

3-phase motor driver

BA6860FS/BA6862FS

The BA6860FS and BA6862FS are 3-phase, full-wave, pseudo-linear motor drivers suited for driving movie camera capstan motors that can be operated at low voltages. The ICs have a torque ripple cancellation circuit to reduce wow and flutter. The drive mode can be switched to either current or voltage-drive with the mode switching pin. A motor power supply control pin is also built in.

●Applications

Capstan motors of video and movie cameras

●Features

- 1) 3-phase, full-wave, pseudo-linear drive system.
- 2) Torque ripple cancellation circuit.
- 3) Output transistor saturation prevention circuit.
- 4) Motor power supply control pin.
- 5) Power saving circuit.
- 6) Current/voltage drive mode switching pin.
- 7) Built-in amplifiers.

●Absolute maximum ratings (Ta=25°C)

| Parameter | Symbol | Limits | Unit |
|--------------------------|--------------------|-----------|------|
| Power supply voltage | V _{CC} | 7 | V |
| Power supply voltage | V _M | 12 | V |
| Power dissipation | P _d | 1000*1 | mW |
| Operating temperature | T _{opr} | -10 ~ 75 | °C |
| Storage temperature | T _{stg} | -40 ~ 150 | °C |
| Allowable output current | I _{OMax.} | 1*2 | A |

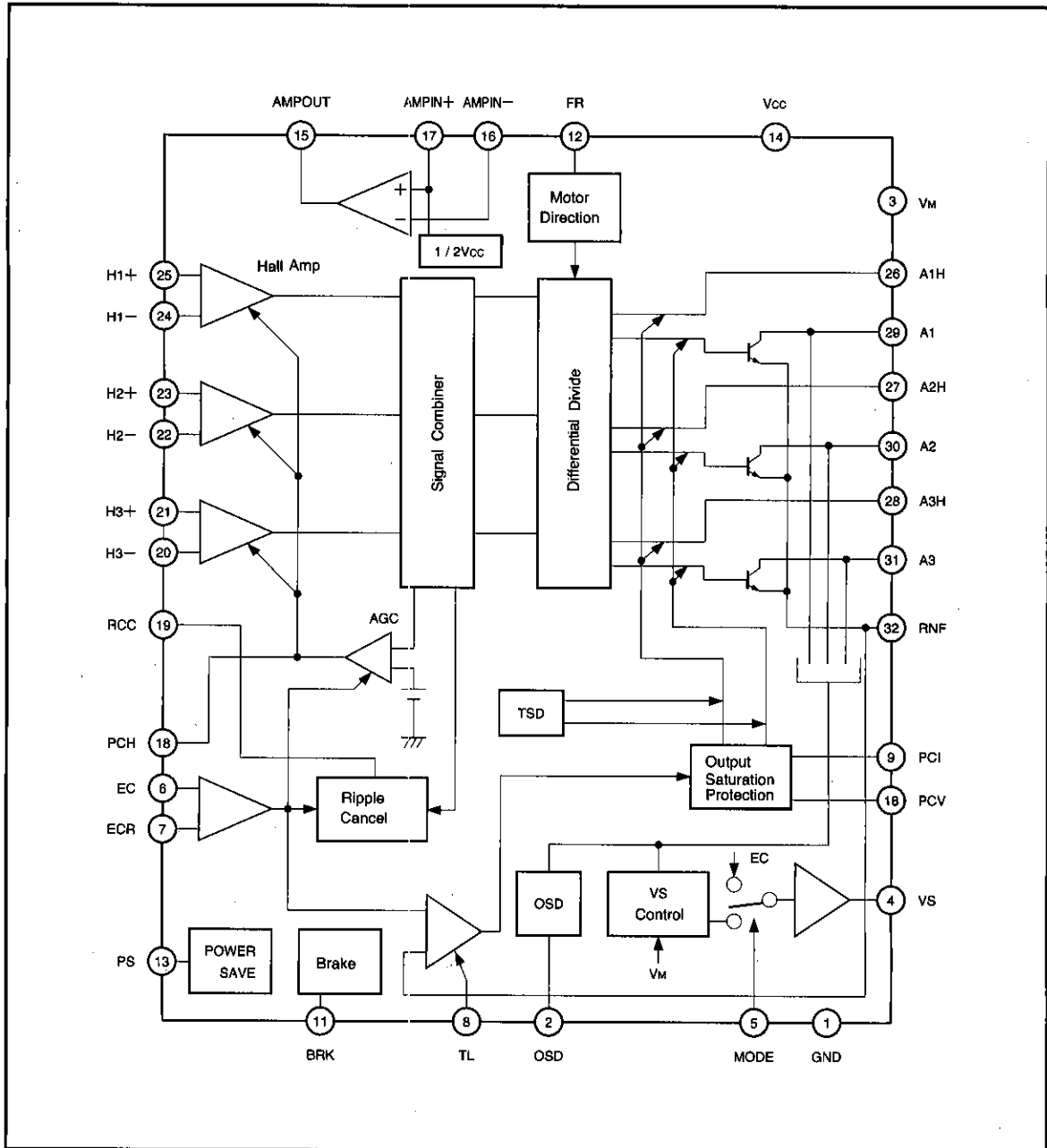
*1 Mounted on a glass epoxy PCB (70 X 70 X 1.6 mm).
Reduce power by 8 mW for each degree above 25°C.

*2 Should not exceed P_d- or ASO-value.

●Recommended operating conditions (Ta=25°C)

| Parameter | Symbol | Range | Unit |
|----------------------|-----------------|------------|------|
| Power supply voltage | V _{CC} | 3.0 ~ 6.0 | V |
| | V _M | 3.0 ~ 10.0 | V |

●Block diagram

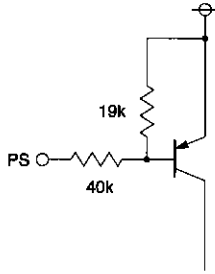


● Pin descriptions

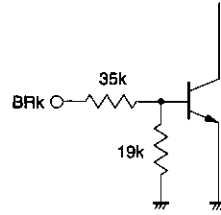
| Pin No. | Pin name | Function |
|---------|---------------------|---|
| 1 | GND | Signal ground pin |
| 2 | OSD | Output short-circuit detection |
| 3 | V _M | Motor power supply |
| 4 | VS | Motor power supply control |
| 5 | MODE | Current/voltage drive mode switching |
| 6 | EC | Torque control input |
| 7 | ECR | Torque control reference input |
| 8 | TL | Torque limit |
| 9 | PCI | Phase compensation for the low-side output saturation prevention circuit |
| 10 | PCV | Phase compensation for the high-side output saturation prevention circuit |
| 11 | BRK | Brake input; brake mode when HIGH, run mode when LOW |
| 12 | FR | Motor direction control input |
| 13 | PS | Power save input; standby when HIGH, run mode when LOW |
| 14 | V _{CC} | Signal power supply |
| 15 | AMP OUT | Amplifier output |
| 16 | AMP IN ⁻ | Amplifier input (-) |
| 17 | AMP IN ⁺ | Amplifier input (+) |
| 18 | PCH | Hall amplifier AGC phase compensation |
| 19 | RCC | Resistor connection pin for changing the ripple cancellation ratio |
| 20 | H3 ⁻ | Hall signal input |
| 21 | H3 ⁺ | Hall signal input |
| 22 | H2 ⁻ | Hall signal input |
| 23 | H2 ⁺ | Hall signal input |
| 24 | H1 ⁻ | Hall signal input |
| 25 | H1 ⁺ | Hall signal input |
| 26 | A1H | Motor output (pre-drive) |
| 27 | A2H | Motor output (pre-drive) |
| 28 | A3H | Motor output (pre-drive) |
| 29 | A1 | Motor output |
| 30 | A2 | Motor output |
| 31 | A3 | Motor output |
| 32 | RNF | Motor ground pin; connect a current-sensing resistor (0.68 Ω recommended) |

● Input/output circuit

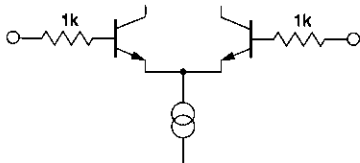
(1) Power save (PS : 13 pin)



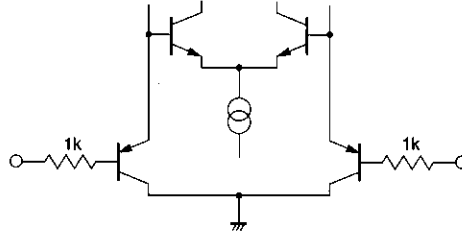
(2) Brake (BRK : 11 pin)



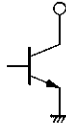
(3) Hall input
(H1⁺, H1⁻, H2⁺, H2⁻ : 25-22 pin)



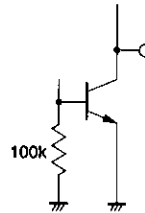
(4) Hall input (H3⁺, 21 pin ; H3⁻, 20 pin)



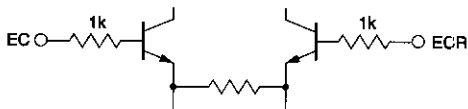
(5) Motor output (A1H, A2H, A3H : 26-28 pin)
Pre-drive



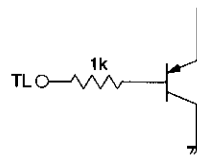
(6) Motor output (A1, A2, A3 : 29-31 pin)



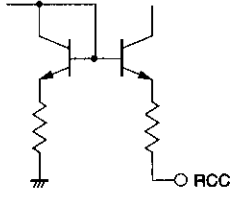
(7) Torque control (EC, 6 pin; ECR, 7 pin)



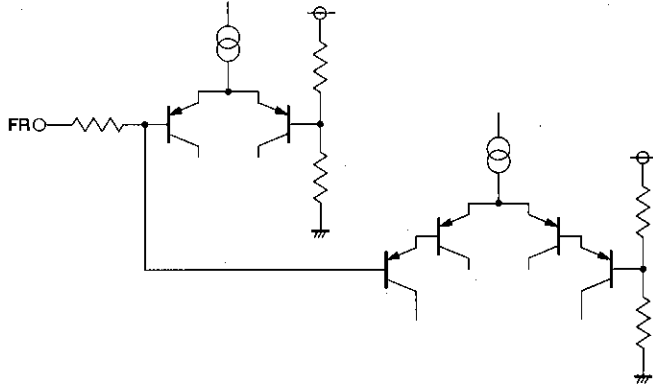
(8) Torque limit (TL : 8 pin)



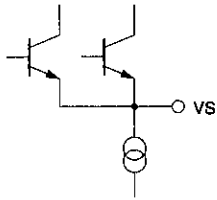
(9) Torque ripple (RCC : 19 pin)



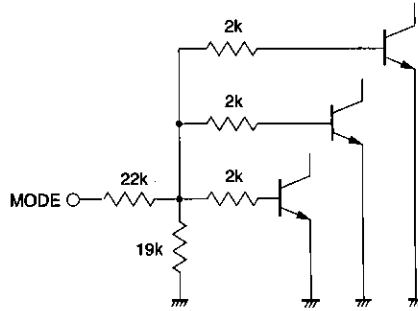
(10) Motor direction (FR : 12 pin)



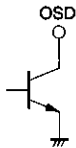
(11) VS (VS : 4 pin)



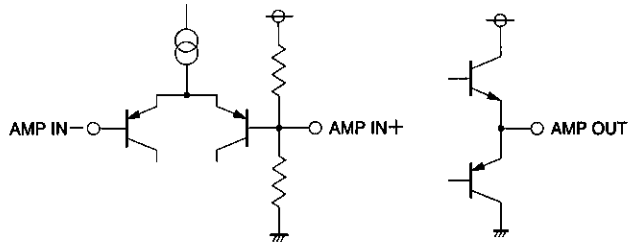
(12) Mode (MODE : 5 pin)



(13) OSD (OSD : 2 pin)



(14) Amplifiers (AMP IN- : 16 pin; AMP IN+ : 17 pin; AMP OUT : 15 pin)



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

Fig.1

Three-Phase Full-Wave Motor Drivers for Capstan Motors

Motor Drivers for VCRs

●Electrical characteristics (unless otherwise noted, Ta=25°C, Vcc=5V, Vm=5V)

| Parameter | Symbol | Min. | Typ. | Max. | Unit | Conditions |
|-------------------------------|--------------------|------|------|------|------|---|
| 〈Total device〉 | | | | | | |
| Circuit current 1 | Icc1 | — | 0 | 0.2 | mA | Power save ON |
| Circuit current 2 | Icc2 | — | 7 | 10 | mA | Power save OFF |
| 〈BA6860FS torque control〉 | | | | | | |
| Torque control I/O gain | G _{io} | 0.29 | 0.39 | 0.49 | A/V | E _{CR} =1.0V, E _C =1.2V, 1.4V |
| Torque control voltage | E _C | 1.0 | — | 4.5 | V | |
| Torque control voltage offset | E _{COFS} | −100 | — | +100 | mV | |
| TL-RNF voltage offset | V _{TLOFS} | 20 | 55 | 90 | mV | V _{TL} =0.2V |
| Ripple cancellation ratio | V _{RCC} | 10 | 15 | 20 | % | E _C =1.2V, R _{CC} =12kΩ |
| 〈BA6862FS torque control〉 | | | | | | |
| Torque control I/O gain | G _{io} | 0.29 | 0.39 | 0.49 | A/V | E _{CR} =1.2V, E _C =1.5V, 1.7V |
| Torque control voltage | E _C | 1.2 | — | 4.5 | V | |
| Torque control voltage offset | E _{COFS} | −150 | — | +150 | mV | |
| TL-RNF voltage offset | V _{TLOFS} | 20 | 55 | 90 | mV | V _{TL} =0.2V |
| Ripple cancellation ratio | V _{RCC} | 10 | 15 | 20 | % | E _C =1.5V, R _{CC} =12kΩ |
| 〈Power save〉 | | | | | | |
| ON voltage | V _{PSON} | 4 | — | — | V | |
| OFF voltage | V _{PSOFF} | — | — | 3 | V | |
| 〈Hall amplifier〉 | | | | | | |
| H1 common-mode input voltage | V _{CM1} | 1.0 | — | 4.5 | V | FR=GND, V _{CC} |
| H2 common-mode input voltage | V _{CM2} | 1.0 | — | 4.5 | V | FR=GND, V _{CC} |
| H3 common-mode input voltage | V _{CM3} | 0.4 | — | 3.8 | V | FR=GND, V _{CC} |
| Hall input offset voltage | V _{HOFs} | −15 | — | +15 | mV | FR=GND, V _{CC} |
| 〈Output〉 | | | | | | |
| Pre-drive output current | I _{OPRE} | 14 | 23 | — | mA | |
| Low-side saturation voltage | V _{SAT} | — | 0.65 | 1.0 | V | I _{OUT} =400mA |
| 〈Motor direction〉 | | | | | | |
| Forward mode voltage | V _{DF} | — | — | 0.8 | V | |
| Stop mode voltage | V _{DS} | 1.2 | — | 2.3 | V | |
| Reverse mode voltage | V _{DR} | 2.7 | — | — | V | |
| 〈Brake〉 | | | | | | |
| ON voltage | V _{BRON} | 2 | — | — | V | |
| OFF voltage | V _{BROFF} | — | — | 1 | V | |
| 〈Mode switching〉 | | | | | | |
| Current-drive ON voltage | V _{IDON} | — | — | 1 | V | |
| Voltage-drive ON voltage | V _{VDON} | 2 | — | — | V | |
| 〈O S D〉 | | | | | | |
| Output voltage | V _{O S D} | — | 0.12 | 0.18 | V | I _{O S D} =3mA |

| Parameter | Symbol | Min. | Typ. | Max. | Unit | Conditions |
|--------------------------------------|--------------------|------|------|------|------|--|
| <VS> | | | | | | |
| Voltage gain | G _{VS} | 4.5 | 5.0 | 5.5 | Mult | |
| HIGH level output voltage 1 | V _{OHVS1} | 3.50 | 4.20 | — | V | MODE=GND, I _{oVS} =-3mA |
| LOW level output voltage 1 | V _{OLVS1} | — | 0.28 | 0.42 | V | MODE=GND, I _{oVS} =50 μA |
| HIGH level output voltage 2 | V _{OHVS2} | 3.50 | 4.20 | — | V | MODE=V _{CC} , I _{oVS} =-3mA |
| LOW level output voltage 2 | V _{OLVS2} | — | 0.08 | 0.12 | V | MODE=V _{CC} , I _{oVS} =50 μA |
| <Operational amplifier> | | | | | | |
| Input offset voltage | V _{IO} | -8 | — | 8 | mV | |
| DC bias voltage | V _{BIAS} | 2.4 | 2.5 | 2.6 | V | |
| Voltage gain 1 | AV1 | 65 | 75 | — | dB | f= 500Hz |
| Voltage gain 2 | AV2 | 30 | 35 | — | dB | f= 50kHz |
| Common-mode input voltage | V _{ICM} | 0.5 | — | 4.0 | V | |
| High-side output voltage | V _{OH} | 3.7 | 4.1 | — | V | I _{oH} =-3mA |
| Low-side output voltage | V _{OL} | — | 0.9 | 1.3 | V | I _{oL} =3mA |

* Current flows out from Ics is negative, and current flows into is positive.

● Circuit operation

(1) Hall I/O

The 3-phase Hall signal is amplified in the hall amplifiers and sent to the matrix section, where the signal is further amplified and combined. After the signal is converted to a current in the amplitude control circuit, the current is supplied to the output driver, which then provides a motor drive current. The phases of the Hall input signal, output voltage, and output current are shown in Fig. 2.

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. This process is called torque ripple cancellation

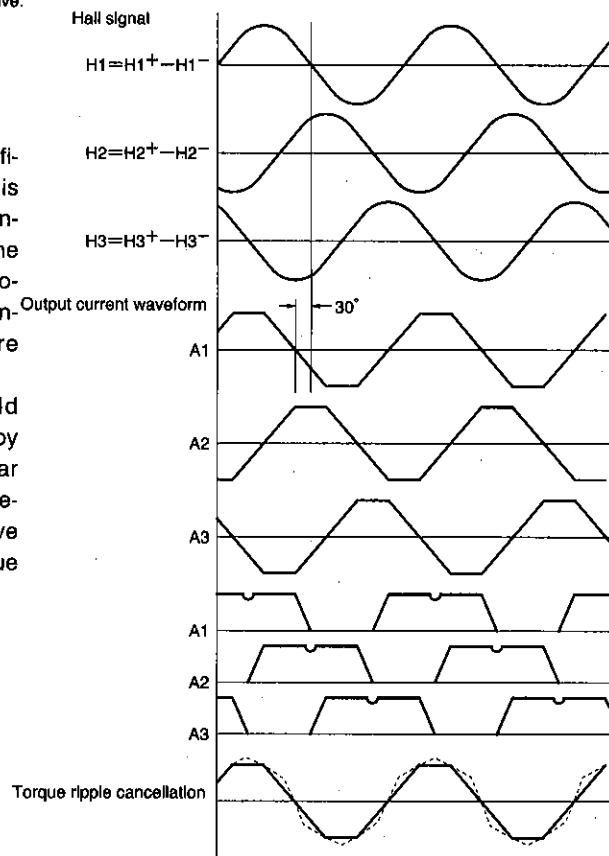


Fig.2 Waveform diagram for the forward mode

● Circuit operation

(2) Torque control pin

The output current can be controlled by adjusting the voltage applied to the torque control pin (EC pin).

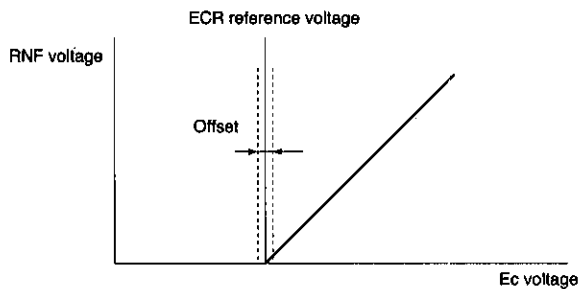


Fig.3

The pins are the inputs to a differential amplifier. A reference voltage of 1.0V (recommended value for BA6860FS) or 1.2V (recommended value for BA6862FS) is applied to pin 7. The offset voltage range is between -100mV and $+100\text{mV}$ for the BA6860FS and between -150mV and $+150\text{mV}$ for the BA6862FS.

(3) Brake

A brake is applied to the motor when the brake pin (pin 11) is put to HIGH. The brake mode is activated when the brake pin voltage is 2.0V or more and deactivated when the voltage is 1.0V or less.

(4) Output current sensing and torque limitation

The RNF pin (pin 32) is the ground pin for the output stage. To sense the output current, a resistor (0.68Ω recommended) is connected between the RNF pin 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 8. The current is limited when pin 8 reaches the same potential as pin 32. The output current (I_{MAX}) under this condition is given by :

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

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

(5) Motor power supply control

Nearly all the power dissipated by the IC is dissipated between the collectors and emitters of the output transistors. More power is consumed as the C-E 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. Because the voltage across the motor decreases with decreasing drive current, the C-E voltage must increase if the supply voltage is fixed.

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 excessive voltage is applied between the transistor collectors and emitters.

The power supply control circuit (VS ; 4 pin) serves for this purpose. The circuit senses the C-E voltage of the high-side output transistor, and outputs a signal from the VS pin to control the motor power supply.

(6) Motor direction control (FR pin)

The motor mode is :

Forward when the FR-pin voltage is less than 0.8V,
Stop when the voltage is between 1.2~2.3V,
Reverse when the voltage is above 2.7V.

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

(7) 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 overloading.

(8) Ripple cancellation circuit

The cancellation ratio of the torque ripple cancellation circuit (Fig. 2) can be adjusted by an external resistor connected to pin 19. Select a suitable value by taking wow and flutter into consideration.

The ripple cancellation ratio can be obtained in the following manner. With $E_c = 1.2\text{V}$ for the BA6860FS or $E_c = 1.5\text{V}$ for the BA6862FS, 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 :

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

(9) Output short-circuit detection

This circuit detects and alarms when outputs A1, A2, or A3 is short-circuited to the GND or V_M pin. Normally, a pulse with a duty ratio of 50% is output from the circuit.

(10) Current/voltage drive mode switching

This circuit turns ON the current-drive mode when the MODE pin is 1.0V or less, and turns ON the voltage-drive mode when the MODE pin is 2.0V or more.

* Note that high- and low-side power transistors are both turned on and a large current flows in the IC when a brake is applied during the voltage-drive mode.

● Application example

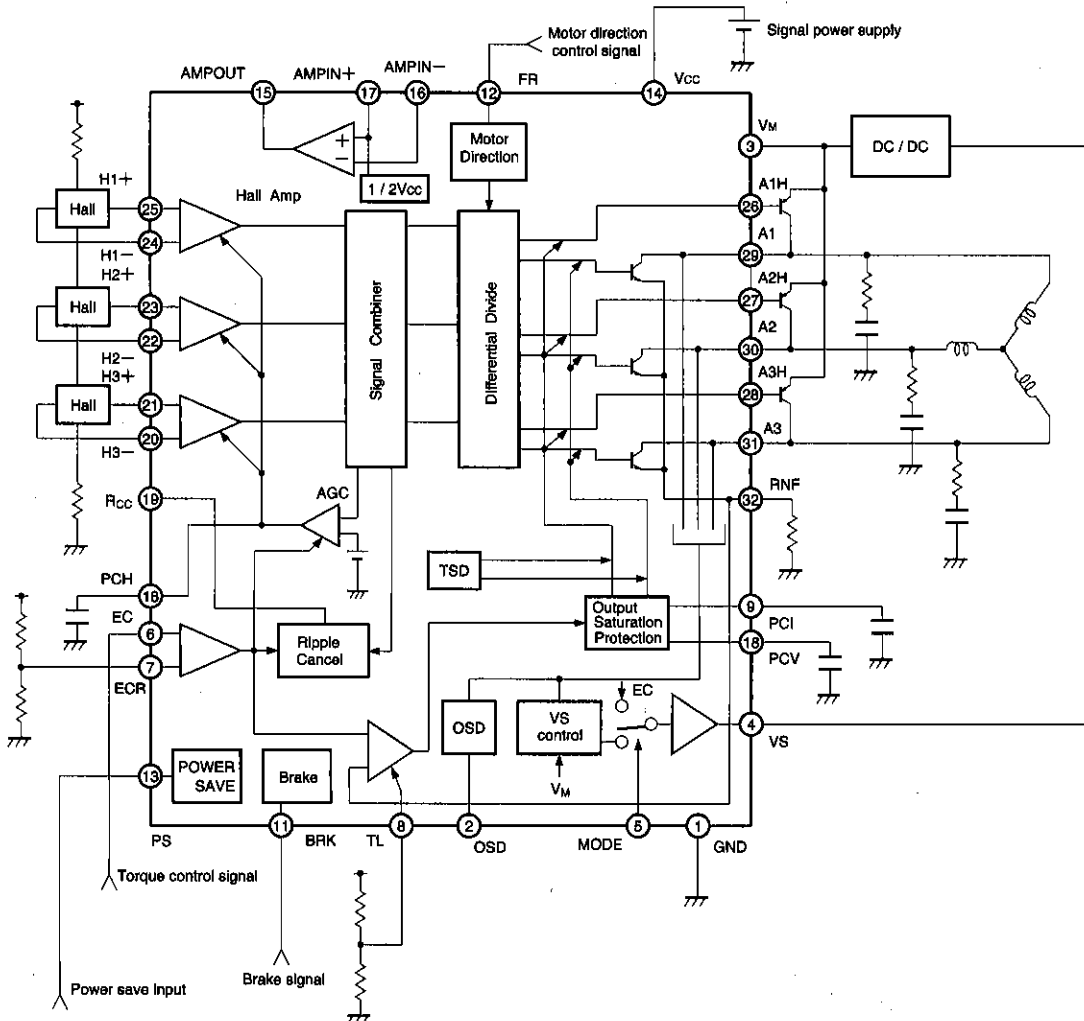


Fig.4

Three-Phase Full-Wave Motor Drivers for Capstan Motors

Motor Drivers for VCRs

●Operation notes

(1) Thermal shutdown circuit

The BA6860FS and BA6862FS has a built-in thermal shutdown circuit to protect the ICs. The circuit is activated at the temperature of 175°C (typical) with a hysteresis width of 20°C (typical).

When the circuit is activated at an elevated chip temperature, the output pins (pins 29, 30, and 31) 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) Hall input

The Hall input circuits are shown in (3) and (4) of input circuits." Hall devices can be connected in either series or parallel. Make sure that the Hall device input voltage stays within 1.0~4.5V for H1 and H2, and 0.4~3.8V for H3.

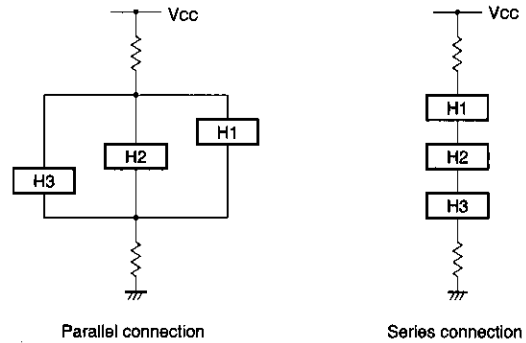


Fig.5

(3) Amplifier

Unpredictable outputs may occur when the amplifier input is outside the recommended range.

●Electrical characteristic curves

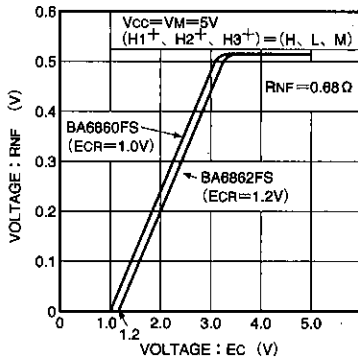


Fig.6 RNF voltage vs. Ec voltage

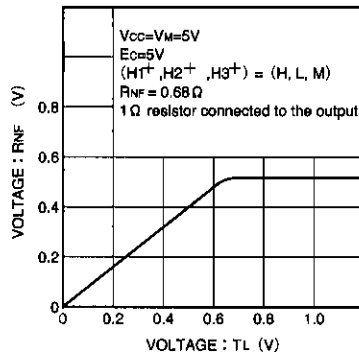


Fig.7 RNF voltage vs. TL voltage

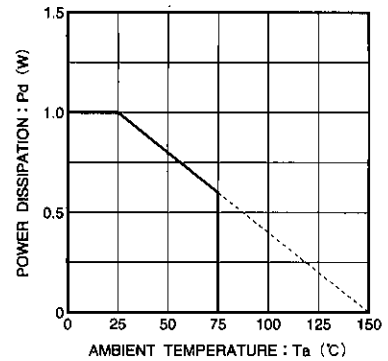


Fig.8 Power dissipation curve

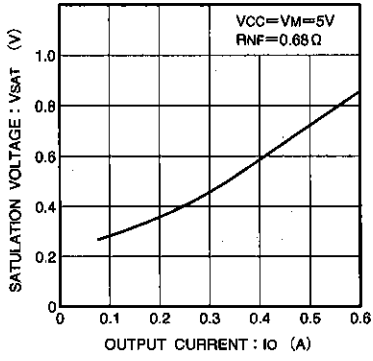


Fig.9 Low-side output saturation voltage vs. output current

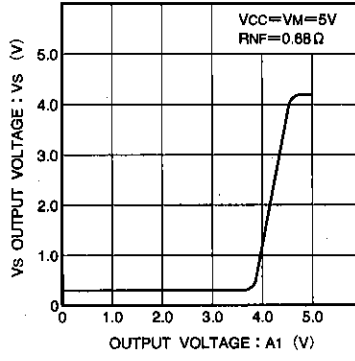
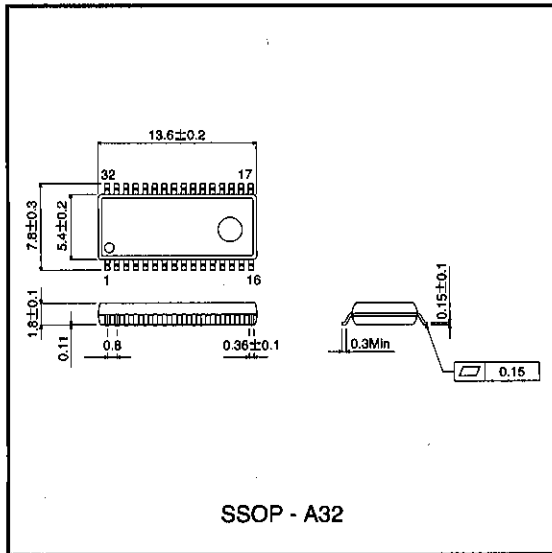


Fig.10 Vs output voltage vs. A1 output voltage

● External dimensions (Units: mm)



Three-Phase Full-Wave Motor Drivers for Capstan Motors

Motor Drivers for VCRs

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