

---

# 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

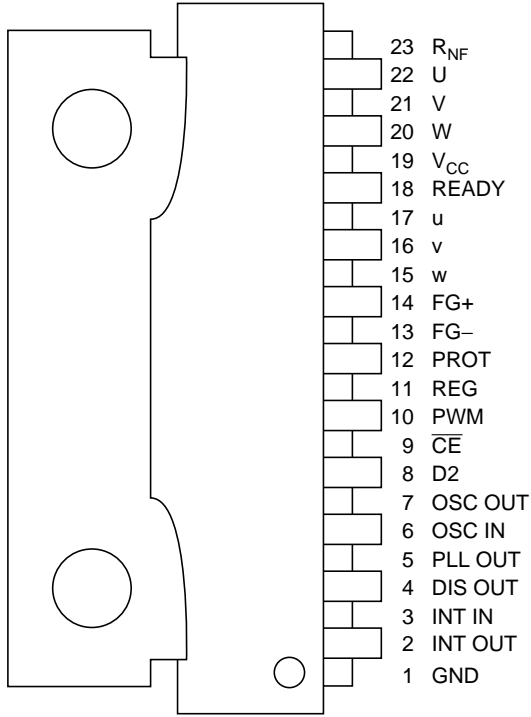
- Low saturation voltage
- Fly wheel diodes built-in
- FG signal digital filter built-in

### Ordering Information

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

---

Pin Arrangement

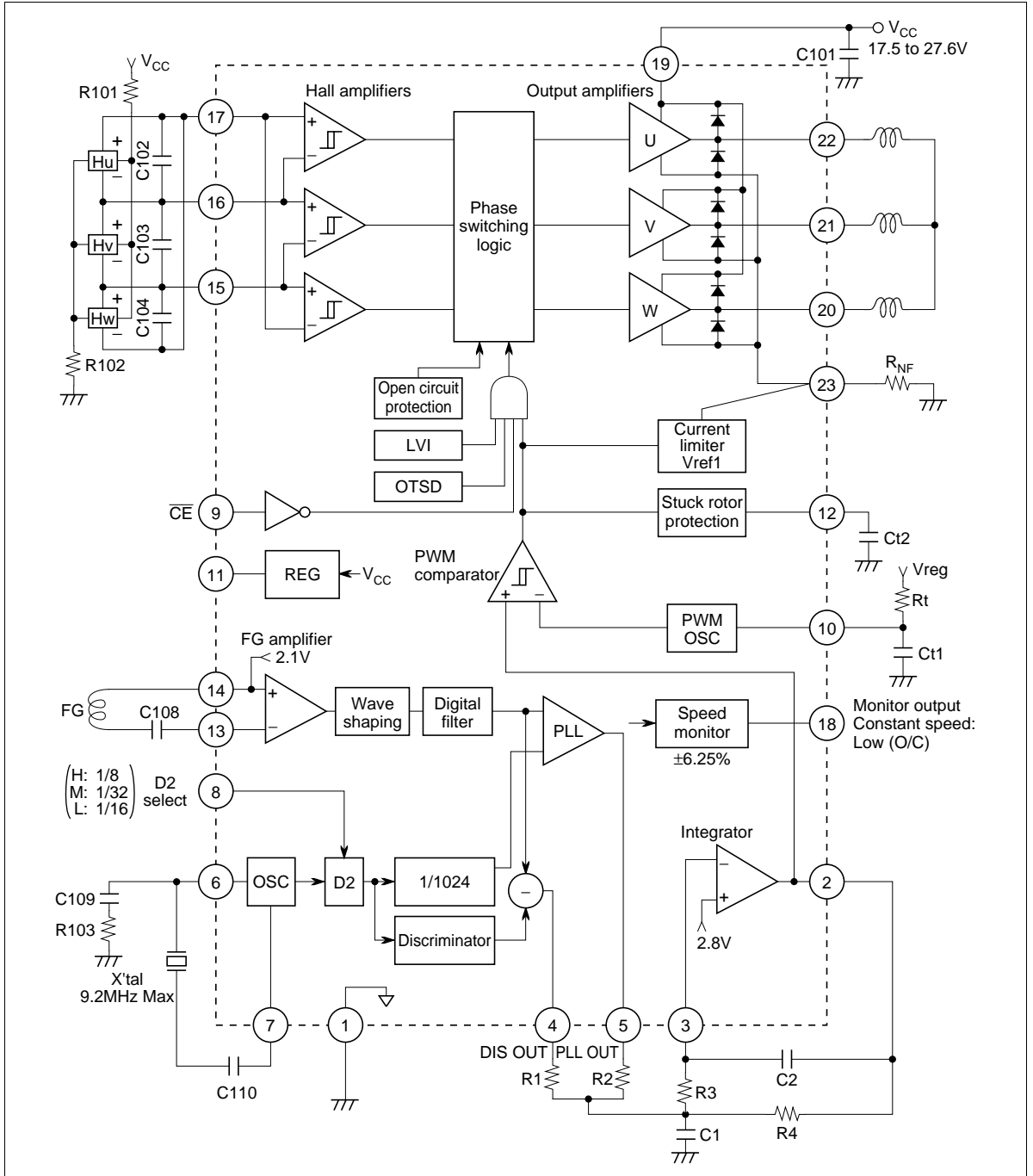


(Top view)

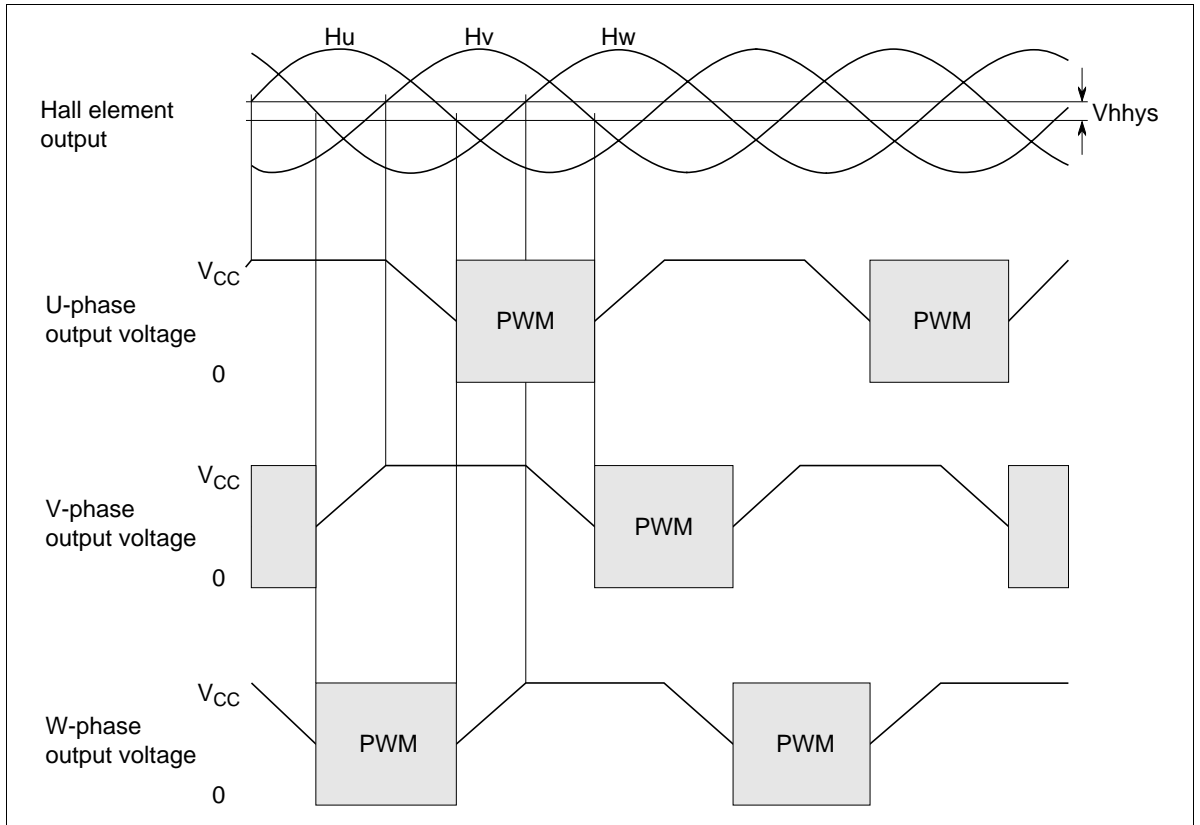
## Pin Functions

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 High: 1/8, Middle or Open: 1/32, and Low: 1/16.
9	$\overline{CE}$	Chip enable input 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 <sub>CC</sub>	Power supply
20	W	W-phase output
21	V	V-phase output
22	U	U-phase output
23	R <sub>NF</sub>	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 <sub>NF</sub>	—	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 guideline:  
First determine the angular frequency of  $\omega_p$  for DIS OUT and PLL OUT.

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

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

$$\omega_M \approx \frac{9.55}{N_O} \cdot \frac{1}{J} \left( K_T \cdot \frac{V_{\text{ref1}}}{R_{\text{NF}}} - T_L \right) \text{ [rad/sec]} \quad (2)$$

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)

$$A = \frac{2 V_{\text{CC}} - 0.83 \cdot V_E - V_{\text{sat}}}{R_m \cdot V_{\text{osc}}}$$

Z : FG pulse per round (P/R)

N<sub>o</sub> : Motor speed (min<sup>-1</sup>)

$\omega_o$  : Control loop angular frequency (rad/sec)

ffg : FG frequency (Hz)

J : Moment of inertia of the motor (kg m<sup>2</sup>)

R<sub>m</sub> : 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 Characteristics)
- $V_E$  : Motor back EMF ( $V_{PP}/T-T$ )
- $R_{NF}$  : Current detection resistor ( $\Omega$ )
- $V_{ref1}$  : Current limiter reference voltage (See the Electrical Characteristics)
- $V_{sat}$  : Saturation voltage (See the Electrical Characteristics)

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

$$R4 = \frac{1}{\omega_p \cdot C2} \tag{5}$$

$$R2 = \frac{R4}{G(E)} \tag{6}$$

$$C1 = \frac{1}{2 \cdot R2 \cdot \omega_O} \tag{7}$$

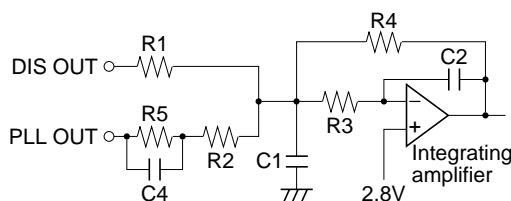
$$R3 = R2 \tag{8}$$

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

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

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:

$$\frac{1}{C4 \cdot R5} < \frac{\omega_p}{20 \cdot 2} \tag{10}$$



**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:

$$I_{max} = \frac{V_{ref1}}{R_{NF}}$$

Where,  $V_{ref1}$  is the current limiter reference voltage. (See the Electrical Characteristics)

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:

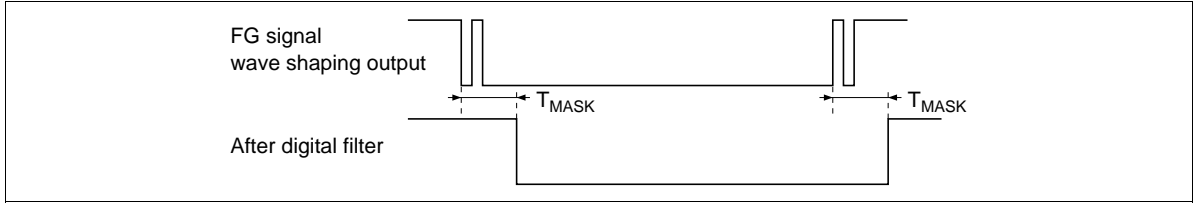
$$C108 (\mu\text{F}) = \frac{220}{\text{ffg (Hz)}}$$

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

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

where, CLK : The reference frequency.

D2 : CLK frequency dividing ratio.

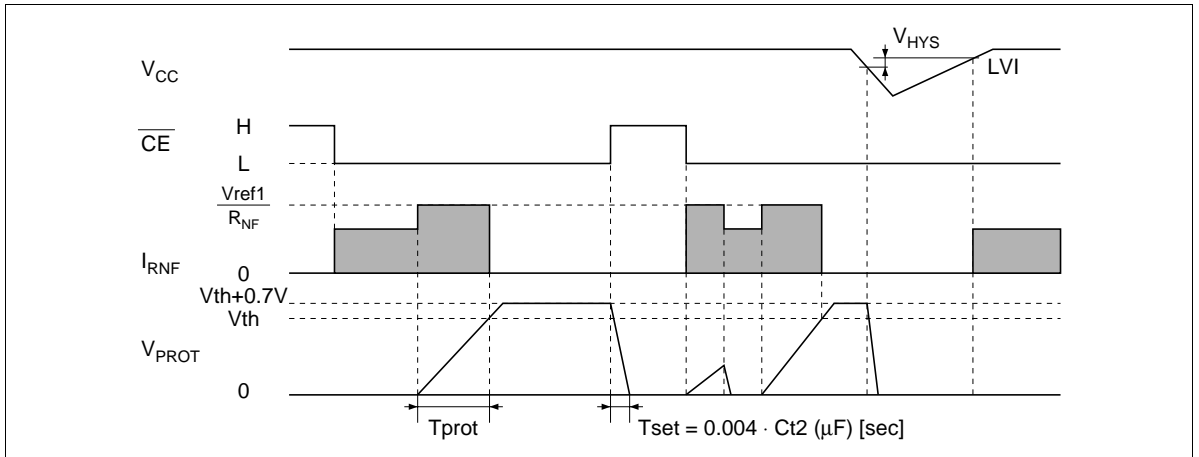


6. The PWM carrier frequency is determined roughly by the following formula:

$$f_{\text{PWM}} = \frac{1180}{R_t (\text{k}\Omega) C_{t1} (\text{pF})} \times 10^3$$

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

$$T_{\text{prot}} = 0.24 C_{t2} (\mu\text{F})$$



**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:

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



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:

$$R_{osc} \geq 2 (V_{IH} - 2.1) - 1.5 \text{ (k}\Omega\text{)}$$

$$R_{osc} \leq 6 (2.1 - V_{IL}) - 1.5 \text{ (k}\Omega\text{)}$$

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.

<b>Oscillator</b>	<b>f c</b>	<b>C110</b>	<b>C109</b>	<b>R103</b>
Crystal	6.0 to 9.2 MHz	10 pF	0.047 $\mu$ F	1 k $\Omega$
	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	$I_{op}$	3.0	A	2
Steady-state output current	$I_o$	2.0	A	2
Input voltage	$V_i$	-0.3 to 7	V	3
Allowable power dissipation	$P_T$	10	W	4
Junction temperature	$T_j$	150	°C	1
Storage temperature	$T_{stg}$	-55 to +125	°C	

Notes: 1. The operating ranges are as follows:

$$V_{CC} = 17.5 \text{ to } 27.6 \text{ V}$$

$$T_{jop} = -20 \text{ to } +125^\circ\text{C}$$

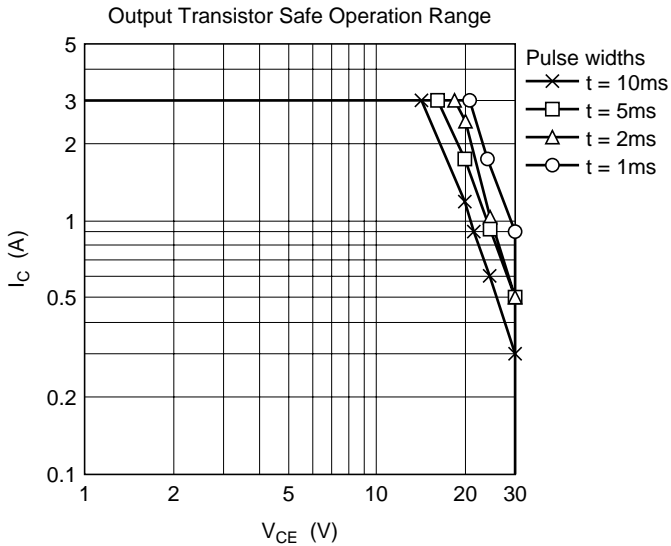
2. See the safe operating range data.

3. Applies to the logic input pins.

4. The allowable value when the TAB temperature,  $T_{tab}$ , is 120°C. However, the thermal resistance is as follows:

$$\theta_{j-c} \leq 3^\circ\text{C/W}$$

$$\theta_{j-a} \leq 40^\circ\text{C/W}$$



Electrical Characteristics (Ta = 25°C, V<sub>CC</sub> = 24 V)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions	Applicable Pins	
Current drain	Standby current	I <sub>CCO</sub>	—	8	11	mA	$\overline{CE} = H, V_{CC} = 30 V$	19	
	Current drain with outputs off	I <sub>CC</sub>	—	32	44	mA	$\overline{CE} = L, Pin\ 3 = H, V_{CC} = 30 V, output\ OFF$		
Logic input 1	Low-level voltage	V <sub>il1</sub>	—	—	0.8	V		9	
	High-level voltage	V <sub>ih1</sub>	2.0	—	—	V			
	Low-level current	I <sub>il1</sub>	—	-0.25	-0.35	mA	V <sub>il</sub> = 0 V		
	High-level current	I <sub>ih1</sub>	-0.1	0	0.1	mA	V <sub>ih</sub> = 7 V		
Logic input 2	Low-level voltage	V <sub>il2</sub>	—	—	1.0	V		8	
	Middle-level voltage	V <sub>im</sub>	2.0	2.5	3.0	V			
	High-level voltage	V <sub>ih2</sub>	4.0	—	—	V			
	Low-level current	I <sub>il2</sub>	—	-0.25	-0.35	mA	V <sub>il</sub> = 0 V		
	Middle-level current	I <sub>im</sub>	—	—	±35	μA	V <sub>i</sub> = 2.5 V		
	High-level current	I <sub>ih2</sub>	—	0.5	0.7	mA	V <sub>ih</sub> = 7 V		
Logic output	Low-level voltage	V <sub>ol1</sub>	—	0.2	0.4	V	I <sub>ol</sub> = 2 mA	18	
	Leakage current	I <sub>oh1</sub>	—	—	±10	μA	V <sub>oh</sub> = 30 V		
Hall amplifier	Commonmode input voltage range	V <sub>h</sub>	2.0	—	V <sub>CC</sub> -2	V		15, 16, 17	
	Differentialmode input voltage range	V <sub>d</sub>	60	—	V <sub>CC</sub> /2	mV			
	Hysteresis *1	V <sub>hhys</sub>	—	20	—	mV	R <sub>h</sub> = 400 Ω		
Output amplifier	Leakage current	I <sub>cer</sub>	—	—	±100	μA	V <sub>ce</sub> = 30 V	20, 21, 22	
	Output drive current	I <sub>B1</sub>	—	49	64	mA	I <sub>o</sub> = 2 A		
		I <sub>B2</sub>	—	35	46	mA	I <sub>o</sub> = 1 A		
	Saturation voltage *2	V <sub>sat1</sub>	—	1.8	2.7	V	I <sub>o</sub> = 2 A		
		V <sub>sat2</sub>	—	1.35	1.7	V	I <sub>o</sub> = 1 A		
	Impulse response time	tphl	tphl	—	—	2	μs		
			tphl	—	—	2	μs		
			t <sub>r</sub>	—	—	0.5	μs		
t <sub>f</sub>			—	—	0.5	μs			
Current limiter reference voltage	V <sub>ref1</sub>	0.45	0.5	0.55	V		23		
Flywheel diode	Forward voltage	V <sub>F</sub>	—	1.15	1.4	V	I <sub>F</sub> = 1 A	19, 20, 21, 22	
	Substrate current	I <sub>sub</sub>	—	6.5	10	%			

## Electrical Characteristics (Ta = 25°C, V<sub>CC</sub> = 24 V) (cont)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions	Applicable Pins
PWM oscillator and PWM comparator	Oscillator frequency range	f <sub>PWM</sub>	2.0	—	30	kHz		10
	Oscillator frequency precision	f <sub>err</sub>	11.7	13	14.3	kHz	Rt1 = 91 kΩ, Ct1 = 1000 pF	
	Oscillator high-level voltage	V <sub>osch</sub>	2.7	3.0	3.3	V		
	Oscillator low-level voltage	V <sub>oscl</sub>	1.0	1.1	1.2	V		
	Oscillator amplitude	V <sub>osc</sub>	1.7	1.9	2.1	V <sub>pp</sub>	V <sub>osch</sub> – V <sub>oscl</sub>	
	Comparator hysteresis *1	V <sub>chys</sub>	—	20	—	mV		2
Integrator	Input current	i <sub>in</sub>	—	—	±250	nA		2, 3
	High-level voltage	V <sub>oh2</sub>	3.2	3.5	—	V	I <sub>o</sub> = –0.5 mA	
	Low-level voltage	V <sub>ol2</sub>	—	0.9	1.1	V	I <sub>o</sub> = 0.5 mA	
	Voltage gain *1	G <sub>i</sub>	—	60	—	dB		
	Gainbandwidth product *1	B <sub>i</sub>	—	0.5	—	MHz		
	Reference voltage	V <sub>p</sub>	2.65	2.8	2.95	V		
FG amplifier and waveform shaping	Input sensitivity	v <sub>fg</sub>	15	—	1000	mV <sub>pp</sub>		13, 14
	Noise margin	nd	—	—	4.0	mV <sub>pp</sub>		
		nc	—	—	1.0	V <sub>pp</sub>		
PLL, DIS	Output high-level voltage	V <sub>oh3</sub>	4.3	4.5	—	V	I <sub>o</sub> = –0.1 mA	4, 5
	Output low-level voltage	V <sub>ol3</sub>	—	—	0.25	V	I <sub>o</sub> = 0.1 mA	
OSC	Oscillator frequency range	f <sub>osc</sub>	2	—	9.2	MHz		6, 7
	Oscillator frequency error *1	Δf <sub>osc</sub>	—	—	±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<sub>CC</sub> = 24 V) (cont)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions	Applicable Pins
REG	Output voltage	V <sub>reg</sub>	4.65	5.0	5.35	V	I <sub>reg</sub> = 20 mA, $\overline{CE} = L$	11
	Power supply regulation	ΔV <sub>reg1</sub>	—	20	100	mV	V <sub>CC</sub> = 17.5 to 27.6 V, $\overline{CE} = L$	
	Load regulation	ΔV <sub>reg2</sub>	—	10	100	mV	I <sub>reg</sub> = 0 to 20 mA, $\overline{CE} = L$	
Stuck rotor protection circuit	Ct2 charge current	I <sub>ct+</sub>	18.5	23	27.5	μA	V <sub>PROT</sub> = 2.5 V	12
	Ct2 discharge current	I <sub>ct-</sub>	1.0	1.4	—	mA		
	Threshold voltage	V <sub>th</sub>	4.5	5.0	5.5	V		
LVI	Operation cleaning voltage *3	V <sub>LVI</sub>	12.5	14.7	16.9	V		19
	Hysteresis	V <sub>hys</sub>	0.75	1.1	1.45	V		
OTSD	Operating temperature *1	T <sub>sd</sub>	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.

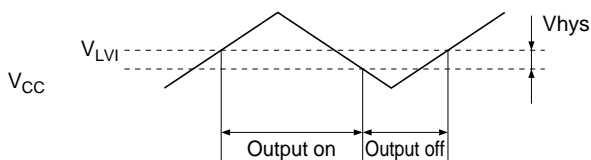
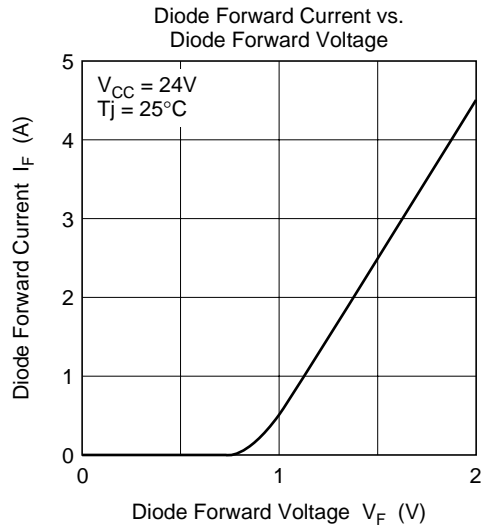
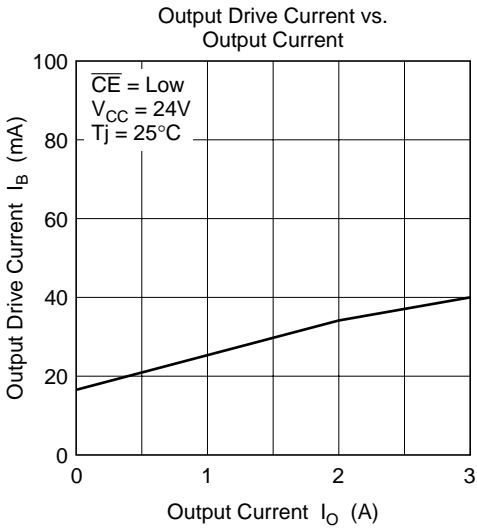
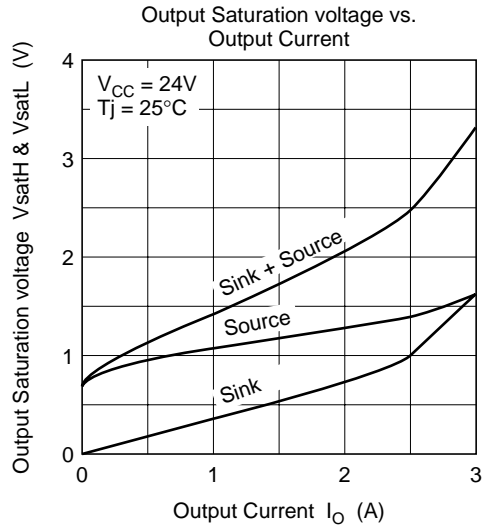
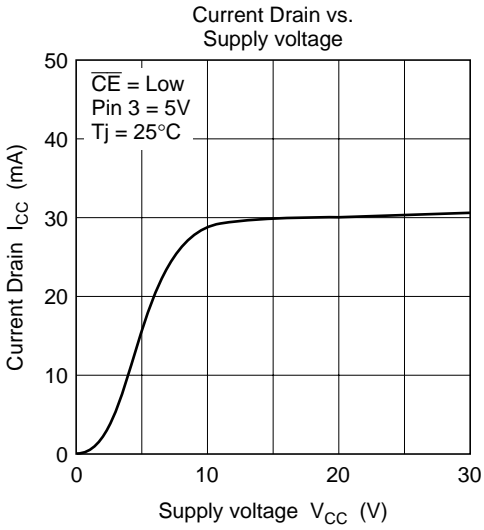
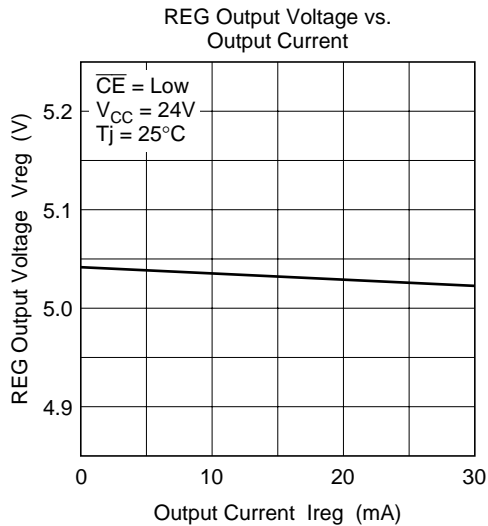
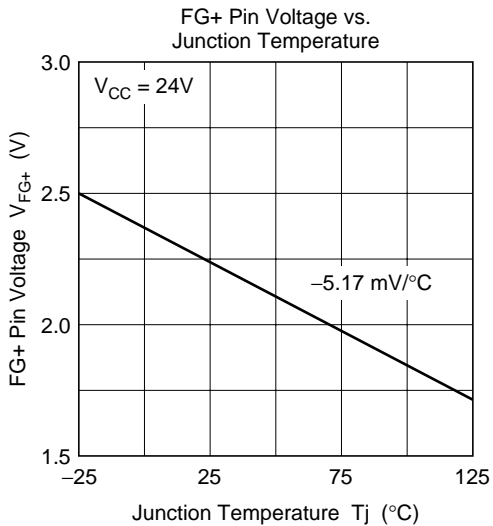
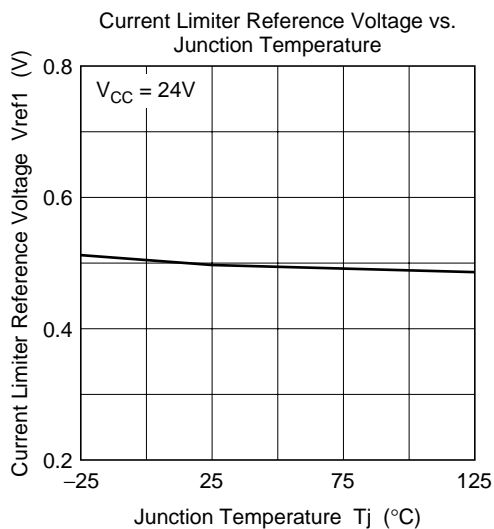
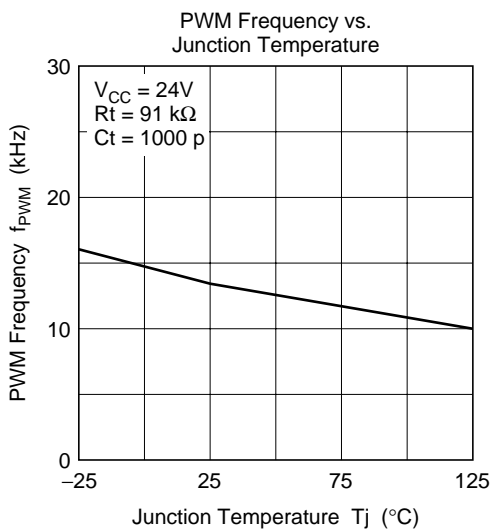


Figure 3

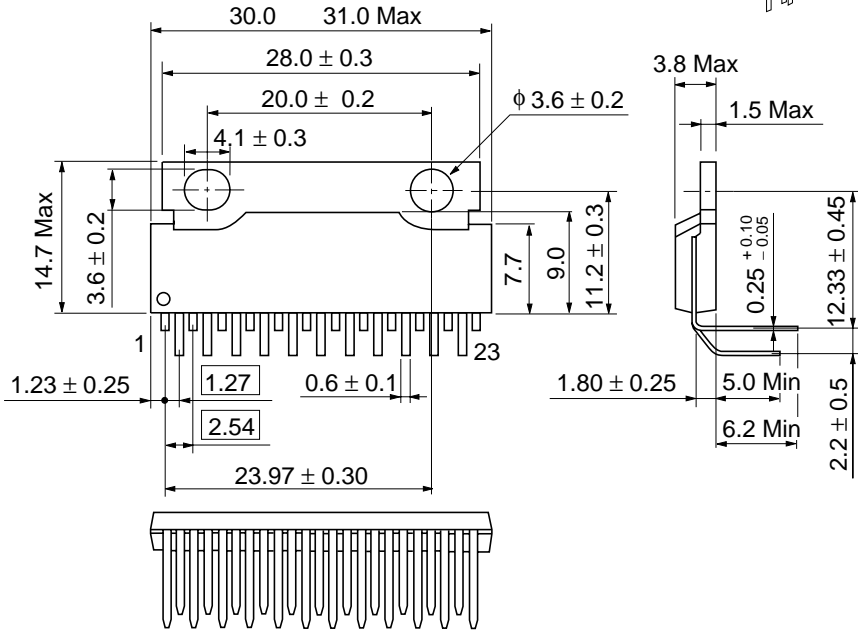
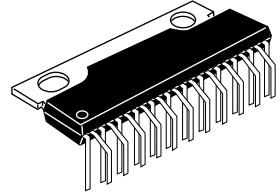
Reference Data





## Package Dimensions

Unit: mm



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





## Cautions

1. Hitachi neither warrants nor grants licenses of any rights of Hitachi's or any third party's patent, copyright, trademark, or other intellectual property rights for information contained in this document. Hitachi bears no responsibility for problems that may arise with third party's rights, including intellectual property rights, in connection with use of the information contained in this document.
2. Products and product specifications may be subject to change without notice. Confirm that you have received the latest product standards or specifications before final design, purchase or use.
3. Hitachi makes every attempt to ensure that its products are of high quality and reliability. However, contact Hitachi's sales office before using the product in an application that demands especially high quality and reliability or where its failure or malfunction may directly threaten human life or cause risk of bodily injury, such as aerospace, aeronautics, nuclear power, combustion control, transportation, traffic, safety equipment or medical equipment for life support.
4. Design your application so that the product is used within the ranges guaranteed by Hitachi particularly for maximum rating, operating supply voltage range, heat radiation characteristics, installation conditions and other characteristics. Hitachi bears no responsibility for failure or damage when used beyond the guaranteed ranges. Even within the guaranteed ranges, consider normally foreseeable failure rates or failure modes in semiconductor devices and employ systemic measures such as fail-safes, so that the equipment incorporating Hitachi product does not cause bodily injury, fire or other consequential damage due to operation of the Hitachi product.
5. This product is not designed to be radiation resistant.
6. No one is permitted to reproduce or duplicate, in any form, the whole or part of this document without written approval from Hitachi.
7. Contact Hitachi's sales office for any questions regarding this document or Hitachi semiconductor products.

# HITACHI

## Hitachi, Ltd.

Semiconductor & Integrated Circuits.  
Nippon Bldg., 2-6-2, Ohte-machi, Chiyoda-ku, Tokyo 100-0004, Japan  
Tel: Tokyo (03) 3270-2111 Fax: (03) 3270-5109

URL      North America      : <http://semiconductor.hitachi.com/>  
             Europe                : <http://www.hitachi-eu.com/hel/ecg>  
             Asia (Singapore)      : <http://www.has.hitachi.com.sg/grp3/sicd/index.htm>  
             Asia (Taiwan)            : [http://www.hitachi.com.tw/E/Product/SICD\\_Frame.htm](http://www.hitachi.com.tw/E/Product/SICD_Frame.htm)  
             Asia (HongKong)        : <http://www.hitachi.com.hk/eng/bo/grp3/index.htm>  
             Japan                     : <http://www.hitachi.co.jp/Sicd/indx.htm>

## For further information write to:

Hitachi Semiconductor  
(America) Inc.  
179 East Tasman Drive,  
San Jose, CA 95134  
Tel: <1> (408) 433-1990  
Fax: <1> (408) 433-0223

Hitachi Europe GmbH  
Electronic components Group  
Dornacher Straße 3  
D-85622 Feldkirchen, Munich  
Germany  
Tel: <49> (89) 9 9180-0  
Fax: <49> (89) 9 29 30 00

Hitachi Europe Ltd.  
Electronic Components Group.  
Whitebrook Park  
Lower Cookham Road  
Maidenhead  
Berkshire SL6 8YA, United Kingdom  
Tel: <44> (1628) 585000  
Fax: <44> (1628) 778322

Hitachi Asia Pte. Ltd.  
16 Collyer Quay #20-00  
Hitachi Tower  
Singapore 049318  
Tel: 535-2100  
Fax: 535-1533

Hitachi Asia Ltd.  
Taipei Branch Office  
3F, Hung Kuo Building, No.167,  
Tun-Hwa North Road, Taipei (105)  
Tel: <886> (2) 2718-3666  
Fax: <886> (2) 2718-8180

Hitachi Asia (Hong Kong) Ltd.  
Group III (Electronic Components)  
7/F., North Tower, World Finance Centre,  
Harbour City, Canton Road, Tsim Sha Tsui,  
Kowloon, Hong Kong  
Tel: <852> (2) 735 9218  
Fax: <852> (2) 730 0281  
Telex: 40815 HITEC HX

Copyright ' Hitachi, Ltd., 1999. All rights reserved. Printed in Japan.

**HITACHI**