FALDIC-α Series, the Compact and High Performance Servo Systems

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1. Introduction

In the market for AC servo systems, easier operation, ability to interface with various high-end devices, installation of serial encoders, enhancement of environment-proof construction, and compliance with overseas safety standards are increasingly being required in addition to smaller size, higher response and a higher degree of accuracy than had been required in the past.

The newly developed FALDIC-α series is an improved version of the conventional FALDIC-II series and has been introduced to the market with the goal of creating new demand.

This paper presents an overview of the FALDIC-α series including its specifications and features.

2. Features

Figure 1 shows an external view of the FALDIC-α series and Fig. 2 its system configuration.

The main features are described below.

2.1 Higher performance

(1) Higher speed response

A frequency response of 500Hz (five times the previous frequency) and positioning settling time of 5ms or less were realized by using a control LSI for high-speed calculation in the current control loop and a 32-bit RISC-CPU (reduced instruction set computer-central processing unit).

(2) Utilization of 16-bit serial encoder

Utilization of a 16-bit serial encoder achieved resolution eight times the previous resolution. Higher accuracy and stabilized control was obtained at low speeds.

(3) Reduction of rotational fluctuation

Rotational fluctuation was reduced to one tenth of

Fig.1 External view of the FALDIC-α series
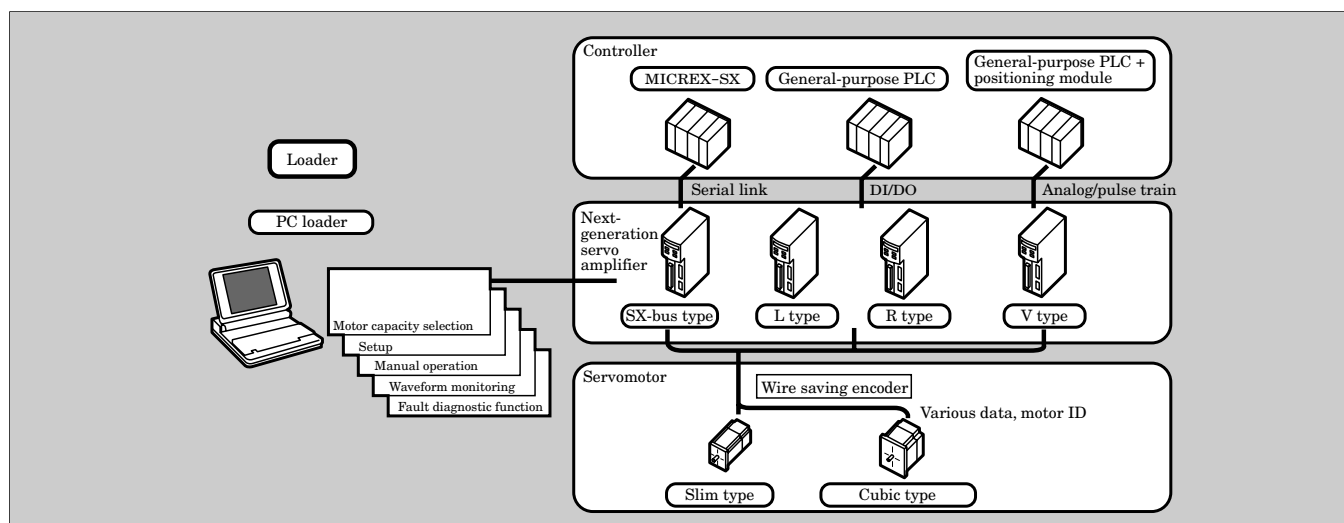

Fig.2 System configuration of the FALDIC-α series

Table 1 Fundamental specifications of servo amplifiers

	Type	RYS□□□○○-V○○	RYS□□□○○-L○○	RYS□□□○○-R○○	RYS□□□○○-○S○
	Main application	Speed control	Linear positioning	Indexing	Speed control/linear positioning
Input power	Voltage	200 to 230V +10 to –10%			
	Frequency	50/60 Hz			
Control specifications	Control system	Totally digitized sinusoidal wave PWM current control			
	Carrier frequency	10kHz (5kHz for some range of capacity)			
	Feedback	16-bit serial encoder			
	Speed control range	1 : 5,000			
	Frequency response	500 Hz			
	Overload capacity	3s / 300%, 1.5s / 450%			
	Positioning resolution	16-bit (equivalent to 16,384 pulses)/revolution			
	Position control	Absolute/incremental (selectable)			
Control function	Speed control	○	○	○	○
	Torque control	○	—	—	○
	Pulse train	○	○	○	○
	Point-to-point positioning	—	○	○	○
	Homing	○	○	○	○
	Positioning by external marker	○	○	○	○
Interface specifications	Input — No. of contacts	8 (DI/DO type)	21 (DI/DO type)		5 (DI/DO type)
	Input — Analog command	2 channels (DI/DO type)	1 channel (DI/DO type)		—
	Input — Pulse input	1 channel (open collector/differential input: both available)			
	Output — No. of contacts	5 (DI/DO type)	10 (DI/DO type)		2 (DI/DO type)
	Output — Analog monitor	2 channels			
	Output — Pulse output	1 channel (differential output)			
Environment	Temperature/humidity	–10 to +55°C, 10 to 90% RH (free from dew condensation)			
	Location/altitude	Indoor, clean atmosphere, 1,000m or less			

its previous value due to progress in electromagnetic field analysis technology and the reduction of motor cogging torque based on high precision machining, and higher response and higher resolution of the encoder as mentioned above.

2.2 Improvement in user interfaces
(1) Development of personal computer loaders

Fuji Electric developed a loader for personal computers to support servo systems from setup to maintenance, realizing facilitated operation and maintenance.

2.3 Flexibility
(1) Standard installation of wire-saving absolute (ABS) encoder

ABS encoders have been provided in the FALDIC-α series as a standard to eliminate the inconvenience of initial positioning (homing action) when power is turned on. This results in a wire-saving absolute system including wiring of lithium batteries contained in servo amplifiers by serial communication.

3. Specifications

3.1 Servo amplifier
The FALDIC-α series was intended for a capacity

range of 30W to 5kW. Servo amplifiers for servomotors up to 1.5kW are already being commercially produced, and higher capacity servo amplifiers will be introduced successively.

Table 1 shows the fundamental specifications of servo amplifiers, which are classified into the following four types.
(1) V type

The V type is capable of positioning operation with pulse train input, speed control operation with analog voltage input, and torque control operation.
(2) L type

The L type incorporates a linear positioning function in the servo amplifier, allowing positioning only with on/off signals from a high-end controller.
(3) R type

The R type is for rotor indexing applications, such as an ATC (automatic tool changer) or an index table.
(4) SX type

The SX type performs various types of motion control through high-speed serial communication with Fuji Electric's new type programmable controller (PLC) MICREX-SX.

3.2 Servomotor
Miniaturization of the servomotors was realized by

Table 2 Cubic motor specifications

Item \ Motor type	GYC101DC1–S	GYC201DC1–S	GYC401DC1–S	GYC751DC1–S	GYC102DC1–S	GYC152DC1–S
Rated output (kW)	0.1	0.2	0.4	0.75	1	1.5
Rated torque (N · m)	0.318	0.637	1.27	2.38	3.18	4.78
Rated speed (r/min)	3,000					
Max. speed (r/min)	5,000					
Max. torque (N · m)	0.955/1.43	1.91/2.87	3.82/5.73	7.17/10.7	9.55/14.3	14.3/21.5
Moment of inertia(kg · m^2)×10^{-4}	0.0583	0.216	0.412	1.21	3.26	4.51
Rated current (A)	1.0	1.5	2.6	4.8	6.7	9.6
Max. current (A)	3.0/4.5	4.5/6.8	7.8/11.7	14.4/21.6	20.1/30.2	28.8/43.2
Winding insulation class	B				F	
Operation duty	Continuous					
Enclosure protection	Totally enclosed, self cooling (IP55)					
Connection terminals (motor)	with cables 0.3m long and connectors				Cannon connectors	
Connection terminals (encoder)	with cables 0.3m long and connectors				Cannon connectors	
Temperature detection	N/A (detected by servo amp.)					
Mounting	Mounted with flangesIMB5 (L51), IMV1 (L52), IMV3 (L53)					
Shaft	Cylindrical shaft with a key					
Painted color	N1.5					
Detector	16-bit serial encoder (absolute system: servo amp with a battery)					
Vibration	V5 or less				V15 or less	
Location/altitude	Indoor / 1,000m or less					
Ambient temperature/humidity	–10 to +40°C / 90% RH or less (free from dew condensation)					
Vibration resistance	49m/s^2 (5G)					

<Note> Values indicated to the right of the backslash (" / ") in the Max. torque and Max. current rows represent values when combined with servo amplifiers one class higher in series.

the adoption of new technologies, such as high-performance cylindrical or circular-arc segment magnets, segment cores, densely embedded windings using regular windings, and resin molds or resin casts.

Installation of 16-bit wire saving serial encoders enabled smaller size, higher-speed response and a higher degree of accuracy.

The FALDIC-α series contains two different shapes of servomotors. The shape may be selected depending upon the application, installation space and other requirements.

The FALDIC-α series has improved environmental resistance as a standard to comply with IP55, and can optionally be made to comply with IP67. This series was developed with the goal of obtaining certification from overseas standards such as CE marking and UL standard, adding to the completeness of the product line.

Table 2 shows cubic motor specifications of 1.5kW or smaller capacity units. A series of servomotors with capacity ranging from 2 to 5kW is planned to be introduced successively.

3.3 ABS encoder

The standard mounting of encoders on servomotors was developed based on the following concepts.
(1) Higher resolution and lower vibration of motors
When using 13-bit encoders, the adjustment of

internal constants of a servo amplifier to realize a response of 500Hz causes a large amount of vibration in the servomotor, leading to mechanical resonance and noise.

Therefore, by utilizing 16-bit encoders whose resolution is as much as eight times that of 13-bit encoders for feedback control, detection ripples in the low-speed range were suppressed and control stability at low speed was dramatically improved.
(2) Standard installation of wire-saving ABS encoders
ABS encoders are installed in the FALDIC-α series as a standard to eliminate the inconvenience of initial positioning (homing action) when power is turned on or when power is restored after a power failure. The FALDIC-α series allows lithium batteries, whose serviceable life is more than five years under normal operating conditions, to be incorporated into servo amplifiers for data backup. Super capacitors are incorporated into the encoders to retain absolute data for at least one-hour even when power is turned off during maintenance work.

Table 3 shows the general specifications of encoders installed in the FALDIC-α series, and Fig. 3 their external view.
(3) Automatic identification of motor ID (type)
There are two series of motors, slim and cubic types. To utilize most effectively the performance of the motors, it is essential to operate each type with the

Table 3 Specifications of 16-bit ABS encoders

Item	Specifications
Resolution/revolution	16 bits/revolution
Multiple turn data	16 bits (=65,536 revolutions)
Data communication specification	RS–485
Communication speed	4M bits/sec
Max. rotation speed	6,000r/min
Backup	For five years with optional lithium battery
Short time backup	For one hour with super capacitor
Storage temperature	−20 to +85°C
Operation temperature	−10 to +85°C
Humidity	90%RH or less (free from dew condensation)
Allowable vibration	5G
Allowable shock	50G
Fault detection	Overload, overheat, overvoltage, abnormal number of pulses, etc.

appropriate constants. Servo amplifiers read and identify the motor type from serial data transferred from the encoders. This allows the motors to be operated with the most appropriate constants (already stored in advance), eliminates the need for input of the motor type and reduces the time for setup.

3.4 High performance
(1) Realization of high-speed response

Figure 4 shows the control block diagram of the FALDIC-α series. The CPU is comprised of a RISC-CPU, a newly-developed exclusive LSI, a control LSI and a serial PG (pulse generator).

External interface signals are input to and output from the control LSI through the connector CN1. Communication with the 16-bit serial encoder is performed through a serial PGLSI and the connector CN2 using a pair of signal cables.

In the FALDIC-α series, to achieve improved frequency response, digital processing is performed on the current control loop, which consists of an ACR (automatic current regulator), a PWM (pulse width modulator) and a current detector. Software processing is performed by the RISC CPU on the speed control loop, which consists of an ASR (automatic speed regulator), a feedback pulse processor and an APC (automatic position controller).

Figure 5 shows the frequency response of the FALDIC-α series and Fig. 6 its step response. Adoption of the RISC-CPU and realization of high-speed computing in the current control loop and speed control loop with a dedicated LSI result in a frequency response of 500Hz.

The ASR shown in Fig. 4 is provided with a real-time automatic tuning function that permits real-time optimizing adjustment of servo system parameters according to load conditions of the mechanical system during setup and actual loaded operation.

Fig.3 External view of an encoder

(2) Realization of smooth control at low speed

Recently, among requirements for servomotors, the most attention has been given to achieving smooth rotation at low speed, because this greatly affects the workmanship of finished products.

As described earlier, a combination of high-performance cylindrical magnets and segmented magnets is utilized for the FALDIC-α series. The core shape and the accuracy of segmentation and fitness exert a great effect on fundamental motor characteristics such as the induced electromagnetic voltage and cogging torque.

By optimizing materials, magnet shapes and sizes, cores and windings and by balancing the combination of magnetic loading and electrical loading through utilization of magnetic field analysis technology, rotational fluctuation in the FALDIC-α series has been reduced to 10r/min, one tenth as large as that of conventional motors. Figure 7 compares rotational fluctuation in the FALDIC-α series to that of conventional motors.

3.5 User support tool (PC loader)

This user-support tool runs on Windows* 95 and has been developed with the aim of improving the efficiency of tasks required of users, such as selection of motor capacity, setup, commissioning and maintenance.

Figure 8 shows a PC screen display of a real-time trace used during setup and maintenance, allowing real-time monitoring of waveform signals such as speed and torque and logic signals such as RUN through external selection. This tool is also provided with a historical trace function that allows the monitoring of phenomenon before and after a trigger point under the condition of triggering by a certain signal change.

In addition, this tool is provided with a diagnostic function to analyze trouble that occurs during commissioning and maintenance and to indicate countermeasures to resolve the problem, leading to a reduction in restoration time.

∗ Windows : A trademark of Microsoft Corporation

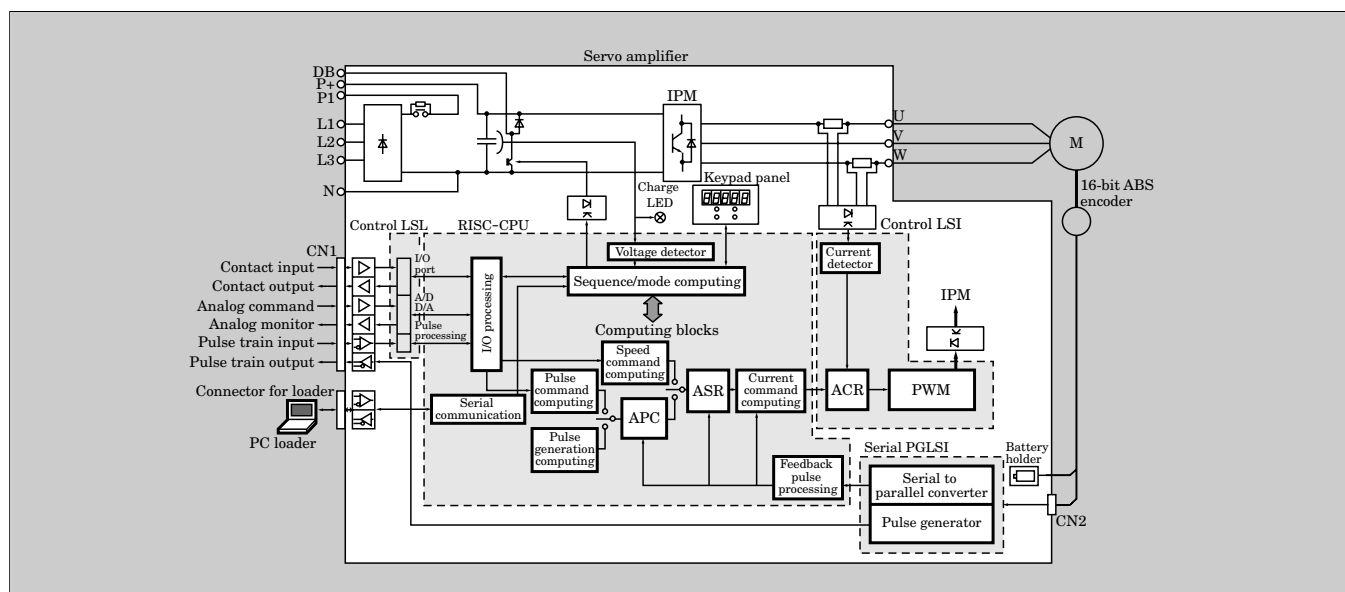Fig.4 Control block diagram of the FALDIC-α series
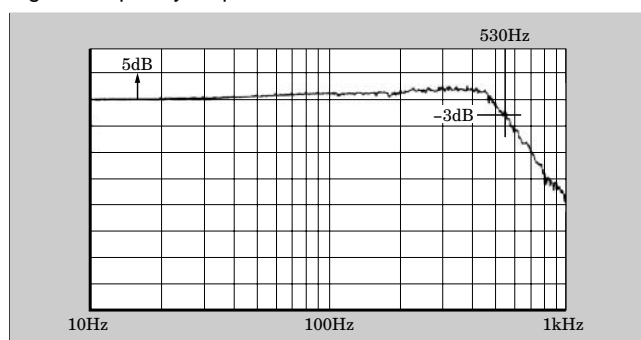

Fig.5 Frequency response

Fig.6 Step response

Fig.7 Rotational fluctuation characteristic
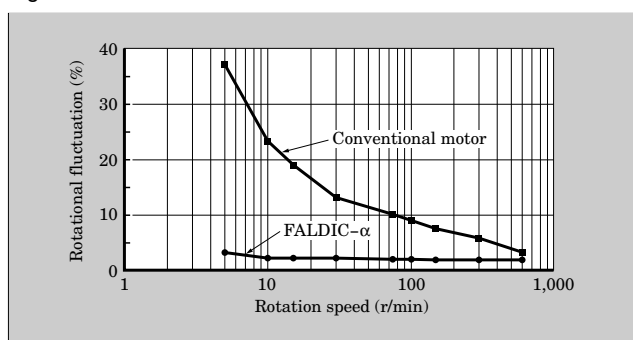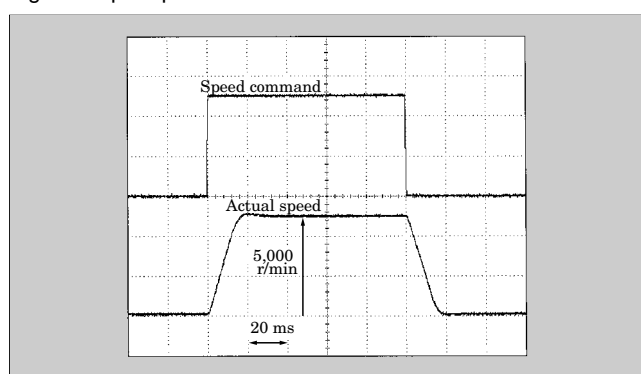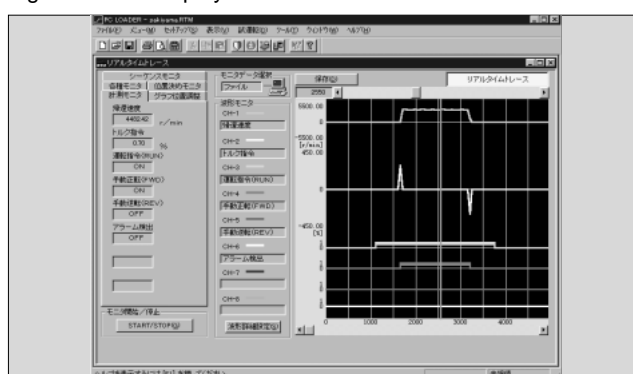

Fig.8 Screen display of real-time trace

4. Conclusion

This paper presented an overview of the FALDIC-α series. Fuji Electric is capable of supplying the market with an easy-to-use service system enabled by smaller-size, higher-performance motors and servo amplifiers, standard-equipped high-resolution 16-bit ABS encoders to eliminate homing action and an improved user-support function with PC loaders.

Fuji Electric is determined to increase the capacity of the FALDIC-α series and to offer the series in a wider variety of shapes, such as a slim type and highly rigid type.

Fuji Electric is also determined to do its best to achieve system flexibility of the FALDIC-α series by pursuing higher precision positioning with encoders of improved resolution, higher performance in the extremely low speed range and improved interface functions for compatibility with open networks.

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