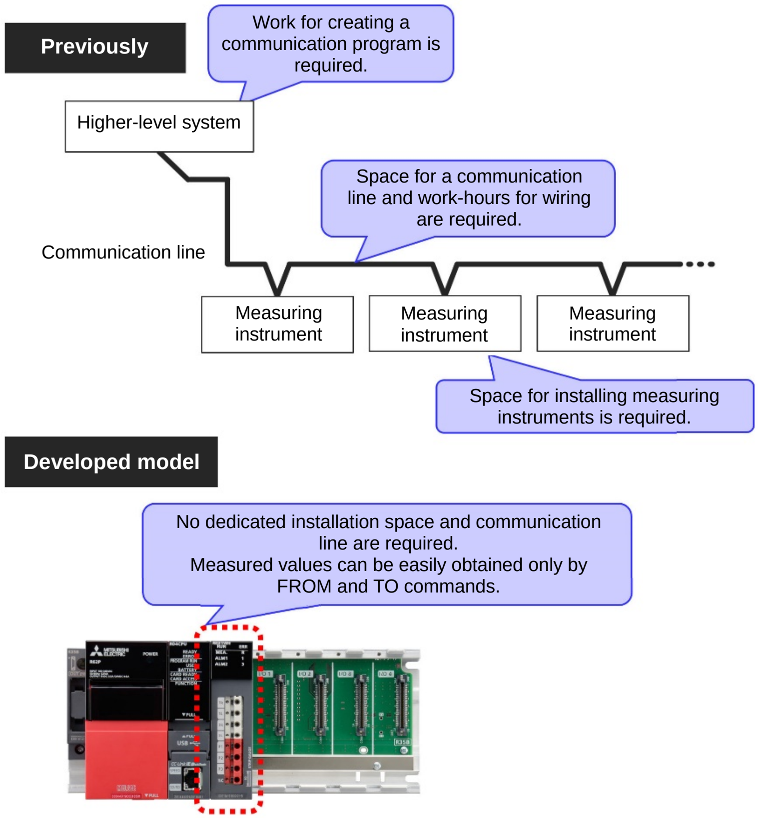


Fig. 3 Advantages of insertion into a sequencer slot

→ : Data order

Time stamp	Instantaneous value
0 μs	1
254 μs	2
508 μs	3
762 μs	4
1016 μs	5
1270 μs	6
1524 μs	7
1778 μs	8
2032 μs	9
2286 μs	10
⋮	⋮

(a) Method of obtaining every data item separately (254 μs)

Time stamp	Instantaneous values						
	0 μs	254 μs	508 μs	762 μs	1016 μs	…	49530 μs
0 ms	1	2	3	4	5	…	196
50 ms	197	198	199	200	201	…	392
100 ms	393	394	395	396	397	…	588
150 ms	589	590	591	592	593	…	784
200 ms	785	786	787	788	789	…	980
250 ms	981	982	983	984	985	…	1176
300 ms	1177	1178	1179	1180	1181	…	1372
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

(b) Method of obtaining a set of data for a certain period at a time

Fig. 4 Example of CSV file output

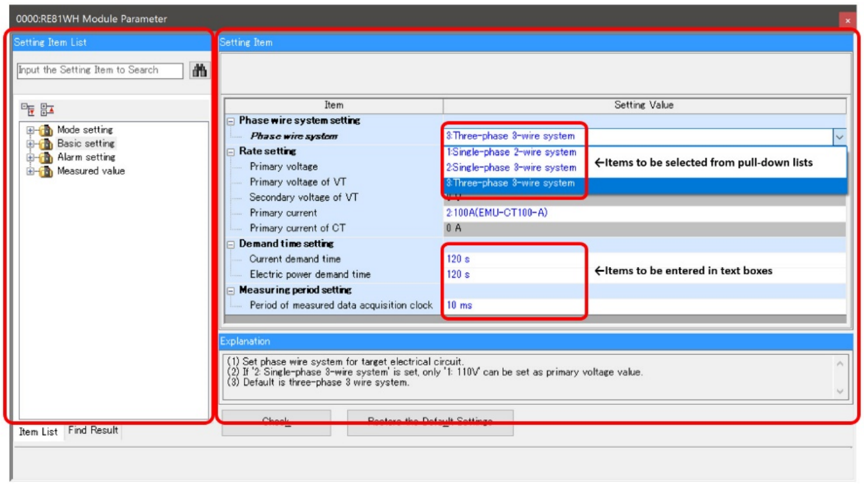


Fig. 5 Parameter setting screen

3.5 Development of an engineering environment

To perform the initial configuration necessary for measurement (e.g., setting of phase and wire type, primary voltage, and primary current) easily, this module has been made compatible with the parameter setting function of intelligent units (Fig. 5). This allows the initial configuration to be performed by easy operations (e.g., selecting options from pull-down lists), thus reducing the hours required for engineering.

4. Conclusion

This paper described the MELSEC iQ-R series energy measuring module that contributes to energy management and maintenance work by customers.

We will continue to develop products that contribute to customers' energy management and maintenance work by improving the functions of this module and proposing comprehensive solutions including stand-alone measuring instruments, such as the EcoMonitor series.

MITSUBISHI ELECTRIC CORPORATION