

TB67B000HG

Usage considerations

Rev.1.0

Summary

The TB67B000HG is a three-phase sine-wave PWM driver for brushless motors. It is a high voltage IC of 500 V. The TB67B000HG has a 2 in 1 (MCP) structure of controller (sine-wave PWM / wide-angle conduction) and a high voltage driver. Rotation speed of a DC brushless motor can be controlled directly by a speed control signal (analog) from a microcomputer.

<p>This is a reference. Please do not determine the final equipment design by this material.</p>
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Contents

Summary	1
Contents	2
Table contents.....	2
Figure contents	3
1. Power supply voltage	4
2. Output current	4
3. Notes in using the motor	5
4. Lead angle control	6
5. Application circuit example	8
6. Notes in designing circuit board	14
7. Power consumption	16
8. Power dissipation.....	18
IC Usage Considerations	19
Points to remember on handling of ICs	19
RESTRICTIONS ON PRODUCT USE	20

Table contents

Table 1 Absolute maximum ratings of power supply voltage ($T_a = 25^\circ\text{C}$)	4
Table 2 Power supply voltage usage range ($T_a = 25^\circ\text{C}$)	4
Table 3 Example of parts value in application circuit example	9
Table 4 Capacitor of Vrefout terminal	10
Table 5 Capacitor of VREG terminal.....	10
Table 6 Capacitor of Vcc terminal	11

Figure contents

Figure 1	Relation of input voltage and lead angle when sine-wave PWM drive(design target)	6
Figure 2	Relation of input voltage and lead angle when wide-angle commutation drive(design target).....	7
Figure 3	Application circuit example.....	8
Figure 4	Relation of external resistor and oscillation frequency (for reference only)	9
Figure 5	Relation of external capacitor and motor lock detecting time (for reference only)	10
Figure 6	Example of board layout	14
Figure 7	Waveform of motor current (Sine-wave drive) (Image).....	16
Figure 8	Calculation data of power consumption	17
Figure 9	Relation of power dissipation and ambient temperature	18

1. Power supply voltage

Power supply voltages of V_{BB} and V_{CC} terminals have two standards of the absolute maximum ratings and the usage range. The absolute maximum rating of the power supply voltage must not be exceeded even for a moment. Please use the IC within the usage range.

Table 1 Absolute maximum ratings of power supply voltage ($T_a = 25^\circ\text{C}$)

Characteristic	Symbol	Rating	Unit
Power supply voltage	V_{BB}	500	V
	V_{CC}	18	

Table 2 Power supply voltage usage range ($T_a = 25^\circ\text{C}$)

Characteristic	Symbol	Min	Typ.	Max	Unit
Power supply voltage	V_{BB}	50	280	450	V
	V_{CC}	13.5	15	16.5	

Sequence of power supply

1. Sequence of power supply: Please supply the power by following procedure of (1) to (3).
 - (1) Apply power supply of V_{CC} .
In applying V_{CC} , connect V_{sp} to GND or open.
In case terminals of CW/CCW, LA, and SS are controlled by signals of external IC, connect them to GND or open. After applying power supply of V_{CC} , set the terminal of CW/CCW, LA, and SS high-level if needed.
 - (2) Apply power supply of V_{BB} .
 - (3) Apply voltage to V_{sp} .
2. Sequence of power shut down: Please shut down the power by following procedure of (1) to (3).
 - (1) Set V_{sp} to 0V.
In case terminals of CW/CCW, LA, and SS are controlled by signals of external IC after setting V_{sp} 0V, connect them to GND or open.
 - (2) Shut down V_{BB} .
 - (3) Shut down V_{CC} .

2. Output current

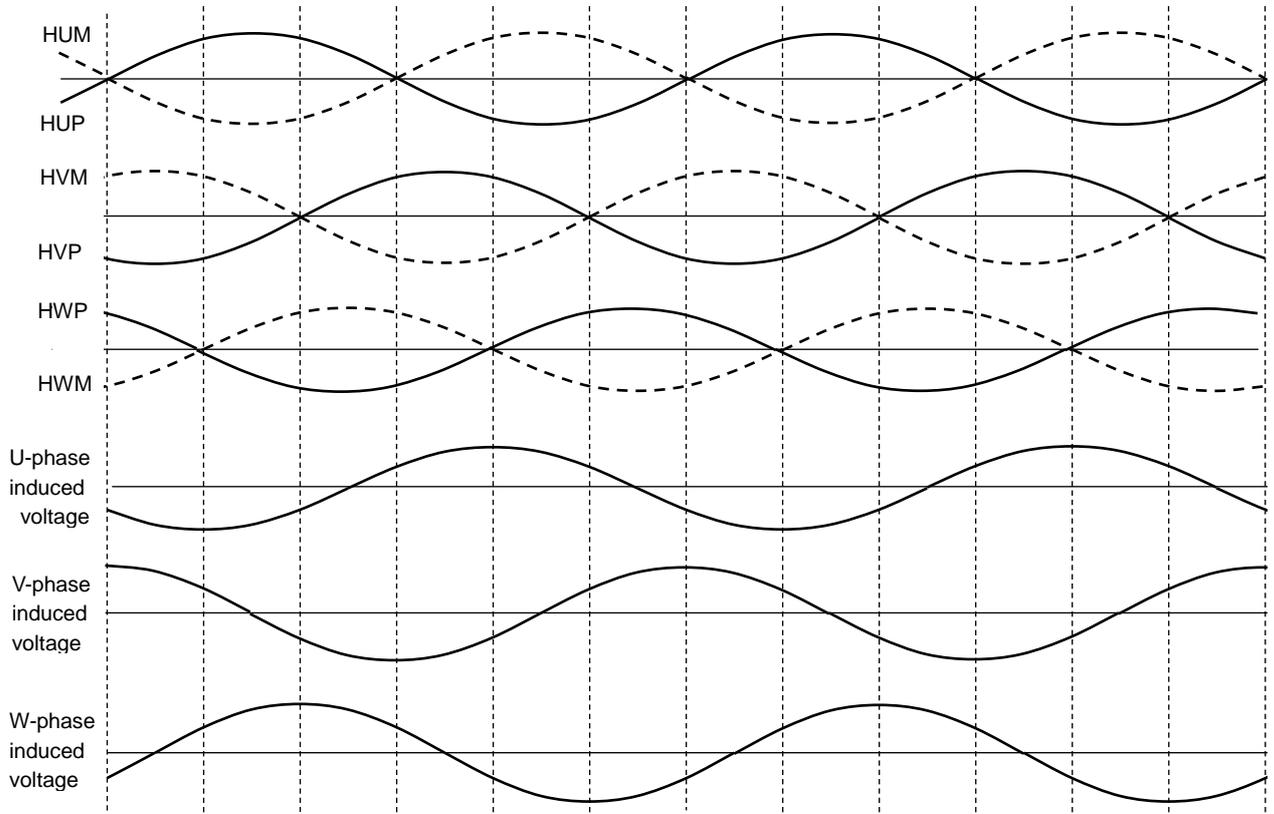
The absolute maximum rating is 2 A that must not be exceeded, even for a moment. Design an actual application system with the IC so as not to make the inrush current and the lockout current exceed the absolute maximum ratings, especially when a motor starts up and gets stuck in the lockout.

The available output current depends on the usage conditions (ambient temperature, mounting board method, and so on). Design an actual application system with a sufficient margin in order that T_j does not exceed 150°C .

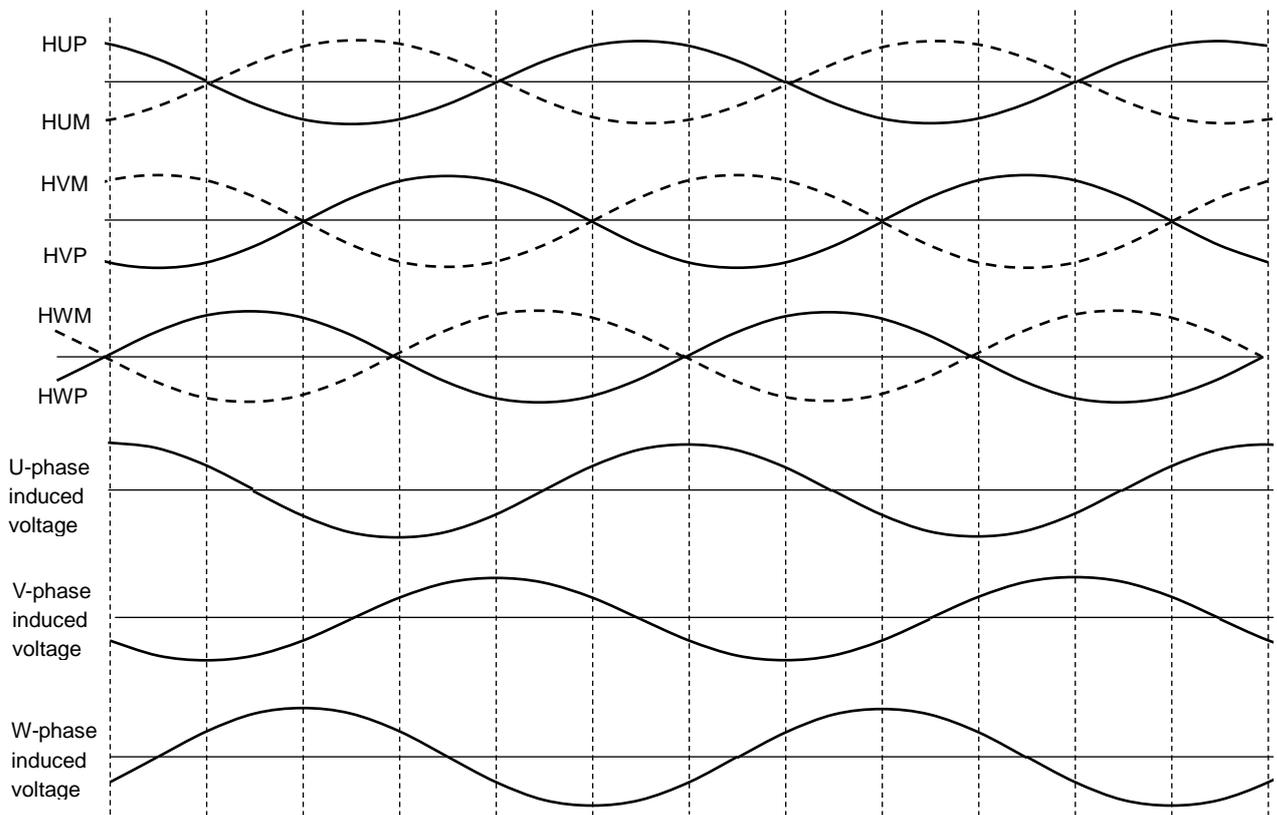
3. Notes in using the motor

Please use the motor whose phase relation between hall sensors and induced voltage corresponds to the following timing chart.

CW/CCW=H



CW/CCW=L



4. Lead angle control

The lead angle of the driver output according to the induced voltage can be adjusted by the input voltage of LA terminal. The range of lead angle is as follows;

Sine-wave PWM drive: 0 to 58°, Wide-angle conducting drive: 0 to 28°

The efficiency of the motor operation can be improved by adjusting the lead angle. In adjusting the motor characteristics by applying the lead angle, change the lead angle by LA terminal and compare the motor current. Adjust the voltage of LA terminal in order to minimize the motor current as comparing the motor current before and after changing the lead angle under the condition that the rotation speed is the same.

SS=L (Sine-wave PWM drive)

LA analog input (0 to 5 V in 32 separate steps)

0 V = 0°

5 V = 58° (A lead angle of 58° is assumed when the LA voltage exceeds 5 V)

(Value is design target)

Step	LA [V]	Lead angle [deg]	Step	LA [V]	Lead angle [deg]	Step	LA [V]	Lead angle [deg]
0	0.000	0.000	11	1.719	20.625	22	3.438	41.250
1	0.156	1.875	12	1.875	22.500	23	3.594	43.125
2	0.313	3.750	13	2.031	24.375	24	3.750	45.000
3	0.469	5.625	14	2.188	26.250	25	3.906	46.875
4	0.625	7.500	15	2.344	28.125	26	4.063	48.750
5	0.781	9.375	16	2.500	30.000	27	4.219	50.625
6	0.938	11.250	17	2.656	31.875	28	4.375	52.500
7	1.094	13.125	18	2.813	33.750	29	4.531	54.375
8	1.250	15.000	19	2.969	35.625	30	4.688	56.250
9	1.406	16.875	20	3.125	37.500	31	4.844	58.125
10	1.563	18.750	21	3.281	39.375	32	5.000	58.125

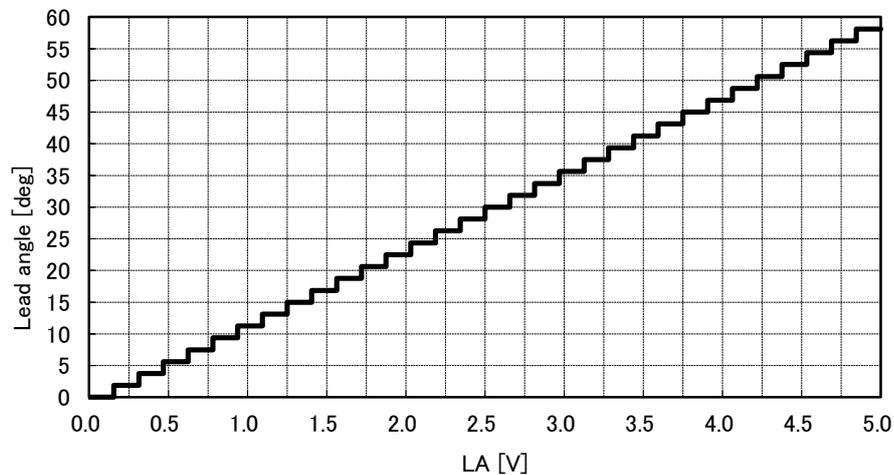


Figure 1 Relation of input voltage and lead angle when sine-wave PWM drive(design target)

SS=H (Wide-angle conducting drive)

LA analog input (0 to 5 V in 16 separate steps)

0 V = 0°

5 V = 28°(A lead angle of 28° is assumed when the LA voltage exceeds 5 V.)

(Value is design target)

Step	LA [V]	Lead angle [deg]	Step	LA [V]	Lead angle [deg]	Step	LA [V]	Lead angle [deg]
0	0.000	0.000	6	1.875	11.250	12	3.750	22.500
1	0.313	1.875	7	2.188	13.125	13	4.063	24.375
2	0.625	3.750	8	2.500	15.000	14	4.375	26.250
3	0.938	5.625	9	2.813	16.875	15	4.688	28.125
4	1.250	7.500	10	3.125	18.750	16	5.000	28.125
5	1.563	9.375	11	3.438	20.625	-	-	-

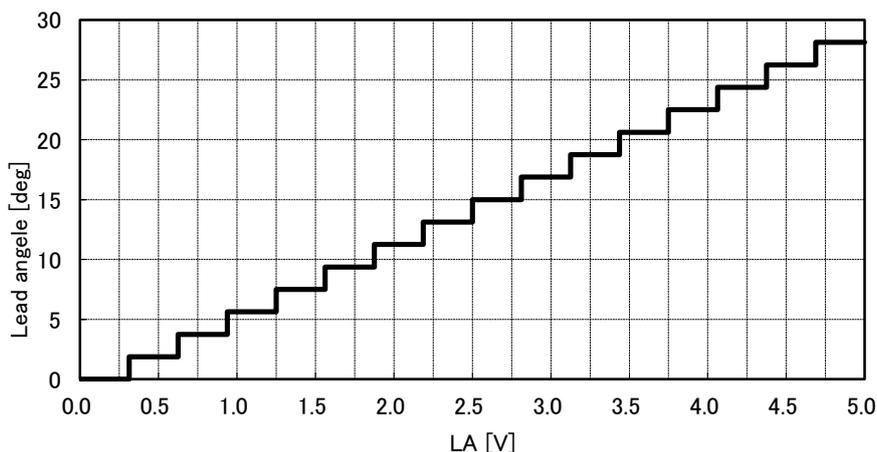
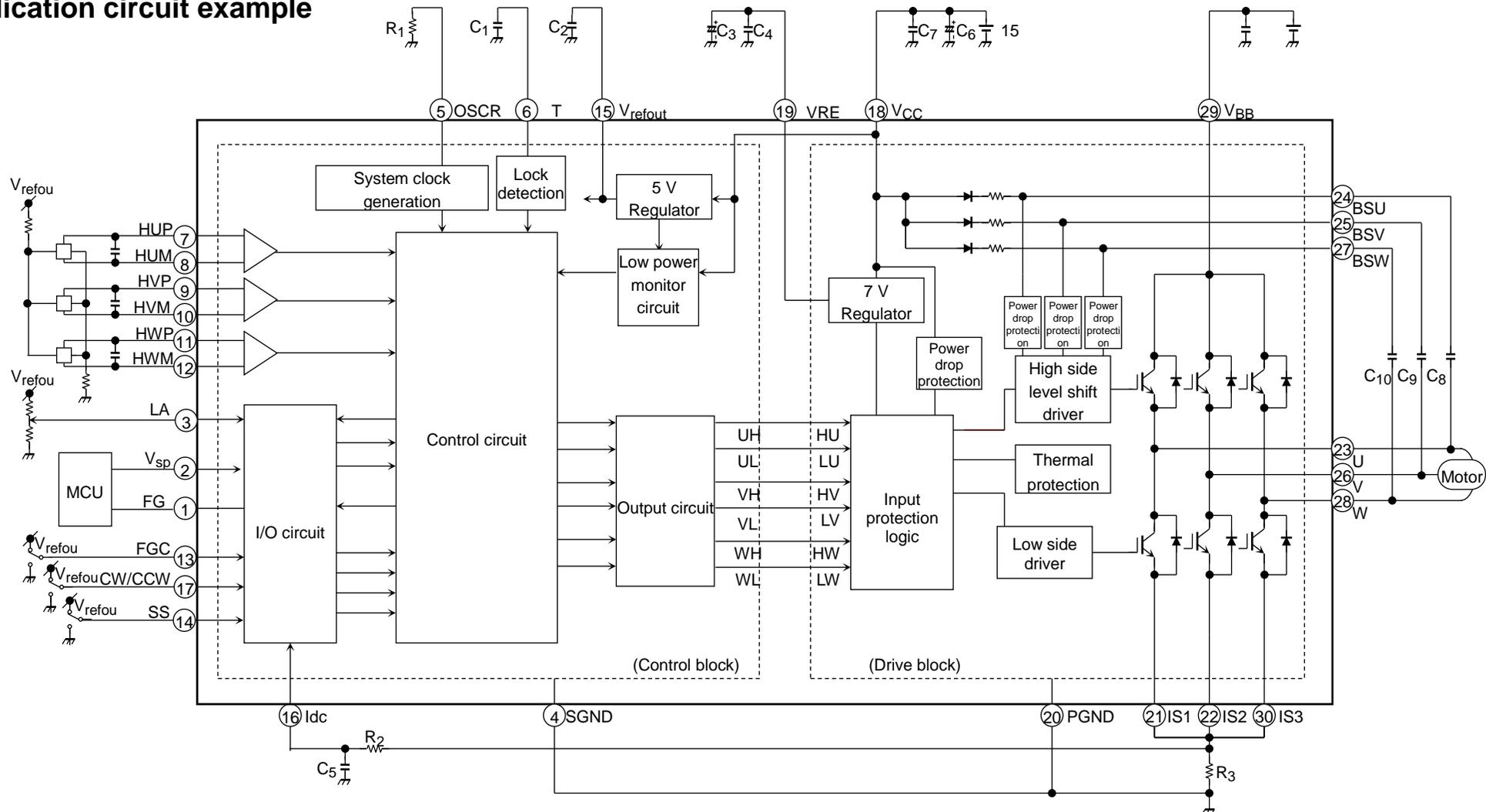


Figure 2 Relation of input voltage and lead angle when wide-angle commutation drive(design target)

5. Application circuit example



Utmost care is necessary in the design of board layout since the IC may be destroyed and cause smoke or ignition by short-circuiting between outputs, air contamination faults, or faults due to improper grounding, or by short-circuiting between contiguous pins. Specially, in the design of the output, V_{BB}, U, V, W, IS1, IS2, IS3 and GND lines which have high voltage and high current, utmost care is necessary. Add overcurrent protection such as a fuse not to allow large current continue to flow in case of over current generation or IC breakdown.

Figure 3 Application circuit example

Table 3 Example of parts value in application circuit example

Symbol	Purpose	Recommended value	Note
R ₁	Internal clock generation	68 kΩ	(1)
C ₁	Motor lock detection	10 V / 0.01 μF	(2)
C ₂	V _{refout} oscillation protection	10 V / 0.1 μF to 1.0 μF	(3)
C ₃	V _{REG} power supply stability	25 V / 1 μF	(4)
C ₄		25 V / 1000 pF	
C ₅	Noise absorber	10 V / 100pF	(5)
R ₂		5.1 kΩ	
R ₃	Overcurrent detection	0.51 Ω ± 1% (1 W)	(6)
C ₆	V _{CC} power supply stability	25 V / 10 μF	(7)
C ₇		25 V / 0.1 μF	
C ₈ , C ₉ , C ₁₀	Bootstrap capacitor	25 V / 2.2 μF	(8)

(1) OSCCR terminal

OSCCR terminal sets reference oscillating frequency.

Connect the external resistor (R₁) between OSCCR terminal and SGND as close to the IC as possible not to be influenced by noise and wiring impedance. When the tolerance of the resistor is low, the setting time and the frequency would be different from the typical values greatly. So, please select a resistor which has as high a tolerance as possible.

Oscillation frequency (F_{osc}) range should be 3.5MHz to 6.4MHz. The relation of the oscillation frequency (F_{osc}) and the PWM frequency (F_c) is as follows; F_c=F_{osc}/252. When R₁= 68kΩ, F_c=20 kHz (typ.), and when R₁= 75kΩ, F_c=18 kHz (typ.).

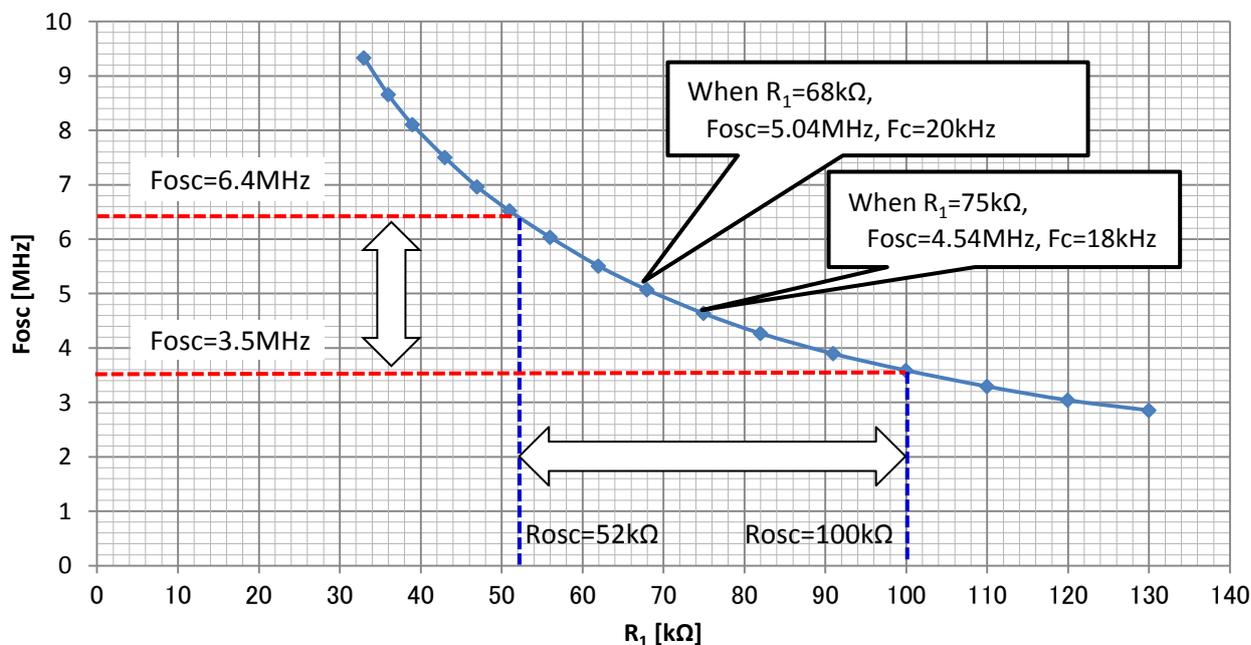


Figure 4 Relation of external resistor and oscillation frequency (for reference only)

(2) TR terminal

When the motor is locked, the motor lock detection operates and the drive output is turned on and off (intermittent operation). Driving OFF period (Toff) and driving ON period (Ton) can be configured by the external capacitor (C1) of TR terminal. When this function is not used, please connect this terminal to SGND. The relation of external capacitor (C1) and driving ON/OFF period is roughly calculated as follows.

•Setting time

Driving ON period $T_{on}[s]=C1 \times (VH-VL) \times 2/I \times 500$ counters

Driving OFF period $T_{off}[s]=C1 \times (VH-VL) \times 2/I \times 3000$ counters

Ex.: When $C1 = 0.01\mu F$, $I = 3\mu A$ (typ.), $VH = 2 V$ (typ.) and $VL = 0.5V$ (typ.), and so $T_{on}[s]=5s$ (typ.) and $T_{off}[s]=30s$ (typ.)

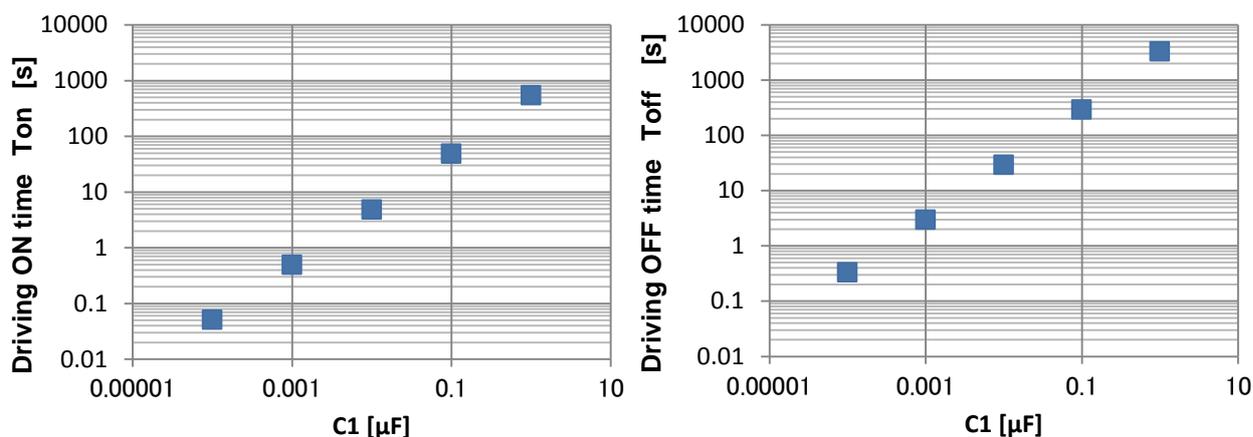


Figure 5 Relation of external capacitor and motor lock detecting time (for reference only)

(3) Vrefout terminal

It is applied to supply power to the hall elements and the hall IC, and configure terminals. In that case, usage range of the output current is up to 30mA.

Please connect the capacitor whose range is 0.1μF to 1 μF between Vrefout and SGND as close to the IC as possible in order to reduce the noise and the fluctuation of the voltage at Vrefout terminal.

Table 4 Capacitor of Vrefout terminal

Item	Parts	Typ.
Between Vrefout and SGND	Ceramic capacitor	0.1μF to 1μF

(4) VREG terminal

Please connect the ceramic capacitor or the electrolytic capacitor between VREG and PGND as close to the IC as possible in order to reduce the noise and the fluctuation of the voltage at VREG terminal. The recommended value of usage external capacitor is approximately from 0.1μF to 1μF.

Table 5 Capacitor of VREG terminal

Item	Parts	Typ.
Between VREG and SGND	Electrolytic capacitor	1μF
	Ceramic capacitor	1000pF

(5) Filter for I_{dc} terminal

Internal IC of I_{dc} terminal incorporates the digital filter of 0.6μs (typ.) and the analog filter of 1.0 μs (typ.). When malfunction, that driving output turns off, occurs because of the noise, please connect the low-pass filter (CR) externally. Select the appropriate constant number of the CR filter to gain the relation that the cut off frequency (f_{cut}) is 10 times or more of the carrier frequency (F_c).

$$\text{Cut off frequency (f}_{\text{cut}}) = 1 / (2\pi\text{CR}) \text{ [Hz]}$$

When Carrier frequency (F_c) =20 kHz and f_{cut} >10×F_c, CR<7.96×10⁻⁷

For example, configure R=5.1kΩ and C=100pF, and confirm the operation.

(6) Resistor for connecting IS1, IS2, and IS3 terminals

Please short-circuit each terminal of IS1, IS2, and IS3. Configure the limit current of the motor output by connecting the detecting resistor between IS1, IS2, and IS3 terminals and PGND. And connect IS1, IS2, and IS3 terminals and I_{dc} terminal. Insert the filter for I_{dc} terminal (described in (5)) between IS1, IS2, and IS3 terminals and I_{dc} terminal if needed.

The relation between the output current (I_{OUT}) and the detecting resistor (R₃) is provided roughly in the following formula.

$$I_{\text{OUT}} = V_{\text{dc}} / R_3$$

Voltage of current detection V_{dc}: 0.475V (min.), 0.5 V (typ.), and 0.525V (max.)

Example) When the resistor (R₃) is configured 0.51 Ω, I_{OUT} (typ.) = 0.5 V (typ.)/0.51 Ω ≈ 0.98 A

Please determine the rating of the external parts with sufficient margins because large current flows in the detecting resistor (R₃). In operating the motor, the power on the detecting resistor (P) is calculated as follows; P=0.525V×0.525V/ R₃ (max.). For example, when R₁=0.51Ω, P=0.540W. So, please apply the resistor of 1 W or more as a rated power.

(7) V_{cc} terminal

Connect the ceramic capacitor and the electrolytic capacitor between V_{cc} and SGND/PGND as close to the IC as possible if needed in order to reduce the noise and the fluctuation of the voltage at V_{cc} terminal. In particular, the power supply fluctuations and the noise, which generate at high frequency, can be effectively reduced by connecting ceramic capacitors near the IC.

Table 6 Capacitor of V_{cc} terminal

Item	Parts	Typ.
Between V _{cc} and SGND/PGND	Electrolytic capacitor	10μF
	Ceramic capacitor	0.1μF

(8) BSU, BSV, and BSW terminals

Connect the bootstrap capacitor (C8, C9, and C10) between BSU and U terminals, BSV and V terminals, and BSW and W terminals. The required bootstrap capacitance value varies depending on the motor drive conditions. The voltage stress for the capacitor is the value of V_{CC} (15V (typ.)). The recommended value of usage external capacitor is 25V/2.2μF.

(9) V_{sp} terminal

Operation and stop of the motor and rotating speed can be controlled by inputting command signal of the output ON duty to V_{sp} terminal. Please input analog voltage as a command signal. Moreover, when rotation speed needs to be controlled, connect it to MCU with V_{sp} signal and FG signal and feedback the speed to control the motor rotation number.

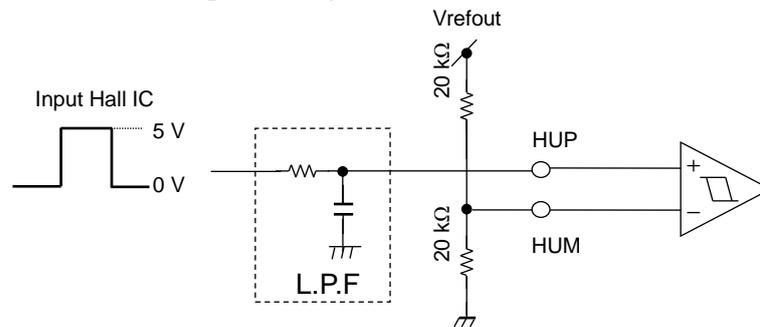
(10) FG terminal

Push-pull circuit of 5V output is constructed. When rotation speed needs to be controlled, input FG signal to MCU to use this signal as the information of the motor rotating number.

< Notes in using the hall IC >

Please configure HUP, HVP, HWP, HUM, HVM, and HWM as follows. It is recommended to adopt low-pass filter between the input terminal and SGND to reduce the noise. However, in this case, delay time of the input signal should be considered.

- (1) HUP, HVP, and HWP: Input voltage: H level = Vrefout, L level = SGND
 HUM, HVM, and HWM: Input voltage: Vrefout/2 * Configure it with resistive dividing voltage between Vrefout terminal and SGND.
- (2) HUP, HVP, and HWP: Input voltage: Vrefout/2 * Configure it with resistive dividing voltage between Vrefout terminal and SGND.
 HUM, HVM, and HWM: Input voltage: H level = Vrefout, L level = SGND



*) In case of V phase and W phase are also the same.

(15) U, V, and W terminals

Connect output terminals of U, V, and W, and the hall signal terminals of HUP, HUM, HVP, HVM, HWP, and HWM, to the motor to have the relation shown in the timing chart of “3. Notes in using the motor”.

(16) VBB terminal

VBB terminal is a power supply terminal for motor operation. In both states of stopping and operating the motor, pay attention not to exceed the rated value of the power supply by adopting the capacitor between VBB and PGND etc. When surge voltage is generated, it is recommended to adopt zener diode whose specification is absolute maximum rating (500V) or less.

(17) SGND and PGND terminals

Please short-circuit SGND and PGND. Especially, please design the circuit not to generate any paths which flows switching current between SGND terminal and PGND terminal.

6. Notes in designing circuit board

In designing board patterns of VBB, SGND, PGND, IS1, IS2, IS3, Vrefout, and Vreg, please pay attention to following notes.

- (1) Widen the circuit wiring pattern because large switching current of VBB, IS1, IS2, IS3, and PGND flows. Short-circuit each terminal of IS1, IS2, and IS3.
- (2) Short-circuit SGND and PGND as close to the IC as possible. Moreover, design the circuit to reduce the path for flowing the switching current between SGND and PGND.
- (3) Place the capacitor between VREG and PGND, and Vrefout and SGND close to the IC as possible.
- (4) Place the capacitor between VBB and PGND close to the IC as possible.

<Board layout example>

Example of board layout is simplified for explanatory purpose.
Do not short the wiring pattern 1 and the wiring pattern 2 in below figure.

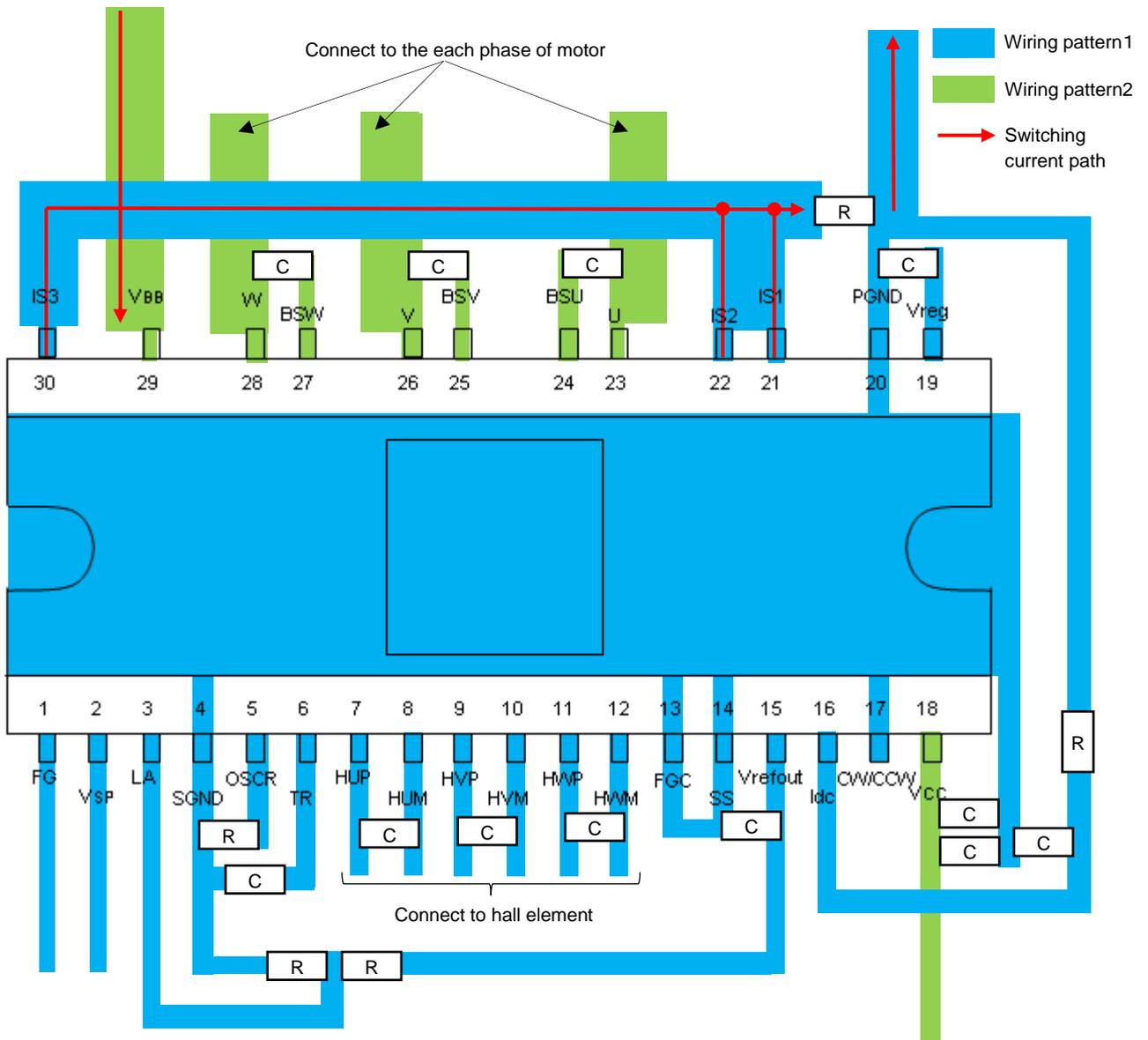


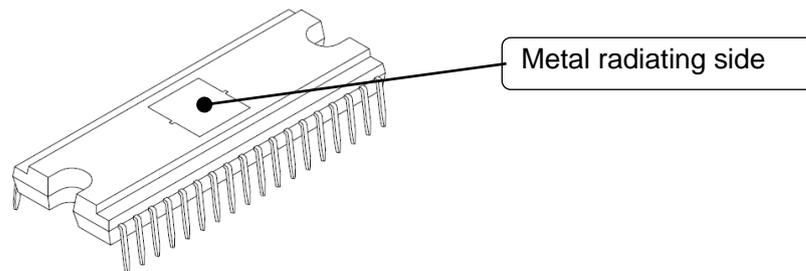
Figure 6 Example of board layout

<How to improve IC heat radiation>

(1) Use heat sink

IC heat radiation is improved by attaching radiating sheet or heat sink on the side of metal heat radiation. The heat radiation effect becomes high when their thermal conductivity is large.

Metal side and GND terminal have the same voltage when insulated measurement by using the heat sink is necessary, please insert insulating sheet between the metal side and the heat sink.



(2) Enlarge the ratio of wiring cover of the board.

When the ratio of wiring cover of the board is enlarged, the temperature gradient of the board surface is equalized and the heat radiation improves.

7. Power consumption

Power of the IC is consumed mainly by the output stages (P_{IGBT}), the control circuit (P_{POW}), and the internal regulator (P_{REG}). Formula of the power consumption in sine-wave drive is as follows; (The formula is simplified.)

$$P_{Total} = P_{IGBT} + P_{POW} + P_{REG}$$

(1) Power consumption of output stages: P_{IGBT}

$$P_{IGBT} = P_{ON} + P_{SW} \text{ [W]}$$

$$P_{ON} = 3 \times (V_{CE_{satH}} + V_{CE_{satL}}) \times I_p / \pi$$

$$P_{SW} = (W_{ton} + W_{toff}) \times f_c / \pi \times 6$$

I_p : Wiring current of the motor (peak) [A]

$V_{CE_{satH}}$, $V_{CE_{satL}}$: Voltage fall of output IGBT [V]

W_{ton} : Turn-on loss [μ J]

W_{toff} : Turn-off loss [μ J]

f_c : PWM switching frequency [Hz]

(2) Power consumption of control circuit: P_{POW} [W]

$$P_{POW} = P_{BB} + P_{CC} \text{ [W]}$$

$$P_{BB} = V_{BB} \times I_{BB} \text{ [W]}$$

$$P_{CC} = V_{CC} \times I_{CC} \text{ [W]}$$

I_{BB} : Power current of V_{BB} [A] *When motor: OFF

I_{CC} : Power current of V_{CC} [A] *When $V_{refout}=0mA$, $V_{REG}=0mA$

(3) Power consumption of internal regulator: P_{REG} [W]

$$P_{REG} = P_{V_{refout}} + P_{V_{REG}} \text{ [W]}$$

$$P_{V_{refout}} = (V_{CC} - V_{refout}) \times I_{refout} \text{ [W]}$$

$$P_{V_{REG}} = (V_{CC} - V_{REG}) \times I_{REG} \text{ [W]}$$

V_{CC} : Power supply voltage of V_{CC} [V]

V_{refout} : Output voltage of V_{refout} [V]

I_{refout} : Output current of V_{refout} [A]

V_{REG} : Output voltage of V_{REG} [V]

I_{REG} : Output current of V_{REG} [A]

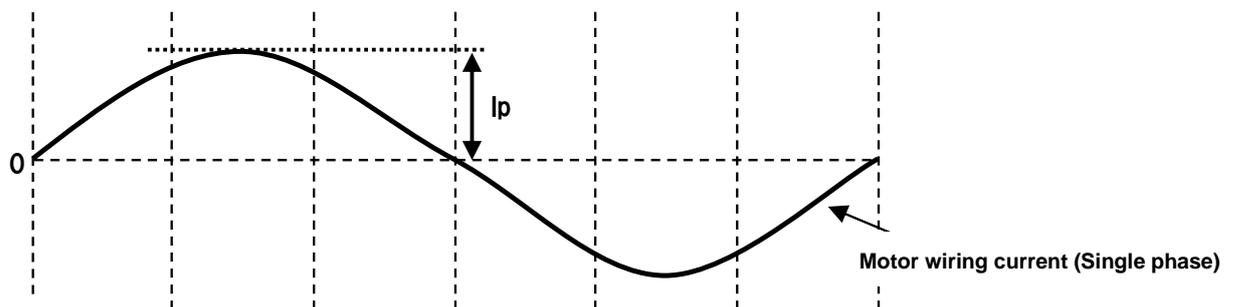


Figure 7 Waveform of motor current (Sine-wave drive) (Image)

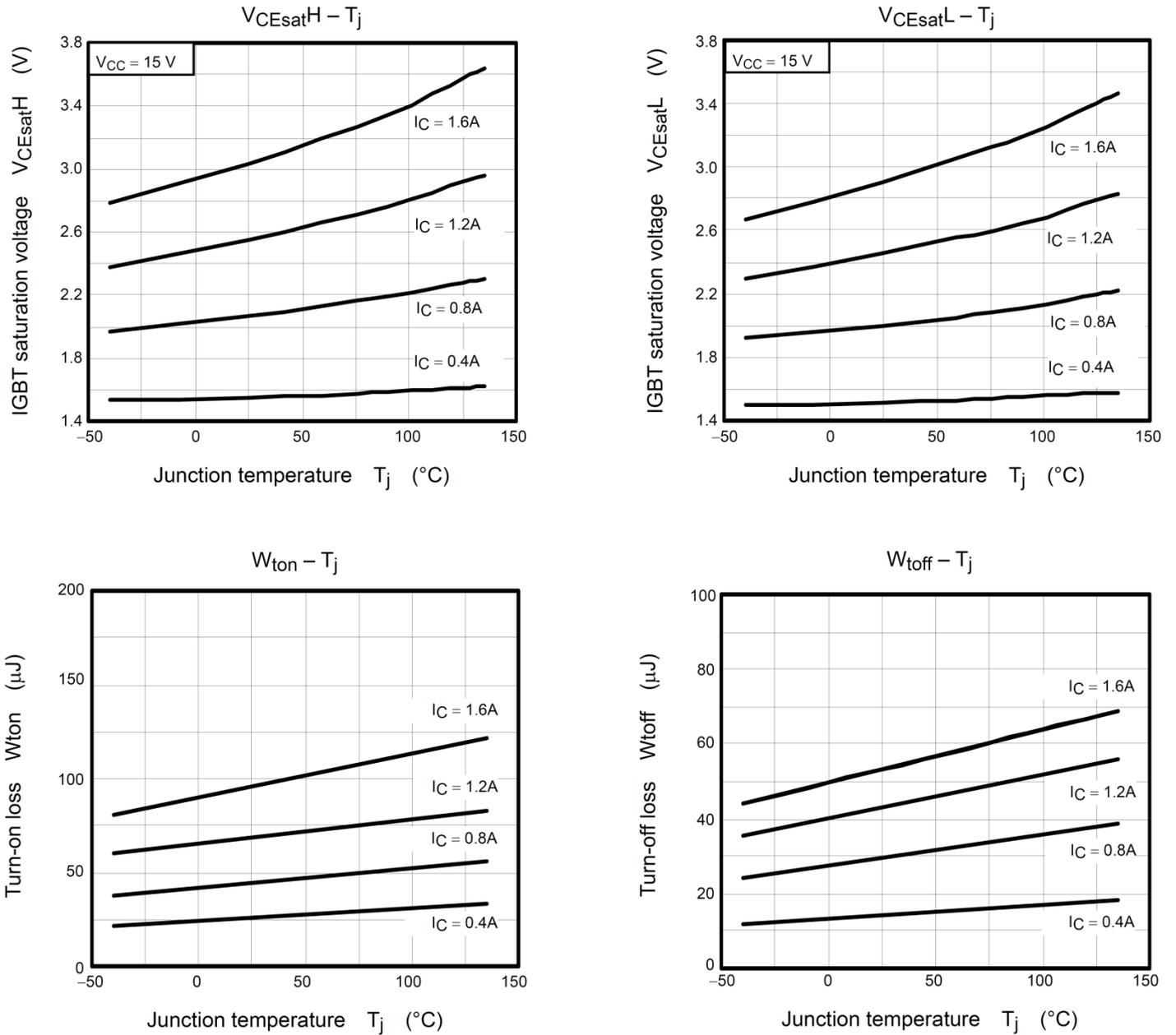


Figure 8 Calculation data of power consumption

(Ex.) Calculation example under the condition that $V_{BB} = 310V$, $f_C = 20kHz$, $I_{refout} = 10mA$, and $I_{REG} = 0mA$ is as follows;

When $I_p = 0.4A$, $V_{satH} = 1.55V$, $V_{satL} = 1.5V$, $W_{ton} = 25\mu J$, and $W_{toff} = 13\mu J$ (gained from above figures)
 Moreover, $V_{CC} = 15V$ (typ.), $V_{refout} = 5V$ (typ.), $V_{REG} = 7V$ (typ.), $I_{BB} = 0.5mA$ (max), and $I_{CC} = 10mA$ (max)

$$P_{IGBT} = P_{ON} + P_{SW}$$

$$= 3 \times (1.55V + 1.5V) \times 0.4A / \pi + (25\mu J + 13\mu J) \times 20 \text{ kHz} / \pi \times 6 = 2.62 \text{ W}$$

$$P_{POW} = P_{BB} + P_{CC}$$

$$= 310V \times 0.5mA + 15V \times 10mA = 0.31W$$

$$P_{REG} = (15V - 5V) \times 10mA + (15V - 7V) \times 0mA = 0.10W$$

$$P_{Total} = P_{IGBT} + P_{POW} + P_{REG} = 2.62 \text{ W} + 0.31W + 0.10W = 3.02W$$

8. Power dissipation

The relation of the ambient temperature (T_a), the junction temperature (T_j), and the heat resistance ($R_{th(j-a)}$) between the ambient temperature and the junction temperature is as follows.

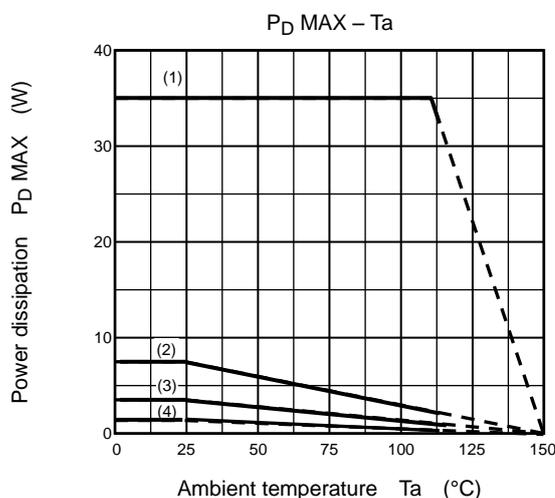
$$T_j = T_a + P_{Total} \times R_{th(j-a)}$$

For example, when $T_a=40[^\circ\text{C}]$, $P_{Total}=3.02[\text{W}]$, and $R_{th(j-a)} = 17 [^\circ\text{C}/\text{W}]$,

(Board conditions: (74.2 × 114.3 × 1.6 mm, Cu 20%), in using heat sink (10 × 10 × 1 mm, Cu)),
 $T_j = 40[^\circ\text{C}] + 3.02\text{W} \times 17^\circ\text{C}/\text{W} = 91.34[^\circ\text{C}]$

The absolute maximum rating of the junction temperature (T_j) is 150°C. Permissible power consumption ($P_{(total)}$) depends on T_a and $R_{th(j-a)}$. When ambient temperature is high, permissible power consumption becomes small accordingly. When heat resistance is high, permissible power consumption becomes small accordingly.

(Reference) Relation of power dissipation and ambient temperature



- (1)With infinite heat sink.
: $R_{\theta j-c} = 1^\circ\text{C}/\text{W}$
- (2)In mounting on board (74.2 × 114.3 × 1.6 mm, Cu20%), Heat sink (10 × 10 × 1 mm, Cu)
: $R_{\theta j-a} = 17^\circ\text{C}/\text{W}$
- (3)In mounting on board (74.2 × 114.3 × 1.6 mm, Cu20%)
: $R_{\theta j-a} = 35^\circ\text{C}/\text{W}$
- (4)IC only
: $R_{\theta j-a} = 53^\circ\text{C}/\text{W}$

Figure 9 Relation of power dissipation and ambient temperature

IC Usage Considerations

Notes on handling of ICs

- (1) The absolute maximum ratings of a semiconductor device are a set of ratings that must not be exceeded, even for a moment. Do not exceed any of these ratings. Exceeding the rating(s) may cause the device breakdown, damage or deterioration, and may result injury by explosion or combustion.
- (2) Use an appropriate power supply fuse to ensure that a large current does not continuously flow in case of over current and/or IC failure. The IC will fully break down when used under conditions that exceed its absolute maximum ratings, when the wiring is routed improperly or when an abnormal pulse noise occurs from the wiring or load, causing a large current to continuously flow and the breakdown can lead smoke or ignition. To minimize the effects of the flow of a large current in case of breakdown, appropriate settings, such as fuse capacity, fusing time and insertion circuit location, are required.

Points to remember on handling of ICs

- (1) Over current Protection Circuit
Over current protection circuits (referred to as current limiter circuits) do not necessarily protect ICs under all circumstances. If the over current protection circuits operate against the over current, clear the over current status immediately.
Depending on the method of use and usage conditions, such as exceeding absolute maximum ratings can cause the over current protection circuit to not operate properly or IC breakdown before operation. In addition, depending on the method of use and usage conditions, if over current continues to flow for a long time after operation, the IC may generate heat resulting in breakdown.
- (2) Thermal Shutdown Circuit
Thermal shutdown circuits do not necessarily protect ICs under all circumstances. If the thermal shutdown circuits operate against the over temperature, clear the heat generation status immediately.
Depending on the method of use and usage conditions, such as exceeding absolute maximum ratings can cause the thermal shutdown circuit to not operate properly or IC breakdown before operation.

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