BA6440FP

3-phase motor driver

The BA6440FP is an IC used for driving video cassette recorder capstan motors.

Features

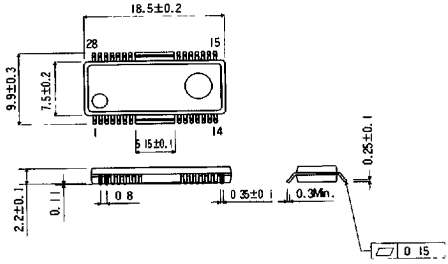
- available in a HSOP28 package
- supply voltage range 4 ~ 6 V (control block) and 3 ~ 20 V (output block)
- power dissipation (1700 mW)
- maximum output current up to 1500 mA
- three-phase full-wave pseudo linear driving system
- built-in thermal shutdown circuit (TSD)
- forward and reverse control
- forced braking circuit
- torque ripple cancelling circuit (to reduce wow and flutter)
- provided with a motor power controller (using a switching regulator)
- FG and hysteresis amplifiers
- output transistor (H side, L side) saturation prevention circuit

Applications

- video cassette recorder capstan motor
- digital audio tape recorder capstan motor

Dimensions (Units : mm)

BA6440FP (HSOP28)



Block diagram

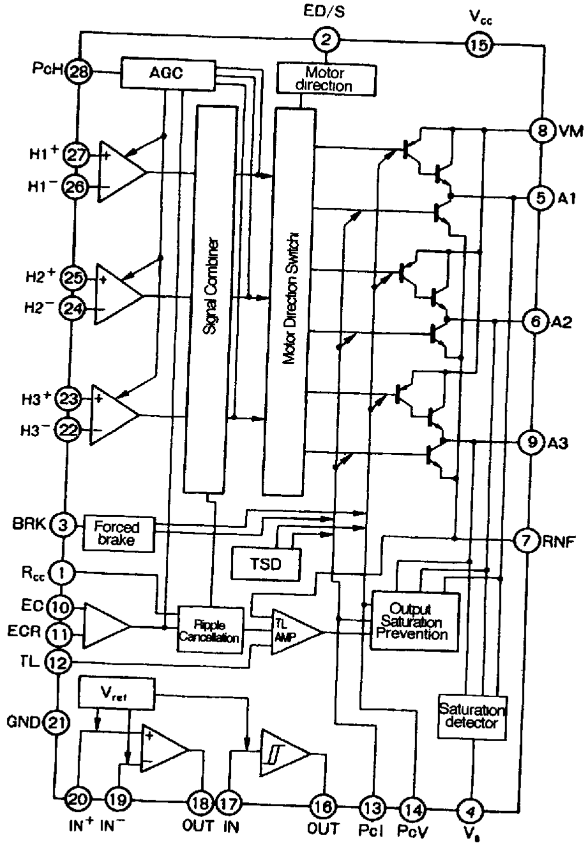


Table 1 Pin description (Sheet 1 of 2)

Pin no	Pin name	Function
1	R_{CC}	Ripple cancellation ratio adjustment pin (connect external resistor)
2	ED/S	Mode select: L = forward, H = reverse, M = stop
3	BRK	Forced braking pin. H sets brake mode
4	V_S	Motor supply voltage control pin
5	A1	Motor output
6	A2	Motor output
7	R_{NF}	Motor ground pin. Connect current sensing resistor (recommend 0.5 Ω)
8	V_M	Motor supply voltage input
9	A_3	Motor output
10	E_C	Torque command control voltage input

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Table 1 Pin description (Sheet 2 of 2)

Pin no	Pin name	Function
11	E_{CR}	Torque command reference voltage input
12	TL	Torque limit pin
13	$P_{C}l$	Low side saturation prevention circuit phase compensation capacitor pin
14	$P_{C}V$	High side saturation prevention circuit phase compensation capacitor pin
15	V_{CC}	Supply voltage input
16	Hys OUT	Hysteresis amplifier (Schmitt trigger) output
17	Hys IN	Hysteresis amplifier (Schmitt trigger input)
18	Amp OUT	Amplifier output
19	Amp IN –	Amplifier inverting input
20	Amp IN +	Amplifier non-inverting input
21	GND	Ground pin
22	H3–	Hall signal input
23	H3+	Hall signal input
24	H2–	Hall signal input
25	H2+	Hall signal input
26	H1–	Hall signal input
27	H1+	Hall signal input
28	$P_{C}H$	Connection point for Hall amplifier AGC circuit phase compensation capacitor

Absolute maximum ratings (T_a = 25°C)

Parameter	Symbol	Limits	Unit	Conditions
Power supply voltage	V_{CC}	7	V	
	V_M	24		
Power dissipation	P_d	1700	mW	Reduce power by 13.6 mW for each degree above 25°C. Mounted on a 50 × 50 × 1 mm paper-phenolic PCB.
Motor drive current	I_{Opeak}	1500	mA	The output current must not exceed the maximum P_d or ASO ratings.
Operating temperature	T_{opr}	–25 ~ +75	°C	
Storage temperature	T_{stg}	–40 ~ +150	°C	

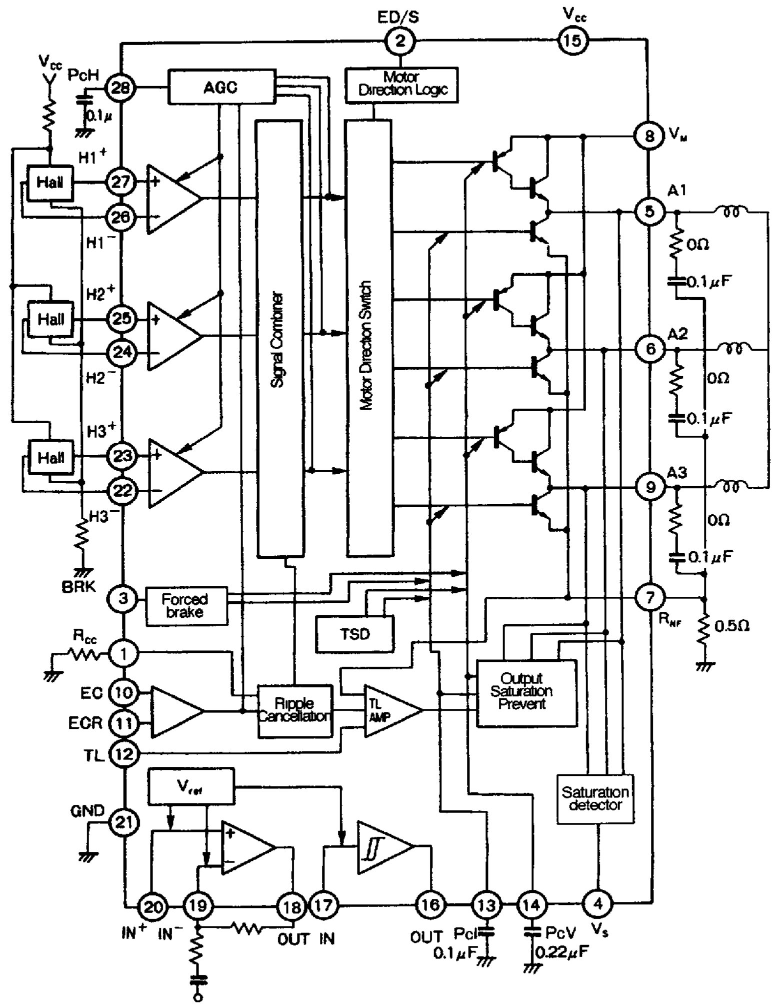
Recommended operating conditions (T_a = 25°C)

Parameter	Symbol	Min	Typical	Max	Unit
Power supply voltage	V_M	3		20	V
	V_{CC}	4		6	
Hall element input voltage		1.5		V_{CC} – 1.5	V

Electrical characteristics (unless otherwise noted, T_a = 25°C, V_{CC} = 5 V, V_M = V_M = 12 V)

Parameter	Symbol	Min	Typical	Max	Unit	Conditions
Supply current	I_{CC}		10	15	mA	$E_C = E_{CR} - 0.1$, ED/S = M, input L, L, H
Hall element input conversion offset	H_{Eofs}	−6	0	+6	mV	
Hall element input conversion offset delta	ΔH_{Eofs}	0		8	mV	
Torque command offset	$E_{C\ ofs}$	−100		+100	mV	
Output idle voltage	$E_{C\ idle}$		0	10	mV	
Torque cmd input gain	G_{IO}	0.52	0.58	0.64	A/V	Inputs L, L, H, E_C = 2.7 ~ 2.8 V, R_{NF} = 0.5 Ω
Brake on voltage	BR_{ON}	3.5			V	
Brake off voltage	BR_{OFF}			0.5	V	
Forward cmd voltage	ED/F			0.9	V	
Stop cmd voltage	ED/S	1.3		3.0	V	
Reverse cmd voltage	ED/R	3.5			V	
TL-R_{NF} offset	TL−R_{Nofs}	35	55	80	mV	TL = 0.35 V, R_{NF} = 0.5 Ω
Ripple cancellation ratio	V_{RCC}	3.6	4.5	5.4	%	R_{CC} = 10 kΩ
Saturation detect output voltage	V_S	2.25	2.5	2.75	V	Output = V_M − 1.65 V
Saturation detect output gain	G_{VS}	1.7	2.1	2.5	V/V	Output = V_M − 1.55 V ~ V_M − 1.75 V
High side output voltage	V_{OH}	1.0	1.4	1.8	V	I_O = 0.8 A
Low side output voltage	V_{OL}	1.05	1.45	1.85	V	I_O = 0.8 A
FG amplifier						
Input impedance	R_{BA}	14	20	26	kΩ	
Open loop gain 1	G_{A1}	65	70		dB	f = 500 Hz
Open loop gain 2	G_{A2}	33	38		dB	f = 20 kHz
DC bias voltage	V_{BA}	2.25	2.5	2.75	V	
Output high voltage	$V_{OH\ A}$	3.6	4		V	I_{OA} = 0.5 mA
Output low voltage	$V_{OL\ A}$		0.9	1.3	V	I_{OA} = 0.5 mA
Input voltage	V_{AB}	1.5		4.0	V	
Hysteresis amplifier						
Hysteresis width	V_{hys}	±115	±155	±195	mV	
DC bias voltage	$V_{B\ hys}$	2.25	2.5	2.75	V	
Output voltage LOW	V_{OLhys}		80	300	mV	I_{OLhys} = 2 mA

Figure 1 Application example



Input and output equivalent circuits (Resistance values are ±30% typically)

Figure 2 ED/S pin (pin 2)

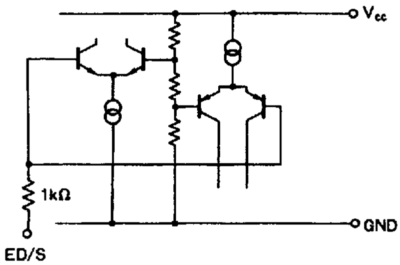


Figure 3 BRK pin (pin 3)

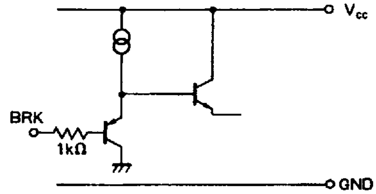


Figure 4 Motor drive outputs (A1, pin 5; A2, pin 6; A3, pin 9)

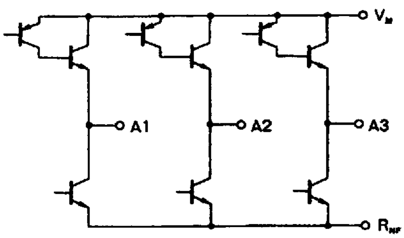


Figure 5 E_C and E_{CR} pins (pins 10, 11)

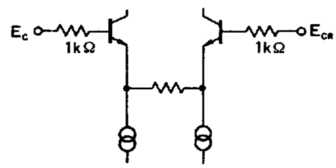


Figure 6 TL pin

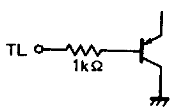


Figure 7 Hall signal inputs (H1+, pin 27; H1-, pin 26, H2+, pin 25; H2-, pin 24; H3+, pin 23; H3-, pin 22)

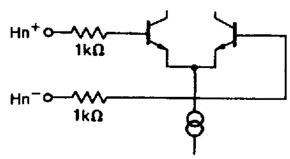


Figure 8 Amplifier input (pins 19 & 20)

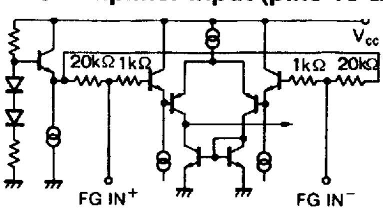


Figure 9 Amplifier out put (pin 18)

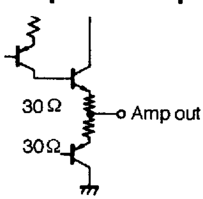


Figure 10 Hysteresis amplifier input (pin 17)

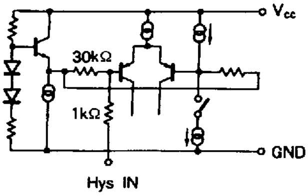
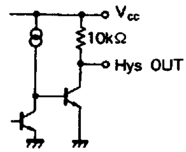


Figure 11 Hysteresis amplifier input (pin 18)



Circuit operation

Pseudo-linear output and torque ripple cancellation

The IC generates a trapezoidal (pseudo-linear) output current waveform, the phase of which leads that of the Hall input voltage by 30 degrees.

A trapezoidal output current, however, would create a zero magnetic field at the crest of each period of the three phase windings. This torque ripple can cause an irregular rotation of the motor. To prevent this, the output is obtained by superimposing a triangular waveform on the trapezoidal wave (see Figure 13). This process is called torque ripple cancellation.

Figure 12 Hall input and output current waveforms

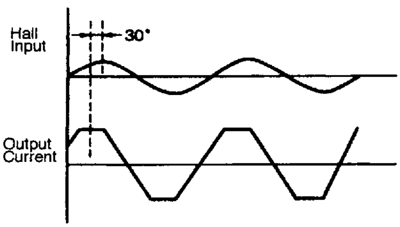
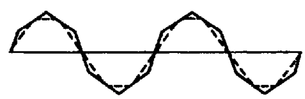


Figure 13 Torque ripple cancellation waveform



The torque ripple cancellation ratio can be adjusted by changing the value of the external resistor connected between pin 1 and ground (R_{Pin1}). When selecting the value for this resistor, be sure to consider any wow and flutter due to the motor installation. The cancellation ratio can be determined from the following test method:

1 Set E_C to 2.7 V

2 Take V_1 as the voltage between the RNF pin and ground when the Hall inputs H1+, H2+, and H3+ are L, L, and H, respectively.

3 Take V_2 as the voltage between the RNF pin and ground when the Hall inputs H1+, H2+, and H3+ are L, M, and H, respectively.

4 The ripple cancellation ratio (R_{CC}) is given by the equation:

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

Figure 14 Determination of ripple cancellation ratio

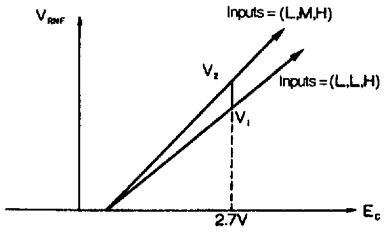
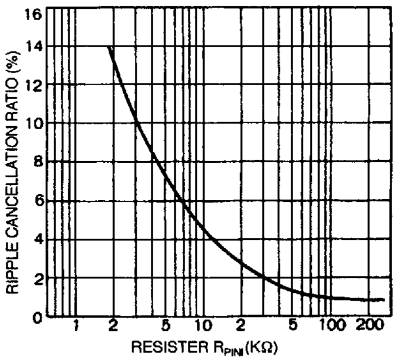


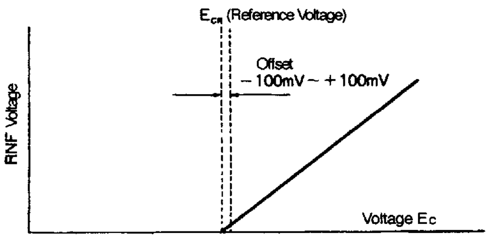
Figure 15 Ripple rejection ratio against resistance R_{Pin1}



Torque control pin

The output motor drive currents can be controlled by a voltage applied to the torque control pin (EC).

Figure 16 Motor torque control



These pins are the inputs to a differential amplifier. Pin 11 is connected to the reference side at a voltage between 2.3 and 3.0 V (2.5 V is recommended).

To stop the motor, pin 3 (BRK) is taken high which activates the brake mode (brake ON voltage ≥ 3.5 V, brake release voltage ≤ 0.5 V).

Output current sensing and torque limitation

Pin 7 (R_{NF}) is the ground terminal for the output stage. To sense the output current, a small resistor (a value of 0.5 Ω is recommended) can be connected between pin 7 and ground. The output current is sensed by applying the voltage developed across this resistor to the TL amplifier input as a feedback voltage.

The output current can be limited by applying a voltage to the TL pin. The limit is applied when the TL pin reaches the same potential as pin 7. The output current (I_{Max}) is given by the formula:

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

where R_{RNF} is value of the resistor connected between pin 7 and ground
V_{TL} is the voltage applied to the TL pin.

Motor supply voltage control function

Almost all of the power dissipated by the IC is dissipated between the collectors and emitters of the output stage transistors. More power is consumed as the collector-to-emitter voltage increases and as the output current increases.

The output transistor C-E voltage is equal to the difference between the supply voltage and the voltage applied to the motor. Therefore, if the supply voltage is fixed, when the drive current decreases, the voltage across the motor decreases, and the C-E voltage must increase by the same amount.

Therefore, to improve the efficiency of the driver (and to prevent the power rating of the IC being exceeded), the supply voltage must be varied in response to changes in the output current. The supply voltage is decreased at low current and increased at high current so that no unnecessary output transistor C-E voltage is applied, and no unnecessary power is dissipated by the transistors.

This is the purpose of the supply voltage controller on pin 4 (VS).

It monitors the C-E voltage on the high side output transistors and outputs a supply voltage control signal which corresponds to the input voltage at pin 4 (VS). This signal is used to control the motor supply voltage.

Motor direction control (pin 2)

Forward: < 0.9 V
Stop: $1.3 \sim 3.0$ V
Reverse: > 3.5 V

In the stop state, all output transistors (high and low sides) are off, putting the outputs in a high impedance state.

Output transistor saturation prevention

This circuit monitors the output voltage and confines the transistor output so that it does not reach saturation.

Operating the transistors in the linear portion of their characteristic curves provides good control from low currents to high currents. This results in good torque characteristics even during adverse conditions such as overload. See Figures 17 and 18.

Figure 17 Transistor high level output voltage

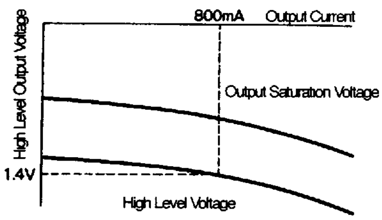
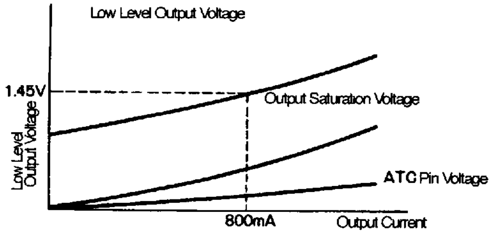


Figure 18 Transistor low level output voltage



Precautions for use

Thermal shutdown (TSD)

The BA6440FP has an internal thermal shutdown circuit (TSD) for the protection of the IC. The thermal shutdown trips if the junction temperature exceeds 175°C (typical). There is about a 20°C difference (typical) between the temperatures at which the TSD trips and resets.

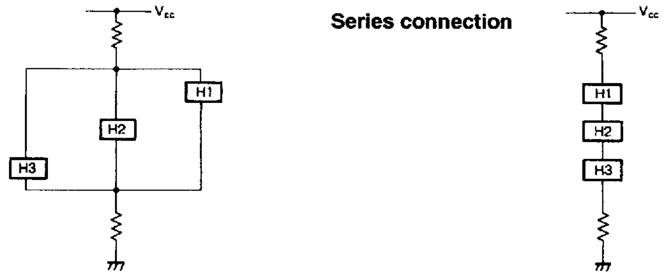
When the TSD trips, the outputs at pins 5, 6, and 9 are set to the open state. This protects the IC against overheating caused by high output current, or shorting the outputs. It does not, however, protect against overheating due to high internal IC currents caused by external factors (for example, pin-to-pin short circuited).

Note: The cooling fins must always be connected to ground.

Hall-effect element inputs

The internal circuit used for the Hall-effect element inputs is shown in Figure 7. The Hall elements can be connected using either a series or parallel connection as shown in Figure 19. The signals applied to the Hall inputs must not be allowed to exceed the Hall element input voltage of 1.5 V ~ (V_{CC} – 1.5 V).

Figure 19 Hall effect element electrical connections



FG amplifier

Unpredictable outputs can occur if inputs applied to the FG amp are allowed to exceed the specified input range (See Electrical characteristics table).

Electrical characteristic curves

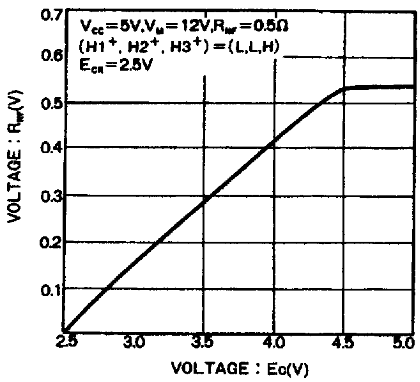


Figure 20

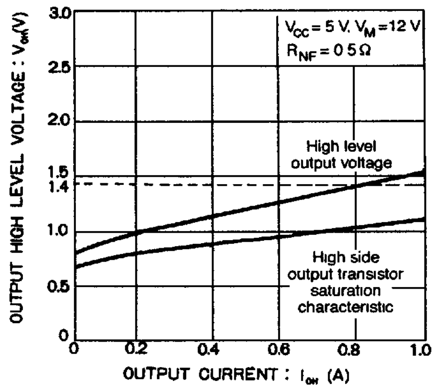


Figure 21

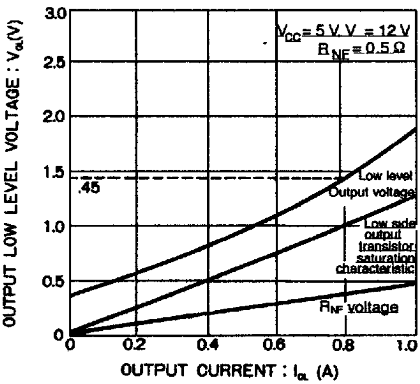


Figure 22

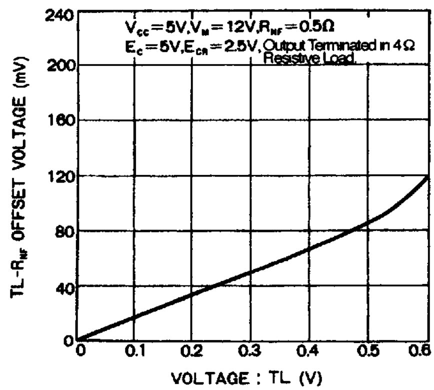


Figure 23

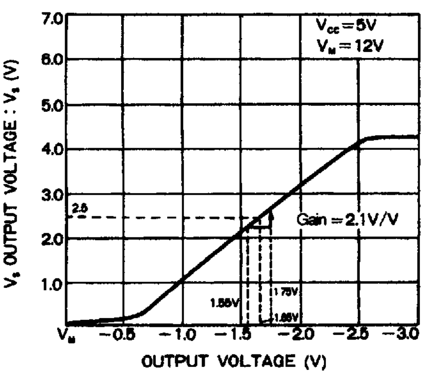


Figure 24

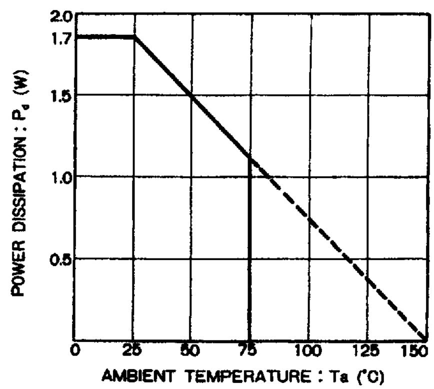


Figure 25