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# HA13536F

## Three-Phase Brushless DC Motor Driver IC

# HITACHI

ADE-207-111B (Z)  
3rd Edition  
July 1996

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### Description

The HA13536F is a 3-phase brushless DC motor driver IC with digital speed control. It is being developed for direct drive of the spindle motor of 5 V floppy disk drives with a height of 3/4" or less. It has the following functions and features.

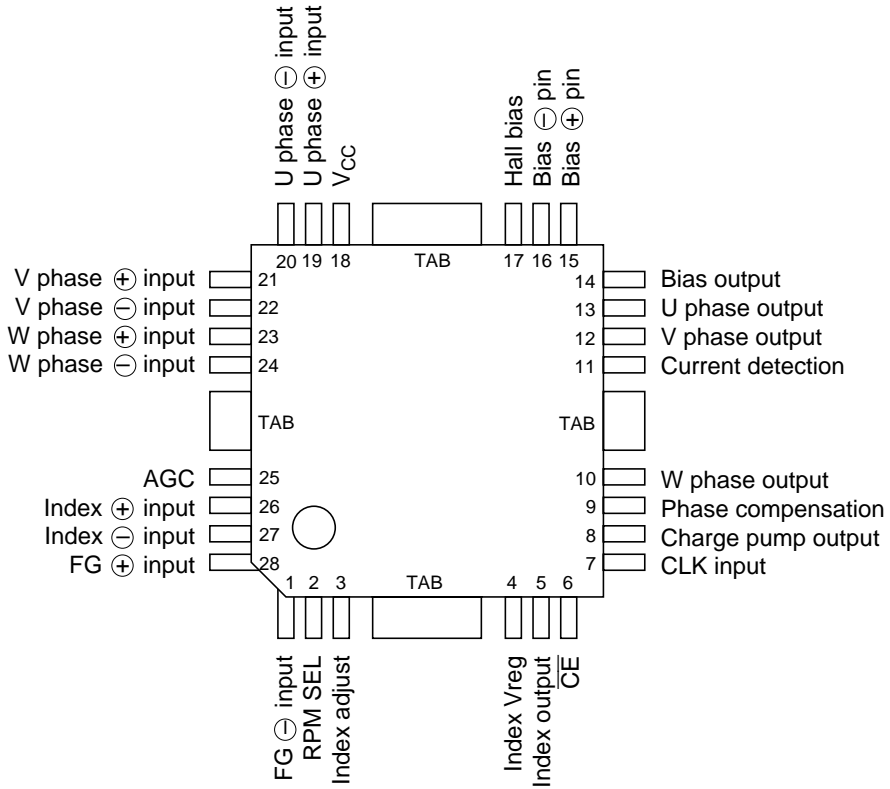
### Functions

- 1.0 A per phase, 3-phase drive circuit (current driver)
- Digital speed control circuit
- FG Amp
- Index circuit
- Current limiter circuit
- Over-temperature shutdown circuit (OTSD)

### Features

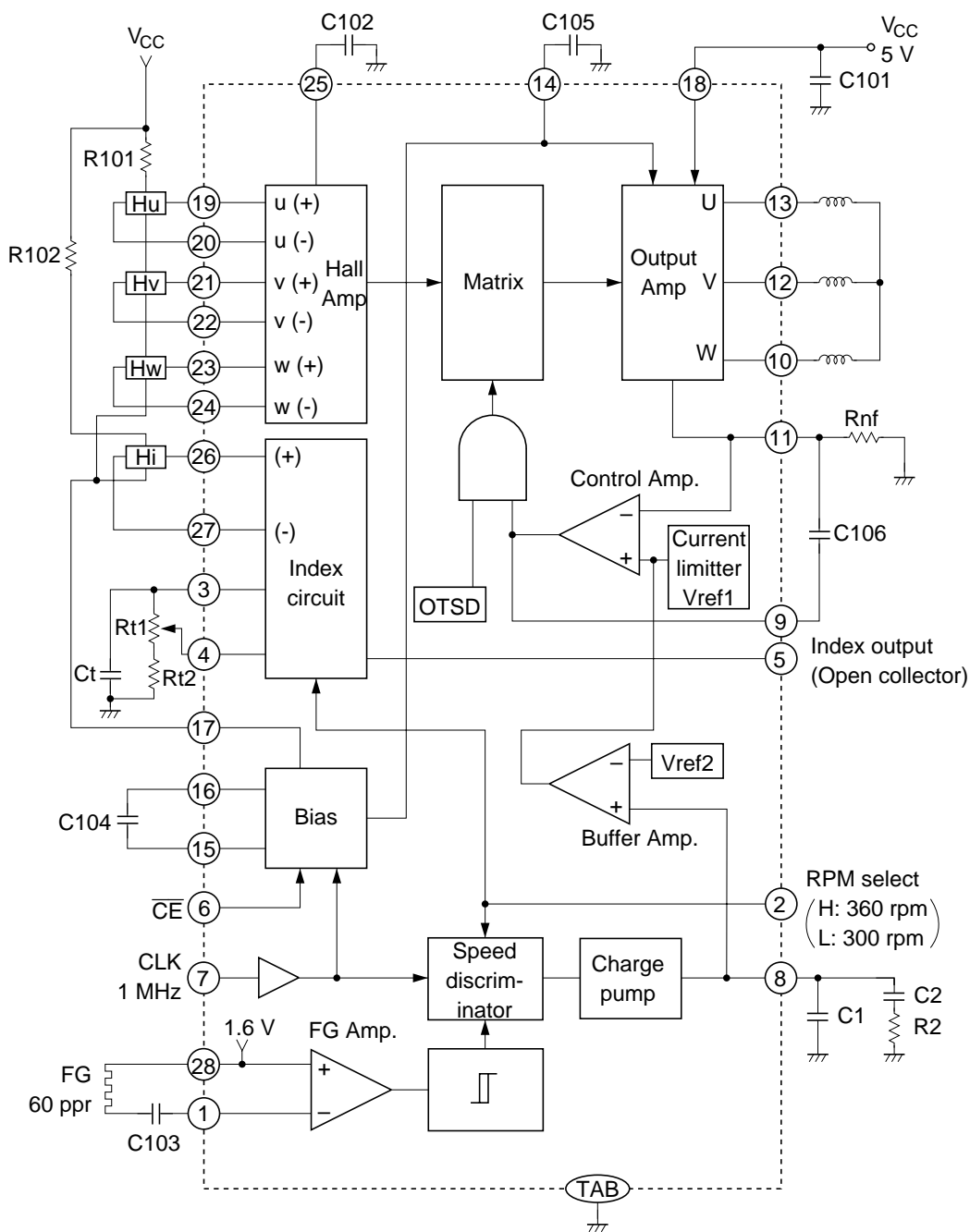
- Low saturation voltage, typically 1.15 V (at 0.7 A)
- Soft switching drive circuit
- No need for an output snubber circuit

## Pin Arrangement



(Top view)

Block Diagram



Note : Pin arrangement is preliminary specification.

**Pin Function**

Pin Number	Pin Name	Function	Pin Voltage
1	FG (-) input	FG Amp. (-) input terminal	
2	RPMSEL	Change terminal for motor rotation speed "L" → 300 rpm, "H" → 360 rpm	$V_{TH} = 1.4 \text{ V Typ}$
3	Index adjustment	Terminal to set up burst time of index circuit	0 V Min, 1.2 V Max
4	Index Vreg	Output terminal for fixed voltage of index circuit	1.5 V Typ
5	Index output	Index output terminal (Open collector)	$V_{OL} = 0.14 \text{ V Typ}$ (@ $I_o = 2 \text{ mA}$ )
6	$\overline{CE}$	Chip enable terminal "L": enable, "H": disable	$V_{TH} = 1.4 \text{ V Typ}$
7	CLK input	CLK input terminal	$V_{TH} = 1.4 \text{ V Typ}$
8	C-PUMP output	Speed error Integration and Phase compensation of speed control	
9	Phase compensation	To prevent the parasitic oscillation of output, insert the capacitor between pin 9 and pin 11.	
10	W phase output	W phase output	
11	Current detection	Output current detection and terminal which is connected with phase compensation capacitor for current control.	
12	V phase output	V phase output	
13	U phase output	U phase output	
14	Bias output	Bias output terminal	
15	Bias (+) pin	Bias (+) pin terminal	
16	Bias (-) pin	Bias (-) pin terminal	
17	Hall bias	Hall bias terminal $\overline{CE} = \text{"L"} \rightarrow \text{Bias}$ , $\overline{CE} = \text{"H"} \rightarrow \text{High impedance}$	2.2 V Typ (@ $I = 10 \text{ mA}$ )
18	$V_{CC}$	Power supply	4.25 V Min, 6.5 V Max
19	U phase (+) input	U phase (+) input terminal	2.0 V Min, $V_{CC} - 0.5 \text{ V Max}$
20	U phase (-) input	U phase (-) input terminal	2.0 V Min, $V_{CC} - 0.5 \text{ V Max}$
21	V phase (+) input	V phase (+) input terminal	2.0 V Min, $V_{CC} - 0.5 \text{ V Max}$
22	V phase (-) input	V phase (-) input terminal	2.0 V Min, $V_{CC} - 0.5 \text{ V Max}$
23	W phase (+) input	W phase (+) input terminal	2.0 V Min, $V_{CC} - 0.5 \text{ V Max}$
24	W phase (-) input	W phase (-) input terminal	2.0 V Min, $V_{CC} - 0.5 \text{ V Max}$
25	AGC	Hall amp output wave form adjustment terminal (Insert capacitor C102 between GND)	

## Pin Function (cont)

Pin Number	Pin Name	Function	Pin Voltage
26	Index (+) input	Index amp (+) input terminal	1.4 V Min, V <sub>CC</sub> – 0.5 V Max
27	Index (–) input	Index amp (–) input terminal	1.4 V Min, V <sub>CC</sub> – 0.5 V Max
28	FG (+) input	FG amp (+) input terminal	DC bias 1.6 V Typ

## External Parts

Part Number	Recommended Value	Purpose	Notes
R2	—	Integration constant	1
R101	—	Hall bias	
R102	—	Index hall bias	
Rnf	—	Current detection and limitation	2
Rt1	0 to 50 kΩ	Index burst adjustment	3
Rt2	100 kΩ	Index pulse width setting	
C1, C2	—	Integration constants	1
C101	≥ 0.1 μF	Power supply bypass	4
C102	0.1 μF	AGC filter	5
C103	0.47 μF	FG amp. coupling	5
C104	0.1 μF	Bias	
C105	≥ 0.1 μF	Bias	7
C106	0.1 μF	Phase compensation	4
Ct	0.1 μF	Index setting	3, 6

Notes: 1. Determine the integration constants from the following formulas:

$$\omega_0 \leq \frac{2\pi f_{FG}}{20} \quad (\text{rad/s})$$

$$R2 = \frac{1}{9.55} \frac{J\omega_0 N_0 \cdot Rnf}{K_T Gctl I_{cp}} \quad (\Omega)$$

$$C1 = \frac{1}{\sqrt{10}} \frac{1}{\omega_0 R2} \quad (F)$$

$$C2 = 10C1 \quad (F)$$

In the above formulas:

$\omega_o$  = Time constant of servo loop

$f_{FG}$  = FG frequency in Hz

$N_o$  = Motor speed in rpm

$J$  = Motor moment of inertia in  $kg \cdot cm^2$

$K_T$  = Motor torque constant in  $kg \cdot cm/A$

Rnf = Current detection in  $\Omega$

Gctl= Control amp gain (see Electrical Characteristics)

Icp = Charge pump output current (see Electrical Characteristics)

2. The current limiter operates according to the following formula:

$$I_{OMAX} = \frac{Vref1}{Rnf} \quad (A)$$

where Vref1 is the current limiter reference voltage (see Electrical Characteristics)

3. The burst time t1 is defined as follows:

$$t1 \approx - Ct \times Rt1' \times \ln (1 - Vth1 (L) / Vreg) \quad (RPM \text{ select input low})$$

$$t1 \approx - Ct \times Rt1' \times \ln (1 - Vth1 (H) / Vreg) \quad (RPM \text{ select input high})$$

where Rt1' is resistance value inter 3 to 4 pin.

4. Place as close to the IC as possible.

5. Determine C102 and C103 according to the following formulas:

$$C102 \geq \frac{200}{N_o P} \quad (\mu F)$$

$$C103 \geq \frac{100}{f_{FG}} \quad (\mu F)$$

where

P = Number of motor poles

6. The index pulse width t2 is determined as follows:

$$t2 \approx - Ct \times Rt2' \times \ln (Vth1 / Vth2)$$

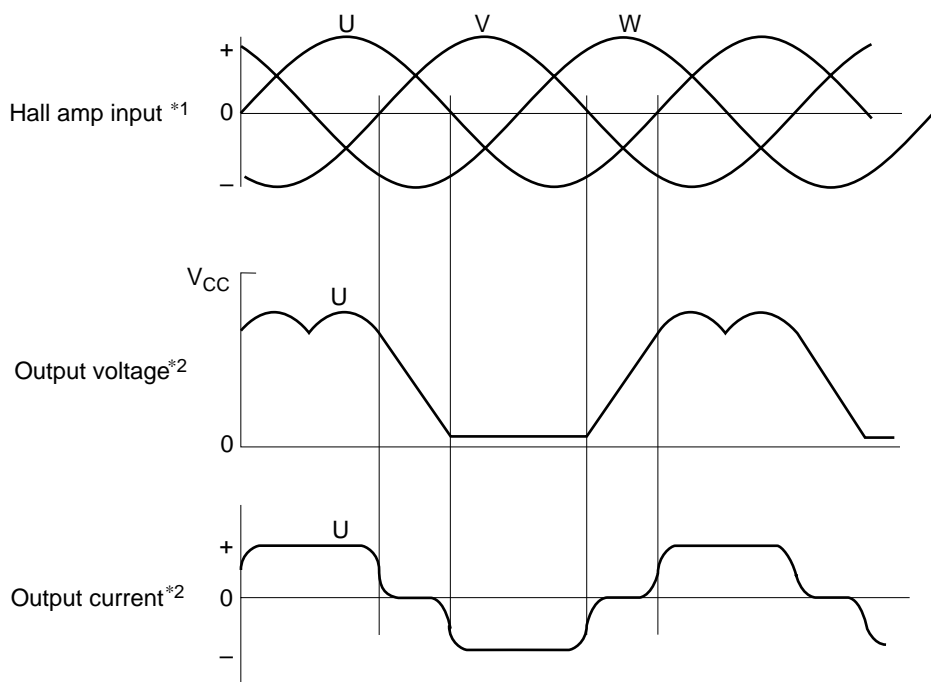
where Vth2 is the threshold voltage (see Electrical Characteristics).

Rt2' : Rt1 (max) + Rt2

7. If the circuit is affected by noise, a large capacitance value should be set.

## Timing Waveforms

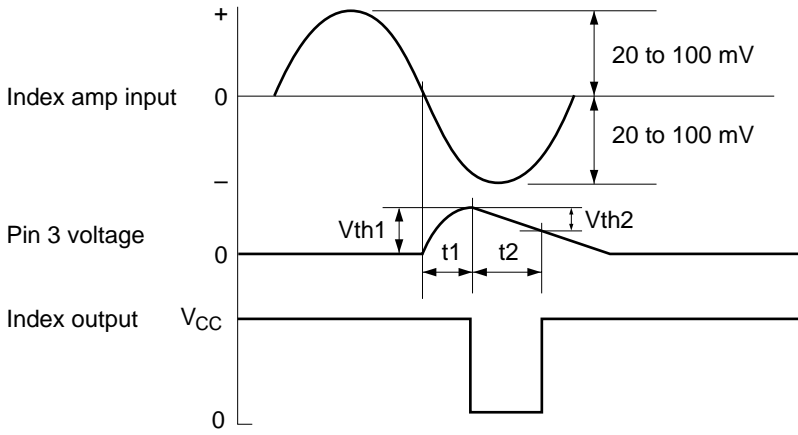
### Hall Amp Input vs. Output Voltage and Current



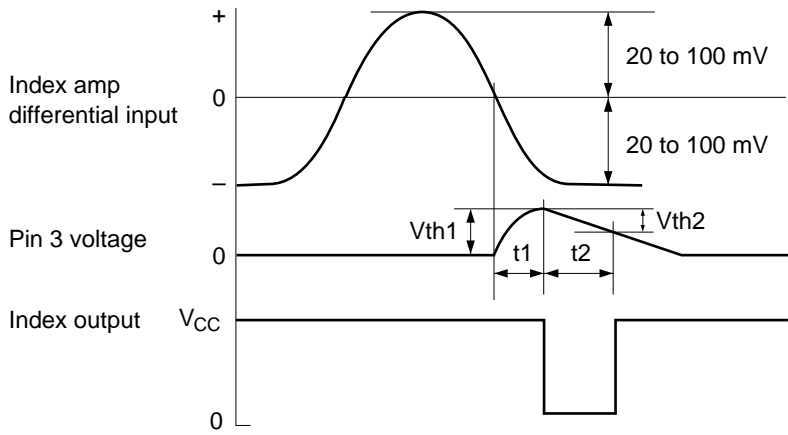
- Notes:
1. The input waveforms to the hall amp should be sine waves with a third harmonic content of less than 20%.
  2. Only the U phase output is shown.

## Index Amp Input vs. Output

- Application 1



- Application 2





**Absolute Maximum Ratings** ( $T_a = 25^\circ\text{C}$ )

Item	Symbol	Value	Unit	Notes
Power supply voltage	$V_{CC}$	7	V	1
Input voltage	$V_{in}$	0 to $V_{CC} + 0.3$	V	2
Peak output current	$I_{OP}$	1.0	A	
Normal output current	$I_O$	0.7	A	
Power dissipation	$P_T$	1.5	W	3
Junction temperature	$T_j$	+150	$^\circ\text{C}$	1
Storage temperature range	$T_{stg}$	-55 to +125	$^\circ\text{C}$	

Notes: 1. The operating ranges is:

$$V_{CC} = 4.25 \text{ to } 6.5 \text{ V}$$

$$T_{jopr} = 0 \text{ to } +125^\circ\text{C}$$

2. Applied to the  $\overline{CE}$ , CLK, and RPM SEL pins.

3. Permissible value when  $T_{pin} = 113^\circ\text{C}$  and thermal resistance is as follows:

$$\theta_{F-pin} \leq 25^\circ\text{C/W}$$

$$\theta_{J-a1} \leq 55^\circ\text{C/W} \text{ (when mounted on a metal substrate)}$$

$$\theta_{J-a2} \leq 80^\circ\text{C/W} \text{ (when mounted on a glass epoxy subtrade)}$$

## Electrical Characteristics (Ta = 25°C, V<sub>CC</sub> = 5 V)

Item	Symbol	Min	Typ	Max	Unit	Test conditions	Pin Nos.	Notes	
Quiescent current	I <sub>CCO</sub>	—	—	0.45	mA	$\overline{CE} = H, V_{CC} = 6.5 V$	18		
	I <sub>CC</sub>	—	9	13	mA	$\overline{CE} = L, V_{CC} = 6.5 V$			
Logic input	Input current I <sub>I1</sub> (6 pin)	-80	—	2	μA	$\overline{VCE} = 0 \text{ to } 6.5 V$	2, 6, 7		
	Input current I <sub>I2</sub> (2 pin)	-2	—	100	μA	V <sub>RPM</sub> = 5.5 V			
	Input current I <sub>I3</sub> (7 pin)	-2	—	450	μA	V <sub>CLK</sub> = 5.5 V			
	Input low voltage	V <sub>IL</sub>	0	—	0.8	V			
	Input high voltage	V <sub>IH</sub>	2.0	—	5.5	V			
Logic output	Output low voltage	V <sub>OL</sub>	—	0.4	V	I <sub>O</sub> = 2 mA	5		
	Leakage current	I <sub>OH</sub>	—	±10	μA	V <sub>CE</sub> = 7.0 V			
Hall amp	Input resistance	R <sub>hi</sub>	7	10	13	kΩ		19 to 24	
	Common-mode input voltage range	V <sub>H</sub>	2.0	—	V <sub>CC</sub> - 0.5	V			
	Differential input voltage range	V <sub>h</sub>	30	—	160	mV <sub>pp</sub>			
Output amp	Leakage current	I <sub>CER(H)</sub>	0	—	5	mA	V <sub>O</sub> = 7.0 V	10, 12, 13	
		I <sub>CER(L)</sub>	—	—	±100	μA	V <sub>O</sub> = 0 V		
	Saturation voltage	V <sub>sat1</sub>	—	1.15	1.65	V	I <sub>O</sub> = 0.7 A		1
		V <sub>sat2</sub>	—	0.6	0.85	V	I <sub>O</sub> = 0.35 A		
FG amp and detector	Input voltage range	V <sub>fg</sub>	2	—	20	mV <sub>pp</sub>		1, 28	
	Noise margin	nd	—	—	0.5	mV <sub>pp</sub>	Differential Noise		
		nc	—	—	0.5	V	COMMON Noise		

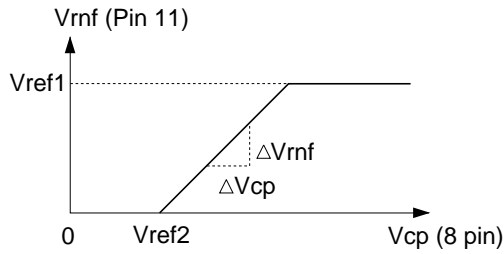
Electrical Characteristics (Ta = 25°C, V<sub>CC</sub> = 5 V) (cont)

Item	Symbol	Min	Typ	Max	Unit	Test conditions	Pin Nos.	Notes	
Speed discriminator and charge pump	Number of counts	N	—	1666.5	—	—	PRMSEL = L		
		—	1388.5	—	—	PRMSEL = H			
	Operating frequency	f <sub>CLK</sub>	0.9	1.0	1.1	MHz		7	
	Leakage current	I <sub>off</sub>	—	—	±50	nA	V <sub>8</sub> = 0.8 V	8	
	Output current	I <sub>cp+</sub>	7	10	13	μA	Speed reduction full scale		
I <sub>cp-</sub>		-7	-10	-13	μA	Acceleration full scale			
Current control	Threshold voltage	V <sub>ref2</sub>	0.55	0.63	0.71	V		8	2
	Voltage gain	G <sub>ctl</sub>	-12	-10	-8	dB		11	
	Current limiter voltage	V <sub>ref1</sub>	157	175	193	mV	R <sub>NF</sub> = 0.47 Ω		
Index circuit	Input voltage (common)	V <sub>index</sub>	1.4	—	V <sub>CC</sub> - 0.5	V		26, 27	3
	Input voltage (different)	V <sub>index</sub>	40	—	300	mV <sub>pp</sub>			
	Hysteresis	hys	—	14	—	mV			
	Input current		—	—	±2	μA			3
	Threshold voltage	V <sub>th1</sub>	0.60 × V <sub>reg</sub>	0.64 × V <sub>reg</sub>	0.68 × V <sub>reg</sub>	V	RPM select = L		
			0.54 × V <sub>reg</sub>	0.58 × V <sub>reg</sub>	0.62 × V <sub>reg</sub>	V	RPM select = H		
	Ct discharge threshold voltage	V <sub>th2</sub>	0.50 × V <sub>reg</sub>	0.54 × V <sub>reg</sub>	0.58 × V <sub>reg</sub>	V	RPMSEL = L	3	3
			0.44 × V <sub>reg</sub>	0.48 × V <sub>reg</sub>	0.52 × V <sub>reg</sub>	V	RPMSEL = H		
Bias	V <sub>reg</sub>	1.3	1.5	1.7	V	I <sub>o</sub> = -0.2 mA	4		
Hall bias	Output voltage	V <sub>hb</sub>	1.9	2.2	2.5	V	I <sub>h</sub> = 10 mA, $\overline{CE}$ = L	17	

## Electrical Characteristics (Ta = 25°C, V<sub>CC</sub> = 5 V) (cont)

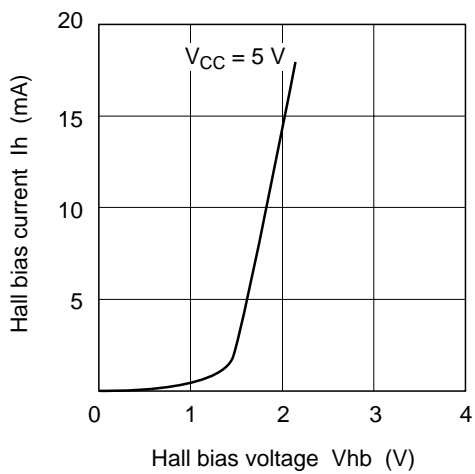
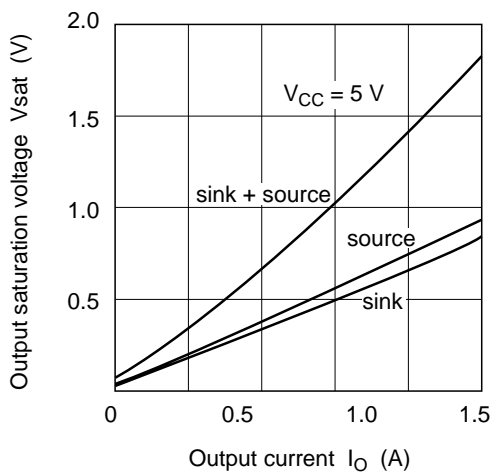
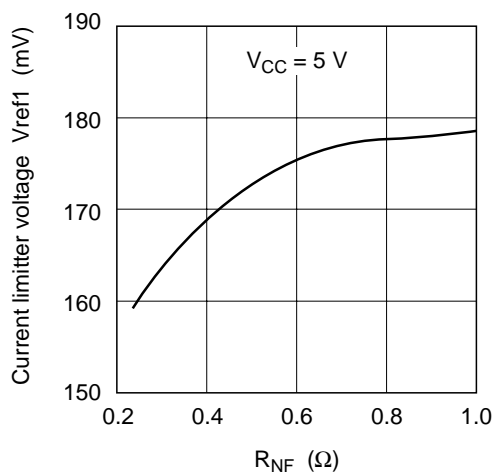
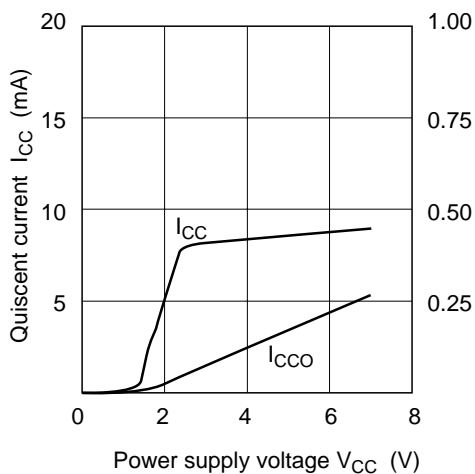
Item		Symbol	Min	Typ	Max	Unit	Test conditions	Pin Nos.	Notes
Hall bias	Leakage current	I <sub>hof</sub>	—	—	±10	μA	$\overline{CE} = H, V_{hb} = 7.0\text{ V}$	17	
OTSD	Operating temperature	T <sub>sd</sub>	125	150	—	°C			4

- Notes:
1. Total of sink and source.
  2. See figure 1.  $G_{ct1} = \Delta V_{rnf} / \Delta V_{cp}$ .
  3. Refer to the timing chart.
  4. Design parameter only (No test).

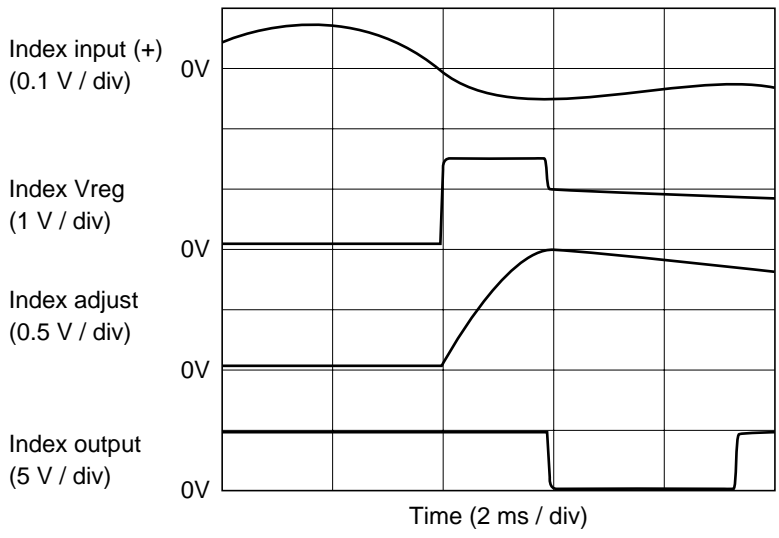
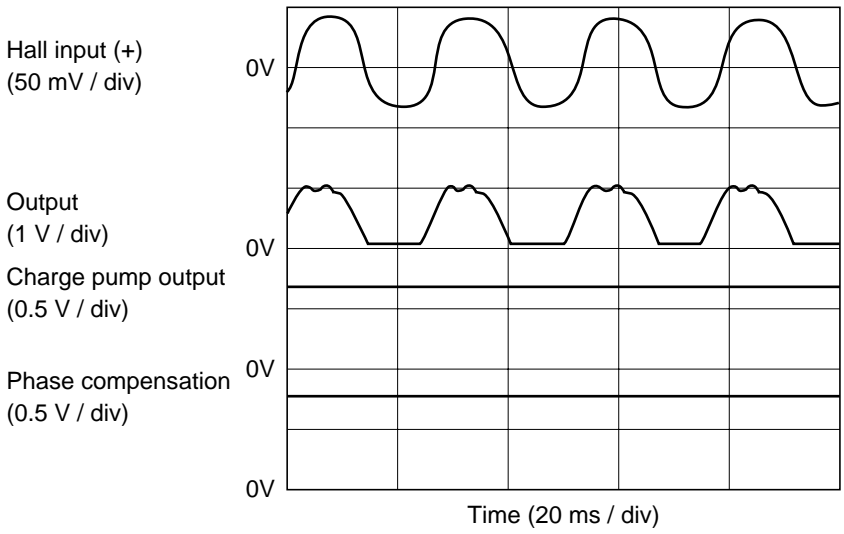


**Figure 1**

Reference Data

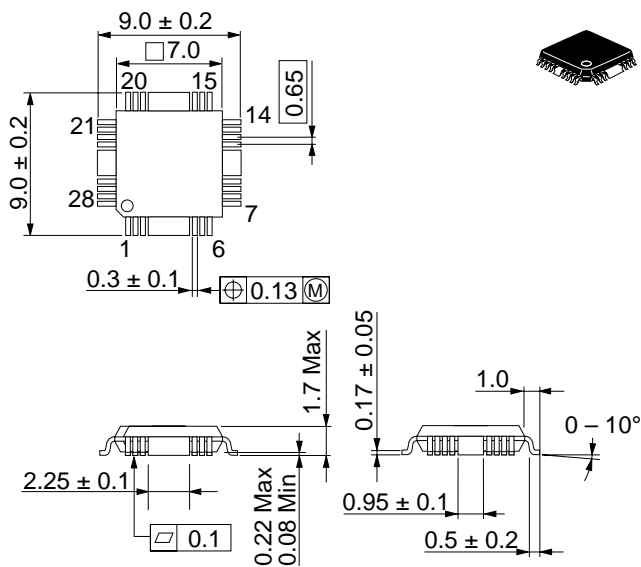


Mount Waveform Characteristics



Package Dimensions

Unit: mm



Hitachi code	FP-28T
EIAJ code	—
JEDEC code	—

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