
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)

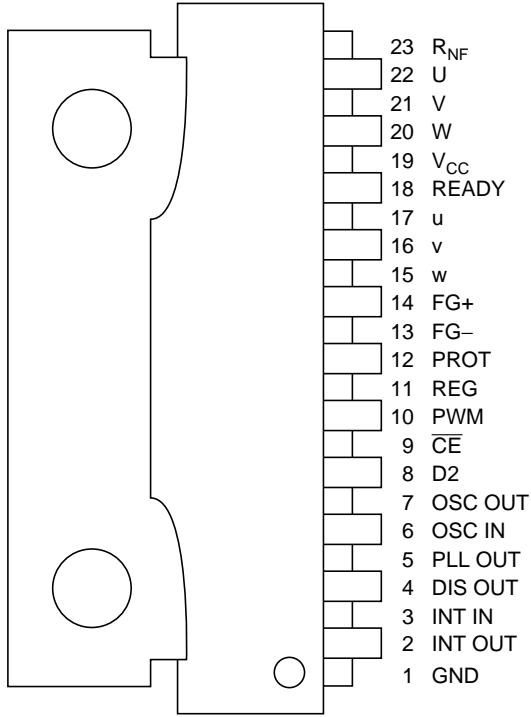
Features

- 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

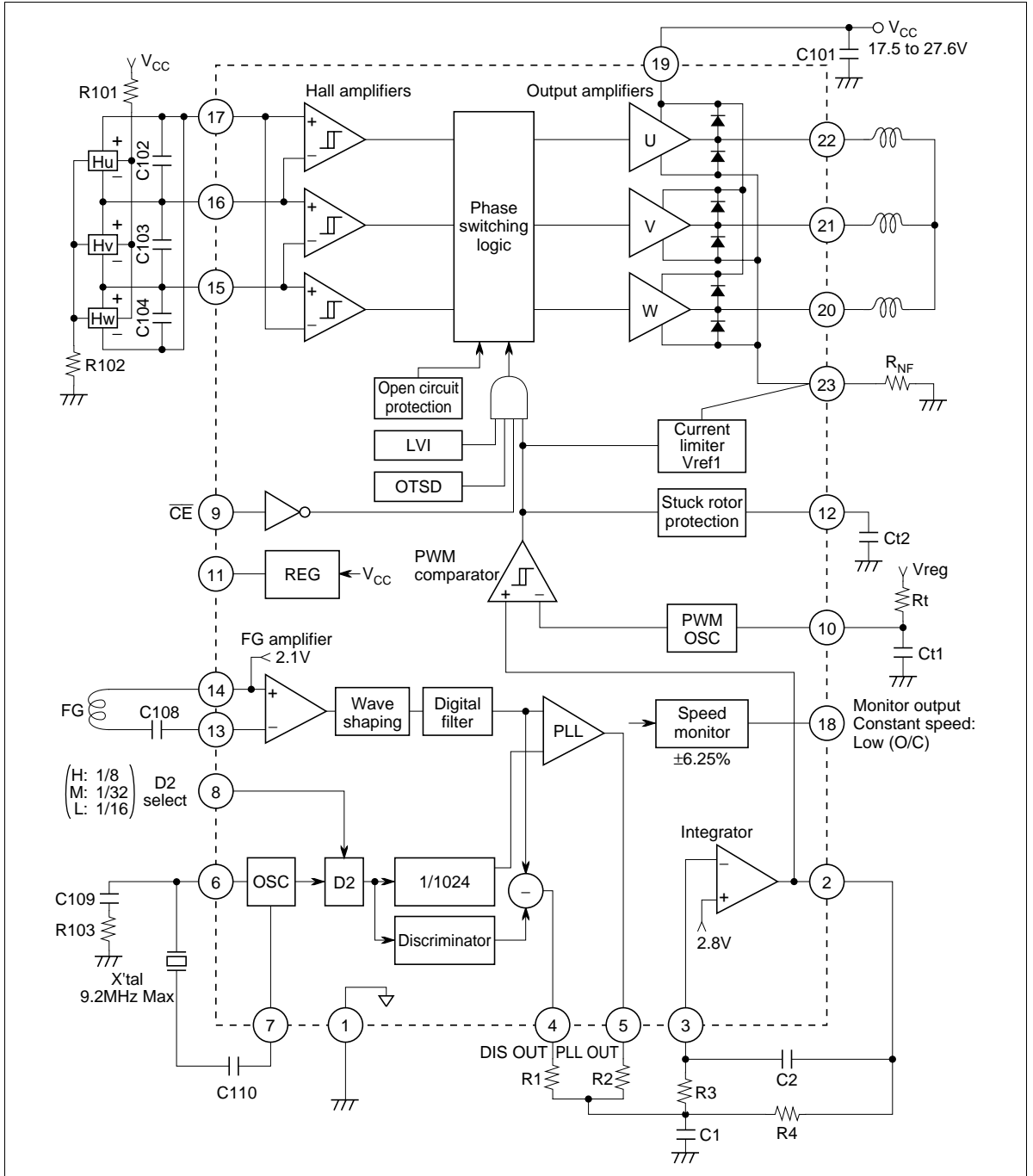


(Top view)

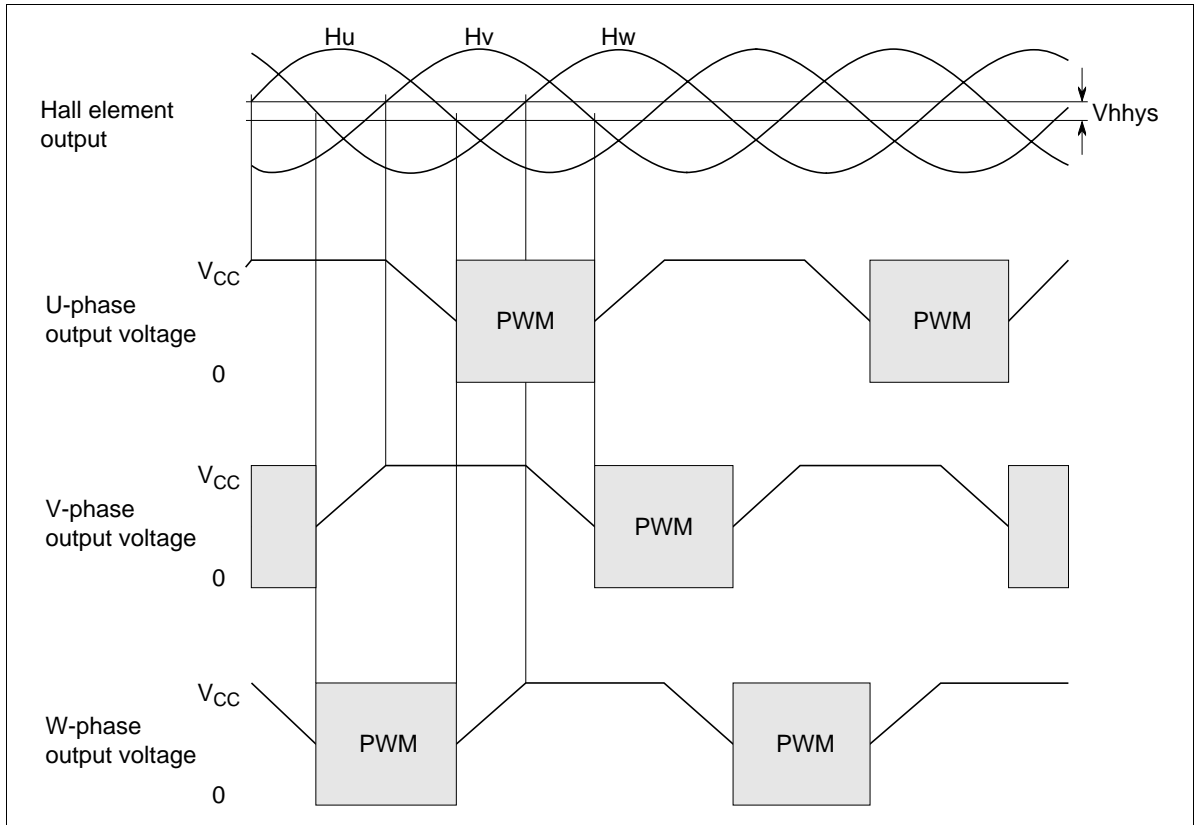
Pin Functions

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 _{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 guideline:
First determine the angular frequency of ω_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 ω_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 ω_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_o : Motor speed (min⁻¹)

ω_o : Control loop angular frequency (rad/sec)

ffg : FG frequency (Hz)

J : Moment of inertia of the motor (kg m²)

R_m : 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 (Ω)
- 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:

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

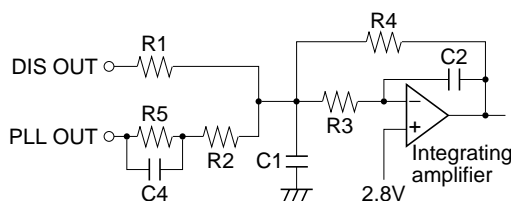


Figure 1 Integration Constants

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:

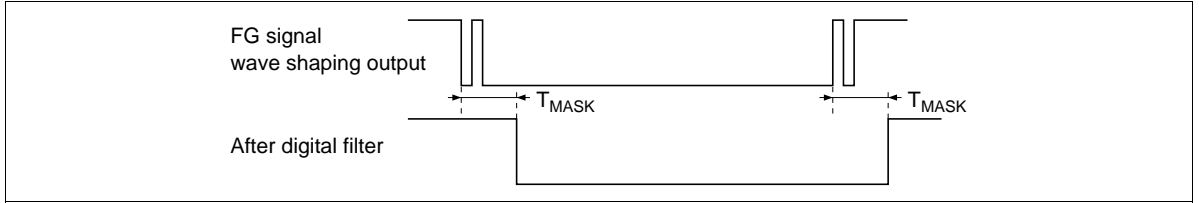
$$C108 (\mu\text{F}) = \frac{220}{\text{ffg (Hz)}}$$

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

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

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_{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_{CC} . Note that a capacitor with a leakage current sufficiently smaller than the charging current $I_{\text{ct+}}$ must be used.

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

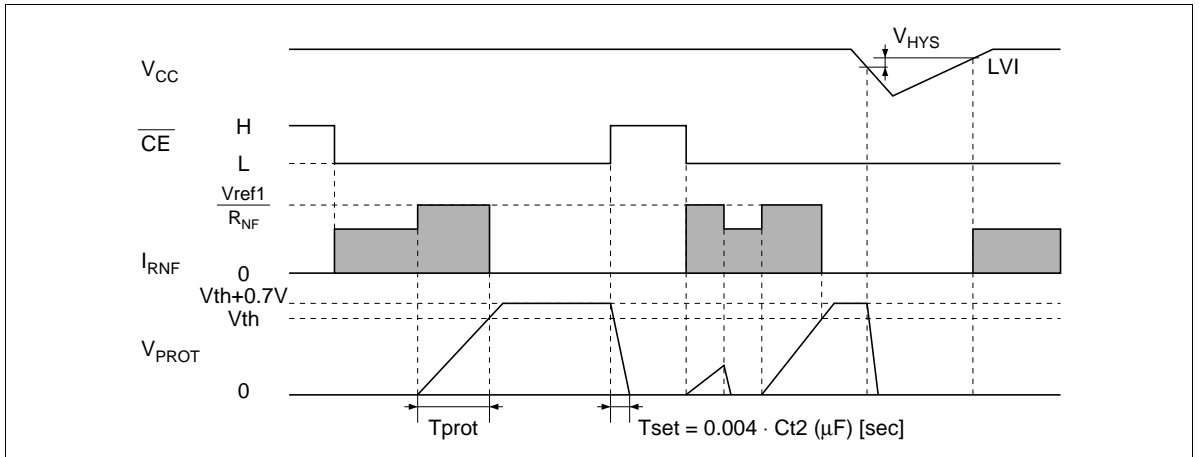


Figure 2 Stuck Rotor Protection Operating Waveforms

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

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

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.

Oscillator	f c	C110	C109	R103
Crystal	6.0 to 9.2 MHz	10 pF	0.047 μ F	1 k Ω
	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:

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

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

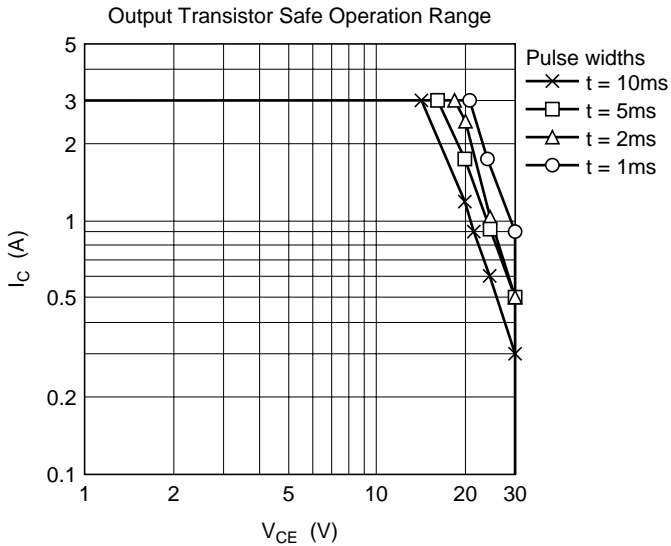
2. See the safe operating range data.

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_{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	V _{il1}	—	—	0.8	V		9	
	High-level voltage	V _{ih1}	2.0	—	—	V			
	Low-level current	I _{il1}	—	-0.25	-0.35	mA	V _{il} = 0 V		
	High-level current	I _{ih1}	-0.1	0	0.1	mA	V _{ih} = 7 V		
Logic input 2	Low-level voltage	V _{il2}	—	—	1.0	V		8	
	Middle-level voltage	V _{im}	2.0	2.5	3.0	V			
	High-level voltage	V _{ih2}	4.0	—	—	V			
	Low-level current	I _{il2}	—	-0.25	-0.35	mA	V _{il} = 0 V		
	Middle-level current	I _{im}	—	—	±35	μA	V _i = 2.5 V		
	High-level current	I _{ih2}	—	0.5	0.7	mA	V _{ih} = 7 V		
Logic output	Low-level voltage	V _{ol1}	—	0.2	0.4	V	I _{ol} = 2 mA	18	
	Leakage current	I _{oh1}	—	—	±10	μA	V _{oh} = 30 V		
Hall amplifier	Commonmode input voltage range	V _h	2.0	—	V _{CC} -2	V		15, 16, 17	
	Differentialmode input voltage range	V _d	60	—	V _{CC} /2	mV			
	Hysteresis *1	V _{hhys}	—	20	—	mV	R _h = 400 Ω		
Output amplifier	Leakage current	I _{cer}	—	—	±100	μA	V _{ce} = 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	V _{sat1}	—	1.8	2.7	V	I _o = 2 A		
		V _{sat2}	—	1.35	1.7	V	I _o = 1 A		
	Impulse response time	tphl	tphl	—	—	2	μs		
			tphl	—	—	2	μs		
			t _r	—	—	0.5	μs		
t _f			—	—	0.5	μs			
Current limiter reference voltage	V _{ref1}	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	I _{sub}	—	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	f _{err}	11.7	13	14.3	kHz	Rt1 = 91 kΩ, Ct1 = 1000 pF	
	Oscillator high-level voltage	V _{osch}	2.7	3.0	3.3	V		
	Oscillator low-level voltage	V _{oscl}	1.0	1.1	1.2	V		
	Oscillator amplitude	V _{osc}	1.7	1.9	2.1	V _{pp}	V _{osch} – V _{oscl}	
	Comparator hysteresis *1	V _{chys}	—	20	—	mV		2
Integrator	Input current	i _{in}	—	—	±250	nA		2, 3
	High-level voltage	V _{oh2}	3.2	3.5	—	V	I _o = –0.5 mA	
	Low-level voltage	V _{ol2}	—	0.9	1.1	V	I _o = 0.5 mA	
	Voltage gain *1	G _i	—	60	—	dB		
	Gainbandwidth product *1	B _i	—	0.5	—	MHz		
	Reference voltage	V _p	2.65	2.8	2.95	V		
FG amplifier and waveform shaping	Input sensitivity	v _{fg}	15	—	1000	mV _{pp}		13, 14
	Noise margin	nd	—	—	4.0	mV _{pp}		
		nc	—	—	1.0	V _{pp}		
PLL, DIS	Output high-level voltage	V _{oh3}	4.3	4.5	—	V	I _o = –0.1 mA	4, 5
	Output low-level voltage	V _{ol3}	—	—	0.25	V	I _o = 0.1 mA	
OSC	Oscillator frequency range	f _{osc}	2	—	9.2	MHz		6, 7
	Oscillator frequency error *1	Δf _{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 ($T_a = 25^\circ\text{C}$, $V_{CC} = 24\text{ V}$) (cont)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions	Applicable Pins
REG	Output voltage	Vreg	4.65	5.0	5.35	V	$I_{reg} = 20\text{ mA}$, $\overline{CE} = L$	11
	Power supply regulation	ΔV_{reg1}	—	20	100	mV	$V_{CC} = 17.5\text{ to }27.6\text{ V}$, $\overline{CE} = L$	
	Load regulation	ΔV_{reg2}	—	10	100	mV	$I_{reg} = 0\text{ to }20\text{ mA}$, $\overline{CE} = L$	
Stuck rotor protection circuit	Ct2 charge current	Ict+	18.5	23	27.5	μA	$V_{PROT} = 2.5\text{ V}$	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	$^\circ\text{C}$		
	Hysteresis *1	Thys	—	20	—	$^\circ\text{C}$		

- 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.

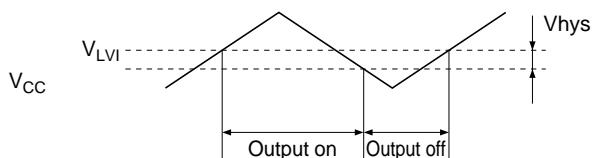
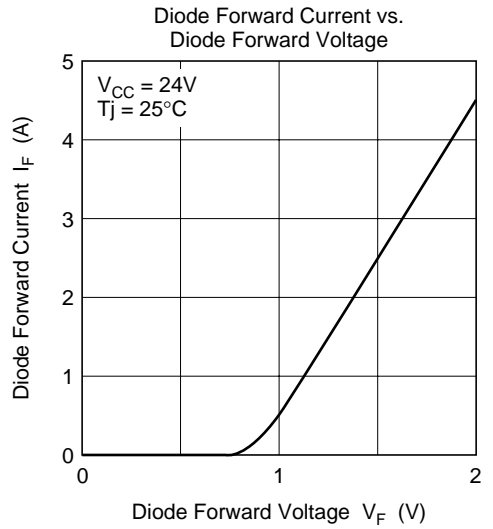
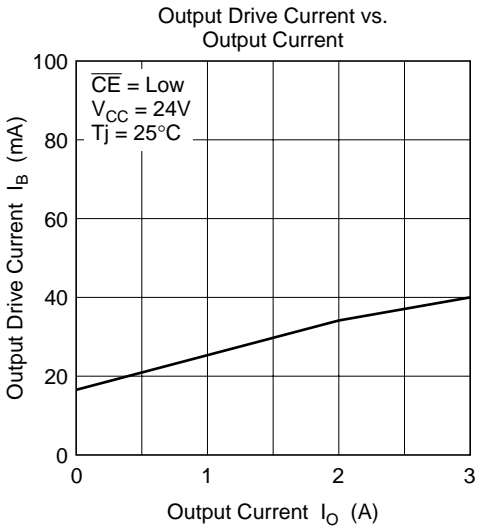
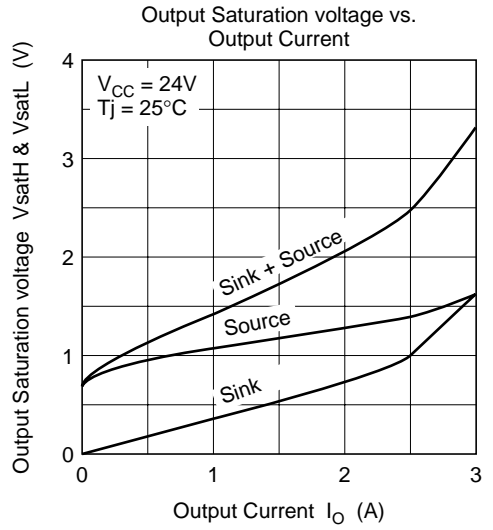
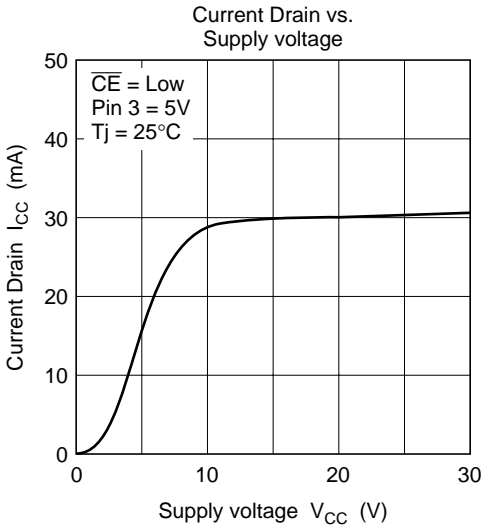
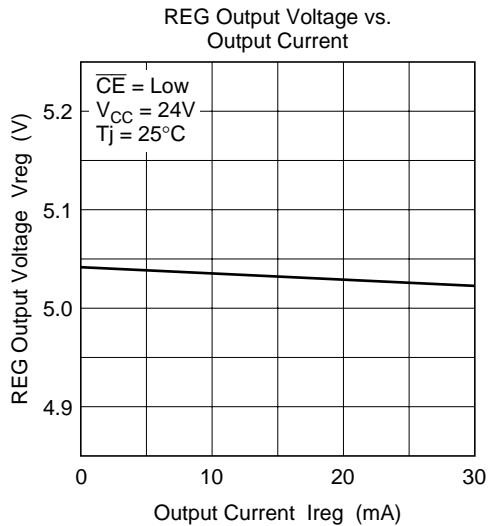
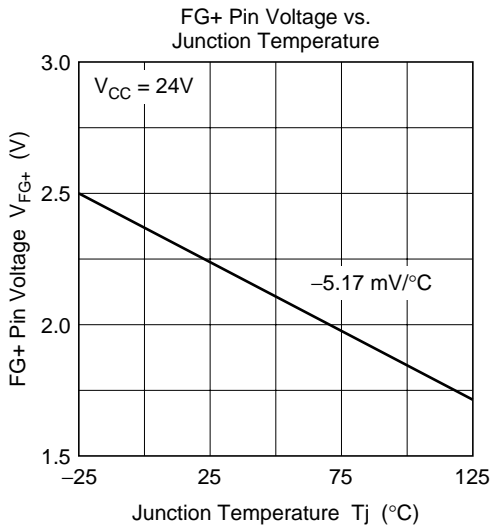
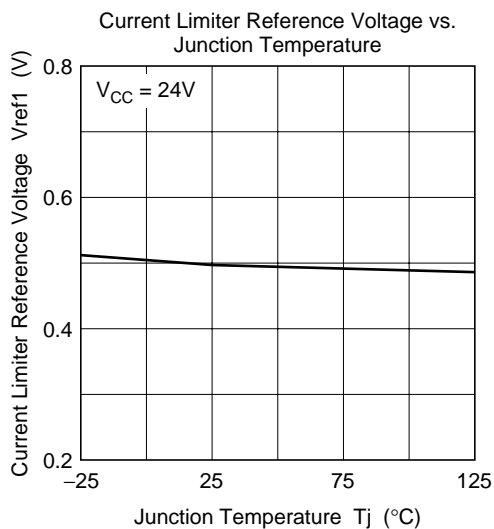
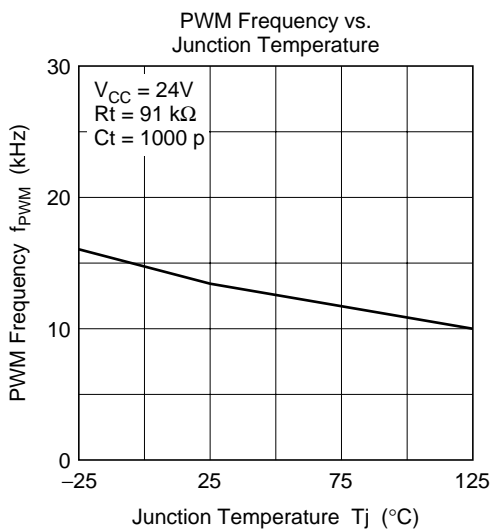


Figure 3

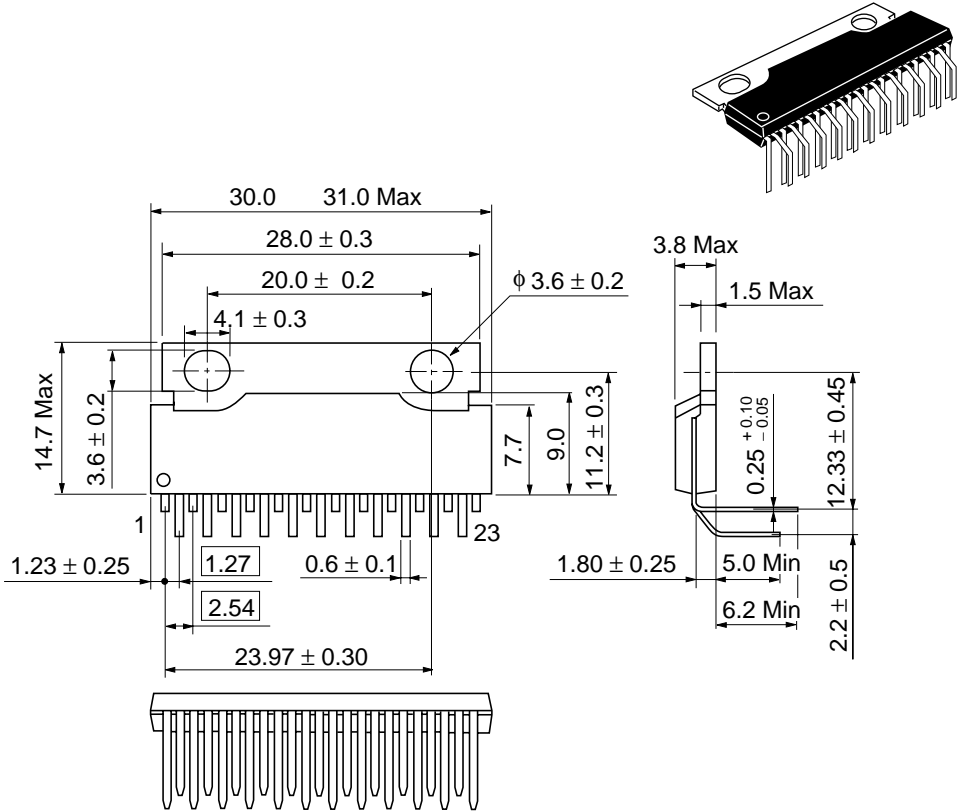
Reference Data





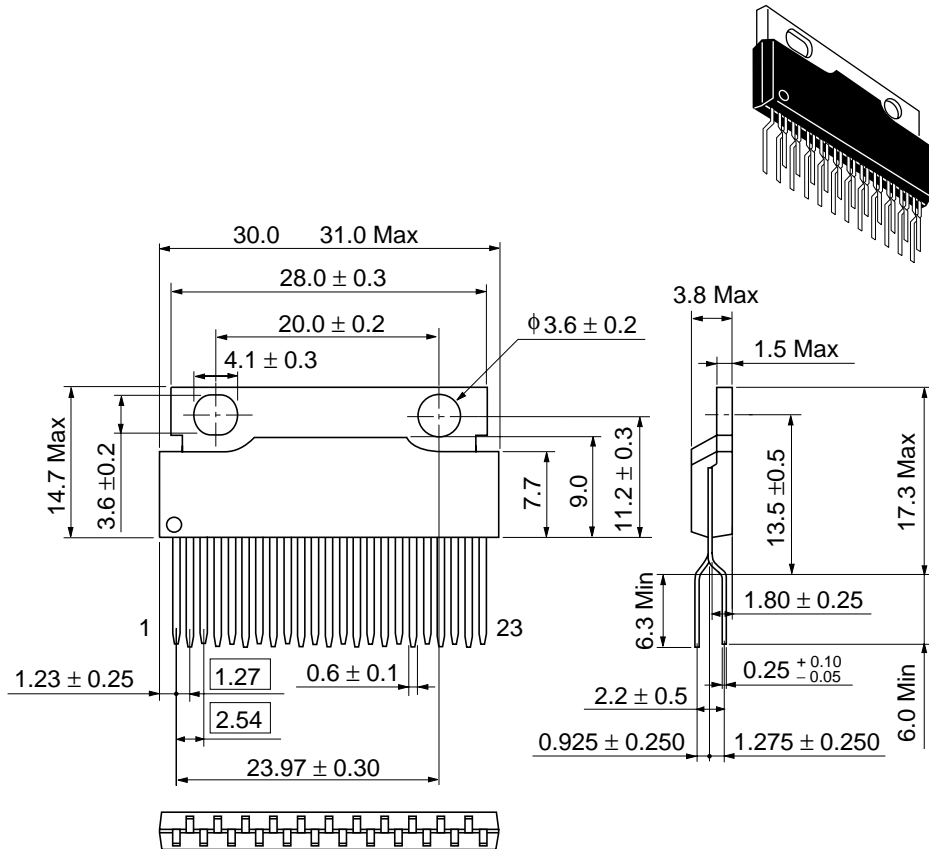
Package Dimensions

Unit: mm



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

Unit: mm



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

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