Mitsubishi Electric Programmable Automation Controllers "MELSEC MX Controller"

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Abstract

As the required control scale and performance differ at increasingly diverse manufacturing sites, it has become a challenge for controllers to meet such requirements. By integrating the control technologies cultivated with MELSEC into a single unit, we developed the "MELSEC MX Controller" as a new product designed to meet customer requirements and bring further transformation to manufacturing sites.

The features of this product are as follows.

(1) High-precision motion control that enables precise assembly and machining, even with multi-axis equipment

In equipment comprising multiple axes, we made it possible to control a "mechanical configuration that requires high-speed, high-precision machining" and a "mechanical configuration that does not require high precision" with different control cycles. This enables optimization of control for the entire equipment.

(2) Enhanced information processing that promotes adoption of Internet of Things (IoT) at factories

To promote the adoption of IoT at factories, Message Queuing Telemetry Transport (MQTT) and OPC UA[*1] are built in, making it possible to build systems with a high affinity with higher-level systems. And as affinity with higher-level systems increases, the risk of cyberattacks also rises; thus cybersecurity countermeasure functions such as encrypted communication and user authentication have been included, enabling the construction of a robust system.

(3) Scalable lineup tailored to customer equipment scale and applications

The performance and scale of control required for the lineup equipment depend on the products being manufactured. A scalable lineup is offered according to program capacity, number of control axes, and performance so that a controller suited to each piece of equipment can be selected.

1. Introduction

In recent years, manufacturing sites have faced increasingly diverse requirements, such as large-scale equipment resulting from process integration, high-precision equipment resulting from more complex processes, the advancement of IoT, and better measures to combat cybersecurity threats.

With conventional sequencers, distributed control that enables flexible systems to be built by combining multiple units has addressed market requirements. However, with increasingly diverse market demands, addressing equipment that requires high performance has become a challenge, including high-speed, high-precision multi-axis motion control for controlling large-scale equipment, management and computation of large-capacity data for managing lines and devices, and data communication with higher-level systems. To respond to such market demands while driving further transformation at increasingly diverse manufacturing sites, we developed the programmable automation controller MELSEC MX Controller (Fig. 1) that integrates the control technologies cultivated with MELSEC into a single unit.

*1 OPC UA is a registered trademark of the OPC Foundation.

Fig. 1 MELSEC MX Controller

2. Product Features

The MELSEC MX Controller strengthens product capabilities for customers seeking high-precision machining and improved production efficiency, and for customers who want to advance IoT implementation and make effective use of data; by integrating various controls and functions into a single controller, it has been developed to provide optimal products tailored to the scale of the equipment.

Its main features include “high-precision motion control that enables precise assembly and machining, even with multi-axis equipment,” “enhanced information processing that advances factory IoT implementation,” and “a scalable lineup tailored to the customer’s equipment scale and applications.”

2.1 High-precision motion control that enables precise assembly and machining, even with multi-axis equipment

In equipment that requires large-scale, high-precision motion control, there is demand to control 100 or more axes with a single controller. Yet the greater the number of axes to be controlled, the more the computation workload increases,and the control cycle for all axes in the system becomes longer. When the control cycle becomes longer, delays in feedback from drive devices and sensor input, as well as lower resolution of control commands from the controller, make high-precision control difficult. Therefore, the MELSEC MX Controller supports multi-rate control that can achieve both multi-axis control and high-precision control: assigning only specific axes that require high-precision control to a high-speed cycle, and assigning the remaining axes to a medium-speed cycle or low-speed cycle, enables control of a large number of axes while maintaining the control accuracy of specific axes.

An example is shown in which multi-rate control is applied to a winding machine, which is part of lithium-ion battery manufacturing equipment that requires multi-axis control and high-precision control (Fig. 2). The winding machine comprises an unwinding unit, a tension control unit, a cutter control unit, and other components. Cutter control needs to cut the electrode sheet at an accurate position. Any deviation in the cut position can result in product defects; therefore, control at a high-speed cycle is required. In contrast, the unwinding unit has a high level of inertia. Given the responsiveness of this unit, a low-speed cycle is sufficient to deliver the required equipment performance. In this way, by applying multi-rate control, optimal control that meets the required performance of each control unit within the equipment can be achieved with a single controller.

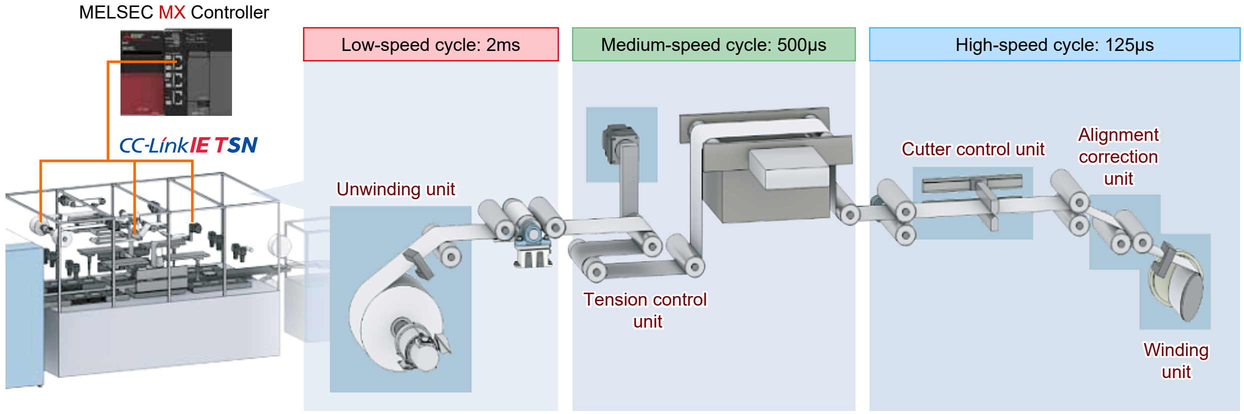

Fig. 2 Overview of the winding machine configuration and an example of applying multi-rate control

2.2 Enhanced information processing that advances factory IoT implementation

At manufacturing sites, improving productivity, improving yield and reducing equipment maintenance costs are always cited as challenges. In recent years, AI has also come to be used to address such challenges at manufacturing sites, and to enable data analysis and learning, better coordination between production equipment and higher-level systems is required. The MELSEC MX Controller promotes better coordination with higher-level systems by incorporating OPC UA and MQTT. For OPC UA in particular, the MELSEC MX controller not only supports server functions, but also client functions and information models, enables easy data linkage with higher-level systems and, as a supervisory controller, achieves centralized management of data within equipment. And while IoT adoption is being advanced, the threat of cyberattacks is also on the rise—the MELSEC MX Controller is equipped with security functions such as encrypted communications and user authentication, enabling the construction of robust systems. An example connection to a higher-level system is shown in Fig. 3.

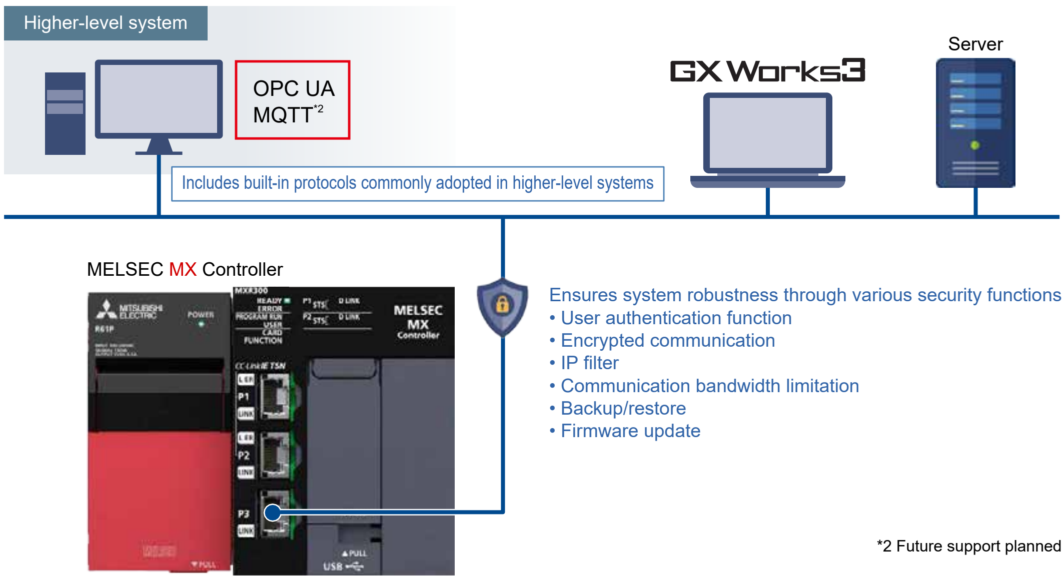

Fig. 3 Example connection to a higher-level system

2.3 Scalable lineup tailored to customer equipment scale and applications

For sequence control, models are selected based on the scale of equipment control, and with the CPU units available with each series of MELSEC, a lineup with different program-memory capacities was provided. Yet for motion control, the number of axes required for each piece of equipment varies widely from a small number to multiple axes depending on the mechanical configuration. The required control performance depends on the machining accuracy and required production volume of the product being manufactured, regardless of the number of axes used or the control scale.

With the MELSEC MX Controller, a scalable lineup is provided so it can meet the performance required by customers.

3. Technologies to Develop the System

The following is an outline of the technologies applied in the development of the MELSEC MX Controller.

3.1 Technologies applied to multi-axis, high-precision motion control

To support having multiple cycles coexisting for the computation processing of conventional models that operated with only a single cycle, the MELSEC MX Controller needed the computation processing to be divided into three cycles—high-speed cycle, medium-speed cycle, and low-speed cycle—and that each be executed with different execution cycle and priority. Furthermore, to make the most effective use of the multicore CPU used with this system, it was also necessary to support parallel execution, where multiple cores work together.

Accordingly, we not only separated the conventional computation processing, which operated on the premise of a single cycle, into three cycles, we also optimized the data structures, processing algorithms, and processing scheduling for parallel processing. In particular, the computation processing in each cycle accessing a large amount of shared data causes competition and reduced CPU cache efficiency, which not only makes performance improvement from parallelization limited, but also reduces the scalability. An example of this is implementing localization to improve data locality—faster processing was achieved by reducing exclusive control during data access and improving CPU cache efficiency (Fig. 4).

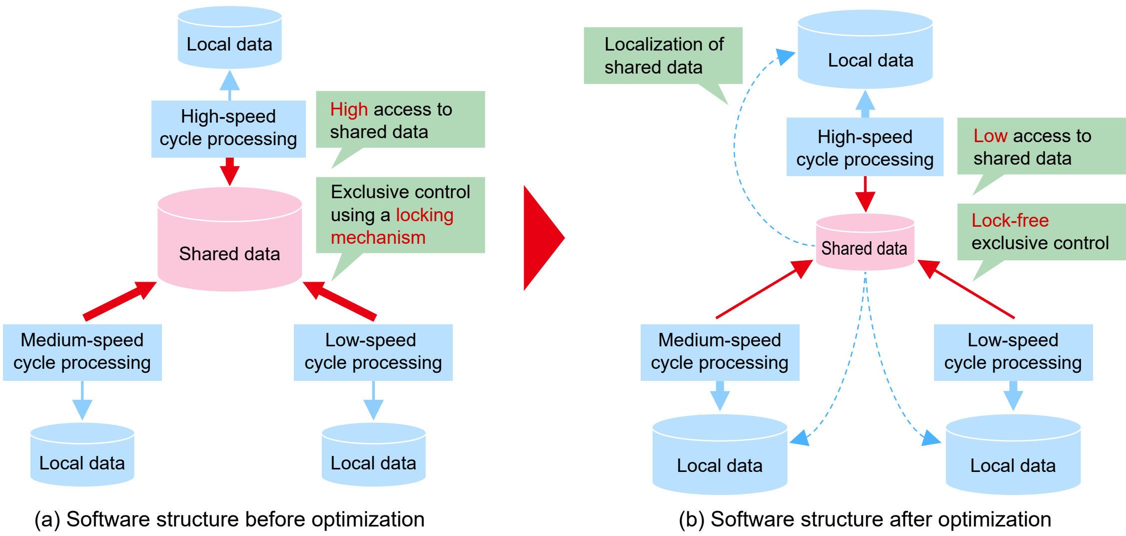

Fig. 4 Software structure optimization

3.2 Technologies applied for advancing factory IoT implementation

Stronger collaboration with higher-level systems is essential for advancing IoT implementation. To that end, the information processing section of the MELSEC MX controller uses Linux*3, which makes it easy to incorporate open networks and general-purpose technologies that are readily adopted on the higher-level system side, and also facilitates a rapid response to vulnerabilities. On the other hand, for control processing that requires real-time performance, such as sequence control and motion control, the timing deviation due to processing jitter affects equipment machining accuracy and tact time, so a real-time OS was adopted for the control processing section. This made it easier to achieve functions and performance in the information processing section and the control processing section respectively, but a key challenge was to minimize the impact on real-time control when the information processing section accesses resources (devices/label data, etc.) managed by the control processing section.

To resolve this issue, we adopted a layered architecture (Fig. 5) comprising a driver layer adapted to suit the OS or hardware, a service layer that provides common processing to the control processing

*3 Linux is a registered trademark of Linus Torvalds.

and information processing sections, and an application layer that implements functions such as the control processing and information processing sections. In this architecture, the service layer employs low-overhead mutual exclusion processing and, when calling the common Application Programming Interface (API) provided by the service layer from the application layer, controls the priority and order of shared memory access depending on the caller, thereby reducing the impact on real-time control.

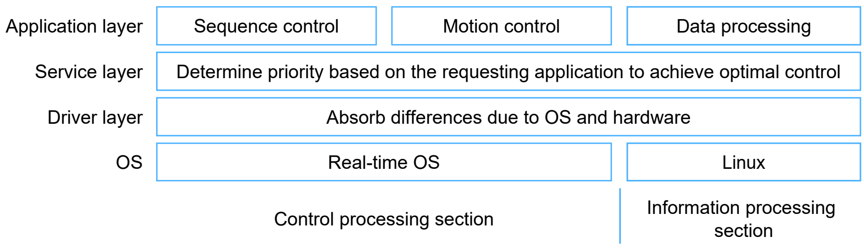

Fig. 5 MELSEC MX controller architecture

3.3 Technologies applied to a scalable lineup

To achieve a scalable lineup of MELSEC MX controllers, in addition to interfaces with a system bus for linking with sequencers and data, and interfaces with devices supporting CC-Link IE TSN, we developed a dedicated IC incorporating a multi-core processor and a general-purpose bus (PCI Express*4). The dedicated IC connects to a general-purpose IC via PCI Express, thereby easily expanding CPU functions and performance, and enabling a flexible hardware configuration that makes it easy to implement software (Fig. 6).

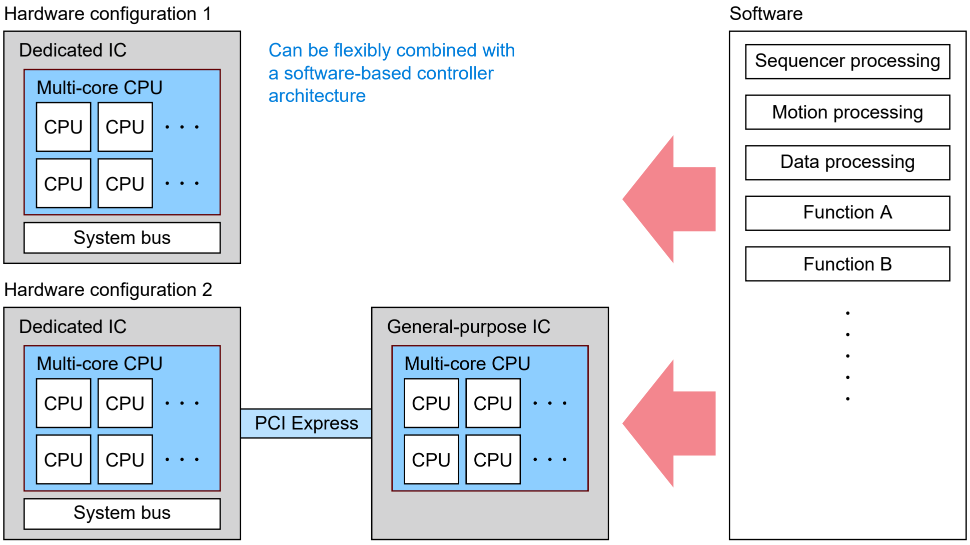

Fig. 6 MELSEC MX controller hardware configuration

Development of a dedicated IC implementing a multi-core processor faced challenges including improving the efficiency and performance of parallel computations for each CPU and managing the power consumption that accompanies higher performance. To improve the efficiency of parallel computations for each CPU, we maximized the efficiency of parallel computations on the multi-core CPU by optimizing the internal bus configuration and the allocation of software processing to each port of PCI Express, through front-loading design such as operation simulation and prototype verification. In terms of power consumption, we implemented circuits that allow the power supply to each function to be shut off individually, and with power management to suit the applicable hardware configuration and the software to be implemented, we achieved both higher performance and lower power consumption for the IC.

With the scalability and flexibility of the dedicated IC, we achieved optimal functions and performance for the information processing section and the control processing section tailored to customer equipment scale and applications, enabling a rapid response to diversifying market needs and technology trends.

*4 PCI Express is a registered trademark of PCI-SIG.

4. Conclusion

This paper outlined the features of the MELSEC MX Controller and the technologies applied to develop them. With the MELSEC MX Controller, whereas previously line and equipment design was performed by prioritizing either product machining accuracy or production takt time, it is now possible to select both, making it possible to improve the cost performance of facilities. Looking ahead, we will continue to firmly identify advances in technology and changes in customer requirements, and lead transformation at manufacturing sites.