Servo Systems Products Offering Value in New Fields

Yasushi Misawa Nobuo Arakawa Yoshiyuki Murata Masao Mizuguchi Yoshihiro Shoji

1. Introduction

Research and development of "service robots" is being promoted to tackle the problem of Japan's shrinking workforce and increased social insurance costs caused by a declining birthrate and aging population. Service robots are expected to advance into various applications including medical, security, nursing, welfare, and customer service. Servo Systems products used in these fields must not only be compact, lightweight, and wire-saving, but also reduce power supply voltage and power consumption while enabling multi-axis systems. Moreover, there is also a need to support a fieldbus capable of high-speed, real-time control of multiple axes, and controllers for their batch control.

This article will introduce products and systems that can be used in such fields.

2. Servo Systems Products for Service Robots

2.1 48 VDC compact 20 mm sq. AC servo motor

For the configuration of compact, lightweight, and high-output servo motors, the design must either be small-diameter, long, thin cylinder or a flat, thin disc. The compact cylindrical type is structured the same way as general servo motors, therefore the basic design is simple. However, the core, winding, and magnet must be arranged in a limited space, so some creative maneuvering was necessary to increase output and reduce loss. Meanwhile, the flat type can be designed with a large torque area, therefore high output is easily achieved; however, the motor's magnetic circuit is complicated, so we creatively arranged the core, bearings, and other components. Both types have their pros and cons but this article will introduce the *SANMOTION R* series 20 mm sq. AC servo motor as a compact cylindrical servo motor achieving high output, low loss, and weight reduction.

Figure 1 shows an external view of the compact 20 mm sq. AC servo motor, while Table 1 shows its main specifications. To increase output and minimize loss and weight, we employed coupled analysis of optimization support tools and electromagnetic field simulation to solve the conflicts between improving motor characteristics and reducing weight.

(1) High output

Through optimization of the core profile and magnet, this product has 17% higher peak torque compared to our existing product. This contributes to the size reduction and high-load drive of equipment.

(2) Low loss

By applying high-space factor winding technology in which the magnet wire is mechanically bent then inserted into the core, copper loss is significantly reduced to achieve low loss. Loss has been decreased by 34% compared to our current model. Loss reduction helps minimize temperature rise in motors, decreasing device heat emissions.

(3) Lightweight

We reduced weight by using a frame with a round cross-section and eliminating the corners of the frame which did not contribute to the magnetic path. The result was 8.5% less weight compared to the current model. A lighter motor contributes to lighter equipment.

This product can also be used in mobile service robots thanks to its 48 VDC support, and its compact, lightweight, high output, low heat generating, and power saving design.

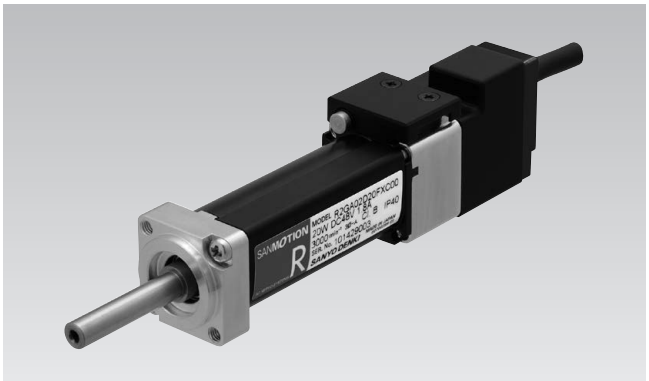


Fig. 1: Compact 20 mm sq. AC servo motor

Table 1: Main specifications of the compact 20 mm sq. AC servo motor

Model number	R2GA02D20F	R2GA02D30F
Flange size	20 mm sq.	20 mm sq.
Input power	48 VDC	48 VDC
Rated output	20 W	30 W
Rated speed	3,000 min^{-1}	3,000 min^{-1}
Maximum rotational speed	6,000 min^{-1}	6,000 min^{-1}
Rated torque	0.064 N·m	0.095 N·m
Continuous stall torque	0.064 N·m	0.095 N·m
Peak stall torque	0.23 N·m	0.38 N·m
Motor mass	0.14 kg	0.18 kg
Encoder (standard)	MA018	MA018
Encoder resolution	13 bit	13 bit
Servo amplifier model number	Pulse input, single-axis RF2G21A0A00 EtherCAT, single-axis RS2K04A2HL5 / RS2K04A2HA5 EtherCAT, multi-axis RF2J24A0HL5 / RF2K24A0HL5	

2.2 24/48 VDC, 4-axis integrated servo amplifier with EtherCAT interface

This section will introduce the 4-axis integrated servo amplifier equipped with an EtherCAT interface.

Figure 2 shows the appearance of the 4-axis integrated amplifier while Table 2 shows its main specifications. This amplifier has an input power of 24 or 48 VDC to enable battery-powered drive, therefore it can be used in mobile service robots. Also, by sharing a common power circuit, regenerative power of a motor can be used to power other motors, contributing to energy savings.

With its multi-axis design, this product has achieved 40% volume reduction and 60% weight reduction compared with four single-axis servo amplifiers. Furthermore, through common use of the power circuit and general-purpose I/O circuit, and the built-in daisy chain connection circuit for host communication, we have significantly reduced the number of power cables and cables used for I/O and communication, thus contributing to a smaller footprint. Moreover, by minimizing heat generation with built-in heat radiator fins and a cooling fan (RF2K24A only), the new product improves the device's thermal management.

From a safety perspective, Safe Torque Off (STO) function has been standardly equipped with this product. All four axes can be controlled via safety circuit. As a result, this product has been certified with a high safety level (SIL3 for IEC 61508, PL=e for ISO 13849-1) with the same 2-input/1-output design as a single axis amplifier, meaning it can be used in fields such as medical and nursing where high safety performance is required.

The fieldbus between the controller and servo amplifier is EtherCAT, which SANYO DENKI has used for some time. With a communication speed of 100 Mbps and minimum communication cycle of 125 μs, this product achieves excellent real-time performance and high-accuracy synchronization. Moreover, the position assist function can compensate the position feedback of two axes to further improve synchronization accuracy.

Fig. 2: Appearance of the 4-axis integrated servo amplifier

Table 2: Main specifications of the 4-axis integrated servo amplifier

Model number			RF2J24A	RF2K24A
Basic specifications	Mass		0.75 kg	0.8 kg
	Dimensions		200 H x 50 W x 130 D mm	
	Input power	Control power	24 VDC ±10%	
		Main circuit power	48 VDC ±10% or 24 VDC ±10%	
	Compatible motor		20 mm sq. 40 mm sq. (20 to 30 W)	20 mm sq. 40 mm sq. 60 mm sq. (20 to 200 W)
	Output limit per axis		30 W or less	200 W or less
	Total output of 4 axes		120 W or less	300 W or less
Function	Host interface		EtherCAT Minimum communication cycle: 125 µs	
	Assist function		Position assist, torque assist	
	General-purpose I/O		Inputs: 8 (common to 4 axes) Outputs: 8 (2 outputs per axis)	
	Safety functions Safety performance level		Safe Torque Off (STO) IEC 61508: SIL3 IEC 62061: SILCL3 ISO 13849-1: PL=e	

2.3 24/48 VDC, 4-axis integrated closed-loop stepping driver with EtherCAT interface

This section introduces the 4-axis integrated closed-loop stepping system equipped with an EtherCAT interface.

Our *SANMOTION Model No.PB* series closed-loop stepping system does not step-out. This system does not require complicated adjustments, therefore it is suitable for such peripherals as a robot's auxiliary axes.

Figure 3 shows the appearance of a closed-loop stepping motor and 4-axis integrated PB driver, and Table 3 provides the main specifications of the driver. The advantages of a compact and wire-saving design resulting from the 4-axis integrated structure are as stated in the servo amplifier section. In addition, as with the 4-axis integrated servo amplifier, the input power is either 24 or 48 VDC to enable the battery-powered drive. Moreover, the power supply connector and the pin arrangement are common with the servo amplifier, therefore the same harness can be used.

Previously, encoders were mounted to a stepping motor to monitor step-out, therefore the emphasis was on low cost rather than high resolution. Nowadays, however, a 16,000 P/R high-resolution incremental encoder comes as standard to achieve smooth control. Furthermore, this product supports the battery-less absolute encoder, *Model No.HA035(HA035). HA035* does not require a battery for retaining multi-turn data so it reduces maintenance while being environmentally friendly. If *HA035* is used, there is no need to wire in a limit sensors or homing sensor. Homing sequence is also unnecessary, delivering new value through short system boot times.

Customers can choose from two control types: closed-loop control and low-deviation closed-loop control. The former offers energy-saving and smooth operation, producing minimal torque, noise, and heat, making it suitable for applications that require human interaction such as medical and nursing fields. Moreover, closed-loop control systems can push at a constant force, thereby replacing a pneumatic actuator to offer further simplification of systems. Meanwhile, the low-deviation closed-loop control is suitable for applications requiring minimal position command delay, trajectory control with multiple axes and synchronized operations. By refreshing position commands with a 250 µs minimum communication cycle, and maximizing the performance of synchronous stepping motors, high-speed and accurate motion can be obtained.

Fig. 3: Appearance of a stepping motor and 4-axis integrated closed-loop stepping driver

Table 3: Main specifications of the 4-axis-in-one type PB driver

Model number			PB4D003E440
Basic specifications	Mass		0.7 kg
	Dimensions		160 H x 60 W x 95 D mm
	Input power	Control power	24 VDC ±10%
		Main circuit power	48 VDC ±10% or 24 VDC ±10%
	Compatible motor		28 mm sq. 42 mm sq. 60 mm sq.
	Compatible encoder		16000 P/R incremental encoder or absolute encoder (28 mm sq. only supports 2000 P/R incremental encoders)
Function	Host interface		EtherCAT Minimum communication cycle time: 250 µs
	Control method		Closed-loop control, Low-deviation closed-loop control
	General-purpose I/O		Inputs: 16 (4 inputs per axis) Outputs: 12 (3 outputs per axis)

2.4 The 24 VDC high-speed processing controller *SANMOTION C*

The *SANMOTION C* is a motion controller for servo-driven industrial machinery. It can control a servo amplifier and closed-loop stepping driver through a network for motion control, thereby controlling the position, speed, and torque of a servo motor and stepping motor. Furthermore, the *SANMOTION C* is equipped with a robot control function and kinematics to support various robot mechanisms, allowing customers to easily build robots themselves.

To improve the drive quality of equipment, we increased the command refresh cycle speed of servo amplifiers for smoother control. Our lineup of products enable complex operation of multiple robots by increasing the number of controllable motor axes. Moreover, with a 24 VDC input, the controller can be battery-driven, making it appropriate for mobile service robots. Additionally, we use an open network EtherCAT as the motion network therefore a different drive units can be combined and used, such as EtherCAT-compatible servo amplifiers and stepping drivers, making it possible to select and use the optimal servo system.

Figure 4 is the appearance of the *SANMOTION C* and the below section introduces its features.

Fig. 4: Appearance of high-speed processing controller *SANMOTION C*

(1) Control function

The *SANMOTION C* is equipped with PLC control, motion control, and robot control functions. The control and programming methods differ between motion control and robot control so the *SANMOTION C* supports both by having various runtime firmware and integrated development tool software to choose from depending on user's application.

(2) Motion control

By using the various standardized MFB (motion function block), anyone can write a motion control program with ease. Table 4 provides details of the motion control function.

Table 4: Motion control function

No. of controlled axes	Max. 64
Communication cycle time	1 to 8 ms
Control method	Position control (PTP), speed control, torque control
Acceleration/ deceleration method	Automatic trapezoidal acceleration/ deceleration, S-shaped acceleration/ deceleration
Unit for positioning control	Arbitrary (pulse, mm, inch, degree)
Max. command value	-2147483648 to 2147483647 (32-bit signed)
Programming language	Complies with IEC 61131-3 (IL, ST, LD, FBD, SFC, CFC)
Motion function block	Homing, incremental mode, absolute mode, constant speed mode, electronic cam, electronic gear

(3) Robot control

By supporting kinematics for various mechanisms and by using original robot language, robot orientation and TCP (tool center point) position can be controlled. Table 5 provides details of the robot control function

Table 5: Robot control function

No. of controlled axes (for each robot)	Max. 9 (6-axis articulated robot＋additional 3 axes)
Communication cycle time	2 to 8 ms
Control method	PTP, 3D linear, 3D circular
Teaching method	Remote teaching, numeric input
Unit for positioning control	Arbitrary (pulse, mm, inch, degree)
Programming language	Original robot language
Supported robot	Cartesian coordinate robot, horizontal articulated robot, vertical articulated robot, parallel link robot, etc.

(4) Processing performance

The high-speed, high-accuracy control of multiple peripheral control devices such as control machinery and multi-axis robots is possible with just one controller unit, making equipment smaller and faster motion. Moreover, finer and smoother motion of equipment is achieved thanks to high trajectory accuracy during positional control and synchronization control of the cam, etc. As a concrete example of high-speed processing performance, Table 6 shows the control performance when combined with one of our servo amplifier equipped with an EtherCAT interface is connected.

- Basic command processing time:
  The shortest processing time for basic commands (floating point arithmetic commands) is 11 ns.
- Maximum no. of controlled axes:
  Up to 64 axes can be controlled.
- Multiple robot control:
  Capable of driving up to two 6-axis articulated robots.

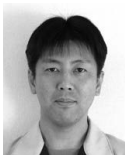
Table 6: Control performance when combined with our servo amplifier equipped with an EtherCAT interface

Control performance	**Communication cycle time**	**Product model**	
		SMC263X	**SMC265X**
Basic command processing time	—	18 ns	11 ns
Max. no. of controllable axes	**4 ms**	64	64
	2 ms	32	64
	1 ms	16	32
No. of controlled robots (6-axis articulated robots)	**8 ms**	2 units	2 units
	4 ms	1 unit	2 units
	2 ms	—	1 unit

3. Conclusion

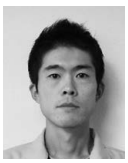
This article has introduced the 48 VDC compact 20 mm sq. AC servo motor, 24/48 VDC EtherCAT interface-equipped 4-axis integrated servo amplifier, 4-axis integrated PB driver, and the 24 VDC high-speed processing controller *SANMOTION C* as Servo Systems products offering value to the “service robot” field, where advancements have been made in R&D.

These products are suitable for “service robots” thanks to their compact, lightweight, wire-saving, and power-saving design, their support of multi-axis systems, and their standardized power supply voltage allowing everything from the servo motor to the controller to be battery-driven. SANYO DENKI believes that Servo Systems products with a common concept can create new value for our customers’ equipment and system development as well as contribute to the development of high-quality products.



Yasushi Misawa
Joined SANYO DENKI in 1999.
Servo Systems Div., Design Dept. 1
Works on the development and design of servo motors.

Nobuo Arakawa
Joined SANYO DENKI in 1982.
Servo Systems Div., Design Dept. 2
Works on the development and design of controllers.



Yoshiyuki Murata
Joined SANYO DENKI in 1995.
Servo Systems Div., Design Dept. 2
Works on the development and design of servo amplifiers.

Masao Mizuguchi
Joined SANYO DENKI in 1998.
Servo Systems Div., Design Dept. 2
Works on the development and design of stepping drivers.

Yoshihiro Shoji
Joined SANYO DENKI in 2006.
Servo Systems Div., Design Dept. 1
Works on the development and design of encoders.