FDD spindle motor driver

BA6477FS

The BA6477FS is a one-chip IC designed for driving FDD spindle motors. This high-performance IC employs a 3-phase, full-wave soft switching drive system, and contains a digital servo, an index amplifier, and a power save circuit. The compactly packaged IC reduces the number of external components required.

●Applications

Floppy disk drivers

●Features

1) 3-phase, full-wave soft switching drive system.
2) Digital servo circuit.
3) Power save circuit.
4) Hall power supply switch.
5) Motor speed changeable.
6) Index amplifier.

●Absolute maximum ratings (Ta=25℃)

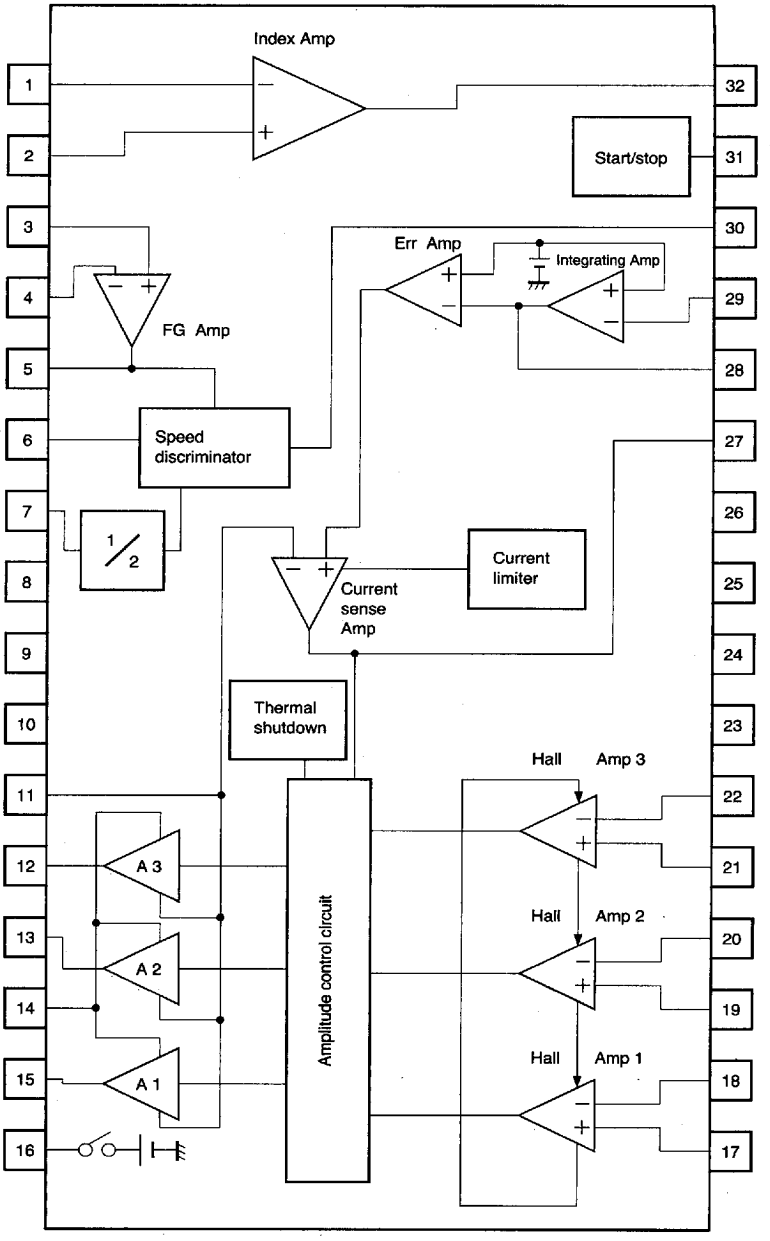
Parameter	Symbol	Limits	Unit
Applied voltage	V_{CC}	7.0	V
Power dissipation	Pd	1000*	mW
Operating temperature	Topr	−25~75	℃
Storage temperature	Tstg	−55~150	℃
Allowable output current	$I_{OMax.}$	1000	mA

* Mounted on a glass epoxy PCB (90 X 50 X 1.6 mm).
* Reduce power by 8.0 mW for each degree above 25℃.

●Recommended operating conditions (Ta=25℃)

Parameter	Symbol	Range	Unit
Power Supply voltage	V_{CC}	4.2~6.5	V

●Block diagram

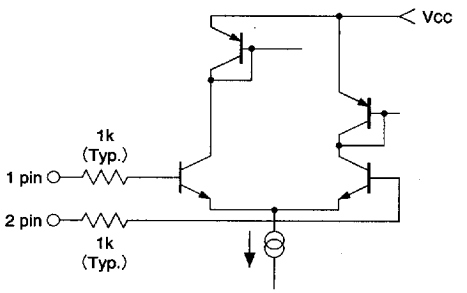


●Pin description

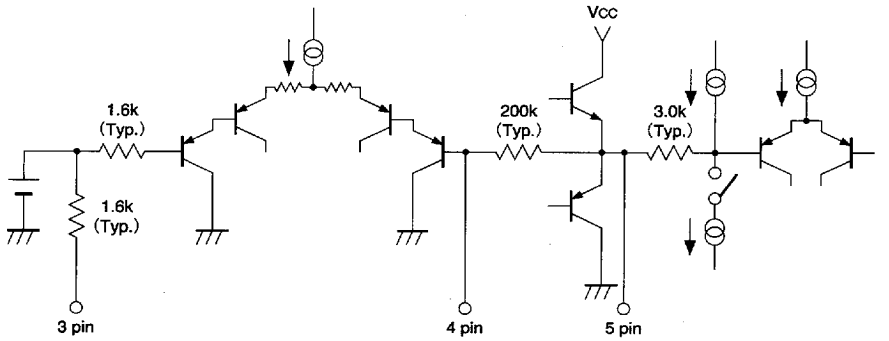
Pin No.	Pin name	Function
1	IDX^-	Index amplifier input (-)
2	IDX^+	Index amplifier input (+)
3	$FGin^+$	FG amplifier input (+)
4	$FGin^-$	FG amplifier input (-)
5	FGout	FG amplifier output
6	SC	Speed control
7	OSC	Oscillator input
8	GND	GND
9	GND	GND
10	V_{CC}	Signal power supply
11	R_{NF}	Driver power supply (current detection pin)
12	A_3	Motor output 3
13	A_2	Motor output 2
14	P—GND	Driver ground pin
15	A_1	Motor output 1
16	H—GND	Hall bias switch (ground)
17	H_1^+	Hall input amplifier 1 input (+)
18	H_1^-	Hall input amplifier 1 input (-)
19	H_2^+	Hall input amplifier 2 input (+)
20	H_2^-	Hall input amplifier 2 input (-)
21	H_3^+	Hall input amplifier 3 input (+)
22	H_3^-	Hall input amplifier 3 input (-)
23	GND	GND
24	GND	GND
25	GND	GND
26	S—GND	Signal ground pin
27	C_{NF}	Current sensing amplifier output (for phase compensation)
28	ERR	Error amplifier input; integrating amplifier output
29	INT	Integrating amplifier inverter input
30	SDO	Speed discriminator output
31	ST / SP	Start/stop pin
32	IDXO	Index amplifier output

●Input/output circuits

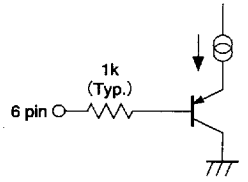
1) Index input (1, 2 pin)



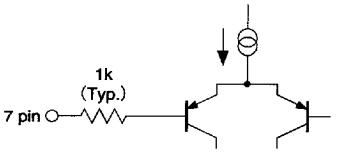
2) FG amplifier (3~5 pin)



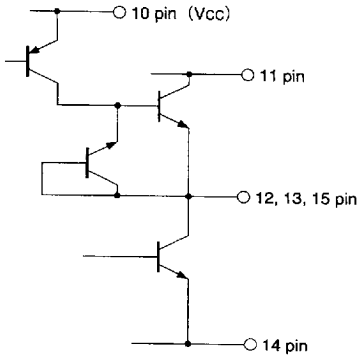
3) Speed control (6 pin)



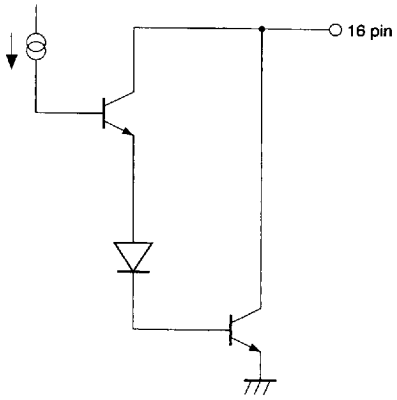
4) External clock input (7 pin)



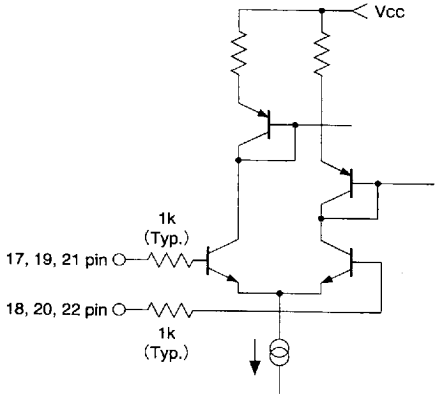
5) Motor output (11~15 pin)



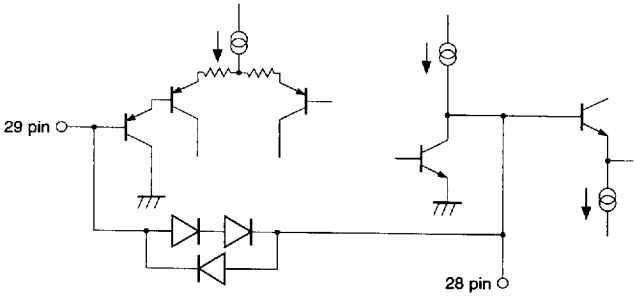
6) Hall bias (16 pin)



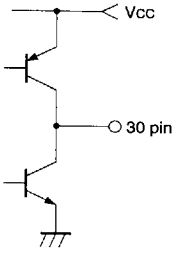
7) Hall input (17~22 pin)



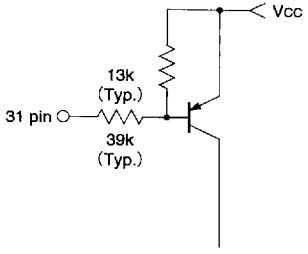
8) Integrating amplifier (28, 29 pin)



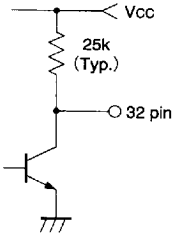
9) Speed discriminator output (30 pin)



10) Start/stop (31 pin)



11) Index output (32 pin)



●Electrical characteristics (Unless otherwise noted, Ta=25℃, V_{CC}=5V)

Parameter	Symbol	Min.	Typ.	Max.	Unit	Conditions
Circuit current 1	I_{CC1}	9	13	20	mA	Operational state
Circuit current 2	I_{CC2}	—	—	3	μA	Standby state
Hall in-phase input voltage range	V_{HB}	1.5	—	4.0	V	
Hall amplifier input sensitivity	V_{Hin}	60	—	—	mV_{P-P}	Differential input
Output saturation voltage 1	Vsat1	—	1.2	1.4	V	Iout = 350 mA (total of upper and lower values)
Output saturation voltage 2	Vsat2	—	1.5	2.0	V	Iout = 700 mA (total of upper and lower values)
Speed discriminator output voltage, HIGH	V_{DH}	4.7	4.9	—	V	When output current is 500 μA
Speed discriminator output voltage, LOW	V_{DL}	—	0.1	0.25	V	When input current is 500 μA
Integrated amplifier output voltage, HIGH	V_{EinH}	2.5	2.7	2.9	V	29pin=2.0V
Integrated amplifier output voltage, LOW	V_{EinL}	1.3	1.5	1.7	V	29pin=3.0V
FG amplifier gain	G_{FG}	39	42	45	dB	f=300Hz
Speed discriminator minimum input	V_{FGmi}	2.0	—	—	mV_{P-P}	FG amplifier input equivalent
Speed discriminator noise margin	V_{FGnm}	—	—	0.5	mV_{P-P}	FG amplifier input equivalent
Error amplifier reference voltage	V_{Err}	2.35	2.55	2.75	V	
Control input gain	G_{Err}	−14.5	−11	−8.5	dB	V28 pin versus V11 pin, R_{NF}=0.5Ω
Current limiter voltage	Vcl	175	205	235	mV	Voltage between V_{CC} and V11 pins R_{NF}=0.5Ω
External clock frequency	f_{CK}	—	1000	1100	kHz	
External clock input threshold voltage	V_{CK}	1.0	—	2.0	V	
Start/stop voltage, HIGH	V_{SSH}	3.0	—	5.0	V	Standby state
Start/stop voltage, LOW	V_{SSL}	0.0	—	1.5	V	Operational state
Revolving speed switch voltage, HIGH	V_{SCH}	2.0	—	5.0	V	Synchronized at f_{FG} = 360 Hz
Revolving speed switch voltage, LOW	V_{SCL}	0.0	—	1.0	V	Synchronized at f_{FG} = 300 Hz
Hall bias saturation voltage	V_{HG}	—	1.5	1.8	V	When input current is 10 mA
Index in-phase input voltage range	V_{BID}	1.5	—	4.0	V	
Index input offset voltage	V_{OSID}	−5	0	+5	mV	
Index input hysteresis 1	V_{hyID1}	12	18	24	mV	
Index input hysteresis 2	V_{hyID2}	−28	−22	−16	mV	
Index output resistance	R_{OID}	17	25	33	kΩ	
Index output voltage, LOW	V_{olID}	—	0.2	0.4	V	When input current is 500 μA

◎Not designed for radiation resistance.

●Circuit operation

1. Motor drive circuit

The motor driver is based on a 3-phase, full-wave soft switching, current drive system in which the position of rotor is sensed by Hall elements. The total drive current of motor is sensed by a small resistor (R_{NF}) and regulated through a voltage comparison. The IC consists of Hall amplifiers, an amplitude control circuit, a driver, an error amplifier, and a feedback amplifier (Fig. 1).

The waveforms of different steps along the signal path from the Hall elements to the motor driver output are shown in Fig. 2. The Hall amplifiers receive the Hall elements voltage signals as differential signals. Next, by deducting the voltage signal of Hall elements 2 from the voltage signal of Hall elements 1, current signal H1, which has a phase 30 degrees ahead of Hall elements 1, is created. Current signals H2 and H3 are created likewise. The amplitude control circuit then amplifies the H1, H2, and H3 signal according to the current feedback amplifier signal. Then, drive current signals are produced at A1, A2, and A3 by applying a constant magnification factor. Because a soft switching system is employed, the drive current has low noise and a low total current ripple.

The total drive current is controlled by the error amplifier input voltage. The error amplifier has a voltage gain of about −11dB (a factor of 0.28). The current feedback amplifier regulates the total drive current, so that the error amplifier output voltage (V1) becomes equal to the the V_{RNF} voltage, which has been voltage-converted from the total drive current through the R_{NF} pin. If V1 exceeds the current limiter voltage (Vcl), the constant voltage Vcl takes precedence, and a current limit is applied at the level of Vcl/R_{NF}.

The current feedback amplifier tends to oscillate because it receives all the feedback with a gain of 0dB. To prevent this oscillation, connect an external capacitor to the C_{NF} pin for phase compensation and for reducing the high frequency gain.

2. Speed control circuit

The speed control circuit is a non-adjustable digital servo system that uses a frequency locked loop (FLL). The circuit consists of an 1/2 frequency divider, an FG amplifier, and a speed discriminator (Fig. 3).

An internal reference is generated from an external clock signal input. The 1/2 frequency divider reduces the frequency of the OSC signal. The FG amplifier amplifies the minute voltage generated by the motor FG pattern and produces a rectangular-shaped speed signal. The FG amplifier gain (G_{FG}=42dB, typical) is determined by the internal resistance ratio.

For noise filtering, a high-pass filter is given by C3 and a resistor of 1.6kΩ (typical), and a low-pass filter is given by C4 and a resistor of 200kΩ (typical). The cutoff frequencies of high-pass and low-pass filters (f_H and f_L, respectively) are given by :

$$f_H = \frac{1}{2\pi \times 1.6k\Omega \times C3} \quad f_L = \frac{1}{2\pi \times 200k\Omega \times C4}$$

The C3 and C4 capacitances should be set so as to satisfy the following relationship :

$f_H < f_{FG} < f_L$

where f_{FG} is the F_G frequency. Note that the FG amplifier inputs have a hysteresis.

The speed discriminator divides the reference clock and compares with the reference frequency, and then outputs an error pulse according to the frequency difference. The motor rotational speed N is given in the following formula.

$$N = 60 \cdot \frac{f_{osc}}{n} \cdot \frac{1}{z} \quad (1)$$

f_{osc} is the reference clock frequency,
n is (speed discriminator count)×2,
z is the FG tooth number.

The discriminator count depends on the speed control pin voltage.

Speed control pin	Count
H	1388
L	1666

The integrator flattens out the error pulse of the speed discriminator and creates a control signal for the motor drive circuit (Fig. 4).

3. Index amplifier

The index amplifier is a hysteresis amplifier with a typical hysteresis width of +18mV and −22mV. The input pin is not biased internally.

4. Other circuits

・Start/stop circuit

The start/stop circuit puts the IC to the operational state when the control pin is LOW, and to the standby state (circuit current is nearly zero) when the control pin is HIGH. The Hall elements bias switch, which is linked to the start/stop circuit, is turned off during the standby state, so that the Hall device current is shut down.

・Thermal shutdown circuit

This circuit shuts down the IC currents when the chip junction temperature is increased to about 175℃ (typical). The thermal shutdown circuit is deactivated when the temperature drops to about 155℃ (typical).

●Circuit operation

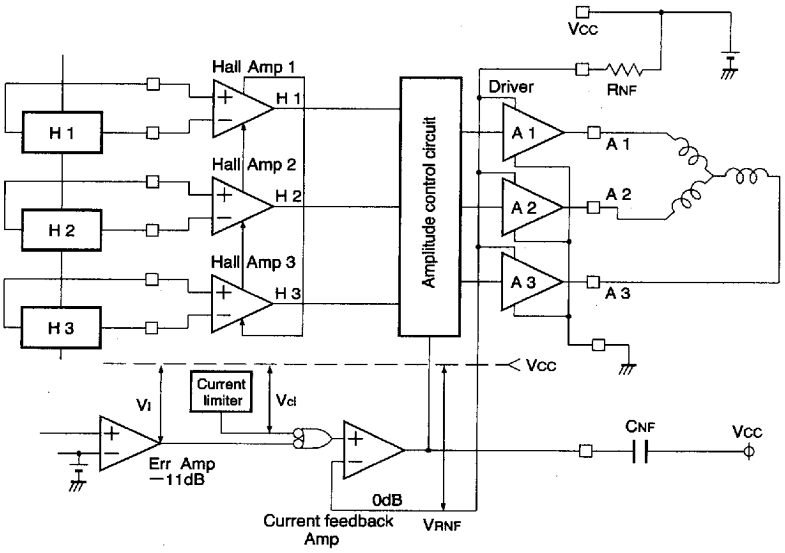


Fig.1 Motor drive circuit

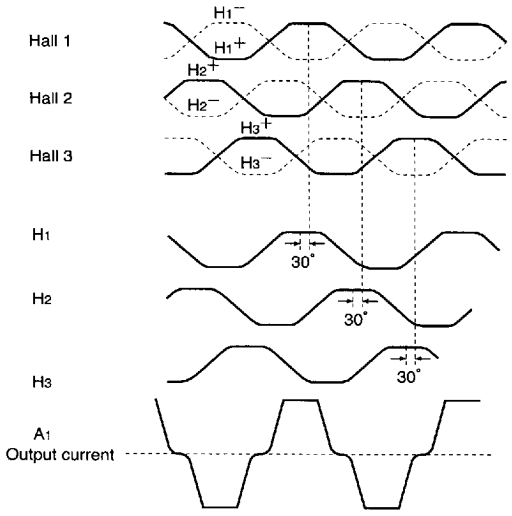


Fig.2 I/O waveforms

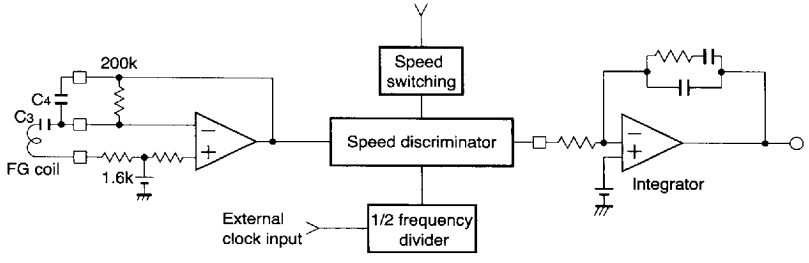


Fig.3 Speed control circuit

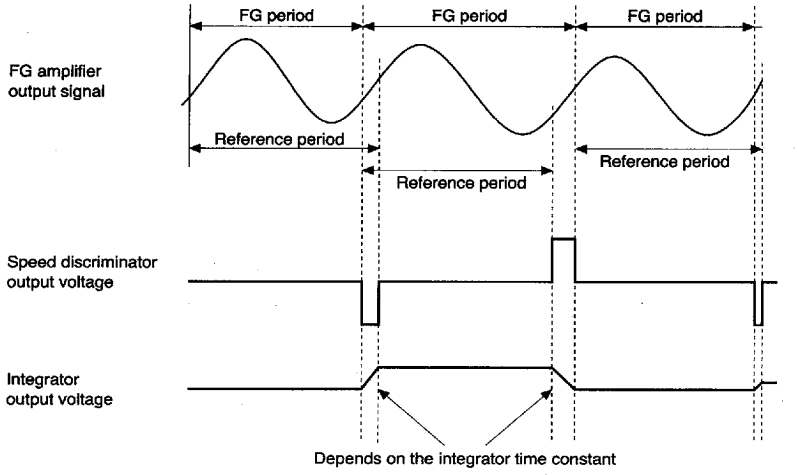


Fig.4 Control signal waveforms

●Operation notes

1. Thermal shutdown circuit

This circuit shuts down all the IC currents when the chip junction temperature is increased to about 175℃ (typical). The thermal shutdown circuit is deactivated when the temperature drops to about 155℃ (typical).

2. Hall elements connection

Hall elements can be connected in either series or parallel. When connecting in series, care must be taken not to allow the Hall output to exceed the Hall common-mode input range.

3. Hall input level

Switching noise may occur if the Hall input voltage (pins 17~22) is too high. Differential inputs of about 100mV$_{P-P}$ are recommended.

4. Driver ground pin (14 pin)

Pin 14, which is the motor current ground pin, is not connected to the signal ground pin (26 pin). Design a proper conductor pattern in consideration of the motor current that flows through pin 14.

5. External clock

Make sure that the pin7 voltage is always less than V_{CC} and more than the ground voltage.

●Application example

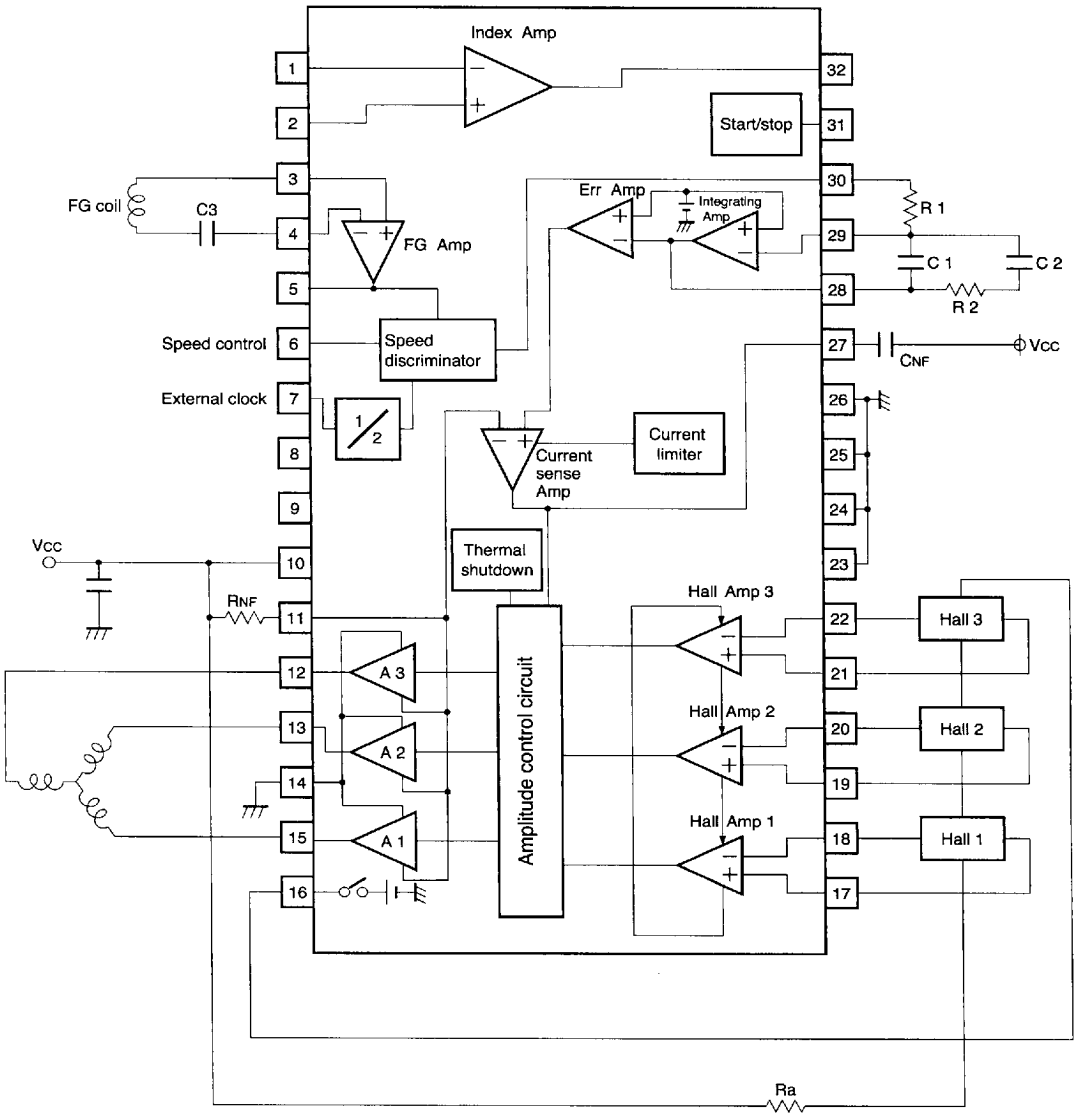


Fig.5

●Electrical characteristic curves

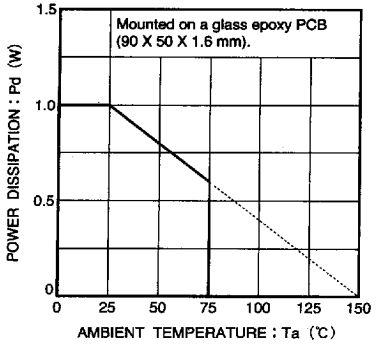


Fig.6 Power dissipation curve

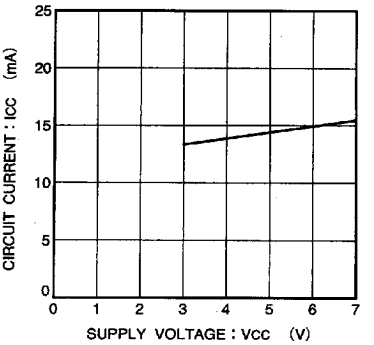


Fig.7 Supply current vs. supply voltage

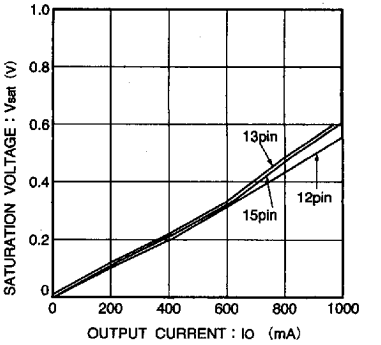


Fig.8 Low-side output saturation voltage vs. output current

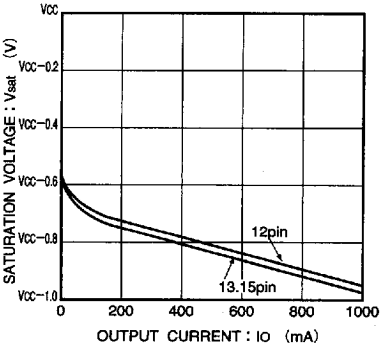


Fig.9 High-side output saturation voltage vs. output current

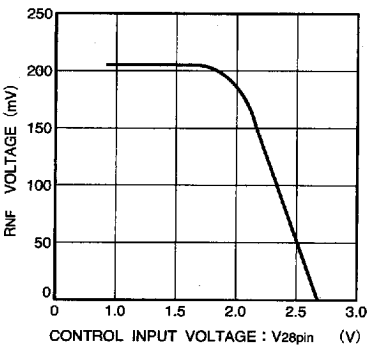
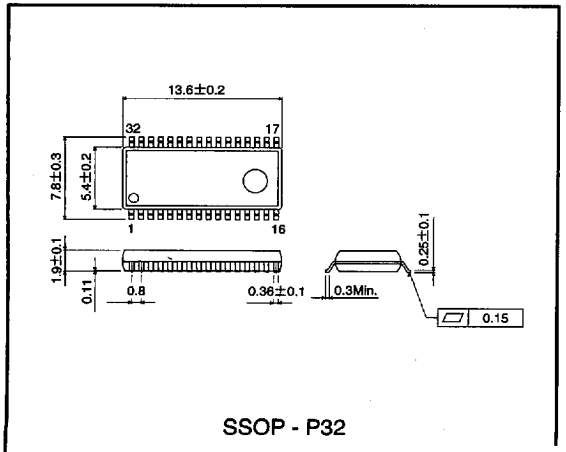


Fig.10 R_{NF} voltage vs. control input voltage

●External dimensions (Units: mm)



SSOP - P32