SANYO DENKI

Technical Report

Feature | Expand into Wider Markets in Depth

1984
Aoki Works

54
November
2022

COLUMN

Cover image:

Aoki Works

1984

The office automation market, which expanded in the 1970s, was even more robust in the 1980s. The electronics industry was growing rapidly with many ambitious capital investments, and production could not keep up with the increase in demand.

SANYO DENKI also put efforts to strengthen its production capacity and newly built and opened Aoki Works in 1984. The factory was designed to accommodate a complete production line of stepping motors and used state-of-the-art equipment of the time.

Aoki Works was built in response to the Aoki village's efforts to attract companies to the area, which is located on the west side of Shioda-daira, also known as “Kamakura of Shinshu”. Conveniently located about 12 km from our then-Ueda Works, it was a world-class, cutting-edge factory at that time.

It is currently named Logistics Center and still plays an important role in the company.

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November 2022

C O N T E N T S

“Broad, Deep” Value Created Together with People

Satoru Onodera Operating Officer

Based on our corporate philosophy of “We at SANYO DENKI Group Companies aim to help all people achieve happiness, and work with people to make their dreams come true,” we have provided products and services that contribute to people’s happiness.

We offer the following three product brands: *San Ace* for Cooling Systems products, *SANUPS* for Power Systems products, and *SANMOTION* for Servo Systems products. These three share a common characteristic. That is, they are all energy converting and controlling devices. With the Cooling Systems products, cooling fans convert electrical energy into fluid energy. With the Power Systems products, UPSs convert electrical energy into higher-quality electrical energy. Lastly, the Servo Systems products convert electrical energy into mechanical energy.

The value of these energy converting devices lies in the energy conversion efficiency. Therefore, we have been committed to develop and provide our customers with products that are more efficient, compact, lightweight, and low-noise.

Conventionally, our products have been used in a relatively narrow range of applications. For example, our cooling fans have focused on contributing to the cooling of factory automation and ICT equipment, as well as data center servers. Our UPSs have been used in applications that require stable power.

And the Servo Systems products have been optimally customized to each customer for use in industrial robots, semiconductor manufacturing equipment, machine tools, and injection molding machines. In this way, we have been working closely with each customer to provide the most suitable customized products for their manufacturing applications.

However, in addition to manufacturing applications, our products are now getting more widely used; for example, in medical equipment such as CT scanners and in analysis equipment such as PCR testing equipment and gas chromatographs. Recently, our linear servo motors have been used in remote control systems for cell culture pipetting. We believe that our products will contribute to wider range of applications in the future.

To achieve this, we not only need to expand the scope of target applications and markets but also to create "new value." The key of creating new value is co-creation where we work with all the people involved.

For example, by combining the strengths and core technologies of customers and suppliers with those of our own, we will be able to create new meaning, new significance, and new value for society.

At SANYO DENKI, we specialize in fluid technology for creating smooth wind flow, technology for cleaning and controlling power, and servo technology for running and stopping motors as intended. We also specialize in customization, which we have developed over many years. To deliver optimal custom designs tailored to each customer, we need to gain a deep understanding of our customers. Delivering optimal custom solutions to our customers can be achieved by gaining a deep understanding of the issues faced by our customers, the problems they seek solutions to, and a clear image of "how they wish things to be." We also specialize in production technology for efficiently producing high-quality products.

By further deepening these strengths, tackling new challenges, and engaging in co-creation with all those involved, we hope our products will make greater contributions in wider markets.

In this issue, we will be introducing our products and services that we hope will penetrate "wider markets in depth."

We will be introducing products and technology developed through understanding and working together with our customers as well as striving to be of benefit to people.

With these technologies, products, and services, SANYO DENKI will continue to contribute "broadly and deeply" to the health and safety of people, preservation of the global environment, and use of new, eco-efficient energy sources.

SANYO DENKI offers energy converting devices under three product brands of *San Ace*, *SANUPS*, and *SANMOTION*. We hope that these products of ours will continue to contribute greatly in our customers' equipment by delivering high-quality, efficient energy.

Expand into Wider Markets in Depth

Michinori Watanabe

1. Introduction

SANYO DENKI's Cooling Systems Division has been developing and offering fans chiefly for the purpose of cooling the inside of equipment. Starting with AC fans, we developed brushless DC fans responding to changing market trends, and now we also offer ACDC fans, which are brushless DC fans that can be powered by AC power by internally converting AC power to DC power.

Conventionally, our fans have mainly been used in information and communication equipment such as in servers and ICT equipment. As this equipment has become smaller in size and higher in performance, cooling fans have been required to offer better performance—high airflow, high static pressure, and low power consumption. In response to this, we have developed new products using new technology.

These products have come to be used in various fields and applications in which fans had not previously been used. Also, new demands started to emerge, requiring new kinds of fans that support recent social and environmental trends, which we have not offered previously.

This article discusses the markets in which our cooling fans and related products have conventionally been used, as well as potential new markets into which we expect to expand in the future.

2. Our Conventional Markets

Here we introduce the conventional target markets for and the technology used in our Cooling Systems products.

2.1 Markets for high-performance fans

Conventionally, our fans have mainly been used in information and communication equipment such as in servers and ICT equipment. The popularization of technologies such as the Internet and mobile phones has led to an increase in capacity and speed of ICT equipment. As a result, this equipment has become sophisticated and smaller in size, becoming denser and generating more heat. In the early days of this market, high airflow of cooling fans had been in strong demand. However, as the heat generation of equipment increased, it has become increasingly necessary to develop "high-performance fans" featuring not only high airflow but also high static pressure to cool equipment more efficiently. Moreover, fans with less power consumption had also been demanded for preserving the global environment and lowering equipment running costs.

For example, 1U servers are the mainstream in the server market. Because of their small size, 1U (44.45 mm) servers typically use 40 × 40 mm brushless DC fans. Today's 1U servers are extremely dense inside and generate high heat, requiring fans with high airflow and high static pressure performance.

In response, we used to meet the required performance by using our old product developed in 1990s as a base and improving its speed by revising its drive circuit. However, simply increasing the fan speed was not enough to achieve the required airflow performance nor was it optimal power consumption-wise.

Fan performance is determined by (1) aerodynamic performance of the impeller and frame, (2) motor performance, and (3) drive circuit performance. It is therefore important to optimize each fan component so that these three performance parameters are increased with the overall balance of parameters also optimized.

To achieve higher static pressure, we formed the frame spokes (parts securing the motor to frame) located behind the impeller (rotor blades) into a blade-like shape (stator blades), which proved to be effective. With 40 × 40 × 28 mm axial fans, for example, we have offered the 9GV type (2008), 9GA type (2012), 9HV type (2015), and 9HVA type (2020) with progressive improvements in performance responding to the market demand at the time. Figure 1 shows the

change in product performance. Our latest 9HVA type fan delivers approximately 3.3 times higher maximum airflow of 1.05 m³/min and approximately 22.4 times higher maximum static pressure of 2300 Pa compared to our first product for 1U servers (9P type: 109P0412H3013).

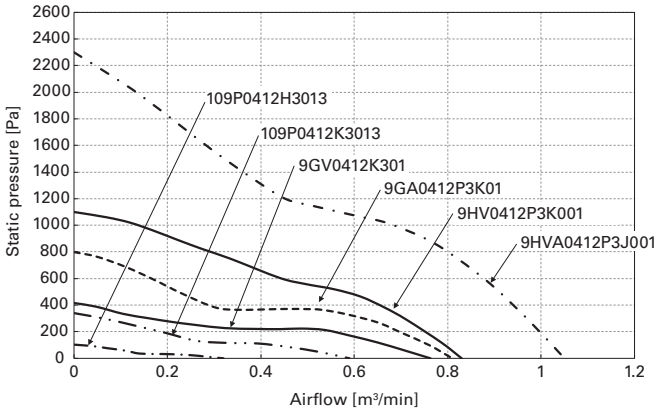

Fig. 1 Airflow vs. static pressure characteristics of our 40 × 40 × 28 fans

One way of achieving even higher static pressure is placing two fans in series, but the impact of the airflow discharged by the inlet fan with the rotor blades of the outlet fan causes a great loss, and therefore static pressure cannot be increased effectively. To resolve this issue, we newly developed a Counter Rotating Fan, where two fans rotating in opposite directions to each other are combined in series. This enabled us to significantly improve airflow characteristics. We have developed and offered 40 × 40 × 56 mm Counter Rotating Fans: the first one is the 9CR type in 2004, and followed by a few models, the 9CRH type in 2017 and 9CRJ type in 2020. Figure 2 shows a Counter Rotating Fan and its impellers. The 9CRJ type fan delivers approximately 1.5 times higher maximum airflow of 1.06 m³/min, and approximately 4.7 times higher maximum static pressure of 2400 Pa compared to the 9CR type, the first of the Counter Rotating Fan series.

As stated above, we have met high airflow and high static pressure requirements for information and communication equipment such as servers and ICT equipment, contributing to the development of this equipment. In short, we have pursued higher fan performance for use in relatively limited markets and applications, and therefore our fans have been used in and focused on a narrow range of markets.

Recent years, however, the use of such high-performance fans featuring high airflow, high static pressure, and low power consumption is not limited only to the ICT equipment market, and they are now being used in various applications where strong winds need to be sent in tight spaces.

The use of such fans has been growing particularly in the energy field, such as in solar power generation systems, storage batteries, fuel cells, fast EV chargers, and lithium-ion battery charge/discharge test equipment, expanding from the conventional narrow markets to wider markets.

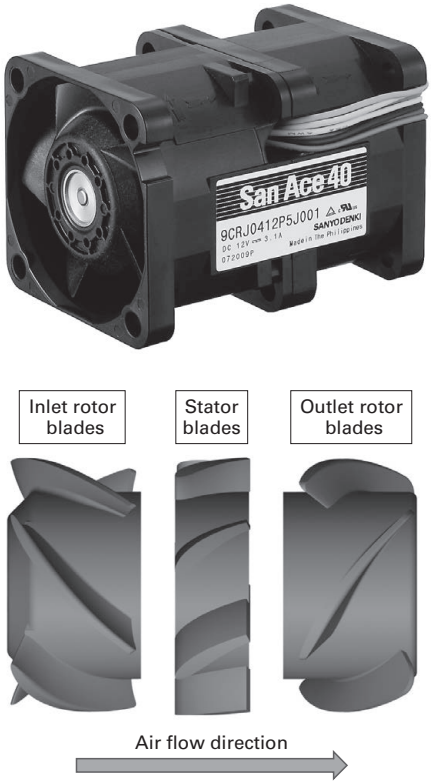

Fig. 2 Structure of our 40 × 40 × 56 mm Counter Rotating Fan

2.2 Markets for Splash Proof Fans

The first Splash Proof Fans were developed for cooling cellular base stations and launched in 1996. Cellular base stations are installed outdoors, and fans for cooling them require not only cooling performance (high airflow and high static pressure) but also environmental durability (water and temperature resistance) and long-term reliability. In response to these requirements, we have developed a series of Splash Proof Fans, which have contributed to the development of 3G, 4G, and 5G mobile communication networks.

Our Splash Proof Fans feature IP55, IP56, or IP68-rated water protection* as standard. As shown in Figure 3, protection from water intrusion is ensured by completely covering electrical live parts including the coil and circuit with highly water-resistant material. Moreover, components exposed to outside air including the magnet and frame employ highly water-resistant materials, and antirust treatment is done on the surface.

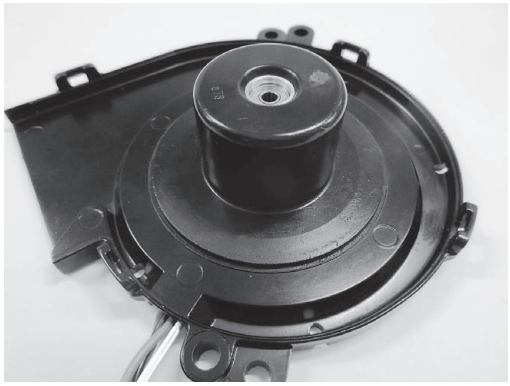

Fig. 3 Our Splash Proof Fan's live parts protection

* IP55/IP56/IP68 ingress protection rating
The degree of protection (IP code) is defined by IEC (International Electrotechnical Commission) 60529 "Degrees of Protection Provided by Enclosures (IP Code)."

Since around 2010, Splash Proof Fans have been adopted not only in conventional cellular base stations but also in new applications such as PV inverters, fast EV chargers, and digital signage. As with cellular base stations, these devices are installed outdoors and therefore require both cooling performance and environmental durability. We have met this demand by developing cooling fans featuring high airflow, high static pressure, and water protection, which contributed to the environment as high-performance fans are high-efficiency energy converting devices and environmentally friendly.

As described above, with water protection added to high airflow and high static pressure, our Splash Proof Fans have previously been employed mainly in applications for cooling equipment installed outdoors. They have pursued the high performance required in these limited applications, and their use has been limited to and focused on the narrow markets.

Recently, however, their use has been increasing in equipment installed indoors and also for non-cooling purposes as follows. The following applications use Splash Proof Fans because exposure to water is inevitable, but as they are non-cooling applications, high airflow or high static pressure is not necessarily required.

(1) Food manufacturing equipment:
This equipment needs to be kept clean, and fans are exposed to water when washing it. Therefore, Splash Proof Fans are required.
During a food processing using flour, fans are used to shake off excess flour or batter, which requires appropriate airflow and control of air direction.

(2) Plant cultivation equipment:
Splash Proof Fans are used as continuous operability in high humidity environments is required.
Appropriate airflow and control of air direction are required to circulate air uniformly inside equipment.

In this way, the application range of our Splash Proof Fan is not limited to outdoor equipment but has been expanding.

3. Expected Future Markets and Required Technology

Moving forward, companies are and will be expected to offer products and services that take environmental aspects into consideration, and achieving carbon neutrality is now a major challenge for the entire world.

The following sections will be introducing IoT-based preventive equipment maintenance and air purifier markets, which are expected to grow in the future.

3.1 For achieving carbon neutrality

Like many countries, Japan has declared its intention to "achieve carbon neutrality (net-zero emissions of greenhouse gases) by 2050."

To make our Cooling Systems products compliant with carbon neutrality, we currently believe that pursuing low power consumption is the most effective way to go regardless of the application. It is expected that demand for low power consumption will be more and more strong in the future. For our fans, we intend to achieve even higher-performance fans with lower power consumption by improving the three performance metrics mentioned in section 2.1.

Moreover, we will help customers achieve low power consumption by expanding our fan lineup with the addition of PWM control models enabling optimum control of fan speed according to the amount of heat generated by equipment, we are helping customers reduce the amount of power consumed by their equipment by expanding our lineup of fans equipped with a speed control function using PWM control.

3.2 Markets for IoT-based preventive facility maintenance

There has been a market demand for a device featuring remote control and status monitoring of fans for preventive equipment maintenance and efficient cooling and ventilation with various sensors combined. In response to this, we developed and launched the *San Ace Controller*, an

IoT-based product.

Figure 4 shows an example system configuration of the *San Ace Controller*.

It enables remote control of fans for efficient cooling of equipment, contributing to the aforementioned reduced equipment power consumption. Moreover, measurement data and alarm history generated during status monitoring can be downloaded to a computer, and this data can be used not only for equipment preventive maintenance but also for new product development and defect analysis. This can contribute to stable equipment operation, helping make equipment even safer and more reliable.

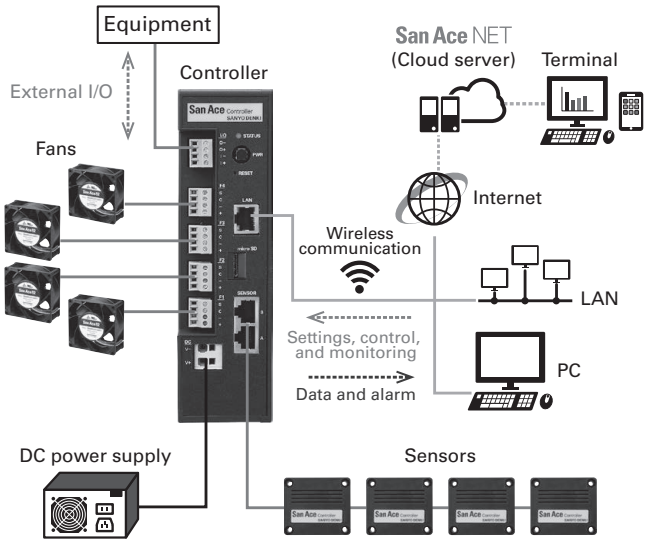

Fig. 4 *San Ace Controller* system configuration example

3.3 Markets for air purifiers

In recent years, demand for air purifiers has been growing in response to worsening air pollution and the spread of COVID-19, and the market for these products has been booming.

Conventionally, SANYO DENKI had had only limited involvement with this market by only providing fans to some air purifier manufacturers. However, by leveraging our expertise in fan technology and know-how in high-efficiency air flow channel design, we made the decision to develop and commercialize our own air purifiers for this market.

The air purifier we developed is shown in Figure 5. This air purifier is capable of delivering high airflow of 16.5 m^3/min and cleaning a large 127 m^2 space in only 30 minutes. Noise produced during operation is a mere 54 dB(A), and only 90 W of power is consumed.

For details, please refer to the article on this product in this Technical Report.

Fig. 5 *San Ace Clean Air* 9AP type air purifier

4. Conclusion

This article introduced past and current target markets for our cooling fans and related products, and discussed our expected future markets and technologies.

We have conventionally focused on increasing the performance demanded by the information and communication equipment markets. In recent years, however, the high-performance products we've developed have found new opportunities in a variety of fields and applications: such as in the energy field, typified by solar power generation, and for non-cooling purposes in food manufacturing equipment.

We have also released new kinds of products leveraging our specialty technology and know-how, such as IoT-based products for equipment preventive maintenance and the air purifier that use our fans.

Applications for our fans have expanded from the previous "narrow markets in depth" where we pursued high performance in specific markets to "wider markets in depth" by targeting a wide variety of fields leveraging our technical expertise, as well as new fields where demand for fans is emerging.

We intend to continue identifying more new market needs for our products and contributing to solving our customers' problems in wider markets by developing new technologies and new products.

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San Ace Clean Air 9AP Type Air Purifier

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1. Introduction

Amid heightened awareness of measures to prevent infection due to the spread of COVID-19, there has been growing demand for the use of air purifiers in large spaces of public facilities such as hospitals and city halls where many people gather.

Conventionally, air purifiers on the market have either been very large ones requiring installation work, or compact, portable ones for household use. Both have their downsides: the installation of large air purifiers to existing facilities is quite a hassle, and compact purifiers do not offer sufficient capacity for commercial applications. Against such a background, SANYO DENKI leveraged its accumulated general fan expertise and high-efficiency air flow channel design expertise to develop an easily installed, portable *San Ace Clean Air* 9AP type air purifier capable of purifying the air in large rooms.

This article introduces the performance and features of this new product, as well as the key points of development.

2. Product Overview

The new product is an air purifier with low noise and high airflow that can filter, sanitize, and deodorize the air in large rooms.

It boasts high dust removal performance using high efficiency particulate air (HEPA) filters and high airflow thanks to its two built-in dedicated Centrifugal Fans that we newly developed using our proprietary low noise technology. In addition to high airflow, low noise and low power consumption have also been achieved by employing an air flow channel design which draws in polluted air from both sides of the product and discharges cleaned air from the top.

The product is also equipped with sanitization and deodorization capabilities. Excellent deodorizing capability has been achieved with a two-pronged approach: an activated carbon filter for absorbing odor molecules and a photocatalyst for decomposing them. With HEPA filters and photocatalyst filter, it sanitizes the air and reduces airborne viruses, bacteria, and molds.

Moreover, the product has a slim profile and is equipped with casters, allowing it be moved around easily and be installed in existing facilities, despite being capable of delivering high airflow.

Figures 1, 2, and 3 show views of the product, and Figure 4 shows its dimensions.

Fig. 1 Appearance
San Ace Clean Air 9AP type

Fig. 2 Operating panel enlarged view for *San Ace Clean Air* 9AP type

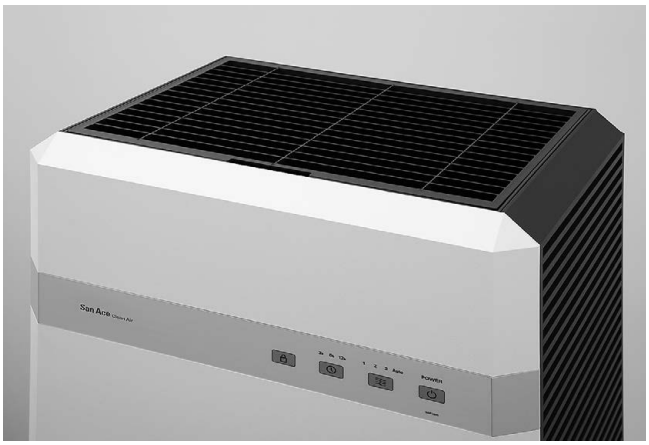

Fig. 3 Outlet duct

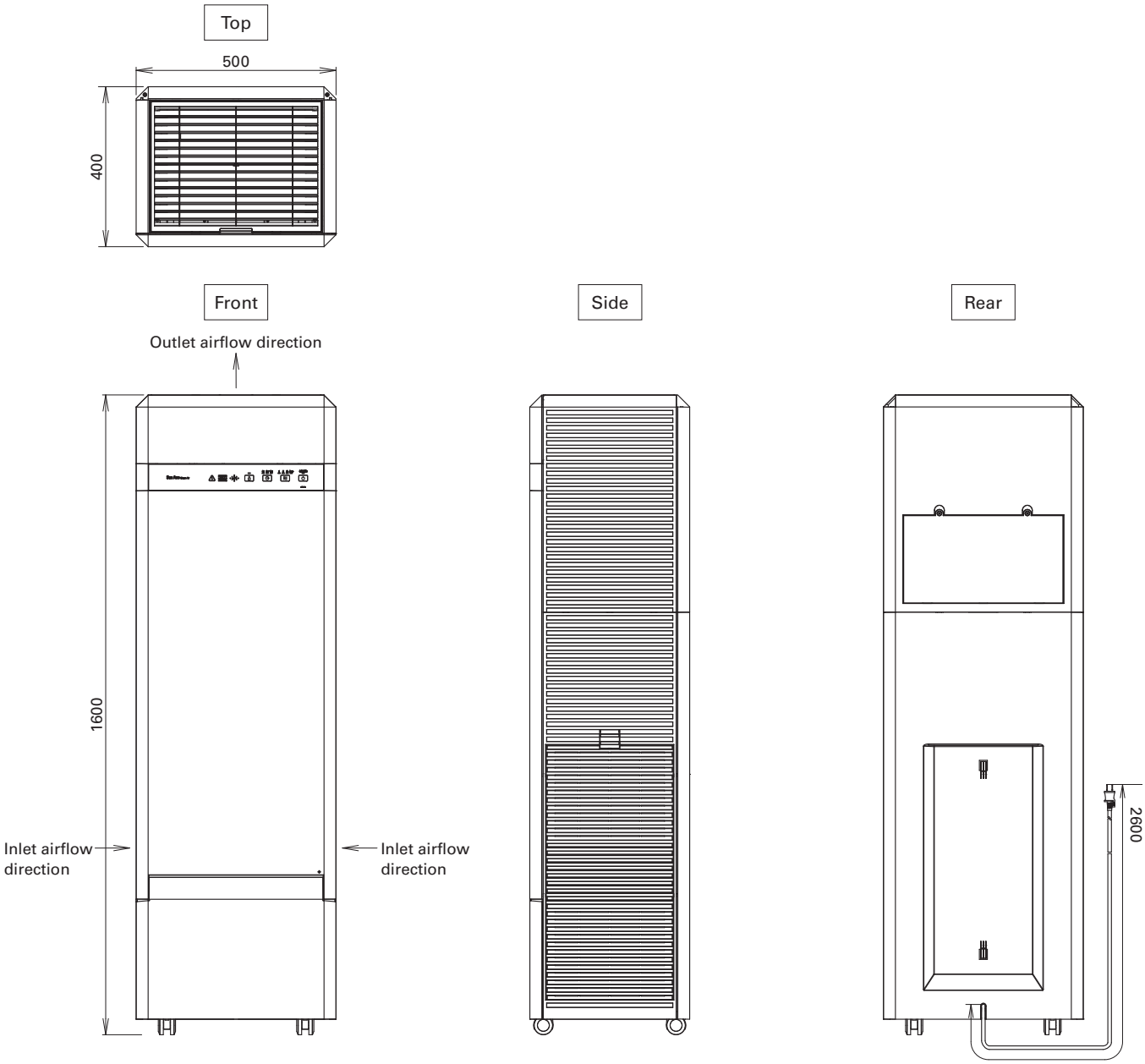

Fig. 4 Dimensions of *San Ace Clean Air* 9AP type (Unit: mm)

3. Product Features

3.1 High airflow, low noise, and low power consumption

The product is capable of delivering high airflow of 16.5 m^3/min and thereby cleaning a large room of 127 m^2 in only 30 minutes when run in operation mode 3 (High).[1] Moreover, noise produced during operation is a mere 54 dB(A), and only 90 W of power is consumed.

To realize high airflow, an in-house developed, dedicated large centrifugal fan was employed inside for circulating air, and the product has two of these fans placed in parallel. Furthermore, dust removal filters are installed on both sides of the product to secure a large air inlet. Also, we designed an efficient air flow channel for guiding air from the side inlets to the top of the unit using fluid analysis simulations to achieve high airflow, low noise, and low power consumption. Figure 5 shows the flow of air inside the product, and Figure 6 shows the fluid analysis results.

The product has a dust sensor and odor sensor inside it. The automatic mode achieves even lower noise and power consumption by detecting air contamination levels with these two sensors and optimizing airflow from the range of 3.2 to 16.5 m^3/min according to the contamination level detected.

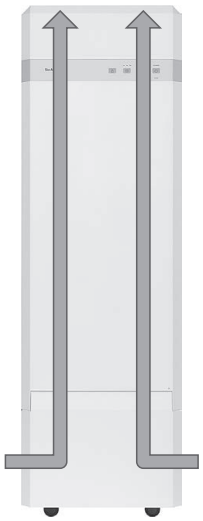

Fig. 5 Internal air flow

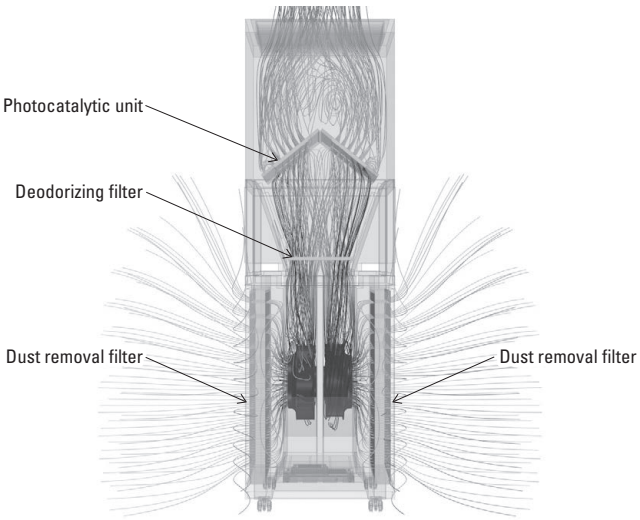

Fig. 6 Fluid analysis results

3.2 Efficient air circulation

The product employs a design that draws in contaminated air from both sides and discharges cleaned air from the outlet at the top. The discharged air will be dispersed along the ceiling, providing ideal air circulation in the room.

To achieve this ideal air circulation, the outlet height and louver angle were optimized using simulations.

3.3 High dust removal performance

The dust removal filter employs a high-efficiency particulate absorbing (HEPA) filter. A HEPA filter is capable of removing over 99.97% of fine particles of 0.3 μm or larger from the air.[2] Figure 7 shows the dust removal filter.

We secured a large filtration area by installing HEPA filters on the left and right sides, realizing high airflow. This large filtration area means that it takes a long time for filters to become clogged, which increases maintainability. The product is also equipped with a sensor for detecting the clogging in filters.

Fig. 7 Dust removal filter (pre-filter + HEPA filter)

3.4 Deodorization and sanitization

In addition to HEPA filters, the product also has an activated carbon filter for absorbing and deodorizing odor particles. Figure 8 shows the deodorizing filter.

The activated carbon filter is capable of reducing a high concentration of odor, such as cigarette smoke, by half in 30 minutes.[1].

Also, the product has a photocatalytic filter. With the surface of the photocatalytic filter irradiated by ultraviolet light, the photocatalytic coating on the filter surface gets oxidized, which decomposes contaminants like bacteria and viruses into CO_2 and water, sanitizing and deodorizing the air drawn into the air purifier. Figure 9 shows a photocatalytic unit.

Combination use of the HEPA filters and photocatalytic unit ensures the removal of over 99% of contaminants such as bacteria and viruses.[3]

Fig. 8 Deodorizing filter (activated carbon filter)

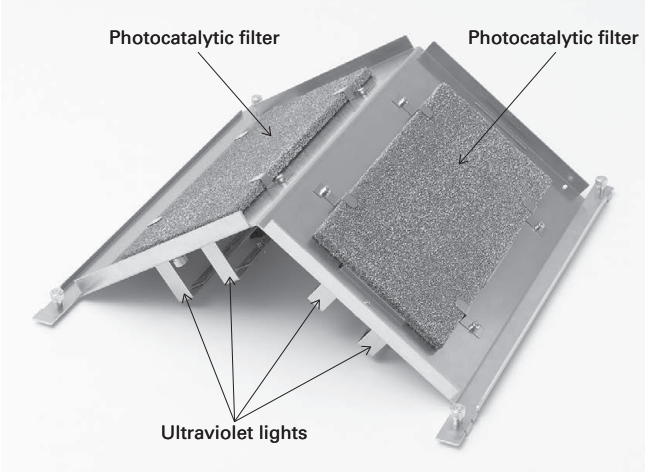

Fig. 9 Photocatalytic unit
(photocatalytic filters + ultraviolet lamps)

4. Specifications

Table 1 shows the specifications of the product.

Table 1 Specifications of the new product

Suitable airflow can be selected from four operation modes: 1 [Low], 2 [Medium], 3 [High], and [Auto].

Model no.	9AP1600-1
Dimensions [mm]	500 (W) × 400 (D) × 1600 (H)
Mass [kg]	40
Power supply	Single-phase 100 V (50/60 Hz supported)
Power cord length [m]	2.6
Room coverage	Up to 127 m^2*

* Calculated by the test method based on the JEMA's JEM 1467 standard.

Operation mode	1 [Low]	2 [Medium]	3 [High]	Auto
Airflow [m^3/min]	3.2	10.5	16.5	Built-in sensors detect dust and odors to automatically select the optimal operation mode.
Power consumption [W]	18	28	90	
Noise level [dB(A)]	30	45	54	

Sensor	Dust, odor
Dust removal	HEPA filter
Sanitization, deodorization	Photocatalytic filter, deodorizing (activated carbon) filter
Functions	Auto-off timer (3/6/12 hours), key lock function (disables all buttons except the power off to prevent accidental button presses)

4.1 Operation modes

The product features 3-speed operation modes, which deliver airflow in Low, Medium, and High levels, and an automatic operation mode linked to internal sensors. The airflow levels can be set in a wide range from 3.2 to 16.5 m^3/min, and the Low operation mode runs quietly with only 30 dB(A) noise.

5. Conclusion

This article introduced some of the features and performance of the *San Ace Clean Air* 9AP type air purifier for commercial use.

Incorporating SANYO DENKI's accumulated fan technology and new technology has made it possible to develop the high-airflow air purifier capable of cleaning the air in large rooms. Against the background of increasing air pollution and the spread of COVID-19, we believe that

this product can contribute greatly to society's demand for clean air.

We will continue to help our customers create new value by providing products that promptly address market demand.

(1) Calculated by the test method based on the Japan Electrical Manufacturers' Association (JEMA) standard, JEM 1467.
(2) This is the filtration performance of the filter and not about the filtration of the entire room.
(3) This effect was confirmed in a closed test space of 25 m^3 as per JEMA's JEM 1467 standard and not in actual practice.

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40 × 40 × 20 mm and 40 × 40 × 28 mm *San Ace 40W* 9WPA Type High-Performance Splash Proof Fans

Yuto Horiuchi Koji Ueno Yukihiro Nagatsuka Masaki Kodama

Kenya Horiuchi Sho Matsushita Hiromitsu Kuribayashi

1. Introduction

In recent years, outdoor equipment such as base stations, quick EV chargers, and surveillance cameras is becoming more compact and sophisticated in design and increasing in density, generating more heat. This has raised demand for compact splash proof fans with better performance.

Previously, SANYO DENKI has proposed its compact splash proof fans—40 × 40 × 20 mm 9WP type and 40 × 40 × 28 mm 9WL type Splash Proof Fans—but nowadays increasingly more cases are requiring higher performance.

In response to this demand, we newly developed and launched a *San Ace 40W* 9WPA type Splash Proof Fan in 40 × 40 × 20 mm and 40 × 40 × 28 mm sizes (hereinafter, new 20 mm thick models and 28 mm thick models) offering the industry's highest(1) airflow and static pressure.

This article introduces the features and performance of these new models.

(1) Based on our own research as of June 28, 2022, conducted among equally-sized splash proof fans on the market.

Fig. 1 40 × 40 × 20 mm *San Ace 40W* 9WPA type

2. Product Features

The new 20 mm and 28 mm thick models are compatible in frame size and mounting with our current 40 × 40 × 20 mm *San Ace 40W* 9WP type and 40 × 40 × 28 mm *San Ace 40W* 9WL type fans, respectively, while achieving higher airflow, higher static pressure, and lower power consumption.

Figures 1 and 2 show the new models.

Fig. 2 40 × 40 × 28 mm *San Ace 40W* 9WPA type

The new models' structural features are as follows.

(1) Electrical live parts (windings and circuits) are coated with highly water-resistant material. Figure 3 shows how it looks.
(2) Each pair of the new and current models has compatibility in frame size and mounting, and the new models use a highly environmental durability resin material in the frame and blades.

Fig. 3 Coating of electrical live parts
(New 28 mm thick model)

3. Product Overview

3.1 Dimensions

Figures 4 and 5 show the dimensions of the new models.

3.2 Characteristics

Table 1 to 4 shows the specifications of the product and Figures 6 to 13 show the airflow vs. static pressure characteristics of the new models.

Rated voltages of 12 V and 24 V are available to support operation in a wide range of applications. The new models are available in high-speed (G speed) and low-speed (H speed) models.

The G-speed models have a PWM control function. This function controls fan speed according to the heat generation inside equipment to keep the cooling performance optimized at all times, enabling low power consumption and low noise.

The new models have an expected life of 40,000 hours at 60°C (survival rate of 90%, run continuously at rated voltage and normal humidity in free air).

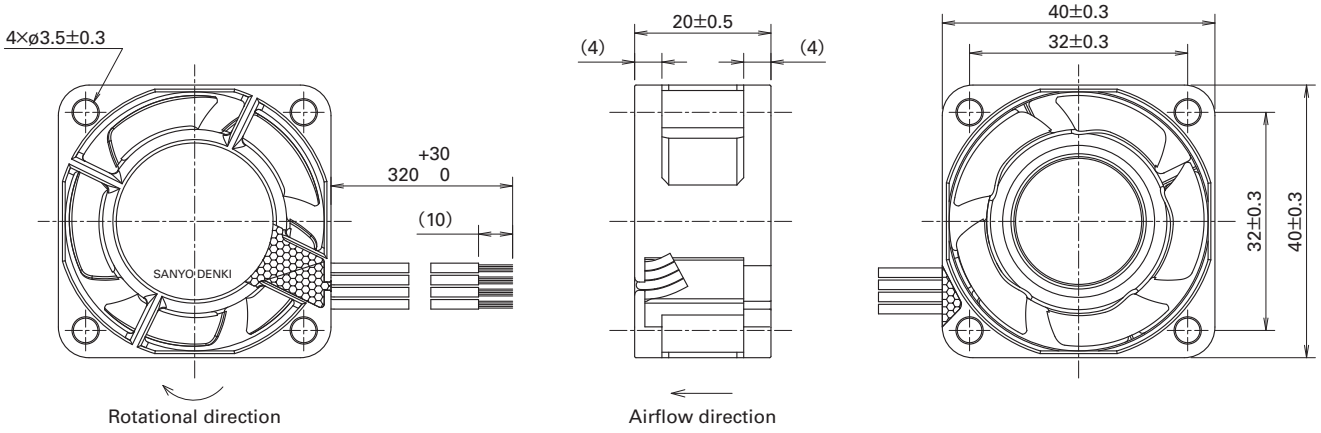

Fig. 4 Dimensions of 40 × 40 × 20 mm *San Ace 40W* 9WPA type (Unit: mm)

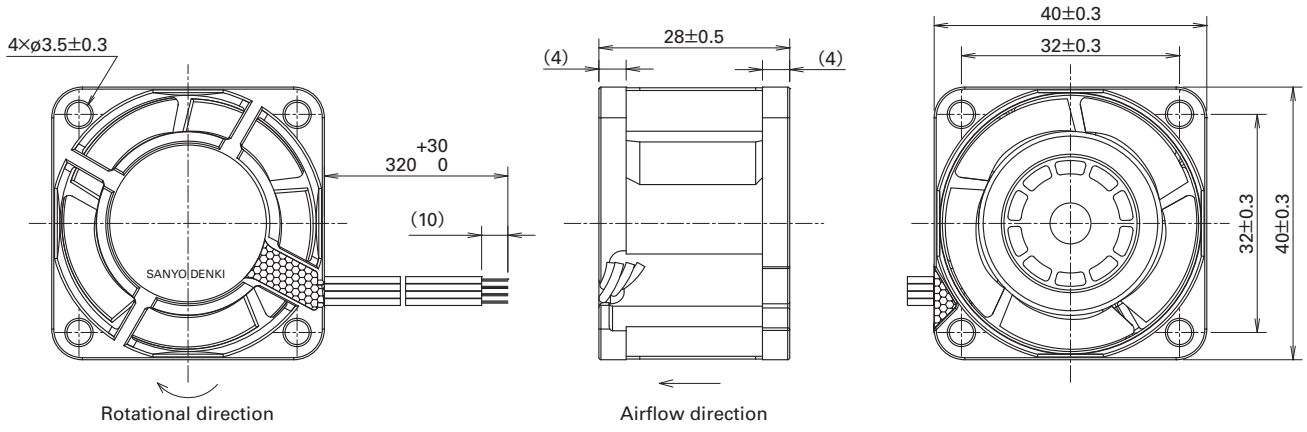

Fig. 5 Dimensions of 40 × 40 × 28 mm *San Ace 40W* 9WPA type (Unit: mm)

Table 1 General specifications of 40 × 40 × 20 mm *San Ace 40W* 9WPA type high-speed model

Model no.	Rated voltage [V]	Operating voltage range [V]	PWM duty cycle* [%]	Rated current [A]	Rated input [W]	Rated speed [min^{-1}]	Max. airflow [m^3/min]	Max. airflow [CFM]	Max. static pressure [Pa]	Max. static pressure [inchH$_2$O]	Sound pressure level [dB(A)]	Operating temperature range [°C]	Expected life [h]
9WPA0412P6G001	12	10.8 to 13.2	100	0.17	2.0	13700	0.38	13.4	210	0.84	44	-20 to +70	40000 at 60°C (70000 at 40°C)
			25	0.03	0.36	3000	0.07	2.5	9.8	0.04	12		
9WPA0424P6G001	24	21.6 to 26.4	100	0.09	2.0	13700	0.38	13.4	210	0.84	44		
			25	0.03	0.72	3600	0.09	3.2	15	0.06	14		

* Input PWM frequency: 25 kHz. Speed is 0 min^{-1} at 0% PWM duty cycle.

Table 2 General specifications of 40 × 40 × 20 mm *San Ace 40W* 9WPA type low-speed model

Model no.	Rated voltage [V]	Operating voltage range [V]	Rated current [A]	Rated input [W]	Rated speed [min^{-1}]	Max. airflow [m^3/min]	Max. airflow [CFM]	Max. static pressure [Pa]	Max. static pressure [inchH$_2$O]	Sound pressure level [dB(A)]	Operating temperature range [°C]	Expected life [h]
9WPA0412H6001	12	7 to 13.8	0.075	0.9	8800	0.24	8.5	81	0.33	34	-20 to +70	40000 at 60°C (70000 at 40°C)
9WPA0424H6001	24	14 to 27.6	0.038									

Table 3 General specifications of 40 × 40 × 28mm *San Ace 40W* 9WPA type high-speed model

Model no.	Rated voltage [V]	Operating voltage range [V]	PWM duty cycle* [%]	Rated current [A]	Rated input [W]	Rated speed [min^{-1}]	Max. airflow [m^3/min]	Max. airflow [CFM]	Max. static pressure [Pa]	Max. static pressure [inchH$_2$O]	Sound pressure level [dB(A)]	Operating temperature range [°C]	Expected life [h]
9WPA0412P3G001	12	10.8 to 13.2	100	0.50	6.0	22200	0.63	22.2	555	2.22	53	-20 to +70	40000 at 60°C (70000 at 40°C)
			20	0.06	0.72	5000	0.14	4.9	28.1	0.11	21		
9WPA0424P3G001	24	21.6 to 26.4	100	0.25	6.0	22200	0.63	22.2	555	2.22	53		
			20	0.06	1.44	9200	0.26	9.1	95	0.38	34		

* Input PWM frequency: 25 kHz. Speed is 0 min^{-1} at 0% PWM duty cycle.

Table 4 General specifications of 40 × 40 × 28 mm *San Ace 40W* 9WPA type low-speed model

Model no.	Rated voltage [V]	Operating voltage range [V]	Rated current [A]	Rated input [W]	Rated speed [min^{-1}]	Max. airflow [m^3/min]	Max. airflow [CFM]	Max. static pressure [Pa]	Max. static pressure [inchH$_2$O]	Sound pressure level [dB(A)]	Operating temperature range [°C]	Expected life [h]
9WPA0412H3001	12	7 to 13.8	0.34	4.1	18500	0.52	18.3	375	1.51	48	-20 to +70	40000 at 60°C (70000 at 40°C)
9WPA0424H3001	24	14 to 27.6	0.17									

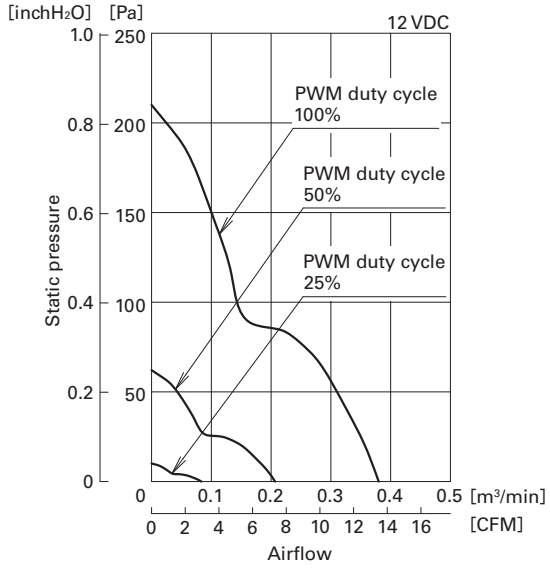

Fig. 6 Airflow vs. static pressure characteristics of 40 × 40 × 20 mm *San Ace 40W* 9WPA type 12 V, high-speed model

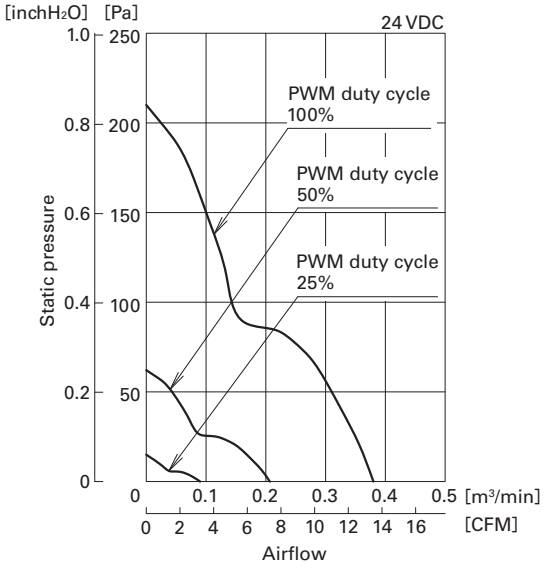

Fig. 7 Airflow vs. static pressure characteristics of 40 × 40 × 20 mm *San Ace 40W* 9WPA type 24 V, high-speed model

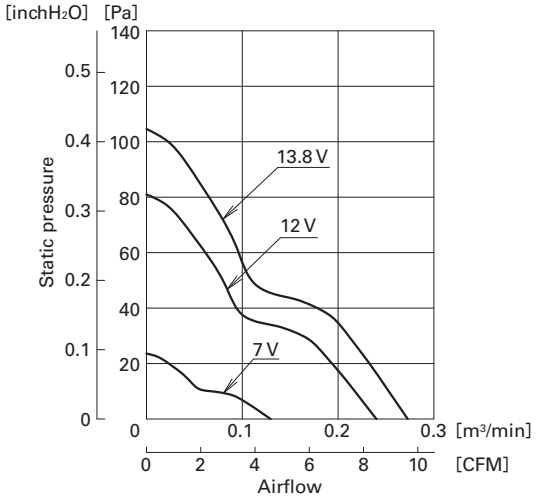

Fig. 8 Airflow vs. static pressure characteristics of 40 × 40 × 20 mm *San Ace 40W* 9WPA type 12 V, low-speed model

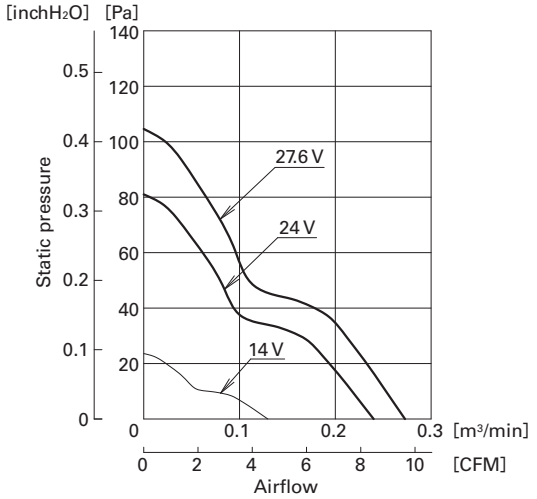

Fig. 9 Airflow vs. static pressure characteristics of 40 × 40 × 20 mm *San Ace 40W* 9WPA type 24 V, low-speed model

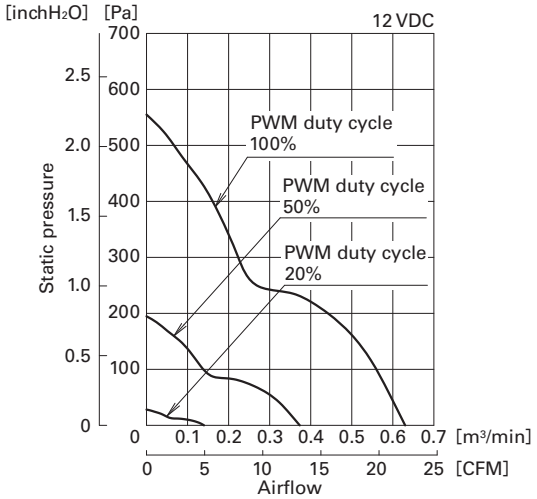

Fig. 10 Airflow vs. static pressure characteristics of 40 × 40 × 28 mm *San Ace 40W* 9WPA type 12 V, high-speed model

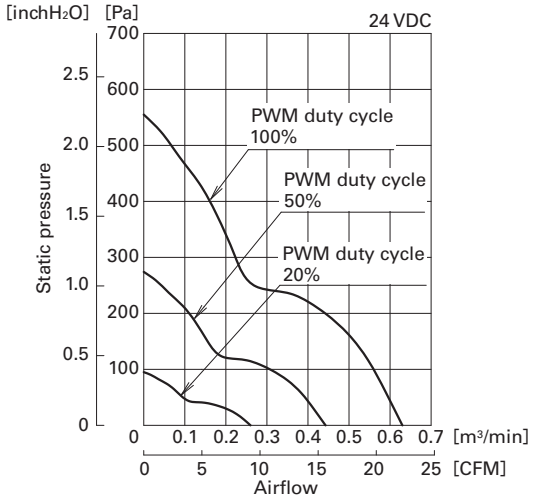

Fig. 11 Airflow vs. static pressure characteristics of 40 × 40 × 28 mm *San Ace 40W* 9WPA type 24 V, high-speed model

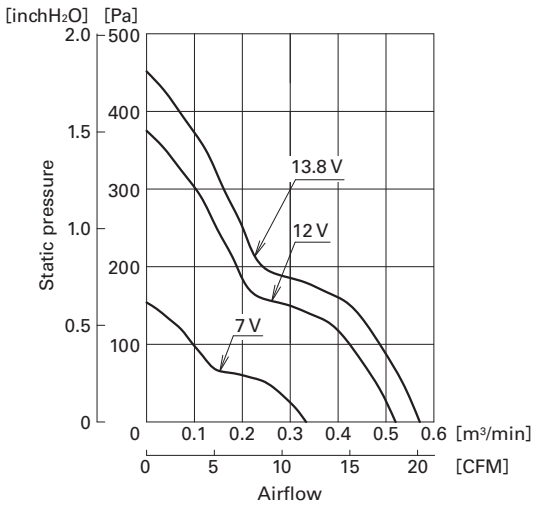

Fig. 12 Airflow vs. static pressure characteristics of 40 × 40 × 28 mm *San Ace 40W* 9WPA type 12 V, low-speed model

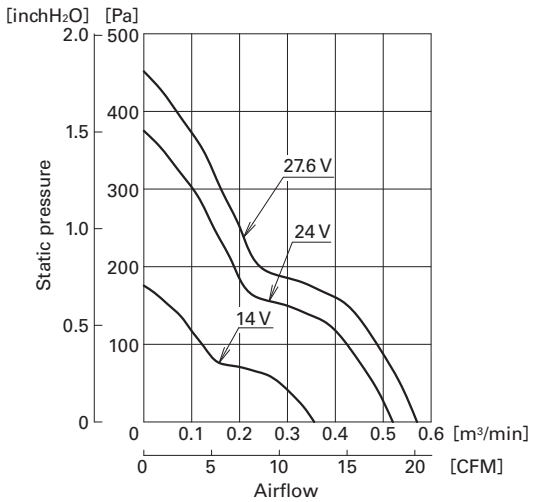

Fig. 13 Airflow vs. static pressure characteristics of 40 × 40 × 28 mm *San Ace 40W* 9WPA type 24 V, low-speed model

4. Comparison of New and Current Models

4.1 Comparison of airflow vs. static pressure characteristics

Figures 14 and 15 show a comparison of airflow vs. static pressure characteristics for the new and current models.

Compared to the current 9WP type model, the new 20 mm thick model achieves 69% higher maximum airflow and 220% higher maximum static pressure.

Compared to the current 9WL type model, the new 28 mm thick model achieves higher static pressure across all operating ranges and 38% higher maximum static pressure.

5. Key Points of Development

The new models use a high-efficiency motor for faster speed, and frame and blades are newly designed and thereby achieve significantly higher airflow, higher static pressure, and lower power consumption than the current models. The new models also feature high IP68-rated water and dust protection.(2) From the early phase of development, the design team put an effort in making manufacturing productivity as high as possible in addition to improving fan performance and reliability.

The key points of development are described below.

(2) IP68 ingress protection rating
The degree of protection (IP code) is defined by IEC (International Electrotechnical Commission) 60529 "Degrees of Protection Provided by Enclosures (IP Code)."

5.1 Structural design

The resin material most suitable for the product specifications was selected for the frame, and the frame shape was designed to deliver faster speed.

The fan blades were made strong enough for faster speeds and designed to achieve high airflow and high static pressure.

To achieve water and dust protection, all electrical live parts were covered with a highly water-resistant resin coating. Moreover, both reliability and productivity were secured by devising the optimal coating shape and thickness.

5.2 Motor and circuit

By optimizing the motor and its drive system for individual voltages and speeds, we successfully developed a high-efficiency motor with reduced heat generation from the motor and its circuit. As a result, the new 20 mm and

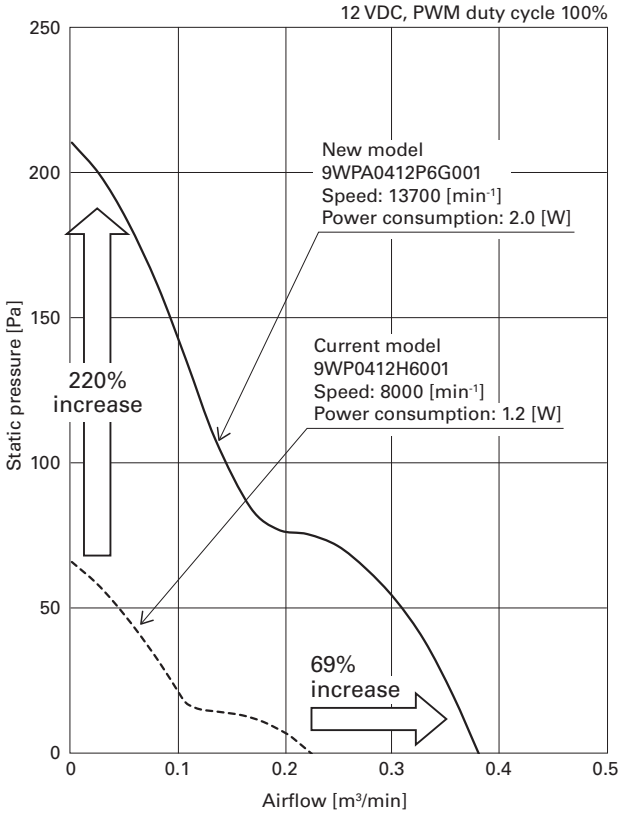

Fig. 14 Comparison of new 40 × 40 × 20 mm *San Ace 40W* 9WPA type with current model

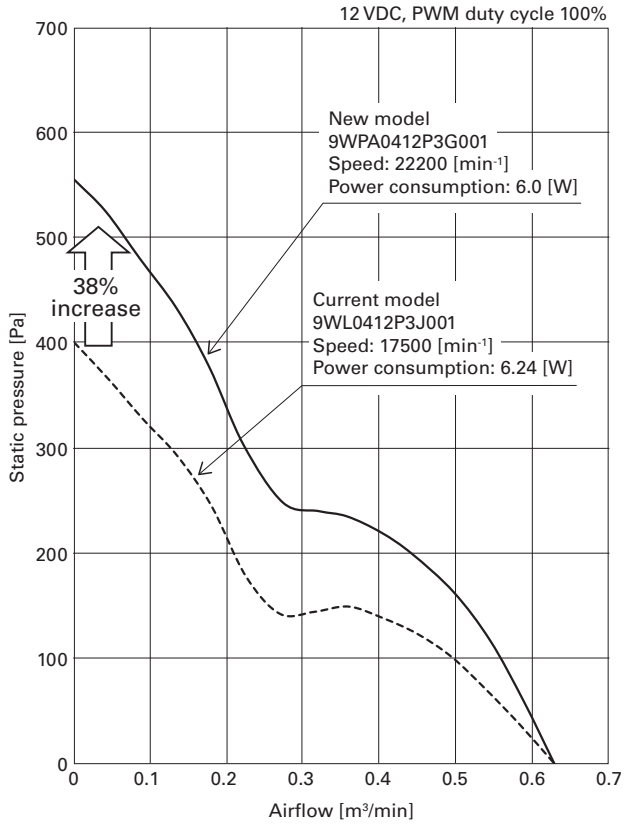

Fig. 15 Comparison of new 40 × 40 × 28 mm *San Ace 40W* 9WPA type with current model

28 mm thick models are 1.5 times and 1.3 times faster than the current models, respectively, and both achieve reduced power consumption.

As an example, Figure 16 provides a comparison of power consumption for new and current 40 × 40 × 20 mm models at equivalent cooling performance. Compared to the current model, the new model boasts 37% lower power consumption.

Also, compared to the current model, the new model offers higher static pressure and consumes less power across all operating ranges.

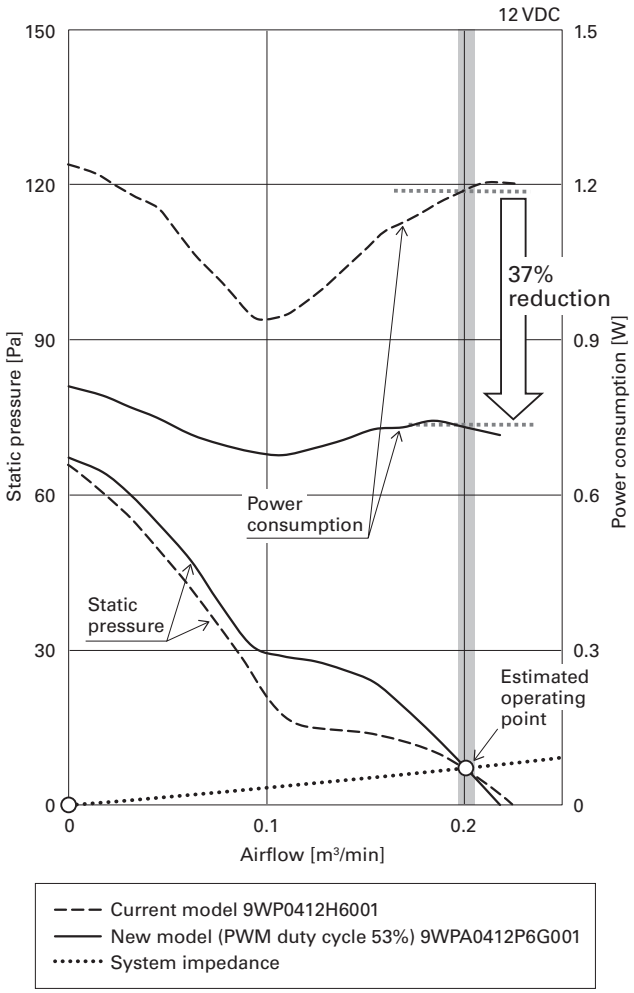

Fig. 16 Comparison of new 40 × 40 × 20 mm *San Ace 40W* 9WPA type with current model at equivalent performance

6. Conclusion

This article introduced the features and performance of the 40 × 40 × 20 mm and 40 × 40 × 28 mm *San Ace 40W* 9WPA type high-performance Splash Proof Fans offering the industry's highest(3) airflow and static pressure.

Compared with the current models, the new models achieve remarkably higher airflow, higher static pressure, and lower power consumption. With these features, we believe that the new models will greatly contribute to outdoor equipment such as base stations, quick EV chargers, and surveillance cameras which requires higher cooling performance and energy efficiency than ever before.

We will continue developing products in response to various market needs. In particular, we plan to continue offering products in a timely manner which contribute to the creation of new value for our customers to help make their dreams come true.

(3) Based on our own research as of June 28, 2022, conducted among equally-sized water-resistant fans on the market.

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High-Performance, High-Reliability UPSs Operable in Various Environments

Chiaki Seki

1. Markets Where UPS is Needed

Use of an uninterruptible power supply (hereinafter, "UPS") had once been limited to special applications but has now become common. Nowadays, for example, UPSs are used in a wide variety of applications such as telecommunications equipment, factory equipment, store equipment, and office equipment, and they are used in many countries. Therefore, UPSs today are required to operate safely even with variations in environmental and power supply conditions.

Also, market demand for more efficient power supply equipment has been increasing in response to increasing initiatives for achieving carbon neutrality by 2050.

Besides, customers focus on the role of a UPS of supplying continuous power efficiently, and they expect UPSs with high added value features such as long life, high efficiency, high reliability, and ease of maintenance.

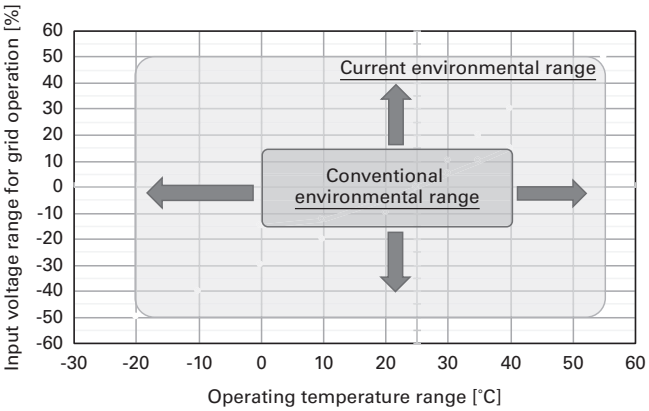
SANYO DENKI's Power Systems Division has been developing and offering UPSs up to customer satisfaction by supporting various installation and power supply environments and improving functionality and performance. This article introduces some of our UPSs in the following sections.

2. Demand for UPSs Supporting Various Operating Environments

As stated above and also shown in Figure 1, UPSs are now required to support a wider range of installation and power supply environments.

UPSs were previously used in limited locations where the temperature was controlled, but recently, they have been installed in environments with insufficient temperature control or poor power quality. Moving forward, UPSs must therefore operate stably in an environment with a wider range of temperatures.

Regarding the power supply conditions, there are regions and countries where grid power is unstable. Even in Japan, the voltage at the end of a power system within the same building may become unstable due to the operation of various equipment. In summary, UPSs are required to keep running on grid power in a wider voltage range.



Note 1: The range extension varies by product.
Note 2: Each product has its own operating conditions and restrictions.

Fig. 1 Change of UPS installation environments

3. Functionality, Performance, and Reliability Required of UPS

On the other hand, we must further reduce the environmental impact of our products to preserve the global environment and achieve carbon-neutral society. The same goes for UPSs and other power supply equipment, and customer requirements won't be met unless we continue to deliver even higher efficiency and longer service life.

Besides, a UPS system must be highly reliable, scalable, and maintainable to ensure a continuous power supply, which is the primary role of a UPS. In addition, customers have demanded less maintenance so that they can focus on providing their own service without being distracted, which can be achieved by using LIB (lithium-ion battery). Figure 2 shows major UPS features required by customers.

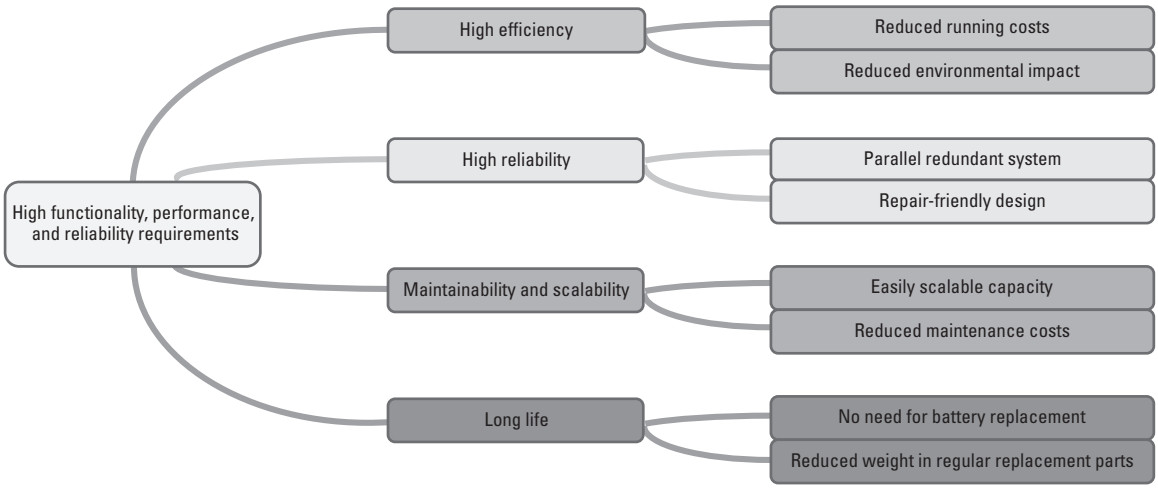


Fig. 2 Functionality, performance, and reliability required of UPS

4. *SANUPS A11K-Li* and *E11B-Li*

The UPSs shown in Figures 3 and 4, in addition to supporting a wider range of operating and power supply environments, offer high efficiency and LIB advantages of longer life and lower running and maintenance costs.

The *SANUPS A11K-Li* is a double conversion online UPS that can supply high-quality power. This UPS has single-phase 100 V input/output voltage, and its lineup is available in output capacities of 1, 1.5, 2, 3, and 5 kVA. It is suitable for power backup of computers and servers.

Fig. 3 *SANUPS A11K-Li* 1.5 kVA model

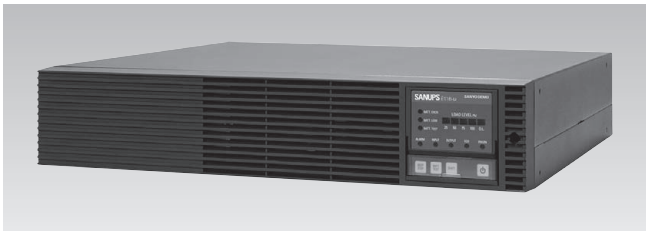


Fig. 4 *SANUPS E11B-Li* 1 kVA model

The *SANUPS A11K-Li* features a wide operating temperature range and can be used at temperatures of -20 to +55°C. The UPS tolerates -40% to +20% deviations from the rated input voltage, and the frequency tolerance can be set by users between ±1% and 7% of the rated input frequency.

In addition, the LIB enables long-term backup while also reducing size and weight.

The *SANUPS E11B-Li* is a hybrid UPS. The lineup is available in single-phase input/output voltages of 100 and 200 V and output capacities of 1, 1.5,[(1)] and 2 kVA, making it a highly versatile UPS that can be used worldwide.

Its hybrid topology features two operation modes: Double Conversion mode offering high-quality power and Economy mode offering high efficiency, which can be set by users according to the operating environment.

When the setting is fixed to Double Conversion mode, the inverter always supplies high-quality power. During Automatic setting, the UPS switches automatically between Double Conversion mode and Economy mode depending on the state of the input power, achieving both high-quality power and high efficiency.

The *SANUPS E11B-Li* features a wider operating temperature range and can operate safely at temperatures of -10 to +55°C. For example, this UPS can be used in extremely hot or cold regions and in buildings without air-conditioning. As for power conditions, the UPS tolerates a wide input voltage range of 55 to 150 V (100 V models) or 110 to 300 V (200 V models) and a wide input frequency range of 40 to 120 Hz. These wide ranges reduce the number of transfers to battery operation and battery wear, supplying stable power to the load even in regions where grid power is unstable and voltage and frequency fluctuate greatly.

UPSs using lead-acid batteries require battery replacement every 5 years, but both *SANUPS A11K-Li* and *SANUPS E11B-Li* use LIBs, which have an expected battery life of approximately 10 years. As the expected life of the UPS unit is also 10 years, maintenance work such as battery replacement will not be required during its service life, reducing maintenance costs for customers.

(1) 1.5 kVA model is available for 100 V only.

5. *SANUPS A11N, A11M,* and *A11M-Li*

The UPSs shown in Figures 5 to 7 cover a wide range of temperature and power conditions and features high efficiency, capacity scalability by combining multiple units, high reliability with parallel redundant operation, and high maintainability with easy addition and replacement of units.

The *SANUPS A11N* is available in two types: a single unit type that has a single 5 kVA base unit with AC output outlets on the back of the unit or a parallel connection type that comes with a power distribution unit and is scalable up to 20 kVA by combining up to four base units in parallel.

The input/output voltage can be set to single-phase 200, 208, 220, 230, or 240 V, making this UPS suitable for use not only in Japan but also in global markets.

Moreover, by using a power distribution unit with a transformer, it can also connect to single-phase 100 V systems or single-phase 3-wire systems.

At full load level, the UPS tolerates input voltage ranging from -20% to +15% of the rated voltage. At low load levels, the UPS can handle a wider -40% to +15% range of input voltage and maintain power supply without switching to battery operation. In addition, by setting to Fixed Frequency mode, the UPS tolerates input frequency ranging from 40 to 120 Hz and supplies 50/60 Hz out power. These wide input voltage and frequency ranges allow the product to be used even in regions with unstable power supply.

Also, when Fixed Frequency mode is selected, the asynchronous startup allows power to be supplied with an output frequency of 50/60 Hz regardless of the local frequency.

The *SANUPS A11M/A11M-Li*, developed based on our *SANUPS E11B/E11B-Li* and featuring the double conversion online topology, offer scalable capacity and parallel redundant operation by combining multiple units. By combining 1 kVA UPS units in parallel, the output capacity can be scalable up to 8 kVA.

Maintaining the *SANUPS E11B/E11B-Li*'s support for wide-ranging operating and power conditions, they can be used with peace of mind in a wide range of temperatures.

Fig. 5 *SANUPS A11N* 5 kVA model, single-unit type (mounted in a rack)

Fig. 6 *SANUPS A11N* 20 kVA model, parallel connection type

Fig. 7 *SANUPS A11M* 8 kVA model (mounted in a rack)

They can be used with little transfer to battery power and minimal battery wear even in regions where grid power supply is unstable and voltage and frequency change drastically while supplying stable, high-quality power to the load thanks to the double conversion online topology.

Also, like the *SANUPS E11B-Li*, the *SANUPS A11M-Li* uses LIBs, which eliminate the need for battery replacement during the product's expected life of 10 years, reducing maintenance work and costs for customers.

The *SANUPS A11N* and *SANUPS A11M/A11M-Li* all use "fully autonomous control" for parallel operation control, which synchronizes each unit's voltage amplitude, phase, and frequency as well as controls the cross current and load sharing between units. This makes it possible to disconnect only the failed units during the parallel redundant operation as shown in Figure 8, providing a highly reliable power supply as well as easy expansion and replacement of units.

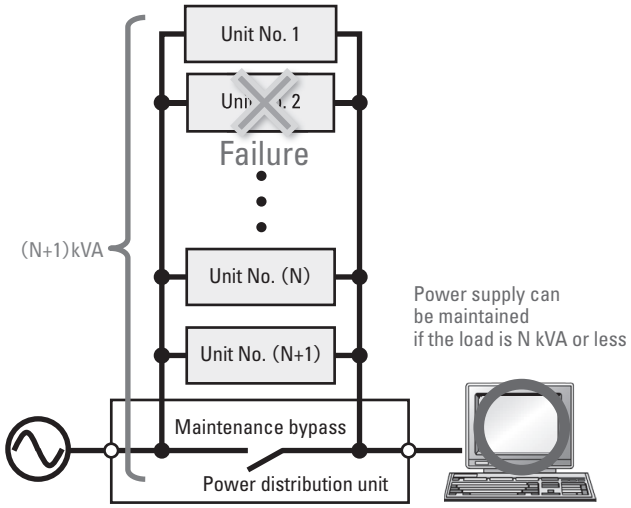


Fig. 8 Parallel redundant system with *SANUPS A11N, A11M(-Li)*

6. *SANUPS A23D*

This product is shown in Figure 9 and supports a wide range of power supply environments, offers high efficiency, and helps minimize running and maintenance costs by using less regular replacement parts.

The *SANUPS A23D*, the successor to our *SANUPS A23C* double conversion online UPS, supports 3-phase 3-wire 200 V systems and offers higher efficiency and functionality. The lineup is available in output capacities of 30, 50, 75, and 100 kVA. The input voltage range is normally 200 V ±15% for 200 V output, but if the load level is 60% or less, the UPS can support an extended range with the lower limit changed to -30%, making it ideal for power backup in buildings with relatively large power supply fluctuations.

The *SANUPS A23D* has also improved the rectifier and inverter control to reduce switching losses and increase efficiency, achieving higher conversion efficiency over the predecessor.

This has resulted in an industry-leading[(2)] conversion efficiency of over 94% (up to 95.6%), which suppresses power consumption and heat generation, reducing running costs and CO_2 emissions.

The *SANUPS A23D* comes with a new "walk-in feature" as standard. Some applications where an uninterrupted, long-term power supply is needed in the event of a power failure require an emergency power supply system combining an emergency generator with a UPS. With this system, power is first supplied from batteries when grid power fails, meanwhile, the AC input of the UPS switches from the grid power to the generator output. After that, the generator will power the connected facilities via the UPS.

If there is a sudden increase in the UPS's AC input during the switchover to the generator, the generator output voltage will fluctuate. If this fluctuation is large, the UPS will detect an AC input error and transfer back to battery power. To keep the fluctuation low, a generator with extra capacity would be required. The walk-in feature provides a solution for this by ensuring that the UPS gradually receives power from the generator. This function reduces output voltage fluctuations of the generator during power restoration, allowing customers to build economic emergency power supply systems by not requiring extra capacity of a generator.

Fig. 9 *SANUPS A23D* 100 kVA model

The expected product life is the same 15 years as the current product, during which some parts need to be replaced periodically. By reviewing the parts selection and improving efficiency, the electrolytic capacitors and cooling fans, which are the main replacement parts, do not need to be replaced for 15 years. This reduces replacement time and costs, thereby reducing maintenance work and costs for customers.

(2) Based on our own research as of March 10, 2022, conducted among UPSs on the market with the same topology and equivalent voltage, capacity, and backup time.

7. Conclusion

SANYO DENKI will continue to offer power supply equipment such as UPS that can be used safely even in harsh environments to meet customer expectations and contribute to a low-carbon society.

In addition, we will endeavor to develop new technologies to introduce higher quality power supplies into new fields that require operations in unusually severe environments.

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Development of the *SANUPS A23D* Online UPS

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Takuya Ota Shohei Ohashi Minoru Yanagisawa Mika Takehara

1. Introduction

The growth of the information society has led to an increase in various information and ICT equipment such as servers for data centers, and outages of such equipment can have a significant impact on society. An uninterruptible power supply (hereinafter, "UPS") has become essential as a backup power source for such equipment. In recent years, with the shift to smart factories, measurement data obtained from IoT and sensors has been leveraged more and more at production sites. However, unstable power supply conditions may result in corrupted data, which can cause a significant impact on product quality. To avoid such risk, UPSs have been increasingly used in production facilities. As described above, UPSs are used in various locations and are required to be highly reliable in supplying power to mission-critical applications. Also, demand for more efficient power supply equipment has been increasing in response to the increase of initiatives for achieving carbon neutrality by 2050.

To meet such demands, SANYO DENKI developed the high-efficiency, high-performance *SANUPS A23D* as the successor to the *SANUPS A23C*[1] double conversion online UPS (hereinafter, "current product"). This article introduces the features of this new product.

2. Product Overview

The newly developed *SANUPS A23D* is available in four models with output capacities of 30, 50, 75, and 100 kVA. Figure 1 shows the appearance of the 100 kVA model and Figure 2 shows a basic circuit configuration of the *SANUPS A23D*. Under normal power conditions, the new product, with its double conversion online topology, converts AC power (grid power) into DC power internally. The converted DC power is then divided into two: one of them charges the UPS battery, and the other is converted back to AC power via the inverter and supplies power to electrical equipment. The double conversion online topology is highly reliable as power is always supplied through the inverter. In the event of a power outage, it doesn't need to switch power sources and provides an uninterrupted power supply without causing voltage fluctuations.

This UPS also features bypass startup where power is supplied from the bypass circuit when the inverter stops, which reduces the possibility of system downtime even if the product fails and its inverter stops.

Fig. 1 *SANUPS A23D* 100 kVA model

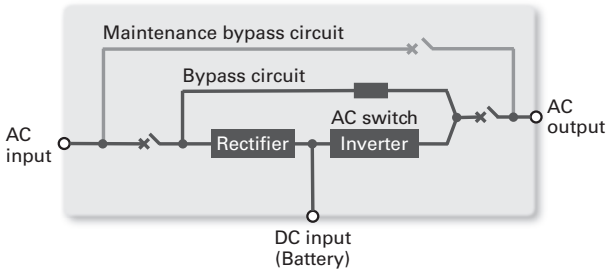

Fig. 2 Basic circuit configuration

3. Features

3.1 High efficiency

To further improve the efficiency of the current product, a 2-phase modulation was used in the rectifier and inverter control system. This 2-phase modulation stops switching devices sequentially in phase order in approximately 1/6 the cycle of the input/output frequency, leading to reduced switching loss and improved efficiency. However, when shifting between the switching devices to stop, a large fluctuation will occur at the neutral point shown in Figure 3. Moreover, if the rectifier and inverter control timings are not synchronized, a large circulating current will flow via the neutral point. These issues will lead to lower efficiency and higher costs due to increased filter circuit capacity.

With this new product, the 2-phase modulation timings of the rectifier and inverter have been synchronized. Also, the 2-phase modulation period and AC filter circuit constant have been optimized. These improvements have reduced neutral point fluctuations and suppressed circulating current, improving efficiency without additional cost. The new product achieves an industry-leading* conversion efficiency of 94% or higher (max. 95.6%), which suppresses power consumption and heat generation, reducing running costs and CO_2 emissions.

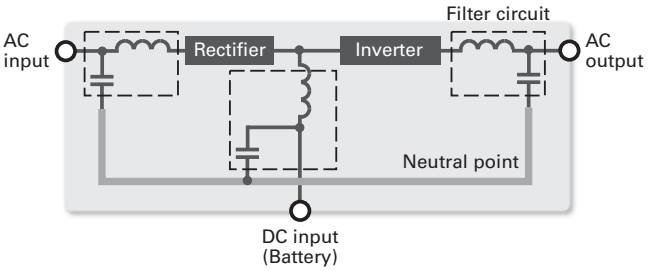

Fig. 3 Simplified A23D circuit block diagram

3.2 Wide AC input voltage range

With the current product, if a voltage dip below the AC input voltage range occurs frequently, charging does not complete in time, leaving the battery not fully charged. If a power outage occurs under this condition, the UPS cannot supply sufficient power to the load equipment. Moreover, a frequent battery discharge will degrade the battery, requiring replacement more frequently.

In response, this product is designed to operate in a wider AC input voltage range. In the case of 200 V rated output voltage, while the voltage range of the current product supports a lower limit of -15% from the rated voltage, the new product supports an extended lower limit of -30% at 60% or lower load levels. This reduces transfers to battery power under unstable input power supply conditions, preventing battery wear and degradation. Figure 4 compares the AC input voltage range of the current and new products. Specifications for other rated output voltages are given in Table 1.

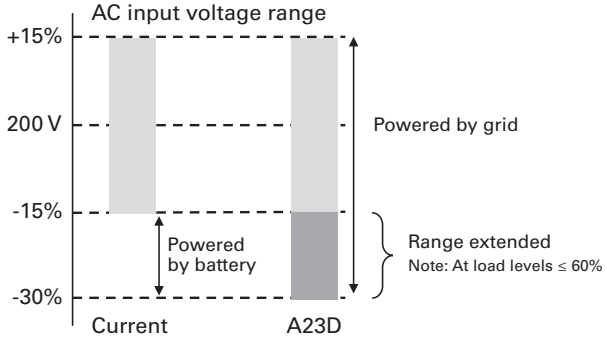

Fig. 4 Wide input voltage range

3.3 Walk-in feature

Some applications require an emergency power supply system combining an emergency generator and a UPS as shown in Figure 5 to provide an uninterrupted, long-term power supply in the event of a power outage. With this system, in the event of an outage, power is first supplied from batteries, meanwhile, the AC input of the UPS is switched from grid power to the generator output. After that, the generator will power the connected facilities via the UPS. If the output power from the generator rapidly increases during this switchover, the voltage fluctuates significantly and the UPS transfers back to battery power. To prevent this from happening, customers needed to select a high-capacity generator to reduce voltage fluctuations.

In response, this product has a walk-in feature that gradually receives power from a generator. Figure 6 shows the voltage and current waveforms when the walk-in feature is used. This function can suppress sudden power fluctuations in the generator during power restoration, allowing customers to build economic emergency power supply systems by not requiring extra capacity of a generator.

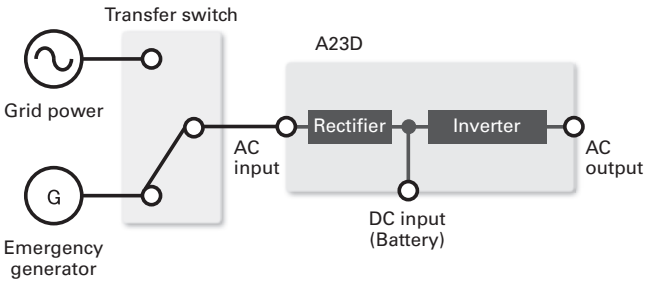

Fig. 5 Emergency power supply system

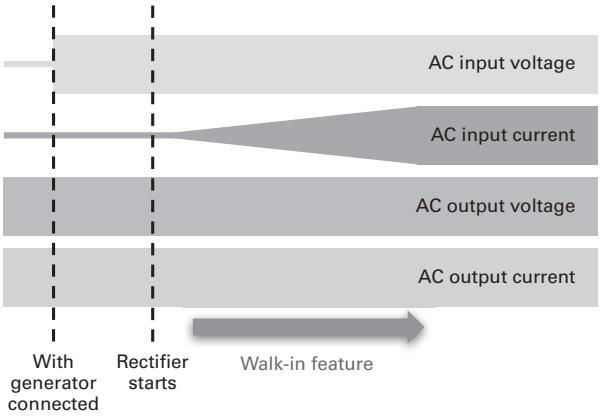

Fig. 6 Walk-in feature

3.4 Reduced maintenance costs

As for the replacement, the expected product life of the current product is 15 years, but some parts such as a cooling fan and electrolytic capacitor need to be replaced during this period. The replacement cycle for these parts is 10 years, which incurs maintenance costs. Moreover, since these parts are mounted on the interior and top of the UPS, their replacement is time-consuming and requires shutting down the UPS for a while.

The expected life of the new product is also 15 years, but redesigning the cooling fan and electrolytic capacitor made them replacement-free during this period. This reduces the cost and time required for part replacement. Although some parts such as fuses and relays need to be replaced after 10 years, they have been relocated to places where they can be easily replaced, enabling quick replacement.

4. Specifications

Table 1 shows the electrical specifications of the new product.

5. Conclusion

This article introduced an overview and the features of the *SANUPS A23D* uninterruptible power supply we newly developed.

The new product has the following features.

(1) Industry-leading* conversion efficiency of 94% or higher
(2) Wide input voltage range to suppress battery wear and degradation
(3) Walk-in feature for receiving power gradually from the generator
(4) Reduced maintenance costs

With these features, the new product can suppress battery wear and degradation, keeping the battery charged and ready to supply power to load facilities in the event of a power outage. The product also helps customers reduce costs on the generator, operation, and maintenance.

SANYO DENKI will continue to swiftly develop and provide more products to meet the needs of our customers.

* Based on our own research as of March 10, 2022, conducted among UPSs on the market with the same topology and equivalent voltage, capacity, and backup time.

References

(1) Shinichi Morita and 4 others: Development of *SANUPS A23C* Medium-Capacity UPS
SANYO DENKI Technical Report No. 17 pp. 12-14 (2004.3)

Table 1 Electrical specifications

Item \ Model			A23D303	A23D503	A23D753	A23D104	Remarks
Output capacity	Apparent power		30 kVA	50 kVA	75 kVA	100 kVA	
	Active power		27 kW	45 kW	67.5 kW	90 kW	
Topology			Double conversion online				
Cooling system			Forced air cooling				
Rectifier			High power factor converter				
Inverter			High-frequency PWM, instantaneous waveform control				
AC input	No. of phases/wires		3-phase 3-wire				
	Rated voltage		200/210/220 V				Same as AC output
	Voltage range		200 V ±15% / 210 V ±10% / 220 V +5%, -10%				At load levels ≤ 60%, the lower limit is -30%.
	Frequency		50/60 Hz				
	Frequency range		Within ±5% of rated frequency				Operation guaranteed within this range
	Current harmonic distortion		5% or less				At rated output
	Input power factor		0.98 or more				At rated output
AC output	No. of phases/wires		3-phase 3-wire				
	Rated voltage		200/210/220 V				
	Voltage regulation		Within ±1% of rated voltage				In grid operation
	Rated frequency		50/60 Hz				Same as AC input
	Frequency regulation		Within ±0.1 Hz of rated frequency				At free run (asynchronous)
	Grid synchronized range		200/210 V ±10%, 220 V +5%, -10% Within ±1% of rated frequency (Can be set to ±2/3/4/5%)				
	Voltage harmonic distortion	At linear load	2% or less				At rated input
		At rectifier load	5% or less				At rated input and 100% rectifier load
	Voltage unbalance		2% or less				At 100% unbalanced load
	Load power factor	Rated	0.9 (lagging)				
		Variation range	0.7 to 1.0 (lagging)				
	Transient voltage fluctuation(1)	Abrupt input voltage change	Within ±2% of rated voltage				Loss/return of input power
		Abrupt load change	Within ±3% of rated voltage				For 0⇔100% load step changes
		Output transfer	Within ±3% of rated voltage				During transfer from bypass to inverter
	Overload capability	Inverter	125% (for 10 min), 155% (for 1 min)				At rated input and rated load power factor
		Bypass	200% (for 30 s), 800% (for 2 cycles)				At rated input and rated load power factor
Overcurrent protection			Uninterrupted transfer to bypass at approx. 155% or more				Automatic retransfer after restored to normal condition
Acoustic noise			65 dB or less				1 m from front of UPS, A-weighting (At linear load)
Heat dissipation			2.1 kW	2.9 kW	4.4 kW	5.8 kW	At rated output, after battery charging completed(2)
Cooling airflow			11 m^3/min	15 m^3/min	23 m^3/min	30 m^3/min	At rated output, after battery charging completed(2)
Battery type			Small-sized valve-regulated lead-acid (VRLA) battery				
Ventilation rate required in battery panel(3)			1.5 m^3/min	2.4 m^3/min	3.6 m^3/min	4.8 m^3/min	
Operating environment			Ambient temperature: 0 to 40°C Relative humidity: 30 to 90% (non-condensing)				

(1) Complies with the transient voltage fluctuation characteristics (classification 1) in JEC-2433:2016
(2) Calculated using conditions of the rated load power factor, a 40°C room temperature, and a 30°C outside temperature.
(3) Calculated using the maximum charge current of the UPS.

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Development of the *SANUPS A11N* Online UPS

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Takuya Ozawa Shogo Yoshinaga Nobuya Otsuki Hiroyuki Hanaoka

1. Introduction

Nowadays, devices that are designed to protect people, such as ICT equipment used in social infrastructure and security and maintenance facilities, are firmly rooted in a wide range of fields. Downtime of these electronic devices can cause significant losses or impact society and the economy. Therefore, the reliability of uninterruptible power supplies (hereinafter, "UPS") that provide backup power to these electronic devices has also become extremely important. Moreover, from the viewpoint of global initiatives to reduce CO_2 emissions, the development of high-efficiency UPSs has been demanded.

In response to these demands, SANYO DENKI has developed the new *SANUPS A11N* UPS capable of parallel operation with ease. It features improved reliability and capacity scalability.

This article provides an overview of this new product.

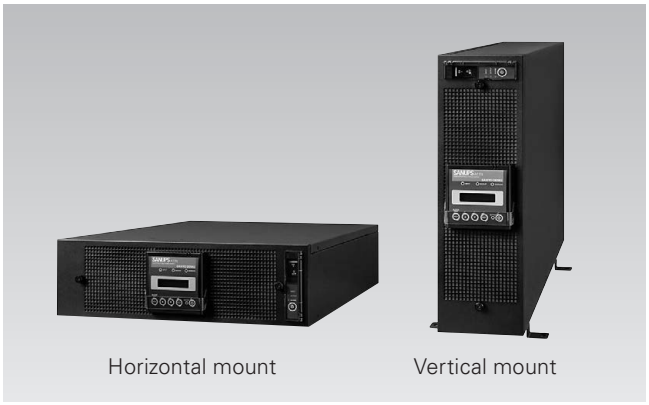
2. Development Background

In recent years, with the popularization of cloud services, data centers and their power supplies have become larger in size. With teleworking being common due to the spread of infectious diseases, small-scale network equipment is also expected to operate continuously, and this led to increasing demand for highly reliable small-capacity UPSs. In light of this, SANYO DENKI employed a parallel redundancy system with proven track records to achieve even higher reliability.

To supply high-quality power, we adopted the double conversion online topology. Moreover, in response to demand for improved efficiency, we set an efficiency target of over 94%, which is industry-leading* among UPSs using this topology.

3. Product Overview

The *SANUPS A11N* is available in two types: a single unit type that has a single 5 kVA base unit with AC output outlets on the back of the unit or a parallel connection type that comes with a power distribution unit and is scalable up to 20 kVA by combining up to four base units in parallel. The single unit type can be mounted vertically and horizontally, and both the single unit type and parallel connection type can be mounted on 19-inch racks. Figure 1 shows a 5 kVA model of the single unit type, Figure 2 shows a 10 kVA model of the single unit type, and Figure 3 shows the parallel connection type.



Horizontal mount Vertical mount

Mounted in a rack

Fig. 1 Single unit type 5 kVA model

Fig. 2 Single unit type 10 kVA model

Fig. 3 Parallel connection type

Considering use not only in Japan but also in global markets, the input/output voltage can be set to single-phase 200, 208, 220, 230, or 240 V.

By using a power distribution unit with a transformer, it is also possible to connect to 100 V systems and single-phase 3-wire systems.

The UPS uses the double conversion online topology, which provides high-quality power independent of the input voltage and frequency, while also achieving high efficiency.

4. Features

4.1 High reliability

4.1.1 Parallel operation with fully autonomous control

Having a central control unit for parallel operation control could hinder the reliability because the system failure rate is influenced by common components. With the *SANUPS A11N*, the synchronization of each unit's voltage amplitude, phase, and frequency as well as cross current and load sharing between units are controlled using "fully autonomous control" technology we have accumulated.

Operations such as unit start and stop, displaying measurement information on LCD, and external signal transmission can all be controlled as a single UPS system.

4.1.2 Achieves high reliability with parallel redundancy

In the case of the parallel connection type, as long as there is an unused capacity of one unit (5 kVA) extra for the load, parallel redundant operation can be performed using one unit as a spare, further increasing the reliability.

4.1.3 Battery management function

The UPS performs battery self-tests automatically at regular intervals, preventing malfunction due to battery run-out in the event of a power failure. And even in the unlikely event that an operator forgets to reinstall the battery back during maintenance work, abnormalities can be detected by periodically monitoring the battery connection status. Also, the new product boasts improved reliability with various battery management functions such as battery life notification and display of total battery run time, charging rate, and estimated backup time.

4.2 Easy maintenance

As shown in Figure 4, the product employs modularized plug-in battery packs and inverter modules, which can be easily removed from the front of the unit for increased maintainability.

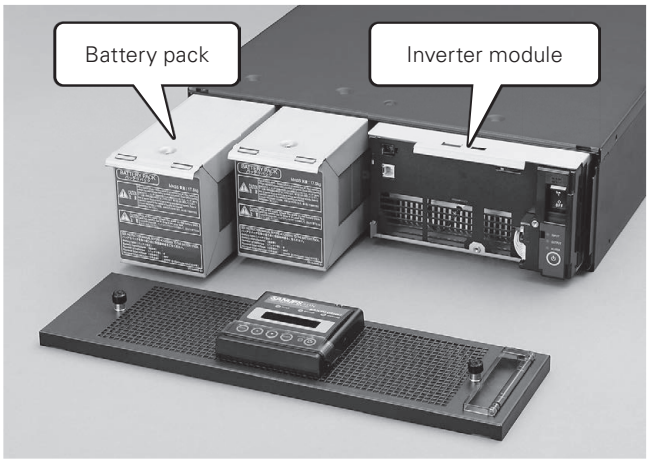


Fig. 4 Battery pack and inverter module

In the unlikely event of a failure, the failed UPS unit can be replaced without interrupting output during parallel redundant operation while maintaining power supply from the inverter. Moreover, the *SANUPS A11N* is equipped

with an internal bypass circuit, which allows module maintenance or replacement to be carried out while continuing to supply grid power even not during redundant operation.

In addition, both the inverter module and battery pack weigh less than 18 kg to reduce the workload of maintenance staff.

4.3 Specifications suitable for wider applications

4.3.1 Wide input range

At full load level, the UPS tolerates input voltage ranging from -20% to +15% of the rated voltage. At low load levels, the UPS can handle a wider -40% to +15% range of input voltage and maintain power supply without switching to battery operation. In addition, by setting to Fixed Frequency mode, the UPS tolerates input frequency ranging from 40 to 120 Hz and supplies 50/60 Hz output power. These wide input voltage and frequency ranges allow the product to be used even in regions with unstable grid power. And asynchronous startup is possible when Fixed Frequency mode is selected, allowing an output frequency of 60 Hz to be obtained easily even in regions with an input frequency of 50 Hz, for example.

4.3.2 LCD Panel

The LCD panel is modularized and can be connected to any unit during parallel operation, allowing system information to be obtained even if the panel is connected to a failed and disconnected unit. Figure 5 shows the LCD panel and some display examples.

Appearance

In English

In Japanese (kana)

Fig. 5 LCD panel

The display employs a 16 × 2 character transparent LCD (with characters lit up) for high visibility regardless of the brightness in the installation location. The display language can be selected from English and Japanese from the settings menu.

4.3.3 Battery cold start

Even when grid power is unavailable and the UPS is not operating, the UPS can be started by battery to supply AC power, serving as an emergency power source.

4.4 Industry's highest efficiency*

By using a 3-level inverter with proven track records and by performing tuning to match the latest switching semiconductor device, this product achieves a maximum efficiency of 95.1% (94% at rated output), which is best-in-class in the industry among CVCF (Constant Voltage Constant Frequency) systems. This reduces running costs and contributes to CO_2 emissions reduction.

4.5 Communication interface

The new product offers various interfaces to support customers' systems.

4.5.1 Management of personal computers (PC)

By connecting the unit's USB port (USB Type-C) to a computer and using the *SANUPS SOFTWARE STANDALONE* UPS management software freely available for download from our website, automatic shutdown of computers in the event of a power outage can be configured easily.

Moreover, using the optional *SANUPS SOFTWARE* UPS management software or LAN Interface Card can help build even more flexible, powerful computer management and network environments.

Fig. 6 LAN Interface Card

4.5.2 External communication signals (Dry contact output interface)

The *SANUPS A11N* features 6 types of external communication signals. Signals “AC input error” and “AC output” are two-way outputs that can both turn on and off when activated. Signals “low battery voltage,” “inverter output,” “bypass output,” and “device error” are for turning on only, but the output can be inverted from the settings menu. Moreover, for “low battery voltage,” “AC output,” “bypass output,” and “device error,” contact signals can be made independent with a switch.

This not only enables the new product to replace the current product in an existing system but also comes in handy when building a new system.

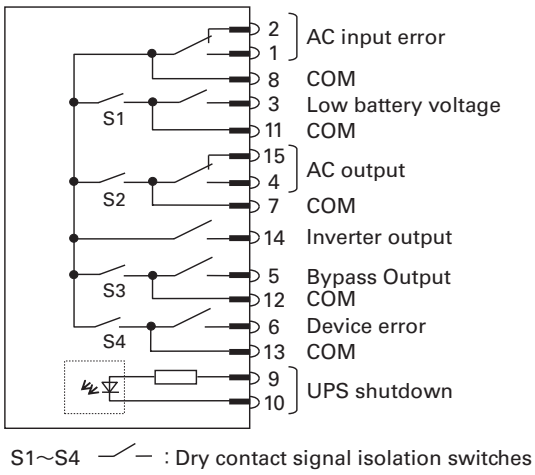


Fig. 7 Dry contact output interface

4.5.3 Remote ON/OFF

The product is equipped with a two-way switch input of remote ON and remote OFF. This can be changed from the settings menu so that only the remote ON is used where output starts and stopped when the switch is pressed and released, respectively.

4.5.4 EPO (Emergency Power Off)

You can connect a UPS emergency stop switch to this terminal. Moreover, contact input logic can be changed from the settings menu.

5. Circuit Configuration

Figure 8 shows the circuit block diagram for the *SANUPS A11N* 5 kVA model.

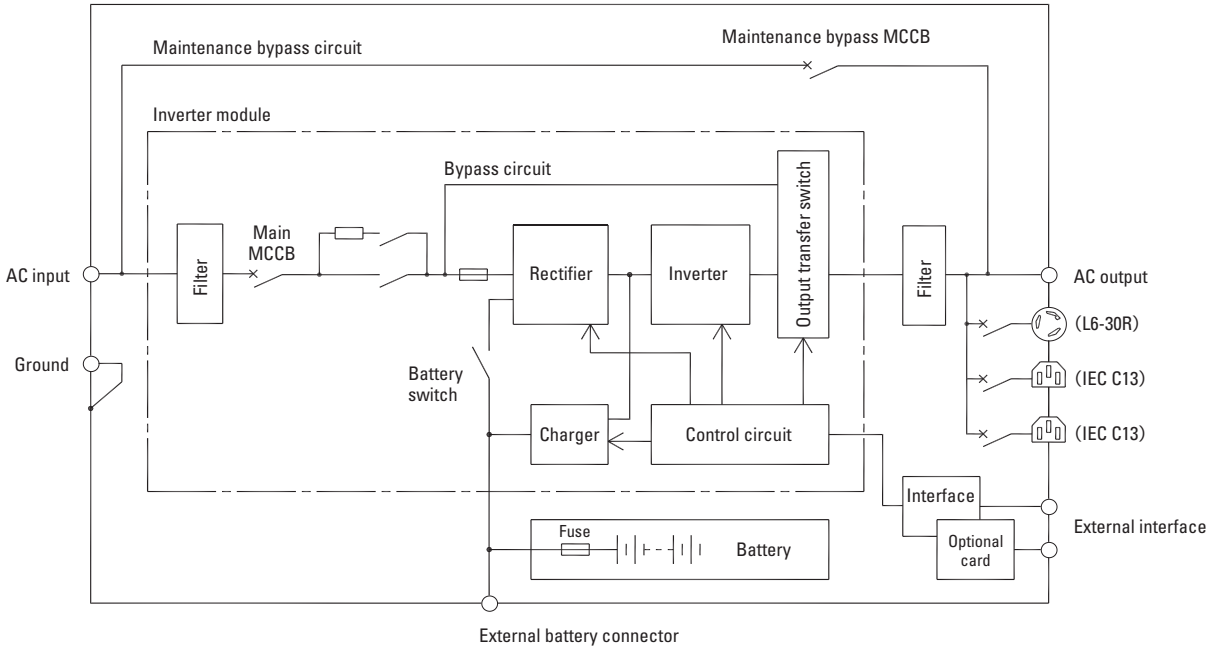


Fig. 8 Circuit block diagram (single unit type, 5 kVA)

5.1 Main circuit configuration

The *SANUPS A11N* consists of components such as a rectifier, inverter, charger, and battery.

5.1.1 Rectifier

Use of a high input power factor chopper has improved the UPS input power factor, widening its voltage and frequency ranges. Moreover, with the chopper also working as a battery booster, the number of parts has been reduced.

5.1.2 Inverter

As mentioned in section 4.4, this product has a 3-level inverter. This scheme provides a near sinusoidal output waveform, allowing the size of the LC filter for converting the output waveform to sinusoidal to be reduced. Moreover, its switching has low voltage fluctuations, reducing switching losses and noise from the unit. These enabled a smaller reactor and improved efficiency.

5.1.3 Charger

The current product uses a PWM-dedicated IC in controlling the charger, but the new product employs digital control. This enables flexible control regardless of conditions such as the battery type and use of external batteries.

5.2 Control circuit configuration

5.2.1 Control ICs and non-volatile memory incorporated into a single chip

The current product uses two control ICs in assigning basic control and parallel control to a high-speed DSP and monitoring, measurement, communication, and display tasks to a CPU, where information is conveyed by serial communication. Also, it uses a non-volatile memory to store failure log and settings information, where reading and writing are done by serial communication.

With the new product, all processing tasks, including control processing, are handled by a single CPU, and settings information is stored in data flash memory on the CPU. Incorporating these tasks into a single chip reduces the risk of control delays due to delayed information transmission or failure history writing errors resulting from a sudden loss of control power.

Moreover, the memory capacity has been expanded, increasing the number of failure history items that can be saved from 4 to 30 and operation history items from 8 to 120 (60 items can be displayed on LCD panel).

5.2.2 Unit-to-unit communication

CAN bus (Controller Area Network: highly reliable communication protocol developed for automotive LANs) is employed for communication between units and for communicating with the LCD.

With CAN communication, it is necessary to assign a communication ID beforehand. Previously, communication IDs used to be assigned either manually or automatically with unique, low-speed communication where only the communication line is shared. The *SANUPS A11N* assigns communication IDs automatically with high speed using CAN communication by devising the communication procedure.

5.3 Electrical characteristics

Table 1 shows the standard specifications of the *SANUPS A11N* 5 kVA model.

6. Conclusion

This article provided an overview of the development of the *SANUPS A11N* double conversion online UPS.

We believe that its high reliability, specifications compatible with a wide range of applications, and industry-leading* efficiency can contribute greatly to customers' peace of mind and safety as well as to protecting customers' assets in a wider range of markets than before.

In the future, infrastructure using ICT technology will become more diverse and involve various new fields more deeply. It is also expected that environmental awareness will grow further, raising the demand for energy savings and facilitating the introduction of environmental regulations both domestically and overseas. This will most likely generate demand for UPSs with higher reliability and efficiency.

We will continue to quickly develop products to meet these market demands and provide products that fulfill our customers' needs.

* Based on our own research as of June 30, 2022, among online UPSs on the market.

Table 1 Standard specifications of *SANUPS A11N* (single unit type, 5 kVA)

Items			Ratings and characteristics	Remarks
Type	Model		A11N502	
	Topology		Double conversion online	Grid synchronous
	Inverter		High-frequency PWM	
	Cooling system		Forced air cooling	
AC input	Rated voltage		200 / 208 / 220 / 230 / 240 V	Same as output voltage Voltage range: Within -40% to +15% of rated voltage (Varies with load level)
	Rated frequency		50 / 60 Hz	Auto-sensing or fixed-frequency mode Factory setting: auto-sensing mode
	No. of phases/wires		Single-phase 2-wire	
	Max. output capacity		5.5 kVA or less	Max. capacity during battery recovery charging
	Power factor		0.95 or more	At rated output When input voltage harmonic distortion < 1%
AC output	Rated capacity		5 kVA / 4.5 kW	Apparent power / active power
	No. of phases/wires		Single-phase 2-wire	
	Rated voltage		200 / 208 / 220 / 230 / 240 V	User-selectable. Factory setting: 200 V
	Voltage waveform		Sinusoidal	
	Voltage regulation		Within ±2% of rated voltage	At rated output
	Rated frequency		50 / 60 Hz	Auto-sensing or fixed-frequency mode Factory setting: auto-sensing mode
	Frequency regulation		Within ±1 / 3 / 5% of rated frequency	In free run (asynchronous): Within ±0.5%
	Voltage harmonic distortion		3% / 7% or less	At linear load / rectifier load, at rated output
	Transient voltage fluctuation	Abrupt load change	Within ±5% of rated voltage	For 10⇔100% load step changes
		Loss/return of input power		At rated output
		Abrupt input voltage change		For ±10% abrupt changes
		Response time	5 cycles or less	Excluding when loads are removed
	Load power factor		0.9 (lagging)	Variation range: 0.7 (lagging) to 1.0
	Efficiency		94% or greater	For reference purposes only
	Overcurrent protection		110% or greater	Automatic transfer to bypass
	Overload capability	Inverter	110% / 118%	1 min / instantaneously
		Bypass	200% / 800%	30 s / 2 cycles
Battery		Type	Small-sized valve-regulated lead-acid (VRLA) battery	
		Backup time	5 min	At a 25°C ambient temperature, load power factor of 0.9, using new, fully charged batteries.
Heat dissipation			287 W	At rated output after battery recovery charging
Acoustic noise			45 dB or less	1 m from front of UPS, A-weighting
			51 dB or less	1 m from front of UPS, A-weighting, at start of charging
Leakage current			5 mA or less	3 mA or less under the setting without asynchronous operation

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Expand into "Wider Markets in Depth"

—Understand customers "in depth" in "wider" applications, and develop technology and products together—

Masahiro Yamaguchi Tsuyoshi Kobayashi

1. Introduction

Servo Systems products have traditionally been widely used primarily in manufacturing applications and have been optimally customized for each customer. To deliver optimal customization, it is vital to know our customers well and deeply understand the problems they have and the solutions they seek, and share a clear image of their ideal goal. In recent years, our products have been used in applications besides manufacturing equipment, and our application range has been expanded.

This article first introduces two examples of customized products for manufacturing applications that were realized through a deep knowledge of the customer. One is high-speed motors for machine tool spindles and the other is a servo product for spring forming machines, which were the cases we solved their issues together with a great understanding of our customers.

Next, we will introduce two non-manufacturing applications in welfare and medical equipment. Powered wheelchairs and radiation therapy equipment are the two examples of using Servo Systems products, which we worked on designing mechanisms and performance from the perspective of wheelchair users and radiotherapy patients from the beginning of the development stage with our customer.

2. Custom Products for Manufacturing Applications Realized by Gaining a Deep Knowledge of the Customer

This chapter introduces two examples in which we solved problems together with the customer by gaining a deep understanding of their problems with machine tools for manufacturing use. The first one is the development of a servo motor for driving machining center spindles, and the second one is the customization technology to incorporate some of the functions of the customer's spring forming machines into our servo amplifier.

2.1 High-speed technology for machine tools Servo motor for driving machining center spindles

2.1.1 Product overview

Motors for driving machining center spindles must be capable of variable speed operation up to the high-speed range and deliver high-torque performance to handle various machining processes. Also, it is important to improve acceleration and deceleration performance to reduce spindle start and stop time. In addition, spindle motors are required to deliver high efficiency with low loss for energy-saving processing.

To meet those requirements, we developed a high-torque, low-inertia servo motor specialized in driving machine tool spindles. Figure 1 shows the appearance of the motor. This servo motor is an interior permanent magnet (IPM) synchronous servo motor (IPM motor), and the permanent magnet is embedded into the rotor. This servo motor contains relatively little magnet material and is capable of delivering high torque up to the high-speed range, as well as high efficiency with little power loss. The rotor moment of inertia is also low, ensuring outstanding acceleration and deceleration characteristics[(1)]. This greatly contributes to improved machine tool performance and energy savings.

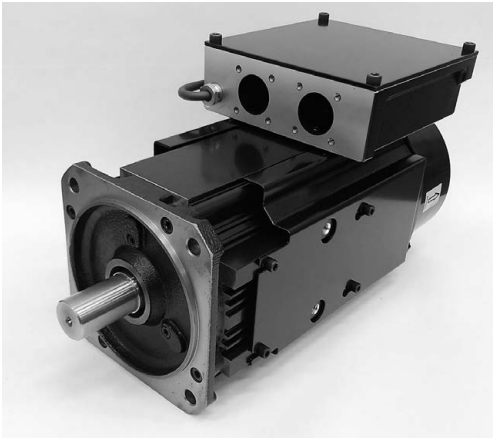

Fig. 1 Motor appearance

2.1.2 Achieving both variable speed operation up to the high-speed range and torque performance

In addition to the torque generated by the permanent magnet, IPM motors are capable of generating torque (reluctance torque) resulting from the difference in rotor magnetic reluctance. Using these characteristics, we were able to generate high torque in a wide speed range up to high speed, helping to realize a spindle servo motor with little power loss.

IPM motors have permanent magnets embedded into the rotor, making it easy to prevent the magnet scattering caused by centrifugal force. Variable speed operation up to 30,000 min^{-1} is also available.

2.1.3 High-acceleration/deceleration operation achieved through low inertia[(2)]

With machine tools, it is necessary to reduce the startup time until spindle machining speed is reached, and perform sharp reversal operation quickly when performing tapping. High-acceleration/deceleration operation is also important to reduce cycle time. This new IPM motor has been optimally designed to minimize rotor moment of inertia and increase torque, achieving high-acceleration/deceleration characteristics.

2.1.4 Low-loss, high-efficiency design

Power loss (iron loss) inside the motor's iron core generally increases at high speed. With our new IPM motor, the shape and material of the iron core were revised to minimize iron loss at high speed. Also, the reluctance torque is optimally controlled based on the rotational speed of the motor to reduce power loss and improve efficiency. Our new motor also has a low rotor moment of inertia, resulting in less power consumption during acceleration and deceleration. These improvements contribute greatly to energy savings in machine tools.

2.1.5 Environmental durability and maintainability

Machining centers normally perform machining using cutting oil, and cutting oil is scatters around the drive motors. For that reason, materials with high oil resistance is used for motor parts. The design also enables easy cleaning and replacement of the cooling fan and other components. Such design featured in environmental durability and maintainability contributes significantly to improving the environmental durability of machine tools and reducing maintenance time.

Through gaining a deep knowledge of the customer's equipment, we worked together and further deepened our technologies to solve problems and contribute to improving machine tool performance.

2.2 Customization technology for machine tools Spring forming machines

2.2.1 Overview of equipment

Spring forming machines produce springs by feeding linear or rod-shaped spring material with rollers, and coiling the material at equal intervals. Springs are often used as important parts involved in ensuring the safety of human lives, requiring high and uniform durability, as well as high machining precision for the equipment.

Figure 2 shows the appearance of equipment from The Itaya Engineering Ltd. a leading spring forming machine manufacturer, and one of our customers.

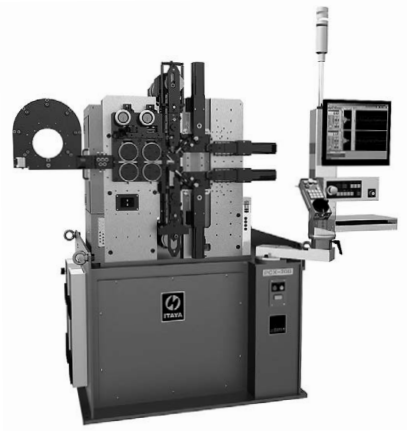

Fig. 2 Spring forming machine
(Image source: The Itaya Engineering Ltd.)

Generally, ball screws or rack and pinions are used to convert motor rotation into linear motion.

By using a simple linkage configuration as shown in Figure 3, the customer has reduced the number of mechanical parts and improved equipment productivity.

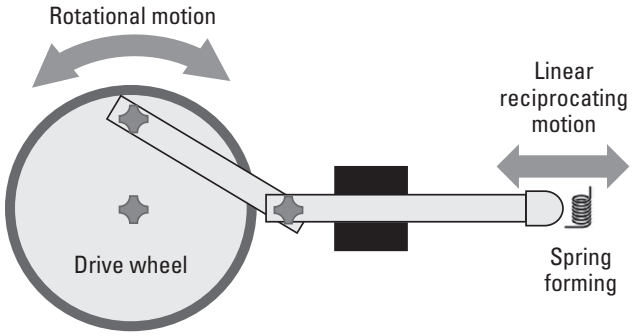

Fig. 3 Simple linkage configuration

2.2.2 Compatibility with new equipment without changing the controller

To achieve the linkage configuration shown in Figure 3, the controller uses virtual cam control. Virtual cam control converts linear position commands to angular position commands.

Machines that process more precise or complex shapes need more axes, and it is difficult to perform processing for all axes within the command update cycle.

To solve this issue, the virtual cam control that had been performed by the controller was installed in the servo amplifier. By allotting functions with the servo amplifier, the controller load is reduced so that all axes can be performed.

Gaining a deep understanding of, and optimally customizing the customer's functions in this way contributed to the development of new equipment without significant changes to the controller.

3. Customization with Deep Involvement in Welfare and Medical Applications

In this chapter, we will introduce examples of welfare and medical applications, two non-manufacturing applications. The powered wheelchairs and radiation medical equipment are examples of using servo systems products, which we worked on designing mechanisms and performance from the perspective of wheelchair users and radiotherapy patients from the beginning of the development stage with our customer.

3.1 Technology that promotes people's health In-wheel motor for powered wheelchairs

3.1.1 Product overview

Figure 4 shows a powered wheelchair developed as a joint project with a wheelchair manufacturer. SANYO DENKI was responsible for designing the in-wheel motor and peripheral mechanisms. The motors are mounted in the center of the wheels of the powered wheelchair, and the main mechanisms are the clutch, brake, and speed reducer, all of which are integrated. We designed and developed the new motor dedicated to the wheelchair to make those mechanisms thin, compact, and lightweight.

The powered wheelchair can extend the range of activities for those with disabilities and support their active lifestyles.

Fig. 4 In-wheel motor for wheelchair (example of installation in a wheelchair)

3.1.2 Required features of the motors

We made the following improvements to develop a servo motor for wheelchairs.

(1) High torque characteristics in the low-speed range

Servo motor torque characteristics were set by specifying the weight of the user, accelerating performance, and maximum speed. The maximum rotational speed was reduced compared to the standard servo motors to achieve higher torque in the low-speed range.

(2) Dustproof and waterproof performance

The joints of the motor are waterproofed to achieve high dust and water protection, even when used in the rain or on muddy or gravel roads.

(3) High efficiency, low heat generation

Since the wheelchair is powered by a battery, the higher efficiency of the motor directly leads to an increase in the driving distance. The low heat generation of the motor is also required in case users touch them with their bare hands. Thanks to low-loss design technology which we cultivated in industrial motors, high efficiency and low heat generation were both achieved.

(4) Silence and weight reduction

To ensure comfortable use of powered wheelchairs, we designed motors to minimize noise during motor rotation. High motor rigidity is required for low-noise operation, while motor weight should also be reduced for easy handling by operators at the same time. The motor structure was optimally designed to ensure both high rigidity and light weight.

(5) Solid encoder that won't break

Considering the impact during operation, the motor is equipped with a solid, hard-to-break magnetic encoder.

High-precision, high-resolution encoders required in industrial equipment are not necessary for wheelchairs. Instead, an encoder with the optimal performance for driving a motor with a human operator is installed.

3.1.3 Joint development with customer

This is an example of joint development where a new powered wheelchair was realized by combining the customer's (wheelchair manufacturer) technological strengths with those of ours.

We worked closely with the customer from the product development stage to deliver the required performance and functionality to ensure that wheelchair users can use the products comfortably and safely. We hope that we were able to bring happiness to people who use wheelchairs.

We were able to develop this new product not only by using technology cultivated in manufacturing applications but also by incorporating a new sense of values and new technology different from those used in servo motors for manufacturing use.

For welfare applications, we considered the performance required from the user's point of view and developed the product with the equipment manufacturer to contribute to user comfort.

3.2 Technology that ensures treatment with peace of mind Servo system for radiation therapy equipment

3.2.1 Overview of equipment

The customer's equipment is radiation medical equipment for brain tumors and is capable of the targeted treatment of lesions only with high-accuracy positioning and high-definition beam irradiation.

The system has a total of 6 axes, including 2 axes to control the beam irradiation direction, and 4 axes to control the cradle (bed) on which the patient lies. The axes which control the beam irradiation direction are generally driven by a rotary motor with a conversion mechanism such as a belt, but this equipment uses an arc-shaped linear servo motor[3]. By driving the arc-shaped linear motor directly, high-accuracy positioning is possible without any backlash or drop in rigidity. Moreover, as shown in Figure 5, axis 2 is mounted on the axis 1 mechanism, and the beam irradiation device is mounted on the axis 2 rotating bases. The tumor can be irradiated with a high-definition beam from any direction by driving these two axes.

We worked closely with the customer from the very concept stage to customize the system to provide high-speed, high-accuracy positioning with stable motion, and notify the user of errors before vibrations and abnormal noises increase.

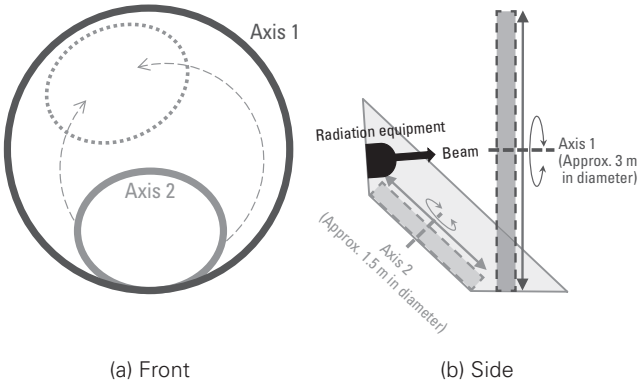

Fig. 5 Beam irradiation direction servo mechanism and size

3.2.2 High-speed, high-accuracy positioning with stable motion

The control axes for the beam irradiation direction mechanism use an ultra multipole motor with linear motor coil arranged in arc and magnets arranged in the circumferential direction[3]. The motor diameter is approximately 3 m for axis 1 and approximately 1.5 m for axis 2, making it extremely long in circumference. As shown in Table 1, there is an extremely large number of motor poles, with 450 poles for axis 1, and 250 poles for axis 2. Moreover, an encoder resolution of 2.2 to 3.3 million subdivisions is required. Our servo amplifiers can control motors with standard 128 poles and encoder resolution of up to 2 million subdivisions.

We were able to realize high-accuracy positioning by changing the electrical angle calculation processing method for current control, and offering compatibility for ultra multipole motors and high-resolution encoders.

Table 1 Motor pole number, encoder resolution, and amplifier limitations

Axis	Motor pole number [poles]		Encoder resolution [subdivisions]	
	Motor used	Amplifier limitations	Encoder used	Amplifier limitations
1	450	128 max.	2,200,000	2,000,000 max.
2	250		3,300,000	

Control of this equipment tends to be unstable due to the large load inertia. To stabilize high-speed positioning, we simulated operation under the customer's equipment load conditions and optimized the servo gain and filter.

3.2.3 Error notification before vibrations and abnormal noises increase

Since there tends to be very little distance between the patient and the medical equipment, the noise and vibration generated by the equipment may upset the patient.

With this system, encoder scale tape is attached to the motor stator periphery, and the motor position is detected by the encoder head mounted on the moving part. If the gap between the encoder scale tape and encoder head exceeds the allowable value due to equipment vibrations, operating temperature or humidity, or degradation over time, the encoder will count incorrectly, which results in large vibrations and abnormal noises.

To address this issue, we ensured to perform maintenance and overhauls before large vibrations occur and abnormal noises are emitted. As shown in Figure 6, by mounting two encoder heads and redundantly monitoring positions from these two heads, incorrect encoder counts caused by positional displacement are detected, and errors are notified before vibrations and abnormal noises increase.

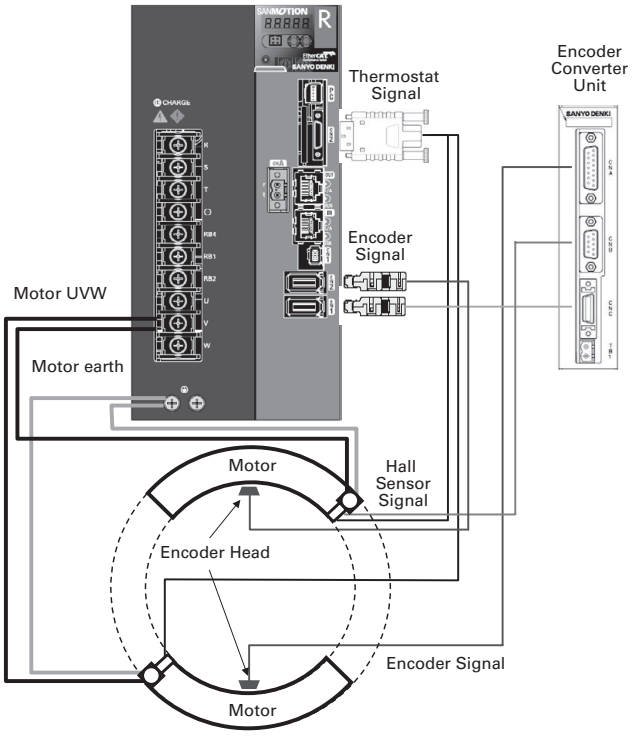

Fig. 6 Image of encoder signal redundancy

In this way, by considering servo performance and functions from the perspective of the treatment recipient and optimally customizing motors, we have contributed to the development of radiation medical equipment that provides safe treatment for patients.

4. Conclusion

This article introduced the following four examples realized by harnessing the strengths of both the customer and SANYO DENKI.

(1) Servo motor for driving machining center spindle
(2) Servo system for spring forming machines
(3) In-wheel motor for powered wheelchairs
(4) Servo system for radiation medical equipment

The technologies and products for spindle servo motors and spring forming machines are examples of how we have achieved optimum customization for "manufacturing" applications through a deep knowledge of our customers.

The technologies and products for motors for powered wheelchairs and radiation medical equipment are examples of applications other than "manufacturing," where we worked with customers to consider and develop mechanisms and servo performance from the standpoint of wheelchair users and radiation therapy patients.

In addition to conventional manufacturing applications, we aim to contribute greatly to "promoting people's health" and "restoring the global environment" by "gaining a deep knowledge" of the needs of both the customer and the world.

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Development of Compact Multi-Axis Integrated Linear Servo Motor Unit

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1. Introduction

There are two types of linear motors: a flat type[1, 2] and cylinder type[3] (cylinder linear motors). The flat type has been used for horizontal axes (X-Y tables, etc.) on electronic component mounters and semiconductor manufacturing equipment, and the cylinder type has been often used for the vertical axes (Z-axis) on PCB drilling machines and electronic component mounters.

The cylinder linear motor is suitable for applications that require fast and precise motion over short distances, but recently, its application range has been extending, such as telemanipulation systems for cell culture pipetting[4].

This article introduces a newly developed "compact multi-axis integrated linear servo motor unit" designed for fast, precise reciprocating motion and multi-axis applications.

First, we'll present the appearance and specifications of the new product. Next, we'll describe its features of compactness, light weight, high thrust and low friction (high precision). Lastly, we'll look at how the product is easy to customize in the number of axes and spacing between axes to best suit the user's application.

2. Appearance and Specifications of the New Product

Figure 1 shows the appearance of the new product, and Figure 2 shows its external dimensions. Table 1 shows the product specifications.

Fig. 1 New product appearance
(4-axis integrated unit example)

The new product integrates multiple axes into a single unit with each axis consisting of a stator, mover, linear encoder, and frame. The mover has a structure that locks rotation using a ball spline on one side of the bearing. The stator is

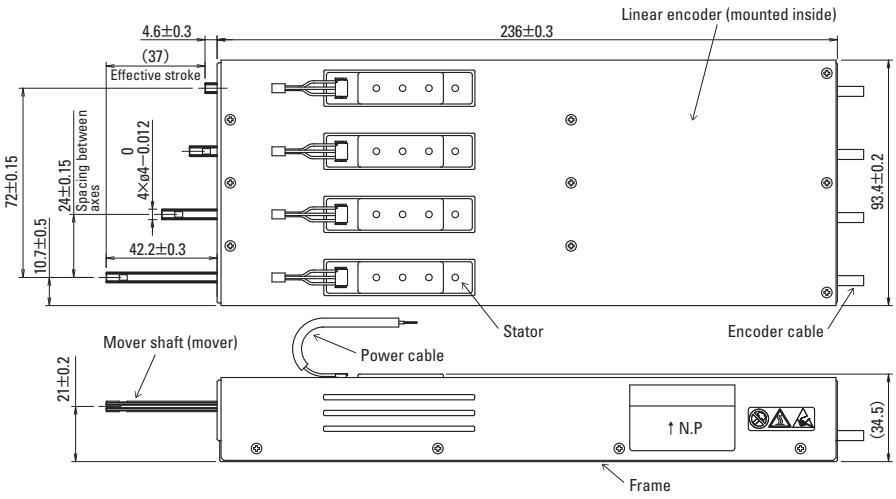

Fig. 2 Dimensions of the new product

resin-molded with the coaxiality of the bearing support and the armature coil's inner diameter ensured. The stator also comes with a power connector, allowing the power cable to be connected and disconnected.

Table 1 Specifications of the new product

Items	Symbol	Unit	Constant
Motor model no.	—	—	DM04GG011A37CX00
Power supply voltage	—	V	DC 48
Spacing between axes	—	[mm]	24
Stroke length	—	[mm]	37
Rated thrust	F_R	[N]	3.5
Maximum thrust	F_P	[N]	11
Rated speed	V_R	[m/s]	1
Maximum speed	V_{max}	[m/s]	1
Encoder resolution	—	[μm]	1

3. Product Features

3.1 Increased thrust density

Thrust density is the thrust produced per unit volume, and the greater the value, the higher the thrust with the smaller size.[1]

Figure 3 shows the motor cross section and gives an outline of the magnetic flux of our current cylinder linear servo motor model. The current model has a structure combining a cylindrical magnet, an armature coil, and a square steel sheet (back yoke), and the distance (magnetic gap) from the back yoke to the magnet is not uniform. The greater the magnetic gap, the more difficult it is for the magnetic flux to reach the back yoke, reducing the amount of effective magnetic flux affecting thrust.

Figure 4 shows the motor cross section and gives an outline of the magnetic flux of the new product. The new product has a structure combining a cylindrical magnet, an armature coil, and a cylindrical back yoke, and the magnetic gap is uniform. With this structure, the magnetic flux reaches the back yoke uniformly. This results in a greater amount of effective magnetic flux, increasing thrust. As shown in Figure 5, rated thrust density and maximum thrust density have improved by 32% and 25%, respectively, compared to the current model.

In this way, the new product is a compact, high-thrust cylinder linear motor that can drive machinery at high accelerations and frequencies.

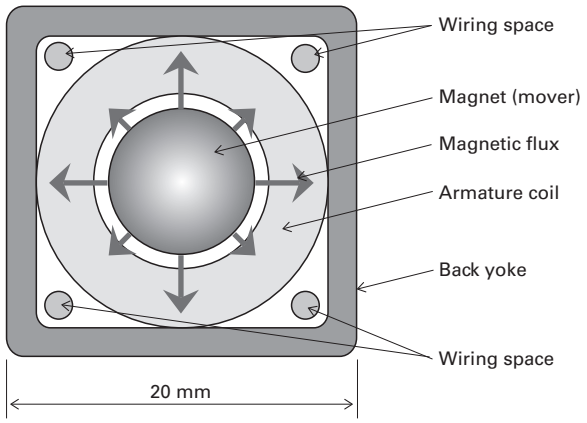

Fig. 3 Cross section view of current model (radial cross section)

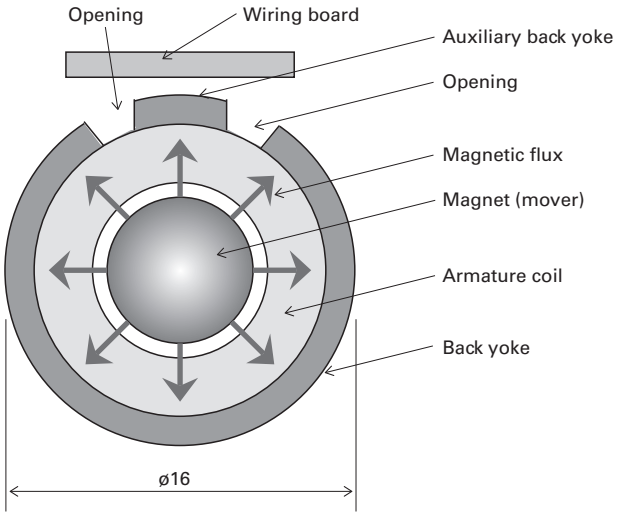

Fig. 4 Cross section view of new model (radial cross section)

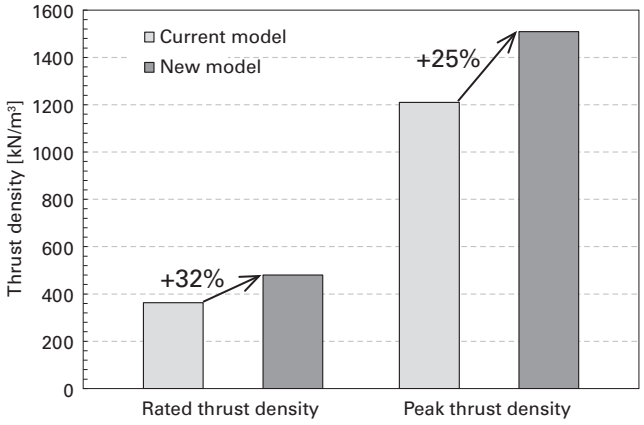

Fig. 5 Comparison of thrust density

3.2 Reduced static friction thrust

3.2.1 Improved coaxiality of fixed bearing

If the two bearings supporting the mover are installed with low coaxiality, an unbalanced load is applied to the bearings, increasing static friction thrust. Since both bearings are mounted to the fixed bearing, static friction thrust can be reduced by improving the coaxiality of the fixed bearing.

Figure 6 shows the stator cross section of the new product. With the new product, the two fixed bearings of the stator were resin-molded with the shaft core placed through them. This structure provides improved coaxiality.

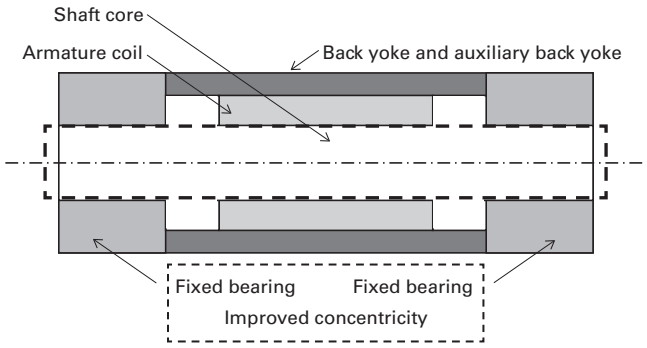

Fig. 6 Cross section view of new product's stator

3.2.2 Improved coaxiality of the mover shaft

As with the fixed bearings, the coaxiality of the mover shaft also affects static friction thrust.

Figure 7 shows the appearance of the mover. The new product has two mover shafts, each of which is securely welded to the magnet housing. To perform welding while maintaining coaxiality, the welding equipment and welding conditions were devised, which successfully improved the coaxiality between the two mover shafts.

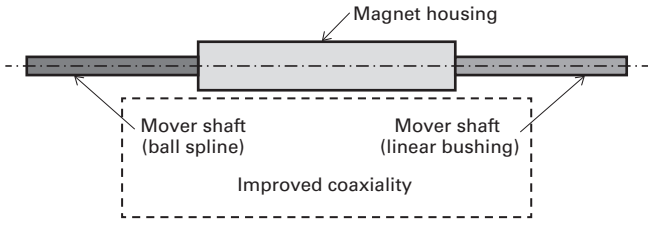

Fig. 7 Appearance of mover

3.2.3 Optimally balanced magnetic force

The current model has space for winding the armature coil inside the back yoke as shown in Figure 3. On the other hand, the new product has a cylindrical back yoke to increase the amount of effective magnetic flux affecting the thrust, leading to no winding space inside the back yoke. This raised the need for outside winding space, therefore openings were made on the back yoke. However, these openings resulted in unbalanced magnetic attractive force acting on the mover, causing the mover to be attracted to the opposite side of the openings. This increases the static friction thrust because this results in an unbalanced radial load exerted on the bearing supporting the mover. To counter this, an auxiliary back yoke was placed as shown in Figure 4, optimizing magnetic balance while securing winding space.

Figure 8 shows a comparison of before and after improving the coaxiality of the fixed bearings and the mover shafts, and static friction thrust with and without the auxiliary back yoke. Static friction thrust has been reduced by 70% in total, enabling a smooth motor driving, which offers high-precision positioning.

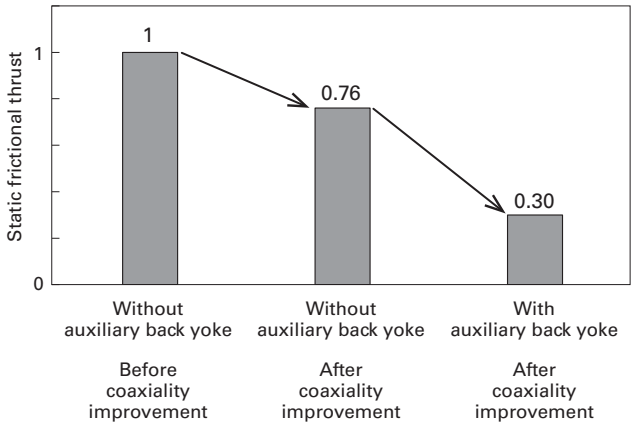

Fig. 8 Comparison of static frictional thrust

3.3 Customizability

With the new product, each linear motor is assembled with high precision in its fixed bearings and mover bearing shafts, requiring no additional adjustment even when multiple axes are combined. This design is optimized for multi-axis configurations, allowing easy customization of the number of mover shaft axes and spacing between axes. This product is suitable for applications where multiple motors are used in equipment because there is no need to adjust the installation position of each axis, greatly reducing the assembly work for customers.

4. Conclusion

This article introduced the compact multi-axis integrated linear servo motor unit which integrates multiple compact cylinder linear motors into a single unit.

The features of the new product are as follows.

1. The product is a compact, high-thrust cylinder linear motor. Thrust density has been improved by 32% (compared with the current model) by optimizing the shape of the steel sheet (back yoke) used for the motor stator. Equipment can be driven with high acceleration and high frequency, contributing to improved productivity for customers' equipment.

2. The linear motor enables smooth driving due to little friction thrust. Static frictional thrust has been reduced by 70% (compared to the current model) by improving the coaxiality of the fixed bearings and mover shaft and devising the magnetic circuit of the stator. It provides stable positioning with high precision and accuracy, contributing to higher precision in customer equipment.

3. Multiple cylinder linear servo motors can be integrated into a single unit, offering easy customization. The number of cylinder linear motor axes and spacing between axes can be laid out freely according to the customer's application. Moreover, no adjustments are required when installing the unit, significantly reducing the assembly workload for customers.

This compact, lightweight, high-thrust cylinder linear motor capable of high-precision positioning can be flexibly customized to suit the customer's equipment, contributing to the creation of new value for our customers.

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Development of *SANMOTION G* AC Servo Systems

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1. Introduction

SANYO DENKI has developed many servo system products over the years, and these systems have contributed to improving the value of customers' equipment as well as to industrial development. Among them in particular, our *SANMOTION R* AC servo systems are still used by many customers due to their high performance and extensive lineup.

Servo systems are essential devices that impact machinery performance, quality, and reliability, and further improvements in performance and functionality are necessary. Moreover, electrically powered equipment efficiency improvements, energy savings, and natural resources saving are also important as measures to counter global heating. The role played by servo systems is becoming more important than ever for industrial development and to resolve problems facing the global environment.

In response to these expectations, we developed new *SANMOTION G* AC servo systems. The new servo system offers servo motors, holding brakes, encoders, and servo amplifiers have been renewed from *SANMOTION R* based on the concepts of "powerful" and "friendly" servo systems.

"Powerful" means that high servo performance and highly reliable products that can be used with peace of mind in various regions and environments. "Friendly" means products that deliver energy savings, that are compact and lightweight, that are friendly to the global environment, and that are easy to use.

This article will begin by showing the appearance of our new products and product lineup, as well as product specifications. Next we'll introduce the "powerful" and "friendly" features of our new products, and the development points.

2. Product Overview

This chapter provides an overview of the new *SANMOTION G* AC servo system products including servo motors, encoders, and servo amplifiers.

2.1 Servo motors and encoders

Figure 1 shows some of the new servo motors. Tables 1 and 2 list the servo motor lineup, and Table 3 shows the specifications of typical servo motor models and encoder.

Fig. 1 Servo motor appearance

The lineup comprises a total of 37 models, with 13 low-inertia models ranging from a 40 mm sq., 50 W model to a 100 mm sq., 1.5 kW model, and 24 medium-inertia models ranging from a 40 mm sq., 30 W model to a 130 mm sq., 1.2 kW model. The lineup includes the same 31 models as the current *SANMOTION R* series, as well as new 40 mm sq., 150 W, 60 mm sq., 600 W, and 80 mm sq., 1 kW models.

The 40 mm sq. to 86 mm sq. models feature an integrated power cable and holding brake cable, and new 6-core integrated connector. The power and holding brake connector, and the encoder connector are directly secured to the motor unit with screws, allowing them to be securely fastened. The 100 mm sq. to 130 mm sq. models employ a circular push-pull connector for easier assembling.

Our combination encoder lineup contains a compact, slim, battery-less absolute encoder with maximum resolution of 27 bits, and a single-turn absolute encoder, realizing high resolution and shorter motor length.

Custom options available are with/without holding brake, with/without oil seal, and circular/keyway shaft.

Table 1 Servo motor lineup (Low inertia)

Flange size	Rated output	Power supply voltage		Servo motor model no.	Newly added model
		100 V	200 V		
40 mm sq.	50 W	✓	✓	GAM1*4005F0	–
	100 W	✓	✓	GAM1*4010F0	–
	150 W	–	✓	GAM1A4015F0	✓
60 mm sq.	200 W	✓	✓	GAM1*6020F0	–
	400 W	–	✓	GAM1A6040F0	–
	600 W	–	✓	GAM1A6060F0	✓
80 mm sq.	750 W	–	✓	GAM1A8075*0	–
	1 kW	–	✓	GAM1A8100F0	✓
100 mm sq.	1 kW	–	✓	GAM1AA100*0	–
	1.5 kW	–	✓	GAM1AA150*0	–

Table 2 Servo motor lineup (Medium inertia)

Flange size	Rated output	Power supply voltage		Servo motor model no.	Newly added model
		100 V	200 V		
40 mm sq.	30 W	✓	✓	GAM2*4003F0	–
	50 W	✓	✓	GAM2*4005F0	–
	100 W	✓	✓	GAM2*4010F0	–
	150 W	–	✓	GAM2A4015*0	✓
60 mm sq.	100 W	✓	✓	GAM2*6010F0	–
	200 W	✓	✓	GAM2*6020F0	–
	400 W	–	✓	GAM2A6040F0	–
	600 W	–	✓	GAM2A6060*0	✓
80 mm sq.	200 W	–	✓	GAM2A8020F0	–
	400 W	–	✓	GAM2A8040F0	–
	750 W	–	✓	GAM2A8075*0	–
	1 kW	–	✓	GAM2A8100F0	✓
86 mm sq.	750 W	–	✓	GAM2A9075F0	–
	1 kW	–	✓	GAM2A9100*0	–
100 mm sq.	750 W	–	✓	GAM2AA075F0	–
	1 kW	–	✓	GAM2AA100F0	–
	1.5 KW	–	✓	GAM2AA150*0	–
130 mm sq.	550 W	–	✓	GAM2AB055D0	–
	1.2 kW	–	✓	GAM2AB120*0	–

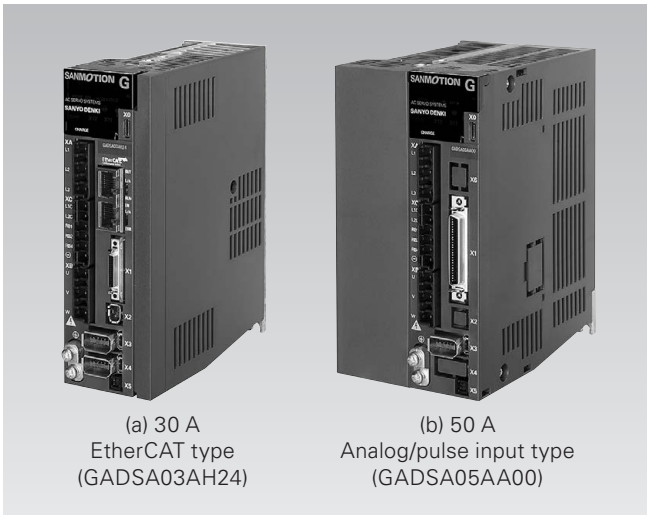
Table 3 Servo motor (typical models) and encoder specifications

Items \ Servo motor model no.				Low-inertia: GAM1A				Medium-inertia: GAM2A					
				4010F0	6040F0	8075F0	A150H0	4010F0	6040F0	8075F0	9100F0	A100F0	B120H0
Flange size		–	mm	40 sq.	60 sq.	80 sq.	100 sq.	40 sq.	60 sq.	80 sq.	86 sq.	100 sq.	130 sq.
Rated output		P_R	W	100	400	750	1500	100	400	750	1000	1000	1200
Rated torque		T_R	N·m	0.318	1.27	2.39	4.8	0.318	1.27	2.39	3.18	3.18	5.8
Continuous torque at stall		T_S	N·m	0.353	1.37	2.55	4.9	0.318	1.37	2.55	3.92	3.92	6.0
Peak torque at stall		T_P	N·m	1.18	4.8	8.5	18.0	1.18	4.8	8.5	14.3	14.7	20.0
Rated speed		N_R	min^{-1}	3000	3000	3000	3000	3000	3000	3000	3000	3000	2000
Maximum speed		N_{max}	min^{-1}	6500	6500	6500	3000	6500	6500	6500	6500	6000	4000
Rated armature current		I_R	A_{rms}	1.00	2.8	5.9	5.2	0.99	2.9	5.9	6.0	5.5	6.7
Continuous armature current at stall		I_S	A_{rms}	1.05	2.8	5.7	3.8	0.96	2.9	5.9	6.8	6.2	6.6
Peak armature current		I_P	A_{rms}	4.1	12.0	22.0	15.5	3.6	10.8	21.4	25.7	26.5	26.5
Rotor inertia	Without brake	J_M	$\times 10^{-4}$ kg·m² ($GD^2/4$)	0.0259	0.213	0.739	1.98	0.06	0.466	1.56	2.45	3.97	7.78
	With brake			0.0324	0.272	0.936	2.31	0.067	0.524	1.76	2.75	4.30	8.86
Encoder inertia		J_S		0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
Motor length	Without brake	LL	mm	93.5	110	125	156.5	68	85.5	92.0	127	128	100.5
	With brake			122	132.5	155.5	193	100.5	111.5	126	153	146	135.5
Mass	Without brake	W_E	kg	0.52	1.4	2.9	5.0	0.4	1.3	2.2	3.4	4.1	5.5
	With brake			0.71	1.8	3.7	6.6	0.6	1.6	3.0	4.2	4.9	7.1
Encoder resolution		–	–	17-bit (131,072 steps), 20-bit (1,048,576 steps), 23-bit (8,388,608 steps), 27-bit (134,217,728 steps)									
Multi-turn encoder		–	–	Batteryless									

2.2 Servo amplifier overview

Figure 2 shows some of the new servo amplifiers. The connectors for the power supply and motor power were changed to a spring-type, push-pull connector for improved workability and safety than the current models.

As shown in Table 4, the lineup contains a total of 21 models based on the power supply voltage, combined servo motor, and host controller and interface specifications. The 100 V type consists of 3 models, with output current capacity of 10 A, 20 A, and 30 A, and the 200 V type consists of 4 models, with output current capacity of 10 A, 20 A, 30 A, and 50 A.



(a) 30 A
EtherCAT type
(GADSA03AH24)

(b) 50 A
Analog/pulse input type
(GADSA05AA00)

Fig. 2 Servo amplifier

An EtherCAT type and analog/pulse train command input type have been prepared for the host controller and interface. The analog/pulse train command input type is available in SINK or SOURCE type as a general-purpose output specification.

Table 5 shows the main specifications of the new servo amplifiers. In comparison with the current model, responsiveness has been enhanced, and servo performance has been improved with an extensive range of control and compensation functions.

Servo tuning can be performed easier using the "SANMOTION MOTOR SETUP SOFTWARE" tool (hereinafter abbreviated to SETUP SOFTWARE) and the linked frequency characteristics measurement function and Advanced Tuning function.

To allow the new product to be used in various regions and environments, environmental durability to conditions such as altitude and ambient temperature have been improved, and reliability has been increased. Moreover, the product has been equipped with an extensive range of monitoring functions used to estimate remaining part life, and monitor the power supply condition and communication quality, improving maintainability.

Table 4 Servo amplifier product lineup

Power supply voltage		Compatible motors	GPO interface		Servo amplifier model no.
100 V	200 V	Rated output	EtherCAT	Analog/Pulse	
✓	–	Up to 30 W	–	Sinking output	GADSE01*A**
✓	–	Up to 30 W	–	Sourcing output	GADSE01*B**
✓	–	Up to 30 W	✓	–	GADSE01*H**
✓	–	Up to 100 W	–	Sinking output	GADSE02*A**
✓	–	Up to 100 W	–	Sourcing output	GADSE02*B**
✓	–	Up to 100 W	✓	–	GADSE02*H**
✓	–	Up to 200 W	–	Sinking output	GADSE03*A**
✓	–	Up to 200 W	–	Sourcing output	GADSE03*B**
✓	–	Up to 200 W	✓	–	GADSE03*H**
–	✓	Up to 150 W	–	Sinking output	GADSA01*A**
–	✓	Up to 150 W	–	Sourcing output	GADSA01*B**
–	✓	Up to 150 W	✓	–	GADSA01*H**
–	✓	Up to 400 W	–	Sinking output	GADSA02*A**
–	✓	Up to 400 W	–	Sourcing output	GADSA02*B**
–	✓	Up to 400 W	✓	–	GADSA02*H**
–	✓	Up to 1.5 kW	–	Sinking output	GADSA03*A**
–	✓	Up to 1.5 kW	–	Sourcing output	GADSA03*B**
–	✓	Up to 1.5 kW	✓	–	GADSA03*H**
–	✓	Up to 2.5 kW	–	Sinking output	GADSA05*A**
–	✓	Up to 2.5 kW	–	Sourcing output	GADSA05*B**
–	✓	Up to 2.5 kW	✓	–	GADSA05*H**

Table 5 Servo amplifier main specifications

Items \ Amplifier capacity			10 A	20 A	30 A	50 A
200 V	Control power supply voltage range		200 to 240 VAC +10%, -15%			
	Main circuit power supply voltage range		Single-/3-phase 200 to 240 VAC +10%, -15%; 300 VDC ±20%			
	Compatible motors	3-phase (single-phase/DC in parentheses)	Up to 150 W	Up to 400 W	Up to 1.5 kW (up to 750 W)	Up to 2.5 kW (up to 1.5 kW)
100 V	Main/Control circuit power supply voltage range		Single-phase 100 to 120 VAC +10%, -15%; 150 VDC ±20%			–
	Compatible motors		Up to 30 W	Up to 100 W	Up to 200 W	–
Continuous output current / Peak current			1.2 Arms / 4.3 Arms	3.1 Arms / 12 Arms	5.2 Arms / 16.3 Arms	12 Arms / 26.5 Arms
Altitude / Operating ambient temperature / Vibration resistance			2000 m or less / 0 to 60˚C / 6.0 m/s^2			
Dimensions			40 W × 160 H × 130 D		50 W × 160 H × 130 D	85 W × 160 H × 130 D
Mass			0.8 kg or less		0.9 kg or less	1.6 kg or less
Structure / Cooling system			Tray type / Passive air cooling	Tray type / Forced air cooling		
Compatible motor types			• Rotary motors • Linear servo motors • Direct drive motors			
Compatible encoders			• Absolute encoders (battery-less, single-turn, and battery backup types) • Wire saving incremental encoder • HEIDENHAIN's EnDat2.2 encoder			
Performances and functions	Responsiveness and maximum applicable resolution		• 3.5 kHz (speed loop frequency response) • 134,217,728 steps per rotation (27 bit)			
	Control functions, compensation functions		• Tandem operation control • Dual position feedback control • Quadrant projection compensation • Friction compensation • Gravity compensation • Disturbance observer			
	Interface		• EtherCAT, analog/pulse train command input			
	Mechanical vibrations, resonance suppression		• Model following vibration suppression • FF vibration suppression • Vibration suppression for trajectory control • Adaptive notch filter • CP vibration control • Minor-vibration control • Torque command notch filter (variable width)			
	Servo tuning		• Frequency characteristics measurement • Advanced tuning • Auto tuning responsiveness (7 characteristics, 40 levels)			
	Start-up, monitoring, diagnosis		• Virtual motor operation • Drive recorder • System power consumption monitoring • Input power supply monitoring • Control power supply frequency monitoring • Encoder/EtherCAT communication quality monitoring • Remaining electrolytic capacitor life • Remaining holding brake life • Regenerative resistor power consumption monitoring • Encoder temperature monitoring • Amplifier temperature monitoring • Relay counter • Relay sticking detection			
Compliance with standards	UL / CSA		UL 61800-5-1 / C22.2 No. 274-13			
	Low Voltage Directive / EMC Directive		EN 61800-5-1 / 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			
	Other		CE Mark, UKCA Mark, RoHS Directive			

3. Features

3.1 "Powerful" servo performance

3.1.1 High-power, high-precision servo motor

The new product features an optimized servo motor, holding brake electromagnetic field construction, and winding specifications. Moreover, improvements have been made to the connector arrangement and motor construction, and the size of the encoder has been reduced, significantly shortening the motor length. Torque density has been improved by reducing the size of the motor, while maintaining the high torque characteristics of the *SANMOTION R* series. Torque density is the torque produced per unit volume, and the larger the value, the more torque that is produced with smaller motor.

Figure 3 shows a comparison of peak torque density. Peak torque density has been improved by up to 13% for low inertia, and up to 28% for medium inertia compared to the current model.

The developed encoder is a high-resolution battery-less absolute encoder, and the resolution can be selected from 17-bit, 20-bit, 23-bit, or 27-bit. Enhancing encoder resolution has made it possible to realize stable repeat operation and highly-responsive positioning.

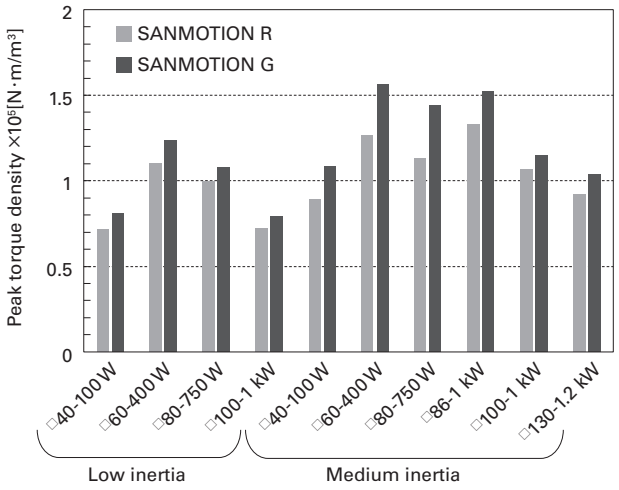


Fig. 3 Comparison of peak torque density

3.1.2 Extended output range

Figure 4 shows a comparison of torque vs. rotation speed characteristics (T-N characteristics). By optimizing the winding specification, the maximum rotation speed of the motor has been increased from 6,000 min^{-1} to 6,500 min^{-1}, an 8% improvement over the current model. The servo amplifier voltage use rate during high-speed rotation, a voltage saturation condition, has been improved, and the motor torque in the high-speed rotation range has been improved by up to 7% by increasing the voltage applied to the motor.

By doing so, the motor output range has expanded by 15%, allowing acceleration and deceleration time to be reduced.

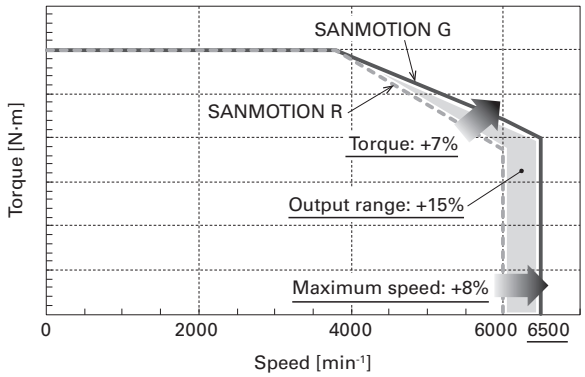


Fig. 4 Comparison of servo motor torque-speed characteristics

3.1.3 Improved responsiveness and shortened positioning time

Figure 5 shows the closed loop frequency response for the speed control system. The responsiveness of the current control system has been doubled over the current model by increasing the control cycle speed and improving the current detection accuracy. And by improving the torque control system, the frequency response of the speed control system has been improved by approximately 1.6 times (3.5 kHz) over the current model.

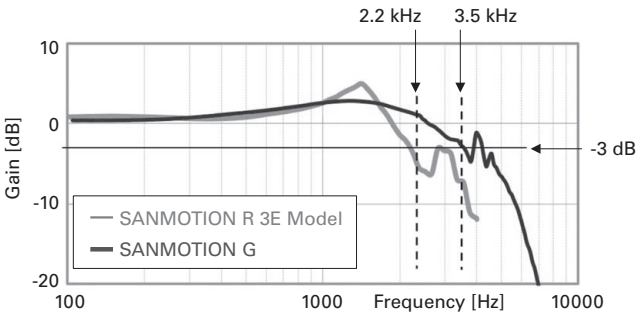


Fig. 5 Comparison of frequency response in speed control system

Figure 6 shows positioning settling characteristics. Using the "SETUP SOFTWARE" tuning function (Advanced Tuning), the positioning settling time has been reduced by 1/3 over the current model by compensating the impact of friction and gravity that hinders settling.

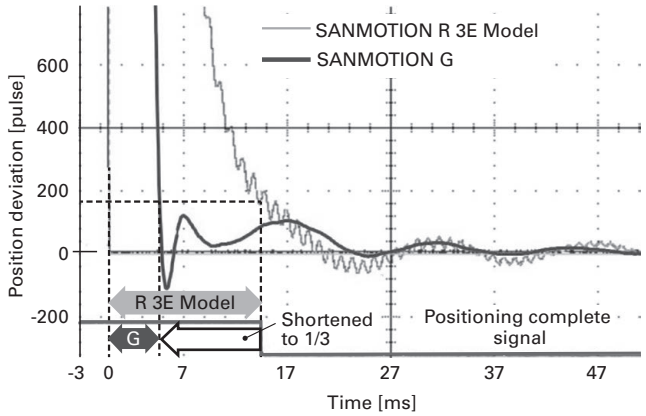


Fig. 6 Positioning characteristics

3.2 "Powerful" environmental durability

3.2.1 Enhanced environmental durability

Table 6 shows a comparison of environmental durability between the current product and new product. The new product can be used in more regions and in harsher environments than the current product.

The higher the altitude, the more air pressure drops, leading to lower air density, and this in turn results in a drop in heat radiation efficiency and withstand voltage. We stipulated a design that would allow the product to be used at altitudes twice as high as the current model, as well as the applicable test method. By clearing these strict tests, we were able to realize a product that can be used at altitudes of up to 2,000 m. Moreover, we significantly expanded the servo motor vibration resistance to twice the 24.5 m/s^2 value for the current model to 50 m/s^2. We also developed a high-reliability holding brake with minimal abnormal friction material wear, and this maintains holding torque even in high-temperature and high-humidity conditions.

Both the servo motor and servo amplifier can be used safely with derating specifications stipulated for each usage condition.

Table 6 Environmental durability comparison with current product

Items	Product	SANMOTION R (Current product)	SANMOTION G (New product)
Altitude	Motor	1,000 m or below	2,000 m or below (may require derating)
	Amplifier		
Vibration resistance	Motor	24.5 m/s^2 (10 Hz to 2 kHz)	50 m/s^2 (10 Hz to 2 kHz)
	Amplifier	4.9 m/s^2 (10 to 55 Hz)	6.0 m/s^2 (10 to 150 Hz)
Ambient temperature	Amplifier	0 to 55°C	0 to 60°C (may require derating)
Ambient humidity	Amplifier	90% RH or less (non-condensing, non-frozen)	95% RH or less (non-condensing, non-frozen)

3.2.2 Reduced radiated emissions

The main cause of rising emission levels is parts that work at high speed and with high accuracy. To address this, we analyzed the PCB magnetic near field, and optimized the pattern layout.

Figure 7 shows the servo amplifier (capacity: 30 A) radiated emissions. As the obtained data in this chart shows, the radiated emissions level in the high frequency range caused by reference clock signals such as those from the oscillator have been significantly lowered than the current model. By carrying out this test using a 10 m anechoic chamber in the new building of our Technology Center completed in 2021, we were able to significantly shorten the evaluation period.

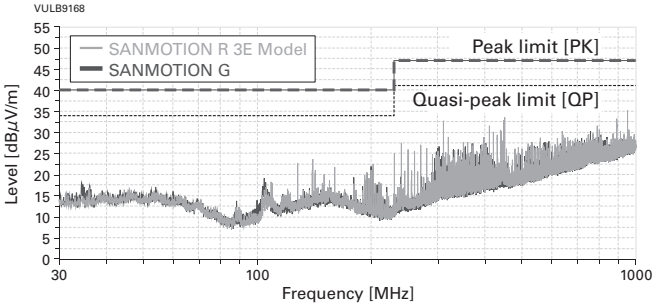


Fig. 7 Radiated emissions (10 m, horizontal)

3.3 "Powerful" maintainability

3.3.1 Preventive maintenance functions

We equipped the servo system with a remaining part life function for the parts used in servo motors and servo amplifiers to help with failure prevention and maintenance.

The motor holding brake is calculated from the amount of rotation when the motor is stopped by braking with respect to the wear limit. Electrolytic capacitor deterioration is calculated from the main circuit power supply and servo ON condition. The remaining life of the fan motor and relays is calculated from the operating time and operation count with respect to the expected life.

Failures can be prevented by systematically replacing and overhauling servo motors and servo amplifiers based on this information.

3.3.2 Environmental diagnosis

We added functions to help with servo system installation environment diagnosis. Table 7 shows a list of environmental monitoring items. Error rates, etc. for EtherCAT communication and encoder communication have also been included. These functions allow products to be used safely and with peace of mind by conducting surveys of customers'

operating environments to make improvements as quickly as possible.

Main circuit rectifier voltage monitoring detects peak voltage value through 3-phase full-wave rectification of the input power supply voltage. Control power supply frequency monitoring detects power supply frequency in 1 Hz increments. Monitoring of these parameters provide the status of overvoltage, voltage fluctuations, and frequency fluctuations, helping customers diagnose power supply environments and identify the cause when errors occur.

Table 7 Environmental monitoring items list

Monitoring item	Monitoring name	Output unit
Input voltage	Main circuit rectifier voltage monitoring	V
	Main circuit DC voltage monitoring	V
Frequency	Control power supply frequency monitoring	0.1 Hz
Communication quality	Motor encoder communication error rate	–
	External encoder communication error rate	–
	EtherCAT communication error rate	–

3.3.3 Early diagnosis

We added sub-codes to alarm codes to improve troubleshooting when alarms occur. Each alarm code is subdivided up into to 15 types of cause, and these are displayed as sub-codes.

This helps identify the cause quickly, reducing equipment downtime.

3.4 "Friendly" to (global) environment

3.4.1 High-efficiency, compact, lightweight servo motor

Figure 8 compares the motor length and Figure 9 compares the motor weight of the current and new models (without holding brake in both figures). As mentioned earlier, the servo motor length and weight have been reduced by improving the electromagnetic field and motor mechanism and reducing the size of the encoder. The motor length has been shortened by up to 11% for low-inertia models and by up to 22% for medium-inertia models. The motor weight has been reduced by up to 12% for low-inertia models and up to 26% for medium-inertia models. Also, the reduced motor length and weight have led to a reduction in the amount of materials used by up to 28%.

Although shortening motor length usually reduces its efficiency, we achieved up to 9% higher efficiency by optimizing the electromagnetic field, improving the winding fill factor, and using low-loss materials. This resulted in up to 48.3 % lower CO_2 emissions.

Use in combination with a battery-less absolute encoder eliminates the need for battery backup for retaining multi-turn data when the power is turned OFF. Consequently, there are no batteries that need to be periodically replaced, contributing to natural resources saving, reduced industrial waste, and improved maintainability.

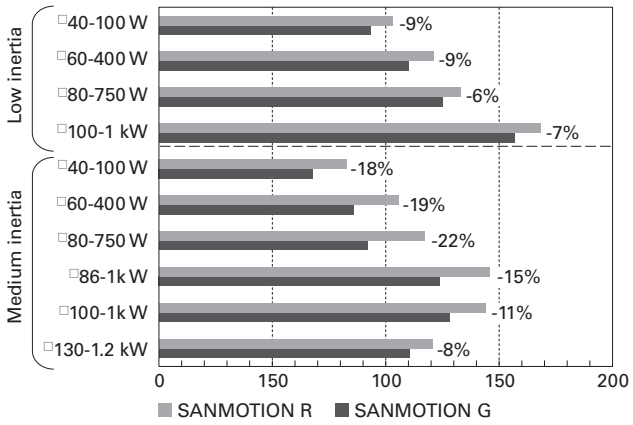


Fig. 8 Comparison of motor length (Without holding brake)

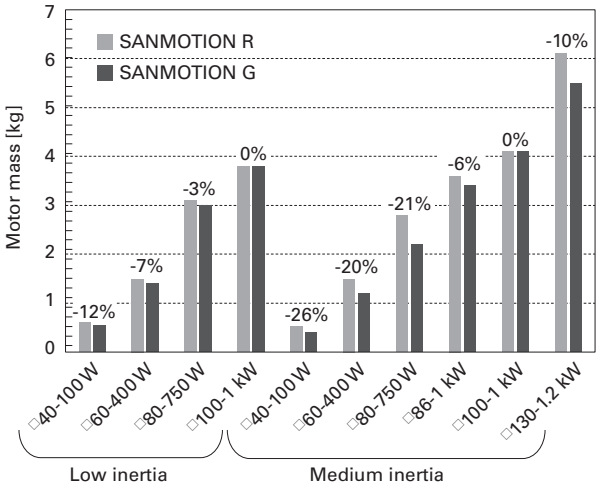


Fig. 9 Comparison of motor mass (Without holding brake)

3.4.2 Servo amplifier with low loss

To increase servo amplifier output, we improved the maximum output current of the power device by up to 5%. To increase responsiveness, switching frequency of the power device has been made 16% faster under normal conditions and up to 55% faster in the mode for reducing the noise caused by switching frequency when the motor

is stopped. Increased output current and faster switching frequency usually result in increased loss and lower efficiency. Despite this, amplifier power consumption has been reduced by up to 22% by replacing high power consumption parts. This resulted in up to 18.9% lower CO_2 emissions.

Moreover, by reducing part size and optimizing thermal design, amplifier weight has been reduced by up to 5.5% while maintaining the same size as the current models.

3.5 "Friendly" to operators

3.5.1 High-precision measurement of machinery characteristics

High-precision system analysis has been added to our conventional system analysis to offer a new measurement mode. Conventionally, a dedicated measurement device (servo analyzer) was used to measure machinery frequency characteristics including servo control loop with high precision. The new amplifier achieves high-precision measurement by generating sinusoidal commands, calculating the frequency spectrum, and executing the frequency analysis of SETUP SOFTWARE.

3.5.2 Optimized tuning of servo parameters

We developed Advanced Tuning, which measures machinery characteristics and optimize parameters for it.

Advanced Tuning automatically performs the following series of characteristic measurements and parameter adjustments in (1) to (4).

(1) Adjust feedback control parameters using the conventional system analysis.
(2) Using friction and gravity measurement, estimate friction and gravity and then compensate.
(3) Using the high-precision system analysis, adjust feedback control parameters more precisely to ensure stability.
(4) In positioning operation, adjust model control parameters to improve responsiveness.

This optimizes adjustments and shortens startup time, improving ease of use.

3.5.3 Update of motor parameters

SETUP SOFTWARE is revised with a new servo motor parameter update function. Previously, it was necessary to update the firmware to run servo motor models that were newly added to the lineup.

With this new servo system, the servo motor parameters can be updated easily by the customer on site using SETUP SOFTWARE.

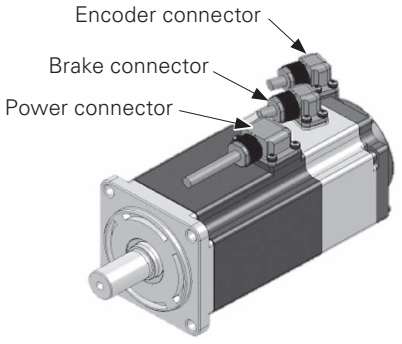
3.6 "Friendly" to customers

3.6.1 Makes replacement easy

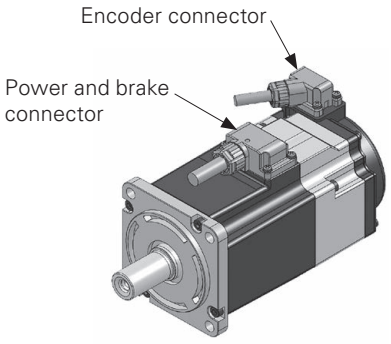
The servo motor has the same flange dimensions, mounting dimensions, and output shaft shape as the *SANMOTION R* for mounting compatibility. The motor power cable and holding brake cable on the current model were separate, but they have been integrated into a single cable as shown in Figure 10, reducing the number of parts.

The servo amplifier has the same external dimensions and mounting dimensions as the current model. Current functionality has been retained, and newly developed compensation and functions have been added.

By enhancing compatibility, *SANMOTION G* can be easily substituted into customers' existing equipment.



(a) SANMOTION R (Current product)

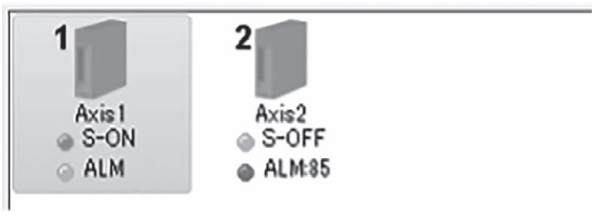


(b) SANMOTION G (New product)

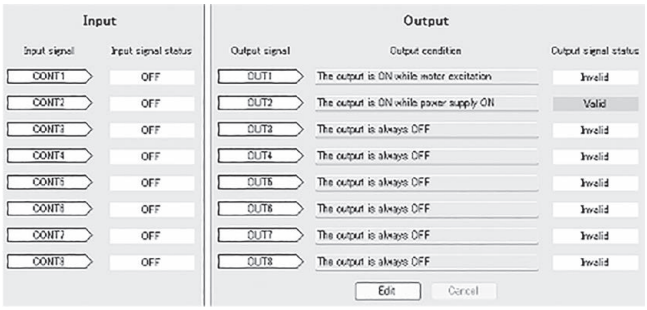
Fig. 10 Servo motor connectors

3.6.2 Increased visibility and usability

The same "SETUP SOFTWARE" interface is used, improving visibility and ease of use. As shown in Figure 11, the servo amplifier status and general-purpose input/output status can be intuitively grasped by displaying them visually on the screen.



(a) Servo amplifier status display



(b) GPIO status display

Fig. 11 Monitoring screens on SETUP SOFTWARE

4. Key Points of Development

To improve productivity and quality over the current model, it was necessary to construct a test environment in which designs which allowed products to be manufactured on automated lines and various tests could be performed automatically. This chapter introduces aspects of the development and creative ideas we incorporated into our development work.

4.1 Increased servo motor productivity and production quality

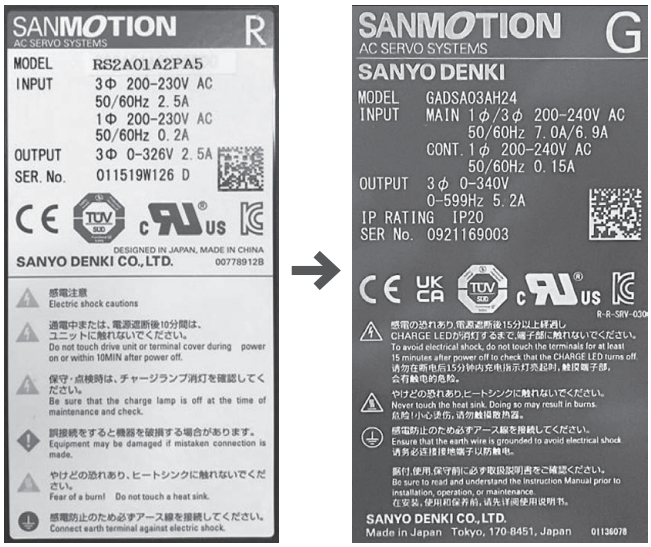
All servo motor models were constructed with an aluminum frame, and the structural skeleton was unified using a similar design. The basic construction is the same for all models, making it possible to switch between production models quickly. Moreover, assembly of the stator and rotor, key motor components, was automated for each process for improved productivity.

New automatic equipment used to produce the rotating disk module is adopted for the encoder. The rotating disk centering and bonding processes that were previously carried out manually are now carried out using a camera and robot, and this has greatly improved productivity.

4.2 Increased servo amplifier productivity and production quality

4.2.1 Increased productivity

As shown in Figure 12, the main servo amplifier nameplate has been changed from the label for the current model, which involved attaching a printed seal, to a nameplate that is printed directly onto the amplifier body with a laser marker, eliminating the need for manual label attachment work.



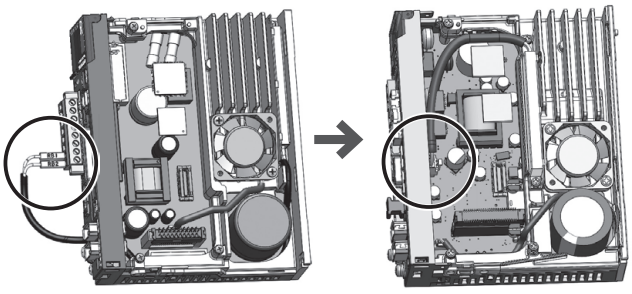
(a) SANMOTION R (Current product)

(b) SANMOTION G (New product)

Fig. 12 Text printed label (left) and laser-printed text (right)

As shown in Figure 13, the wiring for the built-in regenerative resistor in the current model is connected to the connector on the front after assembly is complete, and the work was complex. On the new product, the connector is connected to a board inside the servo amplifier.

Wiring no longer becomes trapped, making work easier.



(a) SANMOTION R RS3A02 (current product)

(b) SANMOTION G GADSA02 (new product)

Fig. 13 Built-in regenerative resistor wiring

Firmware is written automatically when assembling by the automated line robot. The weight of the write jig is greater than the withstand load of the robot hand, and so the jig has been installed on the robot unit. A 3 m cable is required to connect the write jig to the tip of the robot arm, but the cable

from the manufacturer is only 0.2 m long, and so cannot be used.

In response to this, we produced a communication jig capable of transmitting high-speed signals corresponding to automatic writing using the robot over long distances as shown in Figure 14.

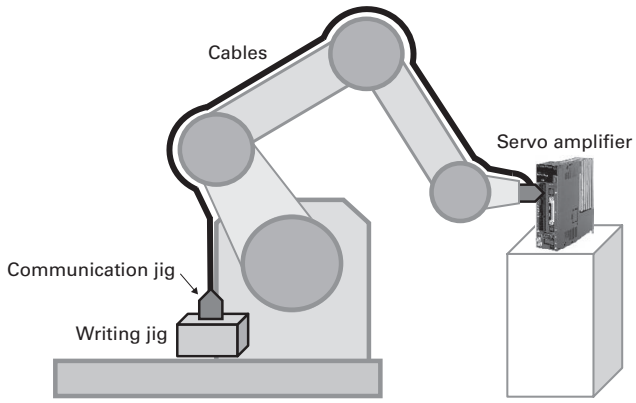


Fig. 14 Automatic writing using robot

4.2.2 Increased software quality

Servo systems are used in a variety of applications. Conditions and environments tend to be complex, and it is difficult to carry out exhaustive testing manually.

To carry out effective and efficient testing for this development, we constructed a test simulator capable of simulating the actual operating environment. We created a template for the test pattern, and developed a tool used to run tests by automatically generating patterns based on condition settings. For the test simulator, we created vertical and horizontal units, as well as a rotary unit. By anticipating the customer's actual equipment, we were able to carry out various tests by using a proximity sensor, holding brake, loading device, speed reducer, and external encoder.

This helped us to discover potential defects at an early stage, ensuring stable quality in a short space of time.

5. Conclusion

This article provided a product overview, and introduced the features and development points of the *SANMOTION G* AC servo system developed based on the concepts of "powerful" and "friendly."

In comparison with the current model, the *SANMOTION G* offers the following enhancements.

(1) Peak torque density improved by up to 28%, and the output range in the high-speed area expanded 1.15 times. By increasing the encoder resolution by 16 times (max. 27 bit) and the speed loop frequency response by 1.6 times (3.5 kHz), we were able to realize stable, highly-responsive operation.

(2) We improved vibration resistance by 2 times for the servo motor, and 1.2 times for the servo amplifier. We increased the altitude at which the product can be used from 1,000 m to 2,000 m, and expanded the operating temperature range. Improving the environmental durability allows the product to be used in a variety of regions, even in harsh environments.

(3) We equipped the new product with functions such as holding brake and electronic component life prediction, and input power supply and communication quality monitoring to help with servo system preventive maintenance, and equipment environment monitoring and diagnosis. These functions have led to improved machinery maintainability.

(4) We made the system smaller and lighter by reducing the servo motor length by up to 22%, and reducing the weight by up to 26%. We realized energy savings by reducing servo motor energy loss by up to 8%, holding brake power consumption by up to 44%, and servo amplifier energy loss by up to 22%.

(5) We were able to shorten equipment startup time with an Advanced Tuning function used to measure machine characteristics with high accuracy, and automatically adjust servo parameters to their optimum values.

(6) The motor power and holding brake cables have been integrated. The cable connector direction can also be changed, increasing the degree of wire freedom to make wiring work easier.

(7) The new product has exterior size and mounting interchangeability with the current model, and functionality has been retained, allowing the current model to be easily substituted for the new product.

This *SANMOTION G* AC servo system features significantly evolved servo performance and higher reliability, and can be used at high power even in harsh environments for peace of mind. Energy savings, and size and weight reductions have been realized, making the new product both easier to use, and friendly to both the global environment and to users.

In the future, we intend to expand the series lineup, and develop optimally customized products tailored to customer applications through development with deep customer involvement.

Note 1: Current servo motors refer to SANMOTION R motors.
Note 2: Current servo amplifiers refer to SANMOTION R 3E Model amplifiers.
Note 3: EtherCAT® is a registered trademark and patented technology, licensed by Beckhoff Automation GmbH, Germany.

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