

# 3-phase motor driver

## BA6446FP / BA6446FM

The BA6446FP and BA6446FM are 3-phase, full-wave, pseudo-linear motor drivers suited for VCR capstan motors. The IC has a torque ripple cancellation circuit to reduce wow and flutter, a forced brake circuit that allows abrupt change of operational mode, and an output transistor saturation prevention circuit that provides superb motor control over a wide range of currents. The IC also contains FG and hysteresis amplifiers.

### ●Applications

VCR and DAT capstan motors

### ●Features

- 1) 3-phase, full-wave, pseudo-linear drive system.
- 2) Torque ripple cancellation circuit. (cancellation ratio adjustable)
- 3) Forced brake circuit.
- 4) High- and low-side output transistor saturation prevention circuit.
- 5) FG and hysteresis amplifiers.
- 6) Thermal shutdown circuit.

### ●Absolute maximum ratings (Ta = 25°C)

Parameter		Symbol	Limits	Unit
Applied voltage		V <sub>CC</sub>	7	V
Applied voltage		V <sub>M</sub>	36	V
Power dissipation	BA6446FP	P <sub>d</sub>	1700*1*3	mW
	BA6446FM		2200*2*3	
Operating temperature		T <sub>opr</sub>	-25~+75	°C
Storage temperature		T <sub>stg</sub>	-40~+150	°C
Allowable output current		I <sub>o peak</sub>	1500*4	mA

\*1 Reduced by 13.6 mW for each increase in Ta of 1°C over 25°C.

\*2 Reduced by 17.6 mW for each increase in Ta of 1°C over 25°C.

\*3 When mounted on a glass epoxy board (70×70×1.6 mm).

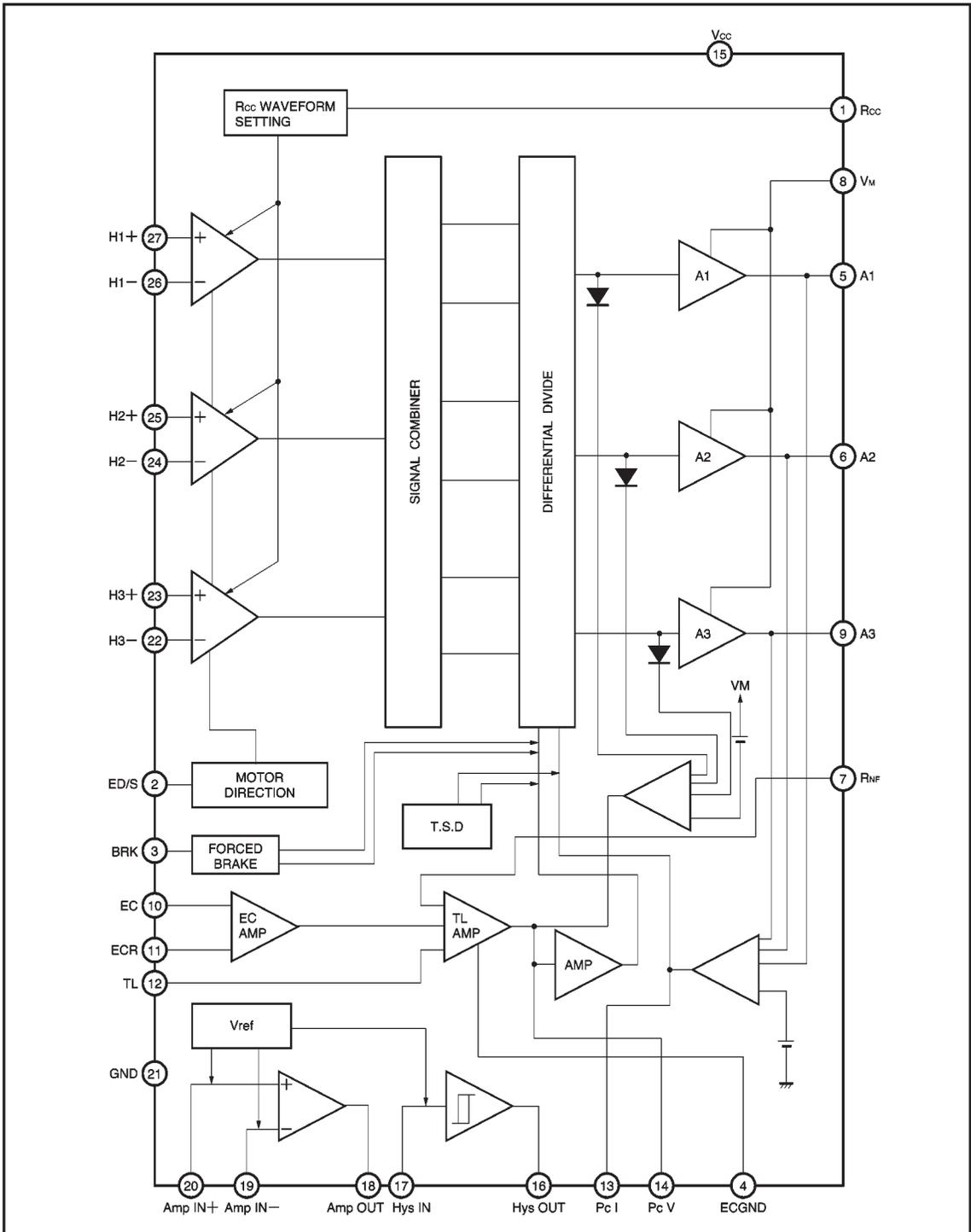
\*4 Should not exceed P<sub>d</sub> or ASO values.

### ●Recommended operating conditions (Ta = 25°C)

Parameter	Symbol	Limits	Unit
Operating power supply voltage	V <sub>CC</sub>	4~6	V
	V <sub>M</sub>	3~32*5	V
Hall signal input voltage	H <sub>n</sub> ±	1.5~ (V <sub>CC</sub> -1.8)	V

\*5 Should not exceed ASO value.

● Block diagram

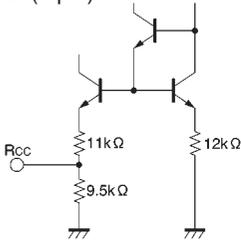


## ● Pin descriptions

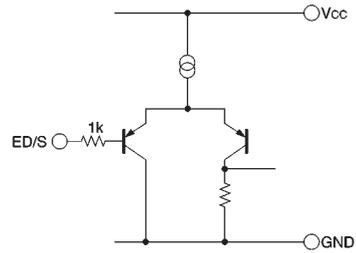
Pin No.	Pin name	Function
1	R <sub>CC</sub>	Resistor connection pin for changing the ripple cancellation ratio
2	ED / S	Forward when LOW, reverse when HIGH
3	BRK	Forced brake pin; brake mode when LOW
4	ECGND	Torque amplifier ground
5	A1	Motor output
6	A2	Motor output
7	R <sub>NF</sub>	Motor ground pin; connect a resistor (0.5 Ω recommended) for current sensing
8	V <sub>M</sub>	Motor power supply
9	A3	Motor output
10	E <sub>C</sub>	Torque control voltage input
11	E <sub>CR</sub>	Torque control reference voltage input
12	TL	Torque limit
13	P <sub>Cl</sub>	Capacitor connection pin for phase compensation of the low-side saturation prevention circuit
14	P <sub>CV</sub>	Capacitor connection pin for phase compensation of the high-side saturation prevention circuit
15	V <sub>CC</sub>	Power supply
16	Hys OUT	Schmitt trigger amplifier output
17	Hys IN	Schmitt trigger amplifier input
18	Amp OUT	Amplifier output
19	Amp IN <sup>-</sup>	Amplifier input, inverted
20	Amp IN <sup>+</sup>	Amplifier input, non-inverted
21	GND	Ground
22	H <sub>3</sub> <sup>-</sup>	Hall signal input
23	H <sub>3</sub> <sup>+</sup>	Hall signal input
24	H <sub>2</sub> <sup>-</sup>	Hall signal input
25	H <sub>2</sub> <sup>+</sup>	Hall signal input
26	H <sub>1</sub> <sup>-</sup>	Hall signal input
27	H <sub>1</sub> <sup>+</sup>	Hall signal input
28	N.C.	—

● Input / output circuits

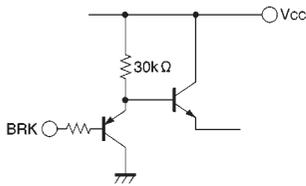
(1) R<sub>CC</sub> pin (1 pin)



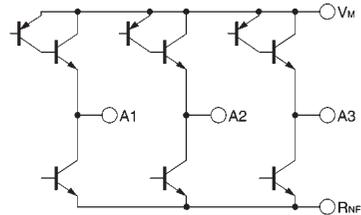
(2) ED / S pin (2 pin)



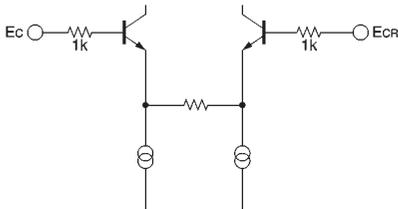
(3) BRK pin (3 pin)



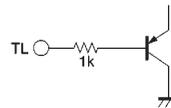
(4) Motor output (A1, 5 pin; A2, 6 pin; A3, 9 pin)



(5) E<sub>c</sub> and E<sub>CR</sub> pins (10 pin, 11 pin)

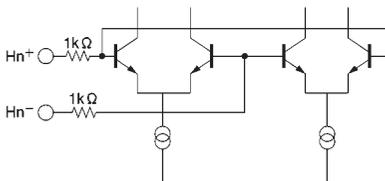


(6) TL pin (12 pin)

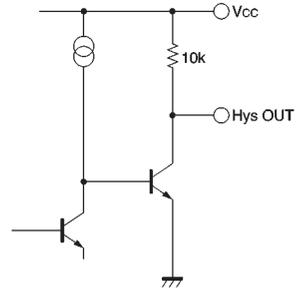
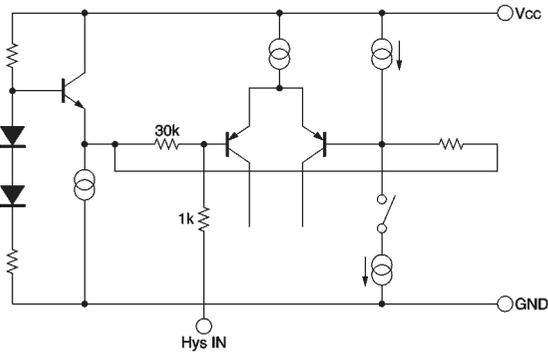


(7) Hall signal input pins

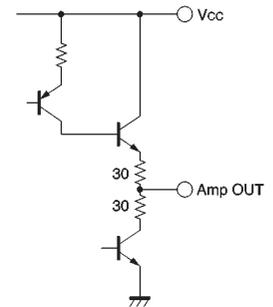
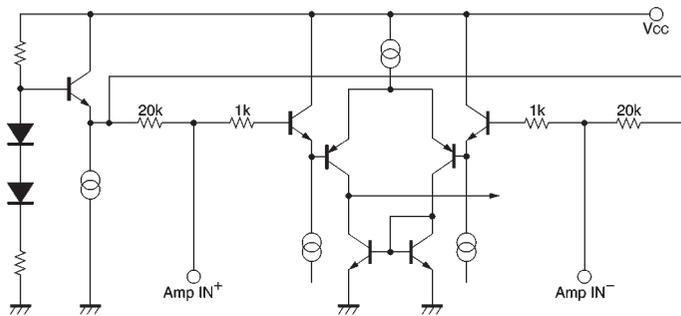
(H<sub>1</sub> + : 27 pin, H<sub>1</sub> - : 26 pin, H<sub>2</sub> + : 25 pin,  
H<sub>2</sub> - : 24 pin, H<sub>3</sub> + : 23 pin, H<sub>3</sub> - : 22 pin)



(8) Schmitt trigger amplifier I / O pins (17 pin, 16 pin)



(9) Amplifier I / O pins (20 pin, 19 pin, 18 pin)



●Electrical characteristics (unless otherwise noted,  $T_a = 25^\circ\text{C}$ ,  $V_{CC} = 5\text{V}$ ,  $V_M = 12\text{V}$ )

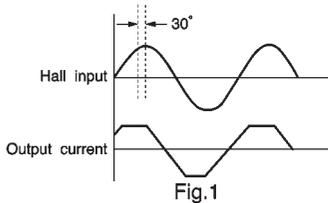
Parameter	Symbol	Min.	Typ.	Max.	Unit	Conditions
Supply current	$I_{CC}$	—	9	14	mA	$E_C = E_{CR} - 0.1$ , ED / S=L Input = (L, L, H)
Hall element input conversion offset	$H_{Eofs}$	-10	0	+10	mV	
Torque control offset	$E_{Cofs}$	-120	—	+120	mV	
Output idle voltage	$E_{Cidle}$	—	0	10	mV	
Torque control input gain	$G_{io}$	0.52	0.58	0.64	A / V	$E_C = 2.7 \rightarrow 2.8$ , input = (L, L, H) $R_{NF} = 0.5\ \Omega$
Brake ON voltage	BR ON	—	—	0.7	V	
Brake OFF voltage	BR OFF	2.0	—	—	V	
Forward ON voltage	ED / F	—	—	2.2	V	
Reverse ON voltage	ED / R	2.8	—	—	V	
TL-R <sub>NF</sub> offset	TL-R <sub>Nofs</sub>	38	60	88	mV	TL=0.35V
Output high level voltage	$V_{OH}$	1.0	1.35	1.7	V	$I_{oA} = 0.8\text{A}$
Output low level voltage	$V_{OL}$	1.15	1.6	2.05	V	$I_{oA} = 0.8\text{A}$
Output current capacity	$I_{OMAX}$	1.4	—	—	A	$V_{CC} = 4.5\text{V}$ , input = (H, L, M)
〈FGAMP〉						
Input impedance	$R_{BA}$	14	20	26	K $\Omega$	
Open gain 1	$G_{A1}$	65	70	—	dB	f=500Hz
Open gain 2	$G_{A2}$	33	38	—	dB	f=20kHz
DC bias voltage	$V_{BA}$	2.25	2.5	2.75	V	
Output high level voltage	$V_{OHA}$	3.6	4	—	V	$I_{oA} = 0.5\text{mA}$
Output low level voltage	$V_{OLA}$	—	0.9	1.3	V	$I_{oA} = 0.5\text{mA}$
Input voltage	$V_{AB}$	1.5	—	3.8	V	
〈Schmitt trigger amplifier〉						
Hysteresis width	$V_{hys}$	$\pm 115$	$\pm 155$	$\pm 195$	mV	
DC bias voltage	$V_{Bhys}$	2.25	2.5	2.75	V	
Output low level voltage	$V_{OLhys}$	—	100	320	mV	$I_{oLhys} = 2\text{mA}$

\* Specifications are subject to change without notice.

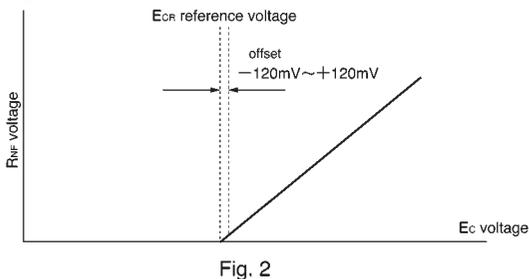
©Not designed for radiation resistance.

● Circuit operation

(1) Pseudo-linear output and torque ripple cancellation  
The IC generates a trapezoidal (pseudo-linear) output current, whose waveform phase is 30 degrees ahead of that of the hall input voltage (Fig. 1).



(2) Torque control  
The output current can be controlled by adjusting the voltage applied to the torque control pins.



The pins are the inputs to a differential amplifier. A reference voltage between 2.3-3.0V (2.5V recommended) is applied to pin 11.

A brake is applied to the motor when the brake pin (3 pin) is put to LOW. The brake mode is activated when the brake pin voltage is 0.7V or less and deactivated when the voltage is 2.0V or more.

(3) Output current sensing and torque limitation  
The RNF pin (7 pin) is the ground pin for the output stage. To sense the output current, a resistor (0.5Ω recommended) is connected between pin 7 and the ground. The output current is sensed by applying the voltage developed across this resistor to the TL amplifier input as a feedback.

The output current can be limited by adjusting the voltage applied to pin 12. The current is limited when pin 12 reaches the same potential as pin 7. The output current ( $I_{MAX.}$ ) under this condition is given by :

$$I_{MAX.} = \frac{V_{TL} - (TL - R_{NF} \text{ offset})}{R_{RNF}}$$

where  $R_{RNF}$  is the value of the resistor connected between the RNF pin and the ground, and  $V_{TL}$  is the voltage applied to the TL pin.

(4) Motor direction control (ED / S pin)

The motor mode is :

Forward when the ED / S-pin voltage is less than 2.2V,

Reverse when the voltage is above 2.8V.

(5) Output transistor saturation prevention circuit  
This circuit monitors the output voltage and maintains the operation of the output transistors below their saturation levels. Operating the transistors in the linear characteristic range provides good control over a wide range of current and good torque characteristics even during overloading.

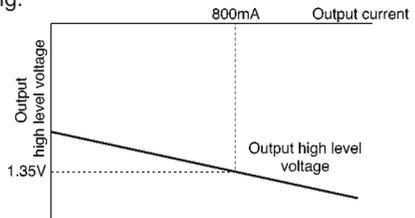


Fig. 3

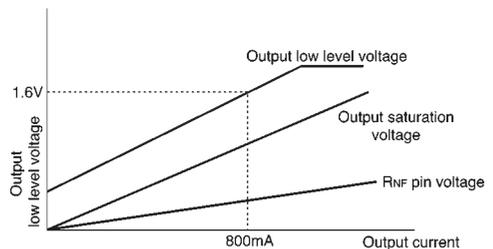


Fig. 4

(6) Ripple cancellation circuit  
The torque ripple cancellation ratio can be adjusted by an external resistor connected to pin 1. Select a suitable value by taking wow and flutter into consideration.

(7) Brake pin

The brake pin threshold depends on the chip temperature as shown in Fig. 5. Make sure that your application will work properly when using the IC at low or high temperatures.

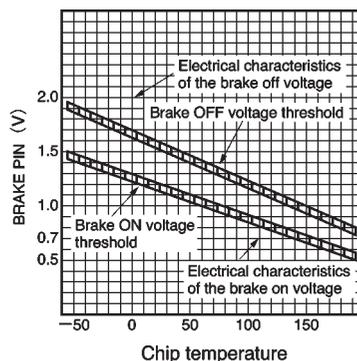


Fig.5 Brake pin threshold vs. chip temperature

● Application example

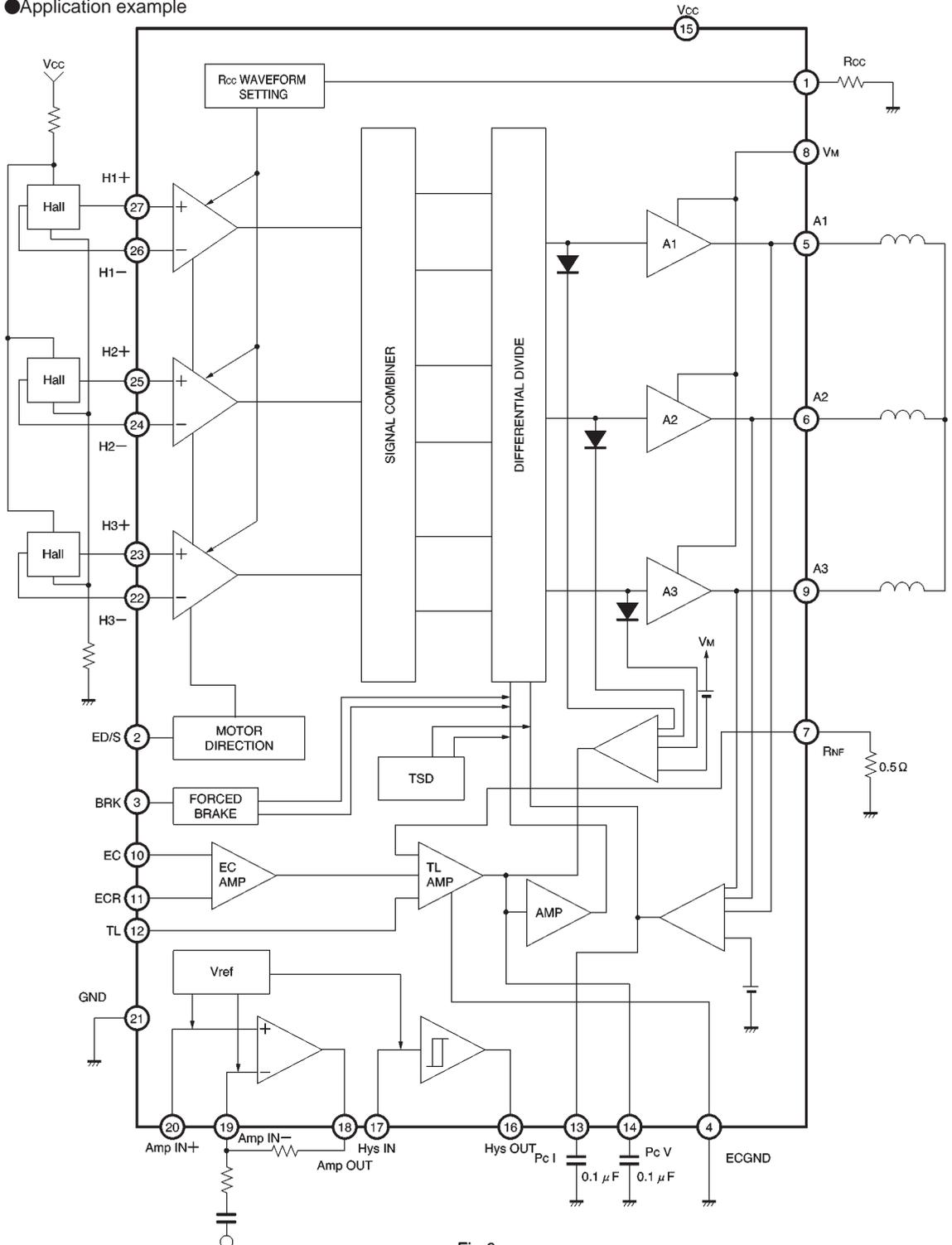


Fig.6

### ● Operation notes

#### (1) Thermal shutdown circuit

The BA6446FP / FM has a thermal shutdown circuit to protect the IC. The shutdown temperature is 175°C (typical) with a hysteresis width of 45°C (typical).

When the circuit is activated due to an increase in the chip temperature, the output pins (pins 5, 6, and 9) are set to the open state. The circuit is functional against excessive power dissipation, output short-circuiting, and other irregularities in the output current, but does not work against overheating caused by high internal currents due to externally caused IC damage or pin-to-pin short-circuiting.

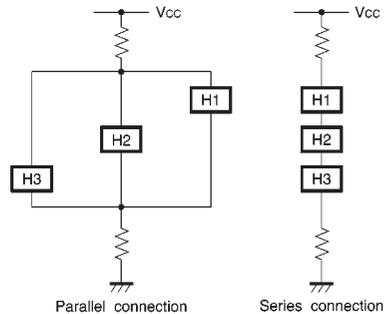
#### (2) Brake circuit

The brake circuit has temperature-dependent thresholds as shown in Fig. 5. Make sure that your application will work properly when using the IC at low or high temperatures.

(3) Be sure to connect the radiation fins to the ground.

#### (4) Hall input

The Hall input circuit is described in (7) of "I / O equivalent circuits." Hall devices can be connected in either series or parallel. Be sure to keep the Hall input within the range of 1.5V to ( $V_{CC} - 1.8V$ ).



#### (5) FG amplifier

Note that unpredictable outputs may occur when the FG amplifier input is outside the recommended range.

#### (6) ECGND pin (4 pin)

Pin 4, a torque amplifier ground pin, should be connected to the ground. By connecting this pin to a point close to the motor ground, you can prevent the effect of GND common impedance on the current-sensing resistor (0.5Ω recommended) connected between  $R_{NF}$  (pin 7) and the motor ground pin.

●Electrical characteristic curves

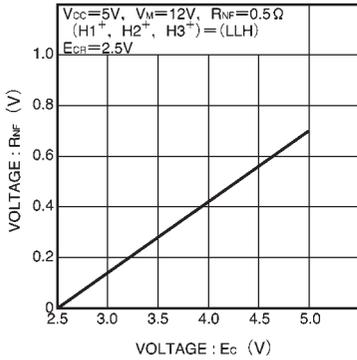


Fig.7 RNF-pin voltage vs. Ec-pin voltage

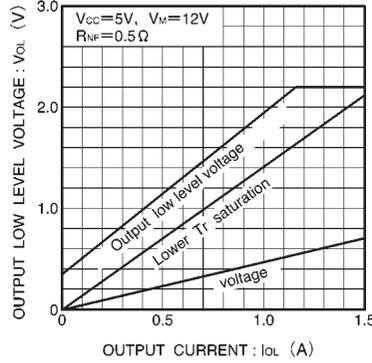


Fig.8 Output low level voltage vs. output current

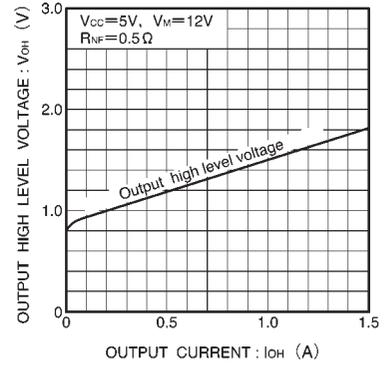


Fig.9 Output high level voltage vs. output current

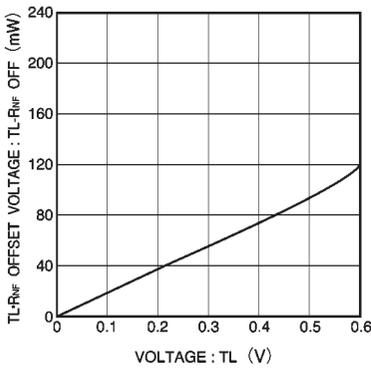


Fig.10 TL-RNF offset voltage vs. TL voltage

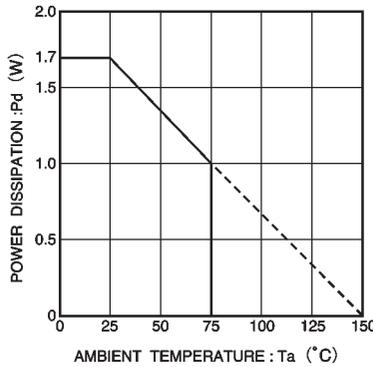


Fig.11 Temperature dependence of power dissipation (BA6446FP)

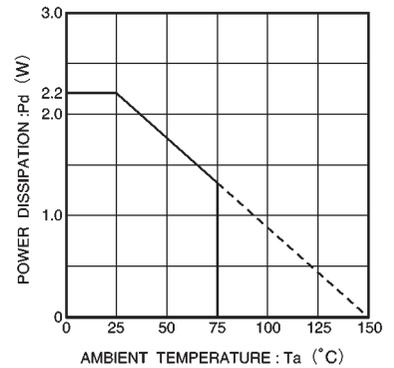


Fig.12 Temperature dependence of power dissipation (BA6446FM)

●External dimensions (Units: mm)

