ISSN 1345-3041

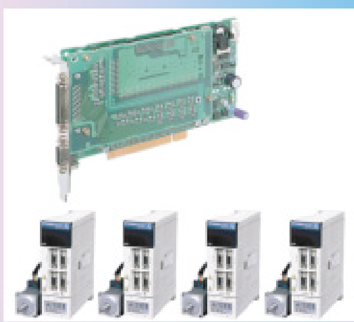
VOL. 106/JUN. 2004

MITSUBISHI ELECTRIC ADVANCE

The latest NC systems, servo systems and peripheral equipment edition.







MITSUBISHI ELECTRIC
Changes for the Better

A Quarterly Survey of New Products, Systems, and Technology
●Vol. 106/June 2004 Mitsubishi Electric **ADVANCE**

The latest NC systems, servo systems and peripheral equipment edition.

CONTENTS

Technical Reports

Cover Story
Mitsubishi Electric's FA Products
Mitsubishi Electric's FA products at the cutting edge of technology meet the demands of factories around the world. Full nano-control CNC for high-precision processing, the optimum servo system for various industrial fields and CC-link devices to promote factory automation... all facilitate the next level in productivity and newfound success.

Editorial Inquiries
Keizo Hama
Corporate Total Productivity Management & Environmental Programs
Fax 03-3218-2465

Product Inquiries
Kenji Katazawa (p2~p17)
Numerical Controller Business Development Dept.
Fax 03-6221-6136, 6137

Kazunori Fukushima (p18~p28)
Overseas Marketing Dept.
Industrial & Factory Automation
Fax 03-3-6221-6075, 6076

Mitsubishi Electric Advance is published on line quarterly (in March, June, September, and December) by Mitsubishi Electric Corporation.

Overview

Higher Precision Production Systems and FA Equipment

*by Akira Sugiyama**

In production systems, it is of prime importance to produce the optimum quantities of product with the best possible timing at the lowest possible cost. These objectives cannot be achieved without configuring process-intensive production systems capable of manufacturing high added-value products, and such systems themselves require the adoption of high added-value compound machine tools and their associated technologies.

First, high added-value compound machine tools are vital for the following reasons. The manufacturing industry has entered the era of information technology, and faces increasingly severe demands for higher precisions and finer processing. High-quality mirror finishes, ultrahigh-precision metal molds and microscopic holes, and high-speed processing of new materials, are called for in processing. Mitsubishi Electric Corporation has always sought to anticipate users' needs, and is carrying out technological developments that enable numerically controlled machine tools to create ultrahigh-precision metal molds. Our servo motors, too, provide for adaptive control, auto tuning, vibration suppression, etc.

Second comes the configuring of production systems to create high added value. The corporation has made major contributions to the minimization of costs by integrating shop-floor production systems with MES, SCM and ERP, etc., to form flexible systems in which information is acquired and analyzed to achieve higher operating ratios, reduced mechanical losses, and lower labor and running costs. The high-speed, high-capacity CC-Link open-field network has spread quickly in factories. Our corporate partners already exceed 450 companies, and the full range of products in various sectors and applications mean that optimum systems can readily be configured.

As an integrated manufacturer of factory-automation equipment, our advanced technologies will always be at the service of those, wherever they may be and whatever the needs of their sector of industry or their specific applications, who face demands for high-precision, efficient and flexible manufacturing. ❑

**Akira Sugiyama is Group President, Factory Automation Systems.*

EZMotion-NC E60: A Compact, High-Performance Controller for China

*by Fumio Iwai and Mutoshi Fukutani**

Even in the Chinese manufacturing industry, whose expansion has been drive by its low production costs, there has been strong demand for better capability to respond with high-quality manufacturing of small lots of multiple product variants. The EZMotion-NC E60, which embodies Mitsubishi Electric's computerized numerical control (CNC) technologies acquired over more than 30 years, is a controller for machine tools that, while providing high performance, is both compact and inexpensive. While the small form factor and low cost ensure an extensive range of applications, even down to facilitating the automation of manually operated machine tools, its high performance and extensibility mean that the EZMotion-NC E60 is destined to become a supporting pillar of Chinese manufacturing industry. Fig. 1 shows the EZMotion-NC E60 unit and Fig. 2 shows the dedicated display and keyboard.

Fig. 1 Photograph of the EZMotion-NC E60 unit (with the dedicated keyboard fitted to the back)

Development goals

Until recently, the Chinese manufacturing industry has been doing its utmost to minimize production costs by mass producing a limited number of parts. Now, however, demand is coming mainly from the many American, European, and Japanese companies that have been shifting their manufacturing bases to China. For these

Fig. 2 External view of dedicated display and keyboard for EZMotion-NC E60

companies, low manufacturing costs alone are not enough to maintain competitiveness and they are generating strong demand for small-lot production of multiple component variants, made to the same high standards of quality and precision available in America, Europe, and Japan.

In China, however, most of the machine tools used by manufacturing industry are either manually operated or driven by simple servo functions or other crude controls, and are non-programmable. Nor does the market demand the same type of machine tools, equipped with functions that enable machining of diverse complex forms, that are the mainstream in the manufacturing industry in Japan and the West.

The EZMotion-NC E60 was developed as a controller that meets the specific needs of machine-tool operation in the Chinese manufacturing industry. Fig. 3 shows the target market in China.

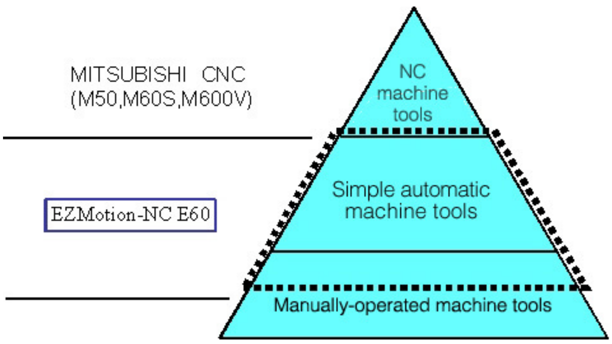


Fig. 3 Target market in China

*Fumio Iwai and Mutoshi Fukutani are with Nagoya Works.

Features of the EZMotion-NC

The development of the EZMotion-NC E60 controller for machine tools, which provides high performance in a compact form factor, was based on Mitsubishi CNC technologies acquired over more than 30 years. By rigorously selecting the functions provided and drastically reducing the component count, the new controller can be offered at a much lower cost than competitive controllers.

Progress in reducing the heat generated by microprocessors and other electronic components has enabled a smaller form factor and mounting footprint. Below shows the main specifications of the EZMotion-NC E60.

Max. no. of control axes		5
	Max no. of NC axes	3 (substrate : x, y, z)
	Max no. of spindles	1
	Max. PLC axes	1
Max. no. of paths		1
Min. control precision		3
Least command increment		1μm
Built-in PLC max. no. of steps		4000step
PLC capacity (basic commands)		2μs/step
PLC development tools		GX - Developer (tools developed by MELSEC)
Program storage capacity		160m (equiv. to 63,000 characters)
Display device		9-inch CRT / 7.2-inch LCD
Max. input/ output points	Machine input/output	256/240 point analog output one point standard
	Operation panel	128/96 points

Technology Adopted in the EZMotion-NC E60

IMPLEMENTATION OF CNC ARCHITECTURE. The EZMotion-NC E60 was designed to share the basic architecture of Mitsubishi CNCs. Functions were selected for inclusion and restricted according to detailed analysis of the needs of the Chinese market. To enable machine tool builders to do their work without concern for inherent mechanical vibration, the functions include both smooth control of acceleration and deceleration and, using electronic filters, automatic suppression of mechanical resonance.

Moreover, an auto-tuning function was incorporated to optimally adjust each axis and institute a simple means of ensuring that the interpolation performance for any axis does not suffer even though the machine operator may be inexperienced with electrical servos.

Furthermore, so that the complexities of tool life management can be handled by the controller, functions to control the tools used were included as standard.

To aid those responsible for machine repair and maintenance, alarm log, operation log and other functions have been supplemented by provision for the installation of an interface facilitating remote implementation of service tasks when, in the near future, the communications infrastructure is sufficiently developed. Fig. 4. shows a typical system configuration.

USE OF 64-BIT RISC MICROPROCESSOR. To achieve high-speed, high-precision machining control in an ultra-compact form factor, a 64-bit RISC microprocessor was used.

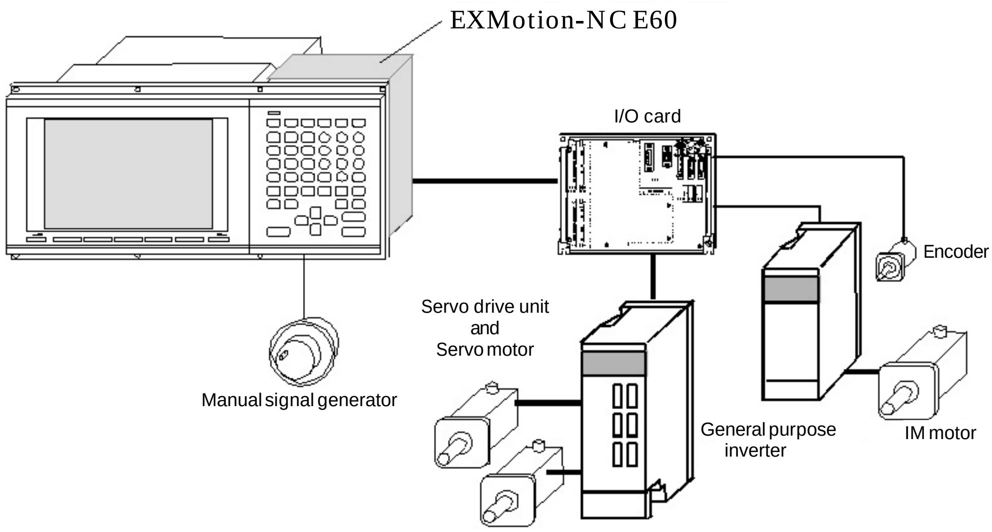


Fig. 4 Typical system configuration

In making units compact it is naturally essential to minimize the component count, but the heat generated by the electronics, particularly the microprocessor, is an even more important issue. Then again, machine tools produce metal swarf and use cutting fluid, which are serious hazards for electronic devices. Consequently, the electronics are usually installed in special metal cabinets within the workplace. Even though the devices themselves are getting more compact, they still generate considerable heat. To dissipate this, the cabinet size has to remain large or some means of cooling has to be installed.

To resolve this issue, instead of the usual type of SISC microprocessor that is found in personal computers, the EZMotion-NC E60 is built around a 64-bit RISC microprocessor that is more powerful and generates less heat.

ULTRA-DENSE CHIP DEVELOPMENT TECHNOLOGY. This is used for specialized applications, taking advantage of the corporation's richly varied experience in chip development, through the application of simulation expertise, to create a single specialized ultra-densely integrated microprocessor. We integrated circuitry peripheral to the CPU by packing in memory control, display control, and servo-drive unit circuits, along with all the requisite high-speed networking and other functions that formerly required separate chips. In this way, we were able to greatly reduce both the device mounting footprint and the heat generated by the circuits.

HEAT SIMULATION AND THERMAL ANALYSIS. We drew upon the corporation's expertise in heat simulation and thermal analysis to design the EZMotion-NC E60 so as to distribute its components optimally and thus avoid localized hot spots inside the unit. Combined with the use of a relatively cool-running CPU, the multiplier effect of using dedicated densely integrated on-chip circuitry and low-voltage control circuits has eliminated the need to install a cooling fan in the controller. Measuring 185 x 125 x 48mm, the unit is extremely compact; the size and thermal characteristics have made it possible to mount the keyboard on the back of the unit, something formerly impractical. This advance, as well as allowing much smaller cabinets to be used for the controllers, contributes to machine cost reduction and greater freedom of design.

POTENTIAL FOR MACHINE FUNCTION UPGRADES. In parallel with the EZMotion-NC E60 itself, a supplemental engine was developed to increase the internal processing performance. This additional engine carries out internal NC sequence processing and other tasks that are normally handled by the main microprocessor (64-bit RISC CPU). Working independently in parallel with the main CPU, there is no need to change the software when adding or removing this supplemental engine.

Even if, after a machine tool has already been received from a supplier, it is necessary to add carrier devices or measuring equipment that requires high-speed sequential control, there is no need to add a separate dedicated programmable logic controller (PLC) because the EZMotion-NC E60 master controller is able to provide the requisite functions.

The Chinese manufacturing industry has registered prodigious growth, and is now ready to make further advances in quality and sophistication. This new controller, carefully tailored to match the specific present and future needs of Chinese industry, will be a key element in its next major expansion. ❑

A Nanometer Control CNC System for Machine Tools

*by Kiyoshi Kuchiki and Mitsuyasu Kachi**

The parts of electronic and optical components used in information technology and requiring precisions of the order of nanometers or tens of nanometers have been increasing rapidly in recent years. Mitsubishi Electric Corporation has developed computerized numerical control (CNC) with the nanometer-level control required for ultrahigh-precision machine tools. This article describes the configuration and the various technologies for the hardware, software and drive section used in the system implementing this nanometer control, and the results of system evaluation.

The new system and the associated technologies are expected to make major contributions to future progress in the precision of processing by machine tools.

The Configuration of the Nanometer Control CNC System

Fig. 1 shows the configuration of the new control system. The following explanation traces operations in order from left to right; the flow is basically the same as for conventional CNC systems. The command analysis section interprets the NC processing program language input as text. The path-analysis section calculates speeds and paths from the data generated by interpreting each command. Then the interpolation section, at constant time intervals (typically of a few milliseconds) synchronized with the basic CNC clock, is called to generate in real time the interpolation data (FΔt below) for each axis and to send the positional and speed data to the servo amp. The most important characteristic of the system is that all data units are in nanometers, including calculations.

The CNC equipment itself is connected to the servo amp by fiber optics and optical communications are used to transfer data at very high frequencies between them. The servo amp is responsible for controlling the current axial posi-

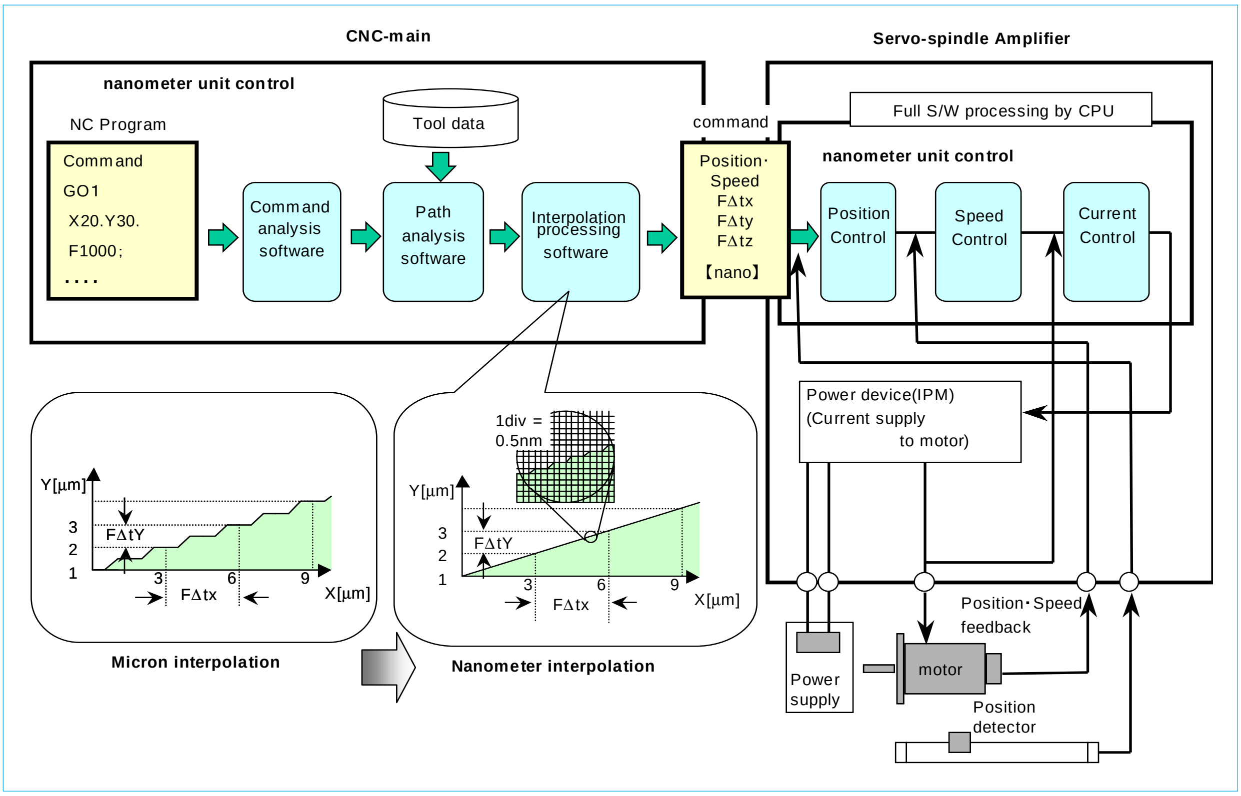


Fig. 1 CNC system control configuration

Kiyoshi Kuchiki and Mitsuyasu Kachi are with Nagoya Works.

tion, and when a new FΔt is sent by the CNC, it ultimately drives the motor by controlling the electrical current under positional and speed control.

Hardware Technologies

An explanation of the hardware developed for nanometer CNC control follows. Since the human-machine interface used for nanometer CNC control is a personal computer, we adopted a PCI card for the CNC control hardware so that it can be mounted on the PCI bus supported as standard on such computers. The external appearance of this hardware is shown in Fig. 2.

Fig. 2 Nanometer control CNC hardware

The latest and most advanced 64bit RISC CPU was adopted for CNC control, and main memory uses synchronous RAM, giving it a basic performance over double that of the previous type. An ASIC was developed that concentrates CNC functions into a single "system" LSI. These functions include communications with the servo amp, mechanical I/O communications, PLC control, external bus control and serial communications. The consequent reduction in component count has increased reliability and operating frequency to give a significantly higher performance with the aim of optimising bus allocation and improving throughput. It results in compact, high-performance hardware. A ten-fold improvement in data-transfer rates has dramatically improved communications with the servo, while moving from electrical to optical communications has enabled the frequency and capacity of data transfer between CNC and servo to be raised to a level fully adequate for nanometer control. The main hardware specifications are given in Table 1.

Software Technologies

The main issue with software is how to enable

Table 1. Nanometer control CNC hardware specifications

Item	Specification	Note
Main CPU	Latest 64bit-RISC processor	
Main memory	32MB	
Servo network	Optical communications	Built-in system LSI
PLC control	Special processor	Built-in system LSI
Machine I/O	2ch	Built-in system LSI
PC Interface	PCI bus	Conforms to PCI2.2 standard
External size	175x107mm	

the consistent use of nanometer units throughout; that is, in the NC processing program, the parameters and other input information, and right through to the output to the servo amp position and speed data. At the same time, the values of position and speed commands support the same range of maximum values as is possible when machining to micrometer tolerances. Previously, if the minimum CNC command unit became smaller, there was the disadvantage that the maximum command values also decreased proportionately. The present system overcomes this problem so that nanometer control can be applied not only to very fine structures but also to the machining of large structures.

In order to achieve this, the bit length of position and speed data was changed from 32 to 64 bits for the nanometer calculations. Further, the fundamental period needs to be speeded up in order to perform very high and ultra-high precision machining smoothly at high speeds. In fact, the software achieves a two- to four-fold increase in speed. The main functions are as given in Table 2.

Table 2. Nanometer Control CNC Basic Functions

Item	Conventional NC	Nanometer NC
Unit of minimum command 1μm	O	O
0.1μm	O	O
0.01μm (10 nano)	x	O
0.001μm (1 nano)	x	O
Range of command (mm)	±99999.999	±99999.999999
Feed rate (m/min) 1μm	Maximum 1000	Maximum 1000
Feed rate (m/min) 1nm	x	Maximum 1000
Nanometer interpolation	x	O

The Effectiveness of Nanometer Control

1. In comparison with the positional commands using command units in microns, interpolations are performed that are smoother by a factor of

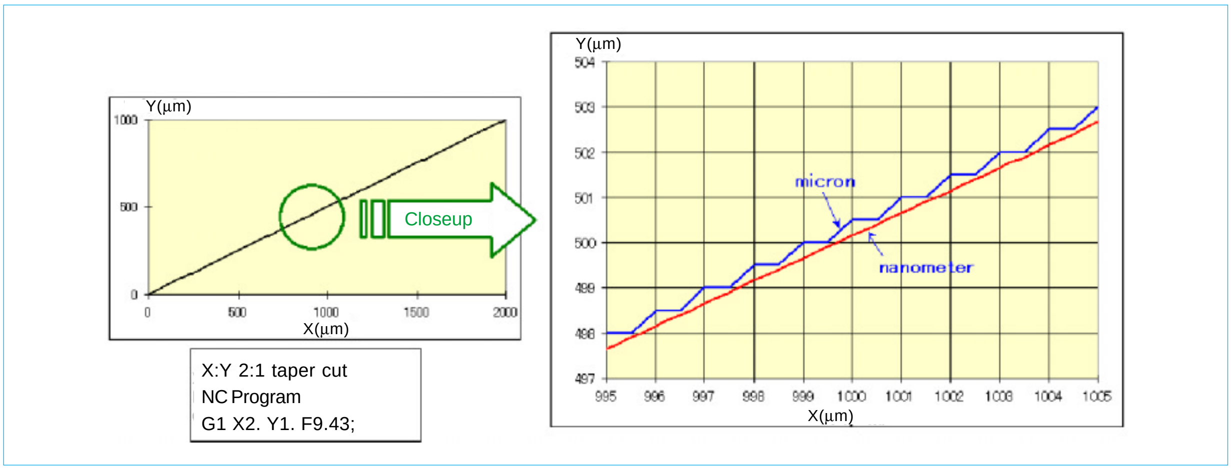


Fig. 3 Nanometer control interpolation path

1/1000, so that the machining movements proceed that much more smoothly, and provide extremely high-grade processing. A comparison of the interpolation paths for micron- and nanometer-unit control is shown in Fig. 3.

2. Velocity fluctuations during interpolation between position commands are also reduced by a factor of 1/1000, and by minimizing the size of the fluctuations in acceleration and deceleration, the striations formed on the surface of the workpiece can be made that much smaller. Fig. 4 gives actual measurements of the fluctuations in velocity during interpolation.
3. Shape accuracy has been raised to new levels, approaching the theoretical limits for the intersections and angles of linear (or circular) paths. For example, the precision of the end point for an angular command or the accuracy of a corner angle under high-speed, high-precision control gives shapes that are essentially free of error.

Drive Technology

To achieve machining to nanometer accuracies, we developed a new high-performance servo amp series, the MDS-Cn. By adopting a CPU with a performance an order of magnitude better than the previous series, developing an ASIC, and enabling it to cope with a high-speed optical fiber network, we achieved a major increase in basic performance. Fig. 5 shows the structure of the nanometer control drive system.

Improvements to Amp and Servo Performance

The following explanation of the improvements achieved by the use of the MDS-Cn servo amp is based on evaluation data.

Fig. 6 shows the smoothness of the actual motor velocity under nanometer servo control. The comparison is with the previous amplifier: the upper part of the diagram is for a constant-velocity command (approx. 400mm/min), while the lower part shows the variations in velocity. For a resolution of 0.5μm in the positional com-

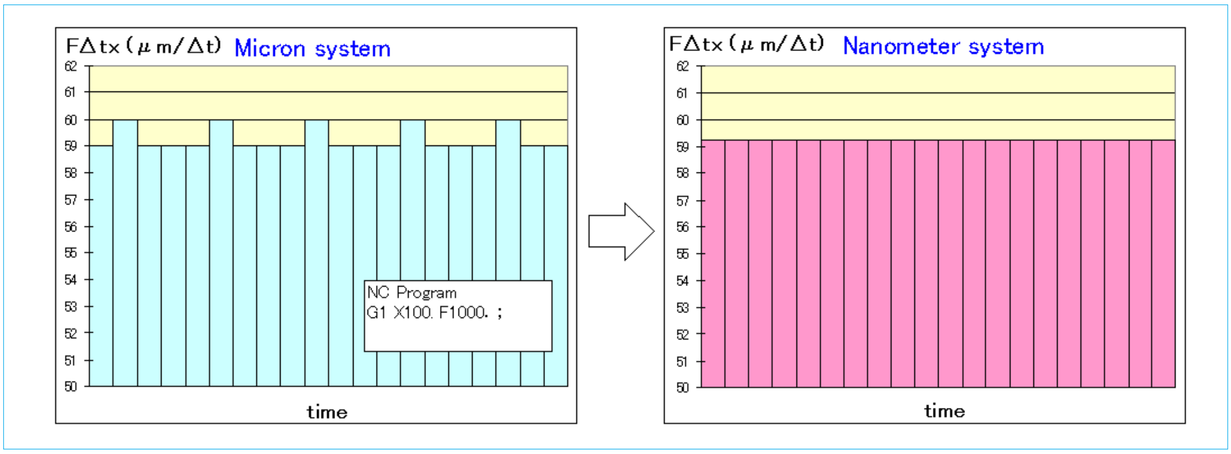


Fig. 4 Nanometer control speed fluctuation

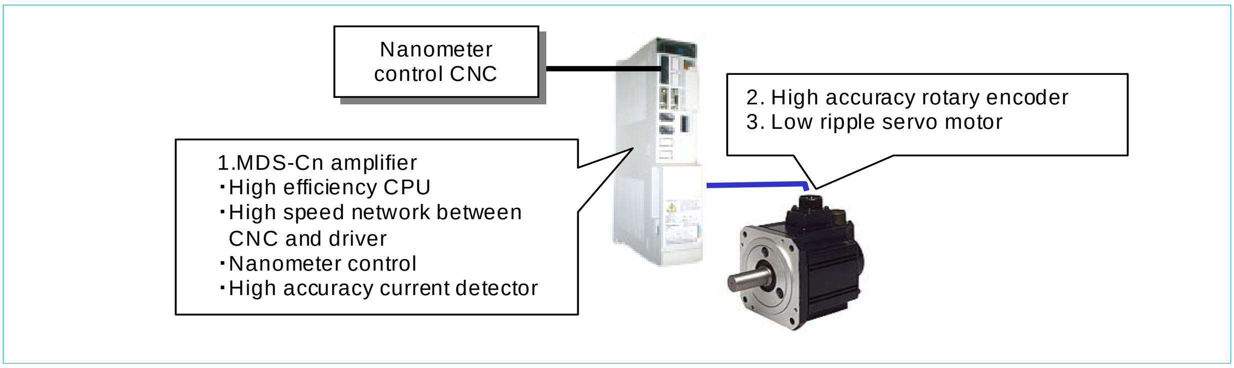


Fig. 5 Nanometer control drive system configuration

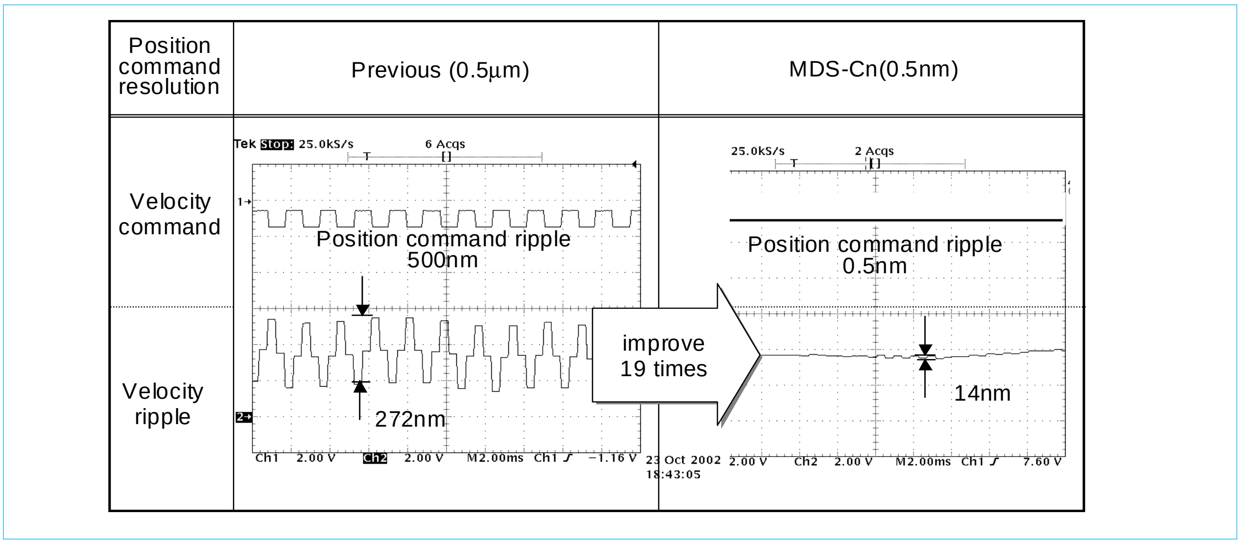


Fig. 6 Smooth velocity loop control (constant velocity command: 400mm/min)

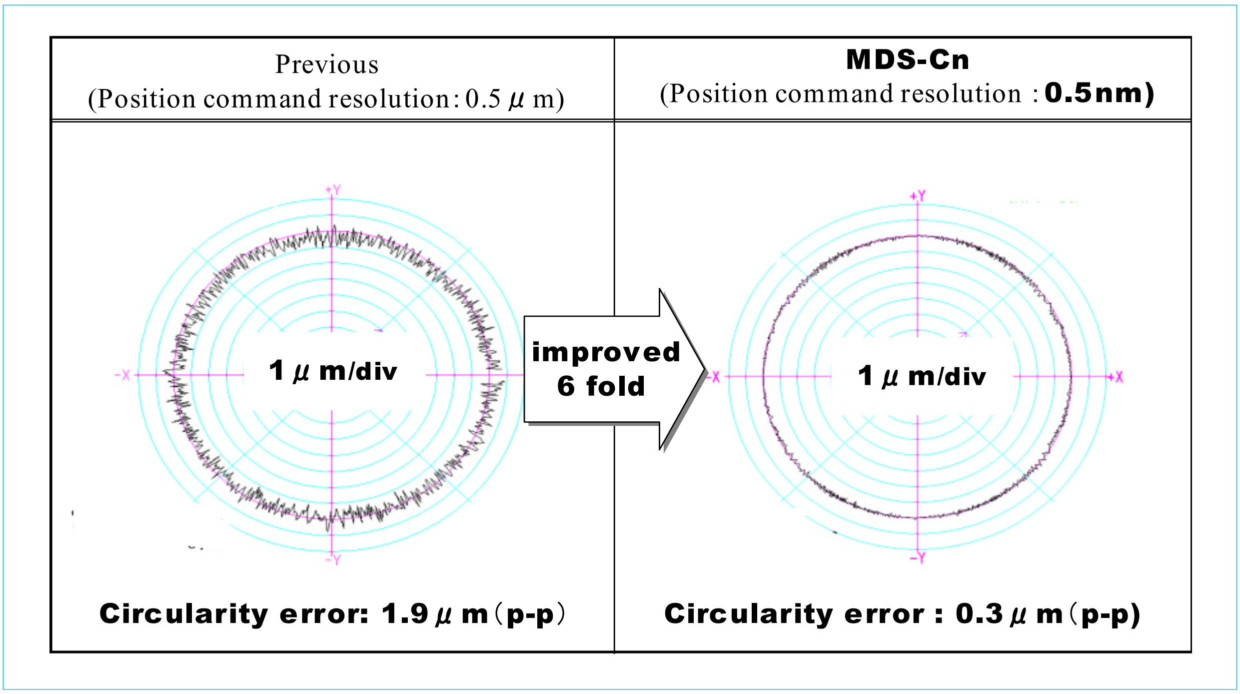


Fig.7 Improvement of circular path accuracy (interpolation between axes)

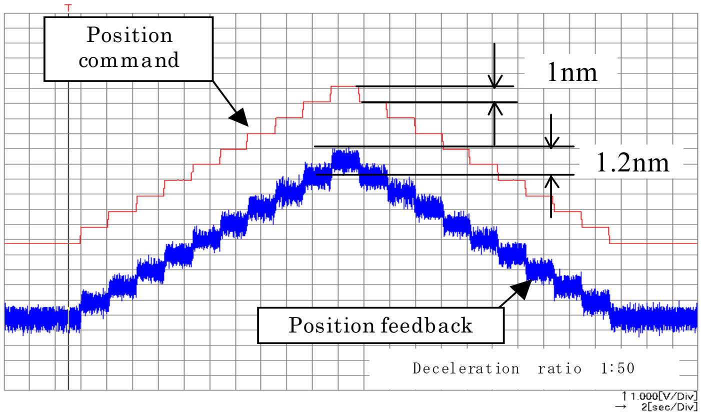


Fig. 8 High response of microscopic position command (1nm)

mand, this translates into a 272nm velocity change, whereas if the positional resolution is increased to 0.5nm, the velocity ripple is only 14nm, achieving highly stable velocity control. (Angular rotation is converted to linear motion assuming a ball-screw thread with 4mm pitch.)

This stable, high-speed control also achieved multi-axis interpolation with very high precision. Fig. 7 shows the results of executing a circular path command (radius 100mm, velocity 10m/min) comparing the motor path obtained with the previous system and the new system. The circular accuracy undergoes a major (six-fold) improvement from 1.9µm to 0.3µm. The effectiveness of this improvement has been confirmed in multiple evaluations using actual machine tools.

The final issue is the step response for nanometer micro-commands. In Fig. 8, the horizontal-axis time divisions are two seconds each and the vertical-axis distance divisions are 0.93nm. The upper step waveform shows the command positions. One-nanometer commands are input every two seconds, and commands totaling a 10nm displacement (and return) are input. The resulting feedback commands are shown in the lower step waveform. It is clear that there is no delay in the response and the commands are followed accurately with no overshoot.

The nanometer control CNC system will undoubtedly play a major role in improving the accuracy of machining in the ultrahigh-precision realm. ❑

Main-Spindle AC Servo Drive System for 400V NC Machines

*by Toshiki Tanaka and Kazuyuki Nakamura**

The world market for machine tools is dominated by systems operating on 400V AC supplies: they account for 70% of the total in Europe, America and Asia. Japanese manufacturers are moving strongly into 400V NC systems for export. Mitsubishi Electric Corporation has developed a full main-spindle AC servo drive system for 400V supplies that meets this market trend and the needs of users for higher speeds, greater capacity and more spindles. The new system represents a major contribution to expanding the world market for CNC products, and the corporation is looking forward to such expansion in rapidly growing markets like China, and to improved performance, lower energy consumption, smaller machine tools, with lower costs and greater resistance to environmental factors.

The 400V Drive System Configuration

This is shown in Fig. 1. The following three drive amps and the different motors–servo motor, linear motor and main-spindle motors (including an internal permanent magnet or IPM type)–form the basic configuration.

POWER SUPPLY. The three-phase AC power supply provides direct current to all the drive motors. The energy recovered when motor speed is reduced is used for electrical regeneration.

SERVO AMP. Drives the servomotor and linear motor in accordance with CNC control commands.

MAIN SPINDLE AMP. Drives the main-spindle motor and the IPM spindle motor.

This 400V driver system accepts input voltage from 380V to 480V, giving widespread coverage of areas throughout the world.

Features of the 400V Drive System

IMPROVED CONTROLLABILITY. The need for machine tools to support greater productivity and compound working has stimulated demand for higher machining speeds and precision, and for greater total positional control of servos and main spindles.

The corporation has already implemented 200V servo drives with the highest gains in the industry, and the application of this technology to the

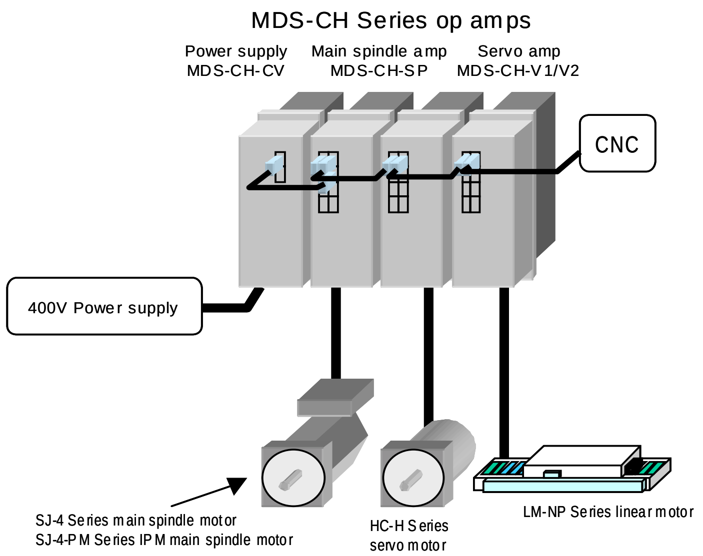


Fig. 1 400V drive system

**Toshiki Tanaka and Kazuyuki Nakamura are with Nagoya Works.*

400V main-spindle servo drive has enabled a significant overall increase in the precision of the entire drive section.

1. Main spindle

Main-spindle control can be applied in either of two modes–high-speed control or positional control. But advances in compound machining have given rise to the demand for improvements in the precision of positional control at the servo level. For main-spindle control, as for the servo, there are three control loops: position, speed and current, but of these the most important by far is the current-control loop. Its importance is due primarily to the fact that improvements in current-control characteristics make it possible to implement speed and positional control with higher gain. However, there is another reason for the importance of current control. The highest rotary speeds of main spindles in today's machining centers are generally between 15,000 and 20,000rpm. For four-pole motors, the current-control frequency is therefore 666Hz, and in order to achieve stable control of this current, improvements are needed in processing frequencies, etc.

The corporation adopted a high-speed microprocessor and developed an application specific integrated circuit (ASIC) embodying specialized circuitry for high-speed operation. This combination gives the required improvement in current-control capabilities. As an example of the effect of high-gain positional control achieved in this way, Fig. 2 shows the comparative synchronization errors for tap-screw cutting. The precision at 400V is more than three times that of the 200V system, clearly demonstrating the higher accuracy of servo synchronization control.

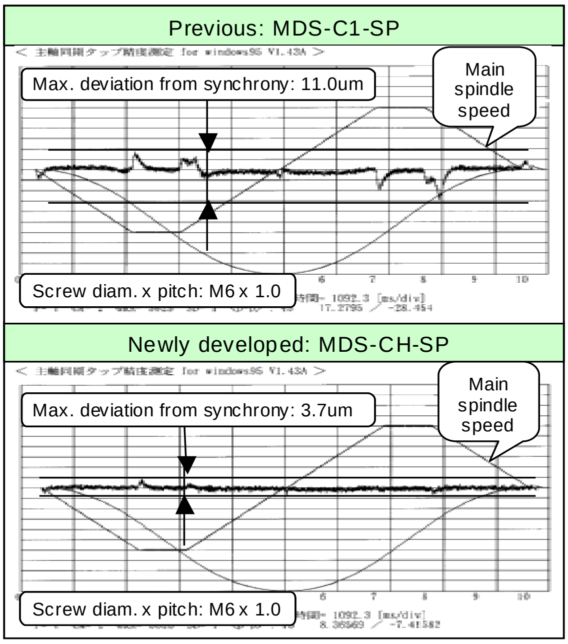


Fig. 2 Synchronization error comparison of the tap screw cutting

2. Servo

For the servo drive, currrent-loop control similar to that for the 200V product is applied to separate processing, and this increasing the control processing frequency. As an example of its effectiveness, Fig. 3 shows the servo circular precision. By combining a high-performance servo drive with a low-ripple servo motor, path accuracy is confirmed at all speeds from lowest to highest for commands at the 1μm level.

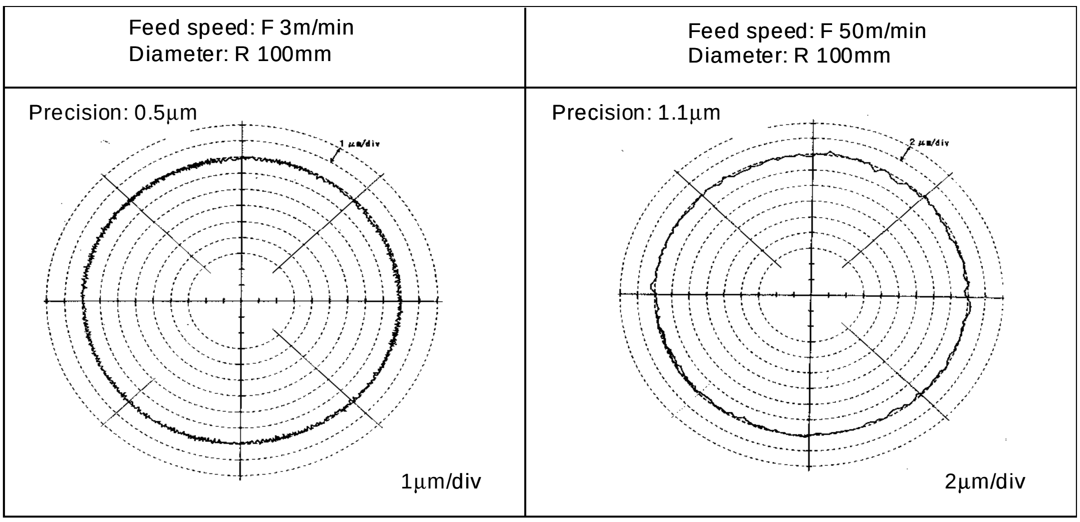


Fig. 3 Servo circle precision

A STRONGER PRODUCT RANGE. Table 1 shows the lineup of motors and drive amps available for configuring 400V drive systems. The full range of products can satisfy a very wide range of user needs throughout the world.

1. Motors
   Developing a rich diversity of motors with a wide range of capacities has made possible machine tools that meet the needs for high productivity and compound usage. The range has been extended to cover low-inertia 2,000rpm servo motors from 0.5kW to 15kW (9kW for 200V systems), and 3,000rpm motors from 0.5kW to 11kW (7kW for 200V). Also included in the range are linear motors, which are regarded as vital for achieving major improvements in processing precision and speed. These are available with thrusts from 1,500 ~15,750N. Small and efficient IPM main spindle motors with short-term torque ratings of 50~670Nm have also been added to the range.

Table 1 400V drive system line up

Parameters		Type	Capacity/Thrust/Torque
Motor	Servo motor 200rpm	HC-H52 ~ 152	0.5~15kW
	Servo motor 3,000rpm	HC-H53 ~ 113	0.5~11kW
	Linear motor	LM-NP Series	1500~1575ON
	Main spindle motor (w/built-in frame)	SJ-4 Series	1.5~75kW
	IPM main spindle motor (w/built-in frame))	SJ-4-PM Series	50~670Nm
Op Amp	Power supply	MDS-CH-CV-37 ~ 750	3.7~75.0kW
	One spindle servo drive	MDS-CH-V1-05 ~ 185	0.5~18.5kW
	Two spindle servo drive	MDS-CH-V2-0505~4535	0.5kW + 0.5kW ~ 4.5kW + 3.5kW
	Main spindle drive	MDS-CH-SP-!5 ~ 750	1.5~75.0kW

2. Drive amps
   To drive the above motors, with their high added value, the range of amps has been expanded to include servo amps with capacities from 0.5~18.5kW (15kW at 200V), and main-spindle amps of 1.5~75kW (55kW at 200V). Power supplies are available with capacities from 3.7~75kW (55kW at 200V).

SMALLER, WITH LESS WIRING. This 400V drive system requires no step-down transformer, reducing the need for wiring and enabling significant miniaturization of machine tools.

1. Transformerless
   Because the 400V supply can be connected directly, there is no need for a step-down transformer (from 400V to 200V). Previously, a large transformer rated at several kVA was needed in the front-end of the 200V drive system.

2. Less Wiring
   In comparison with a 200V system of the same capacity, current drops by half, so cables with smaller cross-sectional areas can be used. For example, for a standard 30kW main-spindle motor, 38mm^2 becomes 14mm^2. For main spindle motors, where several sets of windings are often provided, switching between them to achieve the necessary high-speed, high output power characteristics, this is a very important advantage.

IMPROVED ENVIRONMENTAL PERFORMANCE. The adoption of a regenerative power supply means that the rotary energy of the motors can be returned as electrical energy to the power supply, significantly contributing to energy economy, but in operating environments with poor quality electrical supplies, regenerative control is difficult and in the worst case this can bring the entire system down. So that these 400V systems can be introduced in countries all round the world,whatever the state of their power grids, they have been made particularly resistant to a wide range of electrical faults (see Table 2).

The corporation's power supplies come with a CPU and software dedicated to the control of this regenerative electrical energy, which has resolved the problem. As a result, stable regenerative control can be maintained even in the face of fault distortions exceeding the IEC6100-4 standard for electromagnetic compatibility (a maximum of 8%).

Regenerative control is generally effected by detecting the rise in direct-current flow in the motor drive circuits. There is no problem with this approach in the purely resistive loads of low capacity servo motors, but when there are large swings in the input (mains) voltage, regenerative control can cause excessive regenerative currents, and the potential difference between the input voltage and the regenerative power supply needs to be monitored to achieve stable regenerative current control. Rigorous suppression of rises in the DC voltage driving the motors is the key to obtaining stable current control.

However, when faults occur in the power supply to three-phase AC motors, they are very difficult to detect, and excessive regenerative control may be applied. Here, both the power supply input and the regenerative current both need to be monitored to achieved stable regenerative control (see Fig. 4).

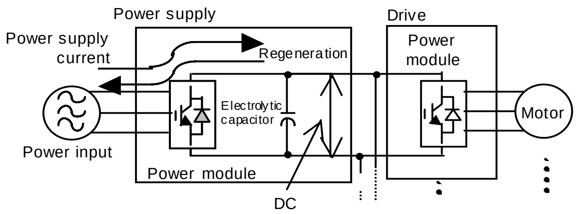


Fig. 4 Regeneration control method

Before starting this development work, we introduced an AC power-supply device for testing the resistance of power-supply units to distortion. This enables supplies to be provided with any required degree of distortion. With a maximum capacity of 135kVA, it has been used to test the environmental resistance of the new 400V systems' power supplies up to 75kW. These tests established that they can withstand distortions twice as large as those specified in international standards at capacities up to their maximum rating.

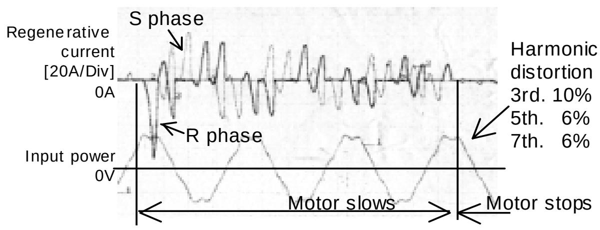
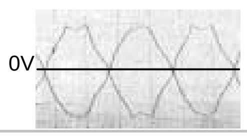
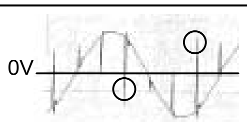
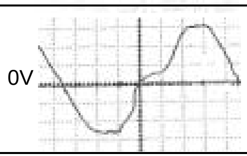
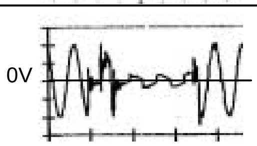


Fig. 5 Regeneration control at power supply distortion

Measurements at sites in Europe have detected distortions exceeding international standards. Fig. 5 shows third-harmonic distortion of 10%, and fifth and seventh harmonic distortions of 6% each. Even under these highly adverse conditions, the power supplies continue to provide stable regenerative control, as evidenced by the regenerative waveform in the upper part of the graph. This ability to withstand the electrical faults that they might encounter anywhere in the world means that these units can operate reliably wherever faster, more productive machine tools are needed. ❑

Table 2 Typical example of power supply disorder

Parameter	Explanation	
Voltage distortion (harmonic)	 Includes 5th harmonic	Voltages at frequencies of multiples of the power-supply frequency are superimposed and constitute distortion problems. This can easily arise when power-supply equipment is overloaded.
Notching		This tends to occur with instantaneous load changes caused by switching operations in semiconductors or other power-supply equipment.
Phase shift		This can arise several times a day when reactive adjustment of power factor is made in response to changing loads.
Instantaneous voltage drop		This is often caused by lightning-induced and other faults in the power supply grid.

High-Speed, High-Efficiency Built-In Spindle Motors

by Akihiro Shimada and Kouki Naka*

While spindle motors for machine tools are servo motors, the importance of their performance at very high rotary speeds means that they have quite distinctive performance characteristics. Recent years have seen increases in the speeds of machine tools, particular machining centers, and this has created strong demand for spindle motors that support high-speed, high-precision machining while dissipating less heat.

Fig.1 Appearance of high-speed high-efficiency built-in IM spindle motor

Induction motors (IM) have been widely used in high-speed machine tools with rotary speeds exceeding 10,000rpm, but for the high-speed regions where the power-supply frequency must exceed 400Hz, the iron losses associated with higher eddy-current losses become an important issue.

Mitsubishi Electric Corporation therefore decided to develop a new high-speed, high-efficiency series of motors targeting electrical losses 50% lower than those of current models in the high-speed region. Tests of the new products have established that losses in the high-speed region during operation under both load and no-load conditions are indeed 50% lower than current models. The external appearance of a typical new spindle motor and its rotor are shown in Fig. 1.

The Range of Application of the Higher Efficiencies

The current series of built-in IM spindle motors falls into three categories in terms of their highest operating speeds and rotor diameters, as shown in Fig. 2. The general series has rotor

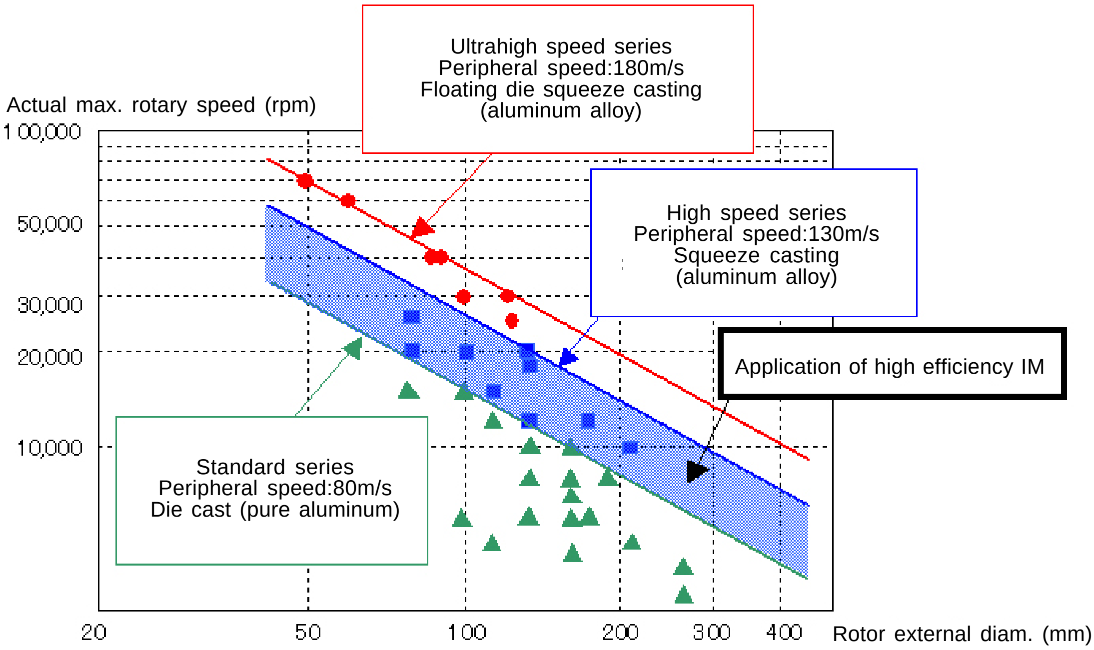


Fig. 2 The series with built-in IM spindle motors

*Akihiro Shimada is with Nagoya Works and Kouki Naka is with the Advanced Technology R&D Center.

peripheral speeds no greater than 80m/s and uses a conventional die-cast structure. The ultrahigh-speed series has peripheral rotor speeds in excess of 180m/s and uses the so-called floating-die squeeze casting to eliminate casting defects in construction. The high-speed series falls between these two and typically has peripheral rotor speeds no greater than 130m/s. As current machining centers largely use spindle motors falling within the high-speed category, it was decided to implement the improvements to high-speed, high-efficiency operation within this category.

Analysis of Present Motor Performance

We selected a member of the present series and analyzed its losses. The specifications of this, which we call the "current" or "present" model below, are listed in Table 1. The results of our measurements of the losses under load and no-load conditions are shown in Fig. 3.

The electrical losses under no-load conditions are largely determined by iron losses. At the maximum rotary speed of 15,000rpm, iron losses account for over 90% of total electrical losses (the sum of primary copper losses and iron losses), as evidenced by Fig. 3a. This is due both to greater losses at the higher fundamental power-supply frequency associated with higher rotary speeds and also to the greater losses at the higher harmonics associated with the impedance-switching current.

Under load conditions, as evidenced by Fig. 3b, although the primary and secondary copper losses both increase, iron losses still contribute a high proportion of total electrical losses. At the maximum rotary speed of 15,000rpm, iron losses account for over 70% of the total (the sum of primary and secondary copper losses and iron losses).

These findings led us to set the following targets for the development project:

1. To reduce total electrical losses at the maximum operating rotary speed to less than half of those for the current model (under both load and no-load conditions).
2. To hold total electrical losses at the base operating speed to levels strictly comparable with those of the current model (also under both load and no-load conditions).

Table 1. Specifications for Current Model

Parameter		Specification
Frame number		100
No. of poles		4
Rated rotary speed (rpm)	Basic (low)	1,500
	Rated output range	6,000
	Max.	15,000
Rated output power (kW)	Continuous	2.2 (0.88)
	Short-term (1/4h)	3.7 (1.5)
Rated torque (kW)	Continuous	14 (0.6)
	Short-term (1/4h)	23.6 (1.0)

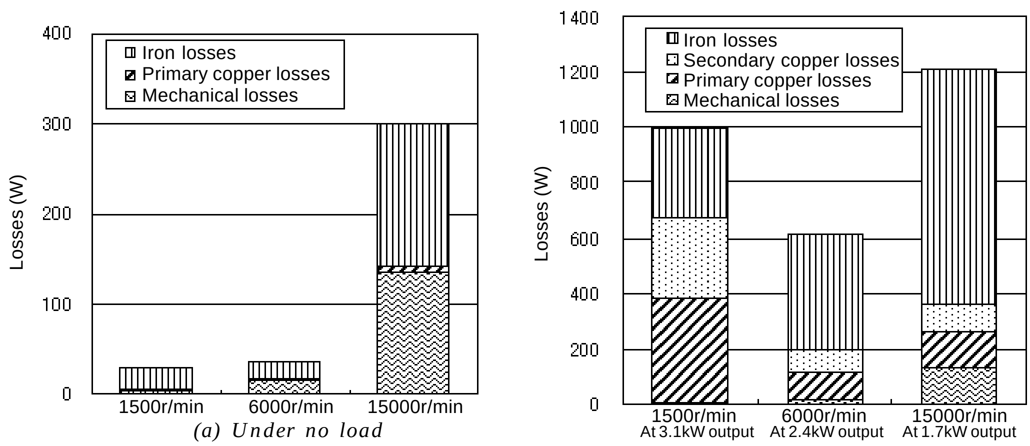
Note: The figures in parentheses are those for maximum rotary speed.

Table 2. No-Load Temperature Rises

Measurement point	Temp. rise (K) Previous type	Efficient sample
Coil end	30	16
Stator core	30	16
Rotor surface	28	15

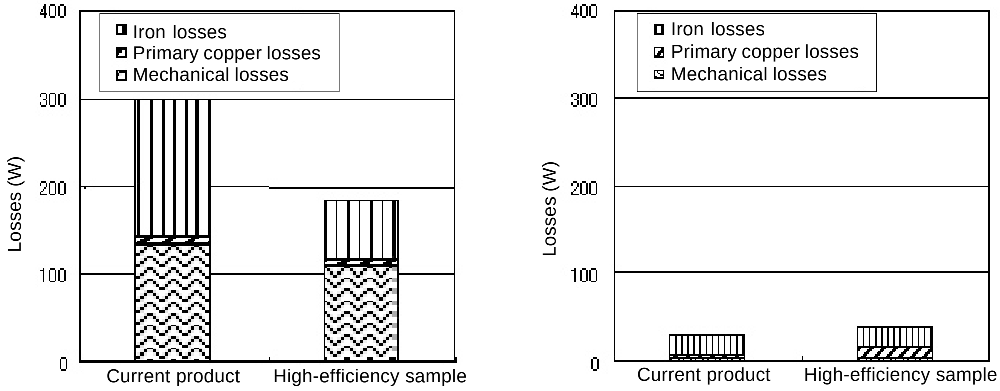
Evaluating the Performance of a Prototype High-Efficiency Motor

Based on the foregoing analysis of the present motor's losses, we applied electrical field analysis to the high-efficiency prototype motor design



(a) Under no load *(b) Under load*

Fig. 3 Results of conventional motor loss analysis



(a) 15,000rpm, With no-load *(b) 1,500rpm, With no-load*

Fig. 4 Comparative losses under no-load conditions

(below, just "high-efficiency" motor). The major changes in specifications are as follows:

1. Upgrading of the magnetic steel sheet.
2. Optimizing of the stator/rotor air gap.
3. Optimizing of the rotor-core specifications (e.g., the number of slots, etc).

We then manufactured a prototype high-efficiency motor and measured its performance characteristics. These–output, torque, etc.–were strictly comparable with the present motor. The experimental results are shown in Fig. 4 and 5.

As will be clear from Fig. 4, the high-efficiency motor's losses under no-load operation at the maximum operating rotary speed of 15,000rpm were 54% lower than the present motor. This is the result of lower iron losses. No-load operation at 1,500rpm, on the other hand, shows comparable losses for both motors.

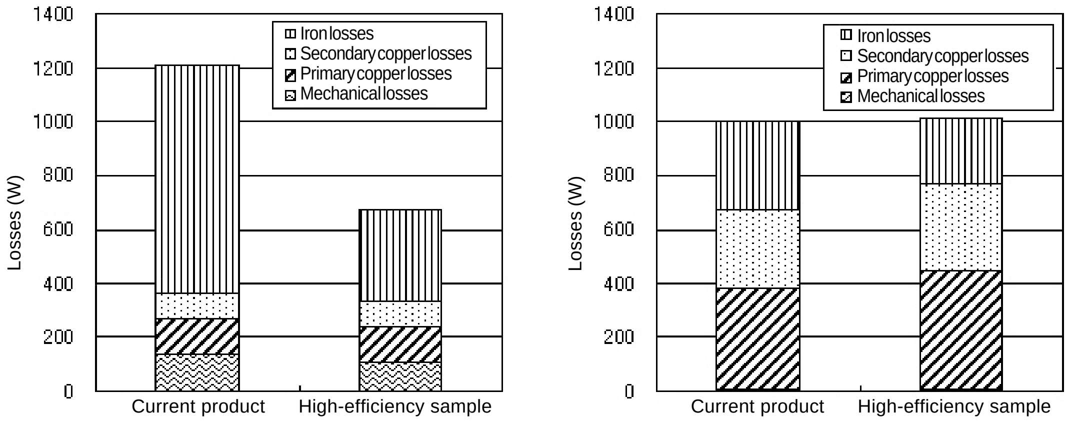
From Fig. 5, the electrical losses at the maximum 15,000rpm and 1.7kW output show that the high-efficiency motor has 47% lower losses than the present motor. Here too, as with no-load operation, the effect comes from lower iron losses. At 1,500rpm and 3.1kW output, the high-efficiency motor suffers a slight rise in primary copper losses, but this is covered by the lower iron losses, so that overall the total electrical losses are comparable for the two motors.

It is worth noting the temperature rises measured for the two motors at 15,000rpm under no-load conditions shown in Table 2. Temperature rises were measured after reaching stability under normal air cooling. Whereas the present motor experienced rises of 28K, these were greatly reduced in the high-efficiency prototype to no more than 15K. This is clear evidence of the effectiveness of higher efficiency.

Characteristics of the High-Speed, High-Efficiency Series

The new products also embody the following improvements in addition to their higher efficiency at high speeds:

1. Adoption of floating-die squeeze molding as standard. This, by ensuring higher precision in the balance of the rotor itself, simplifies the balancing of the spindle.
2. Reduction of stator length (by 20% of present models). This both reduces overall size and increases rigidity.



(a) 15,000rpm at 1.7kW output *(b) 1,500rpm at 3.1kW output*

Fig. 5 Comparative losses under load

Table 3. Overall Dimensions of the Members of the New Series

Frame no.	Poles	Main dimensions (mm)			Max. rotary speed (rpm)	Main applications
		Stator ext. diam.	Rotor ext. diam	Rotor int. diam		
100	4	160	98	60	15,000~25,000	#30 Machining center
112		180	112	75	14,000~22,000	#40 Machining center
132		210	132	85	12,000~20,000	
160-A		230	160	95	10,000~16,000	#50 Machining center
160-B		255				

The overall dimensions of the members of the new series are given in Table 3.

By concentrating the development project for higher efficiency where it could make the biggest contribution, both in terms of the operating conditions (at the very highest maximum rotary speeds) and applications (in spindle motors suitable for the great majority of machining centers), significant improvements were made without compromising any of the basic performance characteristics. ❑

Control Functions for Printing Machines

*by Makoto Nishimura and Koichiro Ueda**

In the past, printing presses have been driven by a single motor that, via a single shaft with a gear and clutch system, delivered power to drive the printing cylinders, ink source, and folder. Recently, the shaft has been eliminated by introducing a series of individual motors to drive each printing component separately. In this move to shaftless design, high-precision synchronous control has been the main concern. We developed a motion controller (Q173CPUN), a large-capacity servo amp (MELSERVO-J2-Super), and a large-capacity servo motor (HA-JFS) suitable for shaftless newspaper printing machines, and submitted it for evaluation to an end user.

Sectional design brings the benefits listed below.

* It gives print-job flexibility
* Eliminates out-of-register printing due to shaft torsion
* Simplifies mechanical set up work
* Reduces the number of mechanical parts
* Increases printing speed

Moreover, advances in the following drive technologies enabled the performance needed to achieve the requisite precision

* Increased servo-amp processing speed
* Increased analytical capacity of encoder (multi-axis synchronous control technology)

Mechanical Structure

Fig. 1 shows the mechanical structure of a sectional newspaper printing machine. In the printing machine discussed here, four servos are used to carry out four-color double-sided printing in each tower (unit drive system).

The number of print towers varies with the type of print job, which results in configurations of one to eight towers. Four servos are used for fine-control of the up/down and left/right alignment of each print axis.

System Configuration

Here we describe the control-system configuration. To synchronize the operation of the servos for a total of 48 axes, there is a multi-CPU configuration comprising two Q173CPUN motion controllers with a Q25HCPU MELSEC-Q Series sequencer (programmable logic controller or PLC). SSCNET (Servo System Controller NETwork) functions in the Q173CPUN connect servos for a maximum of 32 axes to each Q173CPUN. In the base unit, the pair of Q173CPUN chips is linked by a dedicated synchronous control signal in the bus communications of the base unit.

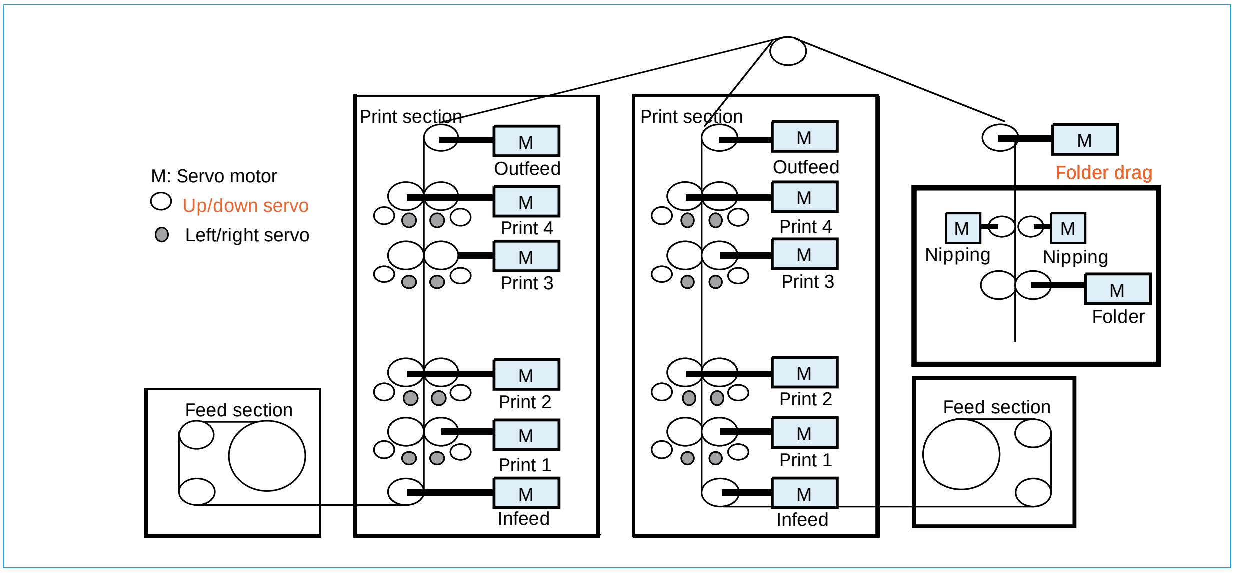


Fig. 1 Mechanical structure.

**Makoto Nishimura is with Nagoya Works and Koichiro Ueda is with the Advanced Technology R&D Center.*

As well as the servo, CC-Link connects the inverter and input power unit, while in the operation panel two A975GOT chips are linked via a dedicated bus signal.

Problems and Solutions

In a shaftless newspaper printing machine, because the load inertia ratio is in the order of tens and disturbances originate within the plate gaps, high-load-inertia and low-rigidity machine disturbance suppression control become an issue. Moreover, it was necessary to incorporate other control functions specifically required by printing machines. We resolved these issues as described below.

By using a 32-bit RISC microprocessor, we developed a large-capacity servo amp with four times more processing power than before.

To improve disturbance response, it was necessary to step up the processing power for the current-control and speed-control loops. For less than 3.5kW, the MELSERVO J2-Super Series (abbreviated below to MR-J2S series) was developed. Subsequently, to match the drive systems of printing machines, we were able to increase the capacity to 55kW.

For the MR-J2S Series, 131072-resolution encoders are standard, but to handle line speeds of 680m/min with printing precision of 20µm we developed a 4194304-resolution encoder.

The load inertia ratio is a major factor in improving control efficiency. Because the relationship between speed-control gain and load-inertia ratio is decisive in improving the actual response speed, it is vital to reduce the load-inertia ratio.

To do this, we developed a motor with a higher inertia than the previous servo motor. Moreover, while improving the inertia characteristics, we managed to maintain dimensional parity with the previous motor. The new motor therefore fits into the same mechanical space for installation.

By installing a servo amp to deal with disturbance suppression control due to the high load inertia and low rigidity of the machinery, we were able to achieve satisfactory control of disturbance without any excessive increase in gain.

In addition to using a servo-system controller (SSC) that supports a mechanical language to handle printing-machine needs, we also carried out the following improvements.

Inclusion of a member of the MELSEC-Q series of PLCs in a multi-CPU configuration to serve as a motion controller has enabled command generation to be synchronized at 0.8ms. Moreover, because each CPU can control 32 axes, the multi-CPU configuration with three CPUs enables synchronous control of up to 96 axes.

Disturbance-Suppression Control

To ensure that there is no color-drift, synchronous control is required to coordinate the movements of multiple spindles during high-precision multicolor printing operations. It is particularly important to resolve positional descrepancies between the axes during constant-speed operations.

Fig. 2 shows the printing-cylinder spindle mechanism (surface-printer section only) of the printing-machine configuration shown in Fig. 1.

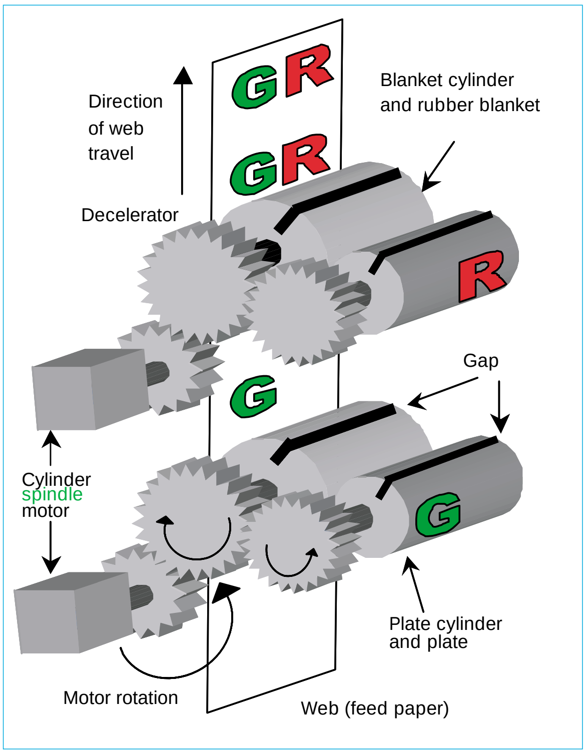


Fig. 2. Cylinder spindle servo mechanism (surface printer section only)

When the plate and rubber blanket are wrapped around the roller, the gaps that occur between the ends of the plate and the ends of the rubber blanket are incorporated in an embedded structure

Even so, every time the rollers turn, a rotational disturbance is generated and this is a major cause of varying positional errors.

Moreover, with so many reduction gears coupled to the mechanism, it is usually a challenge to give printing machines high mechanical rigidity. On top of this, in printing machines the load-inertia ratio for the motors is high. Moreover, reduction-gear backlash is also high. If PI control and other conventional control techniques were used with this type of mechanical system, the printing machine would be prone to mechanical oscillation when operated at high rotary speeds and, because it is not possible to increase gain sufficiently, elimination of such disturbances would be difficult.

Consequently, to contend with mechanical systems that have low rigidity and high backlash, we developed robust and effective disturbance-suppression control functions. This method of control employs a disturbance-suppression controller that is added to the previous control system (Fig. 3). The resultant system, while able to greatly reduce variable positional errors, ensures reliability by using a gain no higher than with the previous controller.

By extending its application to other printing presses in addition to newspaper printing machines, we are working to further advance the corporation's expertise in synchronous-control technology. We are grateful to Seiken Graphics for the generous assistance and cooperation provided during the final stages of development. ❑

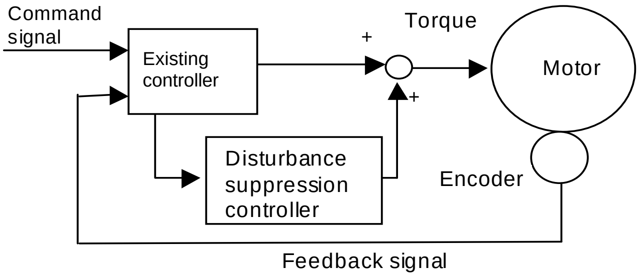


Fig. 3 R&D Disturbance suppression control system

A Universal-Bus Controller-SSCNET & Positioning Board

*by Itsuo Seki**

The positioning board described in this article is compatible with universal buses and, used with Mitsubishi Electric Corporation's servo system control network (SSCNET) for high-speed positioning in real time, achieves the synchronous control of high speed, precision positioning needed in manufacturing today's LCDs and semiconductors, etc. The article introduces both the positioning board and SSCNET.

Features of SSCNET and the Positioning Board

The positioning board is used in a system configured as shown in Fig. 1. The board, at precisely regular intervals, sends and receives via SSCNET positional commands to the servo amps and positional feedback data from them, controlling the servo positions in real time.

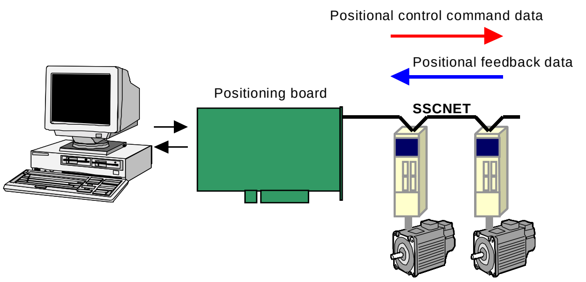


Fig. 1 System configuration

The characteristics of SSCNET and the positioning board are as follows:

1. High-speed, high-resolution control
   Because the positional commands are sent as data, they are not subject to command frequency limitations, enabling the servo amp's full performance to be utilized.
2. Complete synchronization of all servo amps is possible.
3. Requires little wiring and small space.
4. Provides controller-side integration of the control of all parameters.
5. Absolute position systems are readily configured.
6. Reliability is greatly improved.
   The provision of error-checking functions for the communication data improves reliability while, at the same time, continuous monitoring of the feedback positional data means that after emergency stoppages, etc., operation can begin again from the precise position of the stoppage.

SSCNET

SSCNET is a proprietary motion network of Mitsubishi Electric using bi-directional full duplex communications with an RS-485 physical layer (metal cable) and high-level data-link control procedure (HDLC) in the data-link layer.

There are two types of SSCNET. SSCNET I has a communication period of 3.555ms and SSCNET II has one of 0.888ms. When the communication period is 3.555ms, existing SSCNET communication LSIs are used. In order to speed the communications for a 0.888ms period, the communications protocol is optimized for data structure and volume. The two types are used for different applications-SSCNET I is for eight-axis control and SSCNET II is for six-axis control. Table 1 summarizes the main features of SSCNET.

Table 1 Summary of SSCNET Features

Parameter	SSCNET I	SSCNET II
Transmission speed	5.625Mbps	
Communication period	3.555ms	0.888ms
No. of axes	8/channel x n channels	6/channel x n channels
Transmission range	Total length, 30m	
Physical medium	Metal	

Fig. 2 shows how SSCNET sends the data. Procedures for data transmission between positioning board and servo amps are as follows:

1. After synchronizing the communication blocks for the positioning board and the servo amps, positional command data is generated in-board and written to the SSCNET communications LSI.
2. The SSCNET communications LSI broadcasts the data over the SSCNET cable, and each

*Itsuo Seki is with Nagoya Works.

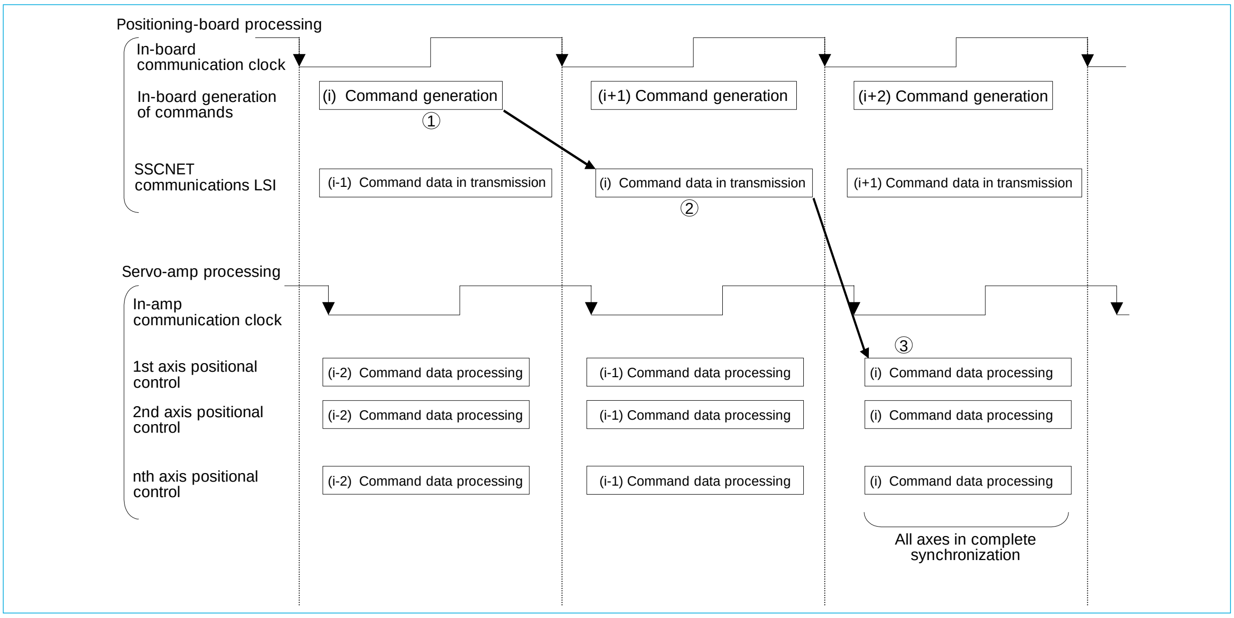


Fig. 2 SSCNET data transmission flow

servo amp accesses its own positional command data.

3. All servo amps then perform positional control in accordance with the positional commands in synchrony.

In this way, SSCNET makes possible identical timing of positional control for multiple servo amps, in perfect sychronization, something that was difficult with pulse trains.

Because the positional commands are sent as numerical data, they are not subject to limitations imposed by the command frequency, enabling the full servo performance to be achieved.

Further, bi-directional full-duplex communication enables simultaneous control of both the positional command transmissions and of the reception of servo amp parameters and status.

Summary of Positioning Board Features

As its name suggests, the positioning board is a board-type controller for operation under the desk-top computer or other host controller's user program, controlling servo amps over SSCNET. The board functions are shown in Table 2.

The series of boards is compatible with almost all of the various universal buses, and although the number of axes controllable via the bus interface varies (with the SSCNET version) they all possess the same functions.

Fig. 3 shows how the positioning board functions. Its internal point-to-point locator function

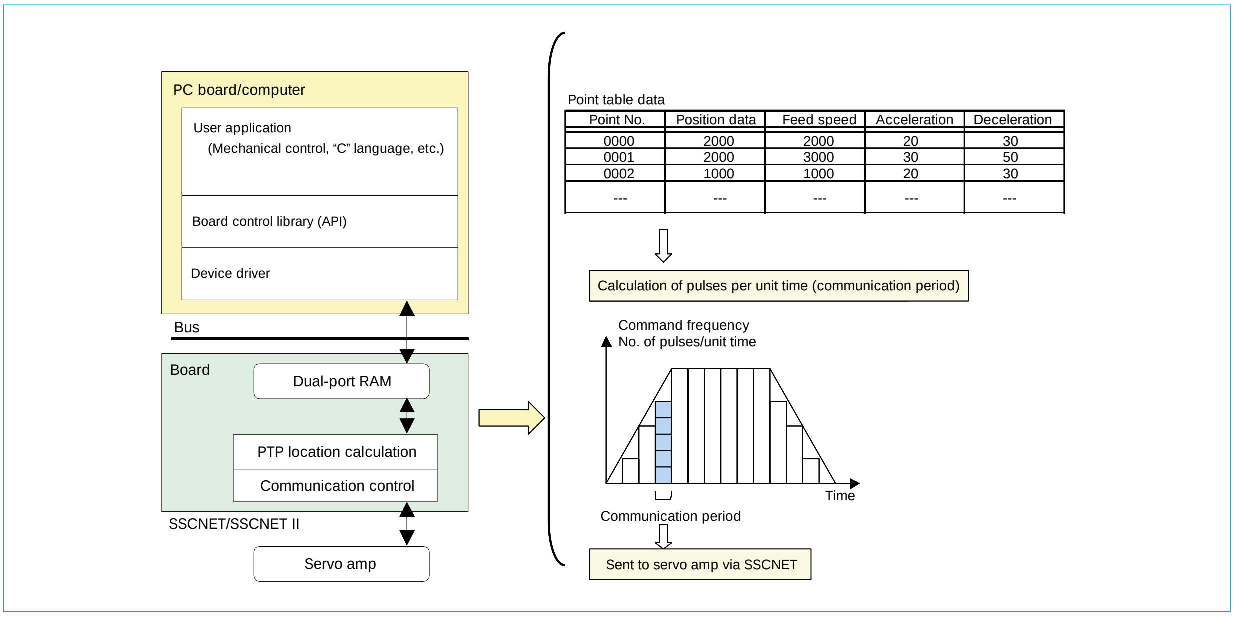


Fig. 3 Positioning board functions

Table 2 A List of Positioning Board Functions

Item		MR-MC10	MR-MC20	MR-MC21	MR-MC30	MR-MC01
Bus spec		PCI	Compact PCI		ISA	VME
Control axes		6 x 2ch		6 x 4ch	6 x 2ch	8 x 1ch
Control period		0.888ms				3.555ms
Positional command generation		Previously established tables of positions, speeds and accelerations are automatically period and sent to the servo amps via SSCNET.				
Command pattern		Trapezoid (MR-MC01 also offers irregular trapezoids, cycloids, and supports freely				
Motion functions	Jog operation	Performs unlimited feed as long as the drive signal is on.				
	Incremental feed	Performs a certain specific amount of feed for each drive signal.				
	Auto operation	Sequential operation using a point table.				
	Linear interpolation	Possible for up to three axes (four axes per channel; MR-MC01 retains its normal maximum of eight channels)				
	Modify command	Used for online changes to position, speed and acceleration				--
Additional functions	Electronic gear	Possible				
	Emergency stop	Two kinds: external emergency stop and software-governed emergency stop				
	Limit switches	Two kinds: external limit switches and software-governed limit switches				
	Interlocks	Possible				
	Crude alignment output	The bit is set (ON) when the command distances is within the parameter				--
	Torque limiter	Torque is controlled by parameter (limiting torque value)				
	Backlash correction	Backlash, arising when mechanical systems reverse direction, is compensated for.				
	Position switches	ON when movements are made within the range of parameters set (informed by interrupt)				
Return to origin		Five types				
Servo parameters		Read/write available for servo parameters				
Monitor		Four items/axis can be monitored.				
Interrupts		Interrupts are output to the host computer whenever situations calling for them arise.				

communicates with the host computer via dual-port RAM. The host computer sets the parameters for each point on the point table in dual-port RAM, setting the location data, the feed rate, and the rates of acceleration and deceleration. Then it performs positional control of the servo motors by addressing the servo amps via SSCNET, calculating the positional data at the intervals of 0.888ms or 3.555ms (the communication period) whenever a feed command is generated via the dual-port memory. The host computer is also informed of the feedback position and status from the servo amp via SSCNET and dual-port memory.

In this way, users can readily control servo motor motion (positional location control) by performing the following operation on dual-port RAM;

- Set up the point table
- Set up the various parameters
- Generate drive commands
- Acquire status, etc.

An application programming interface (API) has also been prepared to facilitate simple high-level control of the positioning board control by users.

Positioning Board Architecture

Positioning boards for SSCNET II must perform calculations to generate the positional commands for the servo motors of multiple axes and process monitor data all within the communication period of 0.888ms, requiring strictly real-time processing. They also need to be able to comply with various user needs, including those for custom functions and additional control axes.

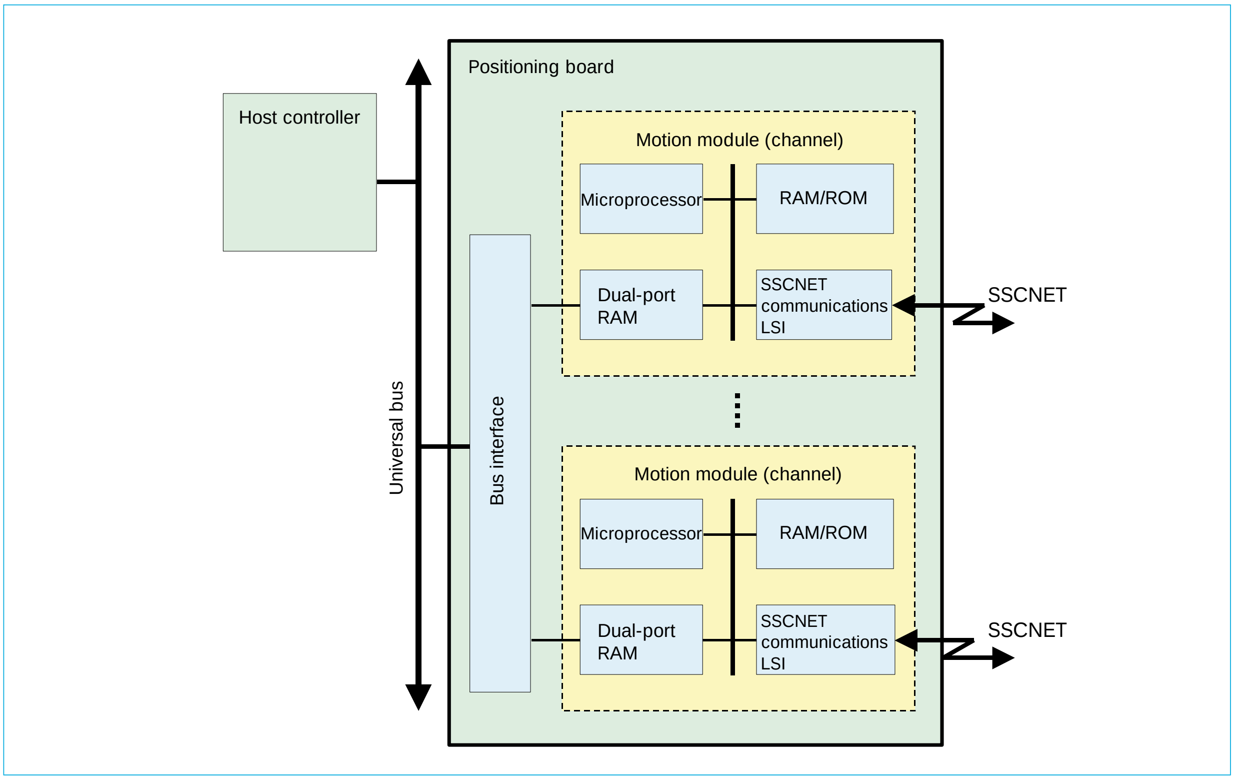


Fig. 4 Block diagram of the positioning board

We adopted multiple microprocessors and parallel processing to meet this requirement. One microprocessor, memory, and the SSCNET communictaions LSI constitute a single module for one-channel (six-axis) control, and each module has been given all the essesntial minimum of capabilities for positional location and control. In response to user needs, positioning boards can have various numbers of modules (channels), and a number of custom functions can be added, providing flexible extensibility, see the block diagram in Fig. 4. Simply changing the interface for the dual-port RAM and the host controller interface gives these boards compatibility with various types of universal bus.

The problem of synchronous processing, that is, of processing strictly in real time, lies at the heart of the control of multiple servo motors in high-precision machine tools. Mitsubishi Electric's SSCNET is being increasingly adopted as the standard for interconnecting the various components of such machining control systems. By providing a fully modular, extensible control unit compatible with standard universal buses in the form of a PC board, designed to work with SSCNET, the corporation greatly simplifies the task of configuring such control systems. ❑

CC-Link and CC-Link/LT Technologies for Open-Field Networks

*by Masanori Kachi **

CC-Link has been widely adopted for open-field networks, where its functions, performance and quality have won an excellent reputation in the high-level integration of information and control communications. Recently, there has been a growing demand for applications involving on the one hand smaller point dispersion and the reduction of wiring within circuit boards and individual items of equipment, and on the other the ability to handle larger volumes of data. In response to these demands, specifications for reduced wiring were published by the CC-Link Partner Association in April 2002 for CC-Link/LT and spefications for larger volumes of data were published in December 2002 for CC-Link Ver.2.

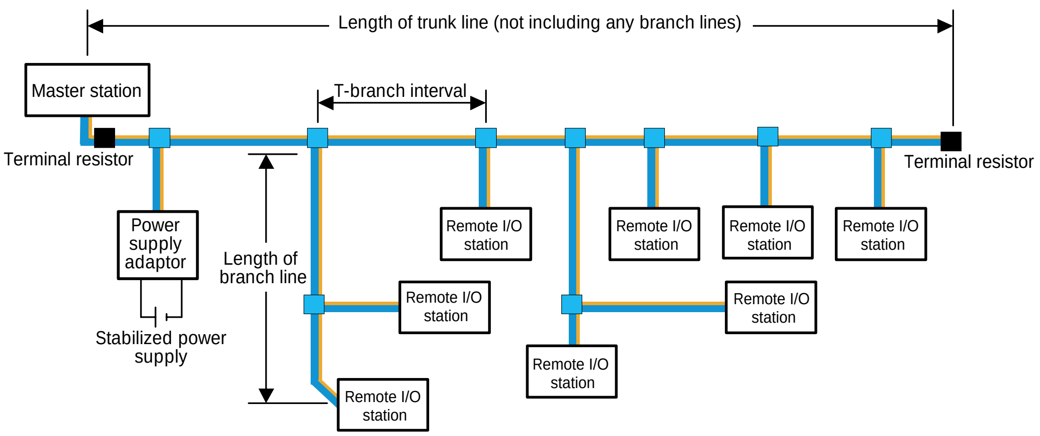
CC-Link/LT

CC-Link/LT is positioned specifically for terminal and branch networks of CC-Link for reduced wiring and bit-rate communications. It retains the outstanding characteristics of CC-Link-open design, high-speed response, etc.-and can be used in combination with it to provide seamless communications with higher-level controllers via CC-Link.

CC-Link/LT facilitates the networking of small- and medium-scale equipment with less wiring, while its integration with CC-Link enables entire, large-scale systems to be covered using consistent concepts right down to the lowest terminal level. As such, it makes major contributions to user convenience and cost reduction. Typical system specifications for CC-Link/LT are shown in Table 1.

Transmission paths for CC-Link/LT adopt the easily expanded T-branch form, enabling highly flexible configurations unhindered by the limitations associated with the wiring of individual machines and control boards. T-branch wiring also facilitates the exchange of units after the

Table 1 CC-Link/LT Network Wiring Specifications



Item (communications speed)	Specifications			Notes
	2.5Mbps	625kbps	156kbps	
Separation between stations	Unlimited			--
Max. no. of connections to each branch line	8			
Max. length of trunk line	35m	100m	500m	Length of cable between terminal resistors
Separation between T-branches	Unlimited			--
Max. length of a branch line	4m	16m	60m	Length of cable for each junction
Total length of branch lines	15m	50m	200m	The sum for all branch lines

**Masanori Kachi is with Nagoya Works.*

system has been fully configured, improves the ease of maintenance, and simplifies additions and expansions. This makes it extremely convenient in use. Fig. 1 shows a typical system configuration.

IMPROVED WIRING. Connections to the CC-Link/LT transmission path are made via snap-on (or "one-touch") connectors, representing a severalfold increase in efficiency over conventional wiring procedures. The special-purpose snap-on connectors and flat cables for CC-Link/LT combine simple and convenient wiring with the prevention of misconnections. For one thing, the snap-on connectors do not come in male/female pairs but are all identical, and the same connectors are used for both T-branch and trunk connections. By making the front and back surfaces of the flat cable unsymmetrical, connecting the cable the wrong way around causes an orange-coloured part of the cable to show through the connection "check" window, giving clearly visible warning of a wrong connection and essentially preventing the trouble caused by misconnections.

HIGH-SPEED RESPONSE. There are many schemes that reduce the wiring in networks by sacrificing their speed of response. In strong contrast, CC-Link/LT achieves transmission speeds of up to 2.5Mbps, the fastest in the industry, enabling wiring to be improved while at the same time retaining high-speed response. While 2.5Mbps may appear slow in comparison with CC-Link or other high-level networks, in fact it provides a very short link-scan response time of only 1.2ms using 2.5Mbps in four-point mode for link scanning a 64-station network.

This remarkably high-speed response of CC-Link/LT is due both to the highly efficient transmission protocol and the adoption of a dedicated LSI for high-speed communication processing.

The CC-Link/LT communications protocol uses broadcast polling + interval-timed response (BITR). The BITR data-transmission procedures are shown in Fig. 2.

First, the master station transmits the refresh data (1) (i.e., tbe remote output data) to all remote stations simultaneously. Next, after the remote stations have received these refresh frames sent by the master station, interval-timed responses (2) (i.e., the remote input data) are sent by each remote station in order, starting with the first station and finishing with the last. The time taken between the master station's tranmsission of the refresh data and the last response from a remote station is called one link scan. Once one link scan is finished, the master station sends the next refresh data.

In other words, CC-Link/LT transmissions add interval-timed responses to the CC-Link protocol for broadcast polling. It is characteristic of this approach that the comparatively simple data processing involved makes it fairly easy to implement the

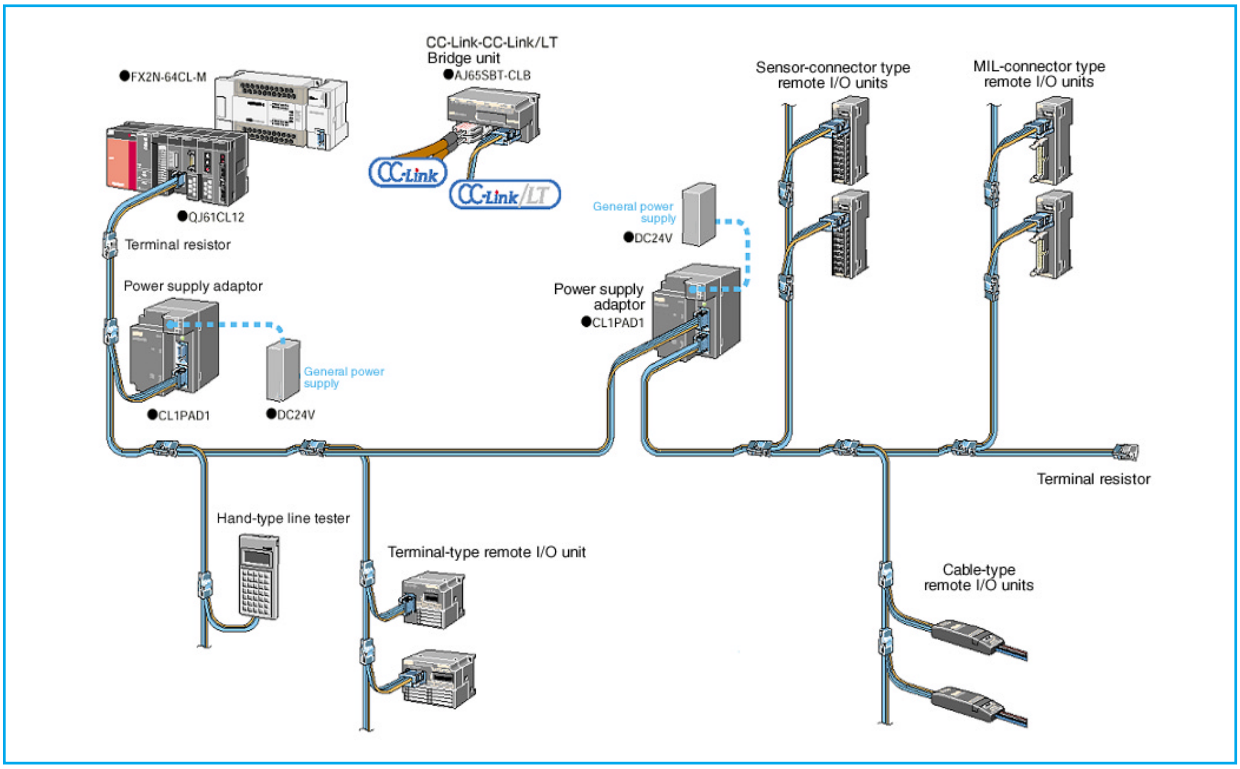


Fig. 1 A typical CC-Link/LT system configuration

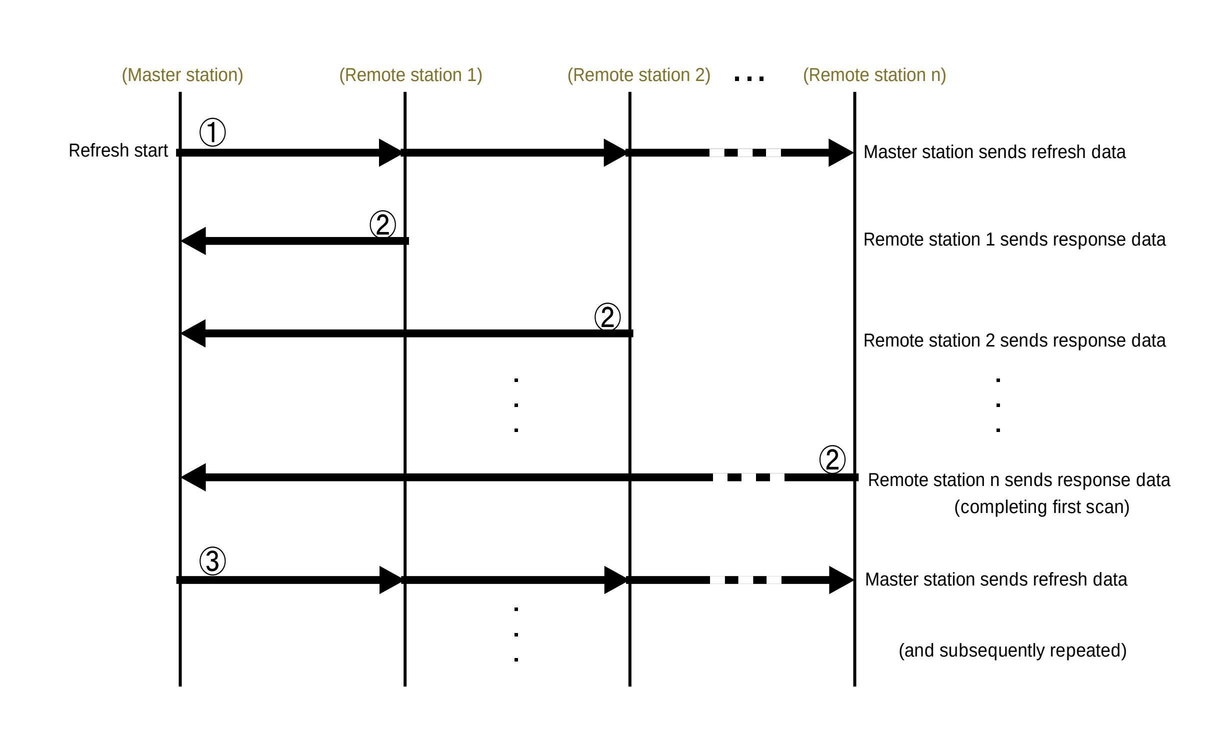


Fig. 2 An overview of CC-Link/CC-Link/LT communication protocol

communications controller, etc., in hardware, and stable link-scan times can be obtained.

THE REMOTE I/O UNITS. CC-Link/LT is available with 16-point or 8-point remote I/O units, and smaller 4-point or 2-point units are also available. By making use of these units, systems with small numbers of points can be readily configured. These units are also only 70% the volume of CC-Link units with the same number of points, making possible smaller, lower-cost equipment and control boards. Also, since the transmission speed is set automatically from the frames circulating through the network on the remote-unit side, there is no need to set the timing separately for each remote unit, eliminating the start-up troubles that can arise from setting errors.

CC-Link Ver.2

CC-Link Ver.2 was devised for applications that go beyond supplying the reduced wiring needs of previous automotive, semiconductor, conveyor, foodstuffs and other factory automation (FA) applications, for instance in the transmission and reception of multiple channels for monitoring and control systems involving digital/analog conversions, which require the transmission of large volumes of data at precise intervals of time. It provides for data transmissions up to eight times larger than those of CC-Link. The communications specifications for CC-Link Ver.2 are shown in Table 2.

Table 2 CC-Link Version 2 Communication Specifications

Item		(Version 2) specs	Current version (Version 1.1) specs	Notes (V2/V1.1)
Max. no. of links		RX/RY: 8192 bits RWw/RWr: 2048 words	RX/RY: 2048 bits RWw/RW: 256 words	Four-fold Eight-fold
No. of links per unit	With 1 station	RX/RY: 32~138 bits RWw/RWr: 8~32 words	RX/RY: 32 bits RWw/RWr: 4 words	Four-fold Eight-fold
	With 4 stations	RX/RY: 128~896 bits RWw/RWr: 16~128 words	RX/RY: 128 bits RWw/RWr: 16 words	Seven-fold Eight-fold
No. of stations per unit		1~4	Same	--
Cyclic expansion settings		1, 2, 4, 8-fold	None	--

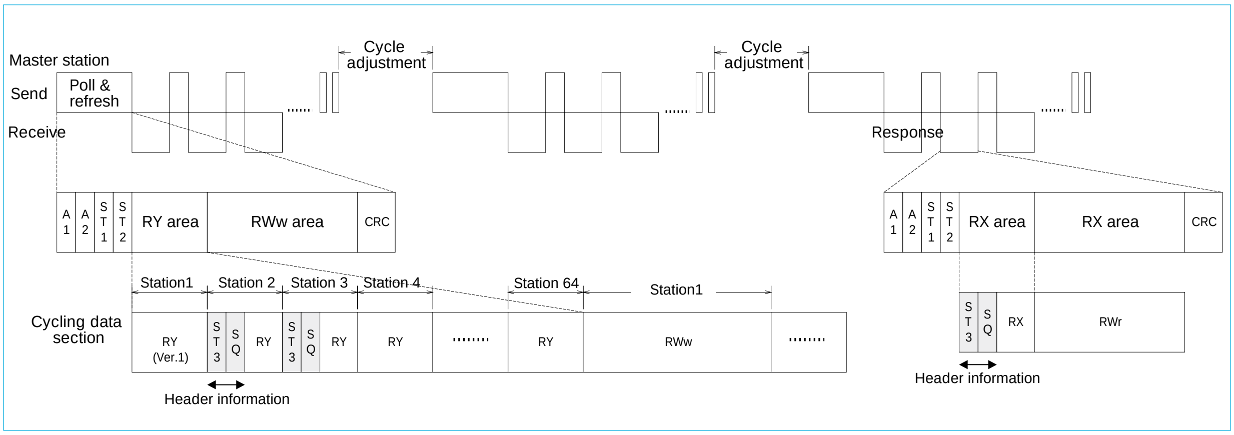


Fig. 3 CC-Link Ver.2 frame configuration overview

PROTOCOL SPECIFICATIONS. The CC-Link Ver.2 protocol expands the number of cyclic data points, and is implemented over CC-Link Ver.1.10.

As shown in Fig. 3, the Ver.2 specifications expand the usual cyclic data header information (ST3, SQ) by two additional bytes, and divides the data among multiple cycles for transmission, so expanding the cyclic data per station.

COMPATIBILITY. Since CC-Link Ver.2 is implemented over CC-Link Ver.1.10, local stations can be configured from only products under the current version (Ver.1.10) or from only new products (Ver.2), or indeed from mixed combinations of products running under either version. Optimum systems can therefore be configured using the ideal combination of products running under either version.

Mitsubishi Electric Corporation is committed to working with the CC-Link Partner Association to configure CC-Link open-field network systems that meet the needs for networks that are safe, with improved wiring, and that combine high reliability with great ease of use. ❑