HA13605A

Three-Phase Brushless Motor Driver

HITACHI

ADE-207-201A (Z)
2nd. Edition
February, 1998

Description

The HA13605A is a three-phase brushless motor driver IC that provides digital speed control on chip. It was developed for use as the drum motor driver in plain paper copiers and has the following functions and features.

Functions

- Three-phase output circuit that can provide a maximum of 4.5 A at 35 V per phase
- Digital speed control
- Crystal oscillator circuit (10 MHz maximum)
- FG amplifier
- Speed monitor (lock detection output)
- Current control circuit
- Overvoltage protection circuit (OVSD)
- Thermal protection circuit (OTSD)
- Low voltage protection circuit (LVI)
- Forward/reverse switching circuit

Features

- High breakdown voltage, large currents
- Direct PWM drive outputs
- Employs DMOS
- Low on resistance: 0.7 Ω/DMOS maximum
- No lower arm flywheel diode is required

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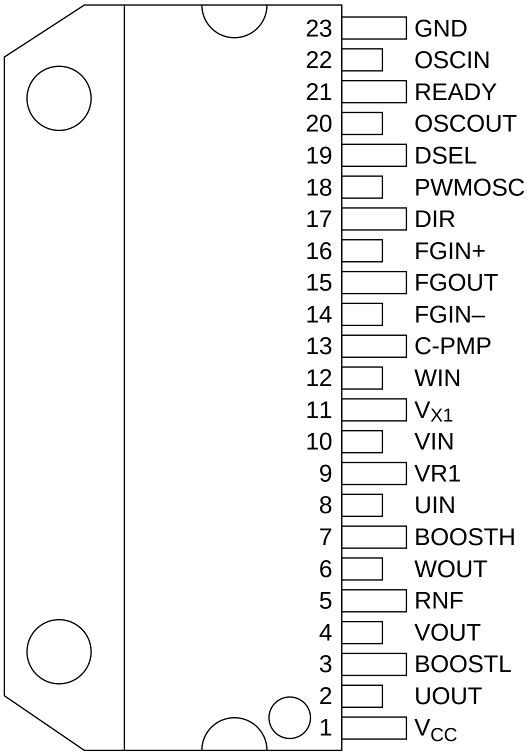
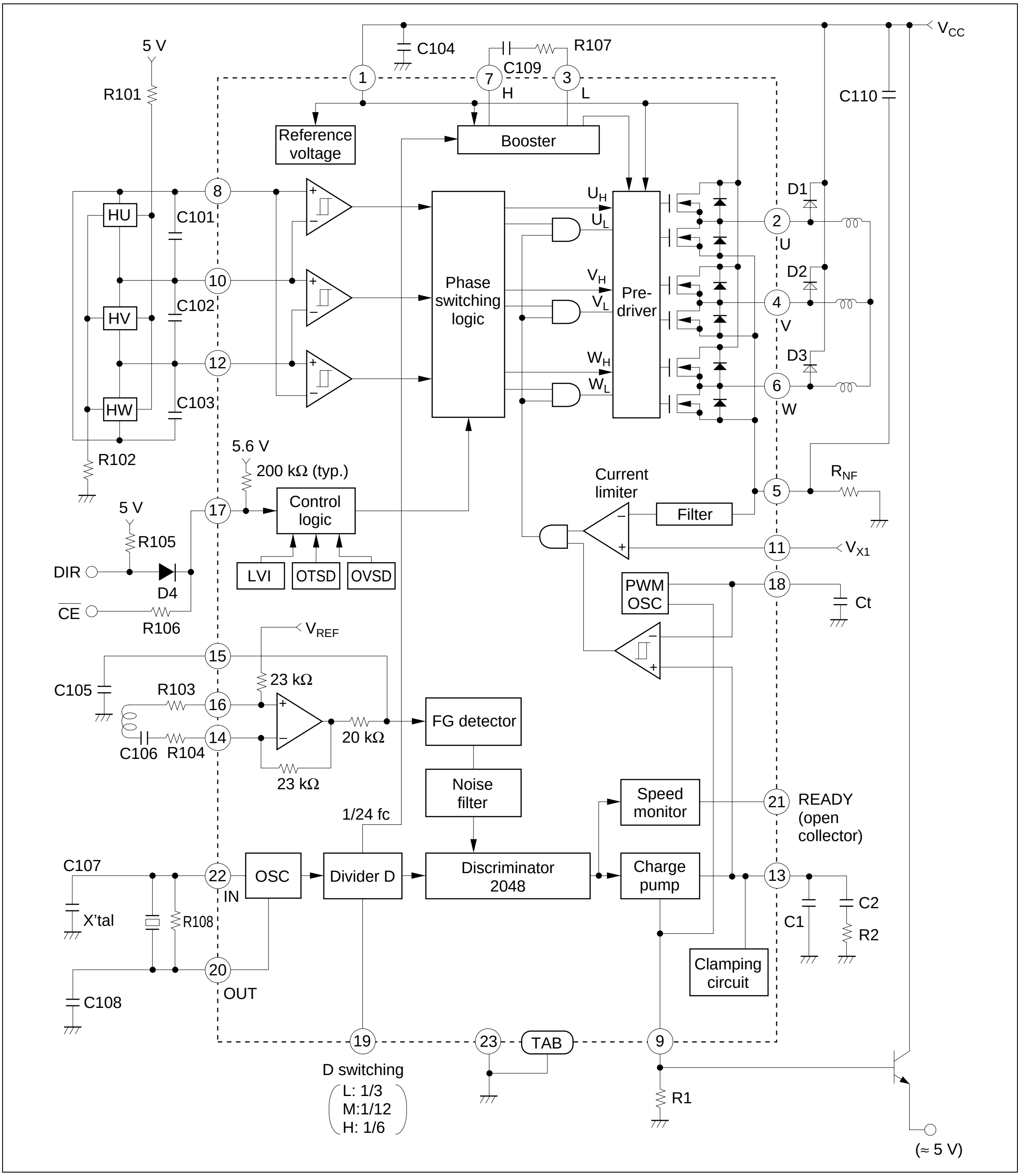
Pin Description

Pin No.	Pin Name	Function
1	V_{CC}	Power supply
2	UOUT	U phase output
3	BOOSTL	Booster pin. (Low side)
4	VOUT	V phase output
5	RNF	Output current detection
6	WOUT	W phase output
7	BOOSTH	Booster pin. (High side)
8	UIN	U phase input
9	VR1	Charge pump reference voltage pin.
10	VIN	V phase input
11	V_{X1}	Output current control voltage input pin.
12	WIN	W phase input
13	C-PMP	Charge pump output pin. Speed error integration and phase compensation of speed control.
14	FGIN-	FG Amp. (-) input pin
15	FGOUT	FG Amp. output pin
16	FGIN+	FG Amp. (+) input pin
17	DIR	Direction, Rotation direction set up pin
18	PWMOSC	PWM oscillator input pin. Set oscillator frequency.
19	DSEL	Divide select pin (L : 1/3, M : 1/12, M : 1/6)
20	OSCOUT	Oscillator output
21	READY	Ready pin. Speed monitor pin. (open-collector)
22	OSCIN	Oscillator input
23	GND	Ground

Pin Arrangement

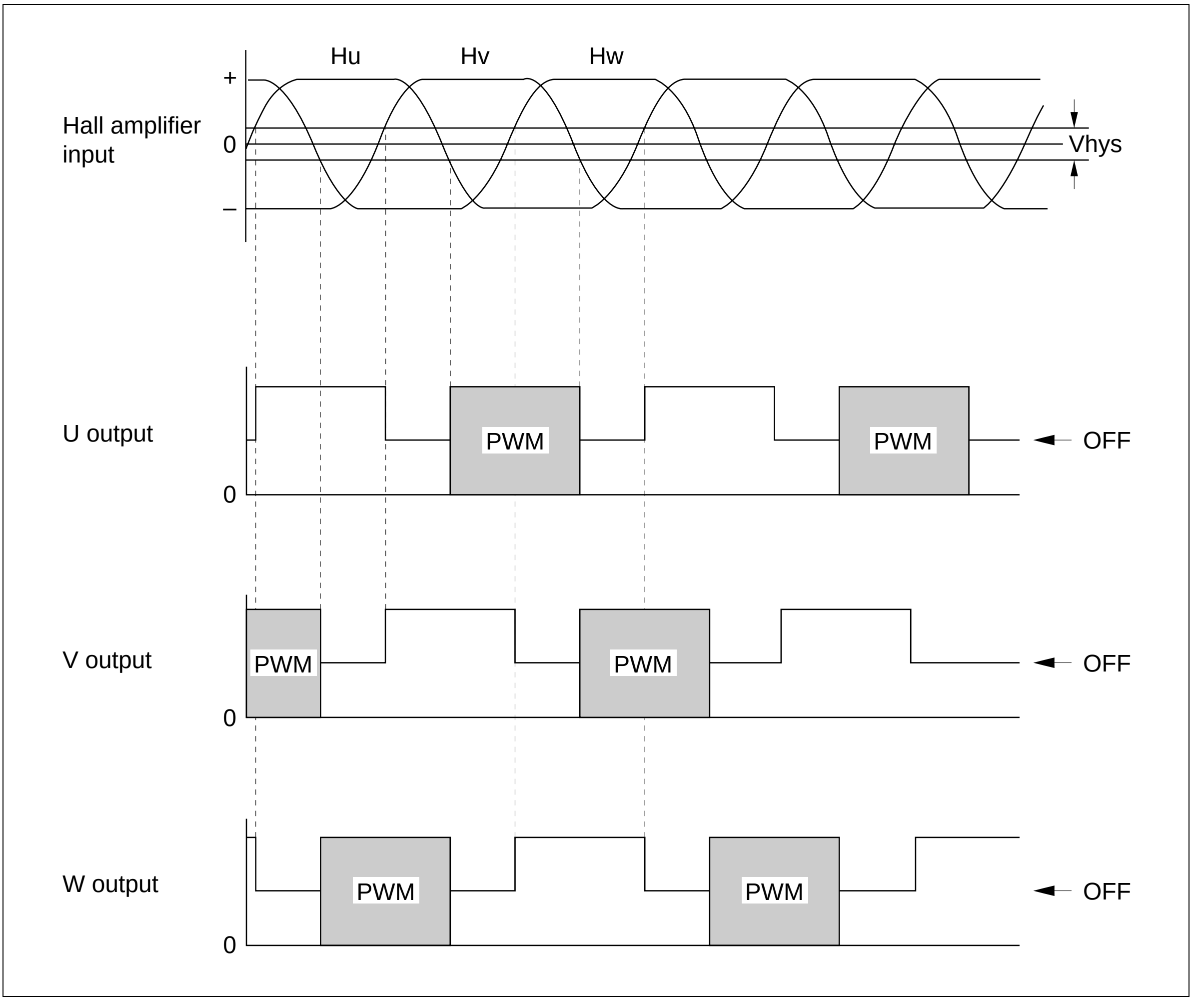


Block Diagram

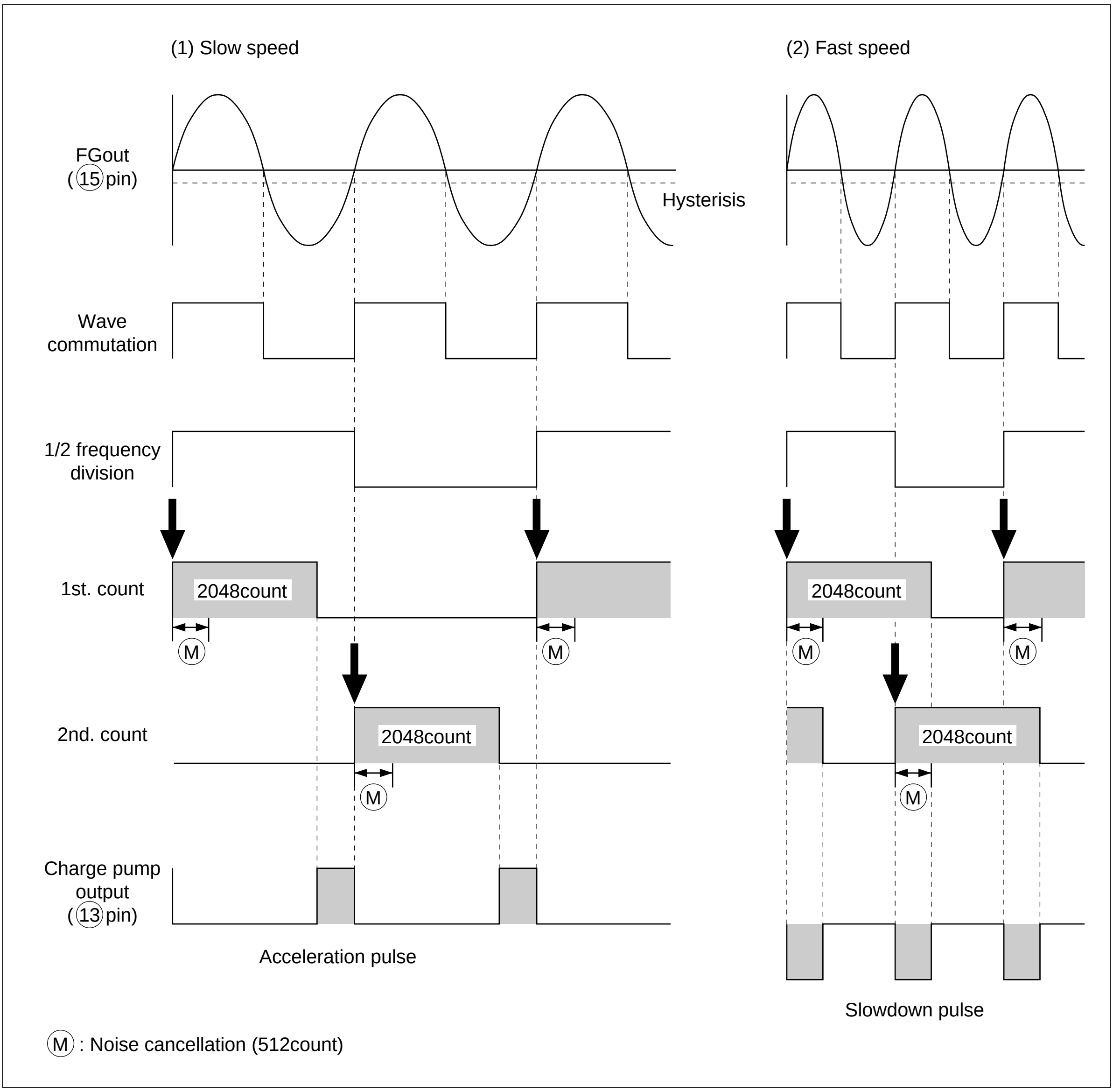


Timing Chart

FWD Mode



Speed control



Truth Value Table

	Hall Amplifier Input			Output		
DIR Input	U-V	V-W	W-U	U	V	W
H (stop)	X	X	X	Z	Z	Z
M (reverse)	H	L	H	PWM	H	Z
	H	L	L	PWM	Z	H
	H	H	L	Z	PWM	H
	L	H	L	H	PWM	Z
	L	H	H	H	Z	PWM
	L	L	H	Z	H	PWM
L (forward)	H	L	H	H	PWM	Z
	H	L	L	H	Z	PWM
	H	H	L	Z	H	PWM
	L	H	L	PWM	H	Z
	L	H	H	PWM	Z	H
	L	L	H	Z	PWM	H

Divider Selector

DSEL	D
H	1/6
M	1/12
L	1/3

External Components

Part No.	Recommended Value	Purpose	Notes
R1, R2	—	Integration constants	1
R101, R102	—	Hall bias	9
R103, R104	—	FG amplifier gain setting	2, 8
R105, R106	10 kΩ	Used in interfacing	
R107	4.7 kΩ	Booster stabilization	11
R108	—	Oscillator feedback resistor	10
R_{NF}	—	Current detection	3
C1, C2	—	Integration constants	1
C101, C102, C103	0.047 µF	Stabilization	
C104	≥ 0.1 µF	Power supply bypass	
C105	—	Determines the FG amplifier band	5
C106	—	FG amplifier AC coupling	6
C107, C108	—	Oscillator circuit elements	10
C109	≥ 300 pF	Booster capacitance	11
C110	≥ 47 µF	Stabilization	
Ct	—	PWM oscillator time constant	4
X'tal	—	CLK oscillator	7
D1, D2, D3	—	Regenerative current path	
D4	—	Used in interfacing	

Notes: 1. Use the following formulas to determine target values for these constants.

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

$$\frac{R2}{R1} = \frac{7.7 J \omega_O No Rm Vosc}{K_T V_{R1} (2Vps - 0.83V_E)}$$

$$3.0 \text{ k}\Omega \leq R1 \leq 15 \text{ k}\Omega$$

$$C1 = \frac{1}{\sqrt{10}} \cdot \frac{1}{\omega_O R2} \quad \text{(F)}$$

$$C2 = 10C1 \quad \text{(F)}$$

Where:

ωo:	Control loop angular frequency	
f_{FG}:	FG frequency	(Hz)
J:	Moment of inertia of the motor	$(kg \cdot m^2)$
No:	Rotation speed	(rad/s)
Rm:	Motor coil resistance	(Ω/T•T)
K_T:	Torque constant	(N•m/A)
V_E:	Motor reverse voltage at speed No	(V_{PP}/T•T)
Vps:	Power supply voltage	(V)
Vosc:	PWM oscillator amplitude	2.2 (V_{PP}: See the electrical characteristics table.)

V_{R1}: Charge pump reference voltage 5.6 (V: See the electrical characteristics table.)

2. The voltage gain (Gfg) of the FG amplifier is determined by the following formula. Here Rfgf is the internal feedback resistance. See the electrical characteristics table.

   However, note that R103 must be equal to R104.

$$Gfg = \frac{Rfgf}{R103}$$

3. The output current limit is given by the following formula.

$$Iomax = \frac{(V_{X1} - 25\ mV)}{Rnf} \quad (A)$$

4. The PWM carrier frequency is determined by the following formula. Here VR1 and K are the charge pump voltage and the oscillator amplitude (see the electrical characteristics table), respectively.

$$f_P \doteqdot \frac{VR1}{KCt\ R1\ V_{OSC}} \quad (Hz)$$

5. The FG amplifier bandwidth BW is determined by the following formula. Here Rfgo is the pin 15 output resistance. See the electrical characteristics table.

   However, when C105 is 0, BW is limited to 8 kHz by the internal capacitance.

$$BW = \frac{1}{2\pi\ C105\ Rfgo} \quad (Hz)$$

6. Determine C106 using the following formula as a rough estimate.

$$C106 \geq \frac{1}{\pi(R103 + R104)\ f_{FG}} \quad (F)$$

   Consult with the oscillator element manufacturer.

7. Relationship of between the CLK frequency fc and the FG frequency f_{FG}. Are determined by the under table.

D	fc (Hz)
1/3	$2048.5 \bullet \frac{f_{FG}}{D}$ But rotation response is 80 ppm down
1/6 1/12	$2048.5 \bullet \frac{f_{FG}}{D}$

8. If an input of $1.25/G_{FG}$ (Vp-p) or higher is applied, irregular rotation may occur due to FG amplifier saturation.
9. The absolute value of the whole amplifier input voltage must be within the in-phase input voltage range.
10. This should be decided after consultation with the oscillator manufacturer.
11. Determine C109 using the following formula as a rough estimate.

$$3\ k\Omega \leq R107 \leq 6\ k\Omega$$

$$300pF < C109 \leq \frac{20}{Fc\ (R108 + 200\ \Omega)} \quad (F)$$

12. TAB should be connected to pin 23 (GND). The FG amplifier may not operate normally, causing irregular rotation, due to parasitism during phase switching.

Absolute Maximum Ratings (Ta = 25°C)

Item	Symbol	Rated Value	Unit	Notes
Power supply voltage	V_{CC}	45	V	1
Input voltage (1)	Vin(1)	–0.3 to 6	V	2
Input voltage (2)	Vin(2)	–0.3 to 6	V	3
Instantaneous output current	Iomax	4.5 (@T ≤ 400 ms)	A	4
Steady state output current	Iout(1)	1.5	A	4
Logic output current	Iout(2)	10	mA	5
Output voltage	Vout	15	V	5
Allowable power dissipation	P_T	25 (@Tc = 112°C)	W	6
Operating junction temperature	Tjopr	–10 to +125	°C	
Storage temperature	Tstg	–55 to +125	°C	

Notes: 1. The operating voltage range is as shown below.
V_{CC} = 20 to 35 V
2. Applies to the hall amplifier. (Pin 8, Pin 10, Pin 12)
3. Applies to the DIR input pin (Pin 17) and the D switchover input pin (Pin 19).
4. Applies to the U, V, and W output pins (Pins 2, 4, and 6). The operation locus of each TRS must not exceed the ASO range shown in figure 1.
However, there is no particular regulation concerning the recovery current. Refer to figure 2 for the temperature rise in the event of rush.
5. Applies to the speed monitor output (Pin 21).
6. The package thermal resistances are shown below.
θj-c ≤ 1.5°C/W (with an arbitrarily large heat sink)
θj-a ≤ 35°C/W (when mounted on a glass-epoxy PC board)

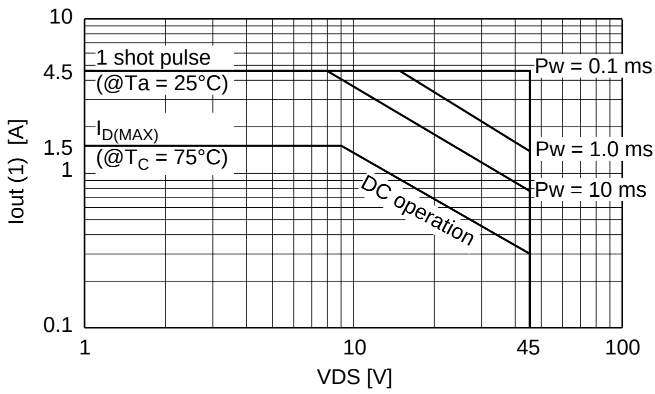


Figure 1 ASO Range

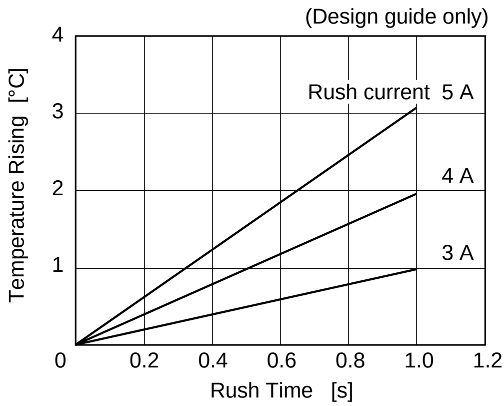


Figure 2 Rush Time vs. Temperature Rising

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

Item		Symbol	Min	Typ	Max	Unit	Test Conditions	Applicable Pins	Notes
Current drain		Icc(1)	—	—	18	mA	V_{CC} = 35 V R1 = 5.6 kΩ		
		Icc(2)	—	—	20	mA	V_{CC} = 45 V		
Hall amplifier	Input current	Ih	—	—	±20	mA		8, 10, 12	
	Common mode input voltage range	Vhc	1.5	2.5	3.5	V			
	Differential mode input voltage range	Vhd	50	—	1000	mV_{PP}			
Output amplifier	Leakage current	Icer	—	—	3	mA	Vds = 35 V	2, 4, 6	
	On resistance	Rdson	—	0.5	0.7	Ω	Io = 1.5 A, Tj = 25°C		1
	Diode voltage	Vfl	—	1.2	2.0	V	I_F = 1.5 A, lower arm		
		Vfu	0.8	1.2	—	V	I_F = 1.5 A, upper arm		
PWM oscillator & Com-parator	Low level voltage	Vl	1.10	1.30	1.50	V		18	
	Oscillator amplitude	Vosc	2.0	2.2	2.4	V_{PP}			
	Correct coefficient	K	12	14	16	—	R1 = 5.6 kΩ		
FG amplifier and FG detector	Input voltage range	Vfg	8	—	300	mV_{PP}	Gfg = 32 dB, R103, R104 = 580 Ω	14, 16	
	Differential noise margin	nd	—	—	1.25	mV_{PP}	Gfg = 32 dB, R103, R104 = 580 Ω,		
	Common noise margin	nc	1.0	—	—	V_{PP}	f = 1kHz		
CLK OSC	Oscillator frequency range	fc	1.0	—	10.0	MHz	Crystal oscillator	20, 22	
Discrimi-nator	Count	N	—	2048	—	—			
	Operating frequency range	fdis	—	—	3.0	MHz			2
Charge pump	R1 voltage	V_{R1}	5.1	5.6	6.1	V	R1 = 5.6 kΩ		3
	Charge current	Icp	0.117	0.130	0.143	A/A	Vo = 1.5 V,	13	4
	Discharge current	Icd	–0.117	–0.130	–0.143	A/A	R1 = 5.6 kΩ		
	Current ratio	IR	0.8	1.0	1.2	A/A	Icp/Icd		
	Leakage current	Ioff	—	—	±50	nA	Vo = 3.5 V		
	Clamp voltage	Vcrmp	4.00	4.25	4.50	V	Icp = 50 mA		

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

Item		Symbol	Min	Typ	Max	Unit	Test Conditions	Applicable Pins	Notes
Speed monitor	Locking range	ΔNo	—	±5	—	%		21	5
	Output low level voltage	Vol2	—	—	0.4	V	Io = –10 mA		
	Output leakage current	Icer2	—	—	±10	µA	Vce = 15 V		
Current limiter	Input current	Icl	—	—	±10	µA	Vx1 = 0 to 2 V	11	
	Offset voltage	Vclos	–10	–25	–40	mV	Vx1 = 0.5 to 2 V		
LVI	Operating voltage	Vsd	—	—	20	V	Turn on	1	
OVSD	Operating voltage	Vovs	35	—	—	V	Turn on	1	
OTSD	Operating temperature	Tsd	125	160	—	—			9
	Hysteresis	Thys	—	15	—	—			
Input interface	Input current	Ii1, Ii2	–10	—	40	µA	Vin = –0.3 V to 5.25 V		
	DIR Input low voltage	Vil1	—	—	1.2	V			
	DIR Input middle voltage	Vim1	1.7	—	3.2	V			
	DIR Input high voltage	Vih1	3.7	—	—	V			
	D Input low voltage	Vil2	—	—	1.5	V			
	D Input middle voltage	Vim2	2.0	—	2.8	V			
	D Input high voltage	Vih2	3.5	—	—	V			
Hall amp.	Hysteresis	Uhys	—	20	—	mV	Rh = 400 Ω		6, 9
Power drive	Transient response time	tphl1	—	—	1	µs	at PWM		7, 9
		tplh1	—	—	1	µs	at PWM		
		tr, tf	—	—	300	ns	at PWM		
Filter	Noise cancellation range	Tn1	—	1.0	—	µs			9
PWMOSC & comp-arator	Oscillation frequency range	fp	2	—	20	kHz			9
	Comparator hysteresis	Vphys	—	50	—	mV			9

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

Item		Symbol	Min	Typ	Max	Unit	Test Conditions	Applicable Pins	Notes
FG amp. & FG detector	Feedback resistance	Rfgf	—	23	—	kΩ			9
	Output resistance	Rfgo	—	20	—	kΩ			9
	Hysteresis	VZXhys	—	–80	—	mV			9
CLK OSC	Frequency error	Dfc	—	—	±0.01	%	Crystal oscillator		9
	Threshold voltage	Vfth	—	2.7	—	V			9
	Oscillation amplitude	Vfc	—	5.6	—	Vpp			9
OVSD	Hysteresis	OVDhys	—	1.5	—	V			9
LVI	Hysteresis	Lhys	—	1.0	—	V			9
Noise filter	Noise cancellation range	Tn2	—	3.0	—	µs	fc = 4 MHz, D = 1/6		8, 9

Notes: 1. The on resistance per single MOS transistor.
2. Stipulated for the discriminator input.
3. See figure 3. See figure 4.
4. Specified as a ratio to the R1 current.
5. The speed monitor output is low when the motor is at the set speed.
6. See figure timing chart.
7. See figure 5.
8. Refer to the operation and the formula for determining the maximum cancelable noise width Tn (figure 6).
Noise cancellation is effective only when the FG detector output is low.
9. Design guide only.

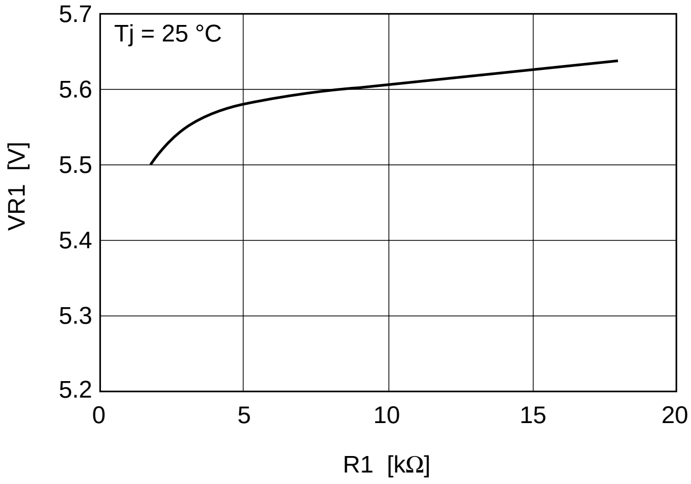


Figure 3 VR1-R1 Characteristics

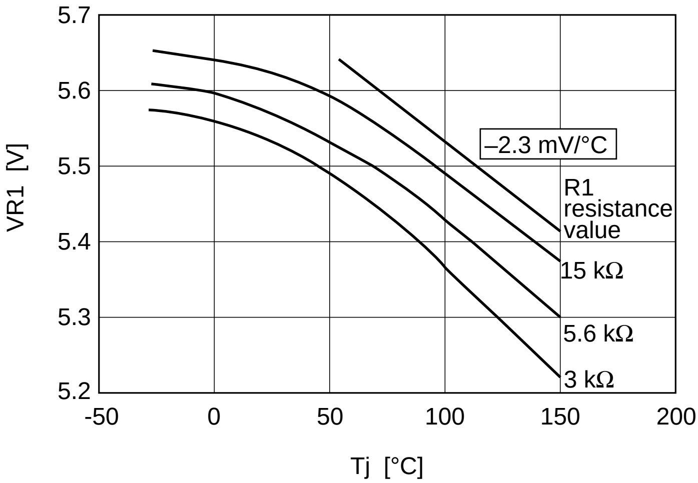


Figure 4 VR1 Temperature Characteristics

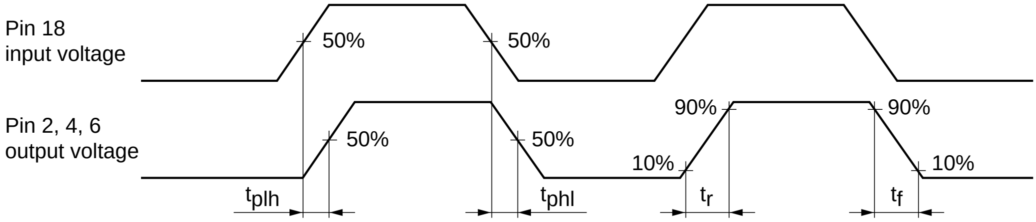


Figure 5

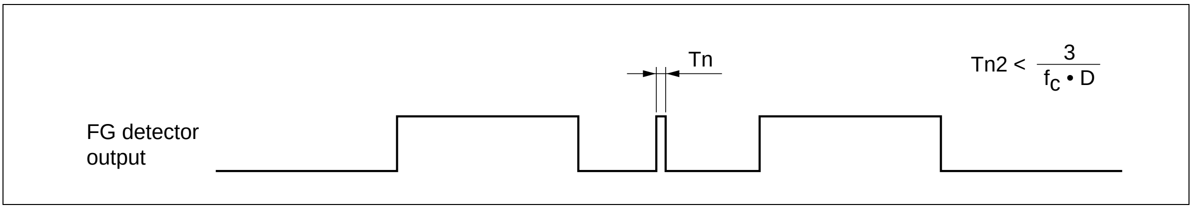


Figure 6

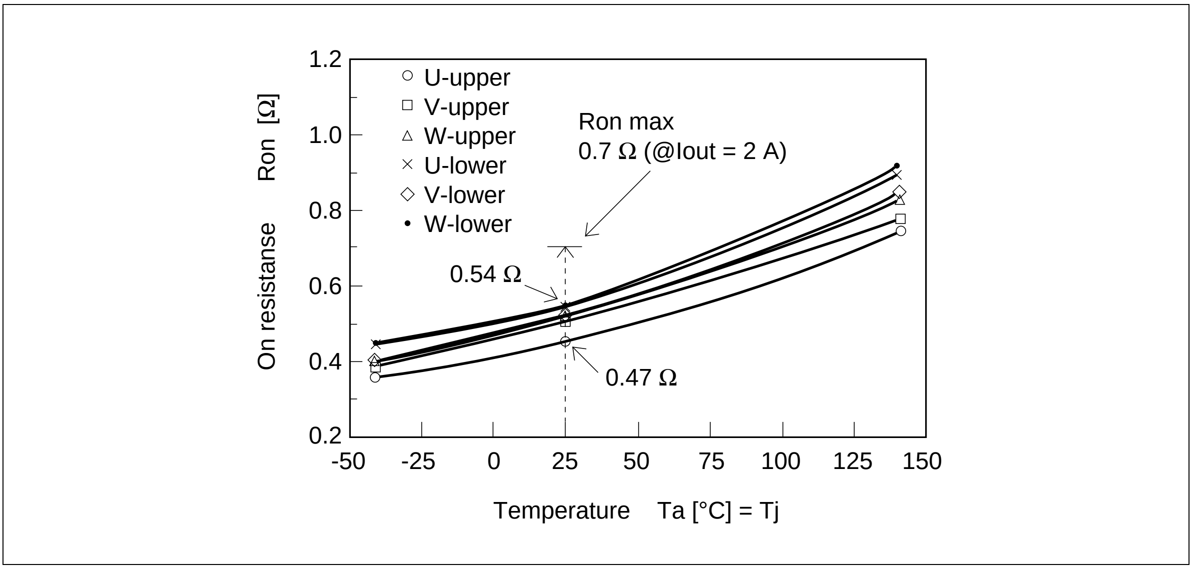


Figure 7 Ron Temperature Dependence Characteristics

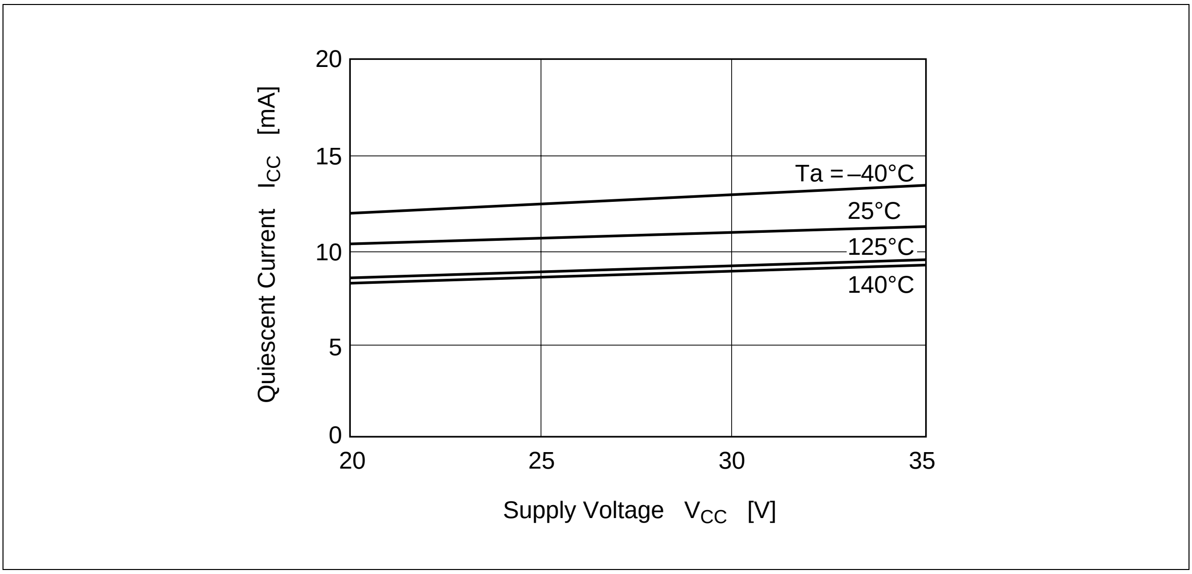
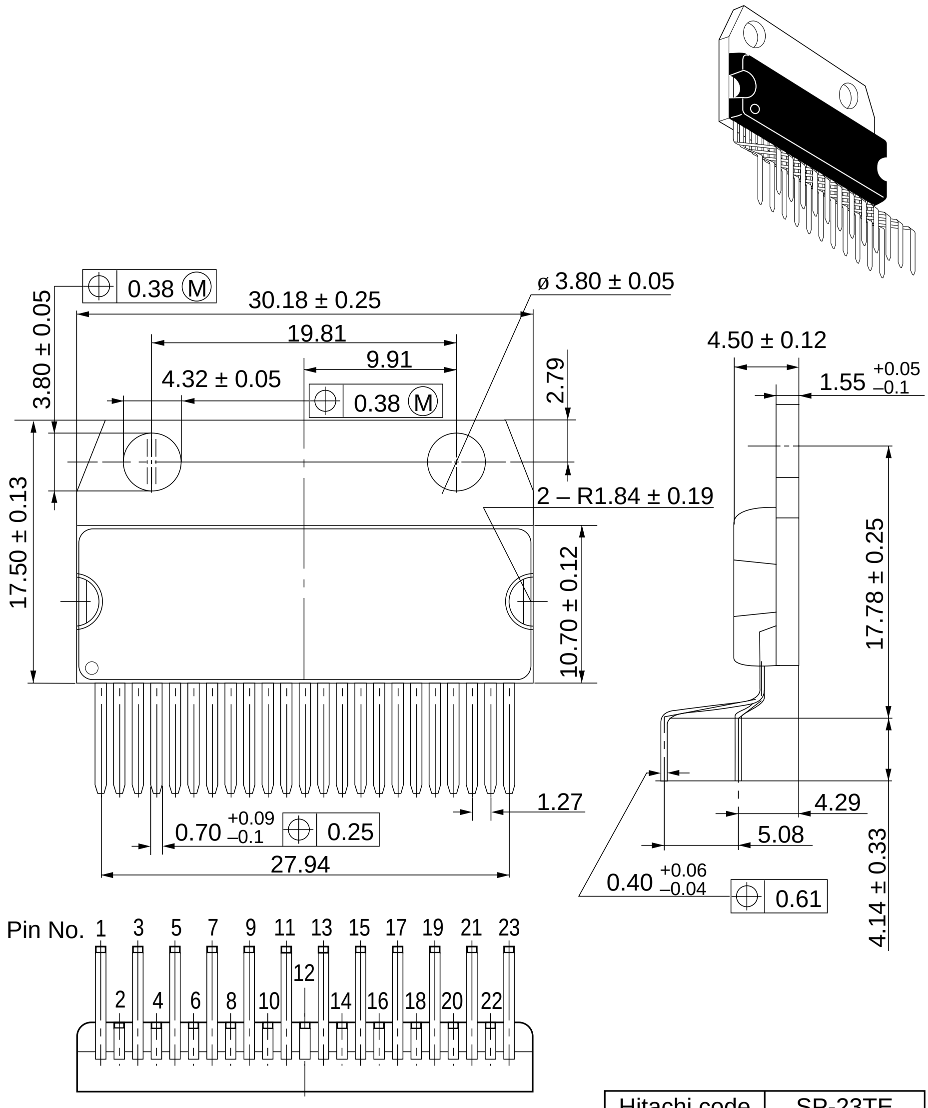


Figure 8 Supply Voltage vs. Quiescent Characteristics

Package Dimensions

Unit: mm



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