# 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

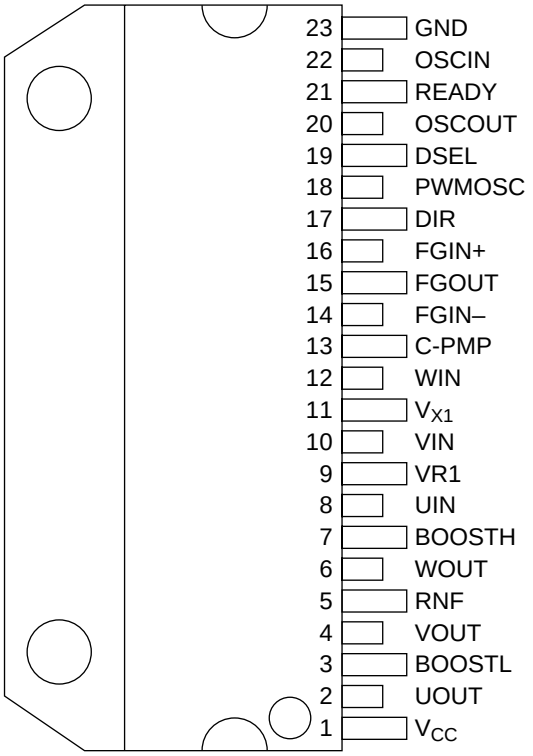
- High breakdown voltage, large currents
- Direct PWM drive outputs
- Employs DMOS
- Low on resistance: 0.7 Ω/DMOS maximum
- No lower arm flywheel diode is required

Hitachi semiconductor

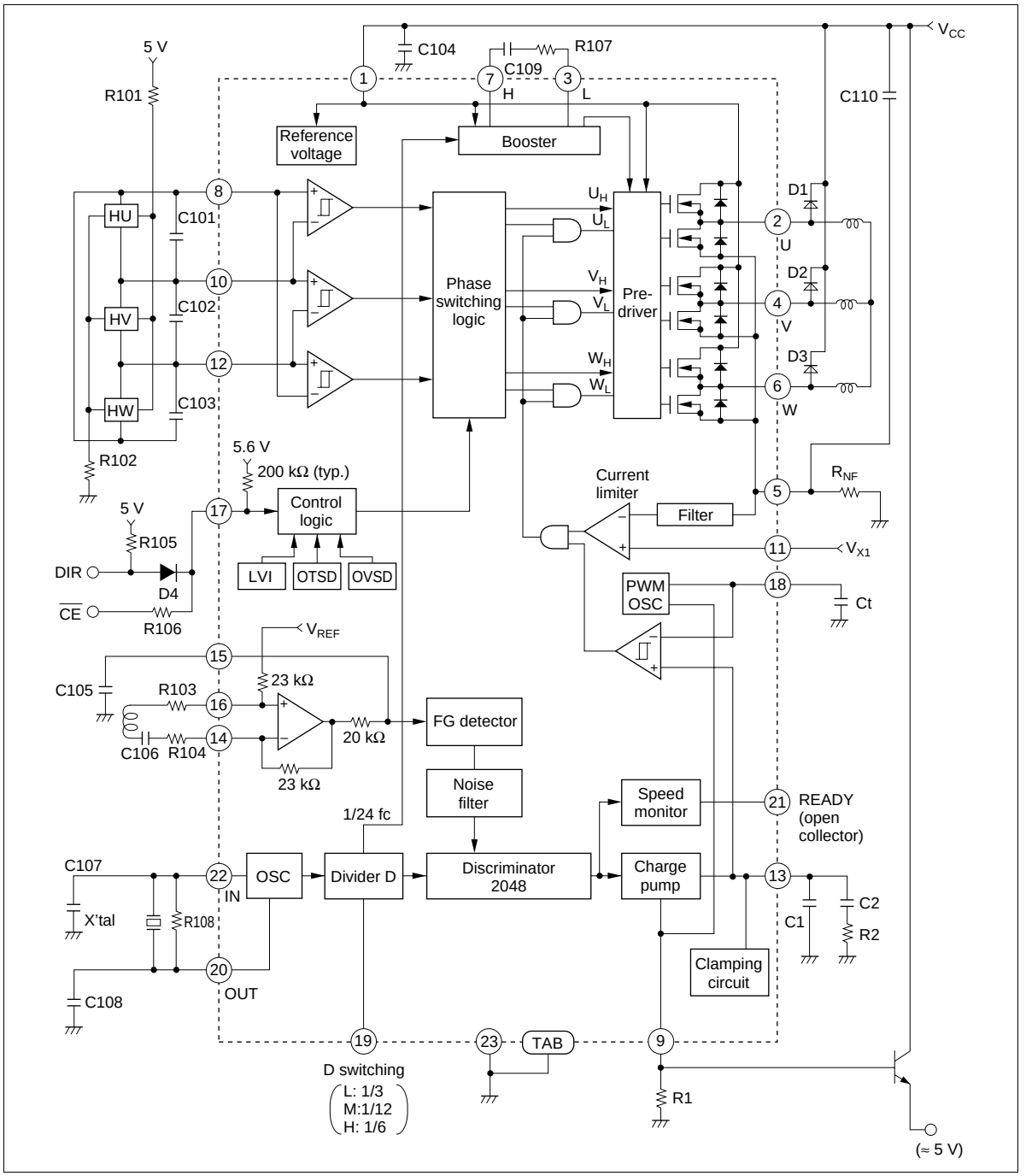
## Pin Description

| 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

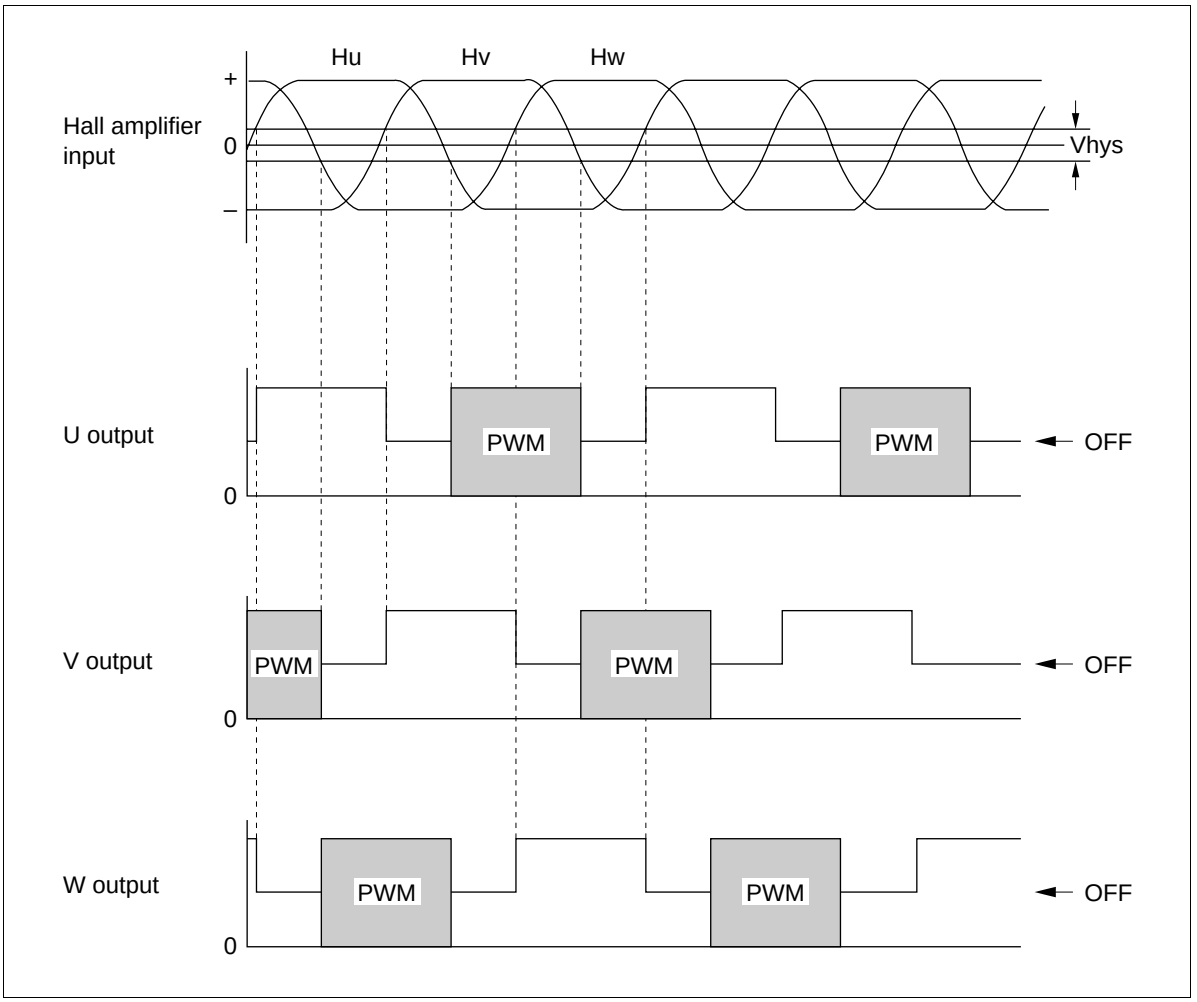


## Block Diagram

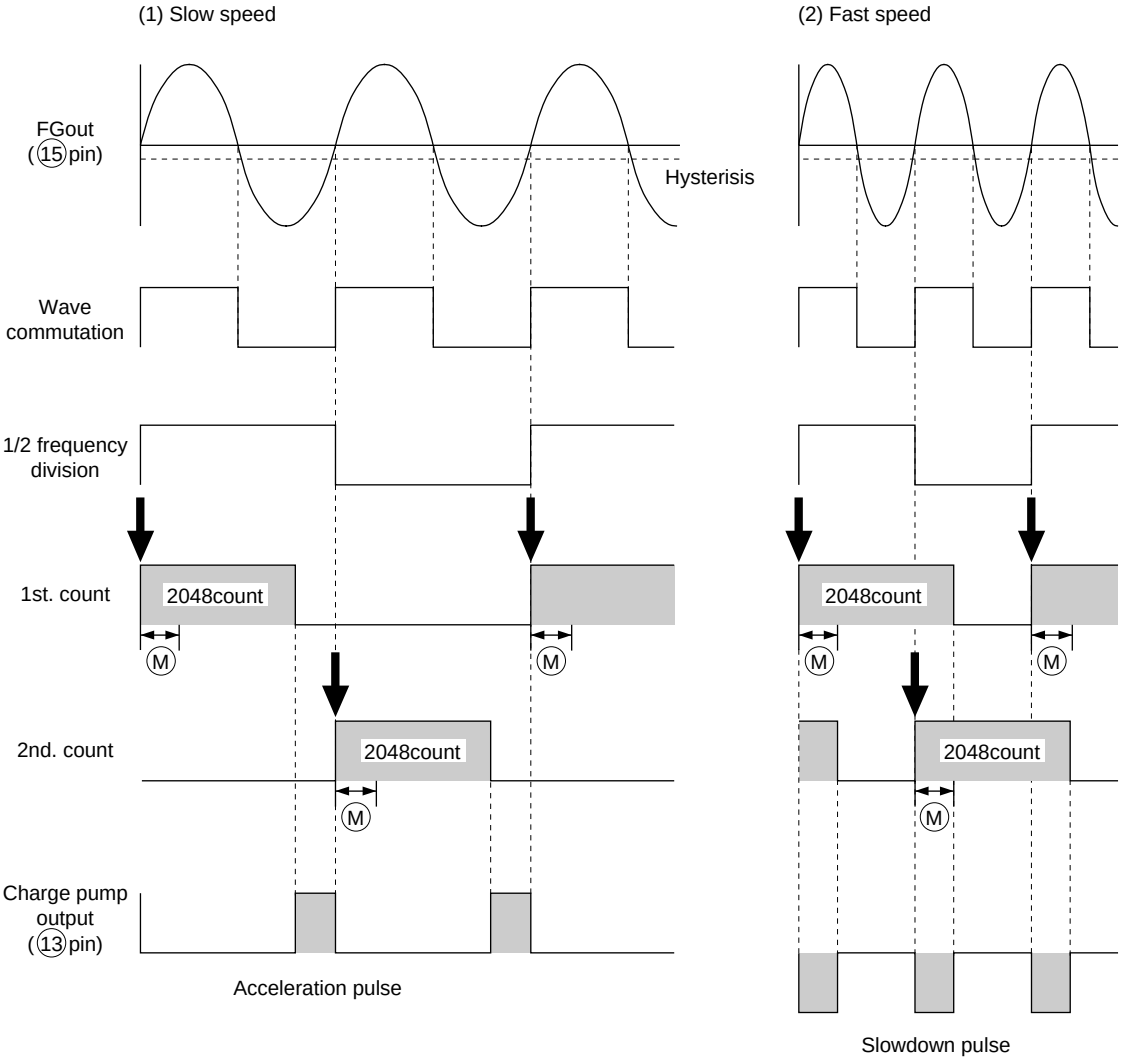


## Timing Chart

### 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.

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

$$\frac{R2}{R1} = \frac{7.7 J \omega_0 No Rm Vosc}{K_T V_{R1} (2Vps - 0.83 V_E)}$$

$$3.0\ k\Omega \leq R1 \leq 15\ k\Omega$$

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

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

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.

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

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<br>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)

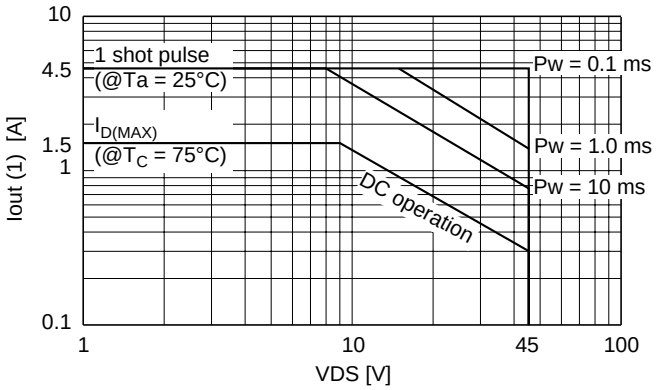



**Figure 1 ASO Range**

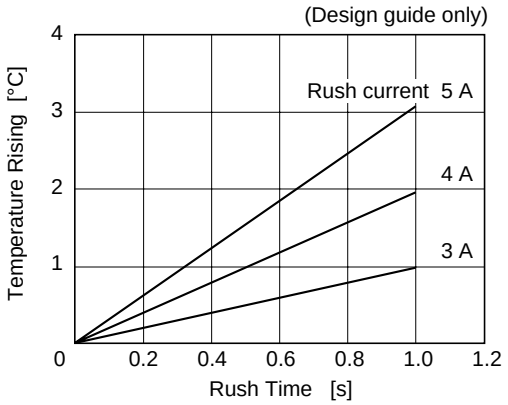



**Figure 2 Rush Time vs. Temperature Rising**

## 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<br>R1 = 5.6 kΩ | | |
| | | Icc(2) | — | — | 20 | mA | $V_{CC}$ = 45 V | | |
| Hall | Input current | Ih | — | — | ±20 | mA | | 8, 10, 12 | |
| amplifier | Common mode input voltage range | Vhc | 1.5 | 2.5 | 3.5 | V | | | |
| | Differential mode input voltage range | Vhd | 50 | — | 1000 | $mV_{PP}$ | | | |
| Output | Leakage current | Icer | — | — | 3 | mA | Vds = 35 V | 2, 4, 6 | |
| amplifier | 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 | Low level voltage | VI | 1.10 | 1.30 | 1.50 | V | | 18 | |
| oscillator & Com- | Oscillator amplitude | Vosc | 2.0 | 2.2 | 2.4 | $V_{PP}$ | | | |
| parator | Correct coefficient | K | 12 | 14 | 16 | — | R1 = 5.6 kΩ | | |
| FG amplifier | Input voltage range | Vfg | 8 | — | 300 | $mV_{PP}$ | Gfg = 32 dB, R103, R104 = 580 Ω | 14, 16 | |
| and FG detector | 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- | Count | N | — | 2048 | — | — | | | |
| nator | Operating frequency range | fdis | — | — | 3.0 | MHz | | | 2 |
| Charge | R1 voltage | $V_{R1}$ | 5.1 | 5.6 | 6.1 | V | R1 = 5.6 kΩ | | 3 |
| pump | 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 | Locking range | ΔNo | — | ±5 | — | % | | 21 | 5 |
| monitor | Output low level voltage | Vol2 | — | — | 0.4 | V | Io = –10 mA | | |
| | Output leakage current | Icer2 | — | — | ±10 | µA | Vce = 15 V | | |
| Current | Input current | Icl | — | — | ±10 | µA | Vx1 = 0 to 2 V | 11 | |
| limiter | 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 | Input current | Ii1, Ii2 | –10 | — | 40 | µA | Vin = –0.3 V to 5.25 V | | |
| interface | 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 | Transient | tphl1 | — | — | 1 | µs | at PWM | | 7, 9 |
| drive | response time | tplh1 | — | — | 1 | µs | at PWM | | |
| | | tr, tf | — | — | 300 | ns | at PWM | | |
| Filter | Noise cancellation range | Tn1 | — | 1.0 | — | µs | | | 9 |
| PWMOSC & comp- | Oscillation frequency range | fp | 2 | — | 20 | kHz | | | 9 |
| arator | 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.

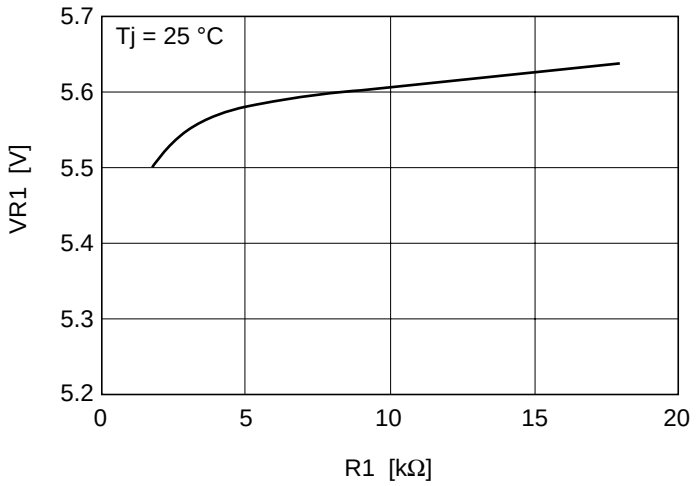



**Figure 3 VR1-R1 Characteristics**

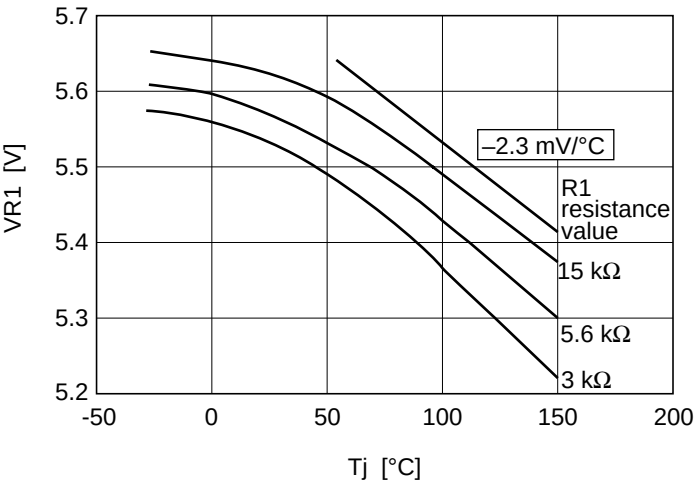



**Figure 4 VR1 Temperature Characteristics**

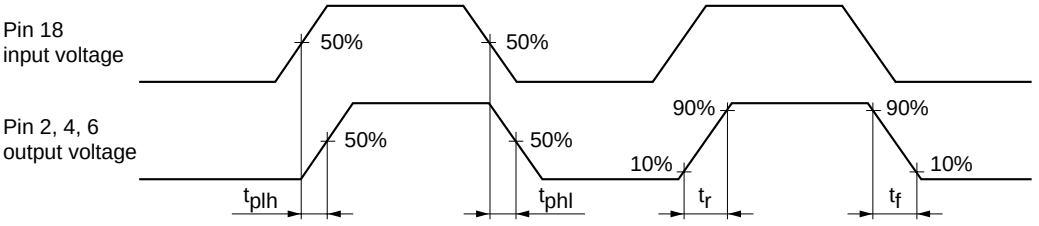



**Figure 5**

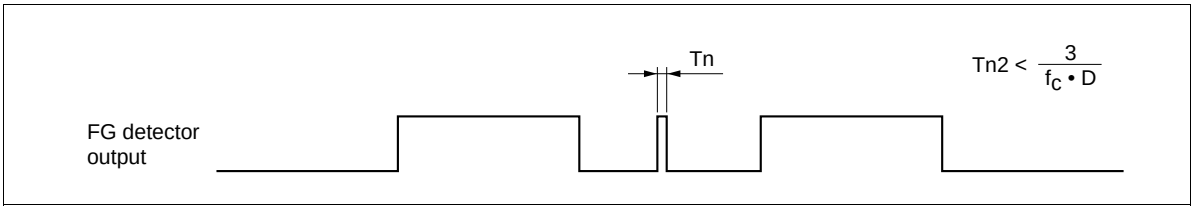



**Figure 6**

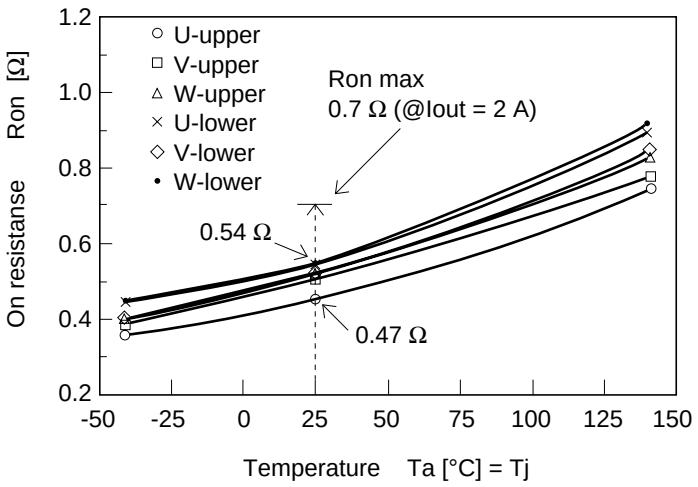



**Figure 7 Ron Temperature Dependence Characteristics**

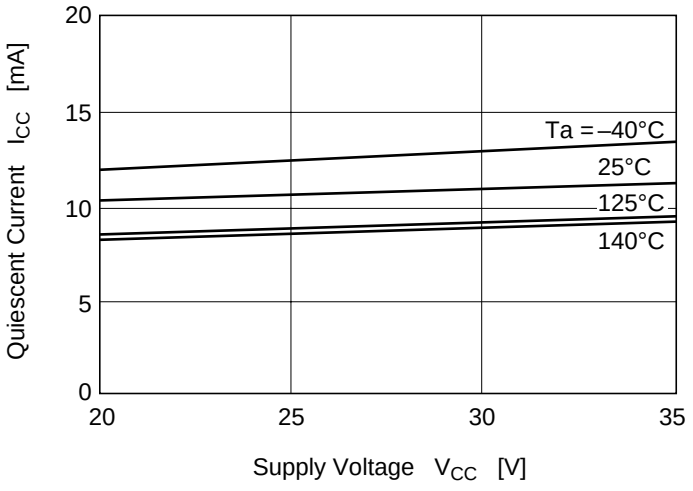
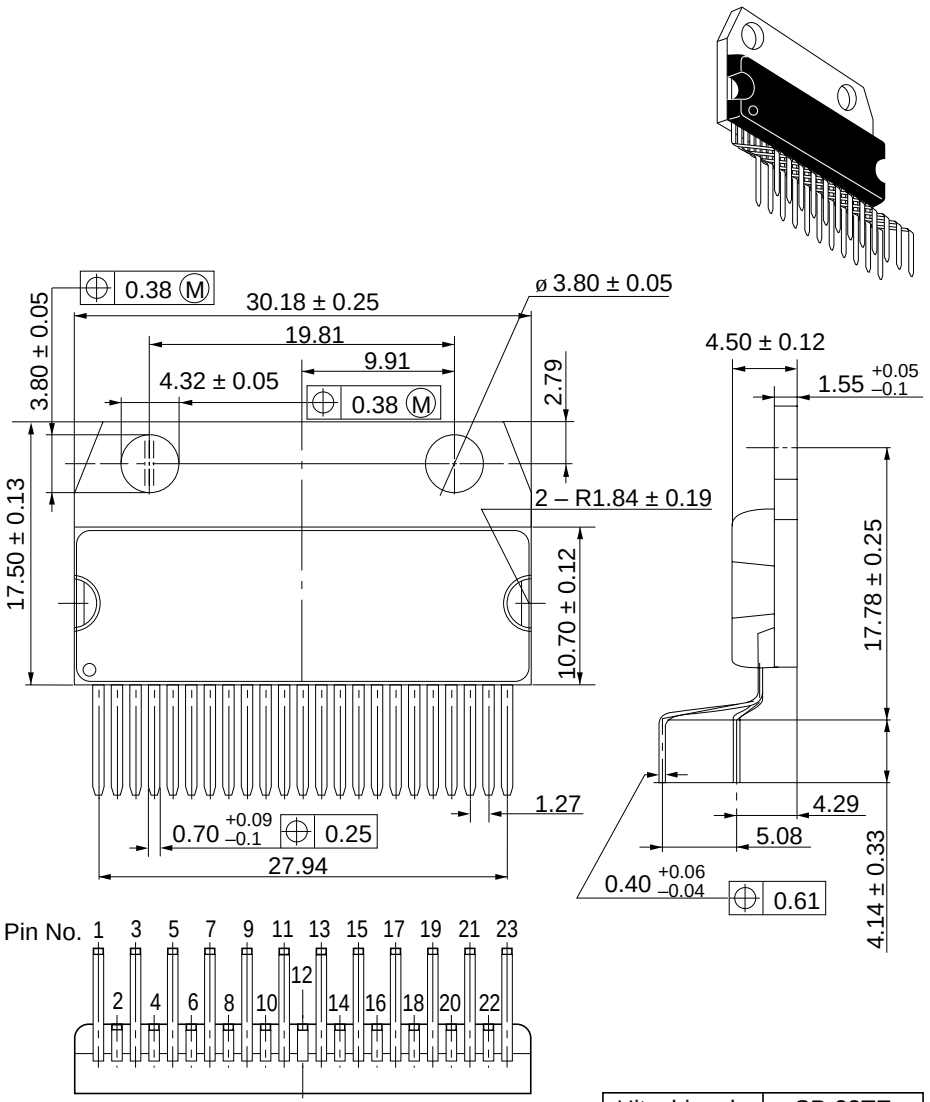



**Figure 8 Supply Voltage vs. Quiescent Characteristics**

## Package Dimensions

Unit: mm

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