TB67S209FTG
Usage considerations

Summary

TB67S209FTG is a stepping motor driver IC, which includes an SMD function that can set the motor control current corresponding to each motor characteristic. Selecting the appropriate SMD setting suitable for the motor enables reducing noise and vibration efficiently.

Main specifications of product

Part number	TB67S209FTG
Control I/F	CLK-IN
Absolute maximum ratings	50 V, 4 A
Package	QFN48
Step resolution	Full, half, quarter, 1/8, 1/16, and 1/32
Other features	Ideal current control of the motor drive using SMD architecture Built-in error detection circuits (Thermal shutdown (TSD), over-current shutdown (ISD), and under voltage lock out (UVLO)) Built-in error detection flags output function Power-on and off sequence are unnecessary because of a single VM power supply.

Note: Selectable Mixed Decay. A method that allows setting the ideal current for a motor's characteristics.
For details, refer to Section 5. SMD Control in this document.

*: Contents described in the application note is as a reference for the product evaluation. Therefore it does not ensure. For details, refer to the technical datasheet.

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Usage of the TB67S209FTG is explained.

1. Power supply voltage

1.1. Power supply voltage and usage range

In using the TB67S209FTG, the voltage should be applied to the VM, and VREF pins. A regulator is built in the IC and the IC can operate with single VM power supply, so that external VCC voltage is unnecessary to be applied. The absolute maximum rating of VM supply voltage is 50V. Usage range of the power supply is 10 to 47V. The absolute maximum rating of VREF voltage is 5V. Usage range of the voltage is 0 to 3.6V. 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.

Table 1.1 Usage range of power supply voltage (Ta=-20 to 85°C)

Item	Symbol	Absolute maximum ratings	Usage range	Unit	Remark
Motor power supply voltage	VM	50	10 to 47	V	—
Constant current threshold setting voltage	Vref	5.0	0 to 3.6	V	—
Internal circuit power supply	VCC	6.0	4.75 to 5.25	V	At external applying

1.2. Power supply sequence

There are no special procedures of inputting the power supply and shutdown because the VM and VCC of TB67S209FTG include the power on reset (POR). When the POR works, the logic is initialized, and the electrical angle is reset to the initial value. However, under the unstable state of inputting the power supply and shutdown, it is recommended to turn off the motor operation. Please operate the motor by switching the input signal after the power supply voltage becomes in the stable state.

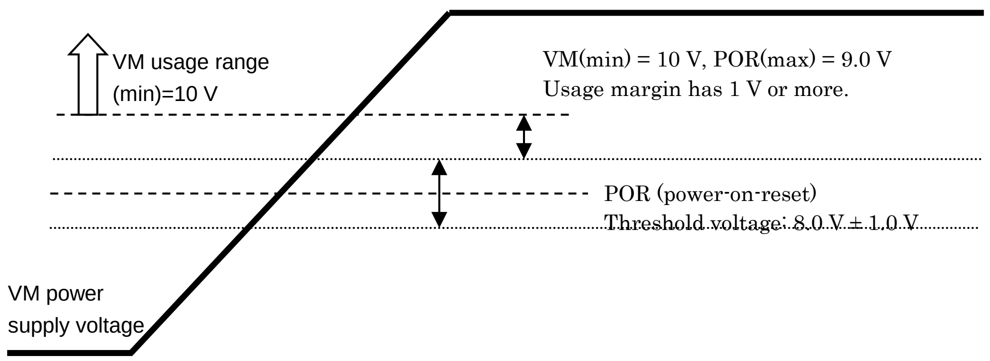


Figure 1.1 Power supply voltage and usage range

2. Output current

Motor usage current should be 3 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 input 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 “1.1 Power supply voltage and usage range.” Especially the Enable pin should be set to Low level for preventing a wrong operation in the power supply usage range. The IC (including output stages) does not operate when the Enable pin is set to low level.

4. Constant current control

4.1. Relation between constant current control and internal oscillation frequency

The TB67S209FTG can adjust the internal oscillation frequency (fOSCM) and the chopping frequency (fchop) of the constant current control, with the constants of the external components connecting to OSCM pin.

Constant current is controlled by corresponding 16 counts of the internal OSCM oscillation waveform to one cycle of chopping.

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

*: External constants for C_{OSCM} and R_{OSCM} (equivalent to f_{OSCM} is about 1.15 MHz (typ.), and fchop is about 72 kHz (typ.) with C_{OSCM} = 270 pF, and R_{OSCM} = 4.7 kΩ)

The formula of the relation between the OSCM oscillation frequency (fOSCM) and chopping frequency (fchop) is as follows.

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

For the relation between external components and oscillation frequency, refer to page 20 and page 21.

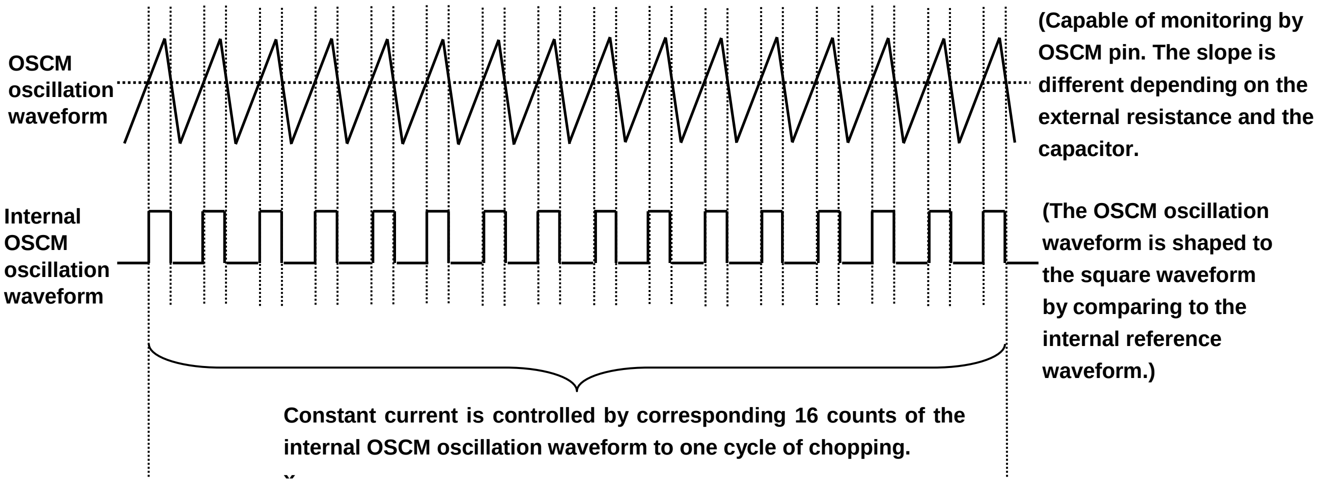


Figure 4.1 Relation between OSCM waveform and internal waveform

4.2. Constant current waveform when chopping frequency is changed

It is recommended that the typical chopping frequency is 72 kHz. When the chopping frequency is raised more than 72 kHz, the motor current pulse can be made small and the waveform quality is improved. Moreover, since the number of chopping is increased, the switching loss also becomes large, and the heat generation becomes large. When the priority is given to a waveform quality, the chopping frequency should be raised. Then if the heat generation would like to be suppressed, the chopping frequency should be lowered.

Example 1: Chopping frequency (fchop) = 100 kHz

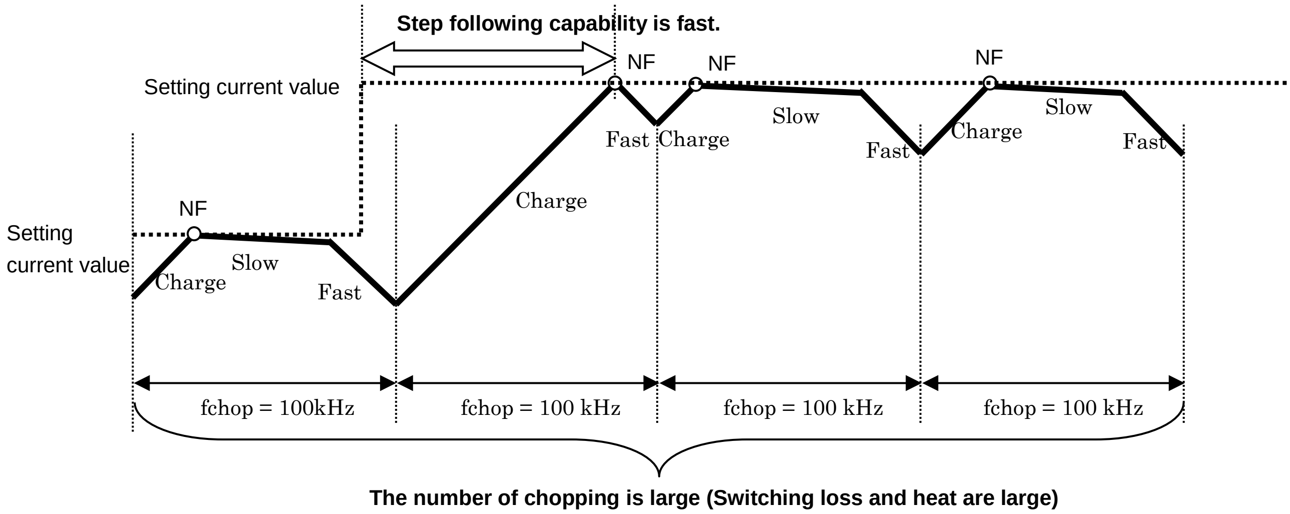


Figure 4.2 Chopping frequency (in case of 100 kHz)

Example 2: Chopping frequency (fchop) = 72 kHz

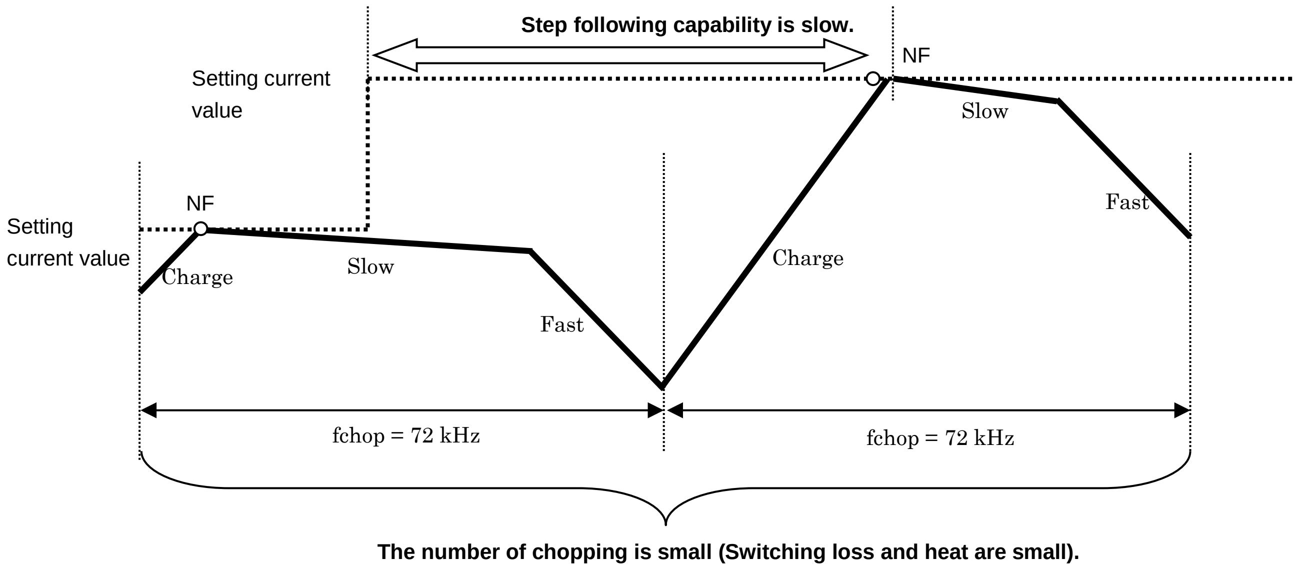


Figure 4.3 Chopping frequency (In case of 72 kHz)

Generally, it is recommended to configure the frequency in the range of 50 kHz to 120 kHz on the basis of 72 kHz.

5. SMD Control

The SMD (Selectable Mixed Decay), which is the greatest feature of this product, is a function that the amount of regenerative current in the period of regenerative current (Decay) can be adjusted by using pins. Switching two Decays, the Slow Decay and Fast Decay, enables Mixed Decay control in itself. This function allows selecting the ratio of Slow Decay and Fast Decay from four settings by two pins, SMD0 and SMD1. The following figure shows an overview of a current waveform when the Fast Decay ratio is changed 12.5 %/37.5 %/50 %/Fast Decay only (100 %). The current following ability to the setting current value is raised by selecting the ideal current ratio suitable for the motor to be used.

Moreover, Toshiba product line-up has the TB67S109AFTG, which can set the Decay ratio automatically. Please select the product according to the use environment.

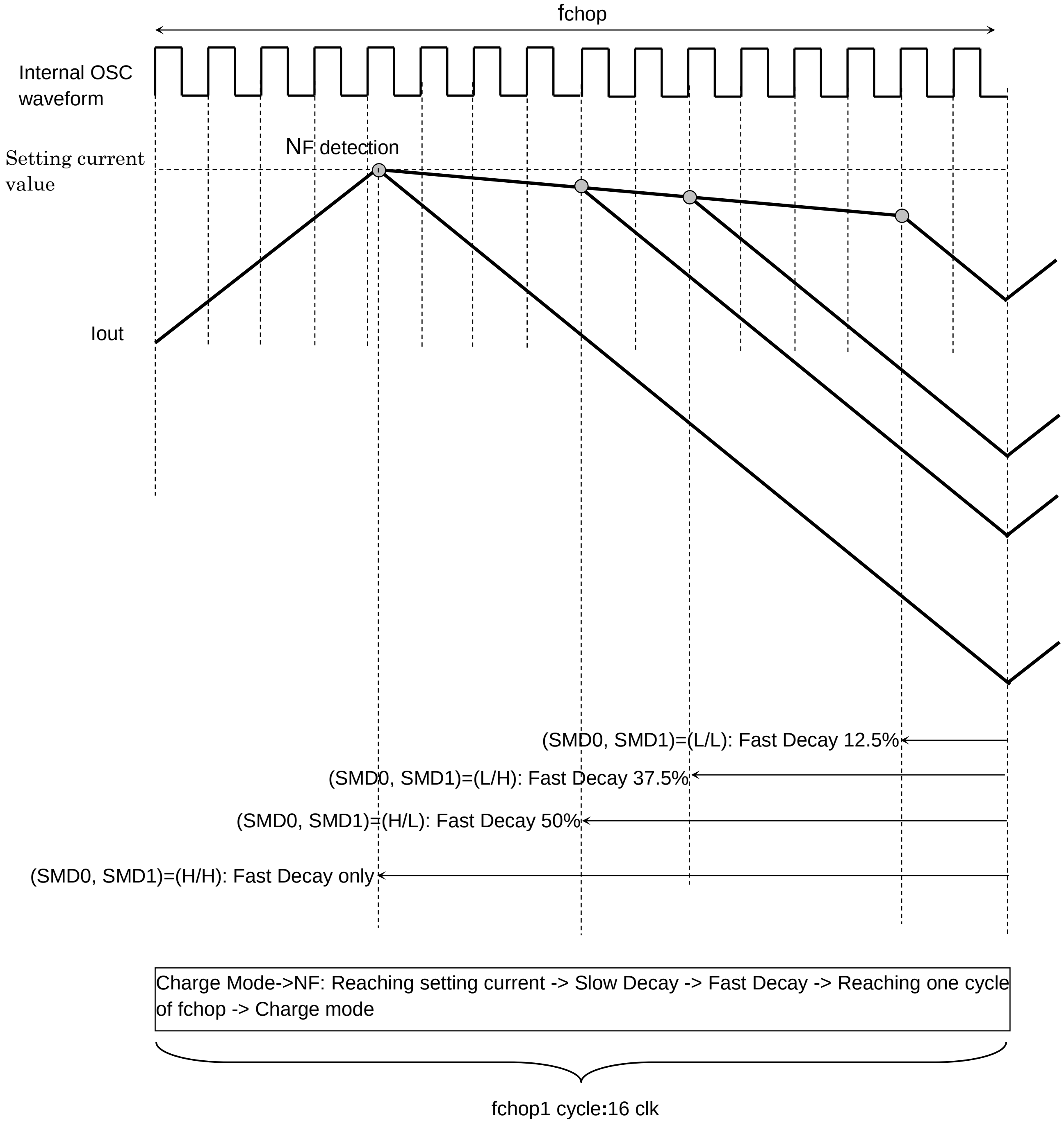


Figure 5.1 SMD control

・Example of Mixed Decay waveform (in case of SMD setting 37.5 %)

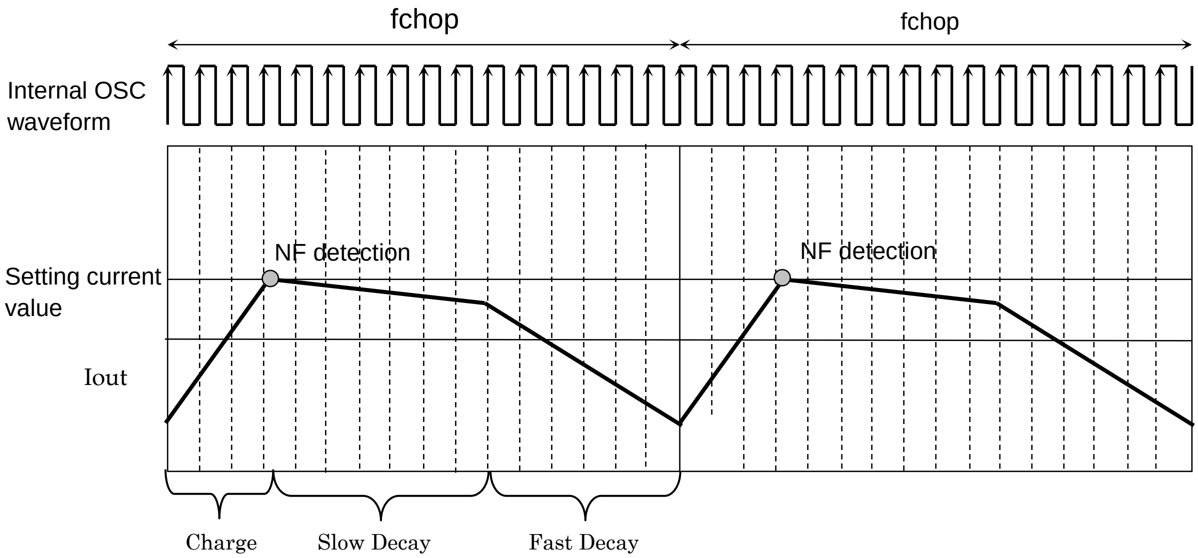
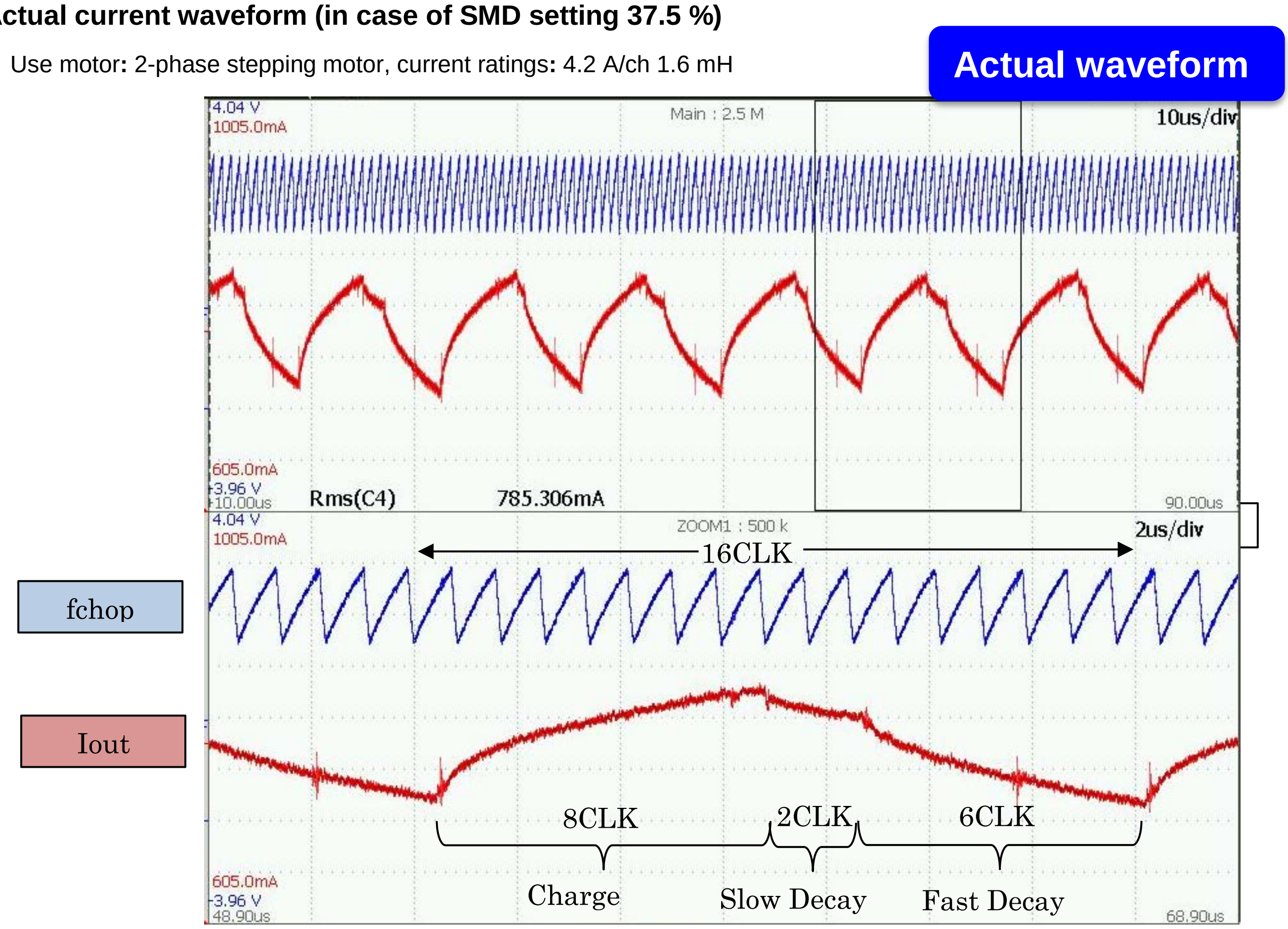


Figure 5.2 Mixed Decay waveform

Timing charts may be simplified for explanatory purposes.

・Actual current waveform (in case of SMD setting 37.5 %)

Use motor: 2-phase stepping motor, current ratings: 4.2 A/ch 1.6 mH



・Each time of constant current PWM operation

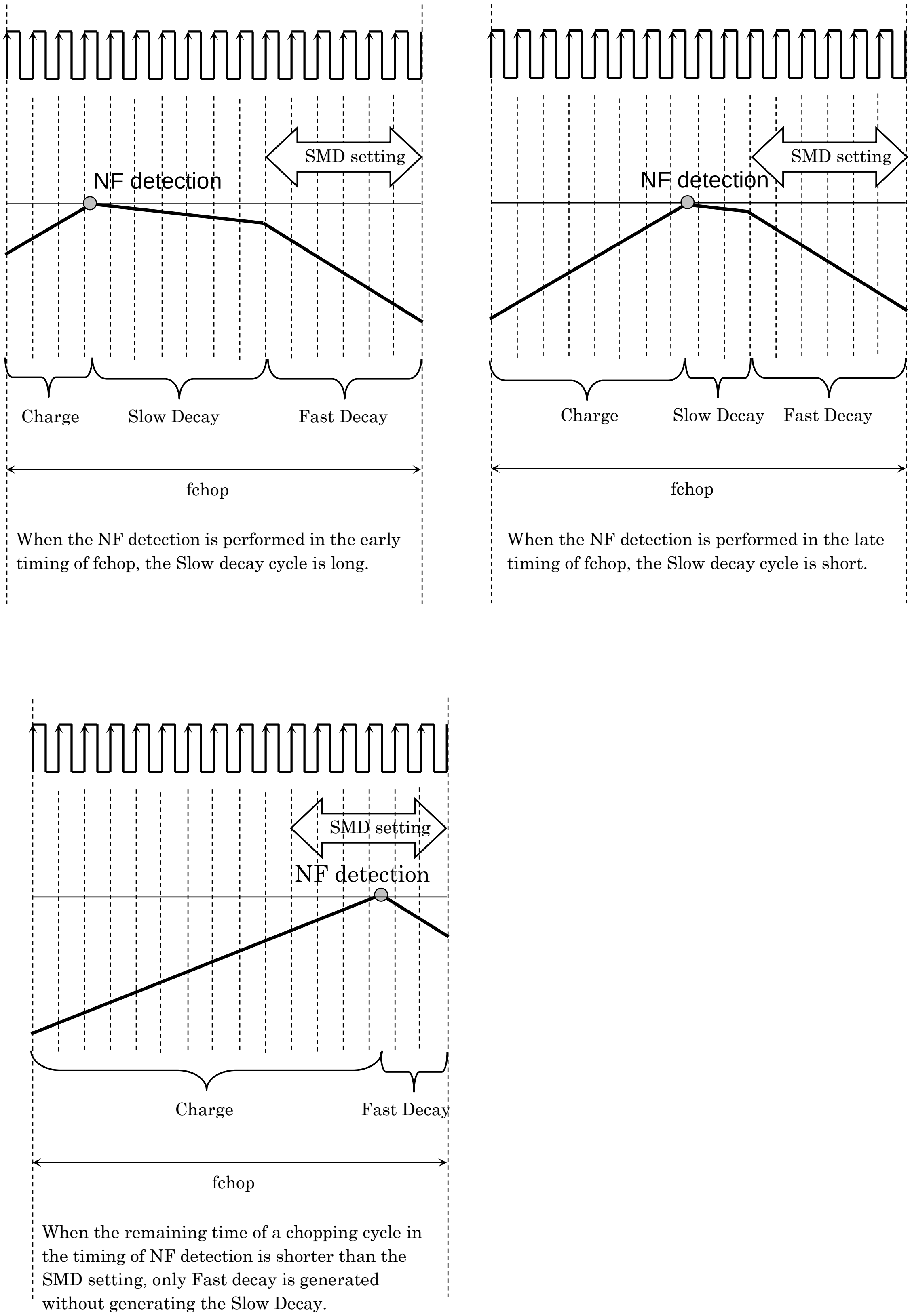


Figure 5.3 Mixed Decay current waveform in case of constant current PWM operation

The time (charge period) when the current which flows into motor reaches the setting current value, changes depending on a drive condition. The timing when the NF detection (the motor current reaches the setting value) is performed in the Mixed Decay chopping cycle (fchop) is changed depending on the conditions at that time. When the NF detection is performed in the comparatively early timing like the example above, the Slow Decay period is long, and when the NF detection is performed after that, the Slow Decay period is short.

Basically the time is calculated as follows; fchop time – (Charge + Fast Decay time) = Slow Decay time
(The time of Fast Decay can be changed by setting the SMD0 and SMD1.)

・When the setting current value increases:

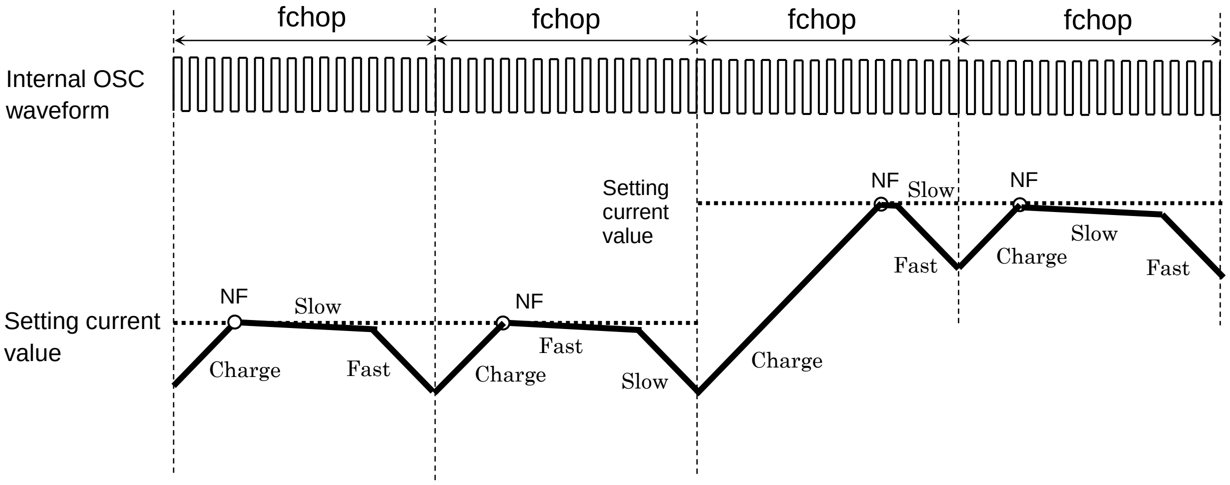


Figure 5.4 Mixed Decay current waveform (when the setting current value increases)

・When the Charge period is fchop 1 cycle or more:

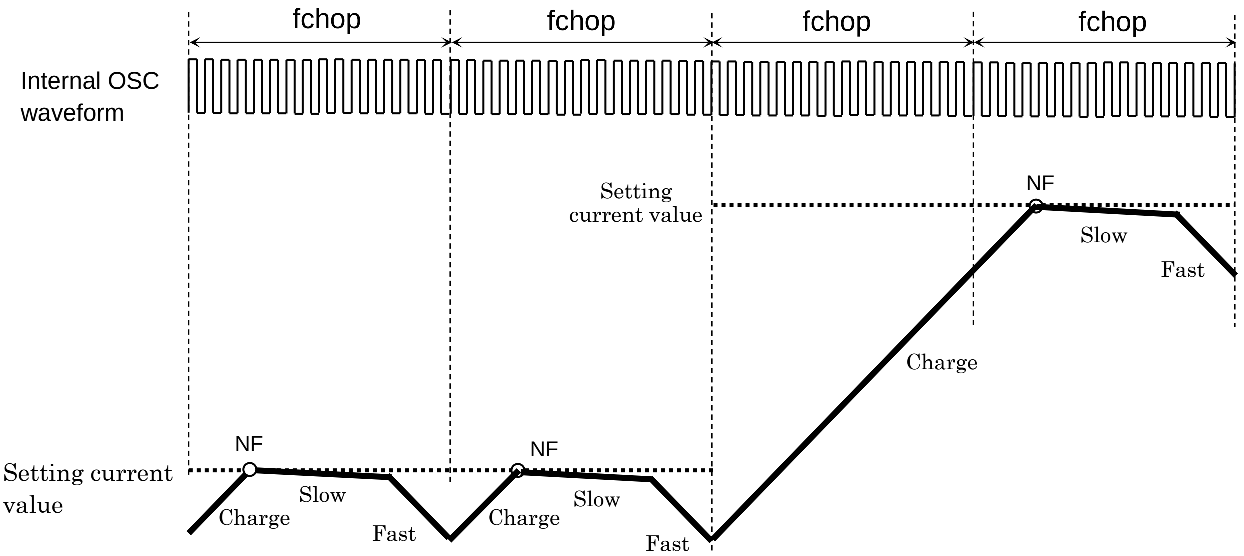


Figure 5.5 Mixed Decay current waveform (fchop 1 cycle or more)

When the period of which the motor current reaches next setting value (Charge period) such as the switching setting current value (step) is over 1 cycle of the chopping frequency (fchop), next fchop cycle continues Charge and moves to the Mixed Decay after reaching NF.

・When the setting current value decreases:

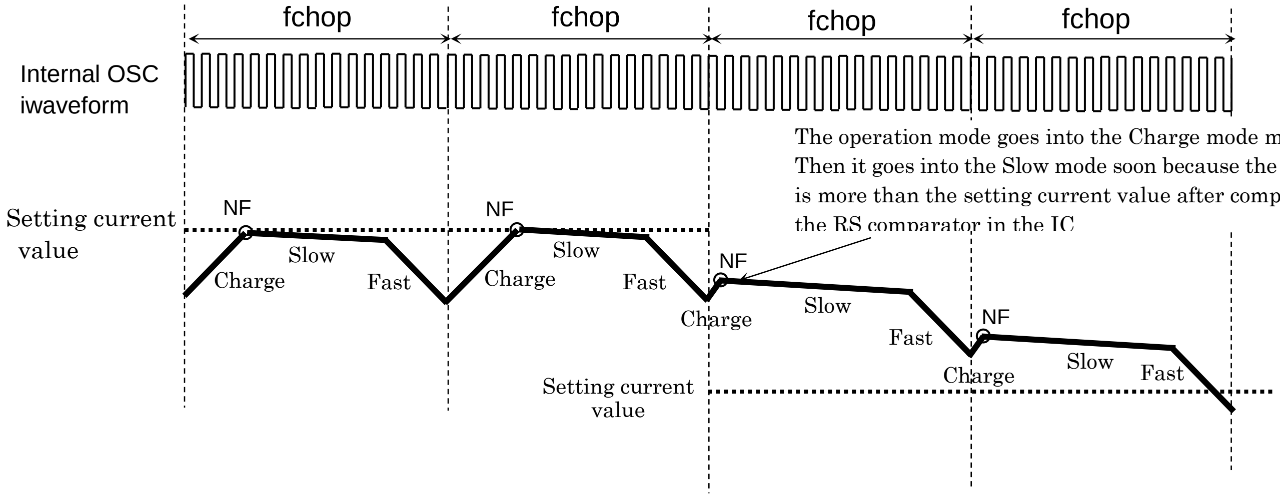


Figure 5.6 Mixed Decay current waveform (when the setting current value decreases)

6. Output switching characteristics

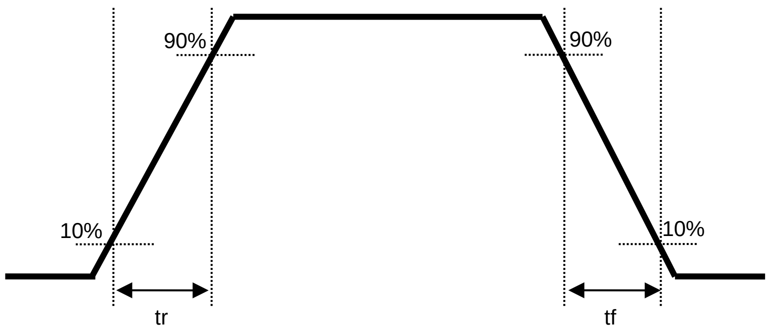


Figure 6.1　Switching characteristics

Table 6.1　Switching characteristics

T_a = 25°C, VM = 24 V, and no load

Item	Typ.	Unit
tr	80	ns
tf	90	ns

7. Function explanation

(1) CLK function

Each up-edge of the CLK signal shifts the motor's electrical angle per step.

Table 7.1　CLK function

CLK input	Function
Up-edge	Shifts the electrical angle per step.
Down-edge	—(State of the electrical angle does not change.)

(2) ENABLE function

The ENABLE pin controls the ON and OFF of the corresponding output stage. This pin serves to select if the motor is stopped in Off (High impedance: Hi-z) mode or activated. Please set the ENABLE pin to 'L' fixed during VM power-on and power-off sequence.

Table 7.2　ENABLE function

ENABLE input	Function
H	Output transistor ON operation (Normal operation)
L	Output transistor OFF operation (High impedance: Hi-Z)

(3) CW/CCW function and the output pin function (output logic at the time of a charge start)

The CW/CCW pins control the rotation direction of the motor. The definition of CW/CCW is as follows.
CW: The current of OUTA is output first, with a phase difference of 90°.
CCW: The current of OUTB is output first with a phase difference of 90°.

Table 7.3 CW/CCW function

CW/CCW input	OUT (+)	OUT (-)
H: Clockwise operation(CW)	H	L
L: Counter clockwise operation(CCW)	L	H

(4) DMODE (step resolution setting) function

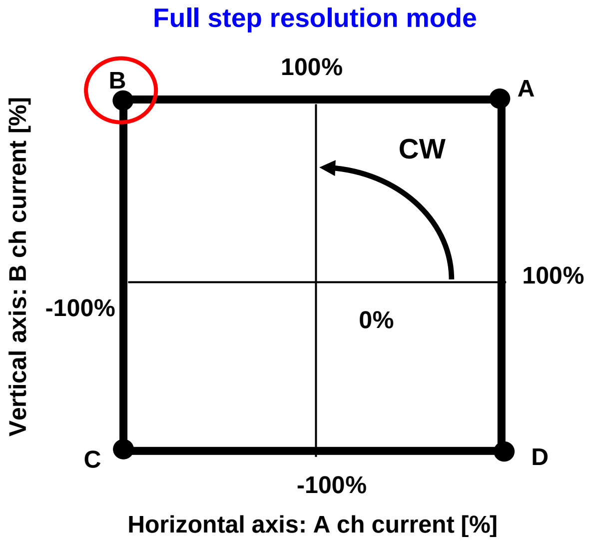
Table 7.4 DMODE function

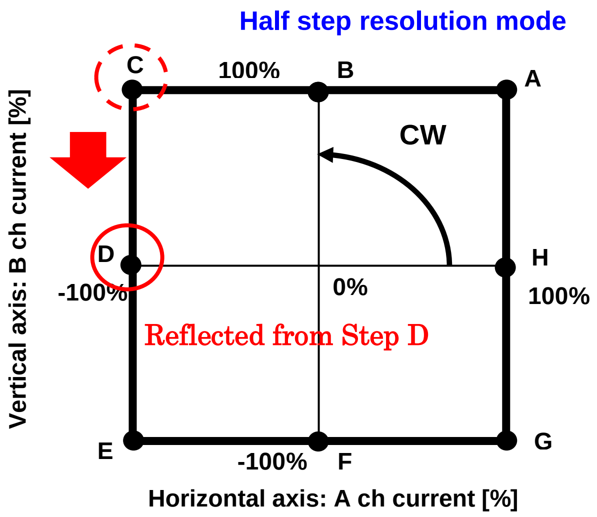
DMODE0	DMODE1	DMODE2	Function
L	L	L	STANDBY MODE (OSCM is stopped, and output transistor operation is stopped.)
L	L	H	Full step resolution setting
L	H	L	Half step resolution (a) setting
L	H	H	Quarter step resolution setting
H	L	L	Half step resolution (b) setting
H	L	H	1/8 step resolution setting
H	H	L	1/16 step resolution setting
H	H	H	1/32 step resolution setting

*: After STANDBY MODE is released, do not input a signal until the internal circuit becomes stable. (1 ms passes after the release of STANDBY MODE is the indication)
When switching the DMODE0,1,2; setting the RESET signal to Low (will set the electrical angle to the initial status), is recommended.

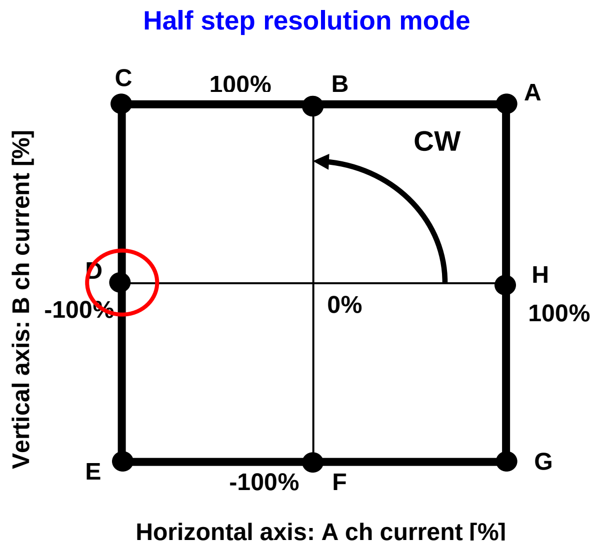
・Operation for switching step resolution mode
If the step resolution mode is changed during a motor rotation, the operation is reflected from next step.

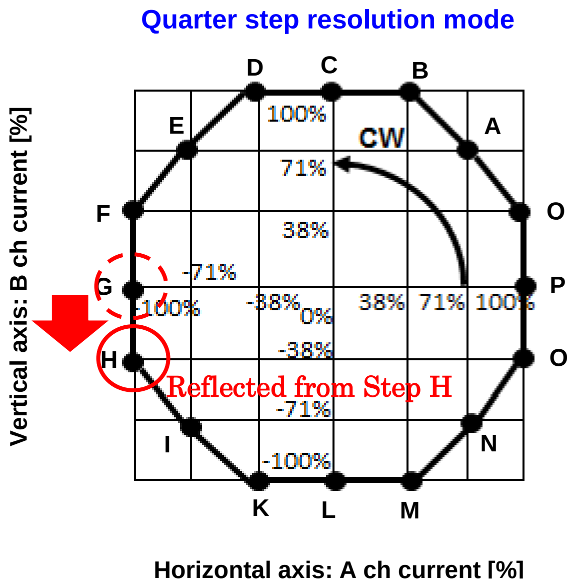
In the case of switching from the full step resolution mode to the half step resolution mode,
*CW rotation: rotation direction of A -> B -> C -> D ->





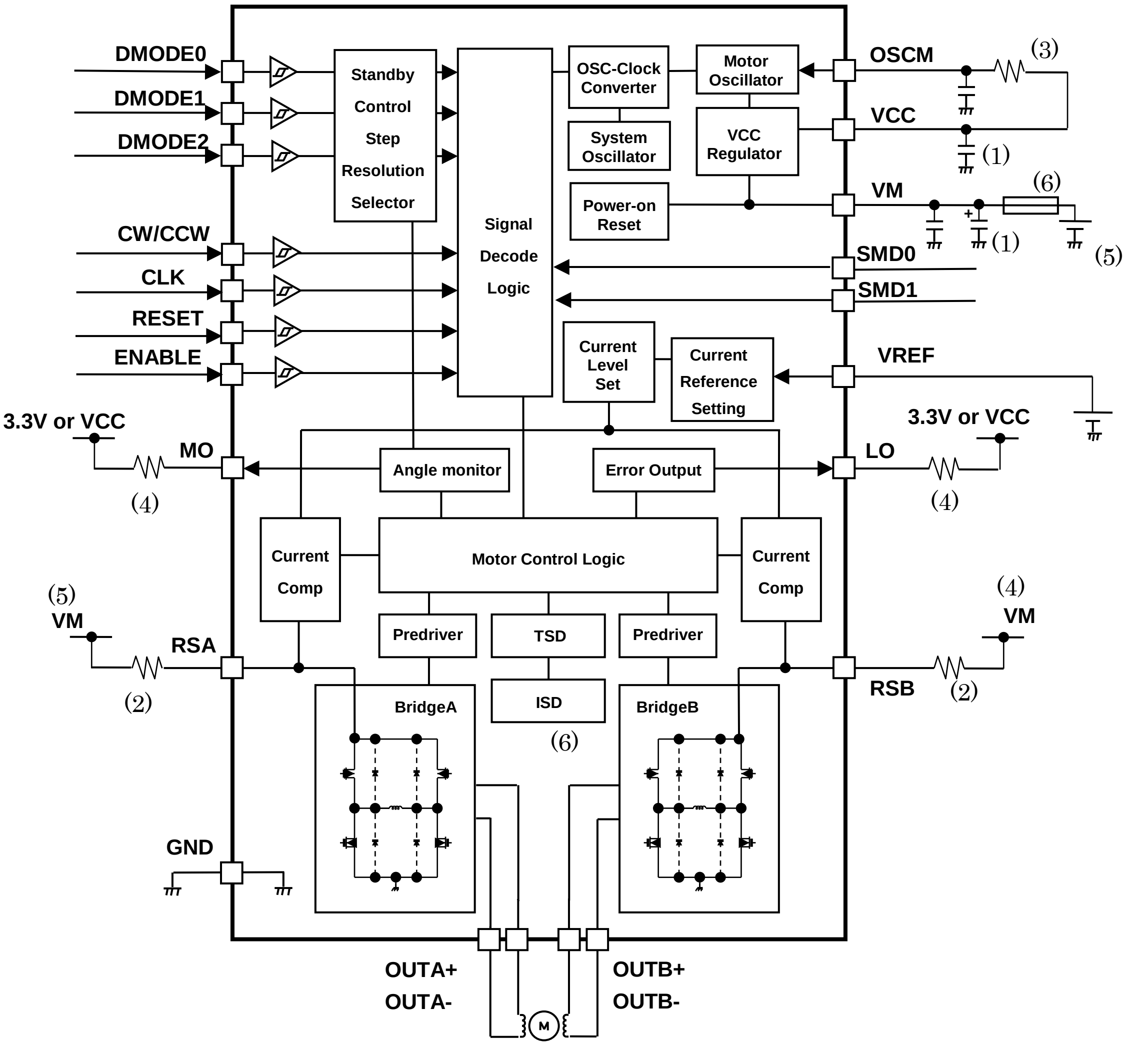
In the case of switching from the half step resolution mode to the quarter step resolution mode,
*CW rotation: rotation direction of A -> B -> C -> D ->





8. Example of application circuit

Some of the functional blocks, circuits, or constants in the block diagram may be omitted or simplified for explanatory purposes.



The application circuits shown in this document are provided for reference purposes only. Thorough evaluation is required, especially at the mass-production design stage.
Number from (1) to (6) in the above figure shows notes. For details, refer to the next page.

Figure 8.1 Example of application circuit

Each external components

(1) Capacitor for power supply pin

To stabilize the power supply voltage of the IC and reduce the noise, connect the appropriate capacitor to each pin. 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 pin

Item	Parts	Typ.	Recommended range
VM-GND	Electrolytic 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 pins. 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	Component	Resistance value (Typ.)	Power rating (Typ.)	Recommended range
VM-RS	Chip / Lead resistance	0.22 Ω (1.5 to 3.0 A)	1.00 W	0.22 to 1.0 Ω
VM-RS	Chip / Lead resistance	0.51 Ω (0 to 1.5 A)	1.00 W	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;

$$\mathrm{Iout(max)} = \mathrm{Vref(gain)} \times \frac{\mathrm{Vref(V)}}{\mathrm{RRS}(\Omega)}$$

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×R). So, in case the same current flows as the case of low resistance, the power dissipation should be larger.

(3) OSCM oscillation frequency

For adjusting OSCM oscillation frequency, external capacitor and resister allows changing oscillation frequency. When adjusting, it is recommended that the capacitor is fixed (270 pF), and the resister is changed. By changing the frequency of the OSCM, it will be able to change the chopping frequency. Please perform the adjustment of chopping frequency refer to the following table.

Driver	TB67S209FTG
Board	Toshiba evaluation board
Power supply voltage	24 V
COSCM	270 pF

Table 8.3 Relation between external resister R and OSCM oscillation frequency (reference data)

ROSCM	fOSCM	fchop
k Ω	MHz	kHz
1.5	2.63	164.38
1.8	2.37	148.13
2.0	2.23	139.38
2.2	2.08	130.00
2.7	1.80	112.50
3.0	1.67	104.38
3.3	1.55	96.88
3.9	1.34	83.75
4.7	1.15	71.88
5.1	1.07	66.88
5.6	0.98	61.25
6.8	0.83	51.88
8.2	0.70	43.75
10.0	0.58	36.25

Setting frequency range
40 k to 150 kHz

Typical value (4.7 kΩ row)

*: The value in this table is only reference, not guaranteed.

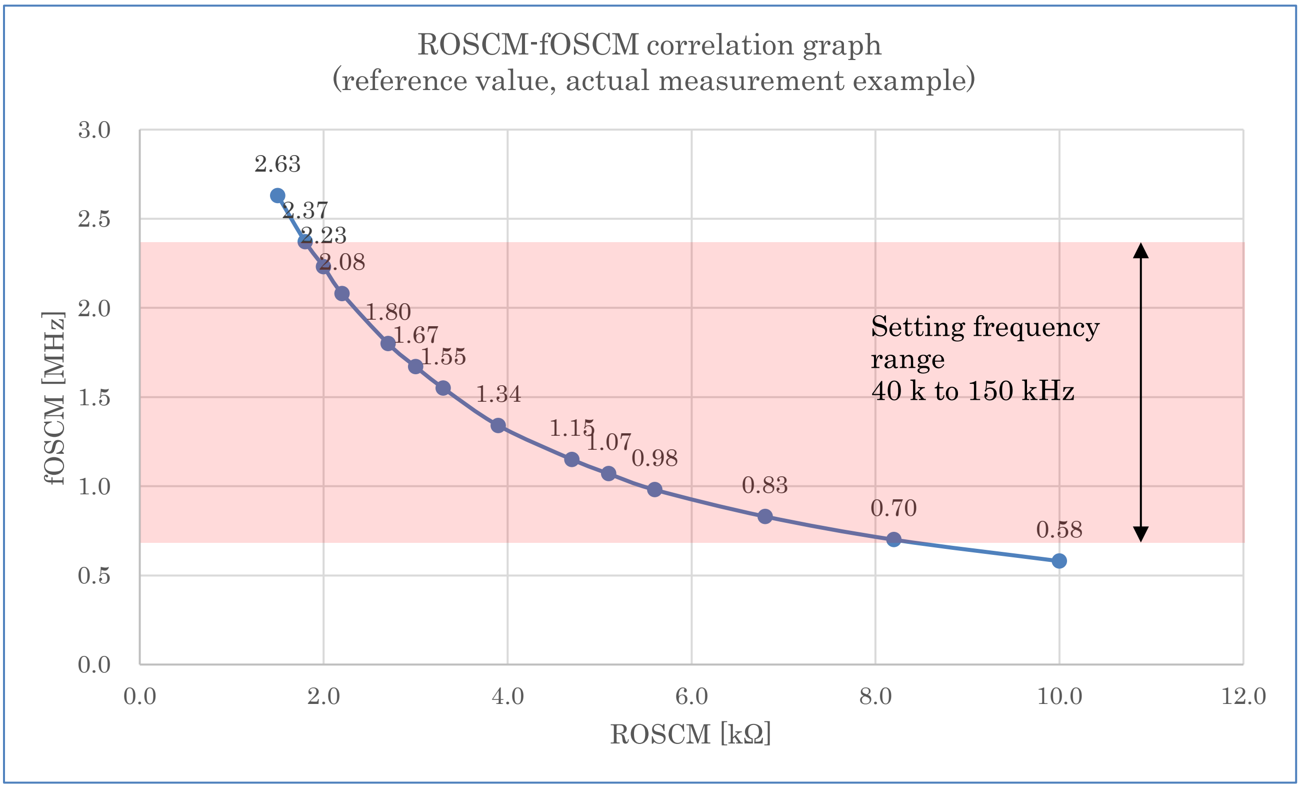


Figure 8.2 ROSCM-fOSCM correlation graph (reference value, actual measurement example)

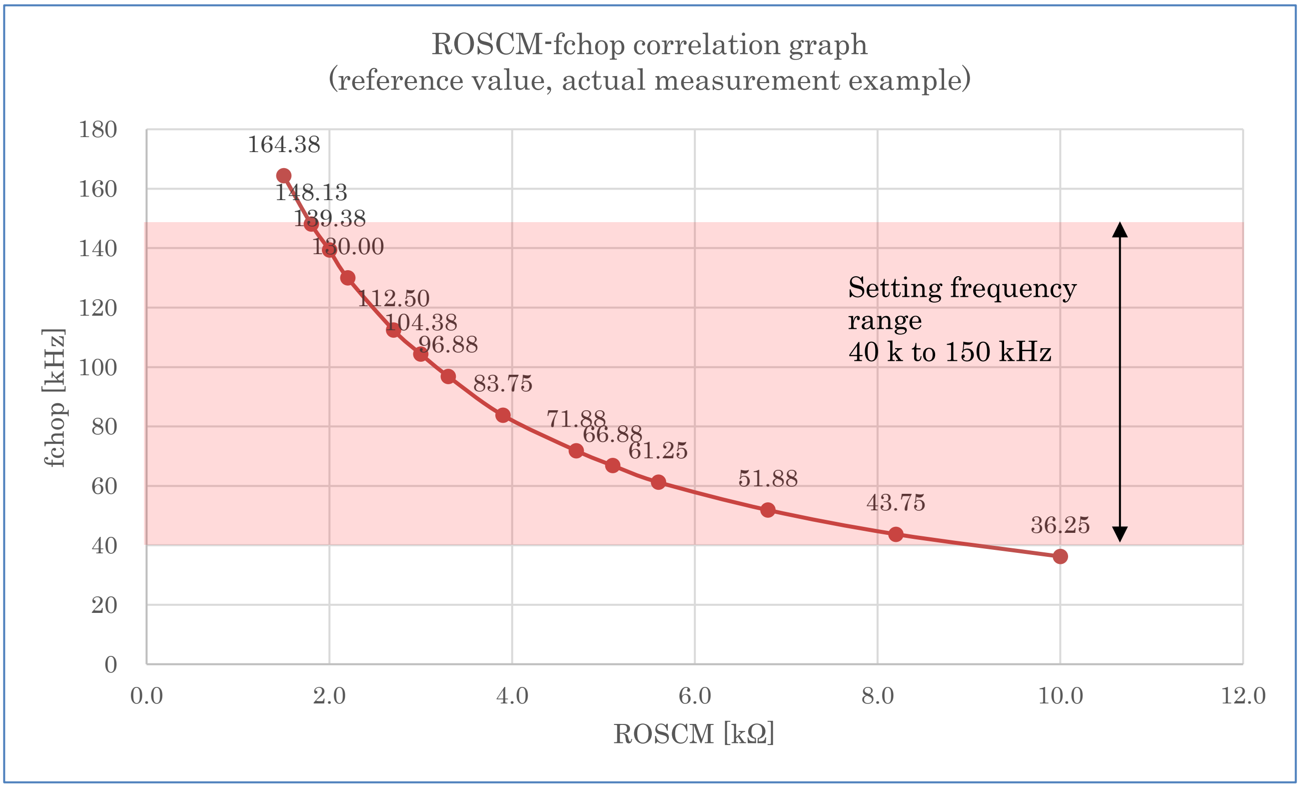


Figure 8.3 ROSCM-fchop correlation graph (reference value, basis of actual measurement)

*: The value in the graphs is only reference, not guaranteed.

(4) Resistance for monitor pin

This IC has two open-drain pins of MO and LO. When internal MOSFET is turned off, it is high impedance as a terminal level. In order to operate the IC with accurate high and low levels, connect the pull-up resistance to the power supply of 3.3 V or 5 V in using.

Table 8.4 Recommended resistance for monitor pin

Item	Component	Typ.	Recommended range
MO, LO- (3.3V or VCC)	Chip / Lead resistance	10 kΩ	10 to 100 kΩ

(5) 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. Refer to the section 12.4 Notes on substrate.

(6) Fuse

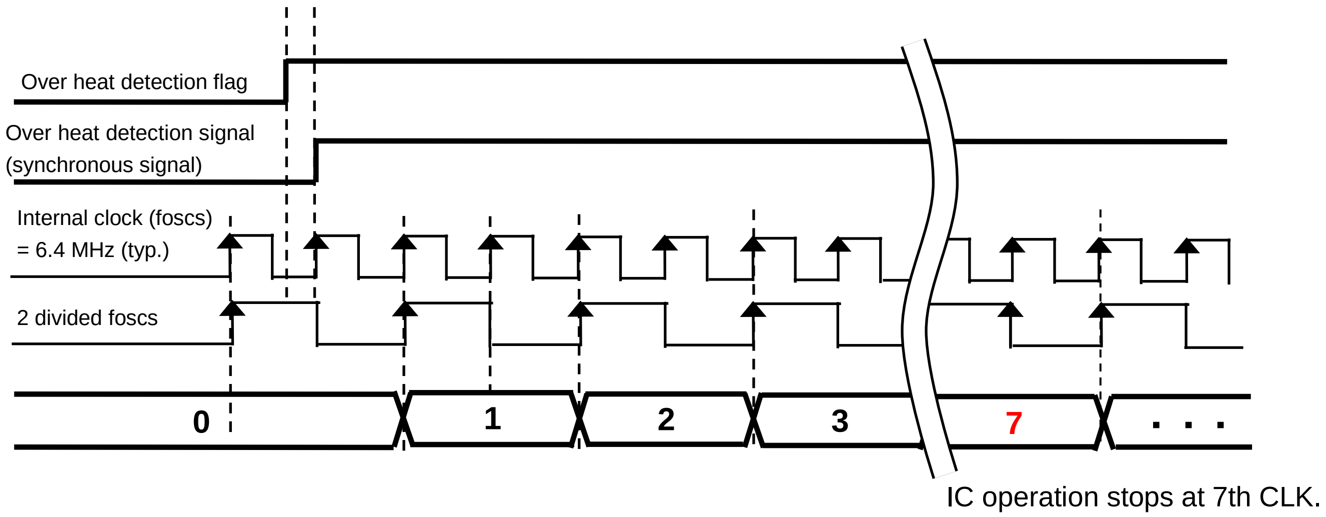
Use an appropriate power supply fuse for the power supply line to ensure that a large current does not continuously flow in the case of over-current and/or IC failure.
The IC will fully break down when used under conditions that exceed its absolute maximum ratings, when the wiring is routed improperly 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.

(7) Abnormality detection function

This IC has the TSD (Thermal Shutdown Detection) and ISD (over current detection) as the abnormality detection function. Explanations of each functions are described below.

- 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 DMODE pin 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.

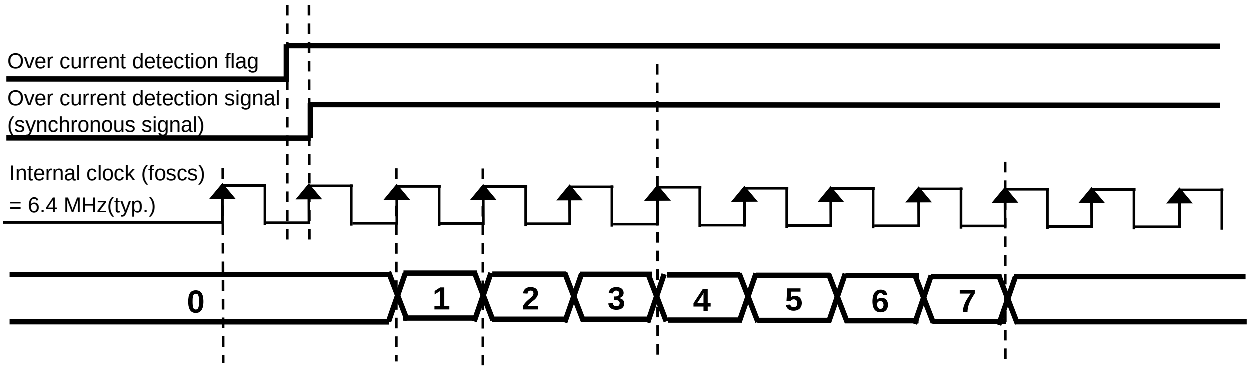
Figure 8.4 Dead band time of thermal shutdown circuit

The system clock (fOSCS=6.4 MHz (typ.)) is built in TB67S209FTG to count up the dead band time of abnormal detection function. Thermal shutdown circuit has a dead band time to avoid false detection by using this system clock.

*: 1 / (foscs / 2) × 7 to 8 clk = 1 / foscs × 14 to 16 clk (2.5 to 2.8 μs)

- 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 DMODE pin to release this function.

Dead band time of ISD



Timing charts may be simplified for explanatory purposes.

Figure 8.5 Dead band time of ISD

The system clock (fOSCS=6.4 MHz (typ.)) is built in TB67S209FTG to count up the dead band time of abnormal detection function. ISD has a dead band time to avoid false detection by using this system clock.

*: 1 / foscs × 7 to 8 clk (1.09 to 1.25 μs)

9. Power consumption of IC

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

P(total) = P(out) + P(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 (out) = Number of H-Bridge × Iout (A) × VDS (V) = 2 (ch) × Iout (A) × Iout (A) × Ron (Ω)…(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;

When Ron = 0.49Ω, Iout (peak: Max) = 1.5 A, VM = 24 V,
P (out) = 2 (ch) × 1.5 (A) × 1.5 (A) × 0.49 (Ω)……………………………………………………(2)
= 2.205 (W)

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

I (IM3) = 5.5 mA (typ.) : Operating
I (IM2) = 3.5 mA (typ.) : Stopping

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;

P (bias) = 24 (V) × 0.0055 (A)………………………………………………………………………(3)
= 0.132 (W)

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

P (total) = P (out) + P (bias) = 2.205 + 0.132 = 2.337 (W)

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

P = 24 (V) × 0.0035 (A) = 0.084 (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 ($R_{th(j\text{-}a)}$) between junction temperature to ambient temperature is as follows;

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

Example: When 4-layer mounting board (assumption of $R_{th\ (j\text{-}a)}$ = 25°C/W), T_a = 25°C, P (total) = 2.337 W (I_{out} = 1.5 A, full step resolution)

$$T_j = 25\ (°C) + 25\ (°C/W) \times 2.337\ (W) = 83.4°C$$

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

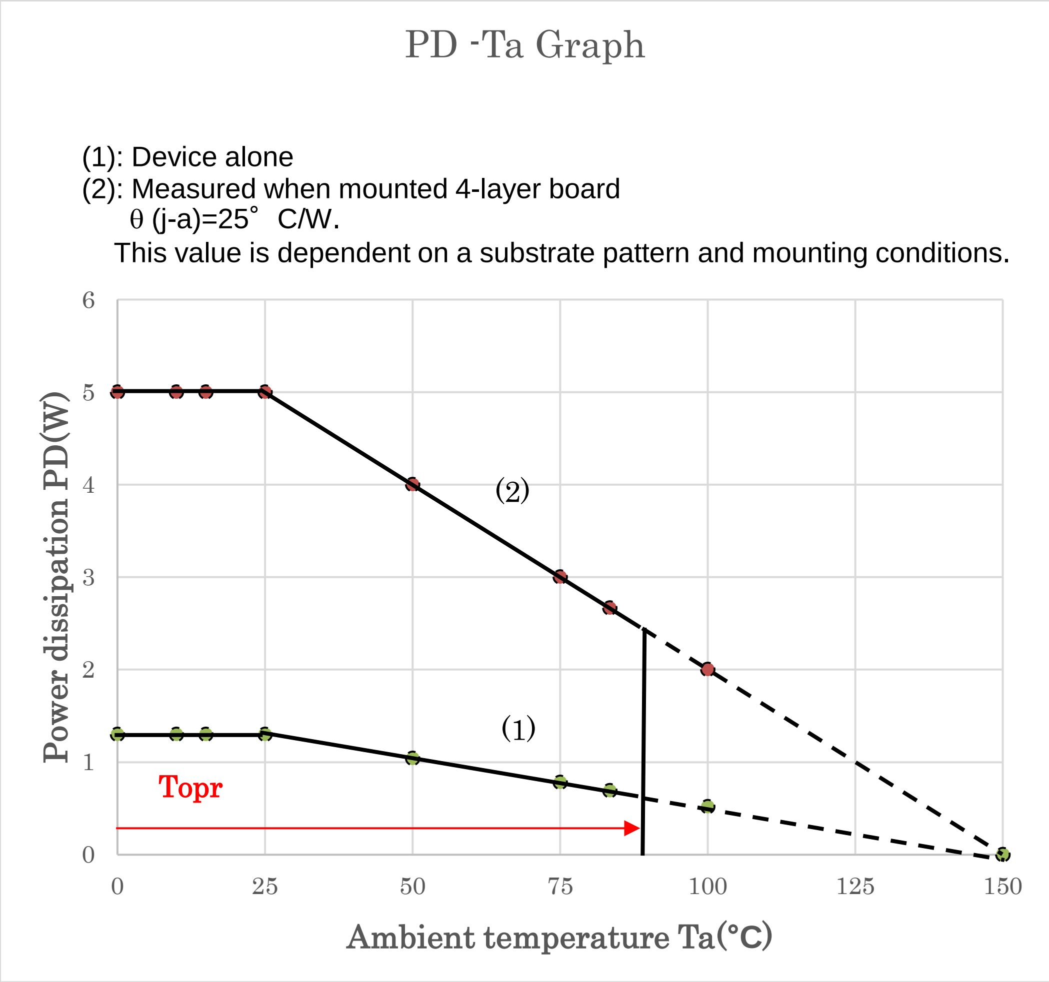


Figure 10.1 QFN48 power dissipation

*: Pay attention that Ta, Rth(j-a), and P(total) depend on the usage environment. When ambient temperature is high, the allowable power consumption decreases.

11. Example of reference foot pattern

Example of QFN48 foot pattern and land of heat dissipation block (Unit: mm)

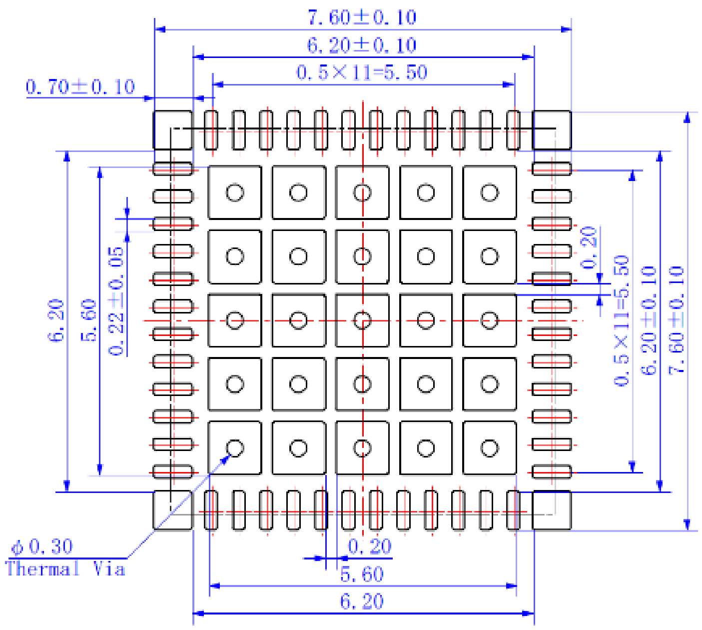


Figure 11.1 QFN48 foot pattern

The application circuit example is for reference only, and does not guarantee the mass production design of the device.
In determining the size of mounting board, design the most appropriate pattern by considering the solder bridge, the solder connecting strength, the pattern accuracy in making board, the heat sink of leads, and the mounting accuracy of the IC board.

12. Board dimensions

12.1. Input

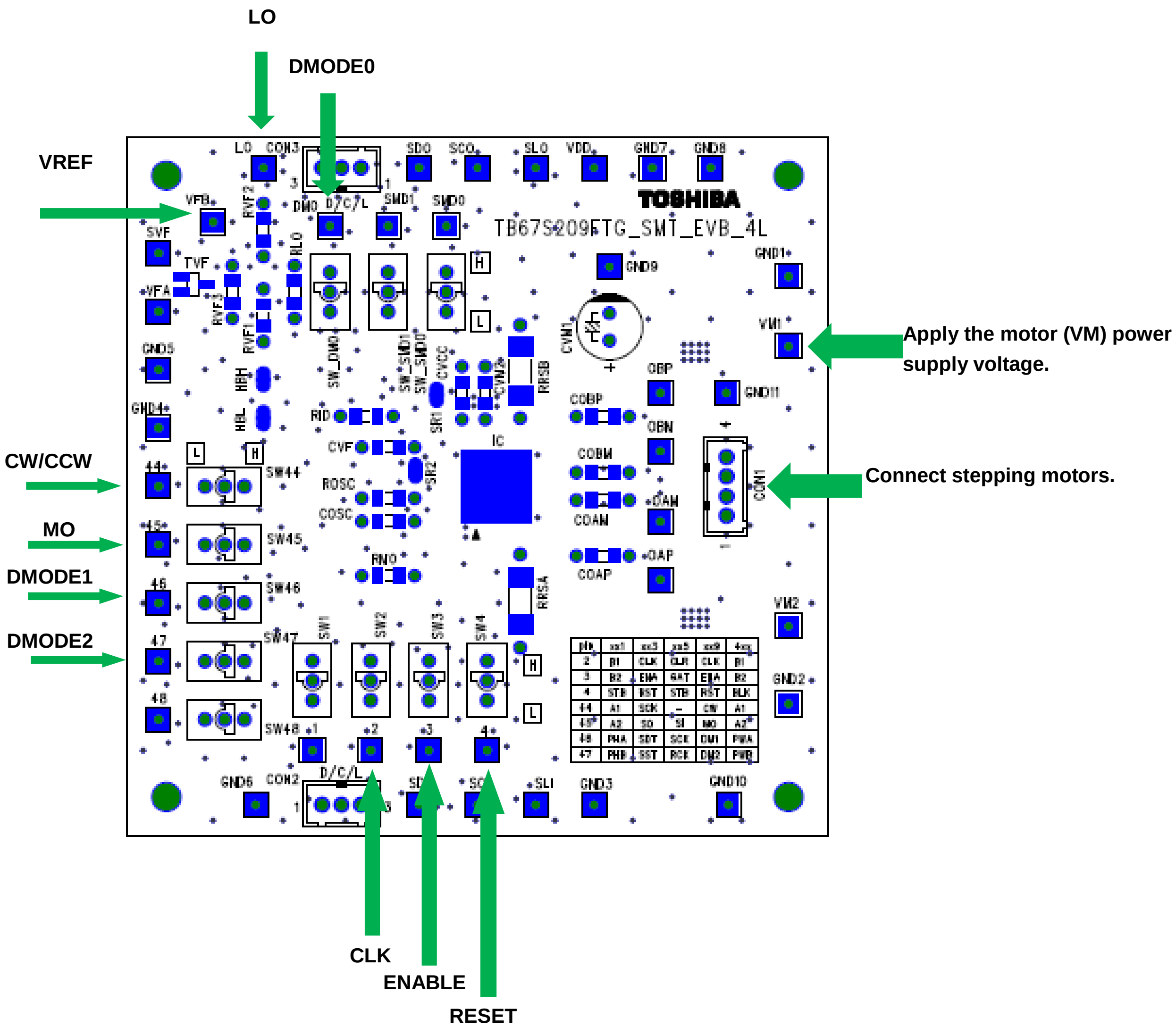


Figure 12.1 Input

Input each power supply and control signals according to the figure shown above.

12.2. Main parts

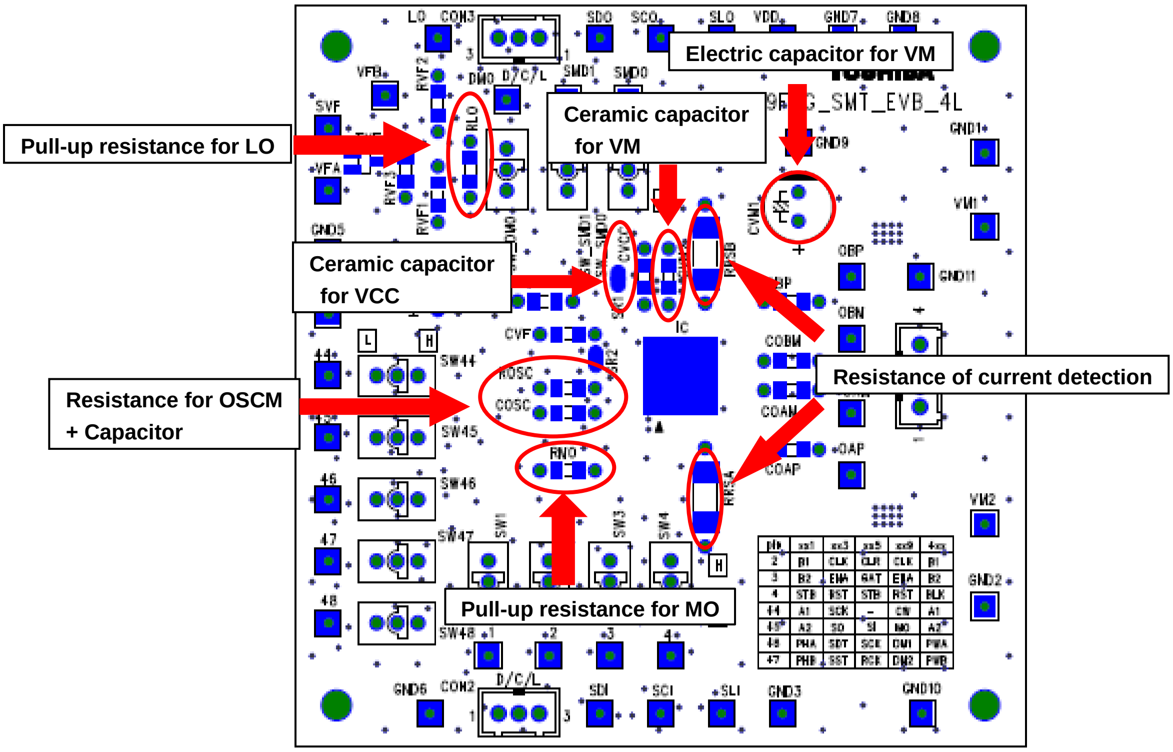


Figure 12.2 Main parts

Connect each external components referring to “8. Example of application circuit.”

12.3. Options

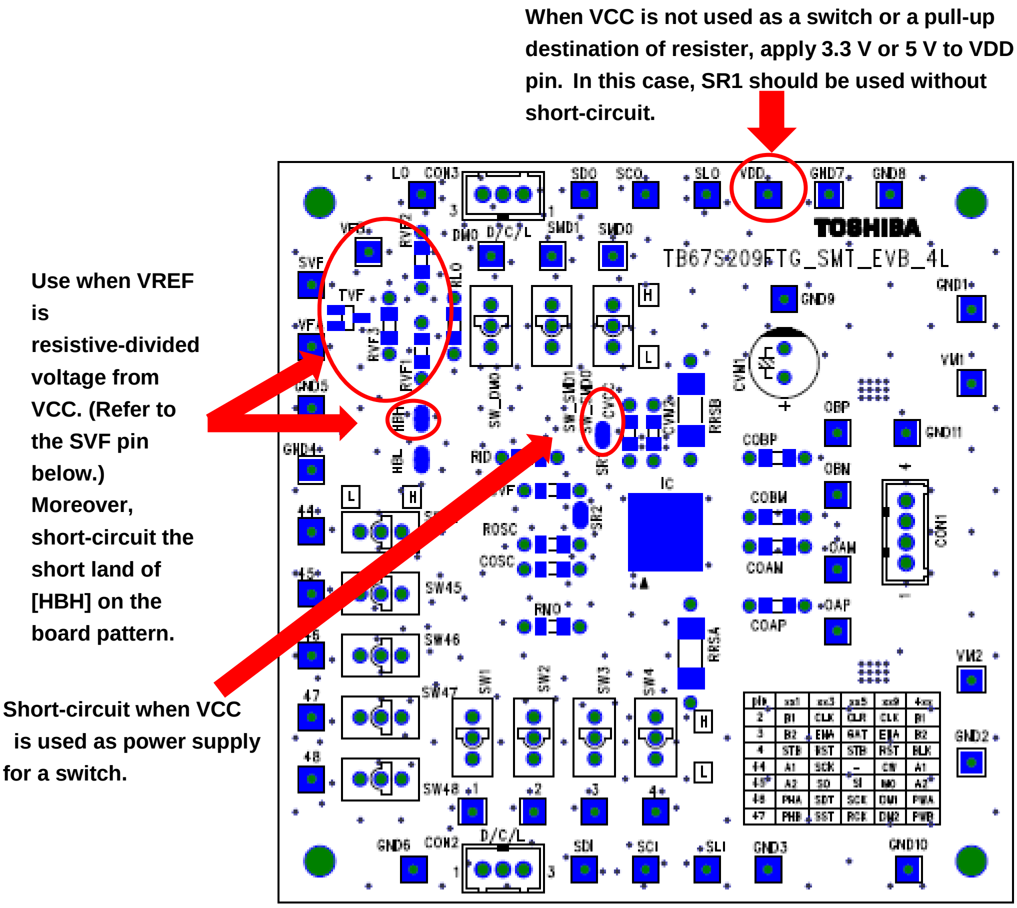
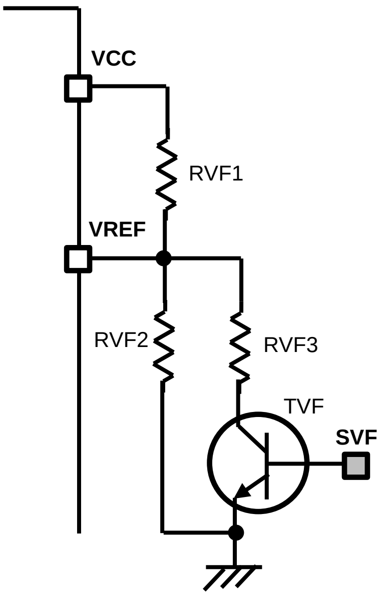


Figure 12.3 Options

・SVF pin

Option patterns are prepared on the board for changing a motor current or torque during operating. (Refer to the following circuit diagram.) By turning ON or OFF of transistor, the ratio of resistive-divided voltage is changed. Then applying voltage to VREF can be adjusted.



Note:

・Please use in the range of which the total value of the resistance inserted between VCC and GND is set to 10 k to 50 kΩ regardless of the ON or OFF state of a transistor.

・TVF recommended product: Toshiba NPN transistor RN1401

12.4. Notes on substrate

Notes on the substrate are explained by using an example of Toshiba evaluation board, which can be provided.

(1) Current flowing line pattern

The wiring pattern should be made thick for the influence reduction to the wiring pattern when driving in large current.

Wiring to Ach / Bch (VM-RSA/VM-RSB) should be same distances.

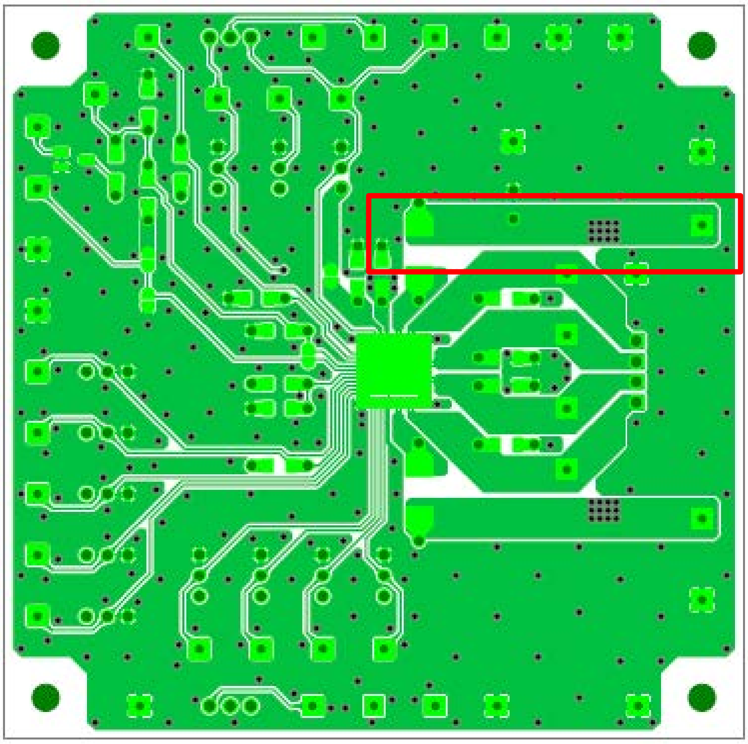


Figure 12.4 Current flowing route pattern

(2) Wiring of VM power supply

For a supply voltage stabilization to the IC, and noise influence reduction in driving with large current, the wiring from VM power supply is separated with VM line, which is connected VCC to Regulator in the IC, and the line connected to MOSFET via current detection resistor (RSA and RSB).

In order to reduce the number of component, the capacitor of VM power supply is arranged to the junction point of current flowing route to the voltage supply line and MOSFET.

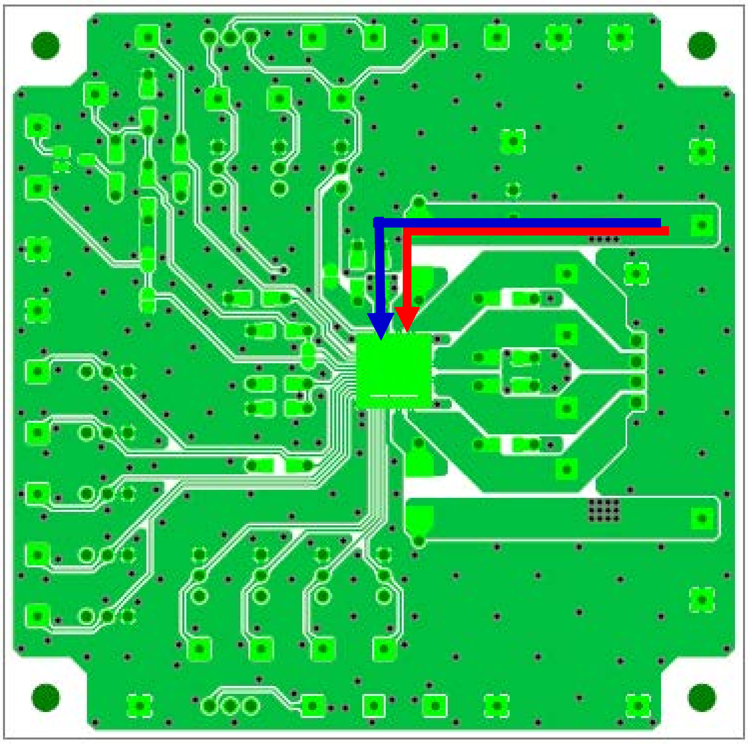


Figure 12.5 Wiring diagram of VM power supply

(3) Arrangement of peripheral components

Components such as a capacitor for power supply pin, a current detection resister, and resisters and capacitors for adjusting OSCM oscillation frequency should be arranged near the IC as possible. Especially for a capacitor between VCC and GND, since the VCC-Regulator (5.5 V) is built in the IC, the GND voltage change may not be suppressed enough if the capacitor is arranged to the entrance of the board power supply, when it is far from the IC.

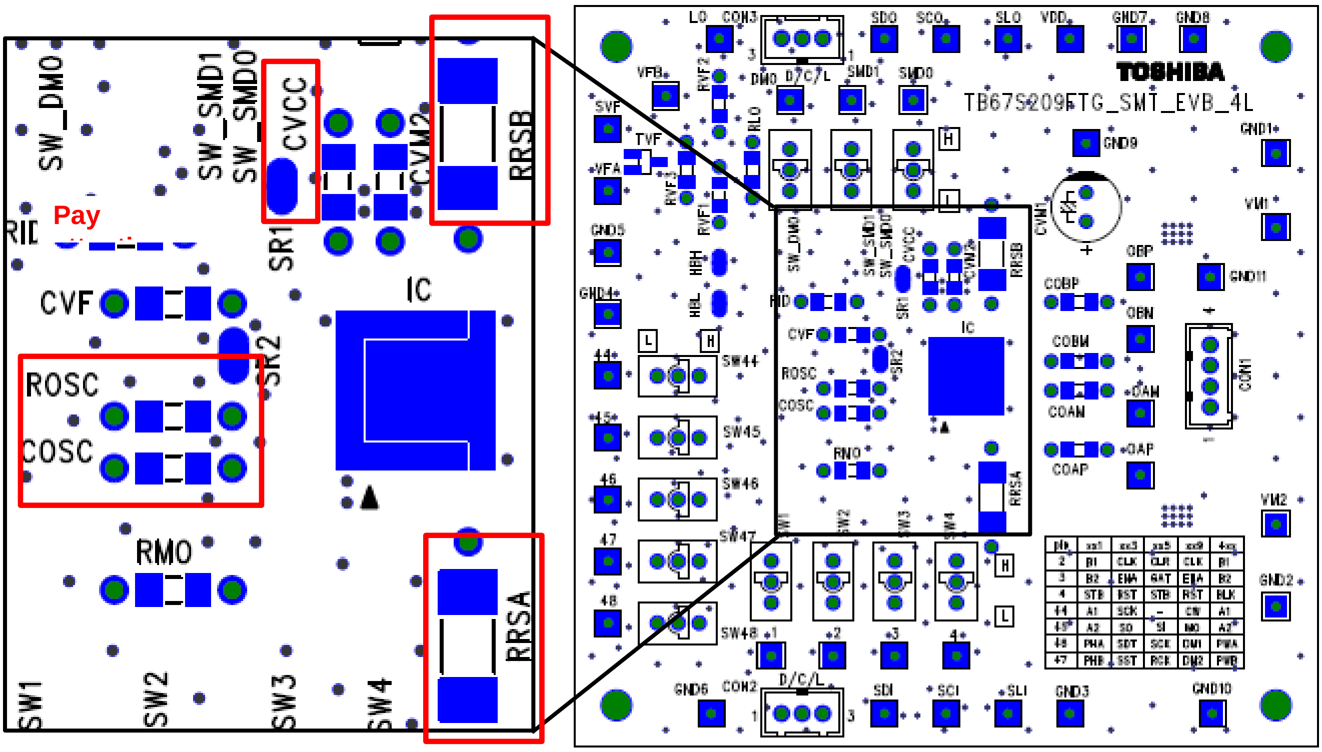
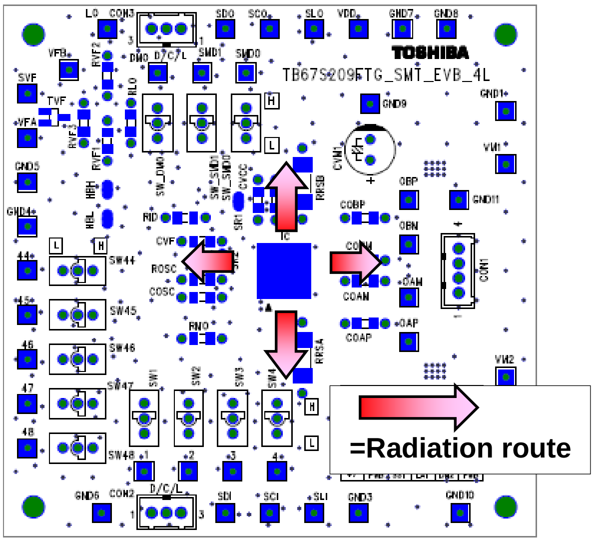


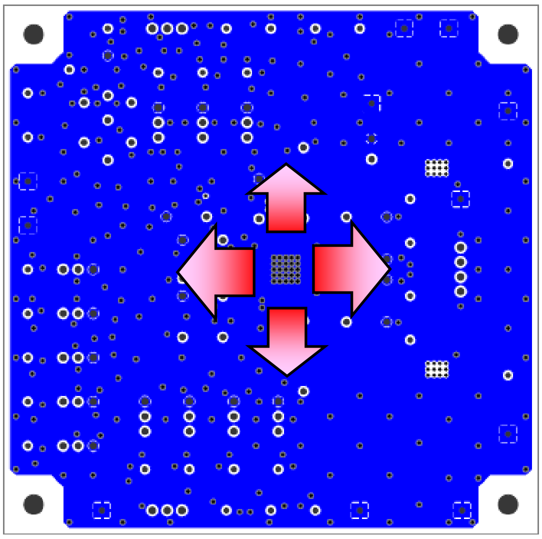
Figure 12.6 Arrangement example of peripheral components

(4) Heat radiation

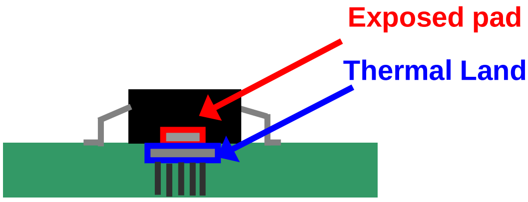
<Front of board>



<Back of board>



<Substrate sectional view>



In using a flat package, it is very important to radiate heat from the Exposed pad on the back to the substrate.

Figure 12.7　Board radiation route

12.5. Recommended GND pattern

As above-mentioned, radiating heat from the heat dissipation pad on the back of the IC to the GND pattern on the board enables heat dissipation of the IC efficiently. Therefore, it is recommended that the GND area is held around the IC (about 1 cm from four sides of the IC) without patterns breaking off. However, if the wiring is layout surrounding heat radiation route, the heat may not radiate to the whole of substrate, and may concentrate near the IC. Please pay attention to the substrate wiring.

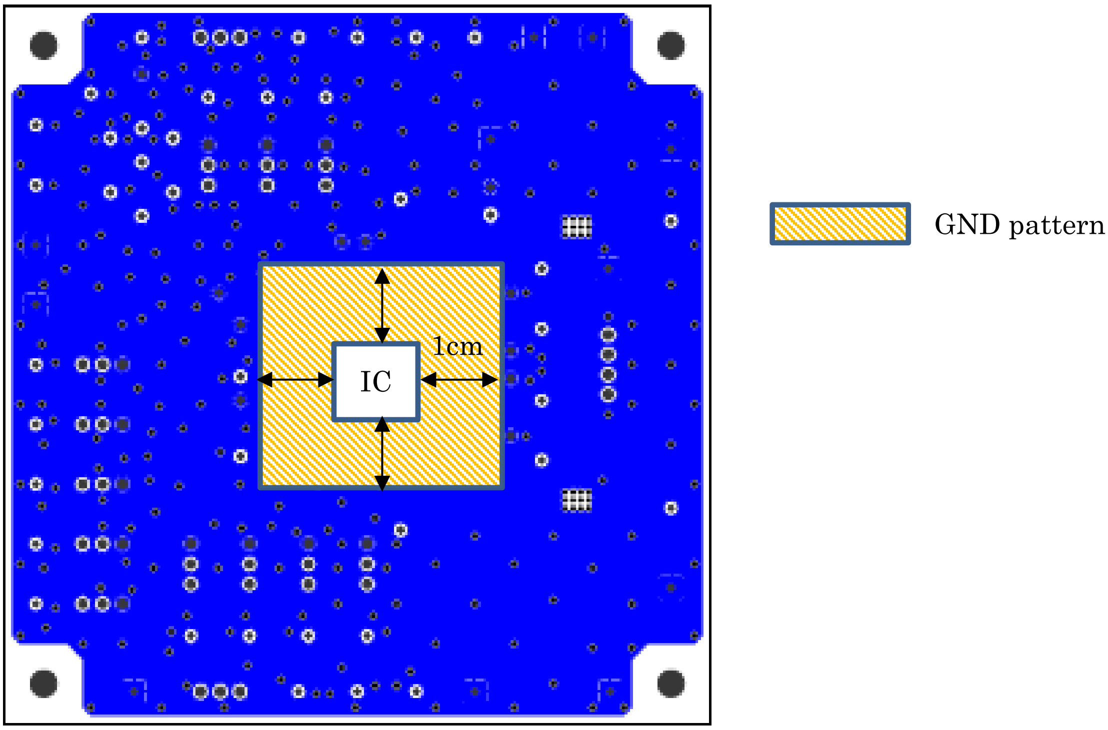


Figure 12.8 GND pattern example

Notes on Contents

1. Block Diagrams
   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 Circuits
   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 the device breakdown, damage or deterioration, and may result injury by explosion or combustion.

(2) 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.

(3) 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.

(4) 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.

(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 (Tj) 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 considerate 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 pins 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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