TB67H410

Usage considerations

Summary

The TB67H410 is a DC brushed motor driver of a PWM chopper-type. The TB67H410A is a dual channel H-SW driver which can control two brushed DC motors. Moreover, since the parallel control function (Large mode) of the output is built in, one channel can respond to a large current drive. Fabricated with BiCD process, rating is 50V and maximum current 2.5A (2ch)/4.0A (1ch).

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1. Power supply voltage

1.1. Power supply voltage and operating range

In using the TB67H410, the voltage should be applied to the terminals of VM, VREFA, and VREFB. The maximum rating of VM supply voltage is 50V. Operating range of the power supply voltage is 10 to 47V. The slew rate in inputting a power supply should use 0.05V/µs or less.
The maximum rating of VREF voltage is 5V. Operating 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.

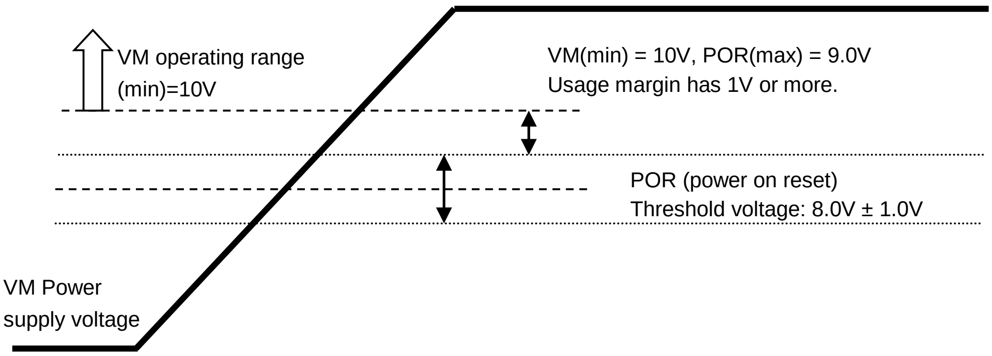


Figure 1.1 Power supply voltage and usage range

1.2. Power supply sequence

There are no special procedures of inputting a power supply and shutdown because the TB67H410 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 1.6A 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 TB67410 can adjust the internal oscillation frequency (fOSCM) and the chopping frequency (fchop) with the constant number of the external parts connecting to OSCM terminal.
The frequency setting is recommended about 100 kHz from 50 kHz based on the frequency about 70 kHz generally.

- The relation equations of the OSCM oscillation frequency (fOSCM) and the chopping frequency (fchop) are as follows;

$$fOSCM = 1 / [0.56 \times \{C \times (R1 + 500)\}]$$
$$fchop = fOSCM / 16$$

C, R1: external constant number for OSCM (fOSCM is about 1.12 MHz (typ.) at C = 270 pF and R1 = 5.1 kΩ. fchop becomes considerable at about 70 kHz (typ.).)

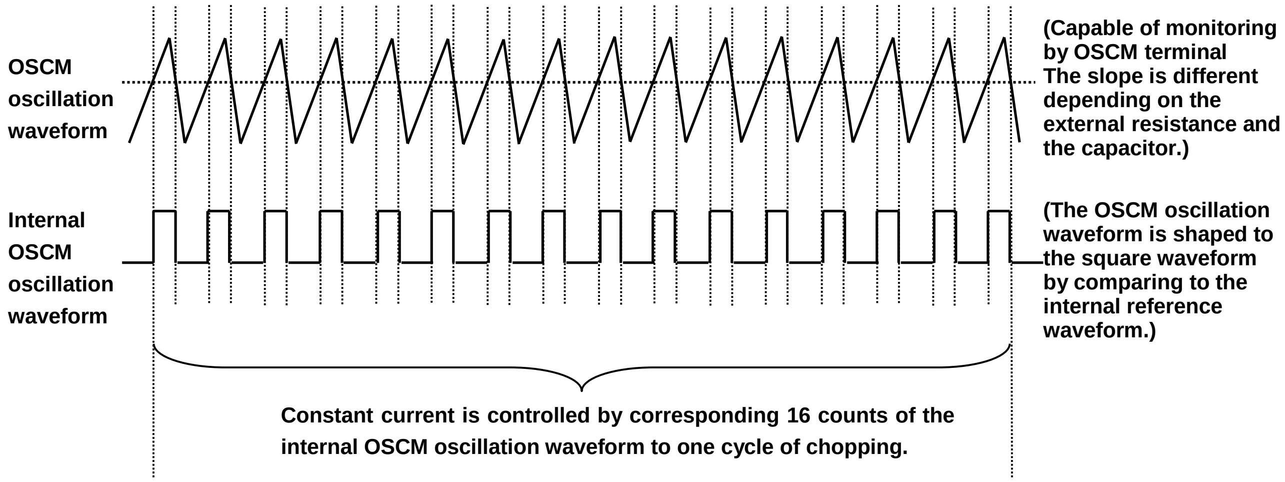


Figure 4.1 OSCM oscillation frequency

5. Mixed Decay Control

This product has the constant current control of the Mixed Decay Mode.
In the case of constant current control, the rate of the Mixed Decay Mode which determines current Ripple is fixed to 37.5%.

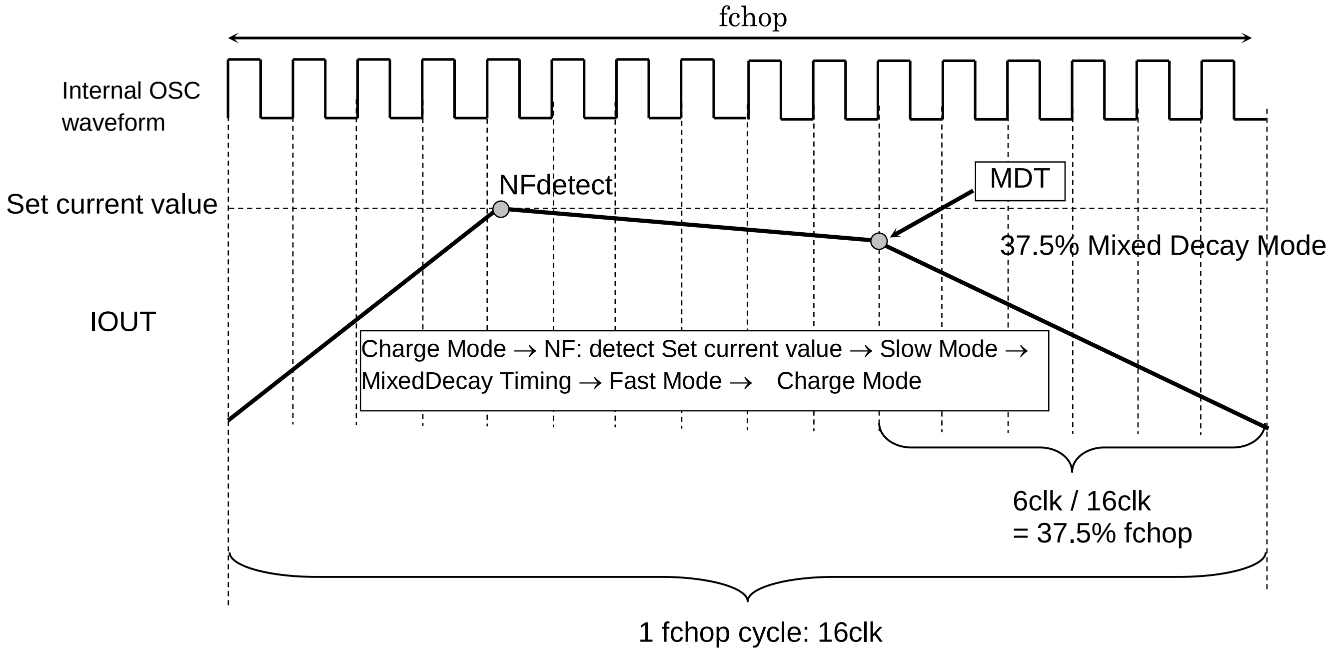


Figure 5.1 Current waveform of Mixed Decay Mode

Timing charts may be simplified for explanatory purpose.

Current waveform in Mixed Decay Mode

･When a current value increases (Mixed-Decay point is fixed to 37.5%)

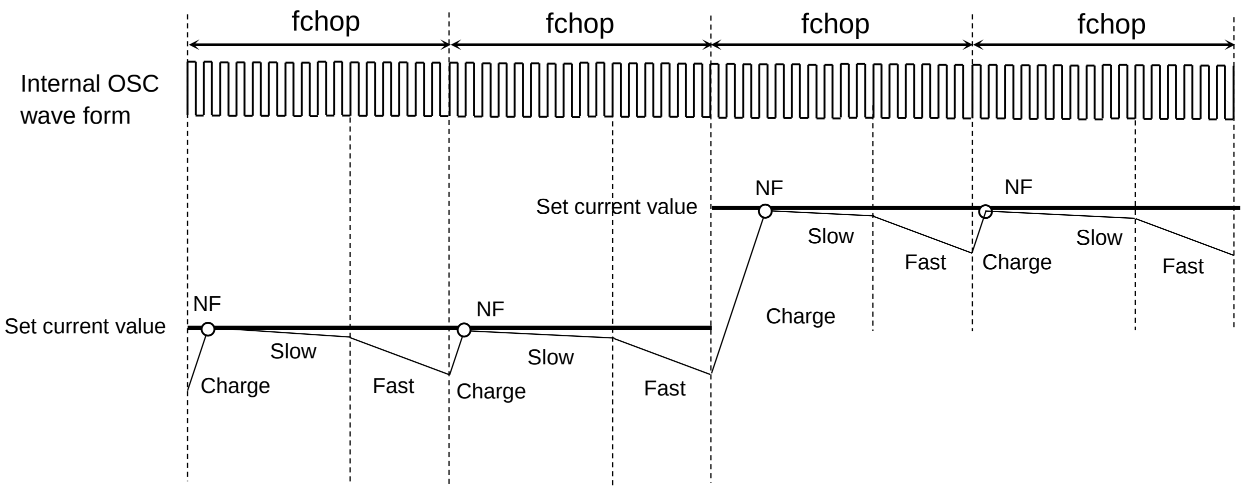


Figure 5.2　Current waveform in Mixed Decay Mode (When current value increases)

･When a current value decreases (Mixed-Decay point is fixed to 37.5%)

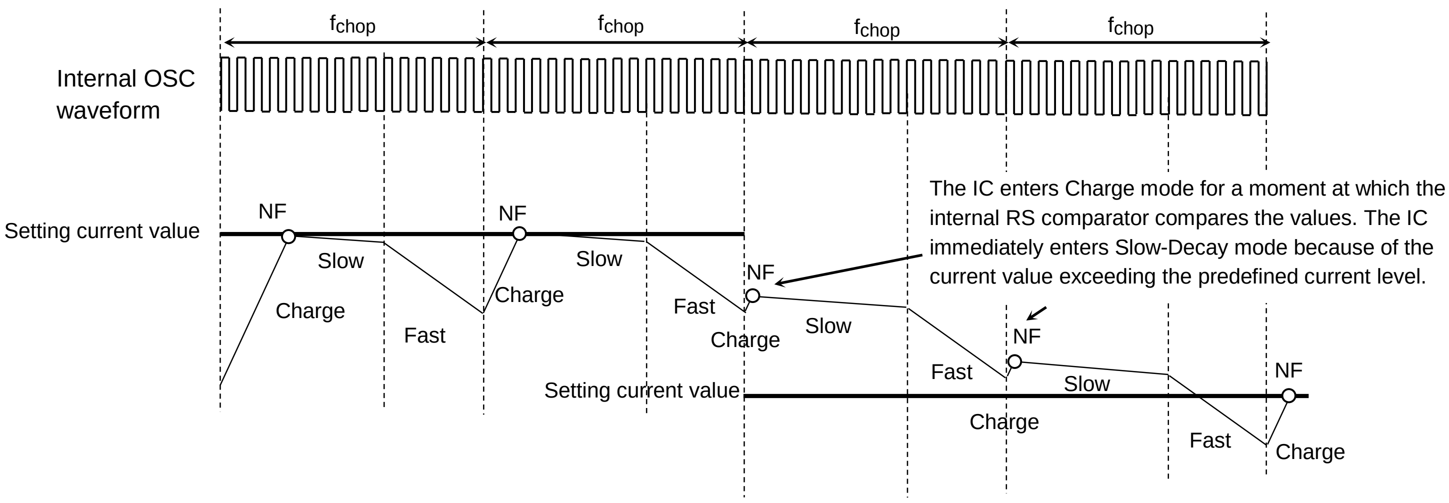


Figure 5.3　Current waveform in Mixed Decay Mode (When a current value decreases)

The Charge period starts as the internal oscillator clock starts counting. When the output current reaches the predefined current level, the internal RS comparator detects the predefined current level (NF); as a result, the IC enters Slow-Decay mode.
The TB67H400A transits from Slow-Decay mode to Fast-Decay mode at the point 37.5% of a PWM frequency (one chopping frequency) remains in a whole PWM frequency period (on the rising edge of the 11th clock of the OSCM clock).
When the clocks of the OSCM terminal are counted 16 times, the Fast-Decay mode ends; and at the same time, the counter is reset, which brings the TB67H400A into Charge mode again.

Note: These figures are intended for illustrative purposes only. If designed more realistically, they would show transient response curves.

Timing charts may be simplified for explanatory purpose.

6. Switching characteristics

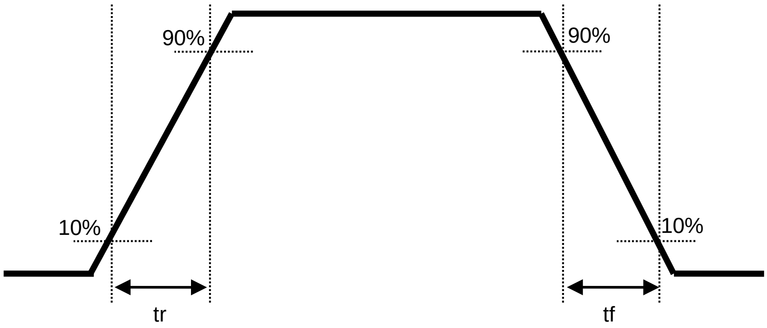


Figure 6.1 Switching characteristics

Table 6.1 Switching characteristics

T_a = 25°C, VM = 24 V, No load

Item	Typ.	Unit
tr	80	ns
tf	90	ns

7. Function explanation

(1) TBLKAB function

This terminal sets the noise reduction time Digital tBLK.
* The Digital tBLK is used to avoid error judgment of varistor recovery current that occurs in charge drive mode when H-bridges are used with DC motors. The Digital tBLK time can be controlled with TBLKAB pin.
By setting Digital tBLK, direct PWM control and constant-current control is possible, but the motor current will rise above the predefined current level (NF) while digital tBLK is active.
* Besides Digital tBLK, Analog tBLK (400ns (typ.)) settled by an internal constant of IC is also attached.

Table 7.1 TBLKAB Function

TBLKAB input	Function
L	Digital tBLK setting time width = fOSCM×4clk
H	Digital tBLK setting time width = fOSCM×6clk

(2) HBMODE function

This terminal sets the H-Bridge operation mode.

Table 7.2 HBMODE function

HBMODE input	Function
L	Small mode
H	Large mode

Note1: When using the Large mode, please make sure that the impedance between A channel and B channel is balanced. Also, make sure that the output pins (OUTA+ and OUTA-, OUTB+ and OUTB-), RS pins (RSA and RSB) are connected to each other when using the Large mode.

Note2: Please set the HBMODE to Low or High with the PCB pattern. (Do not change the logic input level during operation.)

H-bridge connection example

- 2 DC motors (Small mode) operation setting example

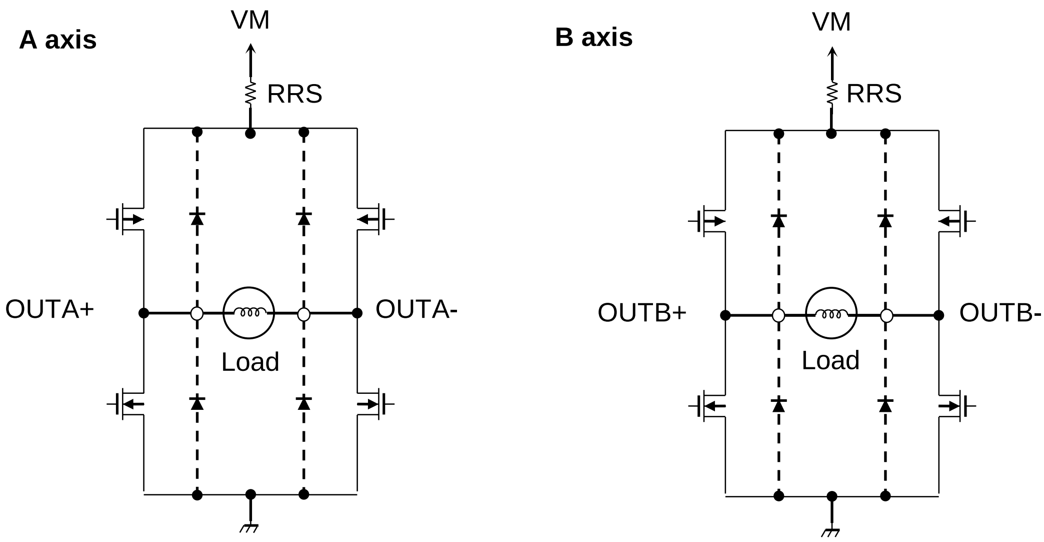


Figure 7.1 2 DC motors (Small mode) operation

- 1DC motor (Large mode) operation setting example

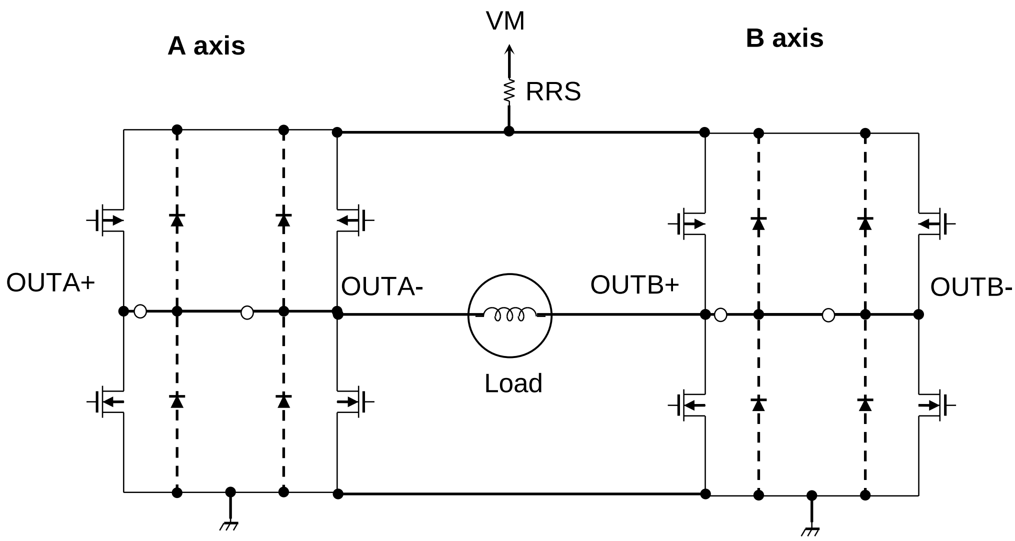


Figure 7.2 1 DC motor (Large mode) operation

Please note that in the equivalent input circuit, functional blocks or constants may be omitted or simplified for explanatory purposes.

(3) Input /output function table

Small mode

(1) INA1 and INA2 terminals

This terminal sets the drive mode for the Bridge A.

Table 7.3 Function of INA1 and INA2(Small mode)

	PWMA	INA1	INA2	OUTA+	OUTA-	Function
Input	L	L	L	OFF (Hi-Z)	OFF (Hi-Z)	* Standby mode
	H					STOP(OFF)
	L	L	H	L	L	Short brake
	H			L	H	Reversed rotation
	L	H	L	L	L	Short brake
	H			H	L	Normal rotation
	L	H	H	L	L	Short brake
	H					

(2) INB1 and INB2 terminals

Drive mode of the motor (Bch) is set.

Table 7.4 Function of INB1 and INB2 (Small mode)

	PWMB	INB1	INB2	OUTB+	OUTB-	Function
Input	L	L	L	OFF (Hi-Z)	OFF (Hi-Z)	*Standby mode
	H					STOP(OFF)
	L	L	H	L	L	Short brake
	H			L	H	Reversed rotation
	L	H	L	L	L	Short brake
	H			H	L	Normal rotation
	L	H	H	L	L	Short brake
	H					

Large mode

These pins set the drive mode for Bridge A and B by controlling them as one H-bridge

Table 7.5 Function of INA1 and INA2 (Large mode)

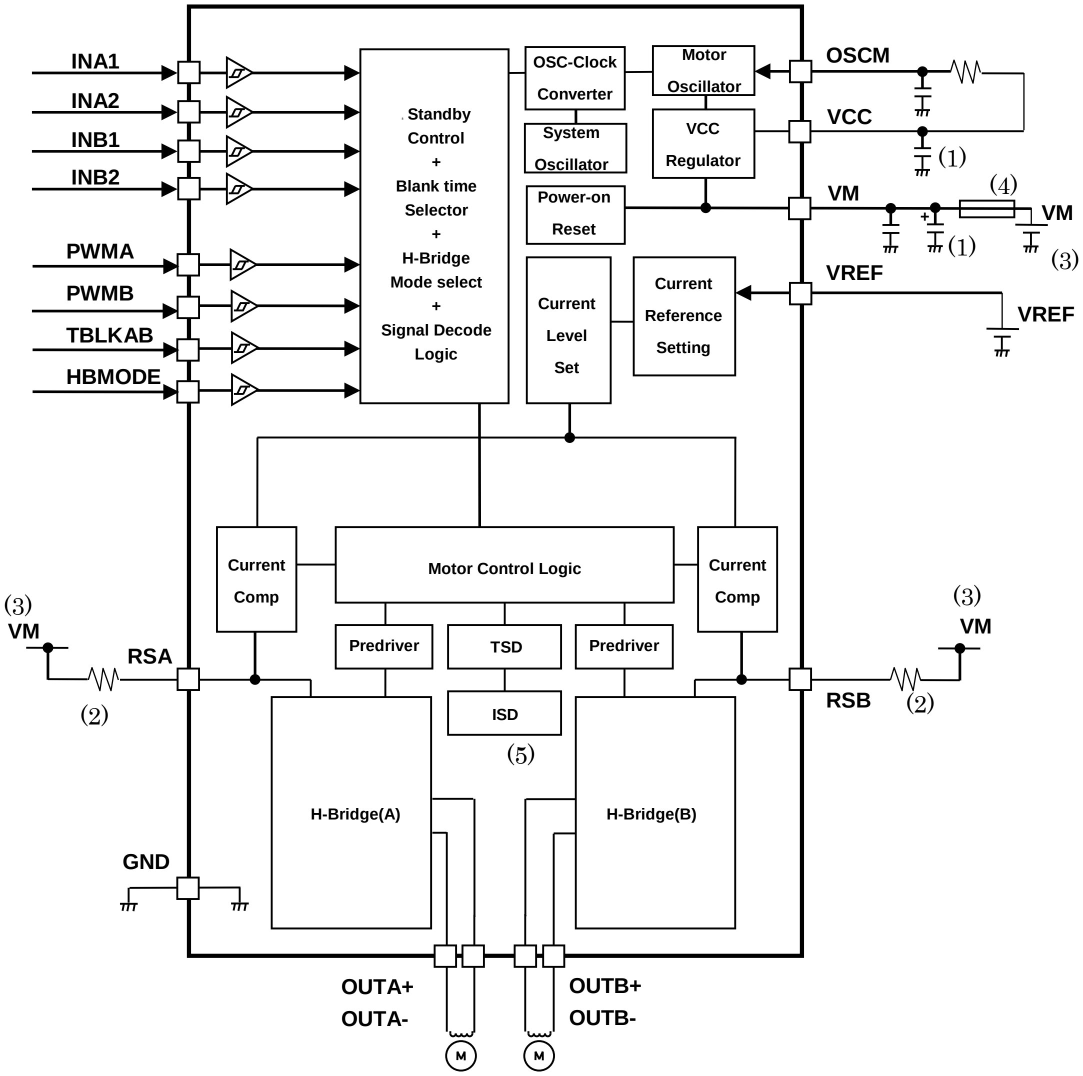
	PWMA	INA1	INA2	OUTL+	OUTL-	Function
Input	L	L	L	OFF (Hi-Z)	OFF (Hi-Z)	*Standby mode
	H					STOP(OFF)
	L	L	H	L	L	Short brake
	H			L	H	Reversed rotation
	L	H	L	L	L	Short brake
	H			H	L	Normal rotation
	L	H	H	L	L	Short brake
	H					

In Large mode, the operation is controlled by terminals for Bridge-A (INA1, INA2, and PWMA). Pay attention that signal inputs for Bridge-B (INB1, INB2, and PWMB) are invalid. (In using Large mode, it is recommended to set to low level all terminals of INB1, INB2, and PWMB.) The terminal of

TBLKAB is valid whether the terminal of HBMODE is set to low or high level.

*Note: The standby mode is only enabled when all 6 logic input pins (INA1, INA2, PWMA, INB1, INB2, and PWMB) are set to Low level.

8. Example of 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.

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	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 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;

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

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) 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.

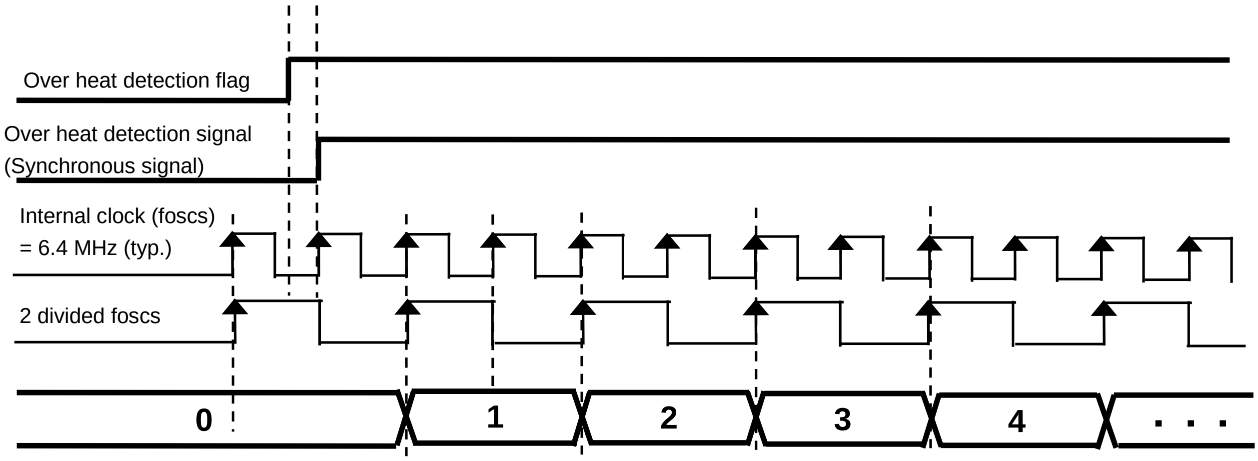
(4) Fuse

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 terminals of INA1, INA2, INB1, INB2, PWMA, and PWMB 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.

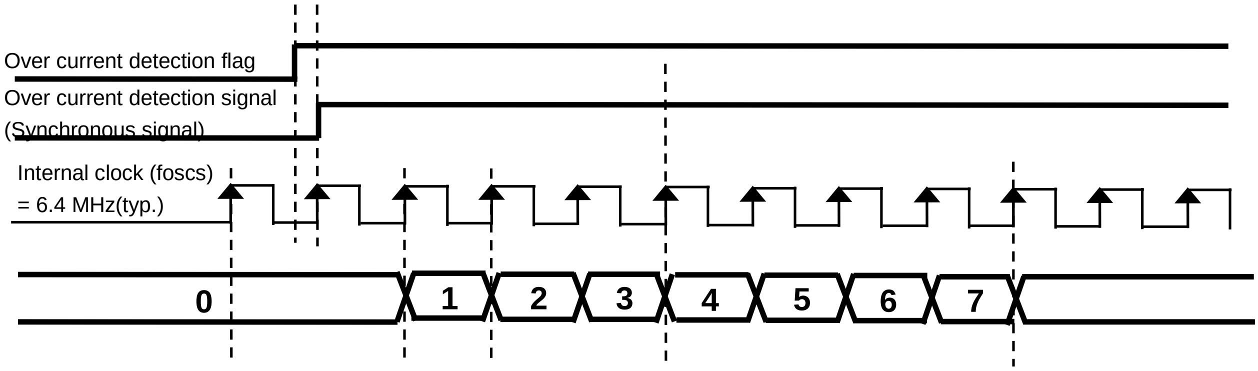
Figure 8.2 Dead band time of thermal shutdown circuit

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 / (foscs / 2) × 7~8 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 terminals of INA1, INA2, INB1, INB2, PWMA, and PWMB 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.

* foscs = 6.4 MHz(typ.) internal clock
1 / foscs × 7 to 8 clk (1.09 to 1.25 μs)

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(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, average power of output block can be provided as follows;

When Ron = 0.8Ω, Iout (peak: Max) = 1.0 A, VM = 24 V
P(out) = 2 (ch) × 1.0 (A) × 1.0 (A) × 0.8 (Ω)…………………………………………………..………………(2)
= 1.6 (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)

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

- Power consumption is calculated as follows;

  P(total) = P(out) + P(bias) = 1.6 + 0.132 = 1.732 (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 (Ta), junction temperature (Tj), and the heat resistance (Rth(j-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 ($R_{th(j\text{-}a)}$ = 25°C/W), T_a = 25°C, P(total) = 1.732 W (I_{out} = 1.0 A, 2Ch)

T_j = 25 (°C) + 25 (°C/W) × 1.732 (W) = 68.3°C

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

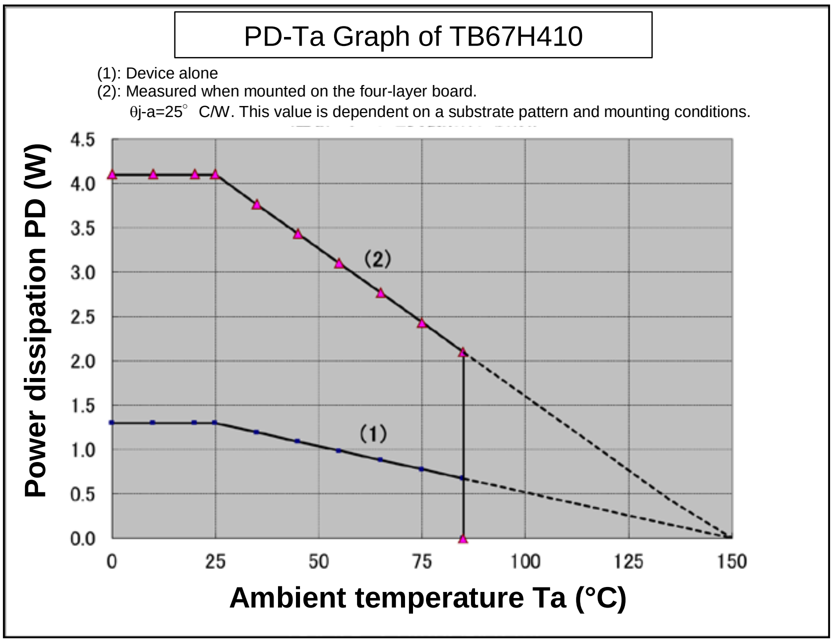


Figure 10.1 Power dissipation

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

(1) QFN48 foot pattern (unit: mm)

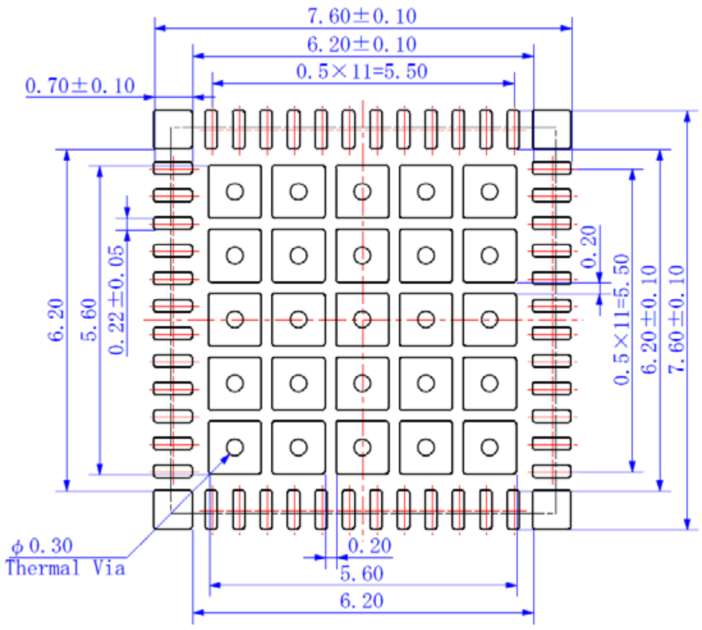


Figure 11.1 QFN48 foot pattern

Toshiba does not guarantee the data for mass production. Please use the data as reference data for customer's application.
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

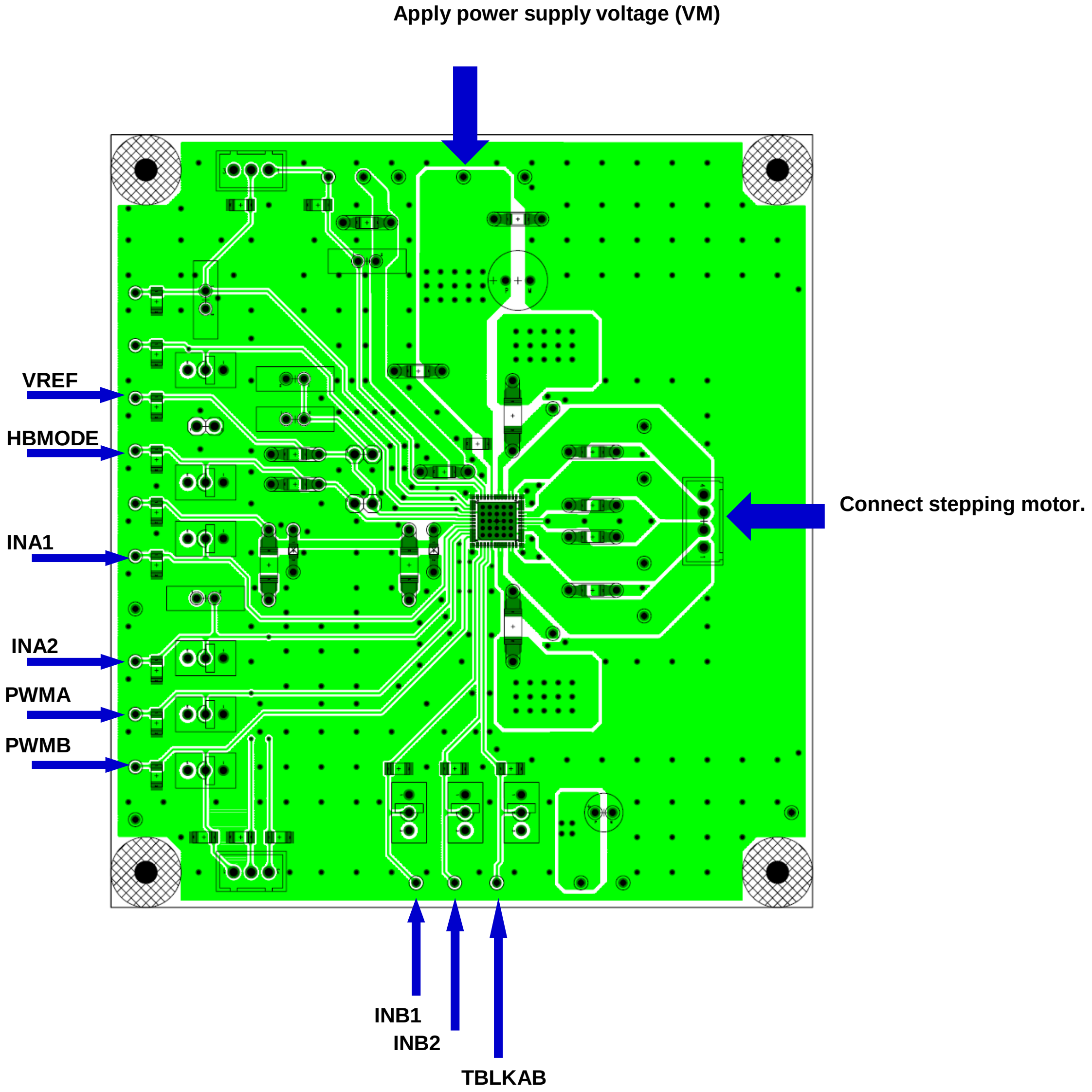


Figure 12.1 Input

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

12.2. Main part

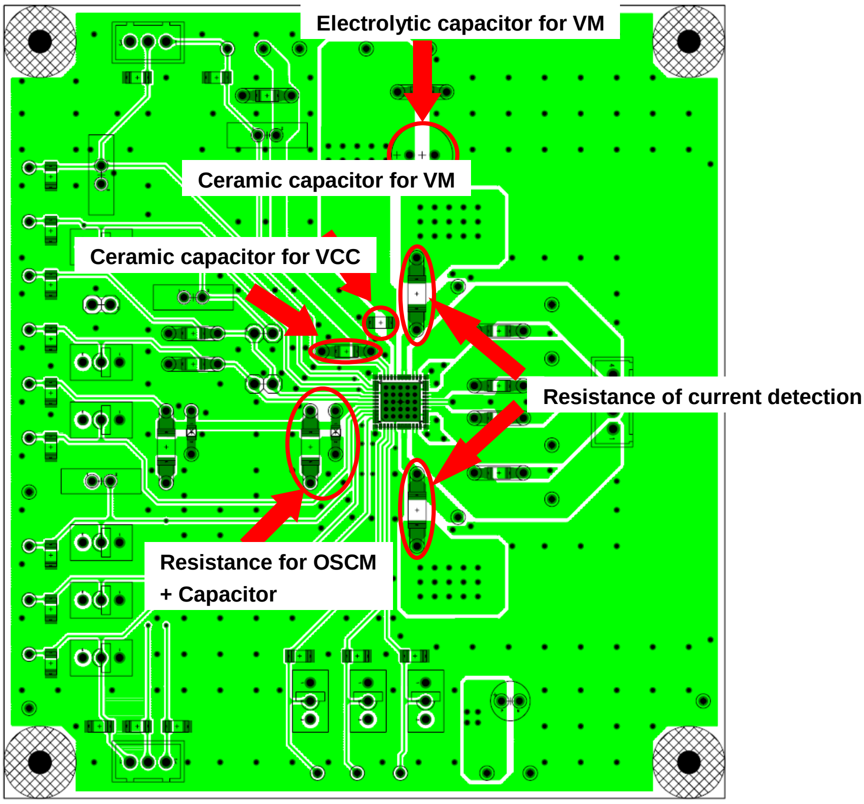


Figure 12.2 Main part

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

12.3. Options

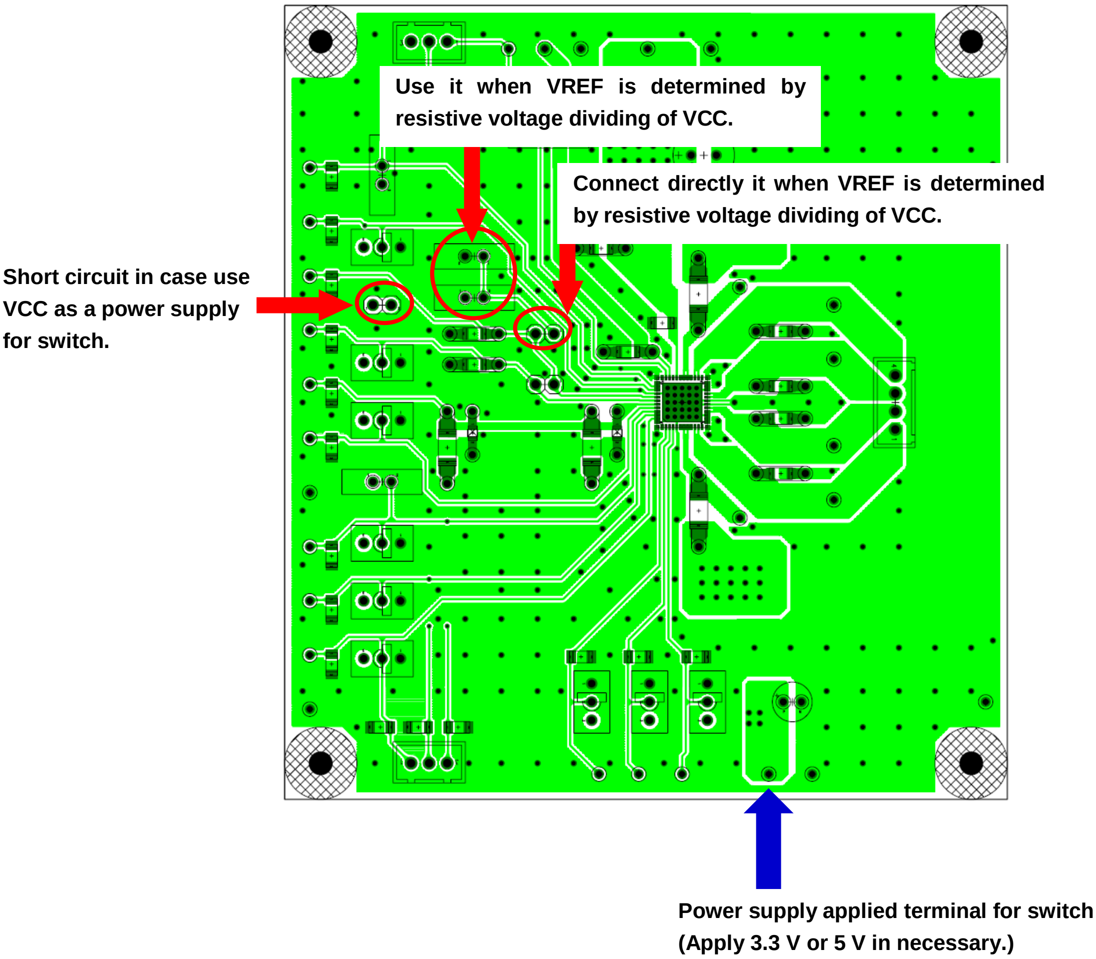


Figure 12.3 Options

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 (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.

RESTRICTIONS ON PRODUCT USE

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