TB67S508FTG

Usage considerations

Summary

The TB67S508FTG is a two-phase bipolar stepping motor driver using a PWM chopper.
Fabricated with the BiCD process, rating is 40 V/3.0 A.

1. Power supply voltage

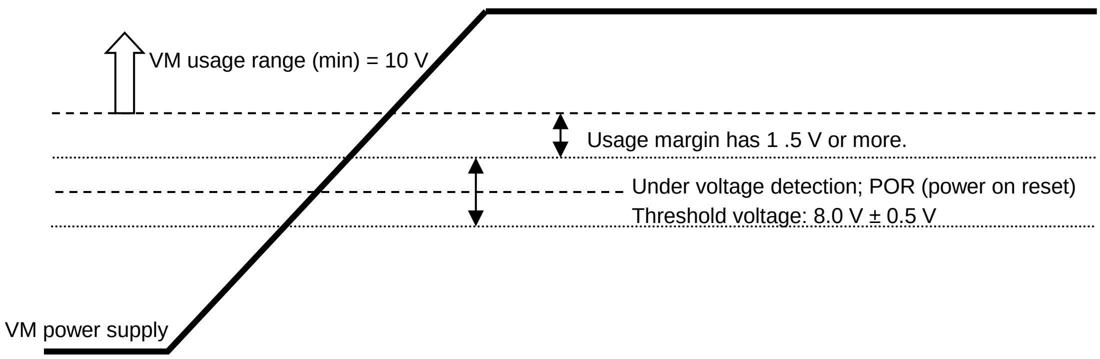
Power supply voltage and usage range

In using the TB67S508FTG, the voltage should be applied to the terminals of VM, VREF_A, and VREF_B. The maximum rating of VM supply voltage is 40 V. Usage range of the power supply voltage is 10 to 35 V. The maximum ratings of VREF_A and VREF_B voltages are 6 V. Usage ranges of the voltages are 0 to 3.6 V.

As for the applied voltages of VREF_A and VREF_B terminals, the resistive divided voltage of the internal regulator of the IC (V_{CC}), which is outputted from CC terminal, can be also used. In this case, recommended sum total of the divided resistance is 10 kΩ to 30 kΩ.

Power supply sequence

There are no special procedures of inputting a power supply and shutdown because the TB67S508FTG incorporates the undervoltage detection. However, in 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 voltage (VM) reaches the usage voltage and becomes in the stable state.



Some of timing charts in this document may be simplified for explanatory purposes.

2. Output current

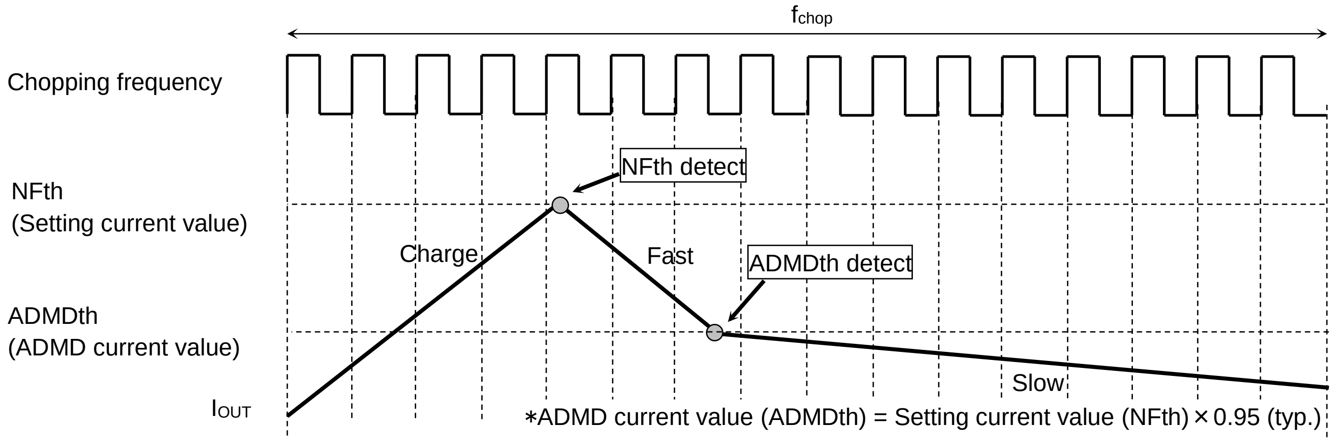
Motor usage current should be 2.8 A or less. The maximum current of the actual usage is limited depending on the usage conditions (the ambient temperature, the wiring pattern of the board, the radiation path, and the exciting design). Configure the most appropriate current value after calculating the heat and evaluating the board under the operating environment.

3. Control input

When the logic input signal is inputted under the condition that the VM is not supplied, the electromotive force from input signal is not generated. However, it is recommended to configure the motor operation off state before the power supply (VM) reaches the usage voltage and becomes in the stable state.

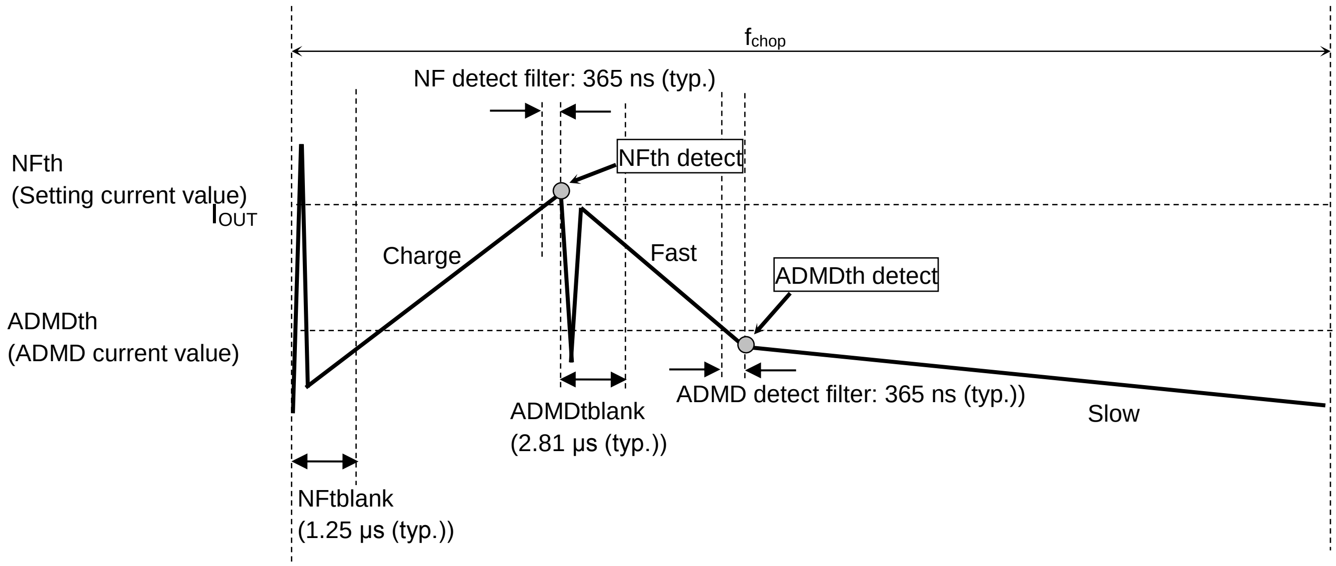
4. ADMD (Advanced Dynamic Mixed Decay) - PWM constant current control -

ADMD control optimizes the fast decay by monitoring both the charge current, which flows from the power supply to the motor, and the regenerative current, which flows from the motor to the power supply. It can control the motor efficiently.
The below timing chart describes the procedure of the ADMD control. The procedure is as follows;
Charge → NF: reach setting current value → Fast → reach ADMDth → Slow → reach one cycle of f_{chop} → return to Charge



Some of timing charts in this document may be simplified for explanatory purposes.
The values in the timing chart are only for reference.

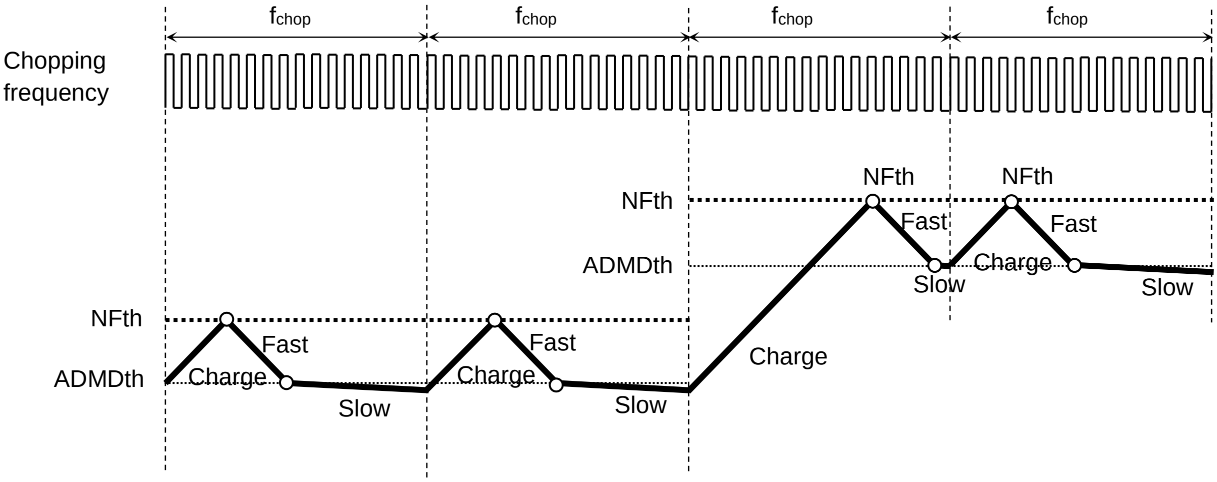
Each filter shown below is adopted to prevent an erroneous current detection, which is occurred by the external noise, etc. When the lower level of the usage motor is low enough for the current value to reach ADMDth (ADMD current value) within the ADMDtblank period, the operation switches to the slow mode after the ADMDtblank period. In this case, the ADMD current value (ADMDth) becomes lower than the value of the setting current (NFth) × 0.95 (typ.).



Some of timing charts in this document may be simplified for explanatory purposes.
The values in the timing chart are only for reference.

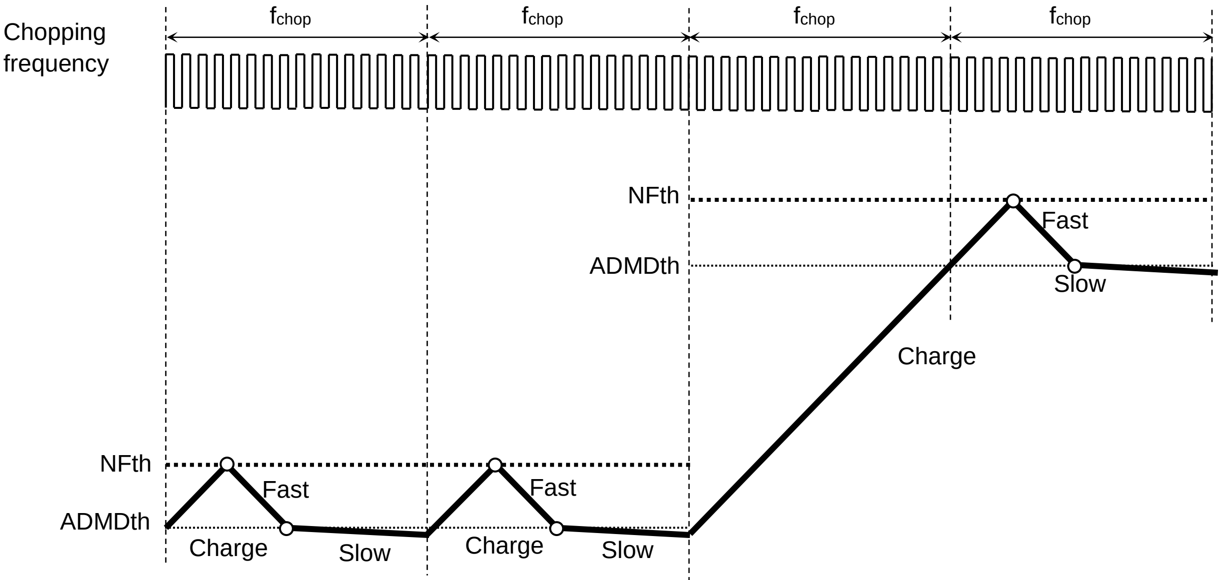
ADMD current waveform

・When the next current step (NFth) is higher



Some of timing charts in this document may be simplified for explanatory purposes.

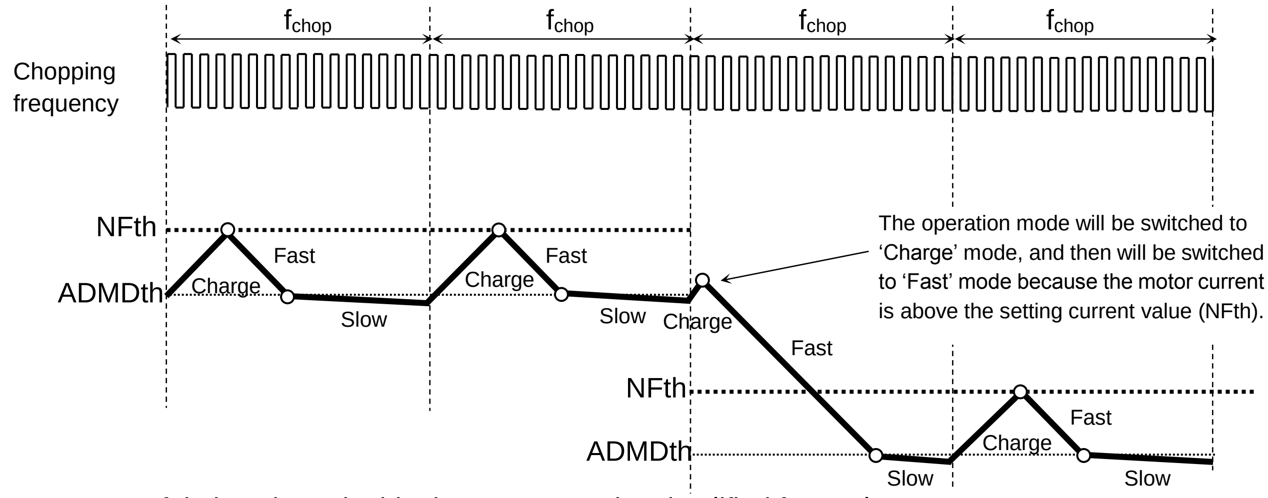
・When Charge period is more than 1 f_{chop} cycle



Some of timing charts in this document may be simplified for explanatory purposes.

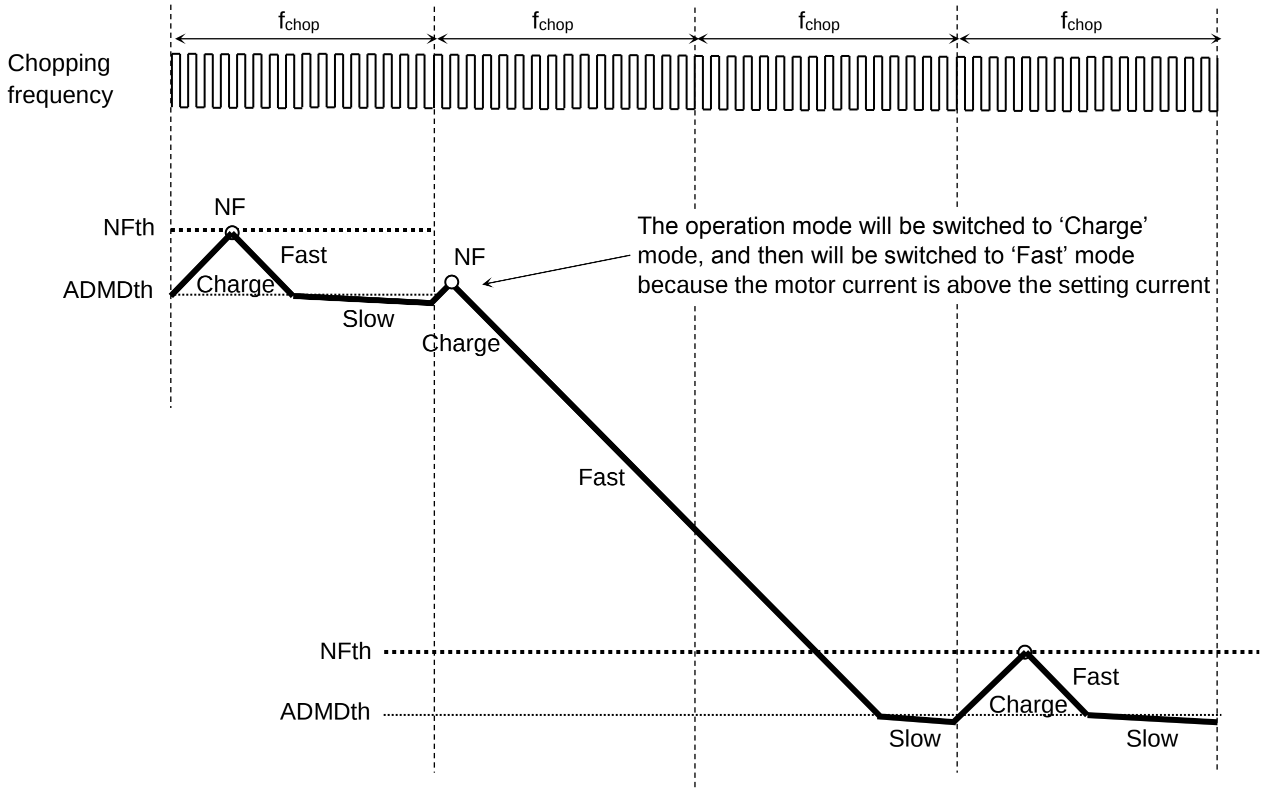
When the period that the motor current reaches the setting value (NFth) is longer than 1 cycle of the configured chopping frequency (f_{chop}), the Charge period will be extended until the motor current reaches the NF threshold. Once the current reaches the NF threshold, the sequence will move to Fast mode.

・**When the next current step (NFth) is lower**



Some of timing charts in this document may be simplified for explanatory purposes.

・**When 1 f_{chop} cycle is shorter than the Fast period (the motor current does not reach the ADMD threshold within 1 f_{chop} cycle).**



Some of timing charts in this document may be simplified for explanatory purposes.

If the motor current is still above the ADMD threshold (ADMDth) after reaching 1 f_{chop} cycle, the output stage function will stay 'Fast' mode until the current reaches the ADMD threshold (ADMDth). Once the current reaches the ADM threshold, the sequence will move to Slow mode.

Setting current value (I_{OUT})

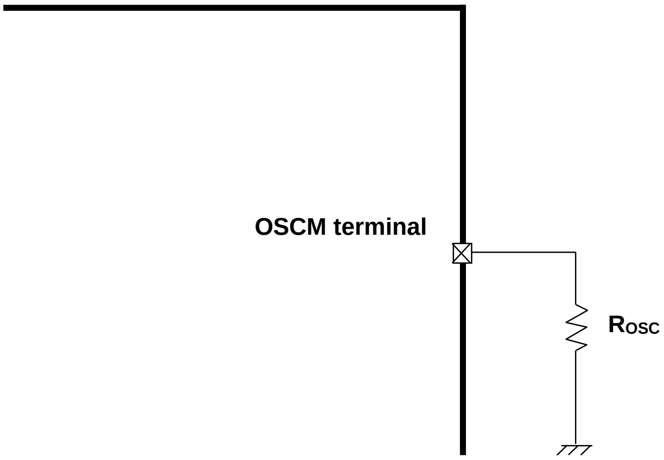
Setting current value of PWM constant current control is determined by setting the reference voltage (V_{REF}) as follows;

Setting current value (I_{OUT}) can be calculated by the following formulas.

$I_{OUT} = V_{REF} \times 0.833$
Ex.): When V_{REF} is 2.0 V, I_{OUT} is 1.67A.

Chopping frequency (f_{chop})

Chopping frequency of the motor constant-current control can be set by the resistor (**R_{OSC}**), which is connected between OSCM terminal and GND terminal. Moreover, fixed chopping frequency can be also used without adopting external components for OSCM terminal.



The equivalent circuit diagrams may be simplified or some parts of them may be omitted for explanatory purposes.

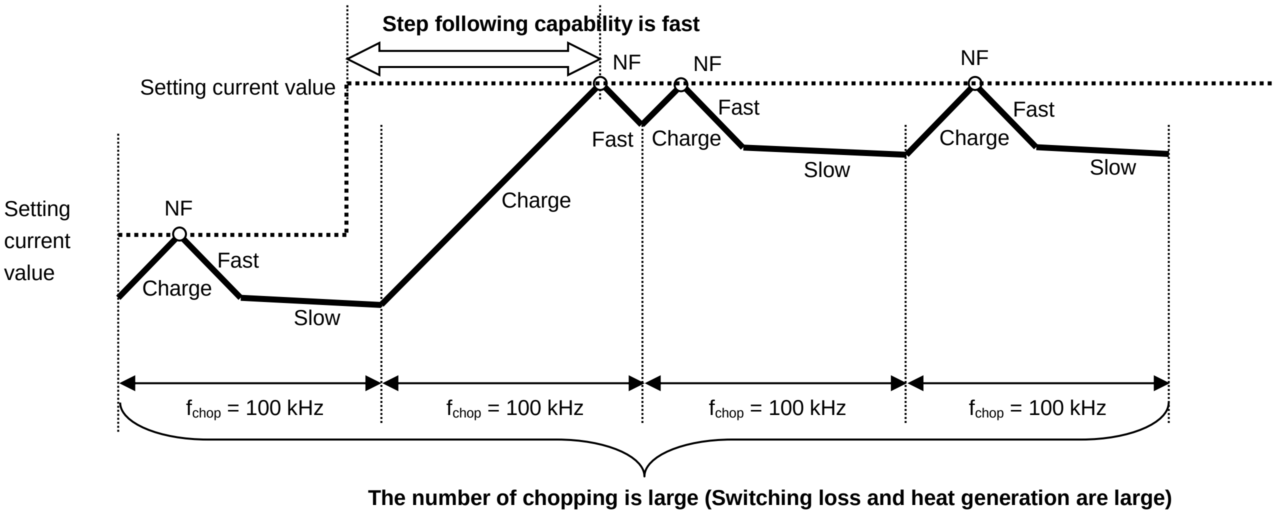
Chopping frequency (f_{chop}) is calculable by the following formulas.
Generally, it is recommended to set the frequency range from 40 kHz to 100 kHz (reference value = 70 kHz)

$f_{chop} = f_{OSCM} / 16$
$f_{OSCM} = 1/ (90.9 \times 10^{-12} \times R_{OSC})$
Ex.): When R_{OSC} is 10 kΩ, f_{OSCM} is 1.1 MHz (typ.) and f_{chop} is 68.8 kHz (typ.).

When OSCM terminal is in open or GND short-circuit state, the operation is performed with the frequency, which is automatically generated in the IC (f_{OSCM2} = 1.080 MHz (typ.) and f_{chop} = 67.5 kHz (typ.)).

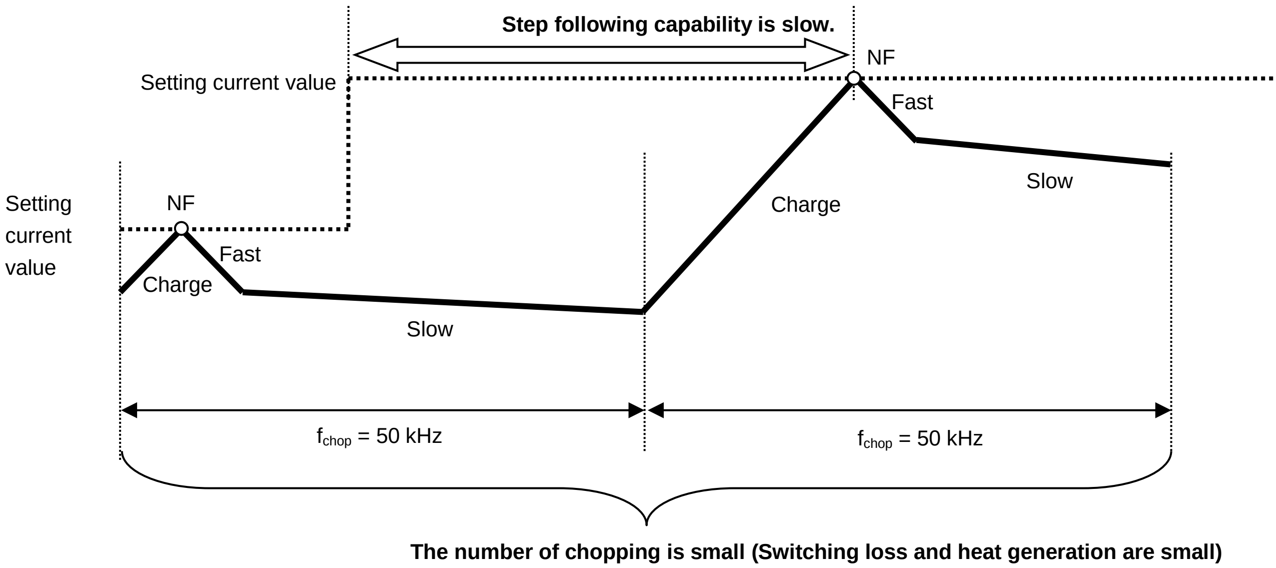
When the chopping frequency is increased, the motor can rotate faster because the following capability of the current steps increases. However, switching loss and heat increase may occur because the number of switching of output MOSFET is larger than the case of low chopping frequency.

(Ex. 1) When chopping frequency (f_{chop}) is 100 kHz,



Some of timing charts in this document may be simplified for explanatory purposes.

(Ex. 2) When chopping frequency (f_{chop}) is 50 kHz,

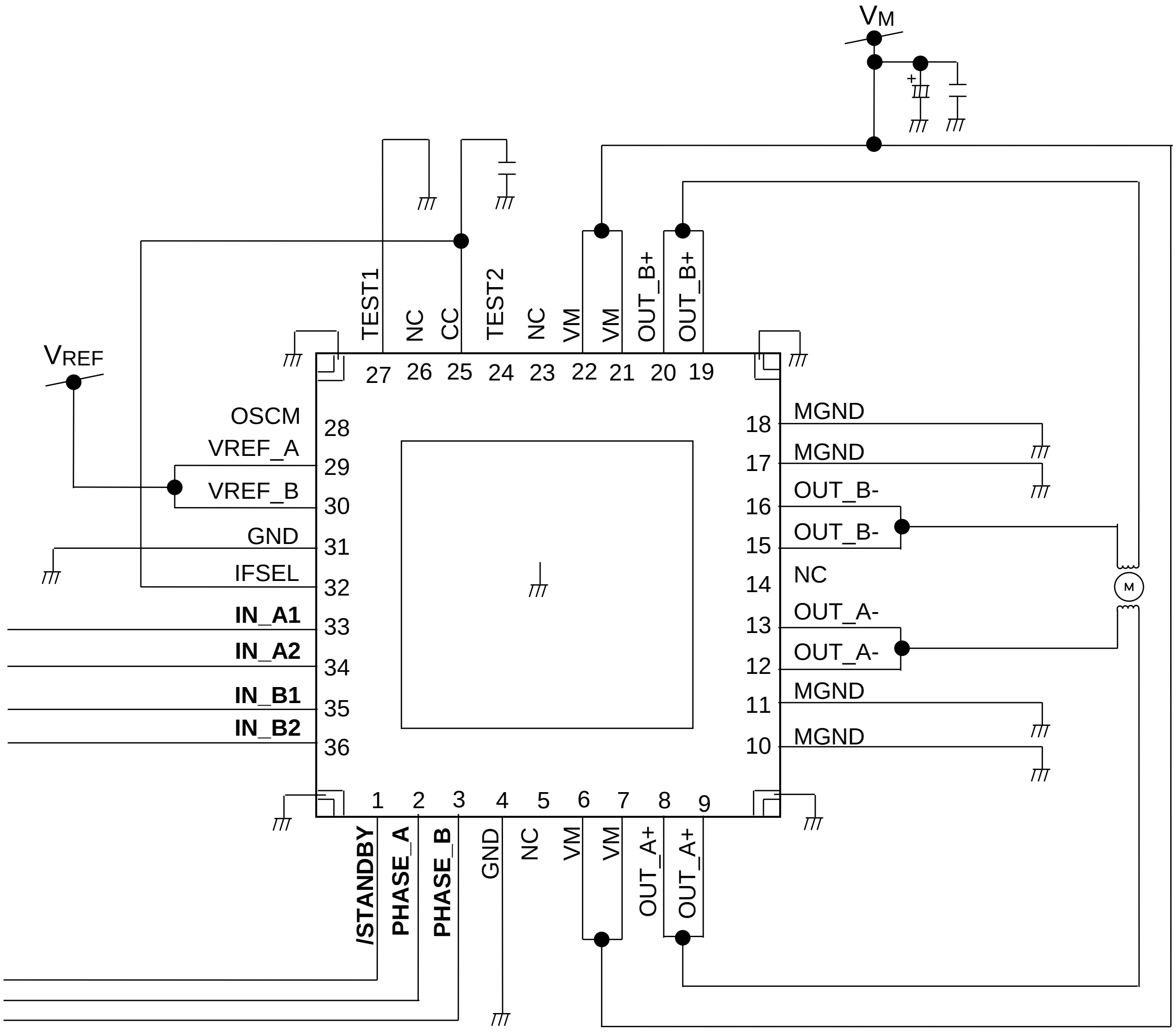


Some of timing charts in this document may be simplified for explanatory purposes.

Generally, it is recommended to set the frequency range from 40 kHz to 100 kHz (reference value = 70 kHz)

5. Application circuit example

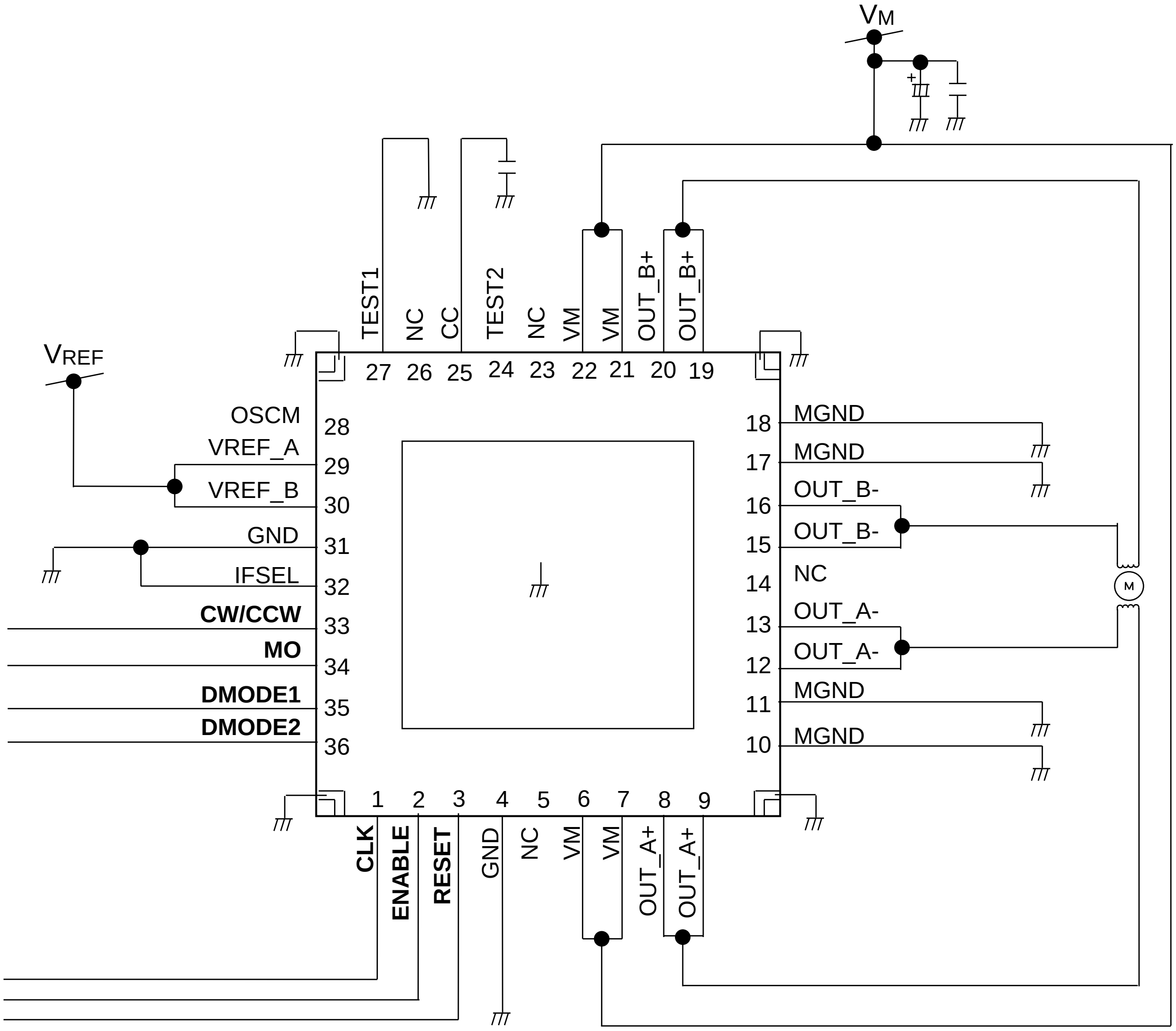
Phase input control mode



Heat dissipation PADs, which are provided on the four corners and the center of the package back side, are recommended to be connected to the GND of the board for further heat dissipation.

The application circuits shown in this document are provided for reference purposes only. Toshiba does not guarantee the data for mass production. The equivalent circuit diagrams may be simplified or some parts of them may be omitted for explanatory purposes.

Clock input control mode



Heat dissipation PADs, which are provided on the four corners and the center of the package back side, are recommended to be connected to the GND of the board for further heat dissipation.

The application circuits shown in this document are provided for reference purposes only. Toshiba does not guarantee the data for mass production. The equivalent circuit diagrams may be simplified or some parts of them may be omitted for explanatory purposes.

(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.

Item	Components	Typ.	Recommended range
VM−GND	Electrolytic capacitor	100 μF	47 to 100 μF
	Ceramic capacitor	0.1 μF	0.01 to 1 μF
CC−GND	Ceramic / Electrolytic capacitor	0.1 μF	0.01 to 1 μF
(VREF_A/B−GND)	Ceramic capacitor	0.1 μF	0.01 to 1 μF

* VREF_A/B−GND: Connect the capacitor in necessary depending on the usage environment.
* The capacitor, which is not the recommended capacitor, can be adopted depending on the motor load condition and the design pattern of the board.

(2) Resistor for electrical angle monitor terminal (used in clock input control mode)

This IC has an open-drain terminal (MO). When internal MOSFET is turned off, the state indicates high impedance as a terminal level. In order to operate the IC with accurate high and low levels, connect the pull-up resistor to the CC terminal or the power supply of 3.3 V or 5.0 V during use.

Item	Components	Typ.	Recommended range
MO—CC (or MO—power supply of 3.3 V/5.0 V)	Chip / Lead resistance	10 kΩ	10 to 100 kΩ

(3) Wiring pattern for power supply and GND

Since large current may flow in VM 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.

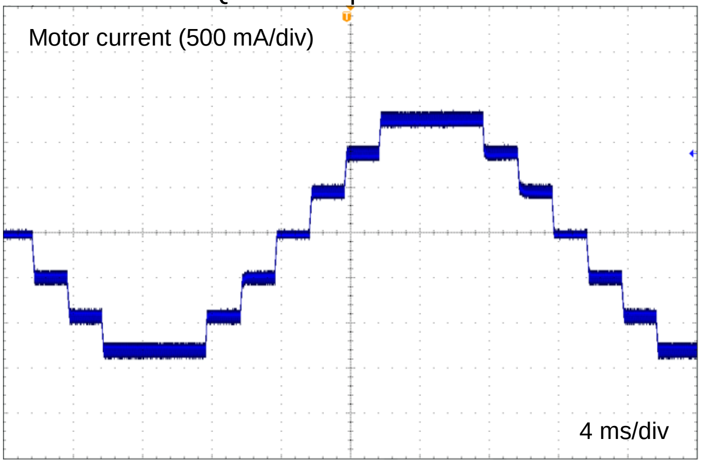
(4) Fuse

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 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.
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.

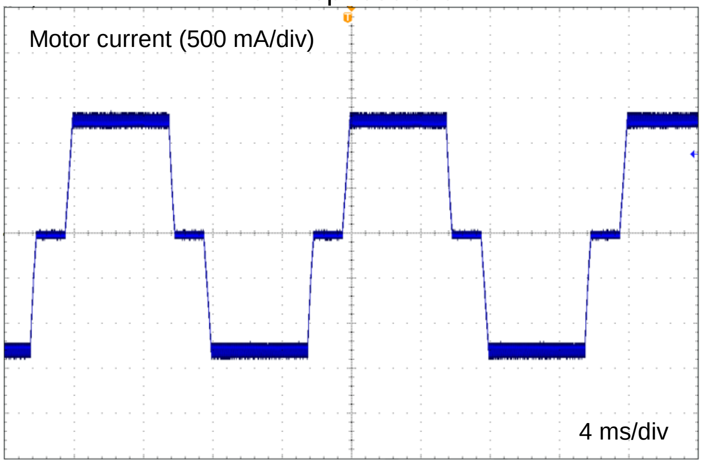
6. Operation waveform (for reference only)

Motor current waveform in configuring each excitation mode
Conditions: V_M = 32 V, V_{REF} = 1.5 V, driving 4.4 mH-stepping motor by clock input control (f_{CLK}=1 kHz).

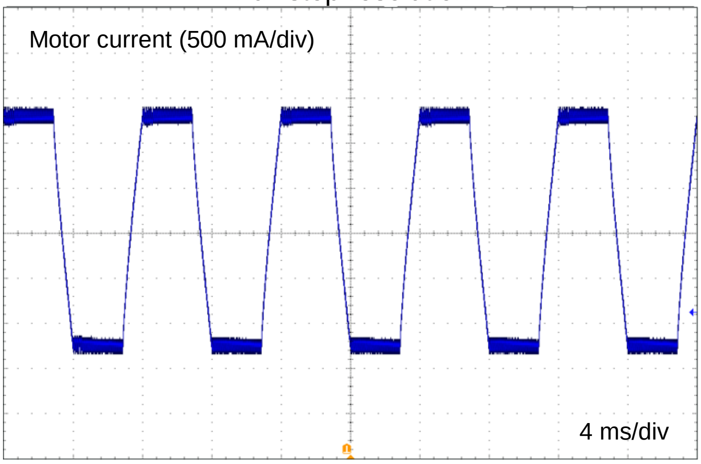
Quarter step resolution



Half step resolution



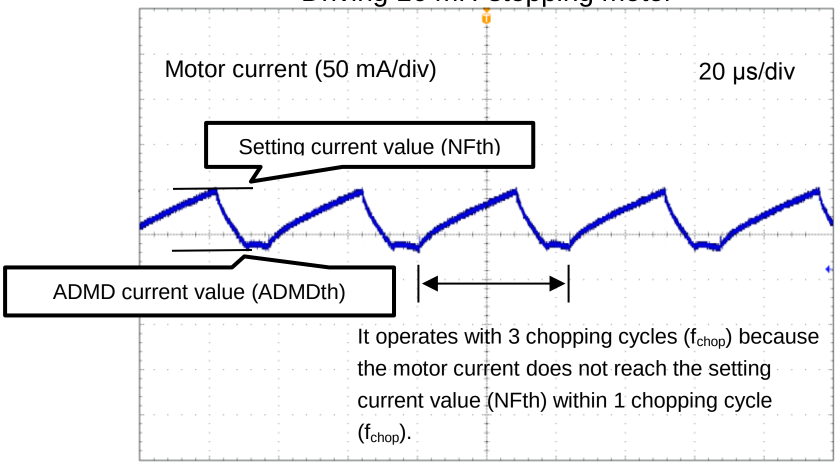
Full step resolution



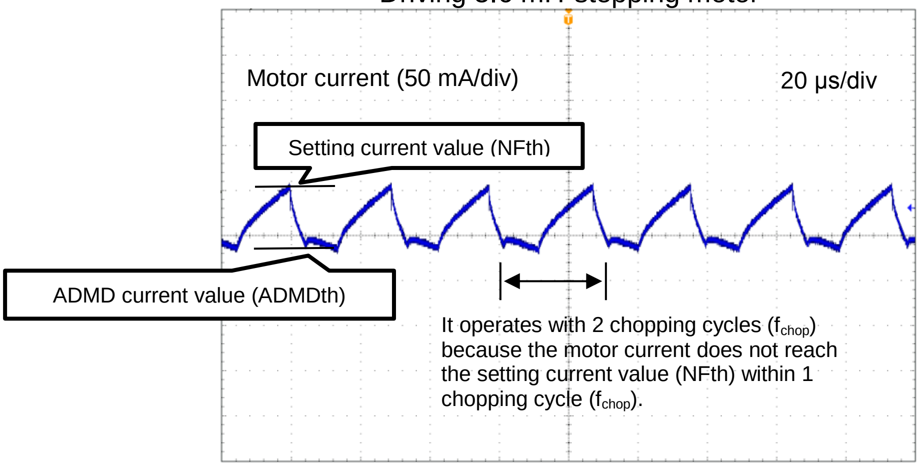
Waveform of PWM constant current control

Conditions: V_M=32 V and V_{REF}=1.1 V

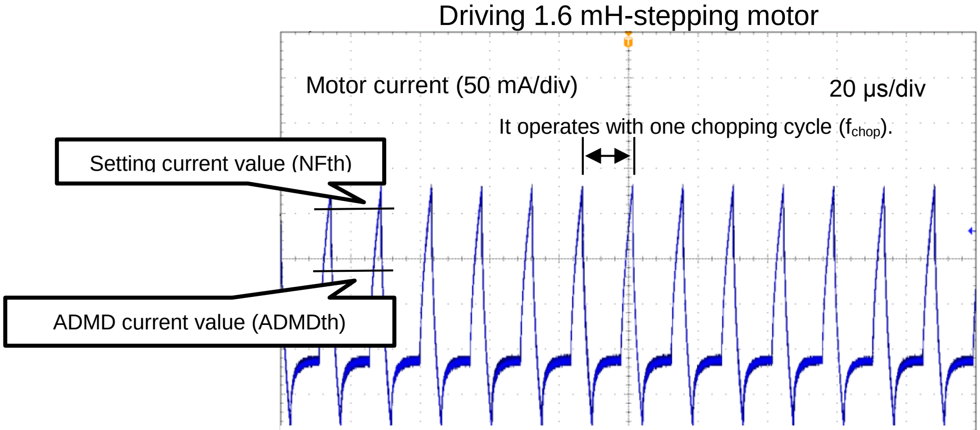
Driving 16 mH-stepping motor



Driving 5.6 mH-stepping motor



Driving 1.6 mH-stepping motor



Since 'L' value of the motor is small, the current value reaches ADMDth (ADMD current value) within the ADMDtblank period. Then, the operation switches to Slow mode after the ADMDtblank period has passed.

7. 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.

1. Power consumption of the transistor output block

Power of the output block is consumed by the transistor of upper and lower H-bridge.
The power consumption of the transistor block of one H-bridge can be calculated by the following formula.

P (out) = Iout (A) × VDS (V) = Iout $(A)^2$ × Ron (Ω)..(1)

When the current waveform of the motor output corresponds to the ideal square waveform by the full step resolution, the average power consumption of the output block can be provided as follows;

When Ron is 0.45 Ω, Iout (peak: Max) is 1.0 A, and VM is 24 V,
P (out) = 2 (Tr) × 1.0 $(A)^2$ × 0.45(Ω)...(2)
= 0.9(W)

2. Power consumption of the logic block

Power consumptions of the logic block are calculated by separating the operation states (operating mode/ stopping mode).

I (IM3) = 7 mA (typ.) : Operating mode
I (IM2) = 4 mA (typ.) : Stopping mode
I (IM1) = 2 mA (typ.) : Standby mode

Output system is connected to VM (24 V). (Output system: Current consumption of the circuit connected to VM + Current consumption of output-step switching)

Power consumption is calculated as follows;

P (IM) = 24 (V) × 0.007 (A) ....(3)
= 0.17 (W)

3. Power consumption

Total power consumption (P) is calculated as follows from the results of ‘1’ and ‘2’ described above.
P = P (out) + P (IM) = 1.07 (W)

The power consumption of standby mode is calculated as follows;
P (standby) = 24 (V) × 0.002 (A) = 0.048 (W)

Please design the heat design of the board, etc. by evaluating the mounted board enough, and configure the appropriate margin.

8. Power dissipation

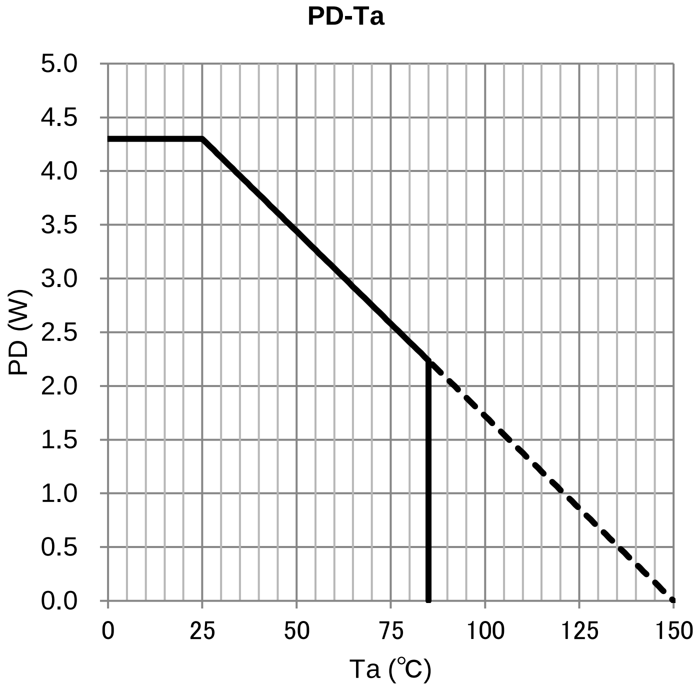
Relation equation of the ambient temperature (Ta), junction temperature (Tj), and the heat resistance (Rth(j-a)) between junction temperature and ambient temperature is as follows;

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

(Example) When mounted on 4-layer board (assumed $R_{th(j\text{-}a)}$ = 29°C/W), T_a is 25°C, and P(total) is 1.07 W (I_{out} = 1.0 A, and 2-phase excitation),

$$T_j = 25\ (°C) + 29\ (°C/W) \times 1.07\ (W) = 56°C$$

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

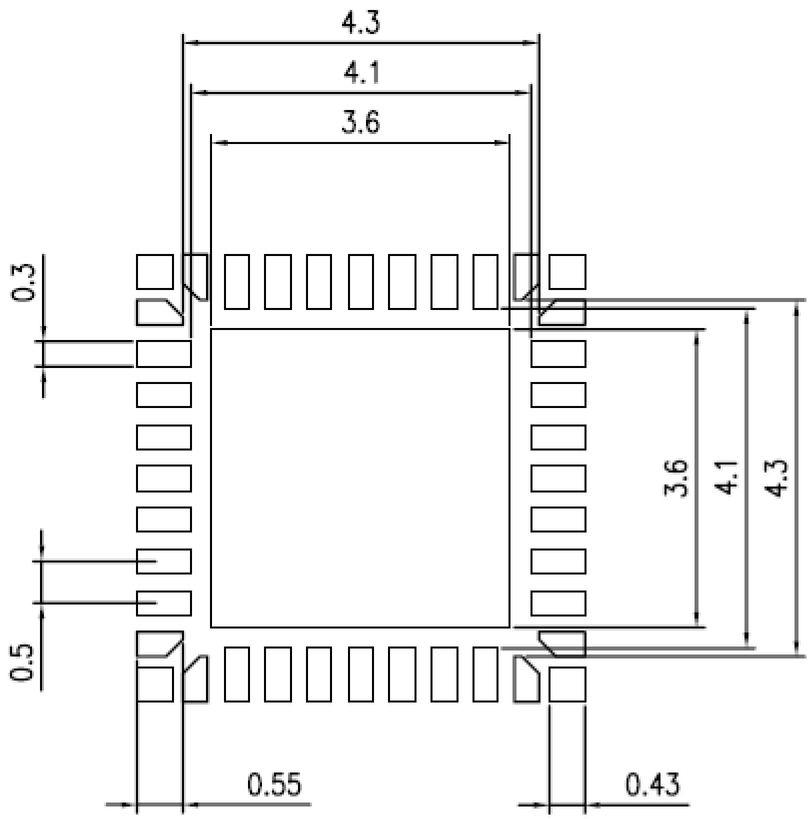


* Pay attention that the power dissipation (P(total)) depends on the usage environment. When ambient temperature is high, the allowable power consumption decreases.

Other reference values: ψjt = 0.3°C/W of the IC (approximately)

9. Foot pattern example (for reference only)

Unit: mm

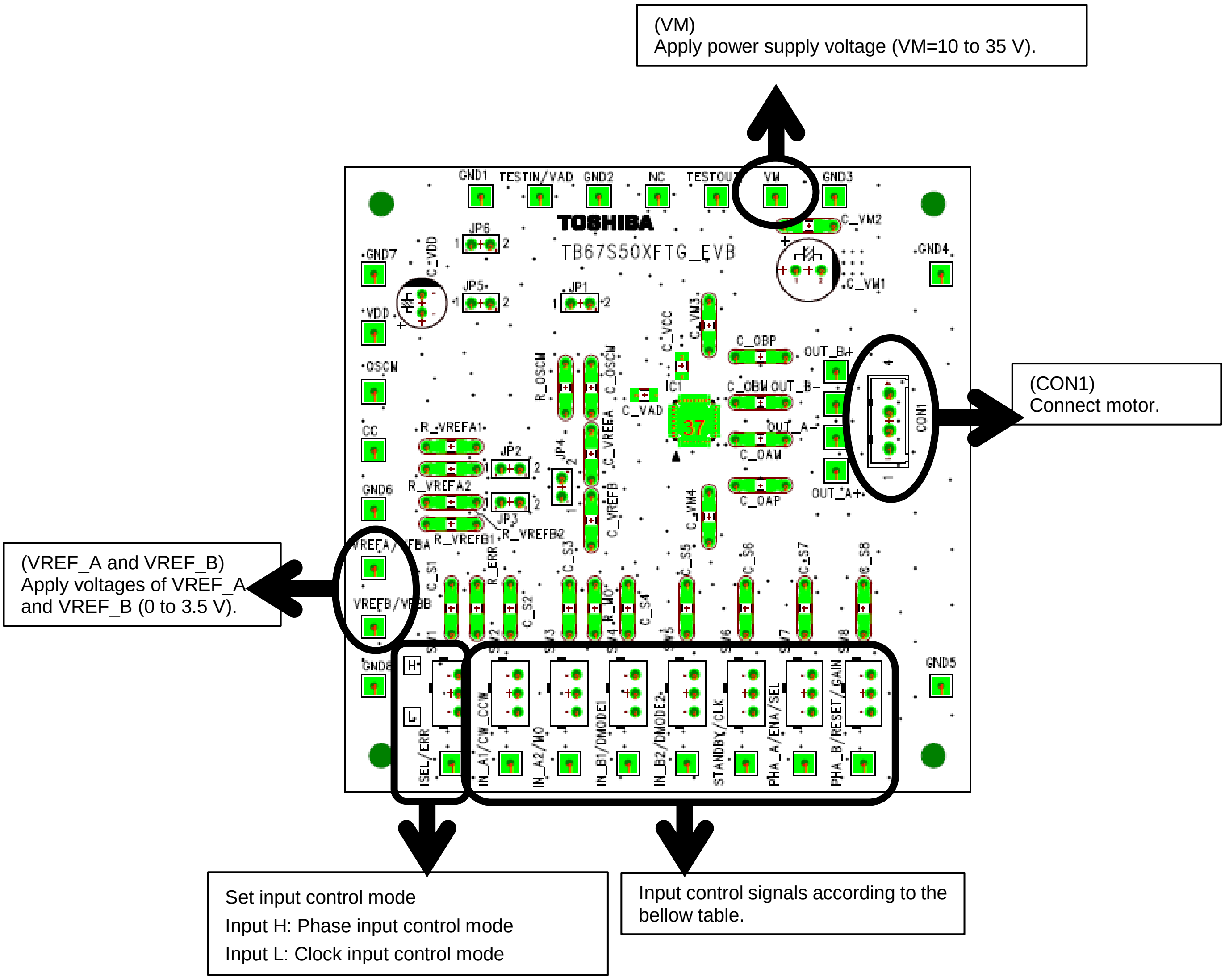


Please use the data as reference data for customer's application. Toshiba does not guarantee the data for mass production.
In determining the size of mounting board, design the most appropriate pattern by considering the solder bridge, the solder connecting strength, the pattern accuracy in making board, and the mounting accuracy of the IC board.

Board dimensions

9.1. Input

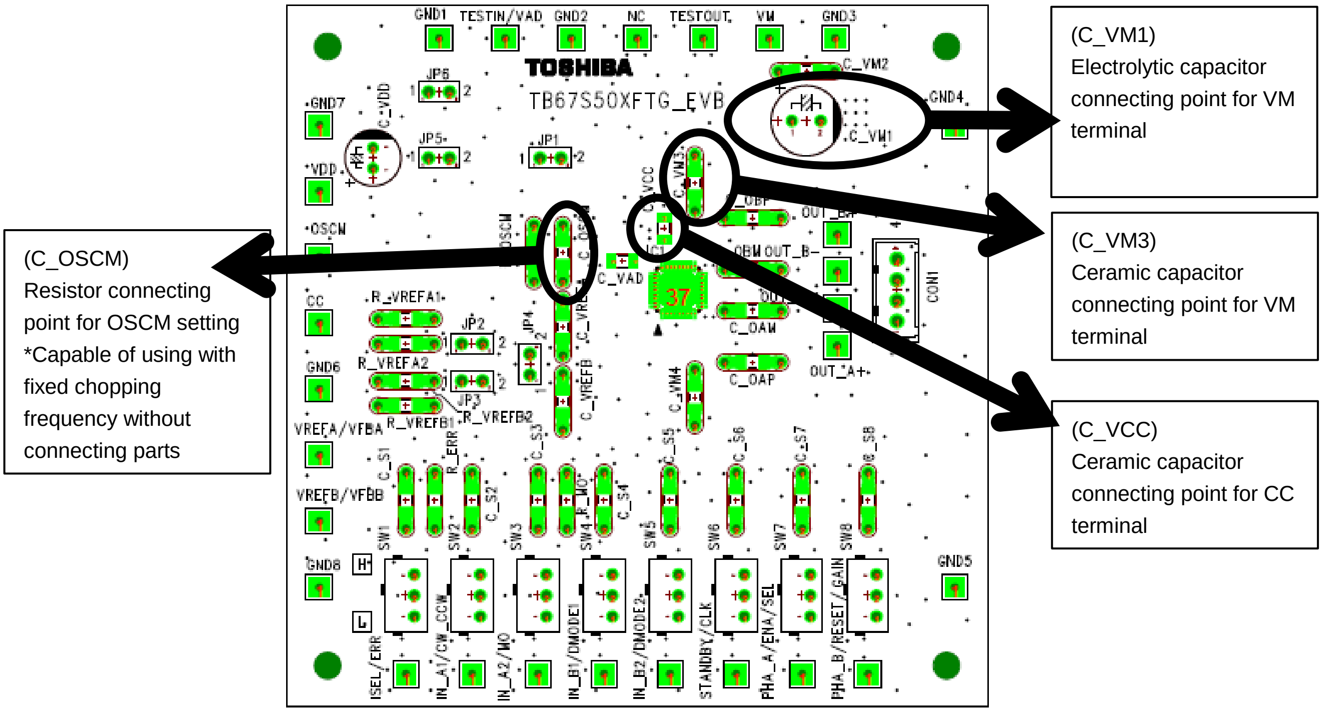
Input each power supply and control signal according to below figure.



Board silk	Phase input control mode	Clock input control mode
IN_A1/CW_CW	IN_A1	CW/CCW
IN_A2/MO	IN_A2	MO
IN_B1/DMODE1	IN_B1	DMODE1
IN_B2/DMODE2	IN_B2	DMODE2
STANDBY/CLK	/STANDBY	CLK
PHA_A/ENA/SEL	PHASE_A	ENABLE
PHA_B/RESET/GAIN	PHASE_B	RESET

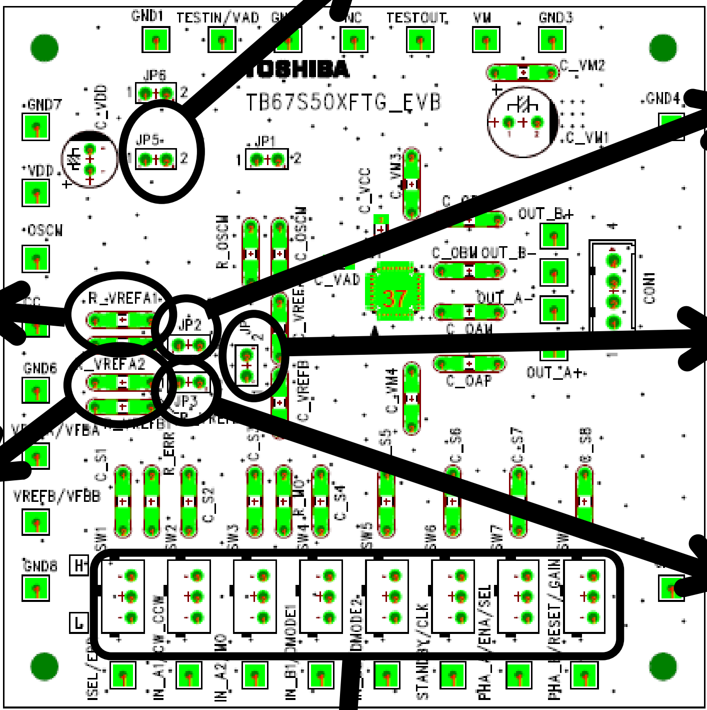
9.2. Main part

Please connect each part referring to “5. Application circuit example”.



9.3. Options

(JP5)
Short circuit when the switching power supply on a board is supplied from the internal 5 V-regulator. When the power is supplied externally through the VDD terminal, please leave it open.



(R_VREFA1 and R_VREFA2)
Connect the resistor for divided voltage when the voltage for VREF_A is applied from the resistive divided voltage of the internal 5 V-regulator.

(JP2)
Short circuit when the voltage for VREF_A is applied from the resistive divided voltage of the internal 5 V-regulator.

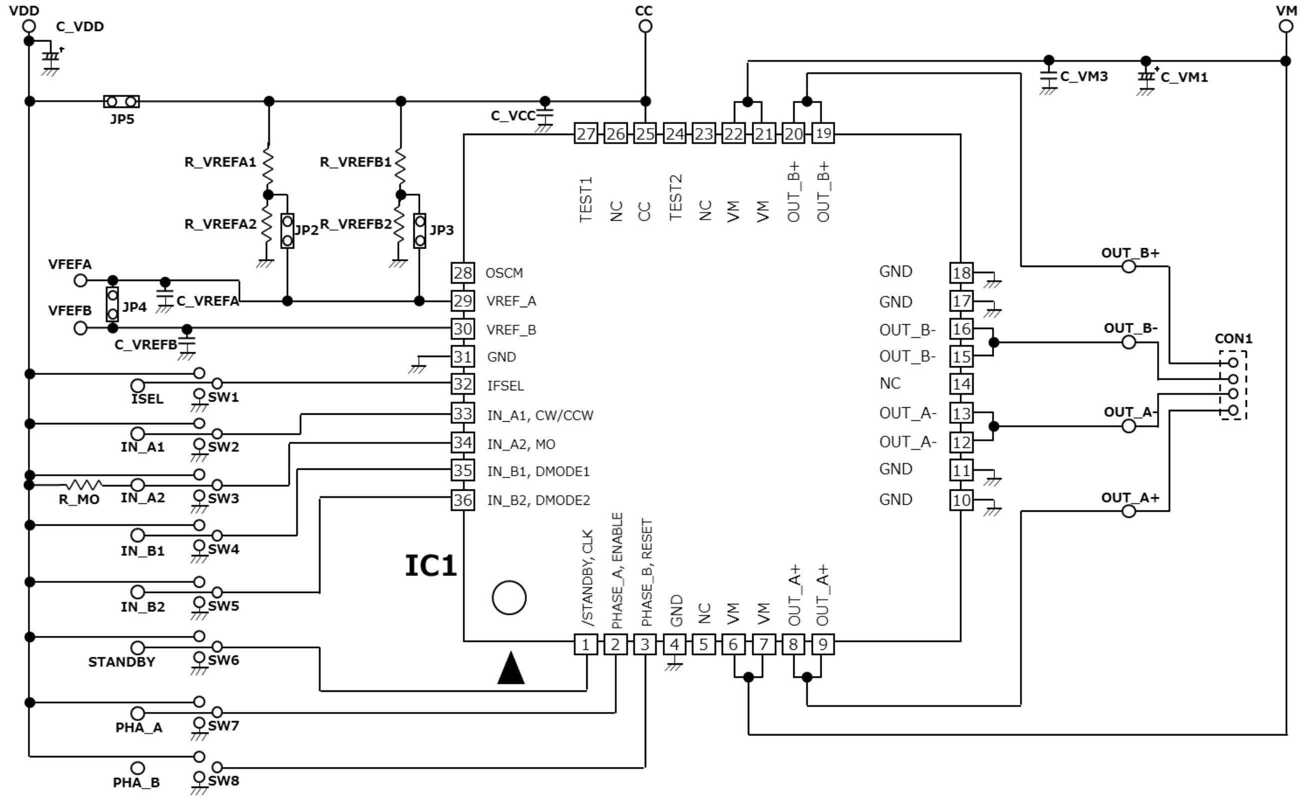
(JP4)
Short circuit when the voltage is applied to VREF_A and VREF_B in common.

(R_VREFB1 and R_VREFB2)
Connect the resistor for divided voltage when the voltage for VREF_B is applied from the resistive divided voltage of the internal 5 V-regulator.

(JP3)
Short circuit when the voltage for VREF_B is applied from the resistive divided voltage of the internal 5 V-regulator.

(SW1, SW2, SW3, SW4, SW5, SW6, SW7, and SW8)
Connect switches when input signals are changed by using switches.

9.4. Board circuit



Notes on Contents

Block Diagrams

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

Equivalent Circuits

The equivalent circuit diagrams may be simplified or some parts of them may be omitted for explanatory purposes.

Timing Charts

Timing charts may be simplified for explanatory purposes.

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.
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Test Circuits

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 device breakdown, damage or deterioration, and may result in injury by explosion or combustion.
In addition, do not use any device inserted in the wrong orientation or incorrectly to which current is applied even just once.

(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 from 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 may cause smoke or ignition. (The overcurrent may 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

Overcurrent detection Circuit

Overcurrent detection circuits (referred to as current limiter circuits) do not necessarily protect ICs under all circumstances. If the overcurrent detection circuits operate against the overcurrent, clear the overcurrent status immediately.
Depending on the method of use and usage conditions, exceeding absolute maximum ratings may cause the overcurrent detection circuit to operate improperly or IC breakdown may occur before operation. In addition, depending on the method of use and usage conditions, if overcurrent continues to flow for a long time after operation, the IC may generate heat resulting in breakdown.

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, exceeding absolute maximum ratings may cause the thermal shutdown circuit to operate improperly or IC breakdown to occur before operation.

Heat Radiation Design

When using an IC with large current flow such as power amp, regulator or driver, design the device so that heat is appropriately radiated, in order not to exceed the specified junction temperature (TJ) at any time or under any 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, when designing the device, take into consideration the effect of IC heat radiation with peripheral components.

Back-EMF

When a motor rotates in the reverse direction, stops or slows abruptly, current flows back to the motor’s power supply owing 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 the absolute maximum ratings. To avoid this problem, take the effect of back-EMF into consideration in system design.

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