

# 3-phase motor driver

## BA6444FP

The BA6444FP is a 3-phase, full-wave, pseudo-linear motor driver suited for VCR capstan motors. The IC has a torque ripple cancellation circuit to reduce wow and flutter, and a forced brake circuit that allows abrupt change of operational mode. The output transistor saturation prevention circuit provides superb torque control over a wide range of current. FG and hysteresis amplifiers are also built in.

### ●Applications

VCR capstan motors, DAT capstan motors

### ●Features

- 1) 3-phase, full-wave, pseudo-linear drive system.
- 2) Torque ripple cancellation circuit.
- 3) Forced brake circuit.
- 4) Output transistor (high- and low-sides) 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        | P <sub>d</sub>      | 1700*1   | mW   |
| Operating temperature    | T <sub>opr</sub>    | −20~+75  | °C   |
| Storage temperature      | T <sub>stg</sub>    | −40~+150 | °C   |
| Allowable output current | I <sub>o peak</sub> | 1500*2   | mA   |

\*1 When mounted on a glass epoxy board (70×70×1.6 mm).

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

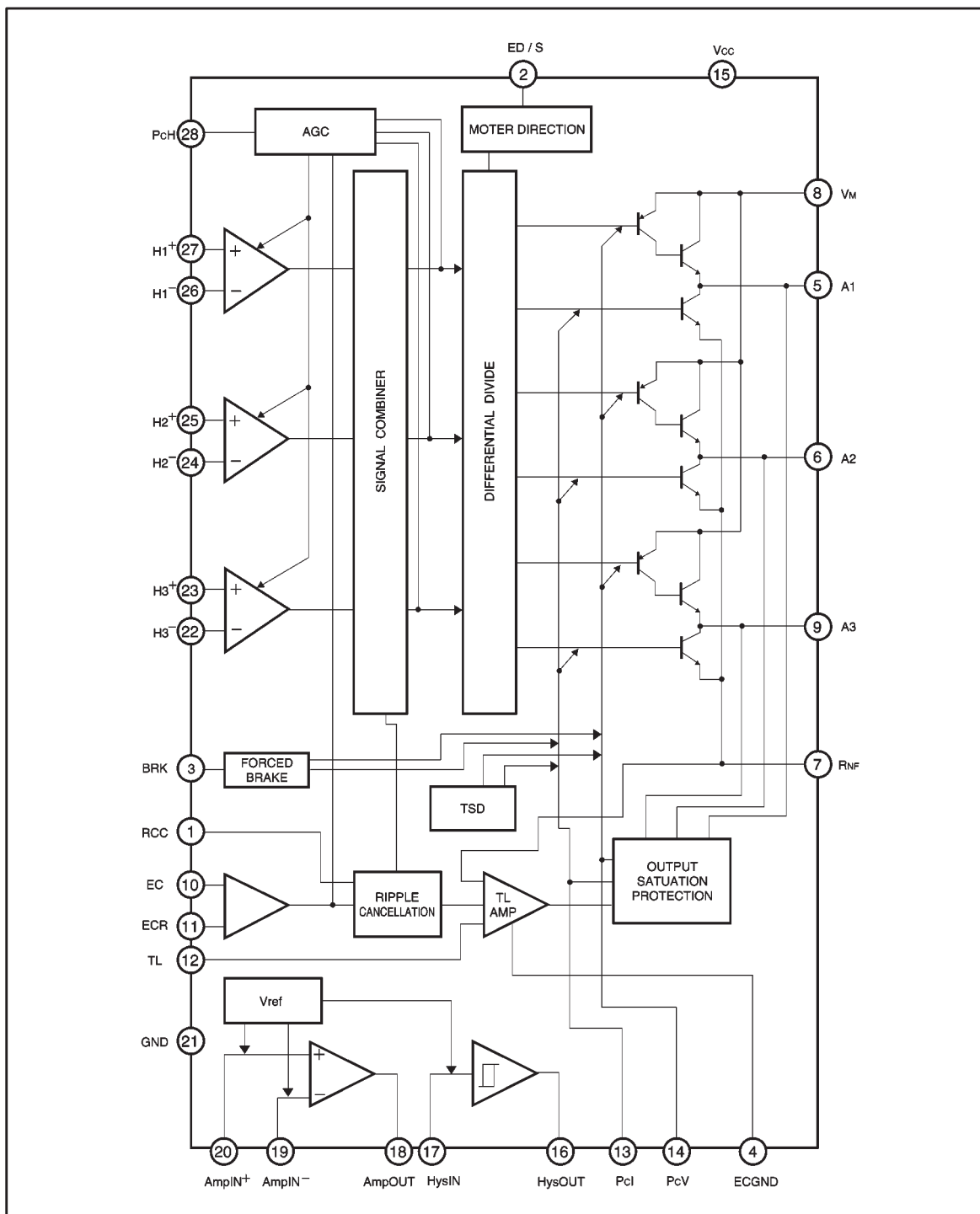
\*2 Should not exceed Pd or ASO values.

### ●Recommended operating conditions

| Parameter                      | Symbol          | Range                       | Unit |
|--------------------------------|-----------------|-----------------------------|------|
| Operating power supply voltage | V <sub>CC</sub> | 4~6                         | V    |
|                                | V <sub>M</sub>  | 3~32*3                      | V    |
| Hall signal input voltage      | Hn <sup>±</sup> | 1.5~ (V <sub>CC</sub> −1.5) | V    |

\*3 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; stop when MEDIUM; 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; connect a resistor (0.5 $\Omega$ 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 for phase compensation of the low-side saturation prevention circuit  |
| 14      | P <sub>CV</sub>             | Capacitor connection 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      | P <sub>CH</sub>             | Capacitor connection pin for Hall amplifier AGC circuit phase compensation                 |

● Input/output circuits

(1) I/O circuit interface

Resistances, in  $\Omega$ , are typical values. Note that the resistance values can vary  $\pm 30\%$ .

1) ED/S pin (2 pin)

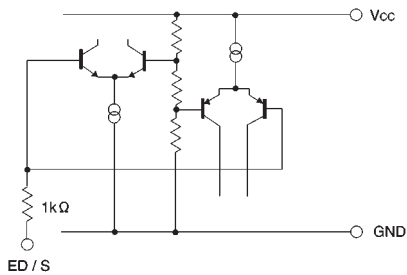


Fig.1

2) BRK pin (3 pin)

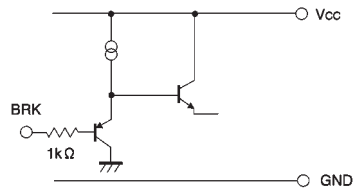


Fig.2

3) Motor output (A1: 5 pin, A2: 6 pin, A3: 9 pin)

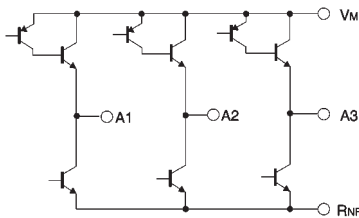


Fig.3

4) Ec and ECR pins (10 pin, 11 pin)

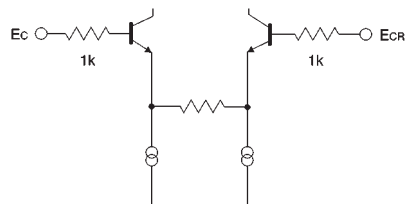


Fig.4

5) TL pin (12 pin)

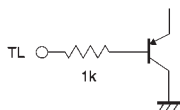


Fig.5

6) Hall signal input pins

(H1<sup>+</sup>: 27 pin, H1<sup>-</sup>: 26 pin, H2<sup>+</sup>: 25 pin, H2<sup>-</sup>: 24 pin, H3<sup>+</sup>: 23 pin, H3<sup>-</sup>: 22 pin)

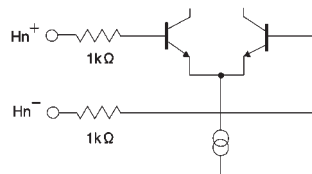


Fig.6

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

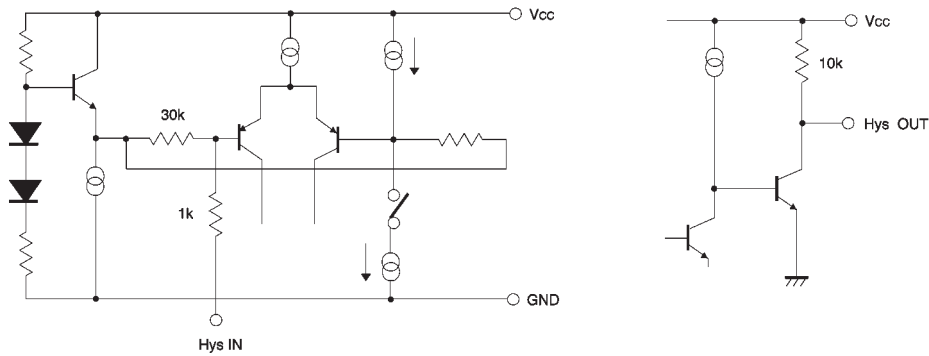


Fig.7

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

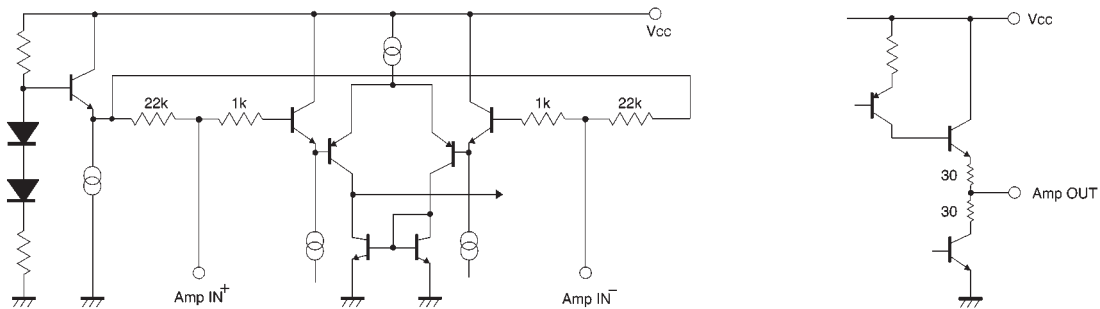


Fig.8

●Electrical characteristics (unless otherwise noted, Ta = 25°C, V<sub>CC</sub> = 5V, V<sub>M</sub> = 12V)

| Parameter                                         | Symbol               | Min. | Typ. | Max. | Unit  | Conditions                                                       |
|---------------------------------------------------|----------------------|------|------|------|-------|------------------------------------------------------------------|
| Supply current                                    | I <sub>CC</sub>      | —    | 10   | 15   | mA    | E <sub>C</sub> =E <sub>CR</sub> - 0.1, ED / S=M, input=(L, L, H) |
| Hall element input conversion offset              | H <sub>Eofs</sub>    | −6   | 0    | 6    | mV    |                                                                  |
| Hall element input conversion offset differential | Δ H <sub>Eofs</sub>  | 0    | —    | 8    | mV    |                                                                  |
| Torque control offset                             | E <sub>cofs</sub>    | −100 | —    | 100  | mV    |                                                                  |
| Output idle voltage                               | E <sub>idle</sub>    | —    | 0    | 10   | mV    |                                                                  |
| Torque control input gain                         | G <sub>io</sub>      | 0.52 | 0.58 | 0.64 | A / V | E <sub>C</sub> =2.7→2.8, input=(L, L, H), R <sub>NF</sub> =0.5Ω  |
| Brake ON voltage                                  | BR <sub>ON</sub>     | —    | —    | 0.7  | V     |                                                                  |
| Brake OFF voltage                                 | BR <sub>OFF</sub>    | 2.0  | —    | —    | V     |                                                                  |
| Forward ON voltage                                | ED / F               | —    | —    | 0.9  | V     |                                                                  |
| Stop ON voltage                                   | ED / S               | 1.3  | —    | 3.0  | V     |                                                                  |
| Reverse ON voltage                                | ED / R               | 3.5  | —    | —    | V     |                                                                  |
| TL-R <sub>NF</sub> offset                         | TL-R <sub>Nofs</sub> | 38   | 60   | 88   | mV    | TL=0.35V                                                         |
| Ripple cancellation ratio                         | V <sub>RCC</sub>     | 3.0  | 3.9  | 4.8  | %     | R <sub>CC</sub> = 10 kΩ, input = (L, L, H)→(L, M, H)             |
| Output high level voltage                         | V <sub>OH</sub>      | 0.8  | 1.2  | 1.55 | V     | I <sub>O</sub> =0.8A                                             |
| Output low level voltage                          | V <sub>OL</sub>      | 1.15 | 1.6  | 2.05 | V     | I <sub>O</sub> =0.8A                                             |
| Output current capacity                           | I <sub>O MAX</sub>   | 1.4  | —    | —    | A     | V <sub>CC</sub> = 4.5 V, input = (H, L, M)                       |
| 〈FGAMP〉                                           |                      |      |      |      |       |                                                                  |
| Input impedance                                   | R <sub>BA</sub>      | 15.4 | 22   | 28.6 | kΩ    |                                                                  |
| Open gain 1                                       | GA 1                 | 65   | 70   | —    | dB    | f=500Hz                                                          |
| Open gain 2                                       | GA 2                 | 33   | 38   | —    | dB    | f=20kHz                                                          |
| DC bias voltage                                   | V <sub>BA</sub>      | 2.25 | 2.5  | 2.75 | V     |                                                                  |
| Output high level voltage                         | V <sub>OH A</sub>    | 3.6  | 4    | —    | V     | I <sub>OA</sub> =0.5mA                                           |
| Output low level voltage                          | V <sub>OL A</sub>    | —    | 0.9  | 1.3  | V     | I <sub>OA</sub> =0.5mA                                           |
| Input voltage                                     | V <sub>AB</sub>      | 1.5  | —    | 3.8  | V     |                                                                  |
| 〈Schmitt trigger amplifier〉                       |                      |      |      |      |       |                                                                  |
| Hysteresis width                                  | V <sub>hys</sub>     | ±115 | ±155 | ±195 | mV    |                                                                  |
| DC bias voltage                                   | V <sub>ehys</sub>    | 2.25 | 2.5  | 2.75 | V     |                                                                  |
| Output low level voltage                          | V <sub>OLhys</sub>   | —    | 100  | 320  | mV    | I <sub>OLhys</sub> =2mA                                          |

◎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. 9).

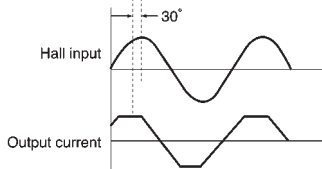


Fig. 9

Fig.10 Torque ripple cancellation

The trapezoidal waveform of output current would create intermittence in the magnetic field generated by the 3-phase motor, and would result in an irregular rotation of the motor. To prevent this, the output waveform is obtained by superimposing a triangular wave on the trapezoidal wave (Fig. 10). This process is called torque ripple cancellation.

(2) Torque control

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

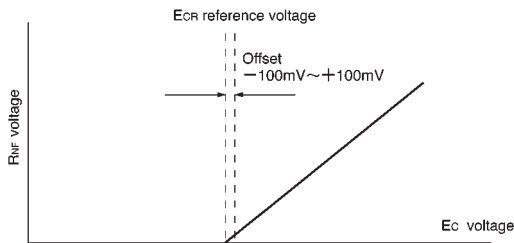


Fig.11

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 (pin 3) 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  $R_{NF}$  pin (pin 7) is the ground pin for the output stage. To sense the output current, a resistor ( $0.5\Omega$  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  $R_{NF}$  and ground pins 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 0.9V,  
Stop when the voltage is between 1.3 ~ 3.0V,  
Reverse when the voltage is above 3.5V.

In the stop mode, high- and low-side output transistors are turned off, resulting in a high impedance state.

(5) Output transistor saturation prevention circuit

This circuit monitors the output voltage and maintain 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 over-loading.

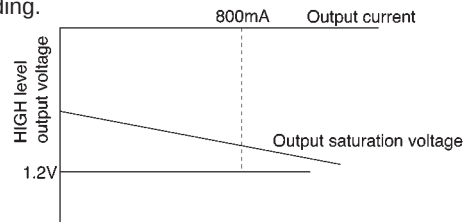


Fig.12 Transistor HIGH level output voltage

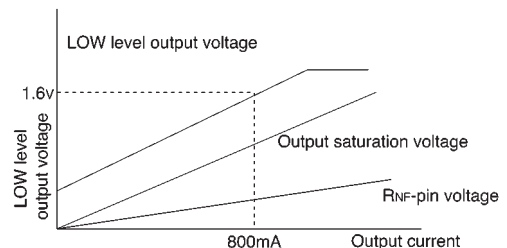


Fig.13 Transistor LOW level output voltage

## (6) Ripple cancellation circuit

The cancellation ratio of the torque ripple cancellation circuit (Fig. 10) can be adjusted by an external resistor connected to pin 1. Select a suitable value by taking wow and flutter into consideration.

The ripple cancellation ratio can be obtained in the following manner. With  $E_C = 2.7V$ , the  $R_{NF}$  value for the Hall input of  $(H1^+, H2^+, H3^+) = (L, L, H)$  is denoted as  $V_1$ , and the  $R_{NF}$  value for the Hall input of  $(H1^+, H2^+, H3^+) = (L, M, H)$  is denoted as  $V_2$ . The ripple cancellation ratio is then given by:

$$R_{CC} = \frac{V_2 - V_1}{(V_1 + V_2)/2} \times 100 (\%)$$

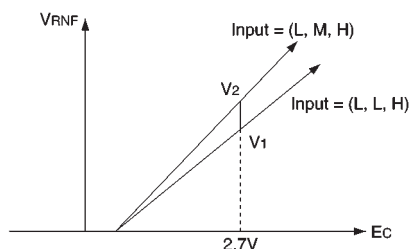


Fig. 14

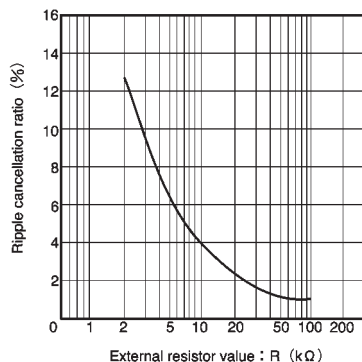


Fig. 15 Ripple cancellation ratio vs. external resistor value (reference curve)

## (7) Brake pin

The brake pin threshold depends on the chip temperature as shown in Fig. 16. Make sure that your application will work properly when using the IC at low or high temperatures.

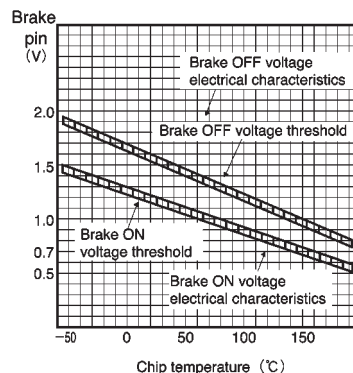


Fig. 16 Brake pin threshold vs. chip temperature

## ●Application example

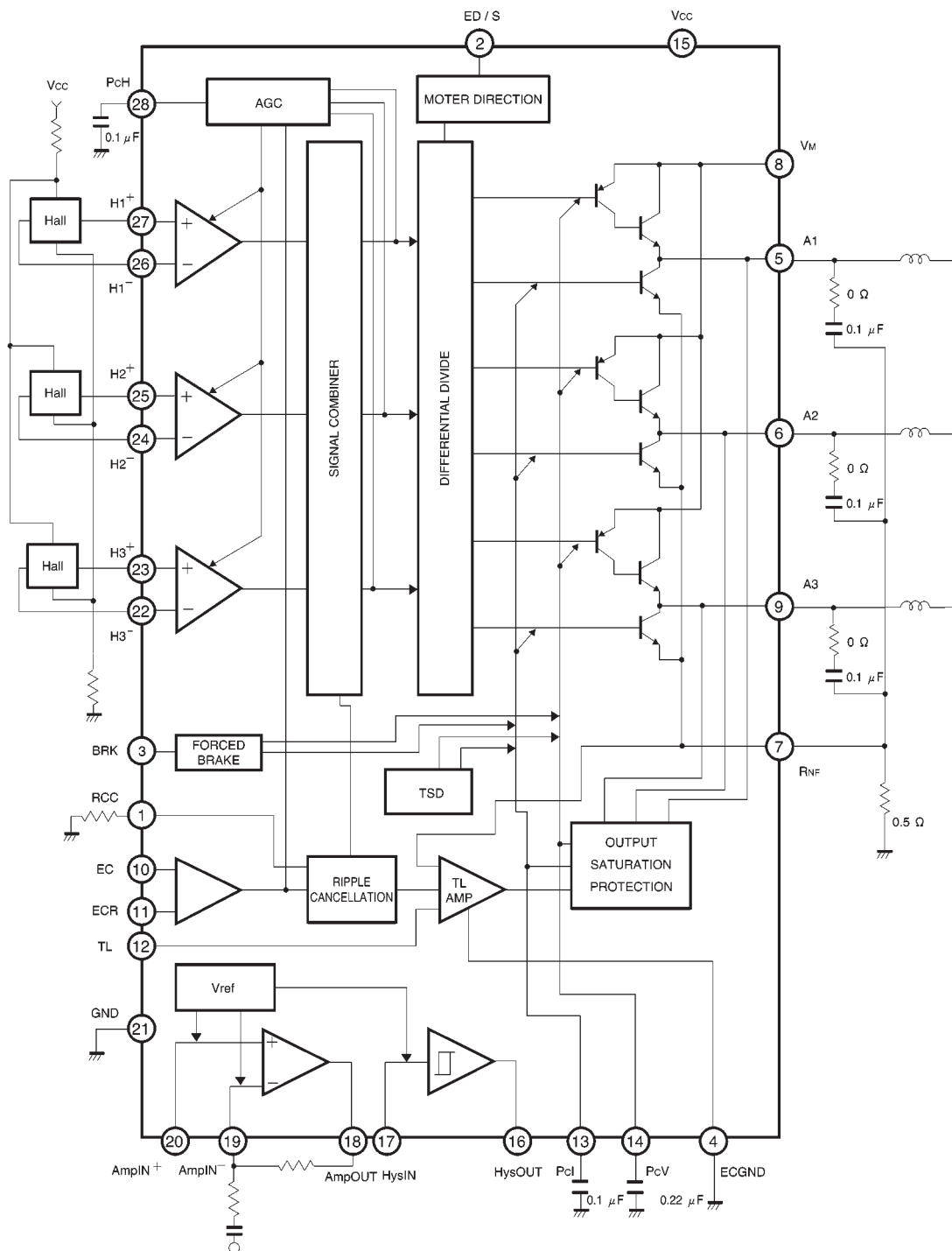


Fig.17

### ● Operation notes

#### (1) Thermal shut down circuit

The BA6444FP has a thermal shutdown circuit to protect the IC. The shutdown temperatures is 175°C (typical) with a hysteresis width of 45°C (typical).

When the circuit is activated due to an increased in 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) The brake circuit has temperature-dependent thresholds as shown in Fig. 16. Make sure that your application will work properly when using the IC at low or high temperatures.

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

#### (4) Hall input

The Hall input circuit is described in (6) 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 ( $V_{CC} - 1.5V$ ).

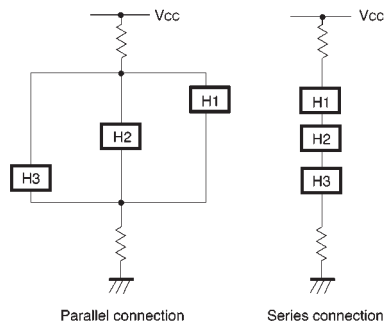


Fig.18

#### (5) FG amplifier

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

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

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 ( $0.5\Omega$  recommended) connected between  $R_{NF}$  (pin 7) and the motor ground pin.

### ● Electrical characteristic curves

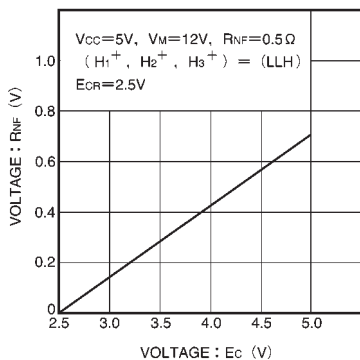


Fig.19 Output voltage vs. torque control voltage

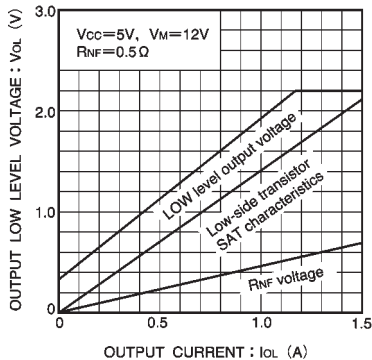


Fig.20 Output low level voltage vs. output current

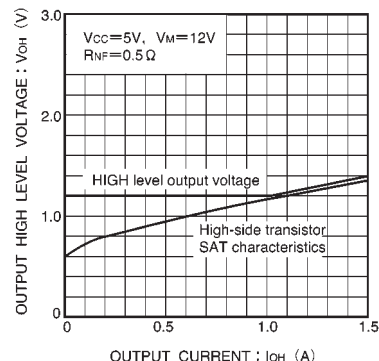


Fig.21 Output high level voltage vs. output current

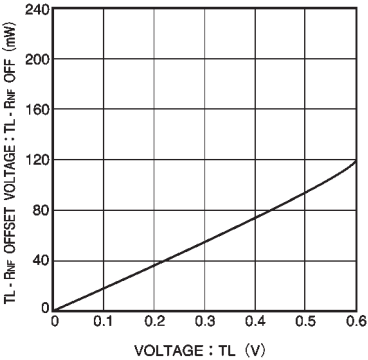


Fig.22 TL-R<sub>NF</sub> offset voltage vs. TL voltage

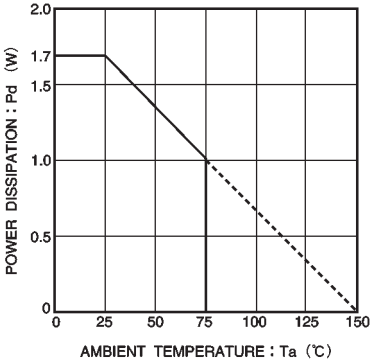


Fig.23 Power dissipation vs. ambient temperature

●External dimensions (Units: mm)

