Digital ES Motor Drive System

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1. Introduction

In the field of general industrial machinery (transfer systems and package machinery), market demands are increasing for inverter or servo system based variable speed motor controls with multiple functions and higher performance.

The previous ES motor drive system, released in 1988, has both the advantages of an AC servo system (easy maintenance, a broad speed control range and high frequency operation capability), and the ease of use and competitive price inherent to an inverter. Based on the numerous expansion applications of the previous ES motor, a digital ES motor has been developed for enriching system compatibility and for reducing the size.

The digital ES motor is an all-digital variable speed motor control system consisting of new hardware and software, including a 16-bit CPU chip and a custom LSI.

The digital ES motor series comes in 9 models, from 50W to 3.7kW.

2. Specifications and Features

Figure 1 shows the appearance of a typical controller and motor, while Table 1 lists the controller data.

2.1 Enhancement of function

(1) Auto tuning function

Formerly, various adjustments of the control system were performed by the user during installation. In the digital ES motor system, the controller automatically performs optimal tuning. This increases the automatization during system startup.

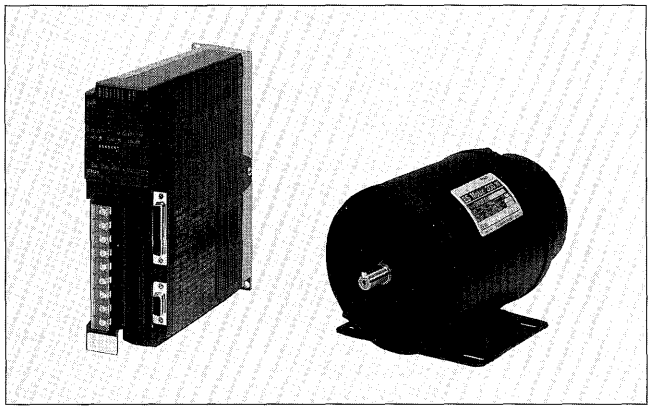
(2) Flexible operation method

In addition to speed-controlled operation, it is possible to select from pulse-train positioning operation and torque-controlled operation (including a winding operation).

(3) High-function loader

With Fuji Electric's custom loader, the following operations may be selected from the menu and performed: parameter setting change, internal status monitoring and test-runs.

Fig. 1 Controller and motor



2.2 Enhancement of performance

(1) Elimination of drift

Due to the all-digital controls, unexpected drift and offset has been eliminated. Therefore, in this digital setting, there is no speed fluctuation and deviation of final position. This contributes to a large improvement in control accuracy.

(2) Reduced unevenness of rotation

Uneven rotation is mainly caused by an offset of the current detection block. The digital ES motor series, however, has succeeded in reducing the rotational unevenness with its automatic offset adjustment function.

(3) Widened speed control range

Speed is controllable over a wide range (1:1,000) due to the A-D conversion of the Δ-Σ modulation system.

3. Circuit Configuration

Figure 2 shows an internal block diagram of the controller. Downsizing (to approximately 75% in volume compared to the former series) has been achieved by integrating functions into the CPU chip, custom LSI and IPM (Intelligent Power Module).

(1) CPU

Table 1 Controller data

Controller model			DES050A	DES100A	DES200A	DES400A	DES750A	DES151A	DES221A	DES301A	DES371A
Applicable ES motor capacity (kW)			0.05	0.1	0.2	0.4	0.75	1.5	2.2	3.0	3.7
Power input supply	Phase		Single or three phase				Three phase				
	Voltage (V)		200/200−220−230 (V) +10 to −15%								
	Frequency (Hz)		50/60 (Hz) ±5%								
Rated output current (A)			1.2	1.4	1.2	2.3	4.0	8.6	13.0	17.2	21.0
Max. output current (A)			2.0	2.0	2.0	3.6	6.0	13.0	19.5	25.8	31.5
Basic control functions	Control		Sine-wave PWM current control (reversible)								
	Carrier frequency (kHz)		10kHz					3kHz			
	Speed detector		Encoder built-into motor (1,000 pulse/revolution), open collector								
	Control accuracy	Loading	±1 r/min max. for 0 to 100% variation								
		Supply voltage	±1 r/min max. for +10 to −15% fluctuation								
		Amb. temp.	15 r/min max. for −10 to +55℃ variation								
	Speed control range		1 : 1,000								
	Frequency response		DC through 50Hz AC min. (when $J_L = J_M$: speed control)								
	Moment of inertia, load		5 times max. of motor rotor (when using positioning control)								
	Overload capability		150% for 60 seconds								
Control type			Speed, positioning or torque								
Speed control	Speed voltage reference (command)		±10V/±2,500 r/min								
	Soft start/stop		0 to 1, 0 to 3 seconds (depending on switch setting: 0 to 10, 0 to 30 seconds)								
	Power supply for speed reference (command)		+10V/30mA (for uni-polarity)								
	Stop control		Selectable for zero speed, Position-lock (servo lock) or external braking								
Positioning control	Position reference (command) pulse		①Reference (command) pulse/code, ②Forward/reverse pulse, ③90° phase difference, 2-signal								
	Max. input frequency		100kHz								
	Input interface		Differential input (open collector input is available)								
	Stop control		Position-lock (servo-lock)								
Control signal	Input		Speed reference (command) = P10, 12 11, Position reference (command) = CA, *CA, CB, *CB, Control signal = run command, forced stop, manual forward or reverse run commands, alarm reset, multi-purpose control input 1 to 4								
	Output		Control output = multi-purpose control output 1 to 3, Alarm output = 30B, 30C (N.C. (b contact), Pulse output = A/N, B/N, Z (open collector), Monitor output = speed monitor (Uni-/Bi-polarity output selectable) and torque monitor								
Other functions	Braking		Regenerating brake								
	Protection		Nine of types, including overload, encoder abnormality, etc.								
	Display		POWER (power on - green light), TUNE (auto, tuning finished - green light), ALARM (alarm detection - 4 red lights)								
	Setting		DIP switch (8 settings)								
Environmental conditions	Amb. temp. and humidity		−10 to +55℃ and 90% RH max. (non-condensation is required)								
	Location altitude		Indoor (Do not install in a dusty location and do not expose to corrosive gases or direct sunlight), Below 1,000m								

A 16-bit CPU chip with 32k bytes of ROM and 1k bytes of RAM is used for calculations which require quick processing, such as servo control and auto tuning. In addition, the CPU performs related calculations and communicates with various I/O units and loaders.

(2) Custom LSI + peripheral circuit

The servo control is responsible for high speed processes beyond the computational capacity of the CPU software. These include processing of the various encoder and reference pulses, PWM calculation, control I/O operation, A-D conversion (for speed reference) of the Δ-Σ modulation system and D-A conversion (for analog monitoring).

(3) Main circuit

The switching element in the main circuit block uses an IPM with internal gate drive circuits to protect against overcurrent, overheating, and gate voltage drop. This protects the system hardware from such problems as output short-circuiting.

4. Operation Characteristics

Figure 3 shows a speed control block diagram of the digital ES motor system in auto tuning mode. Previous speed control systems consisted only of a feedback controller. However, in those systems which used a pulse

Fig. 2 Internal block diagram of controller

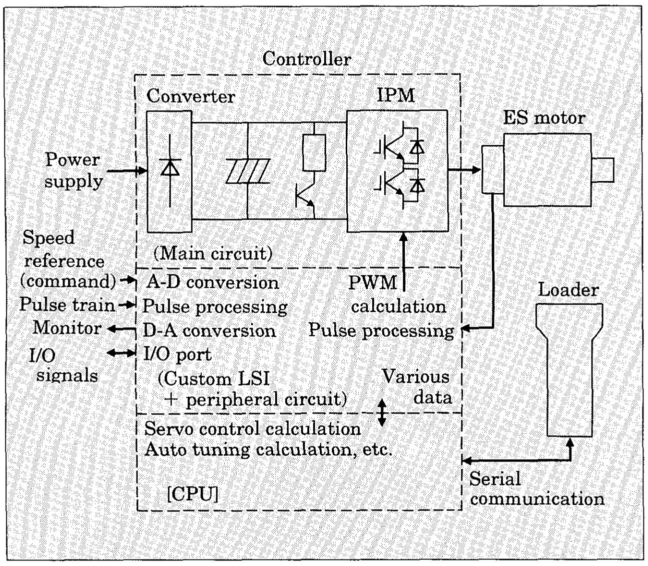


Fig. 3 Speed control block diagram

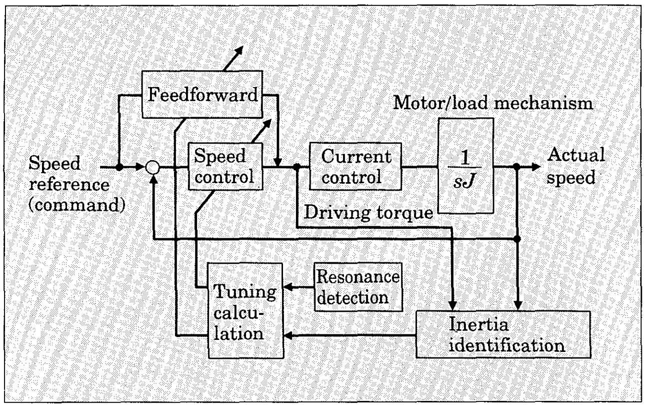


Fig. 4 Linear acceleration/deceleration response

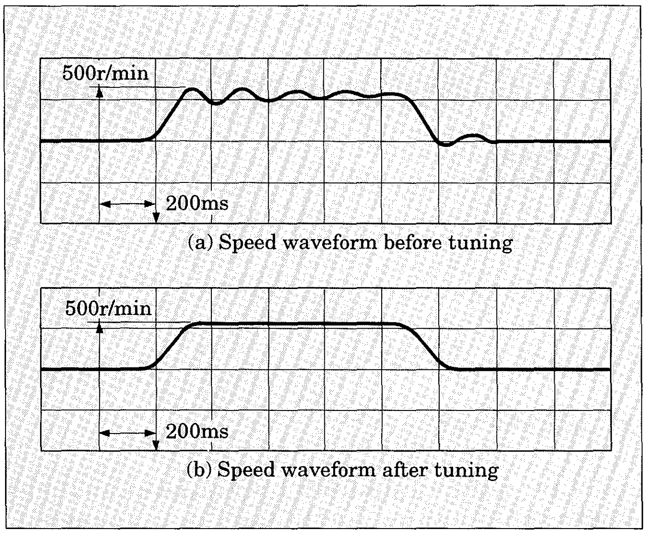
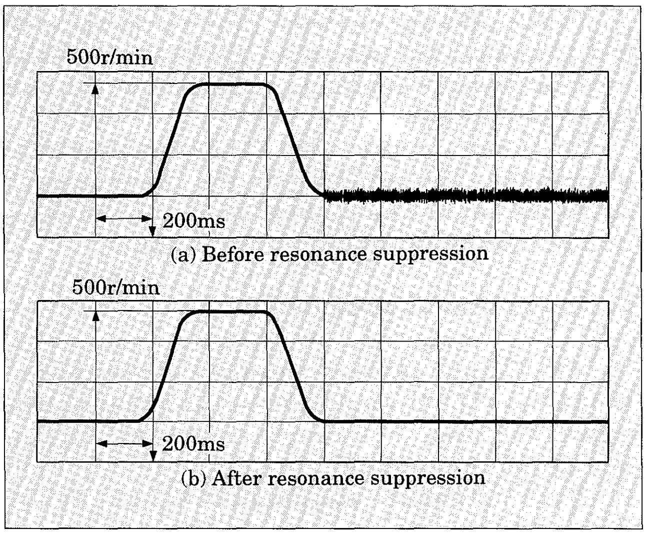


Fig. 5 Speed waveform before and after resonance suppression



encoder as a speed sensor, oscillation was apt to occur when stopped and the feedback gain was increased. In the new auto tuning mode, feedforward control is employed in addition to feedback control, and the feedback gain is tuned relatively lower. Quick responses are now obtainable without degrading the stability when stopped. The feedback gain and feedforward gain are tuned as shown in the tuning calculation block of Fig. 3. The basic tuning calculations are performed according to the results of inertia identification, which is based on the model reference adaptive identification technique. As shown in Fig. 3, the inertia identification utilizes information concerning speed and drive torque.

Figure 4 contrasts the linear acceleration/deceleration response waveforms before and after tuning. Before tuning, overshoot and damped oscillation appear on the response waveform. In contrast, the response waveform after tuning does not show any overshoot, a welcome characteristic. Also, a timing belt or speed-reduction gear may sometimes be used, depending on the application. In these cases, oscillation during stop time is very likely to occur due to belt tension, gear backlash etc. So that auto tuning is possible even when oscillation or machine resonance is apt to occur, a machine resonance detecting function (Fig. 3) is provided. This function suppresses oscillation by changing the control parameters in response to the load mechanism. The response waveforms before and after resonance suppression are compared in Fig. 5. Figure 5 (a) is an example of intense oscillation occurring in the speed waveform when stopped after acceleration/deceleration. Resonance suppression of the same system resulted in a stable control characteristic free from oscillation, as shown in Fig. 5 (b).

5. Conclusion

The digital ES motor boasts high performance due to its use of digital and software technologies.

Auto tuning technology is effective in a variable speed motor control system with feedback because it allows simple adjustment of the control system.