

TB67S261

Usage considerations

Summary

The TB67S261 is a PHASE-in controlled two-phase bipolar stepping motor driver using a PWM chopper. Fabricated with the BiCD process, rating is 50 V/2.0 A.

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1. Power supply voltage

1.1. Power supply voltage and operating range

In using the TB67S261, the voltage should be applied to the terminals of VM, VREFA, and VREFB. The maximum rating of VM supply voltage is 50 V. Operating range of the power supply voltage is 10 to 47 V.

The maximum rating of VREF voltage is 5 V. Operating range of the voltage is 0 to 3.6 V.

As for the voltage of VREF, the voltage of the internal regulator of the IC (VCC) can be also used. (However, if the current is pulled up exceeding the capability of the internal regulator, the regulation of VCC may not be kept. When the voltage of VREF is applied by dividing the voltage of VCC, the total of the voltage-dividing resistance should not be less than 10 kΩ.

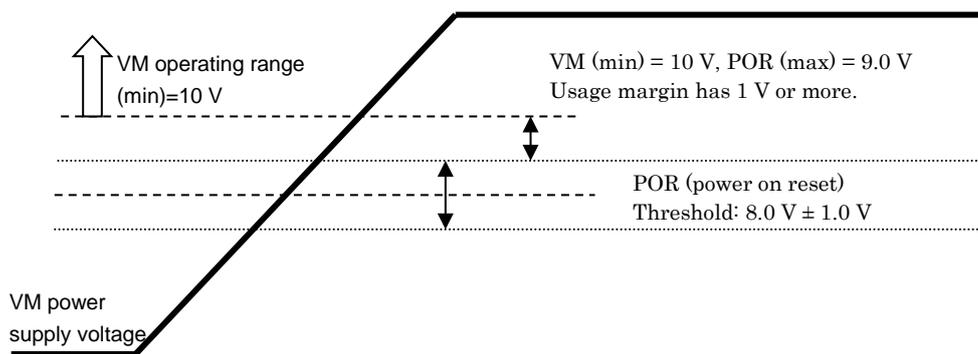


Figure 1.1 Power supply voltage and usage range

1.2. Power supply sequence

There are no special procedures of inputting a power supply and shutdown because the TB67S261 incorporates the power on reset (POR). However, under the unstable state of inputting the power supply (VM) and shutdown, it is recommended to turn off the motor operation. Please operate the motor by switching the input signal after the power supply becomes in the stable state.

2. Output current

Motor usage current should be 2 A or less. The maximum current of the actual usage is limited depending on the usage conditions (the ambient temperature, the wiring pattern of the board, the radiation path, and the exciting design). Configure the most appropriate current value after calculating the heat and evaluating the board under the operating environment.

3. Control input

When the logic input signal is inputted under the condition that the voltage of VM is not supplied, the electromotive force by inputting signal is not generated. However, configure the input signal low level before the power supply is applied by referring to the description of the “1.2. Power supply sequence.”

4. PWM control

The TB67S261 can adjust the internal oscillation frequency (f_{OSCM}) and the chopping frequency (f_{chop}) with the constant number of the external parts connecting to OSCM terminal.

- The relation equations of the OSCM oscillation frequency (f_{OSCM}) and the chopping frequency

$$f_{OSCM} = 1 / [0.56 \times \{C \times (R1 + 500)\}]$$

$$f_{chop} = f_{OSCM} / 16$$

- * C, R1: external constant number for OSCM (f_{OSCM} is about 1.12 MHz (typ.) at C = 270 pF and R1 = 5.1 kΩ. f_{chop} becomes considerable at about 70 kHz (typ.))

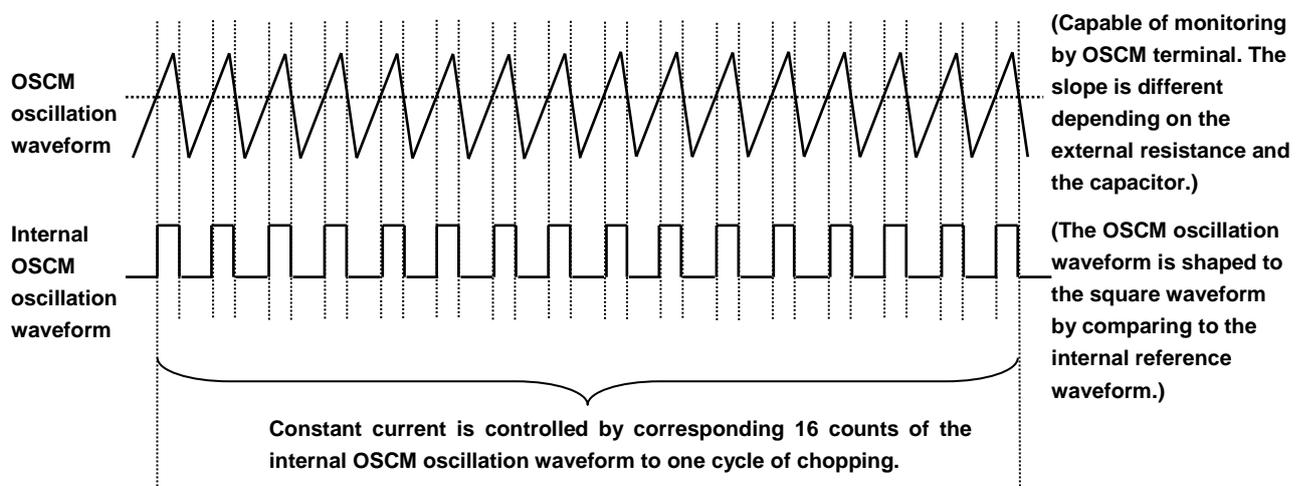


Figure 4.1 OSCM oscillation frequency

When the chopping frequency is increased, the motor can rotate faster because the following capability of the current steps increases. However, switching loss and heat increase may occur because the number of switching of output MOSFET is larger than the case of low frequency of the chopping.

(Example 1) Chopping frequency (f_{chop}) = 100 kHz

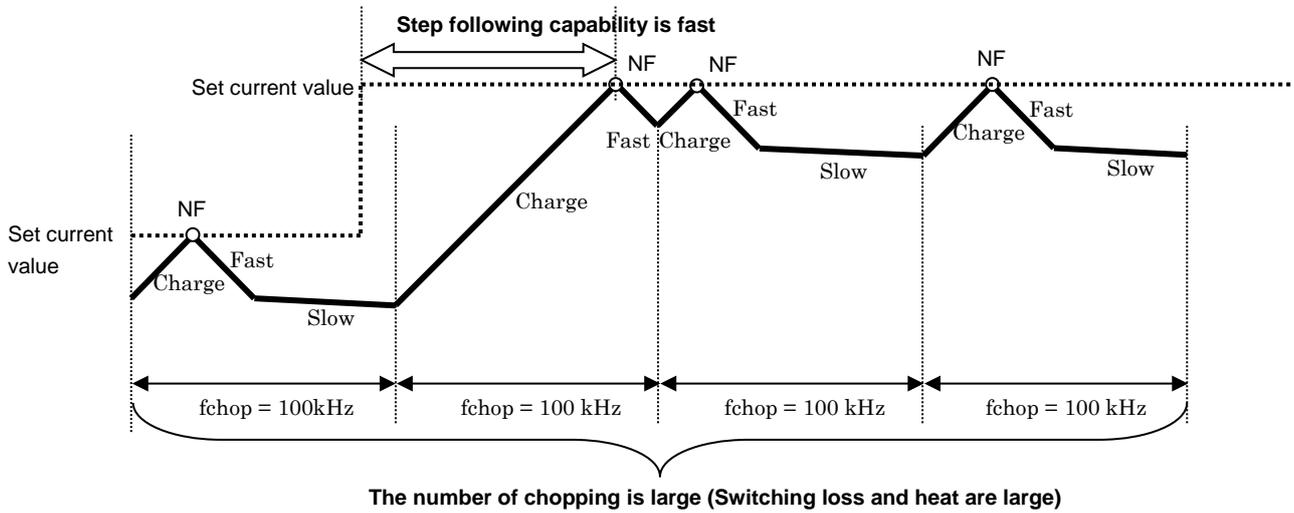


Figure 4.2 Chopping frequency (100 kHz)

(Example 2) Chopping frequency (f_{chop}) = 50 kHz

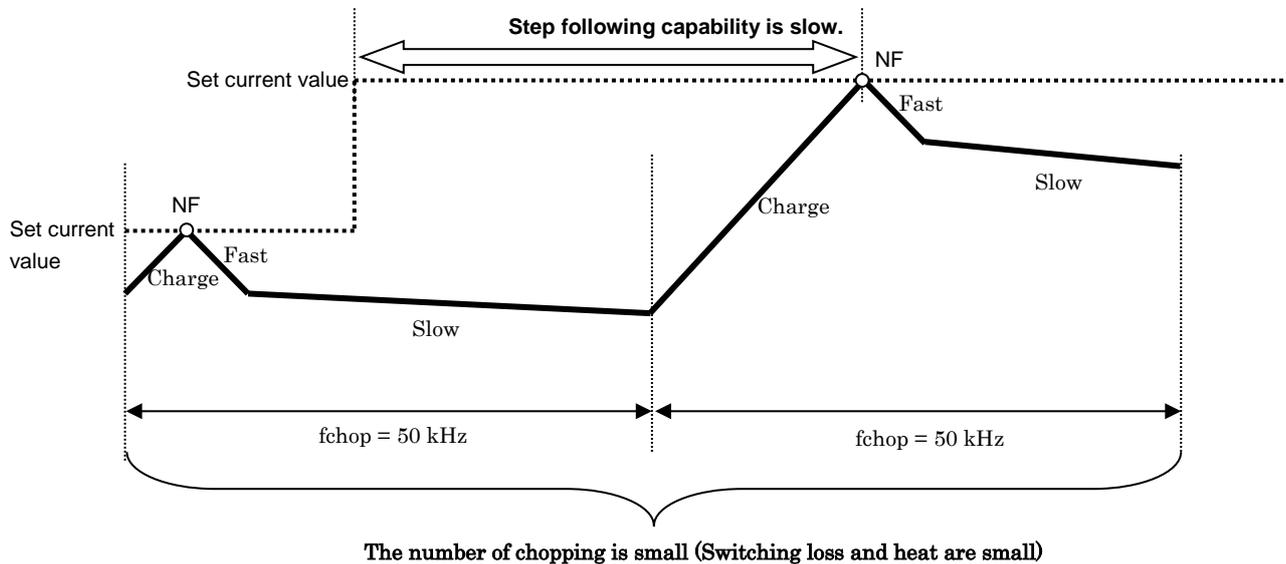


Figure 4.3 Chopping frequency (50 kHz)

Generally, it is recommended to configure the frequency in the range of 50 kHz to 100 kHz on the basis of 70 kHz.

5. ADMD control

The Advanced Dynamic Mixed Decay threshold, which determines the current ripple level during current feedback control, is a unique value.

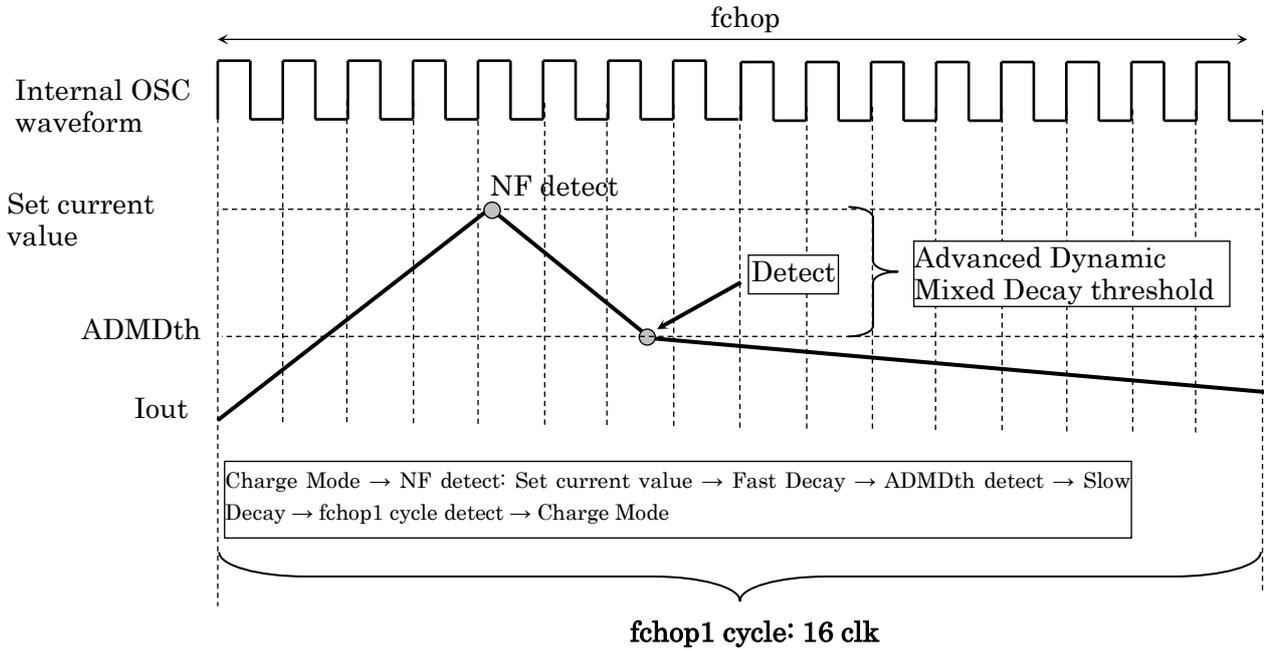
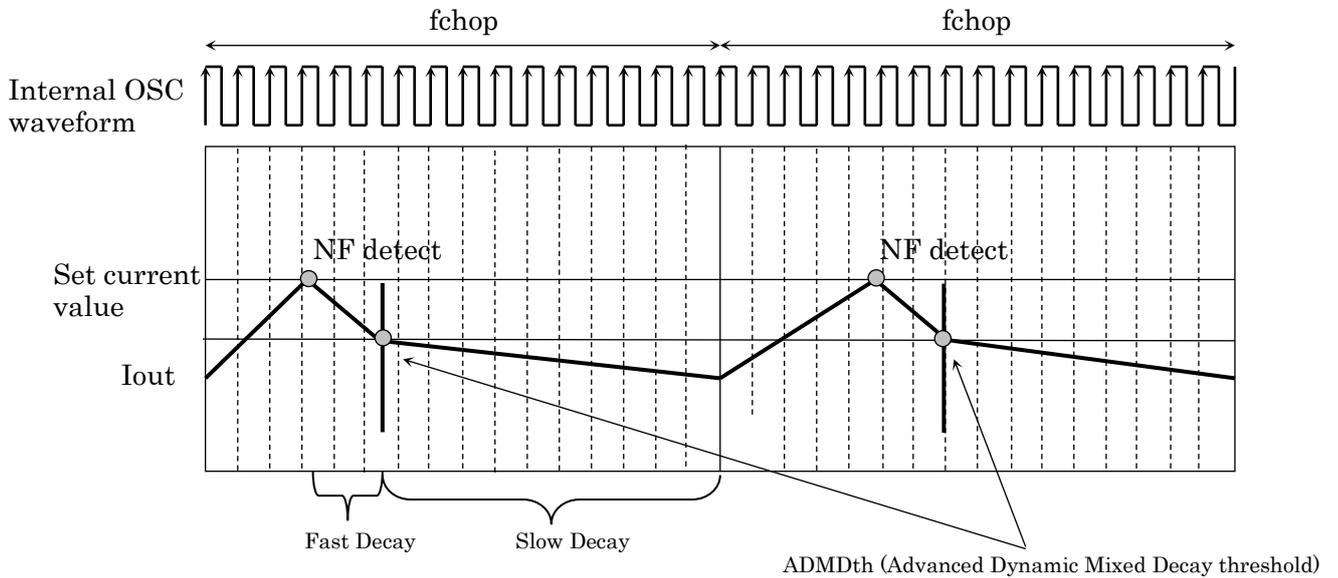


Figure 5.1 ADMD control

Auto Decay Mode waveform (current waveform)



Timing charts may be simplified for explanatory purpose.

Figure 5.2 Auto Decay Mode waveform

ADMD current waveform

- When the next current step is higher

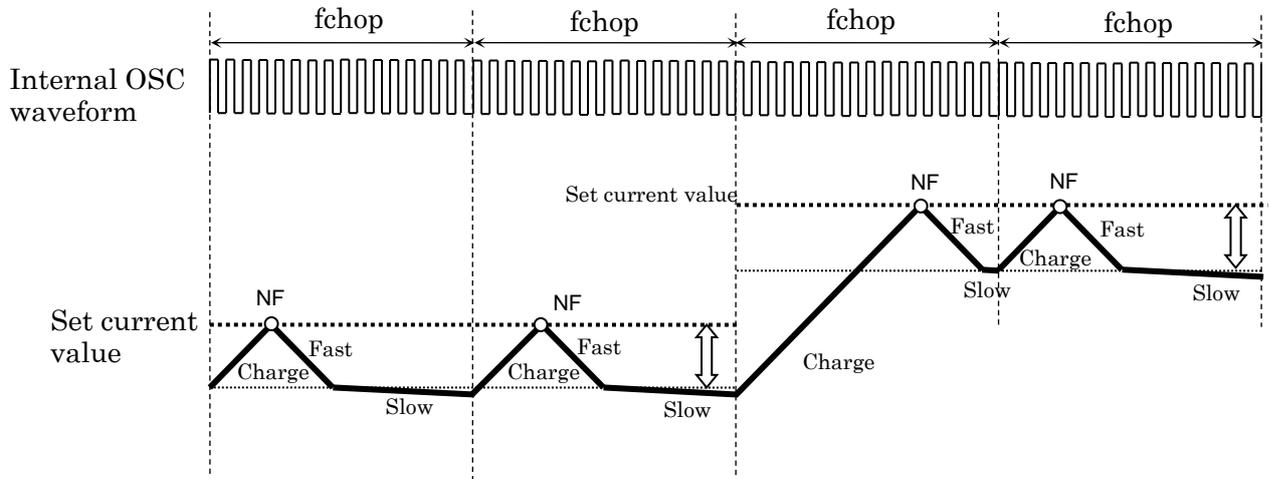


Figure 5.3 ADMD current waveform

- When Charge period is more than 1 cycle of fchop:

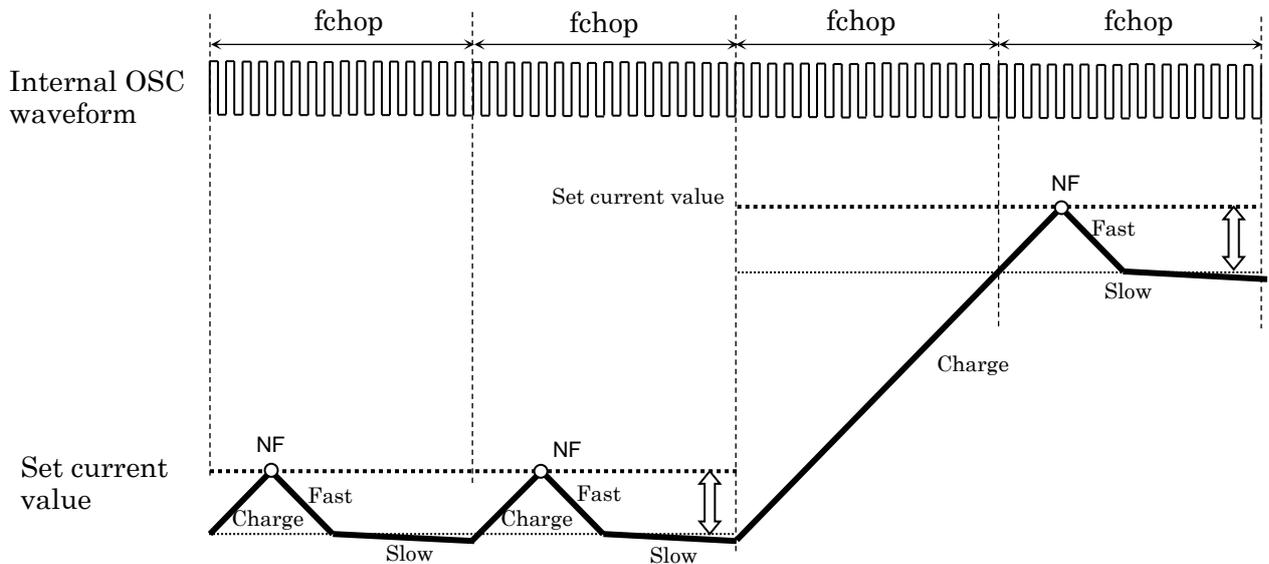


Figure 5.4 ADMD current waveform (When Charge period is more than 1 cycle of fchop)

When the Charge period is longer than 1 cycle of fchop, the Charge period will be extended until the motor current reaches the NF threshold. Once the current reaches the next current step, then the sequence will go on to decay mode.

- When the next current step is lower:

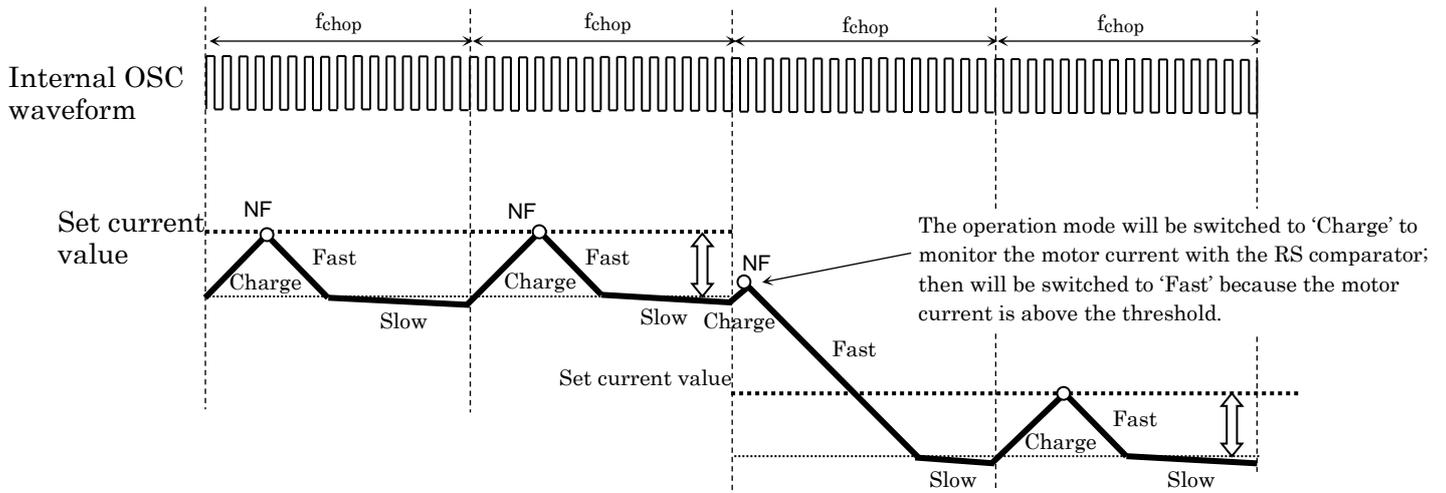


Figure 5.5 ADMD current waveform (When the next current step is lower)

- When the Fast continues past 1 cycle of f_{chop} (the motor current not reaching the ADMD threshold during 1 cycle of f_{chop})

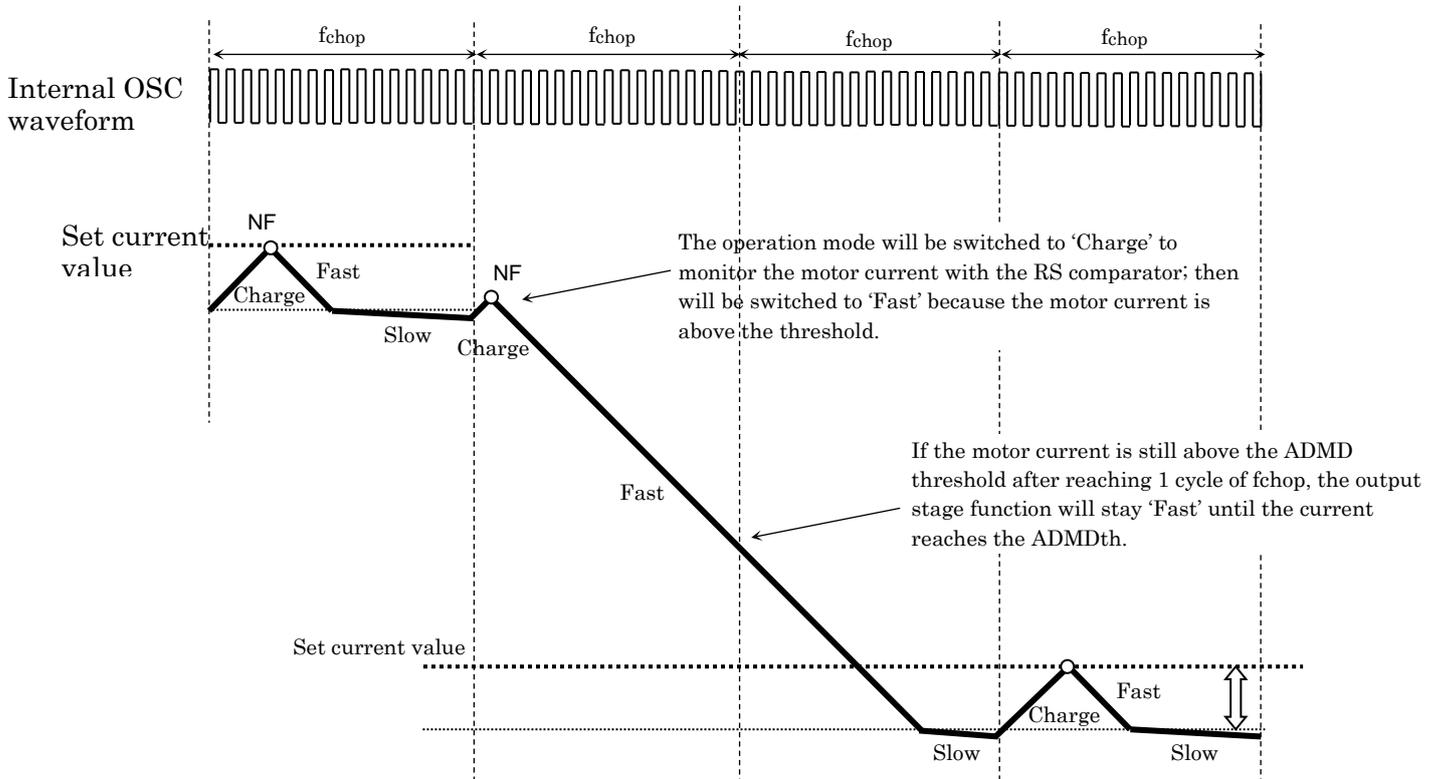


Figure 5.6 ADMD current waveform (When the Fast continues past 1 cycle)

6. Switching characteristics

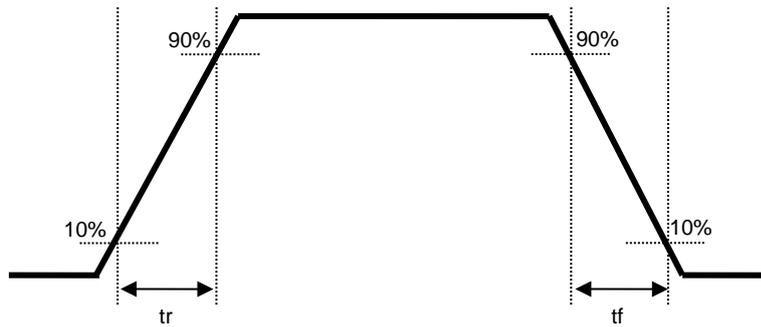


Figure 6.1 Switching characteristics

Table 6.1 Switching characteristics

$T_a = 25^\circ\text{C}$, $V_M = 24\text{ V}$, No load

Item	Typ.	Unit
tr	80	ns
tf	90	ns

7. Function explanation

(1) Input-and-output function

Motor output current (I_{out}): The flow from OUT+ to OUT- is plus current. The flow from OUT- to OUT+ is minus current.

Table 7.1 Input-and-output function

Input			Output		
PHASEA PHASEB	INA1 INB1	INA2 INB2	OUTA+ OUTB+	OUTA- OUTB-	$I_{out}(A)$ $I_{out}(B)$
H	H	H	H	L	100%
	H	L	H	L	71%
	L	H	H	L	38%
	L	L	Output OFF	Output OFF	0%
L	H	H	L	H	-100%
	H	L	L	H	-71%
	L	H	L	H	-38%
	L	L	Output OFF	Output OFF	0%

(2) STANDBY function

In Standby mode, an internal oscillating circuit and a motor output part are stopped. (The drive of a motor cannot be performed.)

Table 7.2 CW/CCW function

STANDBY input	Function
H	Standby release
L	Standby mode

(3) Control sequence at each driving mode

Table 7.3 Control sequence at full step mode

Ach				Bch			
Input		Output		Input		Output	
PHASEA	INA1	INA2	Iout(A)	PHASEB	INB1	INB2	Iout(B)
H	H	H	+100%	H	H	H	+100%
L	H	H	-100%	H	H	H	+100%
L	H	H	-100%	L	H	H	-100%
H	H	H	+100%	L	H	H	-100%

Table 7.4 Control sequence at half step mode

Ach				Bch			
Input		Output		Input			Output
PHASEA	INA1	INA2	Iout(A)	PHASEB	INB1	INB2	Iout(B)
H	H	H	+100%	H	H	H	+100%
X	L	L	0%	H	H	H	+100%
L	H	H	-100%	H	H	H	+100%
L	H	H	-100%	-	L	L	0%
L	H	H	-100%	L	H	H	-100%
X	L	L	0%	L	H	H	-100%
H	H	H	+100%	L	H	H	-100%
H	H	H	+100%	-	L	L	0%

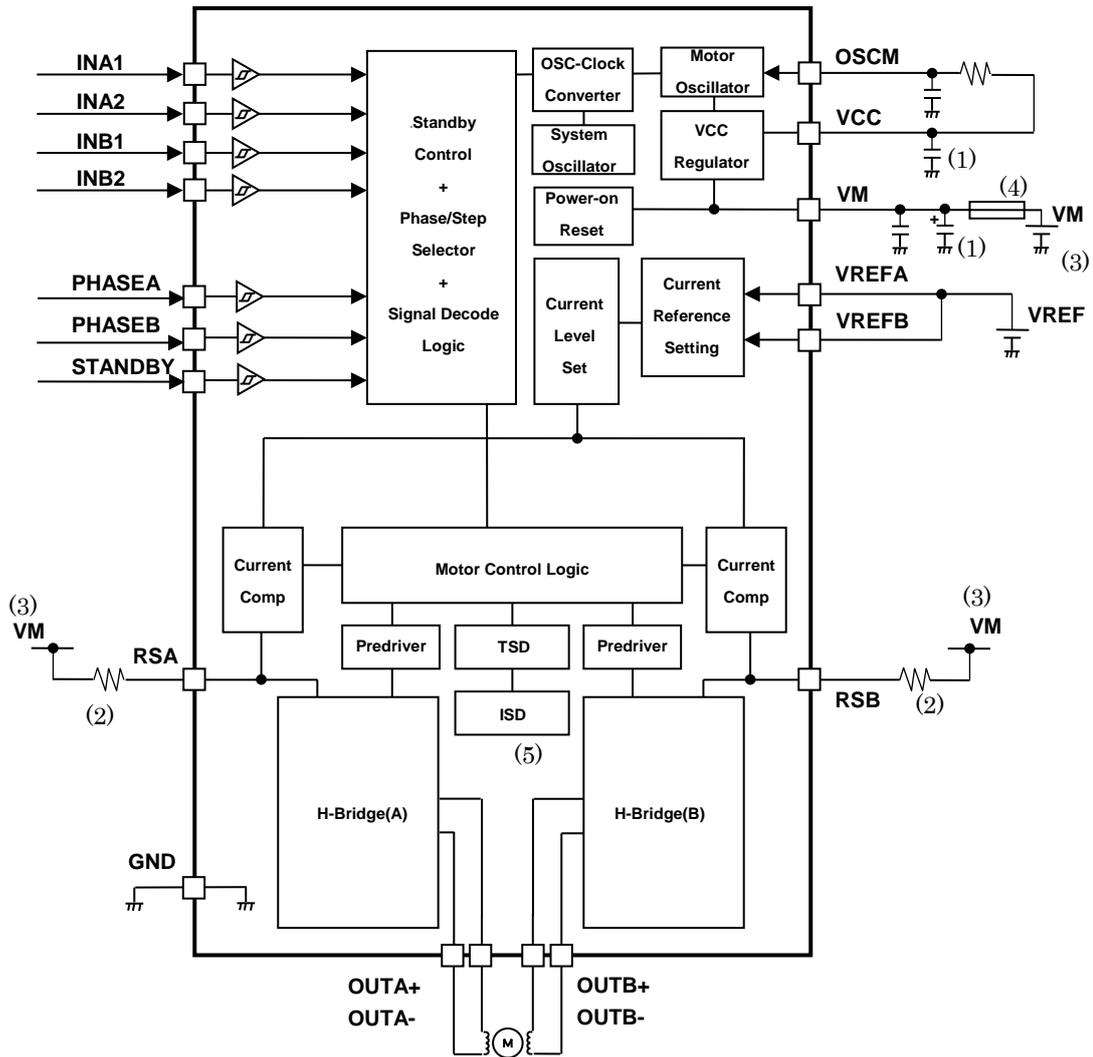
X : Don't care

Table 7.5 Control sequence at quarter step mode

Ach				Bch			
Input		Output		Input			Output
PHASEA	INA1	INA2	Iout(A)	PHASEB	INB1	INB2	Iout(B)
H	H	L	+71%	H	H	L	+71%
H	L	H	+38%	H	H	H	+100%
X	L	L	0%	H	H	H	+100%
L	L	H	-38%	H	H	H	+100%
L	H	L	-71%	H	H	L	+71%
L	H	H	-100%	H	L	H	+38%
L	H	H	-100%	X	L	L	0%
L	H	H	-100%	L	L	H	-38%
L	H	L	-71%	L	H	L	-71%
L	L	H	-38%	L	H	H	-100%
X	L	L	0%	L	H	H	-100%
H	L	H	+38%	L	H	H	-100%
H	H	L	+71%	L	H	L	-71%
H	H	H	+100%	L	L	H	-38%
H	H	H	+100%	X	L	L	0%
H	H	H	+100%	H	L	H	+38%

X : Don't care

8. Example of application circuit



The application circuit example is for reference only, and does not guarantee the mass production design of the device.

Figure 8.1 Example of application circuit

(1) Capacitor for power supply terminal

To stabilize the power supply voltage of the IC and reduce the noise, connect the appropriate capacitor to each terminal. It is recommended to connect the capacitor as close to the IC as possible. Especially, by connecting the ceramic capacitor near the IC, the change of the power supply at the high frequency range and the noise can be reduced.

Table 8.1 Recommended capacitor values for power supply terminal

Item	Parts	Typ.	Recommended range
VM-GND	Electric capacitor	100 μF	47 to 100 μF
	Ceramic capacitor	0.1 μF	0.01 to 1 μF
VCC-GND	Ceramic / Electrolytic capacitor	0.1 μF	0.01 to 1 μF
(VREF-GND)	Ceramic capacitor	0.1 μF	0.01 to 1 μF

* VREF-GND: Connect the capacitor in necessary depending on the usage environment.

* It is possible to use the capacitor, which is not the recommended capacitor, depending on the motor load condition and the design pattern of the board.

(2) Resistance of current detection

This IC configures the threshold of the constant current detection by connecting the resistance of current detection between VM and RS terminals. The detection resistance is recommended to connect near the IC. (The motor can be controlled with the accurate current because the influence of the wire resistance of the board can be reduced.)

Table 8.2 Recommended resistance values for current detection

Item	Parts	Typ.	Recommended range
VM-RS	Chip / Lead resistance	0.22 Ω (1.5 to 3.0 A)	0.22 to 1.0 Ω
VM-RS	Chip / Lead resistance	0.51 Ω (0 to 1.5 A)	0.22 to 1.0 Ω

The relation equation of the threshold of the constant current detection, Vref voltage, and the resistance of RS detection is as follows;

$$I_{out(max)} = V_{ref(gain)} \times \frac{V_{ref(V)}}{R_{RS}(\Omega)}$$

Vref(gain): Vref decay ratio is 1 / 5.0(typ.).

As for the resistance of current detection, the constant number which is out of recommended range can be adopted. In this case, please pay attentions to the followings when the used resistance is high and low.

- When the detection resistance is low, the difference voltage between VM and RS comparing to the internal reference voltage becomes small. So, the current may be largely different from the configured current value.
- When the detection resistance is high, the power applied to the detection resistance increases in motor operation ($P=I^2 \times R$). So, in case the same current flows as the case of low resistance, the power dissipation should be larger.

(3) Wiring pattern for power supply and GND

Since large current may flow in VM, RS, and GND pattern especially, design the appropriate wiring pattern to avoid the influence of wiring impedance. It is very important for surface mounting package to radiate the heat from the heat sink of the back side of the IC to the GND. So, design the pattern by considering the heat design.

(4) Fuse

Use an appropriate power supply fuse for the power supply line to ensure that a large current does not continuously flow in the 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 to smoke or ignition. To minimize the effects of the flow of a large current in the case of breakdown, appropriate settings, such as fuse capacity, fusing time and insertion circuit location, are required.

This IC incorporates over current detection circuit (ISD) that turns off the output of the IC when over current is detected in the IC. However, it does not necessarily protect ICs under all circumstances. If the Over current detection 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 detection 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. To avoid above IC destruction and malfunctions caused by noise, the over current detection circuit has a dead band time. So, it is concerned that the over current detection circuit may not operate depending on the output load conditions because of the dead band time. Therefore, in order to avoid continuing this abnormal state, use the fuse for the power supply line.

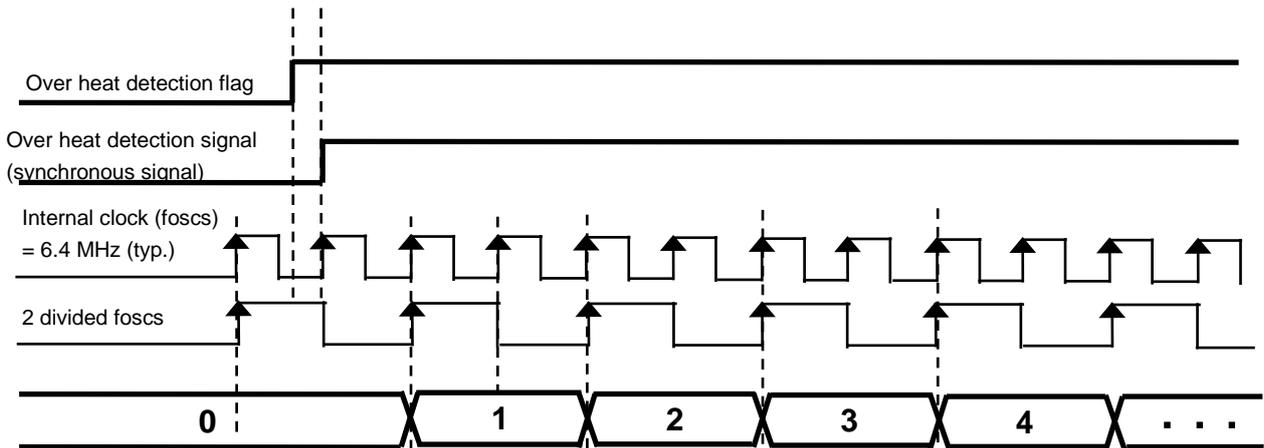
(5) Abnormality detection function

- Thermal shutdown circuit (TSD)

When the IC detects an over temperature, the internal circuit turns off the output MOSFETs. It has a dead band time to avoid TSD misdetection, which may be triggered by external noise.

Reassert the VM power supply or use the standby mode by STANDBY terminal to release this function. The TSD is triggered when the device is over heated irregularly. Make sure not to use the TSD function aggressively.

Dead band time of TSD



Timing charts may be simplified for explanatory purposes.

Figure 8.2 Dead band time of thermal shutdown circuit

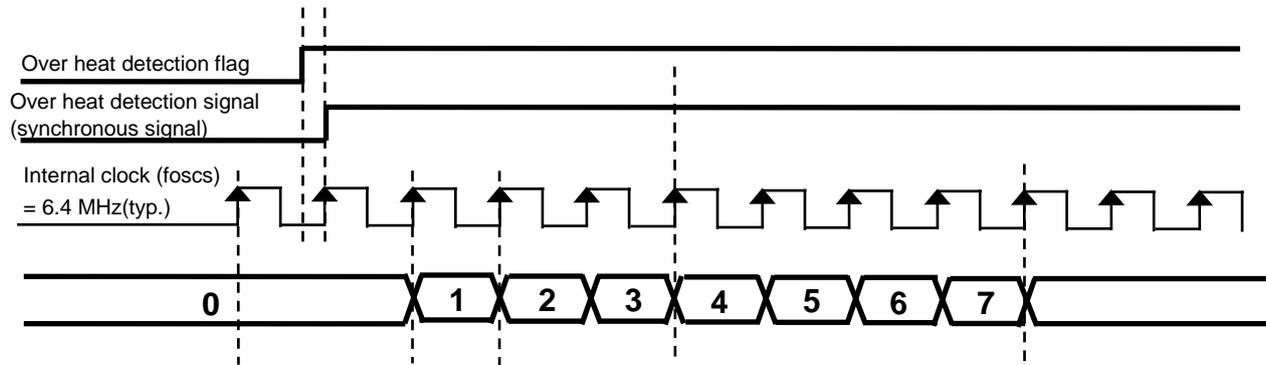
Thermal shutdown circuit has a dead band time to avoid false detection. This dead band time is configured by counting up the internal counter by the fixed frequency (6.4 MHz(typ.)) in the IC.

foscs = 6.4 MHz(typ.) internal clock

$1 / (\text{foscs} / 2) \times 7 \sim 8 \text{ clk} = 1 / \text{foscs} \times 14 \text{ to } 16 \text{ clk} (2.5 \text{ to } 2.8 \mu\text{s})$

- Over current detection (ISD)
When the IC detects an over current, the internal circuits turns off the output MOSFETs. It has a dead band time to avoid ISD misdetection, which may be triggered by external noise. Reassert the VM power supply or use the standby mode by STANDBY terminal to release this function.

Dead band time of ISD



Timing charts may be simplified for explanatory purposes.

Figure 8.3 Dead band time of ISD

ISD has a dead band time to avoid false detection caused by spike current in switching. This dead band time is configured by counting up the internal counter by the fixed frequency (6.4 MHz(typ.)) in the IC.

$$\text{foscs} = 6.4 \text{ MHz (typ.) internal clock}$$

$$1 / \text{foscs} \times 7 \text{ to } 8 \text{ clk (1.09 to 1.25 } \mu\text{s)}$$

9. Power consumption of the IC

Power of the IC is consumed by the transistor of the output block and that of the logic block mainly.

$$P(\text{total}) = P(\text{out}) + P(\text{bias})$$

- Power consumption of the motor output block
 Power of the output block (P(out)) is consumed by MOSFET of upper and lower H-Bridge.

$$P(\text{out}) = \text{Number of H-Bridge} \times I_{\text{out}} (\text{A}) \times V_{\text{DS}} (\text{V}) = 2 (\text{ch}) \times I_{\text{out}} (\text{A}) \times I_{\text{out}} (\text{A}) \times R_{\text{on}} (\Omega) \dots \dots \dots (1)$$

When the current waveform of the motor output corresponds to the ideal waveform (2-phase excitation / square wave), average power of output block can be provided as follows;

$$\begin{aligned} &\text{When } R_{\text{on}} = 0.8\Omega, I_{\text{out}} (\text{peak: Max}) = 1.5 \text{ A, } V_{\text{M}} = 24 \text{ V} \\ &P(\text{out}) = 2 (\text{ch}) \times 1.5 (\text{A}) \times 1.5 (\text{A}) \times 0.8 (\Omega) \dots \dots \dots (2) \\ &= 3.6 (\text{W}) \end{aligned}$$

Additionally, when the maximum resolution (Quarter step, 4 steps) is set using μ step function, P(out) = 2.55 (W) because the average power becomes about 71% (= 1/√2).

- Power consumption of logic and IM systems
 Power consumptions of logic and IM systems are calculated by separating the states (operating and stopping).

$$\begin{aligned} I (\text{IM3}) &= 5.5 \text{ mA (typ.): Operating} \\ I (\text{IM2}) &= 3.5 \text{ mA (typ.): Stopping} \end{aligned}$$

Output system is connected to VM (24V). (Output system: Current consumed by the circuit connected to VM + Current consumed by switching output steps)

Power consumption is calculated as follows;

$$\begin{aligned} P(\text{bias}) &= 24 (\text{V}) \times 0.0055 (\text{A}) \dots \dots \dots (3) \\ &= 0.132 (\text{W}) \end{aligned}$$

- Power consumption
 Total power consumption P(total) is calculated from the values of formula (2) and (3).

$$P(\text{total}) = P(\text{out}) + P(\text{bias}) = 3.6 + 0.132 = 3.732 (\text{W})$$

Standby mode is released. The power consumption in non-operation mode of the motor (waiting mode) is calculated as follows;

$$P = 24 (\text{V}) \times 0.0035 (\text{A}) = 0.084 (\text{W})$$

In actual motor operation, the average current becomes lower than the calculated value because of transition time of the current steps and the ripple of the constant current PWM. Refer to the above equations, evaluate the heat design of the board by the actual board enough, and configure the appropriate margin.

10. Power dissipation

Relation equation of the ambient temperature (T_a), junction temperature (T_j), and the heat resistance ($R_{th(j-a)}$) between junction temperature to ambient temperature is as follows;

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

(Example) When 4-layer mounting board ($R_{th(j-a)} = 25^\circ\text{C/W}$), $T_a = 25^\circ\text{C}$, $P(\text{total}) = 3.732\text{ W}$
 ($I_{out} = 1.5\text{ A}$, 2-phase excitation)
 $T_j = 25\text{ (}^\circ\text{C)} + 25\text{ (}^\circ\text{C/W)} \times 3.732\text{ (W)} = 118.3^\circ\text{C}$

(Reference) Relation between the power dissipation and the ambient temperature

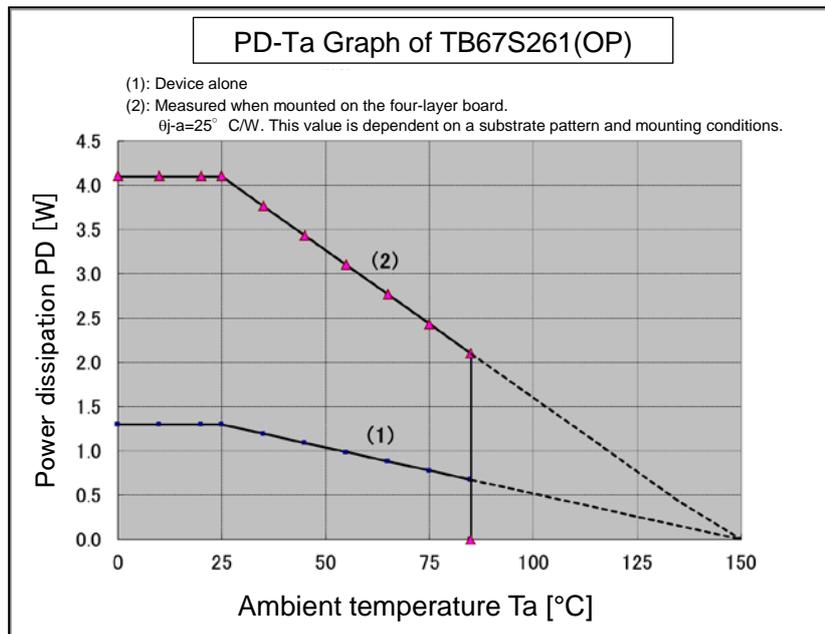


Figure 10.1 Power dissipation

* Pay attention that T_a , $R_{th(j-a)}$, and $P(\text{total})$ depend on the usage environment. When ambient temperature is high, the allowable power consumption decreases.

11. Board dimensions

11.1. Input

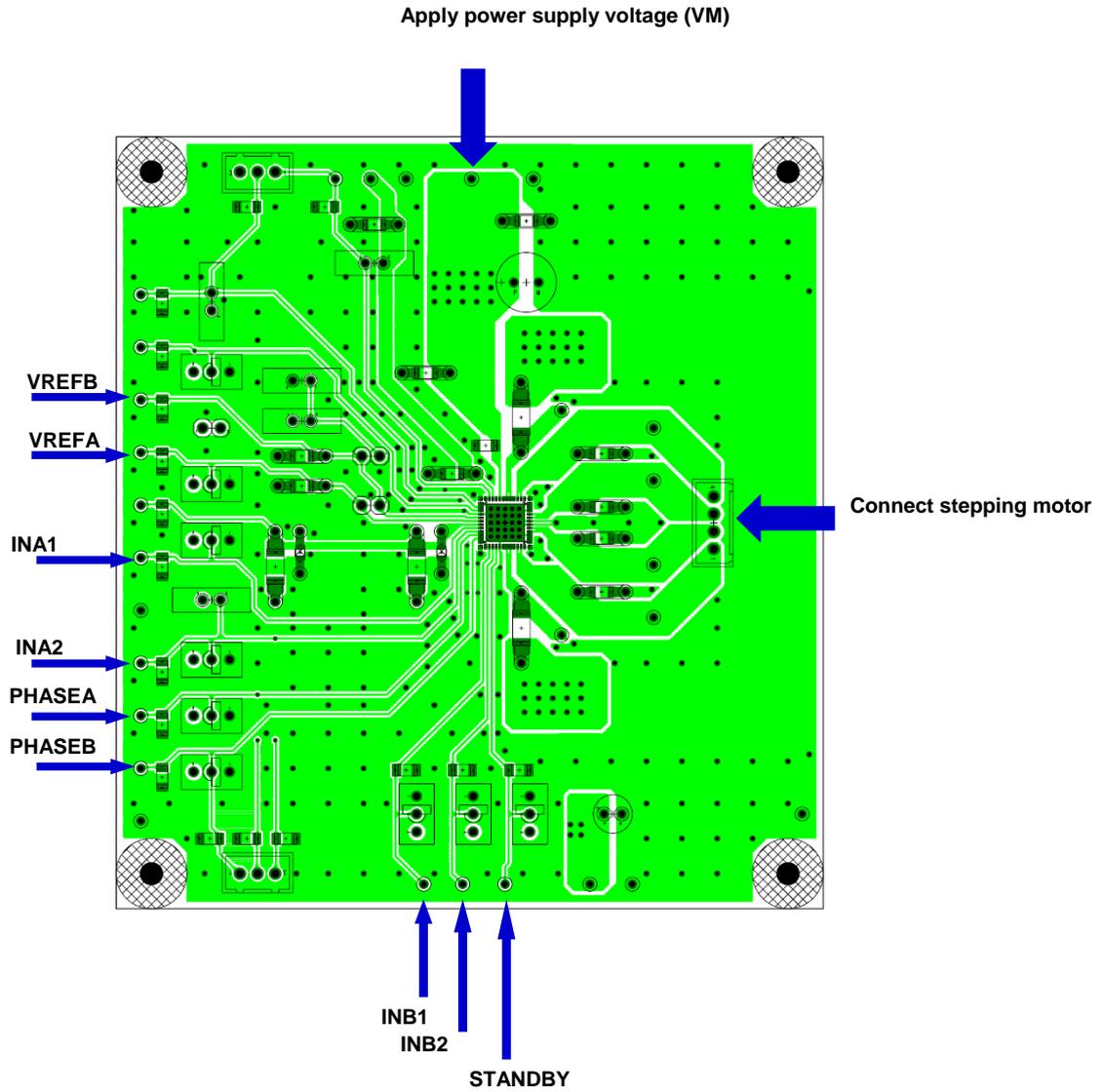


Figure 11.1 Input

Input each power supply and control signal according to above figure.

11.2. Main part

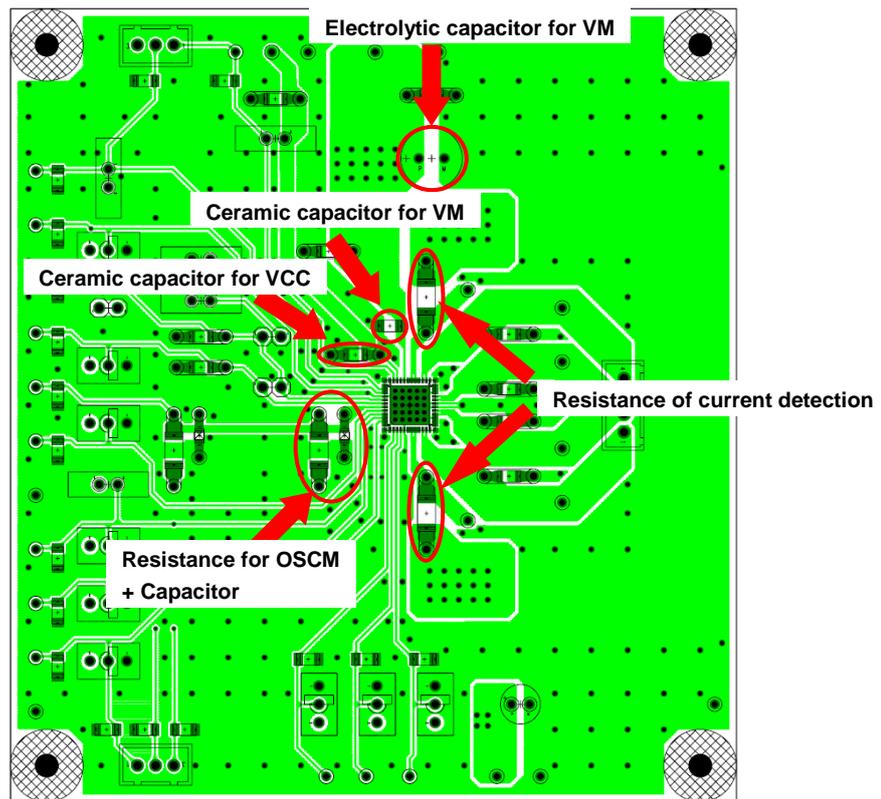


Figure 11.2 Main part

Connect each part referring to "8. Example of application circuit."

11.3. Options

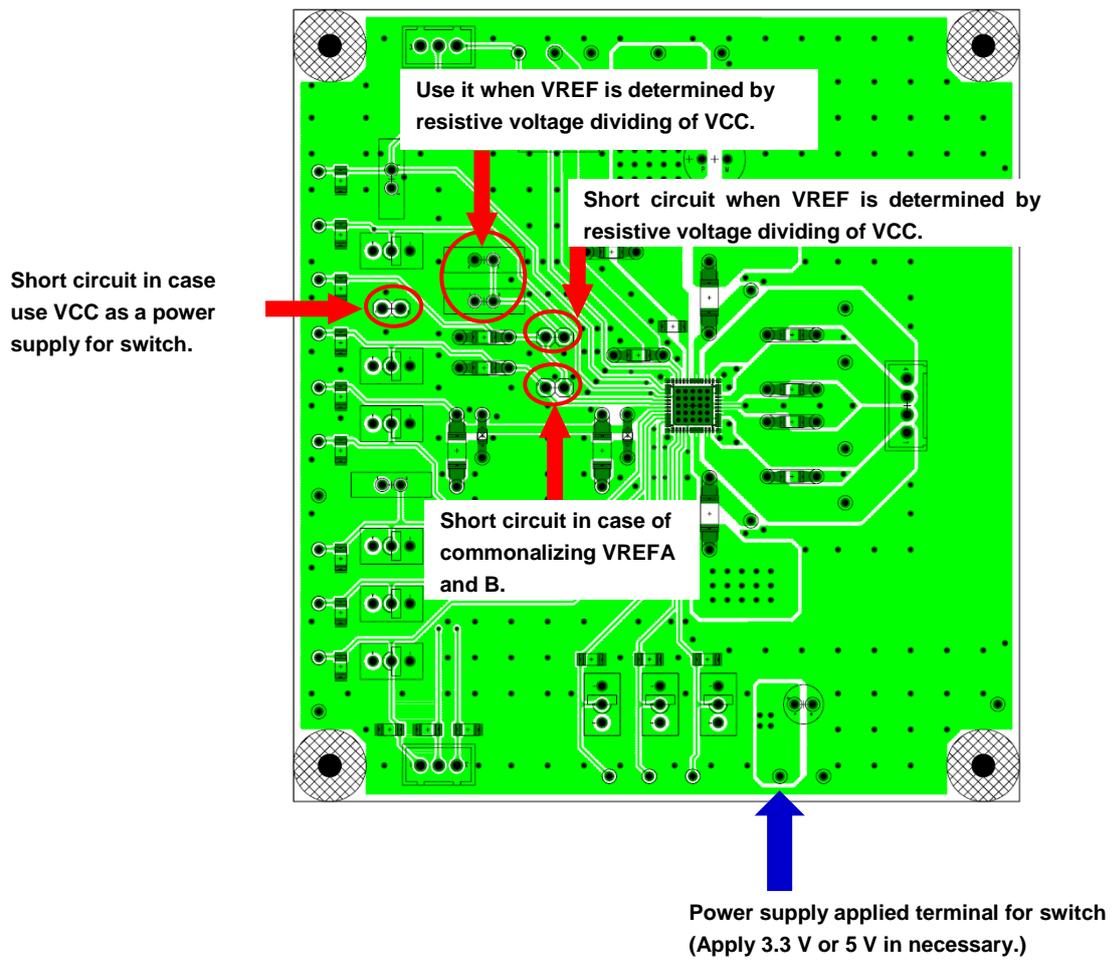


Figure 11.3 Options

Notes on Contents

1. Block diagram
Some of the functional blocks, circuits, or constants in the block diagram may be omitted or simplified for explanatory purposes.
2. Equivalent Circuits
The equivalent circuit diagrams may be simplified or some parts of them may be omitted for explanatory purposes.
3. Timing Charts
Timing charts may be simplified for explanatory purposes.
4. Application Circuit
The application circuits shown in this document are provided for reference purposes only. Thorough evaluation is required, especially at the mass production design stage. Toshiba does not grant any license to any industrial property rights by providing these examples of application circuits.
5. Test Circuit
Components in the test circuits are used only to obtain and confirm the device characteristics. These components and circuits are not guaranteed to prevent malfunction or failure from occurring in the application equipment.

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 device breakdown, damage or deterioration, and may result in injury by explosion or combustion.
- (2) Use an appropriate power supply fuse to ensure that a large current does not continuously flow in the case of overcurrent 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 to smoke or ignition. To minimize the effects of the flow of a large current in the case of breakdown, appropriate settings, such as fuse capacity, fusing time and insertion circuit location, are required.
- (3) If your design includes an inductive load such as a motor coil, incorporate a protection circuit into the design to prevent device malfunction or breakdown caused by the current resulting from the inrush current at power ON or the negative current resulting from the back electromotive force at power OFF. IC breakdown may cause injury, smoke or ignition. Use a stable power supply with ICs with built-in protection functions. If the power supply is unstable, the protection function may not operate, causing IC breakdown. IC breakdown may cause injury, smoke or ignition.
- (4) Do not insert devices in the wrong orientation or incorrectly. Make sure that the positive and negative terminals of power supplies are connected properly. Otherwise, the current or power consumption may exceed the absolute maximum rating, and exceeding the rating(s) may cause the device breakdown, damage or deterioration, and may result injury by explosion or combustion. In addition, do not use any device that is applied the current with inserting in the wrong orientation or incorrectly even just one time.
- (5) Carefully select external components (such as inputs and negative feedback capacitors) and load components (such as speakers), for example, power amp and regulator.

If there is a large amount of leakage current such as input or negative feedback condenser, the IC output DC voltage will increase. If this output voltage is connected to a speaker with low input withstand voltage, overcurrent or IC failure can cause smoke or ignition. (The over current can cause smoke or ignition from the IC itself.) In particular, please pay attention when using a Bridge Tied Load (BTL) connection type IC that inputs output DC voltage to a speaker directly.

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.
- (3) Heat Radiation Design**
In using an IC with large current flow such as power amp, regulator or driver, please design the device so that heat is appropriately radiated, not to exceed the specified junction temperature (T_j) at any time and condition. These ICs generate heat even during normal use. An inadequate IC heat radiation design can lead to decrease in IC life, deterioration of IC characteristics or IC breakdown. In addition, please design the device taking into consideration the effect of IC heat radiation with peripheral components.
- (4) Back-EMF**
When a motor rotates in the reverse direction, stops or slows down abruptly, a current flow back to the motor's power supply due to the effect of back-EMF. If the current sink capability of the power supply is small, the device's motor power supply and output terminals might be exposed to conditions beyond absolute maximum ratings. To avoid this problem, take the effect of back-EMF into consideration in system design.

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