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# HA13563, HA13563V

Three-Phase Brushless Motor Driver

HITACHI

ADE-207-218A (Z)
2nd Edition
December 1998

## Description

The HA13563/V are 3-phase brushless motor driver ICs with digital speed control. It is designed for use as a PPC or LBP drum motor driver and provides the functions and features listed below.

## Functions

- Three-phase brushless motor driver
- Direct PWM drive
- Digital discriminator plus PLL speed control
- Speed monitor
- Stuck rotor protection
- Current limiter
- Thermal protection (OTSD)
- Low voltage inhibit (LVI)

## Features

- Low saturation voltage
- Fly wheel diodes built-in
- FG signal digital filter built-in

## Ordering Information

| Product No. | Package |
|---|---|
| HA13563 | SP-23TA |
| HA13563V | SP-23TB |

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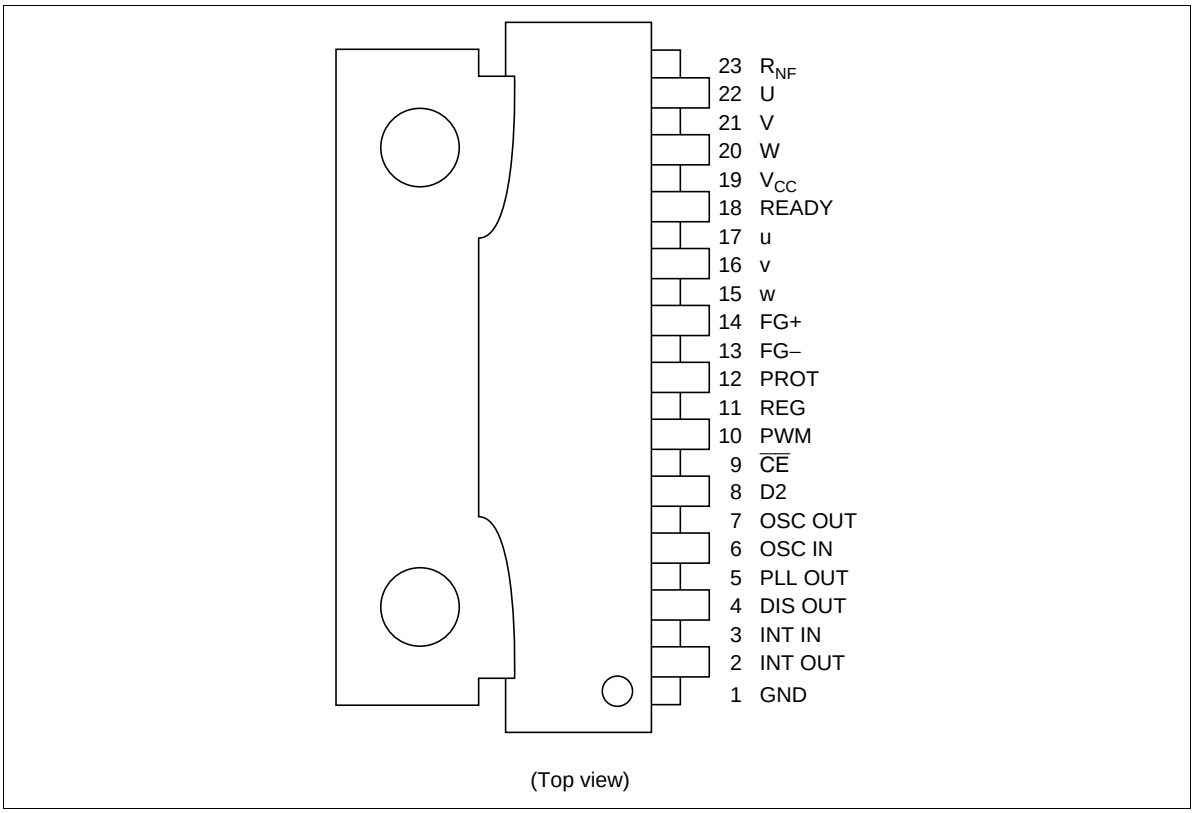
Hitachi semiconductor

## Pin Arrangement

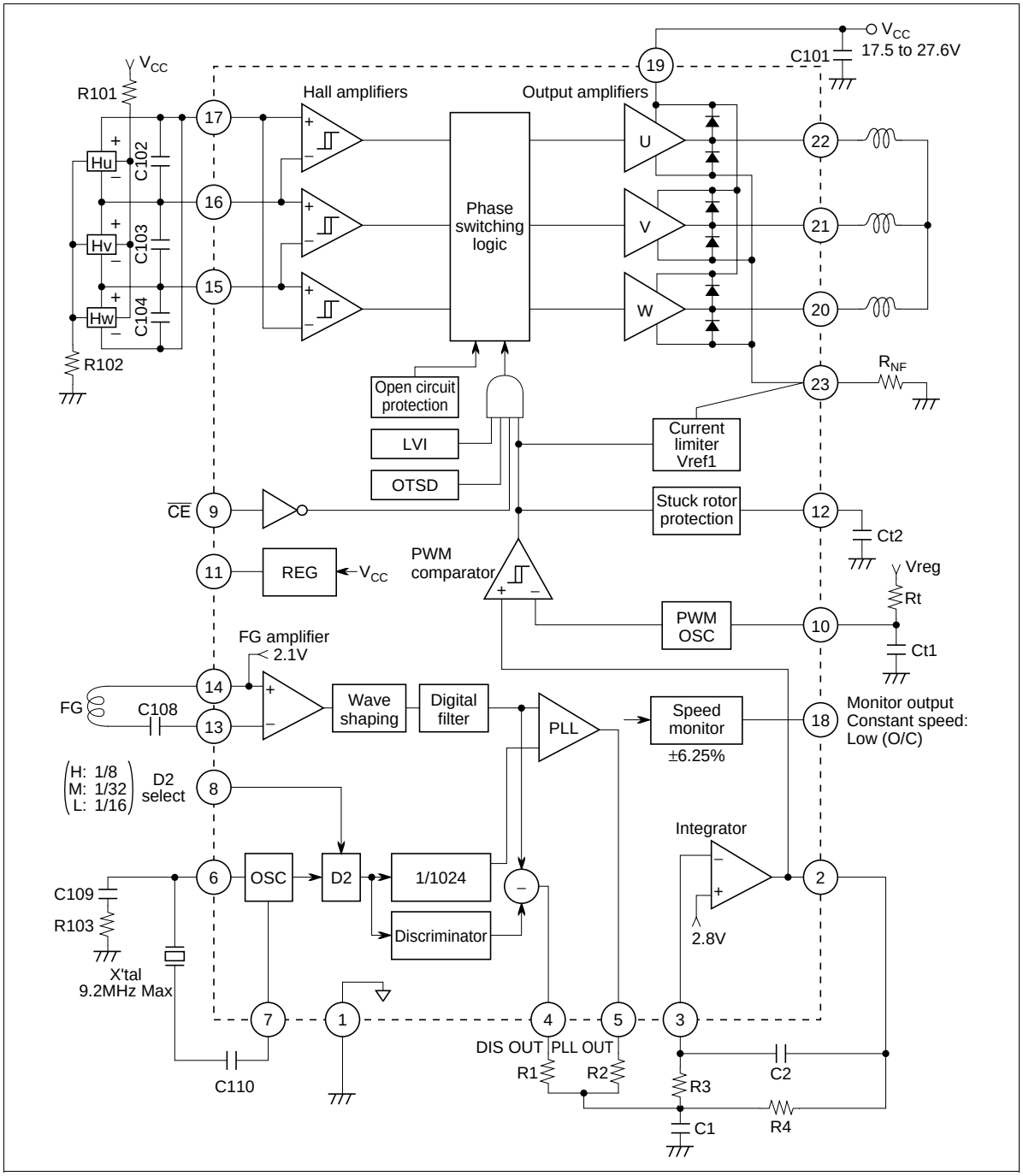



(Top view)

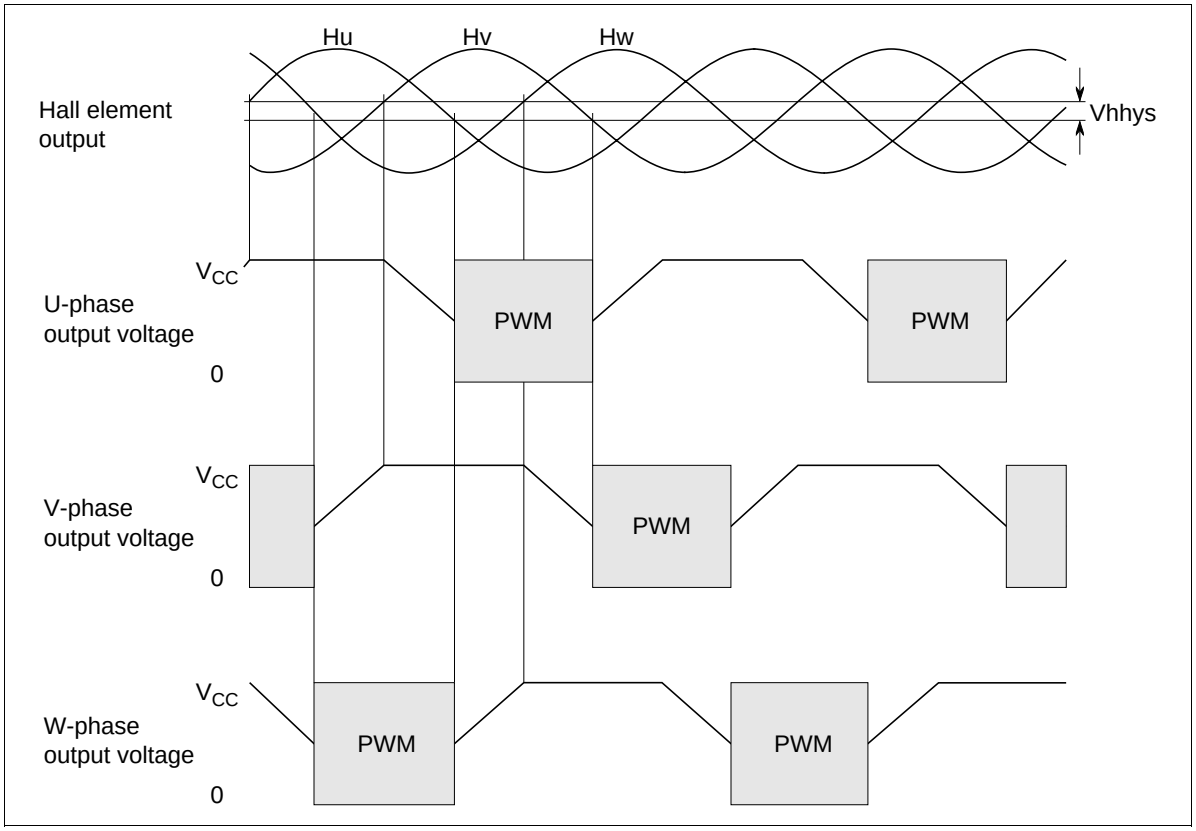
## Pin Functions

| Pin No. | Pin Name | Function |
|---|---|---|
| 1 | GND | Ground |
| 2 | INT OUT | Integrator output |
| 3 | INT IN | Integrator input |
| 4 | DIS OUT | Speed discriminator output |
| 5 | PLL OUT | PLL output |
| 6 | OSC IN | Clock oscillator input. Apply the external clock signal to this pin. |
| 7 | OSC OUT | Clock oscillator output. Use this pin to monitor the oscillator waveform. |
| 8 | D2 | Clock divider selector input<br>High: 1/8, Middle or Open: 1/32, and Low: 1/16. |
| 9 | $\overline{CE}$ | Chip enable input<br>High or Open: stop, Low: drive on. |
| 10 | PWM | PWM carrier oscillator. An external capacitor to charge and discharge, and an external resistor must be provided. |
| 11 | REG | 5 V fixed voltage output. Always output regardless of the state of the $\overline{CE}$ input. |
| 12 | PROT | An external capacitor sets the time until the stuck rotor protection circuit operates. If this pin is shorted to ground, the protection circuit will not operate. After the stuck rotor protection circuit operates, the IC can be reset by turning the power off and then on again, or switching $\overline{CE}$ from low to high. |
| 13 | FG– | FG amplifier – input. |
| 14 | FG+ | FG amplifier + input. This pin is used for temperature monitoring. See the reference data. |
| 15 | w | The w+ and v– Hall amplifier input |
| 16 | v | The v+, u– Hall amplifier input |
| 17 | u | The u+, w– Hall amplifier input |
| 18 | READY | Speed monitor output. Outputs a low level during fixed speed drive. This is an open collector output. |
| 19 | $V_{CC}$ | Power supply |
| 20 | W | W-phase output |
| 21 | V | V-phase output |
| 22 | U | U-phase output |
| 23 | $R_{NF}$ | Current detector. Connect a current detection resistor to this pin. |

## Block Diagram



## Timing Chart



## External Components

| Part No. | Recommended Value | Purpose | Note |
|---|---|---|---|
| R1 to R4 | — | Integration constant | 1 |
| R101, R102 | — | Hall element bias | 2 |
| R103 | 1 kΩ | Clock oscillator stabilization | 9 |
| $R_{NF}$ | — | Current detection | 3 |
| Rt | — | PWM carrier oscillator time constant | 6 |
| C1, C2 | — | Integration constant | 1 |
| C101 | ≥ 0.1 µF | Power supply bypass | 4 |
| C102, C103, C104 | 0.047 µF | Stabilization | 4 |
| C108 | — | FG coupling | 5 |
| C109 | 0.047 µF | Clock oscillator stabilization | 9 |
| C110 | 10 pF | Crystal coupling | 9 |
| Ct1 | 1000 pF | PWM carrier oscillator time constant | 6 |
| Ct2 | — | Stuck rotor protection circuit time constant | 7 |
| X'tal | — | Reference oscillator | 8 |

Notes: 1. Determine the component values using the following as a guidline:
First determine the angular frequency of $\omega_P$ for DIS OUT and PLL OUT.

$$\omega_P = 2\pi \cdot ffg \text{ [rad/sec]} \quad (1)$$

Determine the the angular frequency of $\omega_P$ for motor.

$$\omega_M \approx \frac{9.55}{N_O} \cdot \frac{1}{J}\left(K_T \cdot \frac{Vref1}{R_{NF}} - T_L\right) \text{ [rad/sec]} \quad (2)$$

Determine the $\omega_O$.

$$\omega_O = \sqrt{\omega_P \cdot \omega_M} \text{ [rad/sec]} \quad (3)$$

Determine the integrator's DC gain $G_{(E)}$.

$$G_{(E)} = \frac{J \cdot \omega_O}{9.55 \cdot K_T \cdot A} \cdot \frac{1}{\frac{Z}{60} \cdot 2\pi \cdot \frac{K\phi}{\omega_O}} \quad (4)$$

where, $k\phi$ : PLL gain = 0.4 (V/rad/sec)

$$A = \frac{2\,V_{CC} - 0.83 \cdot V_E - Vsat}{Rm \cdot Vosc}$$

Z : FG pulse per round (P/R)
$N_O$ : Motor speed ($min^{-1}$)
$\omega_O$ : Control loop angular frequency (rad/sec)
ffg : FG frequency (Hz)
J : Moment of inertia of the motor (kg $m^2$)
Rm : Motor coil resistance (Ω/T–T)

$K_T$ : Torque constant (N•m/A)
$T_L$ : Rated load torque (N•m)
$V_{OSC}$ : PWM carrier oscillator amplitude ($V_{PP}$, See the Electrical Charasteristics)
$V_E$ : Motor back EMF ($V_{PP}$/T–T)
$R_{NF}$ : Current detection resistor (Ω)
Vref1 : Current limiter reference voltage (See the Electrical Charasteristics)
Vsat : Saturation voltage (See the Electrical Charasteristics)

Set C2 and derive the integration constants from the following formulas.

$$R4 = \frac{1}{\omega_P \cdot C2} \quad (5)$$

$$R2 = \frac{R4}{G_{(E)}} \quad (6)$$

$$C1 = \frac{1}{2 \cdot R2 \cdot \omega_O} \quad (7)$$

$$R3 = R2 \quad (8)$$

Next, determine R1 to match the phase of PLL output.

$$R1 = \frac{1.89 \cdot R4}{1.6 - 0.33 \cdot R4 / R2} \quad (9)$$

When log $\omega_P/\omega_M$ is greater than 2, a phase advance to compensate for this phenomenon is required. Use the following formula to set the phase advance:

$$\frac{1}{C4 \cdot R5} < \frac{\omega_P}{20 \cdot 2} \quad (10)$$

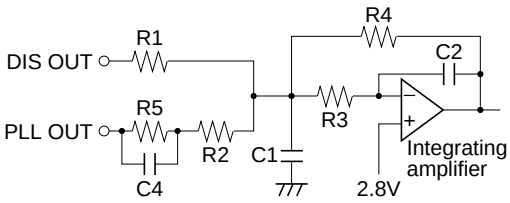



**Figure 1 Integration Constants**

2. The Hall output bias voltage is determined by R101 and R102.
3. The output current is controlled according to the following formula:

$$Iomax = \frac{Vref1}{R_{NF}}$$

Where, Vref1 is the current limiter reference voltage. (See the Electrical Charasteristics)
Mount this resistor as close as possible to the IC and use a resistor with a small inductance component.

4. Connect these components as close to the IC as possible.

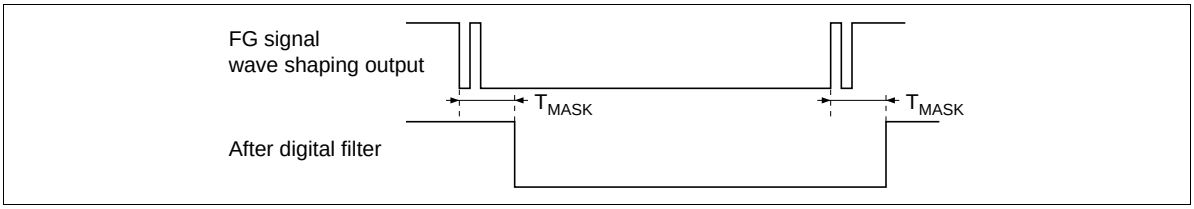
5. Determine the component value using the following formula as a guideline:

$$C108\ (\mu F) = \frac{220}{ffg\ (Hz)}$$

Digital filter time $T_{MASK}$ of FG signal is determined as follows.

$$T_{MASK}\ (sec) = \frac{1}{CLK \times D2} \sim \frac{2}{CLK \times D2}$$

where, CLK : The reference frequency.
D2 : CLK frequency dividing ratio.




6. The PWM carrier frequency is determined roughly by the following formula:

$$f_{PWM} = \frac{1180}{Rt\ (k\Omega)\ Ct1\ (pF)} \times 10^3$$

7. The formula shown below roughly determines the time, Tprot (s), until the stuck rotor protection circuit operates. Figure 2 shows the operating waveforms. The latched state can be cleared by either $\overline{CE}$ or $V_{CC}$. Note that a capacitor with a leakage current sufficiently smaller than the charging current Ict+ must be used.

Tprot = 0.24 Ct2 (μF)

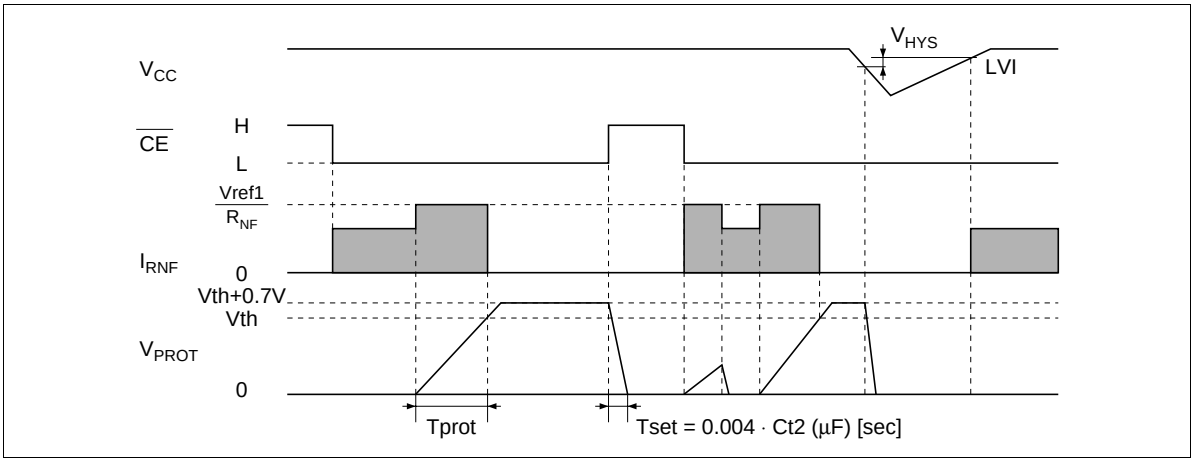



**Figure 2 Stuck Rotor Protection Operating Waveforms**

8. The reference frequency CLK (Hz) and the FG frequency ffg (Hz) are related by the following formula:

$$CLK = \frac{1024\ ffg}{D2}$$

Also note that the value of the resistor (Rosc) inserted between the external clock and pin 6 when an external clock is used can be calculated from the following formulas:

$Rosc \geq 2 (V_{IH} - 2.1) - 1.5$ (kΩ)

$Rosc \leq 6 (2.1 - V_{IL}) - 1.5$ (kΩ)

where, $V_{IH}$ : The clock driver high-level voltage.

$V_{IL}$ : The clock driver low-level voltage.

If an external clock signal is input to pin 6 through a capacitor (Cosc), we recommend using a 10 pF capacitor for Cosc.

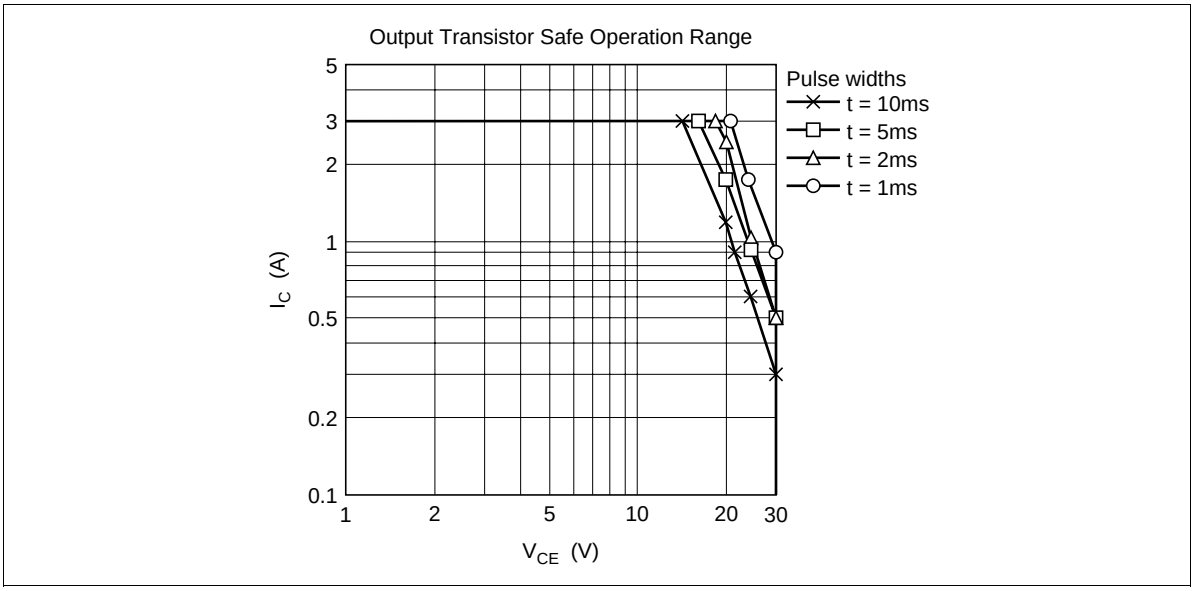
9. The relationship with CLK crystal oscillator frequency refer to the following.

| Oscillator | fc | C110 | C109 | R103 |
|---|---|---|---|---|
| Crystal | 6.0 to 9.2 MHz | 10 pF | 0.047 µF | 1 kΩ |
| | 2.0 to 6.0 MHz | 10 pF | Uselessness | Uselessness |

## Absolute Maximum Ratings (Ta = 25°C)

| Item | Symbol | Rating | Unit | Note |
|---|---|---|---|---|
| Power supply voltage | $V_{CC}$ | 30 | V | 1 |
| Instantaneous output current | Iop | 3.0 | A | 2 |
| Steady-state output current | $I_O$ | 2.0 | A | 2 |
| Input voltage | Vi | –0.3 to 7 | V | 3 |
| Allowable power dissipation | $P_T$ | 10 | W | 4 |
| Junction temperature | Tj | 150 | °C | 1 |
| Storage temperature | Tstg | –55 to +125 | °C | |

Notes: 1. The operating ranges are as follows:
$V_{CC}$ = 17.5 to 27.6 V
Tjop = –20 to +125°C
2. See the safe operating range data.
3. Applies to the logic input pins.
4. The allowable value when theTAB temperature, Ttab, is 120°C. However, the thermal resistance is as follows:
$\theta j\text{-}c \leq 3°C/W$
$\theta j\text{-}a \leq 40°C/W$



## Electrical Characteristics (Ta = 25°C, $V_{CC}$ = 24 V)

| Item | | Symbol | Min | Typ | Max | Unit | Test Conditions | Applicable Pins |
|---|---|---|---|---|---|---|---|---|
| Current drain | Standby current | $I_{CCO}$ | — | 8 | 11 | mA | $\overline{CE}$ = H, $V_{CC}$ = 30 V | 19 |
| | Current drain with outputs off | $I_{CC}$ | — | 32 | 44 | mA | $\overline{CE}$ = L, Pin 3 = H, $V_{CC}$ = 30 V, output OFF | |
| Logic input 1 | Low-level voltage | Vil1 | — | — | 0.8 | V | | 9 |
| | High-level voltage | Vih1 | 2.0 | — | — | V | | |
| | Low-level current | Iil1 | — | –0.25 | –0.35 | mA | Vil = 0 V | |
| | High-level current | Iih1 | –0.1 | 0 | 0.1 | mA | Vih = 7 V | |
| Logic input 2 | Low-level voltage | Vil2 | — | — | 1.0 | V | | 8 |
| | Middle-level voltage | Vim | 2.0 | 2.5 | 3.0 | V | | |
| | High-level voltage | Vih2 | 4.0 | — | — | V | | |
| | Low-level current | Iil2 | — | –0.25 | –0.35 | mA | Vil = 0 V | |
| | Middle-level current | Iim | — | — | ±35 | µA | Vi = 2.5 V | |
| | High-level current | Iih2 | — | 0.5 | 0.7 | mA | Vih = 7 V | |
| Logic output | Low-level voltage | Vol1 | — | 0.2 | 0.4 | V | Iol = 2 mA | 18 |
| | Leakage current | Ioh1 | — | — | ±10 | µA | Voh = 30 V | |
| Hall amplifier | Commonmode input voltage range | Vh | 2.0 | — | $V_{CC}$–2 | V | | 15, 16, 17 |
| | Differentialmode input voltage range | Vd | 60 | — | $V_{CC}$/2 | mV | | |
| | Hysteresis *1 | Vhhys | — | 20 | — | mV | Rh = 400 Ω | |
| Output amplifier | Leakage current | Icer | — | — | ±100 | µA | Vce = 30 V | 20, 21, 22 |
| | Output drive current | $I_{B1}$ | — | 49 | 64 | mA | $I_O$ = 2 A | |
| | | $I_{B2}$ | — | 35 | 46 | mA | $I_O$ = 1 A | |
| | Saturation voltage *2 | Vsat1 | — | 1.8 | 2.7 | V | $I_O$ = 2 A | |
| | | Vsat2 | — | 1.35 | 1.7 | V | $I_O$ = 1 A | |
| | Impulse response time | tphl | — | — | 2 | µs | | |
| | | tplh | — | — | 2 | µs | | |
| | | tr | — | — | 0.5 | µs | | |
| | | tf | — | — | 0.5 | µs | | |
| | Current limiter reference voltage | Vref1 | 0.45 | 0.5 | 0.55 | V | | 23 |
| Flywheel diode | Forward voltage | $V_F$ | — | 1.15 | 1.4 | V | $I_F$ = 1 A | 19, 20, 21, 22 |
| | Substrate current | Isub | — | 6.5 | 10 | % | | |

## Electrical Characteristics (Ta = 25°C, $V_{CC}$ = 24 V) (cont)

| Item | | Symbol | Min | Typ | Max | Unit | Test Conditions | Applicable Pins |
|---|---|---|---|---|---|---|---|---|
| PWM oscillator and PWM comparator | Oscillator frequency range | $f_{PWM}$ | 2.0 | — | 30 | kHz | | 10 |
| | Oscillator frequency precision | ferr | 11.7 | 13 | 14.3 | kHz | Rt1 = 91 kΩ, Ct1 = 1000 pF | |
| | Oscillator high-level voltage | Vosch | 2.7 | 3.0 | 3.3 | V | | |
| | Oscillator low-level voltage | Voscl | 1.0 | 1.1 | 1.2 | V | | |
| | Oscillator amplitude | Vosc | 1.7 | 1.9 | 2.1 | $V_{PP}$ | Vosch – Voscl | |
| | Comparator hysteresis *1 | Vchys | — | 20 | — | mV | | 2 |
| Integrator | Input current | Iin | — | — | ±250 | nA | | 2, 3 |
| | High-level voltage | Voh2 | 3.2 | 3.5 | — | V | $I_O$ = –0.5 mA | |
| | Low-level voltage | Vol2 | — | 0.9 | 1.1 | V | $I_O$ = 0.5 mA | |
| | Voltage gain *1 | Gi | — | 60 | — | dB | | |
| | Gainbandwidth produc t *1 | Bi | — | 0.5 | — | MHz | | |
| | Reference voltage | Vp | 2.65 | 2.8 | 2.95 | V | | |
| FG amplifier and waveform shaping | Input sensitivity | vfg | 15 | — | 1000 | $mV_{PP}$ | | 13, 14 |
| | Noise margin | nd | — | — | 4.0 | $mV_{PP}$ | | |
| | | nc | — | — | 1.0 | $V_{PP}$ | | |
| PLL, DIS | Ouput high-level voltage | Voh3 | 4.3 | 4.5 | — | V | $I_O$ = –0.1 mA | 4, 5 |
| | Ouput low-level voltage | Vol3 | — | — | 0.25 | V | $I_O$ = 0.1 mA | |
| OSC | Oscillator frequency range | $f_{OSC}$ | 2 | — | 9.2 | MHz | | 6, 7 |
| | Oscillator frequency error *1 | $\Delta f_{OSC}$ | — | — | ±0.01 | % | X'tal | |
| Speed discriminator and monitor | Number of counts | N | — | 1023 | — | Count | | |
| | Operating frequency range | CLK | — | — | 1.15 | MHz | | |
| | Lock range | LR | — | ±6.25 | — | % | | 18 |

**Electrical Characteristics** (Ta = 25°C, $V_{CC}$ = 24 V) (cont)

| Item | | Symbol | Min | Typ | Max | Unit | Test Conditions | Applicable Pins |
|---|---|---|---|---|---|---|---|---|
| REG | Output voltage | Vreg | 4.65 | 5.0 | 5.35 | V | Ireg = 20 mA, $\overline{CE}$ = L | 11 |
| | Power supply regulation | ΔVreg1 | — | 20 | 100 | mV | $V_{CC}$ = 17.5 to 27.6 V, $\overline{CE}$ = L | |
| | Load regulation | ΔVreg2 | — | 10 | 100 | mV | Ireg = 0 to 20 mA, $\overline{CE}$ = L | |
| Stuck rotor protection circuit | Ct2 charge current | Ict+ | 18.5 | 23 | 27.5 | µA | $V_{PROT}$ = 2.5 V | 12 |
| | Ct2 discharge current | Ict– | 1.0 | 1.4 | — | mA | | |
| | Threshold voltage | Vth | 4.5 | 5.0 | 5.5 | V | | |
| LVI | Operation cleaning voltage *3 | VLVI | 12.5 | 14.7 | 16.9 | V | | 19 |
| | Hysteresis | Vhys | 0.75 | 1.1 | 1.45 | V | | |
| OTSD | Operating temperature *1 | Tsd | 125 | 150 | 175 | °C | | |
| | Hysteresis *1 | Thys | — | 20 | — | °C | | |

Note: 1. These are design target values and only checked during development.
2. Stipulated ad the sum of the source and sink values.
3. See figure 3.

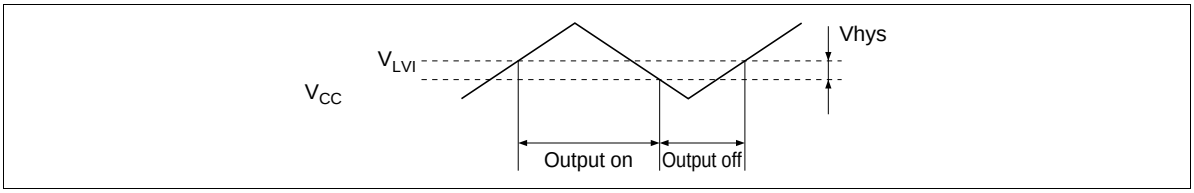
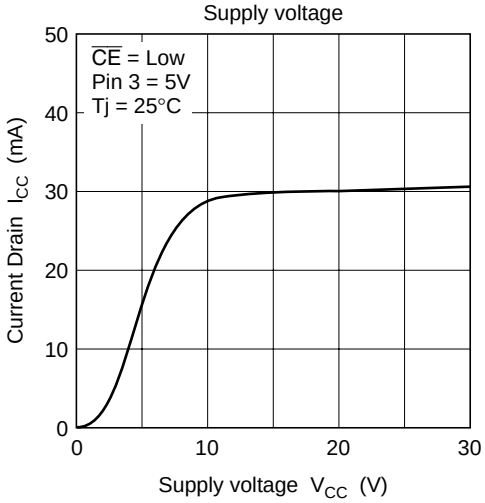


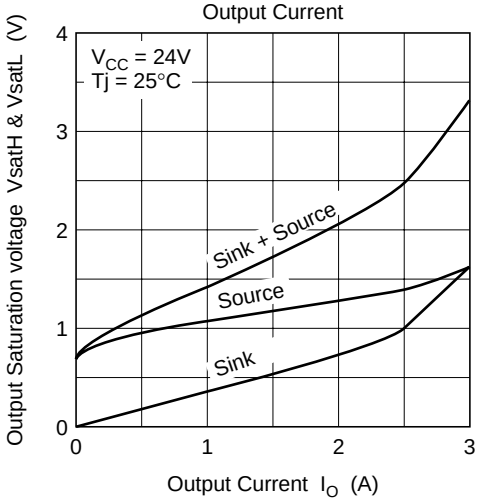

**Figure 3**

## Reference Data

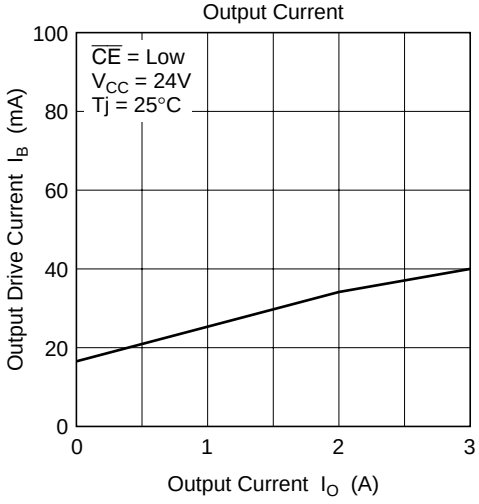
Current Drain vs. Supply voltage



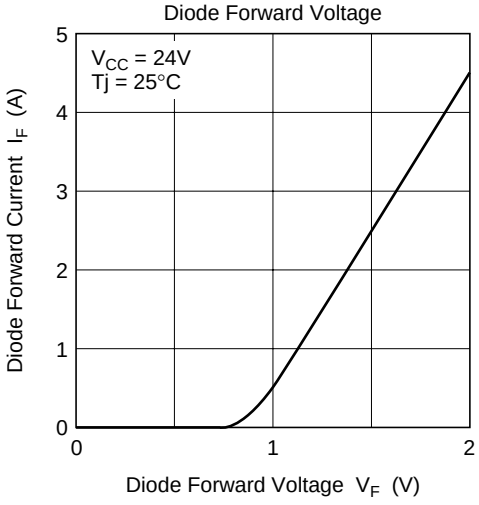

Output Saturation voltage vs. Output Current



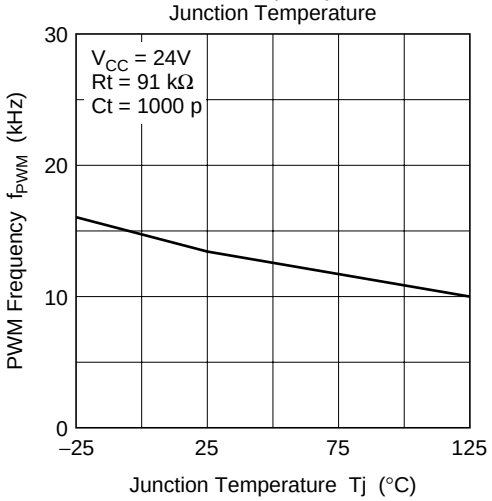

Output Drive Current vs. Output Current



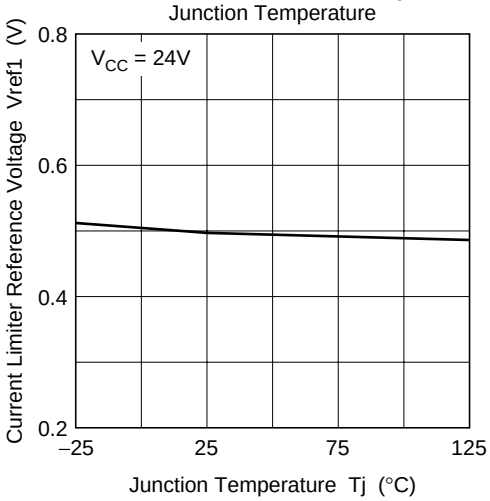

Diode Forward Current vs. Diode Forward Voltage



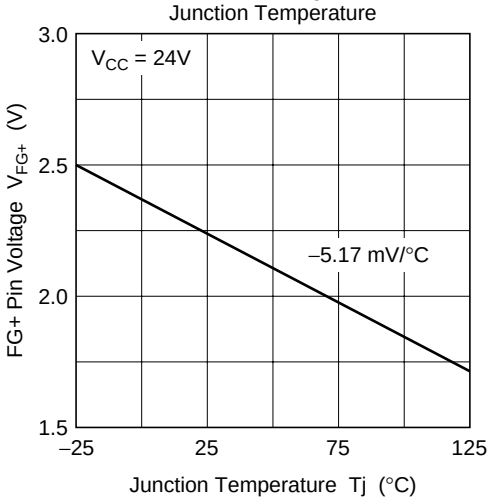
PWM Frequency vs. Junction Temperature



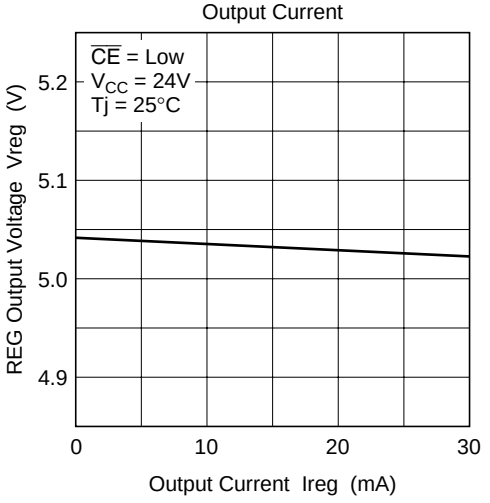

Current Limiter Reference Voltage vs. Junction Temperature




FG+ Pin Voltage vs. Junction Temperature

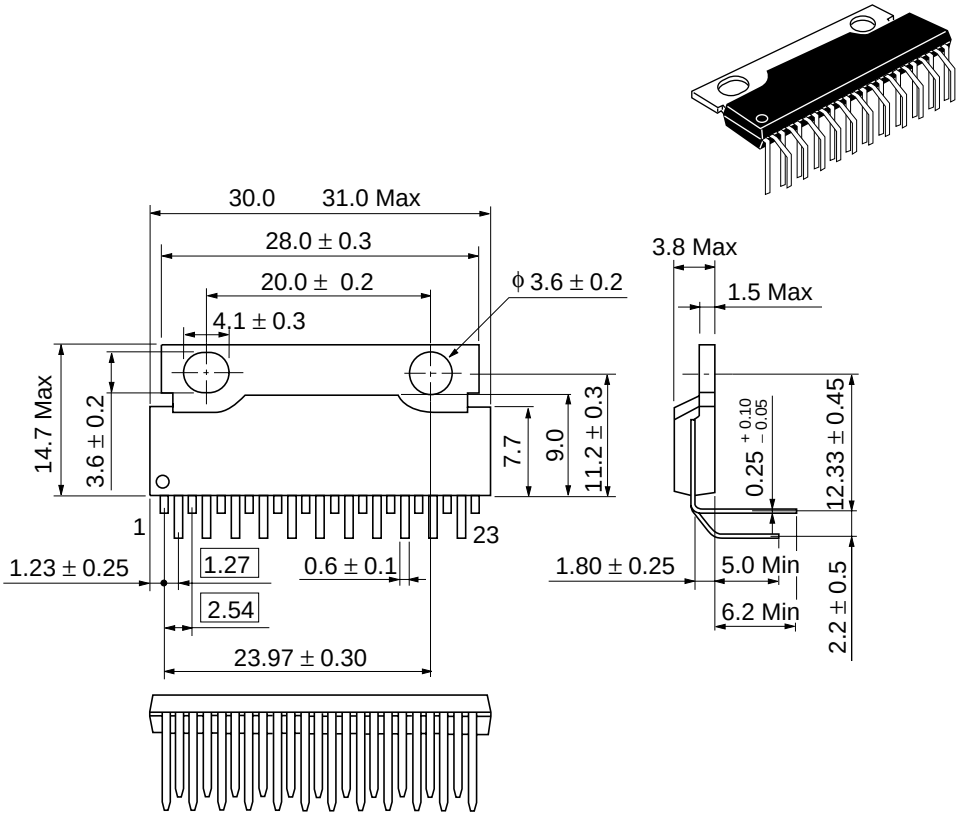



REG Output Voltage vs. Output Current



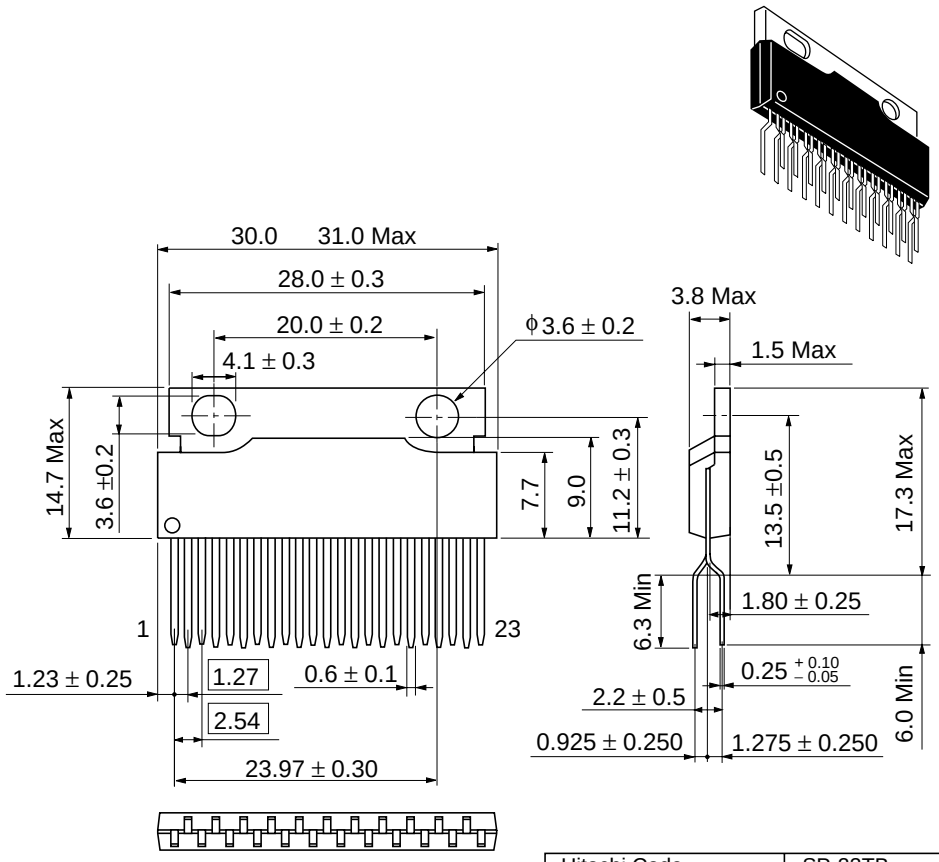
## Package Dimensions

Unit: mm




| | |
|---|---|
| Hitachi Code | SP-23TA |
| JEDEC | — |
| EIAJ | — |
| Weight (reference value) | 4.61 g |

Unit: mm




| | |
|---|---|
| Hitachi Code | SP-23TB |
| JEDEC | — |
| EIAJ | — |
| Weight (reference value) | 4.6 g |

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