Development of High-Output *SANMOTION F* Stepping Drivers

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1. Introduction

SANMOTION F series stepping systems provide high-torque, high-precision operation and are used in a wide range of applications, especially for semiconductor manufacturing equipment and medical equipment. To achieve higher speeds and micromachining of equipment, it is essential to improve the performance of motor systems. In recent years, it has become important to save energy by improving equipment efficiency to protect the environment.

It is against this background that we developed new models of compact stepping drivers with dramatically improved overall performance. The new models are available in a high-power model with high output and high functionality and a basic model compatible with our current drivers for both 2-phase and 5-phase motors.

The high-power model is smaller and lighter than the current model but has much higher torque at high speeds. It also reduces speed variations, which enables the smooth operation of equipment at high speeds. In addition, it has PC-based functions that allow advanced parameter settings and status monitoring.

The basic model improves torque and reduces speed variations while maintaining interface and function compatibility with the current model. It can improve the equipment performance simply by replacing the driver thanks to the compatibility with the motors of the current model.

In this article, we begin by showing the appearance and specifications of the new models. Next, we introduce the performance and functions of the new models.

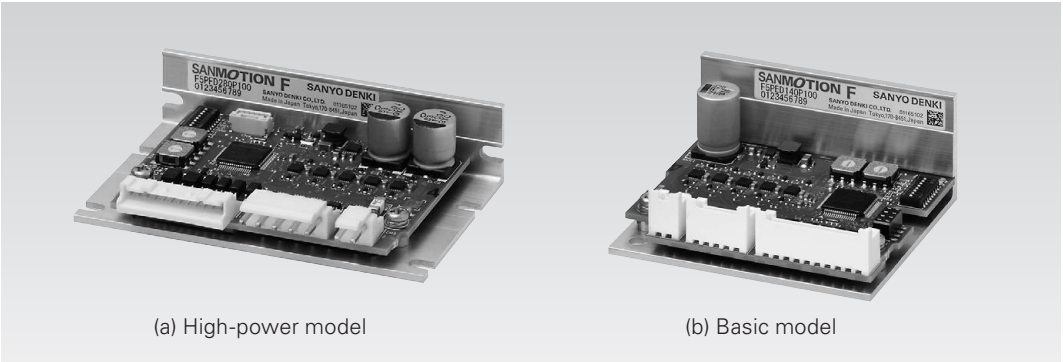
2. Product Overview

2.1 Appearance

Figure 1 shows the new models and Figure 2 shows their external dimensions.

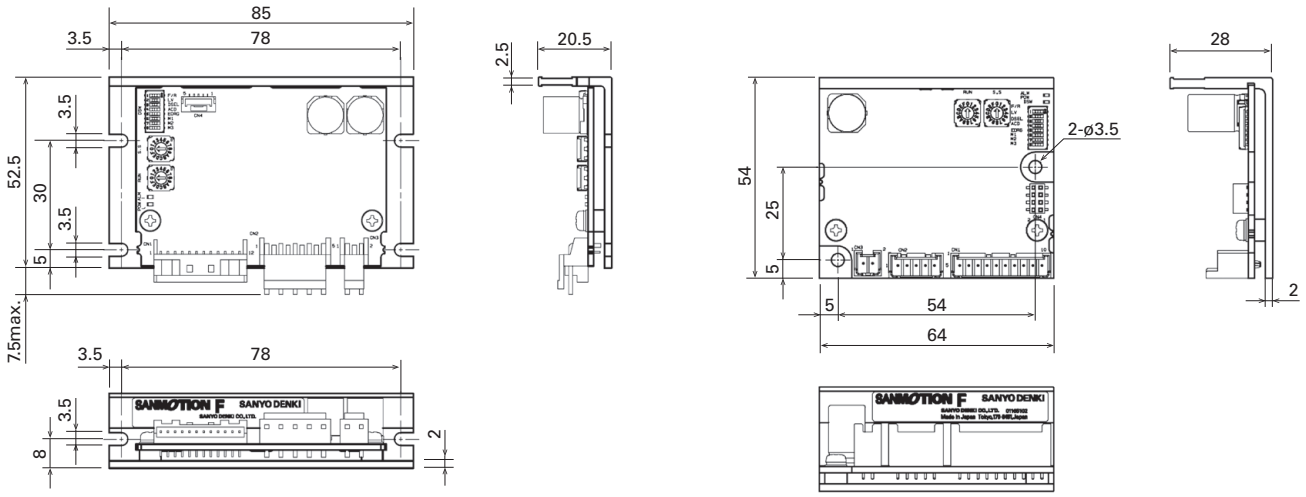
The high-power model has a thin profile and its volume and mass are 63% and 73% smaller, respectively, than the current model of the equivalent output. Since it can be mounted from either the back or the bottom, it provides high flexibility, for example, it can be installed in narrow spaces or the heat-dissipating surface can be attached closely for efficient heat dissipation.

The basic model has the same mounting dimensions for easy replacement of the current model. Through the use of low-loss electronic components to reduce heat generation and make heat sinks thinner, it achieved a 7% reduction in volume and 39% reduction in mass while maintaining almost the same shape as the current model.



(a) High-power model (b) Basic model

Fig. 1 Appearance of new models



(a) High-power model (b) Basic model

Fig. 2 Dimensions of new models (unit: mm)

2.2 Specifications

Table 1 shows the product lineup and specifications. Each model has the same specifications for 2-phase and 5-phase motors, except for the maximum output current and microstepping resolution.

Compared to the basic models, the high-power models feature higher output current and a variety of functions. The high-power model has a higher output current and can operate at higher speeds than the basic model. The high-power model also has PC-based functions, a preventive maintenance notification function, and a function to notify a host controller of alarms.

Table 1 Product lineup and specifications

Items		High-power model		Basic model	
		2-phase	5-phase	2-phase	5-phase
Maximum output current		4.0 A/phase	2.8 A/phase	2.0 A/phase	1.4 A/phase
Input voltage		24 VDC			
Input/Output signal		4/2		3/2	
Product size [mm]		85 × 20.5 × 52.5		64 × 28 × 54	
Mass [g]		60		55	
Microstep		1/256	1/250	1/256	1/250
Compatible motor (flange) size		56 mm sq. 86 mm sq.	60 mm sq.	42 mm sq. 56 mm sq. 60 mm sq. 86 mm sq.	28 mm sq. 42 mm sq. 60 mm sq. 86 mm sq.
Functions	Low vibration mode	✓		✓	
	Excitation phase memory	✓		✓	
	Step resolution compatibility	✓		✓	
	PC-based functions	✓		–	
	Preventive maintenance notification	✓		–	
Protection functions	Voltage monitoring	✓		✓	
	Overcurrent protection	✓		✓	
	Overheat detection	✓		✓	
	Wire breakage detection	✓		✓	
	Alarm notification signal	✓		–	

3. Features

Table 2 shows the features of the new models. The values in the table are the performance improvement ratios compared to the current models as well as the newly implemented functions. Further details on the implementation are described in the subsequent subsections.

Table 2 Product features

Items	High-power model(1)	Basic model(2)
Shape	Thin profile, mountable on two sides	Mounting and size compatibility
Volume	Reduced by 63%	Reduced by 7%
Mass	Reduced by 73%	Reduced by 39%
High-speed torque	1.5 to 2.7 times higher	1.05 to 1.1 times higher
Speed variation(3)	Reduced to 1/4 or less	Reduced to 1/3 or less
Efficiency(4)	8.7% increase	5.5% increase
Preventive maintenance notification	Yes	No (same as previously)
Other advantages	PC-based settings and status monitoring supported	Interface and functional compatibility with current product maintained

(1) Comparison with current model F5PAE140P100
(2) Comparison with current model BS1D200P10
(3) Comparison of the average of speed variations
(4) Comparison of the maximum combined efficiency of driver and motor

3.1 Improved overall performance

The new models can smoothly control the current passing through the motor, achieving high torque and low vibration. They monitor the current of the entire motor and optimally compensate it to improve the voltage utilization ratio to realize higher torque. In addition, they control to balance the current flow in the windings of each phase to reduce speed variations.

3.1.1 Improved high-speed torque

Figures 3 and 4 show the pull-out torque characteristics of the high-power model and basic model, respectively. Compared to the current models of the same output, the pull-out torque at high speeds has been increased up to 2.7 times for the high-power model and up to 1.1 times for the basic model.

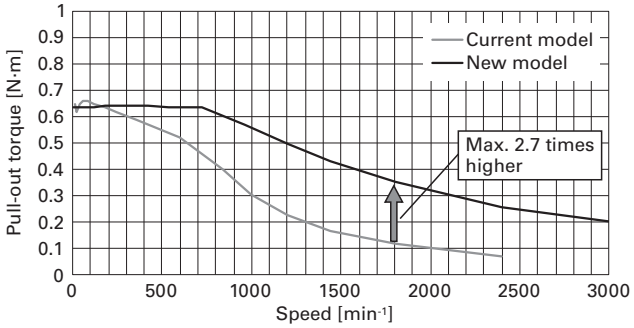


Fig. 3 Pull-out torque characteristics of high-power model

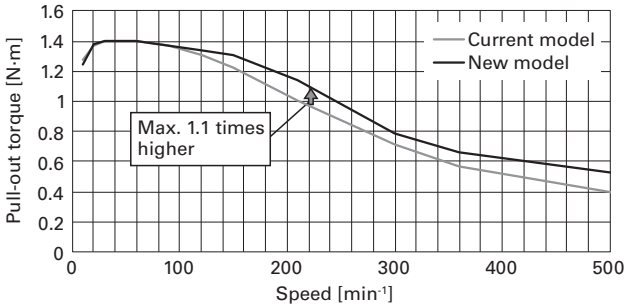


Fig. 4 Pull-out torque characteristics of basic model

3.1.2 Reduced speed variation

In general, stepping motors are prone to large speed variations during low-speed rotation below 150 min^{-1} or during high-speed rotation after voltage saturation. This is because the winding current fluctuates and resonates at the natural frequency of the motor and equipment due to phase switching at low speeds and due to interference between phase switching and the current control cycle at high speeds.

The new models have a well-balanced current flow in each phase winding that smoothen out current variations during phase switching to suppress resonance and reduce speed variation.

Figure 5 compares speed variations of the same motor when it was operated using the basic model and a current driver. It shows that the basic model reduces speed variations at both low and high speeds.

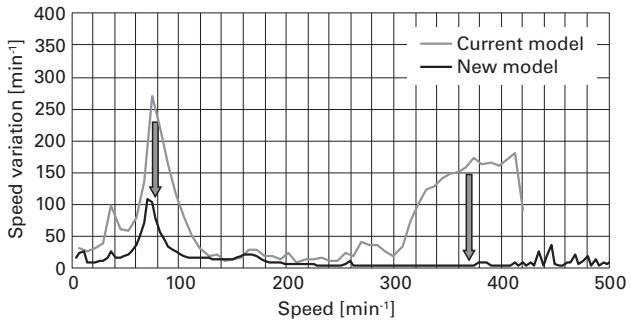


Fig. 5 Comparison of motor speed variation characteristics

3.1.3 Improved efficiency

Reducing speed variations also improves motor efficiency because less power is required which does not contribute to torque. Furthermore, by using low-loss components, the overall efficiency of the driver and motor has been increased by up to 8.7% for the high-power model and 5.5% for the basic model.

3.2 Basic functions

The new models also inherit the low-vibration mode and excitation phase memory functions of the current models. Low-vibration mode performs smooth control by interpolating between command pulses in micro-steps, which helps suppress speed variations at low speeds. The excitation phase memory function automatically saves the motor excitation phase at power shutdown to prevent shaft vibration at the next start of excitation.

In addition to the above functions, the new models possess 2-phase and 5-phase step resolution compatibility to facilitate the replacement of motor systems. This function enables control with a standard 2-phase motor command resolution of 200 P/R while using a 5-phase driver and motor. This allows, for example, users to change from a 2-phase system to a 5-phase system without changing the program on the host controller. This is useful for improving the equipment performance.

3.3 Enhanced protection and monitoring capabilities

The new models have greatly enhanced monitoring and protection functions that ensure safe and reliable use.

3.3.1 Various monitoring items

At power-on, a self-diagnosis function checks the driver's internal power supply voltage, sensor circuit, and motor power cable status. If it detects an abnormality, it issues an alarm before exciting the motor.

During operation, the system constantly monitors for excessive or insufficient input power supply voltages, driver overheating, motor overcurrent, and command speed errors. In particular, it monitors motor overcurrents not only for shorts between power cables but also for ground faults in the equipment housings. When it detects an abnormality, it instantly cuts off the output current.

When an alarm occurs, it stops the motor, notifies the host device with an output signal, and indicates the alarm factor by the number of times the LED blinks.

3.3.2 Warning feature

Current models do not have a function to alert users of abnormalities in input power supply voltage and other conditions. Therefore, it was difficult to detect abnormalities even when using the product at low margins and there were instances of alarms after shipping due to environmental changes or individual differences.

To resolve these issues, the new models are designed to display a warning as insufficient margins of power supply voltage and temperature before an alarm occurs. Normally, warnings are indicated only by LEDs, but the high-power model can also notify host devices using output signals. Since the motor can continue to operate during a warning, host devices can take measures before an alarm occurs.

3.4 PC-based functions

High-power models are equipped with PC-based functions. The driver is to be connected to a PC using a dedicated communication converter. In addition, SANMOTION MOTOR SETUP SOFTWARE, which has a proven track record with our servo amplifiers, is provided as PC software.

Connected to a PC, users can use the following functions.

- Settings of operation parameters
- Internal status monitoring
- Preventive maintenance assistance
- Reading alarm logs

3.4.1 Settings of operation parameters

Users can set parameters related to input/output signal functions, motor control, and preventive maintenance. Since the parameter settings are stored in the driver's nonvolatile memory, once they are set, they are retained and automatically used the next time the power is turned on. Table 3 shows some examples of setting parameters and their functions.

Table 3 Setting parameters

Setting parameters	Function	Benefit
Input signals	Select from excitation off signal, step angle switching signal, current limiter signal, limit sensor signal, etc.	Optimizes the system
2 step resolution modes	Enables switching the command resolution by an input signal.	Advanced motor operation
Speed command filtering	Alleviates shocks caused by acceleration and deceleration.	
Electronic gear	Sets the command resolution more finely than usual.	
Current-limiting value setting	Limits motor current according to the input signal to suppress heat generation.	
Traveled distance for maintenance notification	Issues a warning and prompts for maintenance and inspection when the set travel distance is reached.	Helps preventive maintenance

3.4.2 Internal status monitoring

When developing equipment and troubleshooting problems in the field, it is more efficient if the input status of commands and the operation status of drivers can be easily checked.

The new models provide internal status monitoring to facilitate device debugging. Table 4 shows some examples of the monitored items by this function. As shown in Figure 6, some of the monitored information can be displayed as an operation trace waveform. Users can check the timing of changes and the correlation with the other monitoring results. By using this function, users can check driver input and output and its internal status without measuring instruments. This greatly facilitates analysis and troubleshooting.

Table 4 Monitored items

Monitored items	Function
Command pulse counter	Displays the input pulse accumulative count value (command position).
Speed	Displays the motor speed.
Input power supply voltage	Displays the driver's input power voltage.
Driver internal temperature	Displays the driver's internal circuit temperature.
Output current	Displays the motor's output current.
Input signal monitoring	Displays the ON/OFF status of input signals.

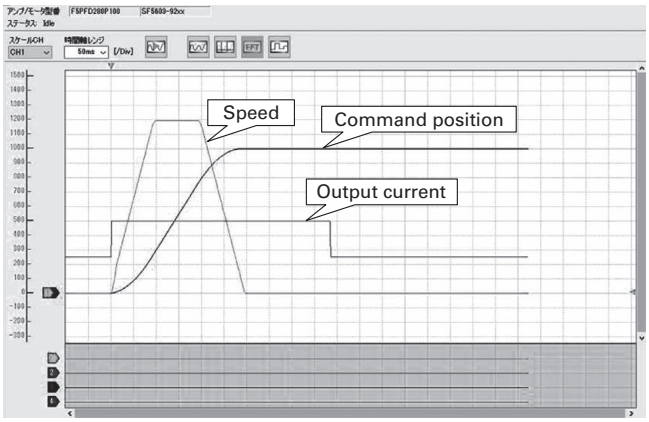


Fig. 6 Graph of motor operation monitoring

3.4.3 Preventive maintenance assistance

Mechanical parts such as ball screws require periodic maintenance to ensure quality. However, this work can be inefficient because even when the mechanical parts are in the same device, the amount of their usage will differ depending on the axis. If maintenance is performed all at once, even axes that do not require maintenance will be checked, which consumes time.

Therefore, the new models come with an accumulative travel distance monitor to manage the preventive maintenance periods. The monitor counts the number of motor rotations and shows the total travel distance actually commanded for the applicable axis. The count value is retained even if the driver's power is cut off. In such a case, it will be automatically restored at the next startup. From the user's perspective, it functions as simple accumulative travel distance information.

When a preset distance is reached, it can issue a warning and notify the user of the need of maintenance.

It enables performing maintenance based on the amount of usage of each axis, minimizing the amount of work required to maintain the quality of equipment.

3.4.4 Reading alarm history

Users can read the log of both past and present alarms. The alarm log records up to 15 alarms with time stamps in milliseconds. Alarms are saved even if the driver's power is cut off. Therefore, users can investigate the causes of past alarms by using the time stamp as a starting point.

4. Conclusion

In this article, we gave an overview of our new *SANMOTION F* stepping systems and described some of their main features.

- The high-power model has a thin profile and reduces volume and mass by 63% and 73%, respectively, compared to our current model of the same power output. Torque at high speeds was increased by 1.5 to 2.7 times, speed variations were reduced to 1/4 or less, and motor efficiency was improved by up to 8.7%.
  It also comes with PC-based functions, allowing users to set parameters according to their equipment and check the operating status.
- The basic model reduces volume and mass by 7% and 39%, respectively, while maintaining installation compatibility with the current model.
  When replacing a current model with the new model using the same motor, torque at high speeds is increased by 1.05 to 1.1 times, speed variations are reduced to 1/3 or less, and motor efficiency is improved by up to 5.5%.
- Both models have greatly enhanced protection and monitoring functions for safer use.

Both models are smaller and lighter than the current models but have increased torque at high speeds and higher power output. They have reduced speed variations compared to the current models, contributing to smaller and lighter equipment, shorter cycle times, and smoother operation. They are also environmentally friendly since they reduce CO_2 emissions during use and transport thanks to their energy-saving improved efficiency and their compact size and lightweight.

Looking ahead, we will leverage the technology we cultivated in these new models to provide faster, smoother, easier-to-use, and more efficient products that create new value for our customers.

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