High-performance Servo System
ALPHA5 Series

1. Introduction

The application of servo systems to general industrial machinery such as semiconductor and LCD manufacturing equipment and electronic parts manufacturing systems has expanded in recent years. For such applications, there is an increasing need for faster speed, higher accuracy, shorter time required for adjustment at system startup, smaller size, and easier maintenance.

The ALPHA5 series is a series of servo systems that meet these needs. In addition to providing higher speed and higher accuracy which improve the basic control performance, and smaller size, the ALPHA5 series is also equipped with a command pulse smoothing function, an automatic notch filter, and a new vibration suppressing control to realize a significant reduction in the time required for adjustment at system startup. Additionally, the PC software support tool (PC loader) has been redesigned, and ease of use has been improved.

The specifications and characteristics of the ALPHA5 servo series are introduced below.

2. Basic Specifications

Figure 1 shows the external appearance of the ALPHA5 series.

Both the servo amplifier and the servo motor are smaller in size than previous models. The servo amplifier requires 25 to 30% less installation space than Fuji

Fig.1 Appearance of the ALPHA5 series

<table>
<thead>
<tr>
<th>Item</th>
<th>Model</th>
<th>GYS (ultra-low inertia series)</th>
<th>GYC (low inertia series)</th>
<th>GYG (medium inertia series)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated output (kW)</td>
<td>0.05 to 0.75</td>
<td>5 types</td>
<td>0.1 to 0.75</td>
<td>0.5 to 1.3</td>
</tr>
<tr>
<td></td>
<td>1.0 to 5.0</td>
<td>6 types</td>
<td>1.0 to 2.0</td>
<td>5 types</td>
</tr>
<tr>
<td>Rated speed (r/min)</td>
<td>3,000</td>
<td>6,000</td>
<td>2,000</td>
<td></td>
</tr>
<tr>
<td>Max. speed (r/min)</td>
<td>6,000</td>
<td>5,000</td>
<td>5,000</td>
<td></td>
</tr>
<tr>
<td>Max./Rated torque ratio</td>
<td></td>
<td>300%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Encoder</td>
<td>20-bit serial encoder (incremental)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protective ventilation</td>
<td>Totally enclosed, self-cooling (IP67)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mounting method</td>
<td>Flange IMB5 (L51), IMV1 (L52), IMV3 (L53)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Installation location, altitude</td>
<td>Indoors, 1,000 m or less</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ambient temperature and humidity</td>
<td>−10 to +40 °C, 90% RH or less (no condensation)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Applicable standards</td>
<td>In accordance with UL/cUL (UL1004), CE marking* (EN60034-1, EN60034-5), RoHS directive*2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*1: CE marking is marking indicating conformity with European product safety standards.
*2: RoHS is restriction of the use of certain Hazardous Substances in electrical and electronic equipment.
Electric's previous models and the servo amplifier can be installed side-by-side without a gap as with previous models, thus enabling an even further reduction in size of the equipment.

The specifications and characteristics of this servo series are introduced below.

### 2.1 Servo motor basic specifications

The basic specifications of ALPHA5 series servo motors are listed in Table 1. The servo motors are classified as three types, GYS, GYC and GYG, according to their inertia. The models are further classified according to their rated output, rated speed, and existence of a brake, to comprise a total of 52 types. ALPHA5 series motors use a new small-size and high resolution 20-bit incremental encoder and 18-bit absolute encoder. As a result, more accurate positioning can be realized and their total length can be reduced by approximately 15% compared to Fuji Electric's previous models. For models of 750 W and below, the increase in maximum speed from 5,000 r/min to 6,000 r/min contributes to a shorter tact time for the machinery. The motor construction provides high environmental durability, and as in Fuji’s previous models, all motor models have an enclosure rating of IP67.

### 2.2 Servo amplifier basic specifications

The basic specifications of ALPHA5 series servo amplifiers are listed in Table 2. There are three types of amplifiers and they are equipped with a general interface, the original high-speed serial bus (SX bus) or a built-in linear positioning function SX bus. A product lineup has been prepared for the general interface type, having the most commonly used pulse train and analog interface.
voltage commands, and the high-speed serial bus inter-
face type, which is expected to become the main type in
the future.
In the internal circuitry of the amplifier, limited
lifespan components of aluminum electrolytic capaci-
tors and cooling fan have an extended service life. Also,
a USB (universal serial bus) is provided as a standard
feature, and since connection to a PC loader is possible
via a commercially available cable, the ease of use has
been improved.

3. Higher Functionality

3.1 Higher-speed and highly accurate positioning
To improve productivity, shorter tact times are in-
creasingly being requested. Moreover, with the miniatur-
ization of electronic components and so on, requests
for more accurate machine processing have increased
as well.

With the ALPHA5, in addition to deploying a newly
developed high-speed processing circuit comprised of a
CPU and custom LSI chip, the control algorithm that
had been developed in conjunction with conventional
servos has been improved further to realize a frequen-
cy response of 1,500 Hz and high-speed positioning
capability. Moreover, a 20-bit, high resolution, highly
accurate encoder was utilized to enable smooth and
precise positioning operation.

Figure 2 shows an example waveform of the posi-
tioning operation for a 10 mm ball screw. Positioning
at 1µm and below is realized with a command delay
(settling time) of 1.5 ms. Application of the ALPHA5 to
semiconductor manufacturing equipment and the like,
wherein high tact and high accuracy are required, en-
ables an improvement in mechanical performance.

3.2 Control functions that have evolved for ease-of-use
(1) Automatic tuning
The application of the aforementioned high-speed
processing circuit and the high-resolution encoder has
enabled more accurate estimation of the load inertia.
Additionally, the automatic notch filter, an
automatic vibration suppressing control and a pulse
smoothing function (to be described below) in a belt
drive or other mechanism having low rigidity, or in a
mechanism that uses coarse command pulses, enables
automatic tuning to be implemented easily and with
high responsiveness.

(2) Automatic notch filter
A notch filter is a filter that attenuates only speci-
fied frequency components. In a servo system, setting
the notch filter to attenuate the mechanical resonance
frequency enables suppression of the vibration compo-
ent only, without impairing the overall response.

The ALPHA5 is newly equipped with an automatic
notch filter that constantly monitors the torque vibra-
tion and automatically sets the vibration frequency.
Analysis of the mechanical system and manual set-
ting of the resonant frequency had previously been
required, but with the ALPHA5, such tasks are now
unnecessary, enabling a reduction in the adjustment
time at startup. Moreover, even in cases where the res-
onant frequency changes due to the complexity or time
degradation of the mechanical system, the ALPHA5 is
always able to set an appropriate resonant frequency
automatically.

Figure 3 shows example waveforms in the cases
where the automatic notch filter has been enabled and
has been disabled. When the automatic notch filter is
disabled, the vibrations continue, but when the auto-
matic notch filter is enabled, torque and speed vibra-
tions are suppressed instantaneously when vibrations
are detected.

(3) New vibration suppressing control
The vibration suppressing control is a function that
suppresses vibration at the tip of a robot arm or the
like after a positioning operation, and enables a reduc-
tion in tact time in machines having low rigidity. In
the past, it had been necessary to perform desktop cal-
culations or a frequency analysis in order to obtain the
frequency of vibration at the tip of an arm, and then to
set that frequency manually. The ALPHA5, however, is
equipped with an online learning function and is pro-
vided with an automatic vibration suppressing control
that functions to set the vibration frequency automati-
cally, thereby achieving a reduction in adjustment time
compared to the previous method of manual setting.

Fig.2 Waveform of positioning operation

Fig.3 Automatic notch filter
Additionally, with the ALPHA5, the inertia (work-piece inertia) of the tip portion of a robot arm is set as a parameter, enabling better vibration suppressing performance than in the past. Figure 4 shows example waveforms of the operation when measuring arm tip vibration with a laser displacement meter in the case where duration of the positioning operation is 125 ms. With the conventional vibration suppressing control, the vibrations are shown to continue with a cycle time of approximately 83 ms. Suppression of this type of a vibration cycle time, which is nearly the time of the positioning operation, had been previously been difficult to accomplish, but such control has been realized with the new vibration suppressing control.

(4) Pulse smoothing function

In cases such as where a stepping motor is replaced with a servo motor, the coarseness of the command pulse resolution has caused torque vibration and mechanical vibration, and a loud operating sound to be generated. The ALPHA5 is provided with a pulse smoothing function to handle such cases. Figure 5 shows example waveforms when the pulse smoothing function is disabled and enabled. This function smoothes the torque and speed to enable smooth high-speed positioning.

4. Improved Ease of Use (PC Loader Function)

4.1 Improved monitor function

Accompanying the higher levels of performance and functionality of servo amplifiers, there has also been an increase in the number of parameters. Moreover, the ability to transfer larger amounts of data at higher speeds has become necessary for the waveform monitor used to verify servo operation during the adjustment of those parameters. However, with conventional general communications, the transfer of data takes a considerable amount of time, and the repeated setting and verifying of data during the adjustment at startup results in extremely poor work efficiency.

The ALPHA5 series, which supports USB communication and is capable of high-speed data transfers, is a stress-free, easy-to-use loader for users.

Table 3 compares the basic specifications of the waveform monitor function (trace function) of a conventional servo system and the ALPHA5 series. With the ALPHA5 series, in order to observe data more accurately, the sample period was shortened, and the number of sampling points were increased significantly. Also, the measurement cursor was improved and a waveform comparison function, a frequency analysis (FFT) function and other functions were added to aid the adjustment at startup.

The waveform comparison function is capable of overlaying and displaying two sets of waveform data. As a result, operating differences based on parameter differences can be assessed easily, and this leads to a reduction in the adjustment time at startup. Moreover, comparisons are also possible to historical waveform data that has been saved, and as shown in the example historical trace comparison screen of Fig. 6, the effect of time degradation on the mechanical system can be observed by comparing waveforms of the adjustment at machine startup and recent waveforms. This function can also be used to verify variances among machines of the same model.

With the frequency analysis (FFT) function, waveform data frequencies can be analyzed, the frequency of torque vibration and the like can be measured, and parameters relating to the notch filter and vibration.
suppressing control can be set easily.

4.2 Simple setup

(1) Easy tuning and profile operation

Previously, in order to set operation-related parameters, adjust the control gain to a suitable level for the machine, verify the load ratio during operation and perform other adjustments at startup of a servo system, the servo motor had to be attached to the mechanical system and be controlled by operating commands from a host controller.

Ever since the “FALDIC-W series,” Fuji Electric servo systems have been equipped with a profile operation function, which operates according to a pattern set by the servo amplifier, and an easy tuning function, which automatically adjusts the control gain during a profile operation, even in cases such as that shown in Fig. 7 where there is no host controller. The ALPHA5 series inherits these functions, and since the servo system can startup even before a host controller is provided, the adjustment at startup of the entire system can be implemented in a shorter amount of time. Furthermore, the combination of these functions with an automatic notch filter enables many types of mechanical systems to realize sufficient response using the easy tuning function only.

(2) Sequence test

Previously, in order to debug a host controller program, the servo motor had to be attached to the mechanical system, and that mechanical system had to be in an operable state.

The ALPHA5 series, as shown in Fig. 8, is newly provided with a sequence test mode capable of debugging the host controller with a servo amplifier only, even when there is no mechanical system or servo motor. According to commands from the host controller, the servo amplifier generates signals and monitor data as if the servo motor attached to the mechanical system was running, and outputs them to the host controller.

With this function, since the host controller’s program is executed and debugged by the servo amplifier itself before the mechanical system is completed, the time required for adjustment at startup of the overall system can be reduced.

4.3 Enhanced maintenance functions

(1) Alarm-associated data

In order to investigate the cause of an alarm that has been generated, the operating state at the time when that alarm was generated must be known.

Fig. 6 Example of historical trace comparison screen

Fig. 7 System configuration of easy tuning and profile operation

Fig. 9 Alarm history monitor screen

Fig. 8 System configuration of sequence test mode

Fig. 10 Warning monitor screen
With the ALPHA5 series, the alarm history have been enriched with those data, which are thought to be useful in investigating the cause of the alarm, such as speed, torque and cumulative conduction time and so on at the time when the alarm was generated. Figure 9 shows the alarm history monitor screen. With this associated data, the cause of the alarm can easily be analyzed, and the amount of time required for such an investigation can be reduced.

(2) Warning monitor

The servo amplifier contains consumable parts such as a cooling fan, main circuit capacitors, and a battery for absolute position data backup, and their replacement timings depend on the cumulative operating time of the servo amplifier. The ALPHA5 series is provided with a warning monitor to notify the user of these replacement times. Figure 10 shows the warning monitor screen. This screen displays not only warning signals, but also displays the elapsed time and remaining time until replacement will be needed, and so on, and helps to improve the ease of maintenance.

5. Postscript

Specifications and features of the ALPHA5 series have been introduced above. The ALPHA5 servo systems realize the industry’s top level of performance and ease of use.

Fuji Electric intends to continue to work toward increasing the capacity of its product series, broadening the motor lineup, expanding functionally by increasing support for Modbus-RTU*1 communications and full-closed control, and supporting the replacement of existing products.

Reference


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