Development of the *SANMOTION R* 400 VAC Input Multi-axis Servo Systems (37 kW, 300/600 A)

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1. Introduction

The *SANMOTION R* 200 VAC input multi-axis servo system developed in 2013 is available in a wide range of models for driving servo motors with output capacities of 550 W to 37 kW. Since its release, it has gained much popularity among customers.

In recent years, the expansion of industrial globalization has increased the need for systems that support 400 VAC input power, primarily in European and Asian regions. In response to this demand, we released 400 VAC input multi-axis servo systems that support output capacities up to 15 kW in 2018.

We developed new models for the 400 VAC input multi-axis servo system for driving 20 kW to 37 kW large-output servo motors. As a result, we now offer an expanded lineup of 400 VAC multi-axis servo amplifiers that can drive 550 W to 37 kW output motors. Furthermore, to improve machinery processing quality and productivity, we developed an EtherCAT interface control unit that maintains the performance and features of our existing *SANMOTION 3E Model*.

In this article, we introduce the features and key development points of the new models: a single-axis EtherCAT control unit, 37 kW power supply unit, and 300 A and 600 A amplifier units.

2. Product Overview

2.1 Appearance and dimensions

Our *SANMOTION R* 400 VAC input multi-axis servo system consists of a control unit, power supply unit, and amplifier unit, allowing for flexible system configurations.

The units are shown in Figures 1 and 2, while their dimensional drawings are shown in Figures 3 to 5.

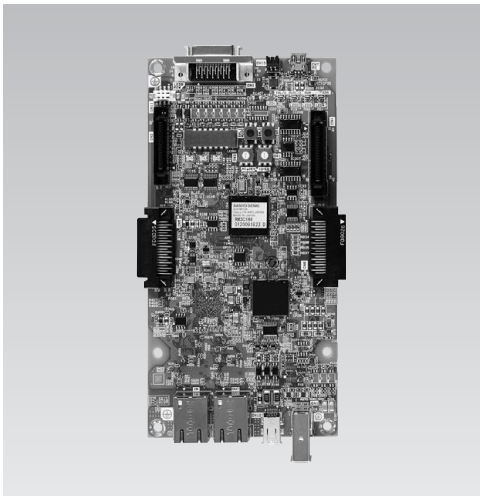

Fig. 1 Appearance
(Single-axis EtherCAT control unit)

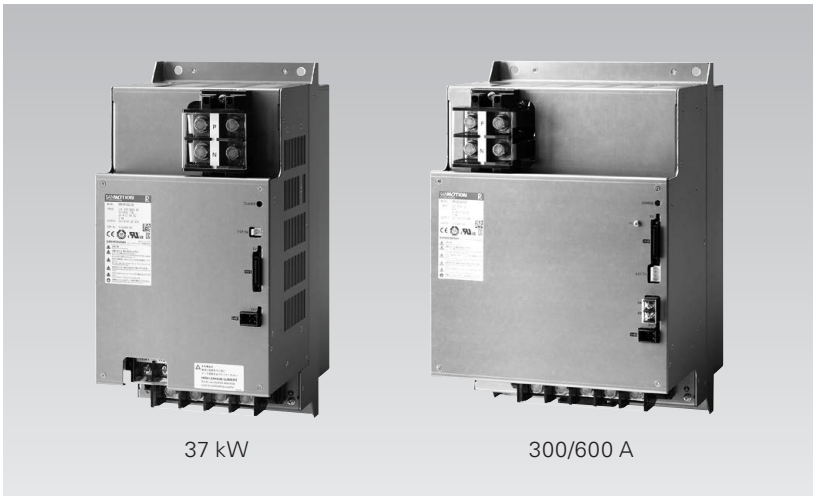

Fig. 2 Appearance
(Power supply unit and amplifier unit)

For the control unit, we added a new single-axis EtherCAT interface model designed based on our existing *SANMOTION R 3E Model* servo amplifier. We also released a 37 kW power supply unit as well as 300 A and 600 A amplifier units capable of driving servo motors with output capacities of 20 kW to 37 kW.

When using multiple control units, the units can be connected to each other with connectors, as shown in Figure 3, achieving both space and wiring savings. The power supply unit and amplifier unit both have a height of 380 mm, which is exactly the same as that of the existing 15 kW system for easy installation in the control panel.

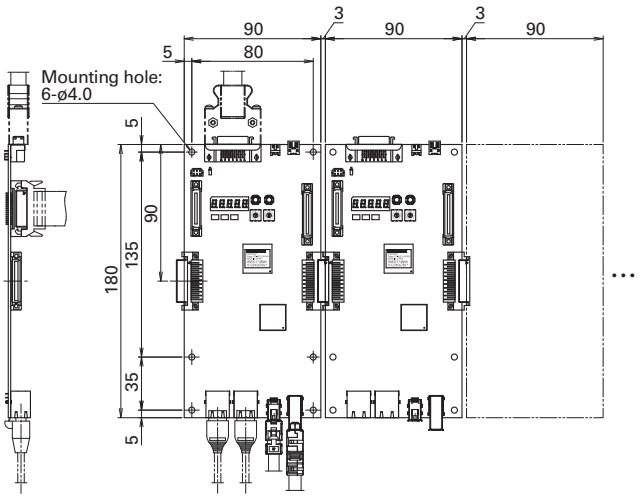

Fig. 3 Dimensions (Single-axis EtherCAT control unit)

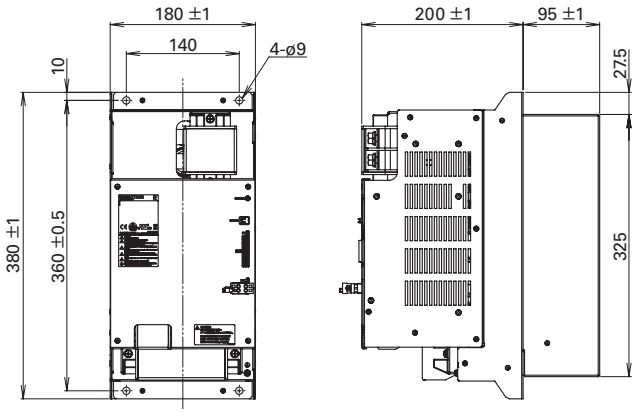

Fig. 4 Dimensions (Power supply unit 37 kW)

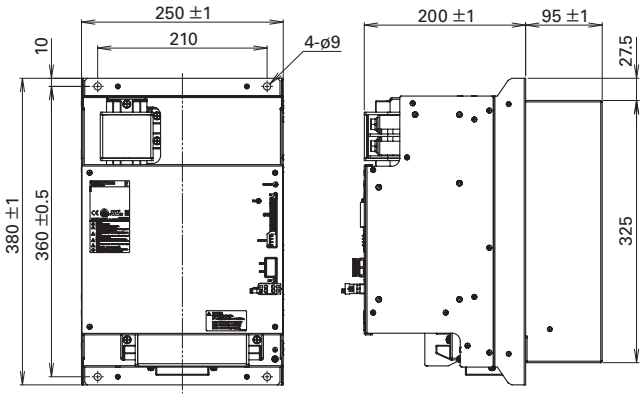

Fig. 5 Dimensions (Amplifier units 300 and 600 A)

2.2 Basic specifications

2.2.1 Basic specifications of units

Table 1 shows the specifications common to all units, and Table 2 to 4 show the basic specifications of individual units.

Table 1 Common specifications for 400 VAC multi-axis servo systems

Environment	**Operating/storage temperature**	0 to +55˚C / -20 to +65˚C
	Operating/storage humidity	Below 90% RH (non-condensing)
	Operating altitude	Below 1,000 m
	Vibration/impact	4.9 m/s^2 / 19.6 m/s^2
Standards	**UL/cUL**	UL 61800-5-1 / C22.2 No274-13
	Low Voltage Directive	EN 61800-5-1
	EMC Directive	EN 61800-3, EN 61326-3-1
	Functional safety*	ISO 13849-1: PL=e EN 61508 SIL3, EN 62061 SILCL3
	KC Mark	KN 61000-6-2, KN 61000-6-4

* Models with Safe Torque Off function

Table 2 Basic specifications of control unit

Interface			EtherCAT
Size			90 (W) × 180 (H) × 21 (D) mm
Mass			0.12 kg
Compatible equipment	**Motors**		*SANMOTION R* rotary motors
	Encoders	**Standard**	Battery-less absolute encoder
			Absolute encoder for incremental systems
		Options	Battery-backup absolute encoder
			Wire-saving incremental encoder
Functions	**Safety functions**		STO (Safe Torque Off)
	EtherCAT communication		• Touch probe • Homing • Firmware update via FoE (File access over EtherCAT) • Parameter upload/download via FoE
	General-purpose I/O		Input: 7, output: 2
	Mechanical vibration/ resonance suppression		• Feedforward (FF) vibration suppression control (2 levels) • Vibration control for track control • Adaptive notch filter
	Servo tuning		• Auto tuning response 40 levels • Servo tuning support function
	Start-up,monitoring, diagnosis		• Virtual motor operation • Driver recorder • Encoder/amplifier temperature monitoring • Power consumption monitoring • Encoder communication quality monitoring • Service life diagnosis (Relay and holding brake)

Table 3 Basic specifications of power supply unit

Output capacity		**37 kW**
Input voltage	**Main circuit**	380 to 480 VAC +10%, -15%
	Control circuit	24 VDC ±15%, 4.6 A (When 5 axes of amplifier units connected)
Size		180 (W) × 380 (H) × 295 (D) mm
Mass		16 kg
Mounting		Wall-mounted
Cooling system		Forced air cooling (ducted cooling)

Table 4 Basic specifications of amplifier unit

Amplifier capacity		**300 A**	**600 A**
Input voltage	**Main circuit**	457 to 747 VDC	
	Control circuit	24 VDC ±15%, 2.2 A	24 VDC ±15%, 2.6 A
Output current	**Rated output**	66 Arms	89 Arms
	Maximum	157 Arms	250 Arms
Compatible motors		Up to 30 kW	Up to 37 kW
Size		250 (W) × 380 (H) × 295 (D) mm	
Mass		20 kg	21 kg
Mounting		Wall-mounted	
Cooling system		Forced air cooling (ducted cooling)	

2.2.2 Unit configurations

This system allows multiple amplifier units and control units to be connected to a single power supply unit.

Table 5 shows the series lineup, and Figure 6 shows various system combinations.

Table 5 System lineup

Control unit	Single-axis analog	4-axis EtherCAT	Single-axis EtherCAT
	+		
Power supply unit	16 kW		37 kW
	+		

Amplifier unit	25 A	50 A	75 A	150 A	300 A	600 A
Compatible motors	Up to 2 kW	Up to 3.5 kW	Up to 5.5 kW	Up to 15 kW	Up to 30 kW	Up to 37 kW

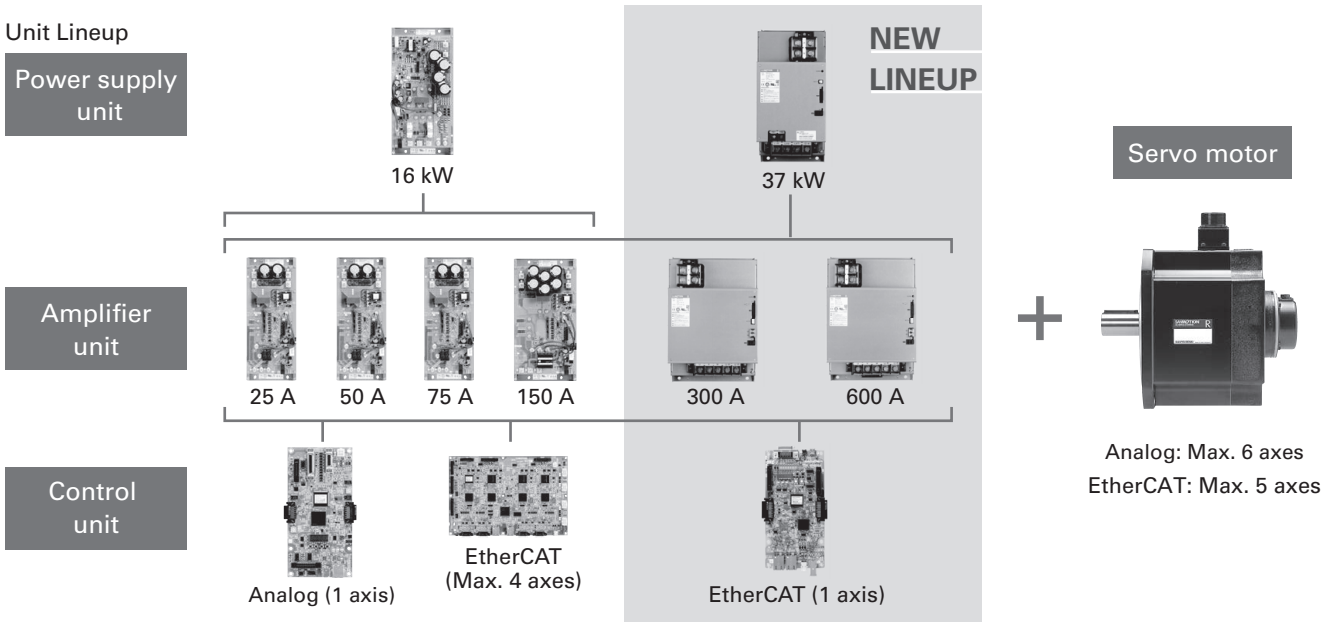

Fig. 6 System unit configurations

3. Features

3.1 Expanded lineup

By adding the 37 kW system to the lineup, we expanded the 400 VAC input multi-axis system lineup to support output capacities ranging from 550 W to 37 kW. The 37 kW power supply unit can also be combined with the existing 25 to 150 A open-frame amplifier units, as shown in Figure 7. As a result, the 400 VAC lineup is now available in comparable output variations to that of our 200 VAC multi-axis servo amplifier.

In addition, the control unit is compatible with both 200 VAC and 400 VAC systems, allowing the 200 VAC system to be replaced without changing the host controller.

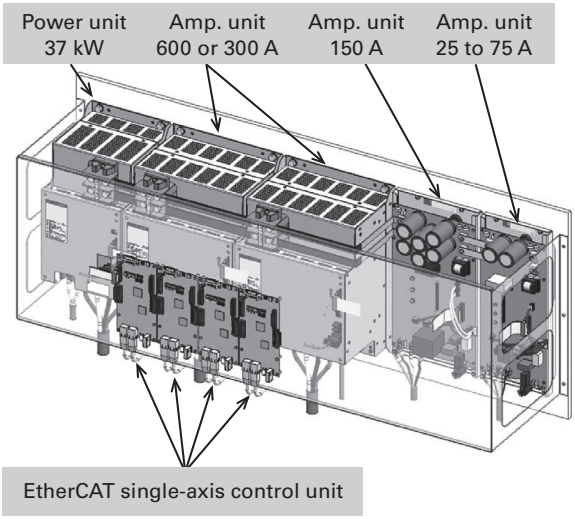

Fig. 7 System illustration

3.2 Downsizing and weight reduction

We used latest power modules in the power supply unit and amplifier unit to reduce power loss. They also use a high-performance heat sink to optimize heat dissipation. Furthermore, we achieved downsizing by using a high-density component layout.

We also reduced the number of components to reduce weight by using an integrated copper bar structure for the unit's internal wiring.

As a result, the new 600 A amplifier unit has been made smaller and lighter, achieving a 61% volume and 60% weight compared to the previous model. This realized the industry's smallest size* as a servo system to be combined with a 37 kW motor.

The downsizing and weight reduction help reduce its occupancy in customer equipment, and build more flexible layouts and downsize customer equipment.

3.3 Increased control unit performance

We newly developed a control unit designed based on the *SANMOTION R 3E Model* servo amplifier. It has better servo responsiveness and suppresses machine resonance and vibration better than the previous model, while also improving machinery productivity and processing quality. It also comes with functions for monitoring the status of power consumption and encoder communication quality and for estimating the remaining life of dynamic braking (DB) relays and holding brakes. These rich features contribute to the environmental diagnosis and preventive maintenance of machinery.

* Based on our own research as of February 2021.

4. Key Points of Development

As mentioned above, the size of the new models has been made much smaller than that of our previous models. The thermal design of a product is a key for downsizing. Also, large-capacity servo amplifiers require larger electrolytic capacitors and other components. These components must be secured with silicone rubber to suppress vibration Conventionally, it had been difficult to automate this process and often needed to be done manually. We will now introduce the key points of development and the technique we used to solve this automation challenge.

4.1 Optimal heat-dissipating structure

These servo systems are often used in the injection axis of injection molding machines.

Injection axes involve a process where melted plastic is cooled and solidified in a mold, which requires the motor to perform above its rated torque to apply pressure for over 10 seconds.

The repetition of this process significantly changes the temperature of the power module (IGBT) used in the amplifier unit, and reduces the life of the component (thermal cycle life).

As a solution to this, we optimized the heat-dissipating structure of the new models to suppress this temperature change. In particular, the thermal cycle life is significantly affected by the thermal capacity of the power module's copper base and heat sink. Recognizing this, we determined the optimal base thickness through the analysis of the temperature change in power modules by modifying the heat sink base thickness using the thermal analysis simulation shown in Figure 8. As a result, we were able to substantially reduce the size, while also securing sufficient component service life and improving the product reliability.

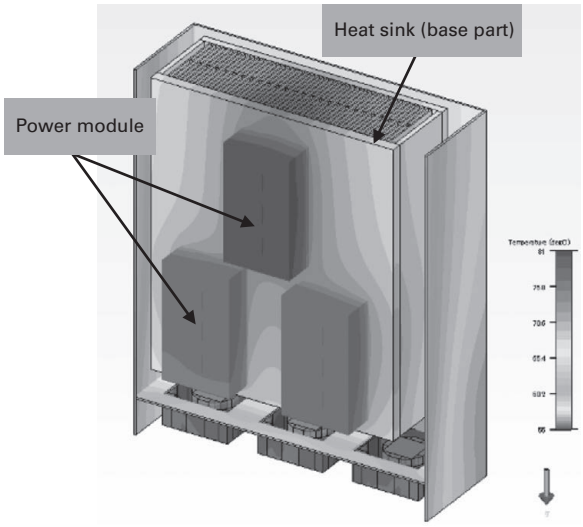

Fig. 8 Heat analysis with heat dissipation fin thickness varied

4.2 Improved fan cover

To achieve higher component density, we equipped the 600 A amplifier unit and 37 kW power supply unit with built-in cooling fans.

We also designed a new fan cover made from sheet metal as a countermeasure against intrusion of foreign objects. Compared to conventionally used filter kits, we were able to improve the airflow vs. static pressure characteristics and reduce noise levels. Moreover, since filter replacement is no longer necessary, they can be used for a long time with peace of mind.

4.3 Increased productivity and production quality

To improve productivity and quality, we have been developing production techniques using automation technology and robots.

As an anti-vibration measure, the new models use silicone rubber to secure their large snap-in aluminum electrolytic capacitors. Conventionally, the application of silicone rubber has been done by workers, resulting in inconsistencies in regard to the application area and amount of silicone rubber. For the new models, we devised a method that uses robots to do the application. By automating this process, we successfully reduced the inconsistency for improved productivity and quality.

5. Conclusion

In this article, we introduced the features and key development points of our new *SANMOTION R Model* 400 VAC input multi-axis servo systems.

(1) A 37 kW power supply unit and 300 and 600 A amplifier units were added to the lineup. Together with our previous models, we now offer an expanded lineup of 400 VAC multi-axis servo amplifiers that can drive 550 W to 37 kW output motors.

(2) We achieved significant downsizing and weight reduction by optimizing their heat-dissipating structures, adopting layouts with higher component density, and reducing the number of components. Therefore, we achieved the industry's smallest* servo system that can drive 37 kW motors.

(3) We released a control unit designed based on our *SANMOTION 3E Model* that can help achieve a higher servo responsiveness and suppress mechanical resonance and vibration better than previous products.

(4) The new models come with functions for monitoring the status of power consumption and encoder communication quality and for estimating the remaining life of components, allowing them to be used for environmental diagnosis and preventive maintenance of machinery.

We expect that the new models will help achieve space and wiring savings in machinery, while also improving productivity and processing quality.

With the addition of new models, the 400 VAC lineup now covers motor outputs ranging from 550 W to 30 kW, which is comparable to our 200 VAC multi-axis servo amplifier lineup, providing customers with an even greater choice of products for their various machinery needs.

Moving forward, we will continue developing and proposing new products that can improve customers' equipment and create value for our customers.

* Based on our own research as of February 2021.

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