

Notes in use of the TB67S149A

Summary

The TB67S149A is a two-phase unipolar stepping motor driver using a PWM chopping control. The clock-in decoder is built in. Fabricated with the BiCD process, this device is rated at 84V/3.0A

※ The contents described in the application note are reference for evaluating the product. Therefore, the contents described cannot be guaranteed. As for the detailed materials, please check the data sheet.

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1. Power supply voltage

1.1. Power supply voltage and usage range

In using the TB67S149A, the voltage should be applied to the VM, and VREF pins. The maximum rating of VM supply voltage is 45V. Usage range of the power supply is 10 to 40 V. The maximum rating of VREF voltage is 6V. Usage range of the voltage is 0 to 4.0 V when using the constant current PWM mode. To turn off the constant current PWM mode, connect the VREF pin to the VCC pin. Always use the VCC to turn off the constant current PWM, and do not use any external power supply. Also, setting the VREF voltage by using the internal VCC regulator voltage with a voltage divider, is possible. If so, please set the resistance value from VCC to GND; between 10 kΩ to 30 kΩ.

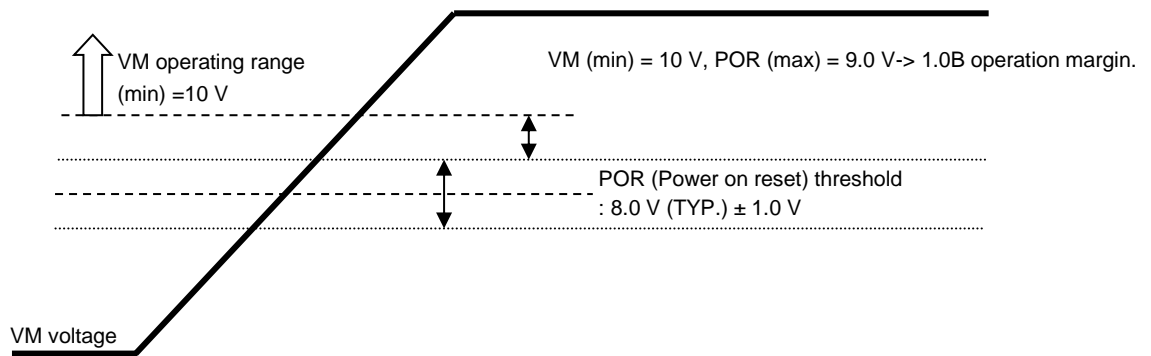


Figure 1.1 Power supply voltage and operating range

1.2. Power supply sequence

There are no special requirements for power-on and power-off sequence because the TB67S149A is a single power operational device (has a built-in VCC regulator). However, to avoid an unstable operation, we recommend setting the ENABLE pin to Low during on and off sequence so that the motor will not start during on/off sequence. Once the VM reaches the operation range, then switch the ENABLE to High, to start the operation.

2. Motor current

Please use the device so that the motor current is set below 3 A (max). Also, note that the peak current may be limited due to usage conditions (ambient temperature, PCB layout pattern, heat issue, step resolution setting, etc.). Please evaluate and check if the device can operate at the required conditions.

3. Control input

If the control input signal is asserted when VM is set off, the device will not malfunction. But, for safe use, please see the '1.2 Power supply sequence' for reference, and set the input signals to Low.

4. Setting of the Constant current control off time

The TB67S149A can set the constant current control off time by pulling down the OSCM pin by external resistance. The relationship between the off time and resistance is shown in the table below.

Note that the number shown in the table below is only for reference and that it does not include the accuracy of the external components.

Table 4.1 OSCM pulldown resistance

Pulldown resistance (ROSCM)	Off time (toff)
3.9 kΩ	4.1 μs
4.7 kΩ	4.9 μs
5.6 kΩ	5.8 μs
6.8 kΩ	7.0 μs
8.2 kΩ	8.3 μs
10 kΩ	10 μs
15 kΩ	15 μs
18 kΩ	18 μs
22 kΩ	21 μs
27 kΩ	26 μs
39 kΩ	37 μs

*Please connect 10kΩ during constant voltage operation also.

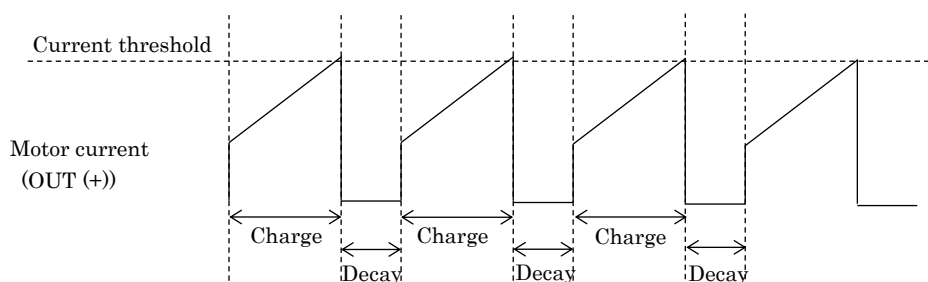
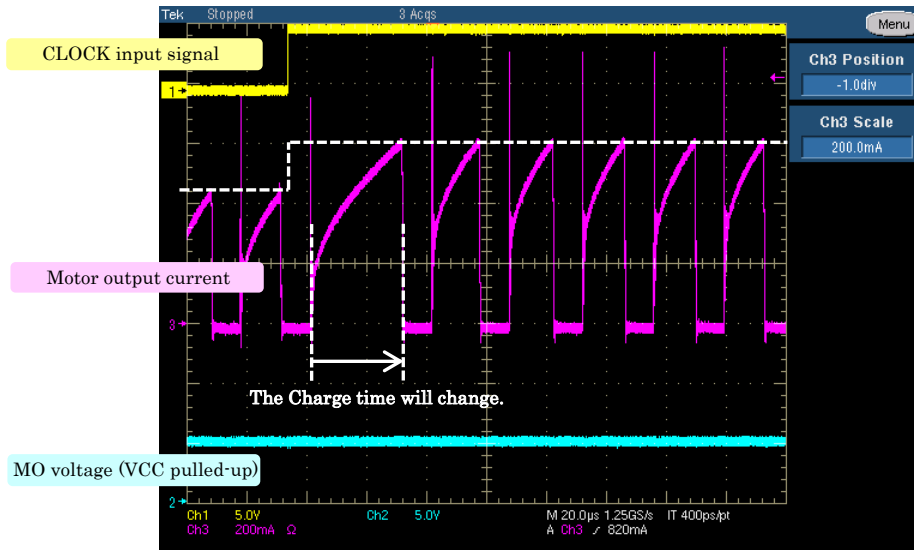


Figure 4.1 Constant current PWM timing chart 1

The off time is shown as 'Decay' in the timing chart above.

About constant current PWM waveform

- When the next current step is higher than the previous step



**Figure 4.2 Constant current PWM waveform
(When the next current step is higher than the previous step)**

When the current threshold (current step) is shifted to the next threshold (step), the 'Charge' time may change, but the 'Decay (=off time)' time will not. (The off time depends on the OSCM resistance.)

- When the next current step is lower than the previous step

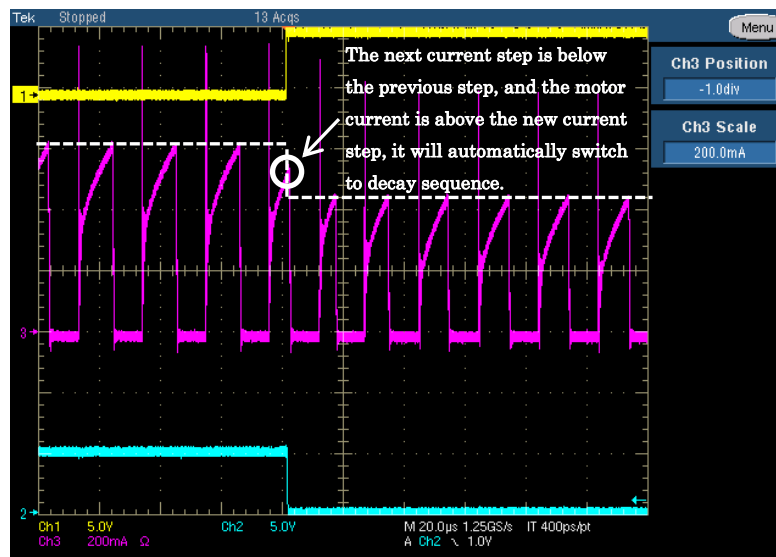


Figure 4.3 Constant current PWM waveform (next step is lower than previous)

When the current step is shifted to the next step: if the motor current is above the PWM threshold, it will then go onto the decay sequence. If the motor current is below the next current step, it will continue on to the constant current PWM.

5. Function explanation

(1) CLK function

The CLK pin controls the rotation speed of the motor. Each CLK signal will shift the motor's electrical angle per step, due to each up-edge of the CLK signal.

Table 5.1 CLK function table

CLK	Function
↑ (Low to High)	Shifts the electrical angle per step.
↓ (High to Low)	— (State of the electrical angle does not change.)

(2) ENABLE function

The ENABLE pin controls the ON and OFF of the output stage. Please set the ENABLE pin to Low level during power-on and off sequence.

Table 5.2 ENABLE function table

ENABLE	Function
High	Output stage='ON' (Normal operation mode)
Low	Output stage='OFF' (High impedance mode)

(3) CW/CCW function

When set to 'CW', the Ach current phase leads the Bch current phase by 90 °.
When set to 'CCW', the Bch current phase leads the Ach current phase by 90 °.

Table 5.3 CW/CCW function table

CW/CCW	Function
High	Clock-wise (CW)
Low	Counter Clock-wise (CCW)

(4) DMODE (Step resolution setting) function

Table 5.4 Function table of DMODE

DMODE0	DMODE1	DMODE2	Function
L	L	L	STANDBY MODE (the OSCM is disabled, and the output stage is set 'OFF'.)
L	L	H	Full step resolution
L	H	L	Half step(a) resolution
L	H	H	Quarter step resolution
H	L	L	Half step(b) resolution
H	L	H	1/8 step resolution
H	H	L	1/16 step resolution
H	H	H	1/32 step resolution

Note) After setting the Standby mode: OFF, the internal circuit will restart from low power mode. During the startup period (10 μs after setting the Standby mode: OFF), please do not send any control signals. (If the signal is sent to the device during the startup period, the device may not be able to accept the signal correctly.)

6. Dead band time of error detection circuits

Dead band time of over current detection (ISD)

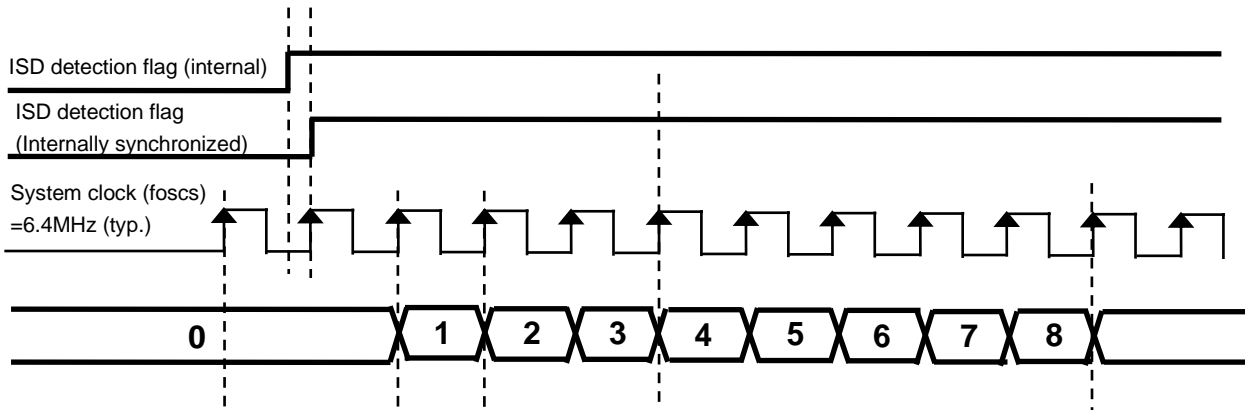


Figure 6.1 Dead band time of over current detection

Timing charts may be omitted for explanatory purpose.

The over current detection circuit has a built-in dead band time to avoid miss-detecting the over current detection due to switching noise or current spikes. The counter for this dead band time is controlled by the internal system clock ($f_{oscs}=6.4\text{ MHz (typ.)}$).

* $f_{oscs}=6.4\text{ MHz (typ.)}$ internal clock
 $1/f_{oscs}\times 8\text{ to }9\text{ clk worth (1.25 }\mu\text{s to }1.4\text{ }\mu\text{s)}$

Note that this detection sequence is an example of an ideal situation when the current flows through the motor continuously, meaning it does not assure the safety of the device at all times. Therefore, to avoid secondary damage of the device, we recommend using a fuse to the VM power line. The proper value of the fuse depends on the operation status, therefore please select the fuse that best fits the operation status.

Dead band time of over thermal detection (TSD)

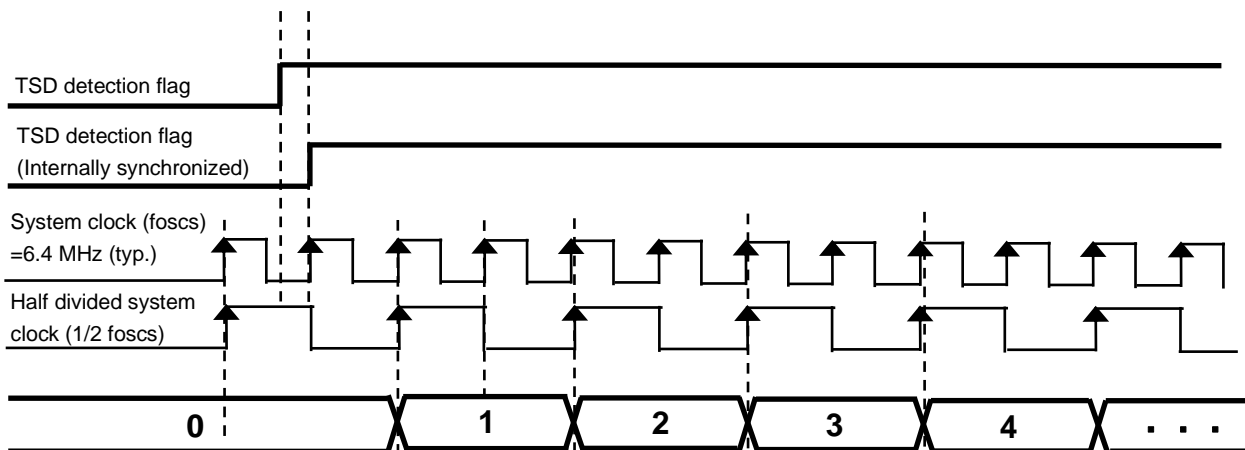


Figure 6.2 Dead band time of over thermal detection

Timing charts may be omitted for explanatory purpose.

The thermal shutdown circuit has a dead band time to avoid miss detection. This dead band time is set by the internal counter (using the system clock).

* $f_{oscs}=6.4\text{ MHz (typ.)}$ internal clock
 $1/f_{oscs}\times 32\text{ to }33\text{ clk worth (5.0 }\mu\text{s to }5.15\text{ }\mu\text{s)}$

7. Power consumption

The power consumption of this device is mainly consumed by the output stage MOSFET and the logic block.

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

- Power consumption of the output stage MOSFET.
The power consumption of the output stage is mainly consumed by MOSFET and SBD.

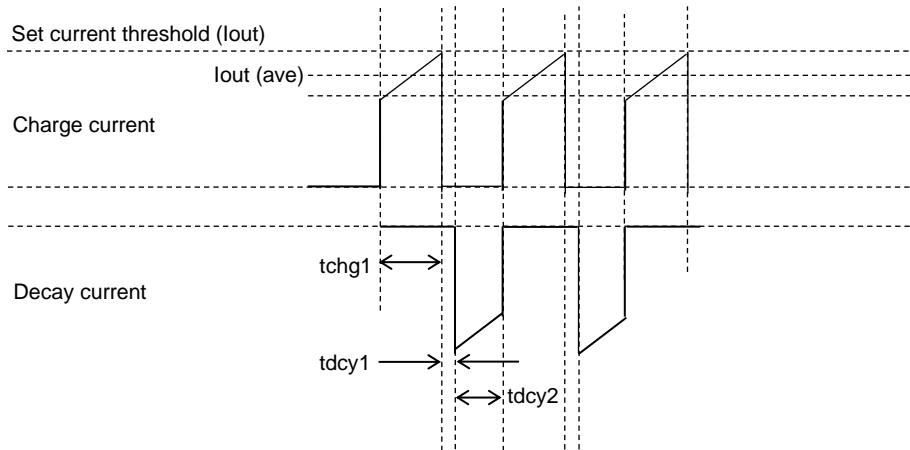


Figure 7.1 Constant current PWM waveform timing chart example 2

tchg1: Charge sequence (The current will flow from the power source to the motor.)

tdcy1: Mutual induction sequence (From Charge -> Decay)

tdcy2: Decay sequence (The current will flow back from the motor to the power source.)

Calculation variable:

- Motor current($I_{out(ave)}$) = Current setting(I_{out}) \times 0.85 (taking current ripple into consideration)
- Current flowing through the common diode (I_{ZD}) = 100% of load current = $I_{out(ave)}$
- Output voltage during decay sequence(V_{OUT}) = VF of regenerative diode
- Setting each sequence duty to tchg1:tdcy1:tdcy2=50 %:3 %:47 % for reference.

From the calculation shown above; Ex: $V_M=24$ V, $V_{ZD}=36$ V, $I_{out}=1.5$ A, Full step resolution,

$$P_{out} = P_{chg1} + P_{dcy1} + P_{dcy2}$$

$$P_{chg1} = I_{out(ave)} \times I_{out(ave)} \times R_{on} \times \text{H-bridge channel} \times \text{Duty},$$

$$= 1.5 \times 0.85 \times 1.5 \times 0.85 \times 0.25 \times 2 \times 0.5 = 0.406 \text{ [W]}$$

$$P_{dcy1} = V_F \times I_{ZD} \times \text{Number of channels} \times \text{Duty of regenerative diode},$$

$$= 1.1 \times 1.5 \times 0.85 \times 2 \times 0.03 = 0.084 \text{ [W]}$$

$$P_{dcy2} = V_F \times I_F \times \text{Number of channels} \times \text{Duty},$$

$$= 1 \times 1.5 \times 0.85 \times 2 \times 0.47 = 1.199 \text{ [W]}$$

$$\therefore P_{out} = 0.406 + 0.084 + 1.199 = 1.689 \text{ [W]} \rightarrow \text{The power consumption of the output stage.}$$

Note that the average running current will drop to around 71 % ($1/\sqrt{2}$, compared to full-step operation) of the set value when using the micro-stepping function.

- Power consumption of the logic block and low power analog block (IM2) = 3.0 mA (typ.)

The output system is connected to VM (24V). (Output system: sum of the current consumed by the circuit connected to VM and the current consumed by the output stage switching)

The power consumption can be calculated as below;

$$P_{\text{bias}} = 24 \text{ (V)} \times 0.003 \text{ (A)} = 0.072 \text{ (W)}$$

- Total power consumption of the device;
The total power consumption (Ptotal) of the device can be calculated by adding Pout and Pbias.

$$P_{\text{total}} = P_{\text{out}} + P_{\text{bias}} = 1.689 + 0.072 = 1.761 \text{ (W)}$$

Note that the actual power consumption can be different, depending on the current step, slew rate, constant current PWM current ripple, etc.

Therefore used the calculated value only as a reference, and evaluate the device enough so that the thermal designing can be set with enough margins.

8. Power dissipation

The power dissipation can be calculated by using the ambient temperature (T_a), junction temperature (T_j), and junction-to-case thermal resistance ($R_{th(j-a)}$).

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

(For example) When mounted to a 4 layer PCB (an assumed $R_{th(j-a)} = 25 \text{ }^\circ\text{C/W}$), $T_a = 25 \text{ }^\circ\text{C}$, $P_{total} = 1.761 \text{ W}$ ($I_{out} = 1.5 \text{ A}$, full step resolution)
 $T_j = 25 \text{ }^\circ\text{C} + 25 \text{ }^\circ\text{C/W} \times 1.761 \text{ (W)} = 69.03 \text{ }^\circ\text{C}$

(For reference) Relationship between power dissipation and ambient temperature

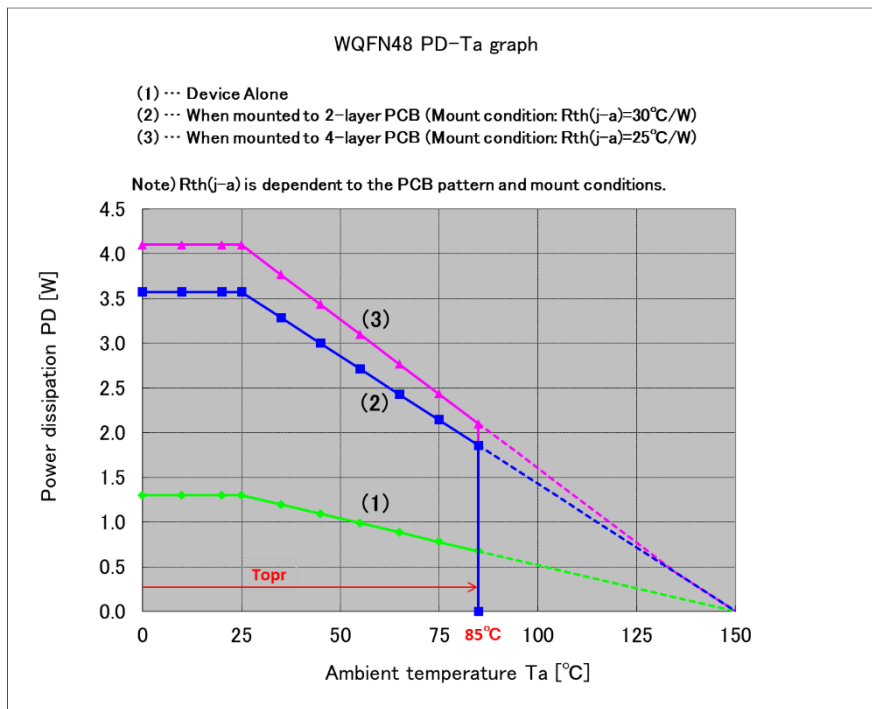


Figure 8.1 Power dissipation

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

For reference only: QFN48 $T(j-c) = 3.5 \text{ }^\circ\text{C/W}$

9. Application circuit example

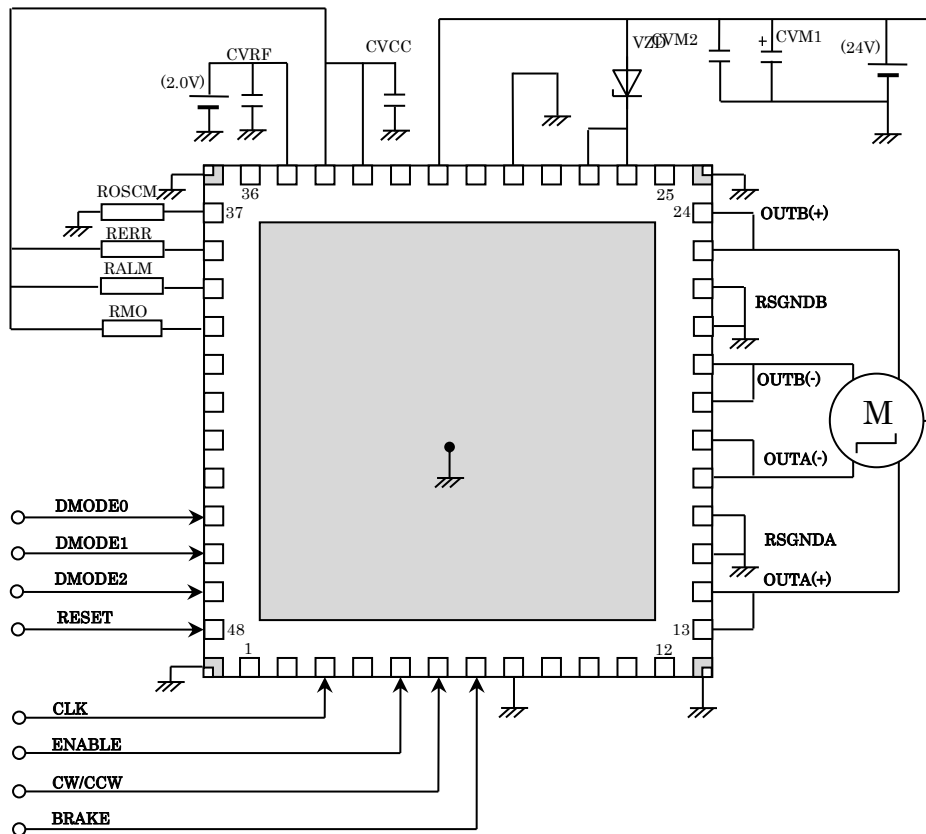


Figure 9.1 Application circuit example

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

(1) Capacitor for the VM power supply

To stabilize the voltage of the power supply, and also to reject any incoming noise, we recommend connecting the proper value capacitor to the VM power line (near the device). Especially the ceramic capacitor should be placed near the device as close as possible, to reject high frequency incoming noise.

Table 9.1 Recommended capacitor values for power supply

Item	Parts	Symbol	Typ.	Recommended range
VM-GND	Electrolytic capacitor	CVM1	100 μ F	47 to 100 μ F
	Ceramic capacitor	CVM2	0.1 μ F	0.01 to 1 μ F
VCC-GND	Ceramic capacitor	CVCC	0.1 μ F	0.01 to 1 μ F
VREF-GND	Ceramic capacitor	CVRF	0.1 μ F	0.01 to 1 μ F

Note) VREF-GND: The voltage for VREF can be set using a resistance divider from VCC. If you wish to use a voltage divider for VREF, please set the resistance (between VCC and GND) in a range of 10 k Ω to 30 k Ω .

Note) The values shown in the table is for reference only, therefore components outside the recommended range can also be used, depending on the motor load condition and the design pattern of the PCB.

(2) Zener diode

This device requires a Zener diode between the VM-VCOM pins for the constant current PWM control. The Zener diode should also be placed near the device.

Table 9.2 Recommended Zener diode values

Item	Parts	Symbol	VM Typ.	Recommended range
VM-VCOM	Zener diode	VZD	10 to 18 V	24 V
			19 to 27 V	36 V
			28 to 40 V	43 V

Note) The values shown in the table above are for reference only, therefore please decides the proper value with evaluation.

(3) Resistance for Logic output pins

This device has three open-drain type logic output pins (MO, ERR, ALM). When the internal CMOS is OFF, the pin voltage level becomes 'high impedance'. Therefore in order to use these functions properly, please pull-up the pin to 3.3 V or 5.0 V power line with a pull-up resistance.

Table 9.3 Recommended pull-up resistance values for logic output pins

Item	Parts	Symbol	Typ.	Recommended range
MO pull-up resistance	Chip or lead type resistance	RMO	10 k Ω	10 to 100 k Ω
ERR pull-up resistance		RERR		
ALM pull-up resistance		RALM		

(4) Wiring pattern for power supply and GND

Since large current may flow in VM, OUT, RSGND, 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.

(5) 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.

10. Board dimensions

10.1. Input

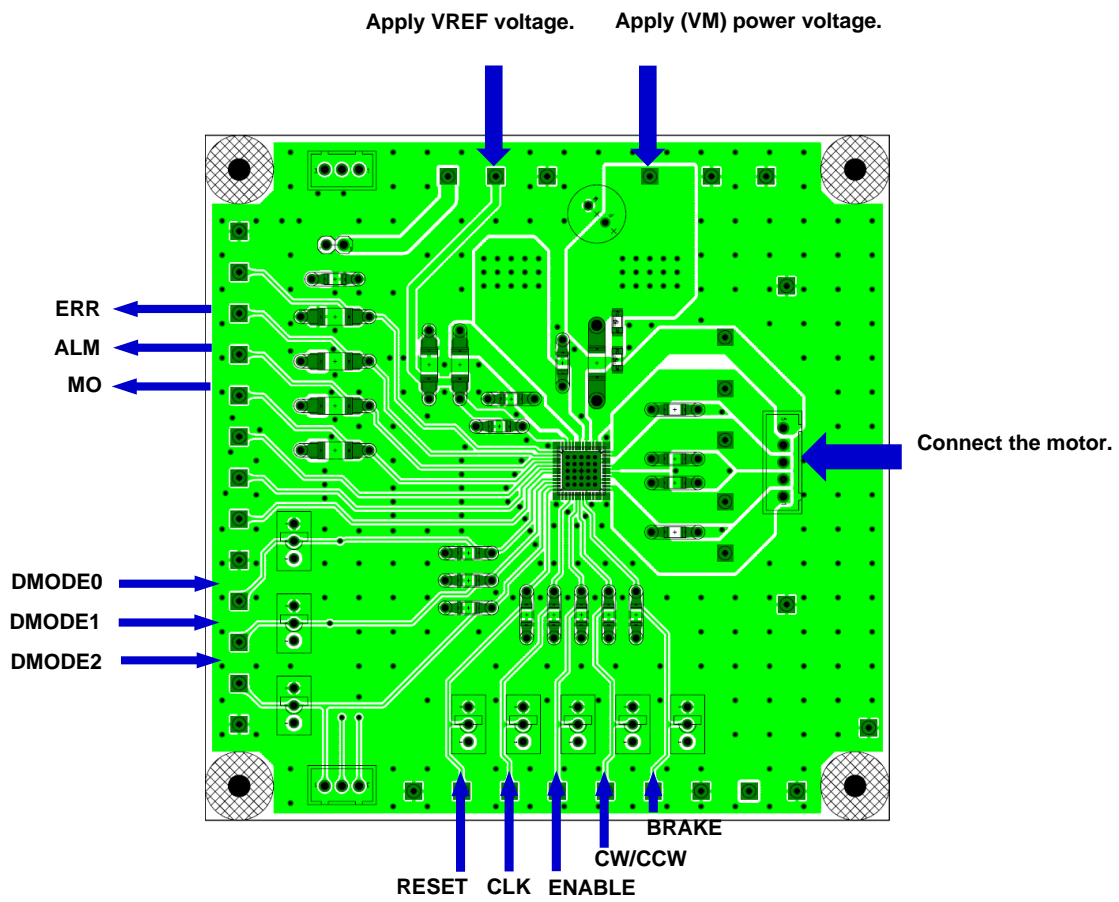


Figure 10.1 Input

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

10.2. Main parts

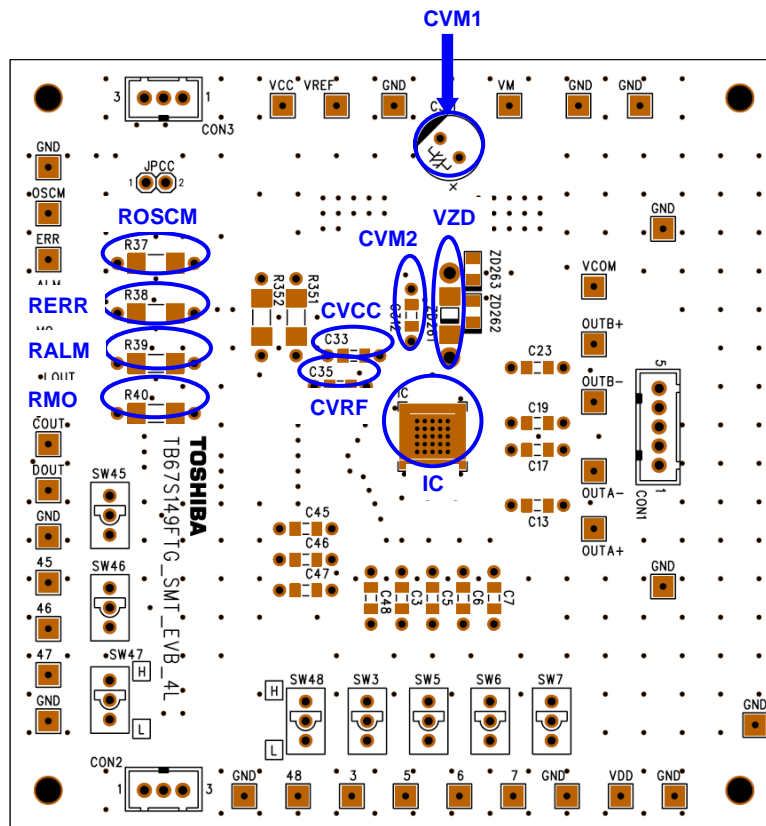


Figure 10.2 Main parts

Connect each external component referring to the example of the application circuit.

10.3. PCB options

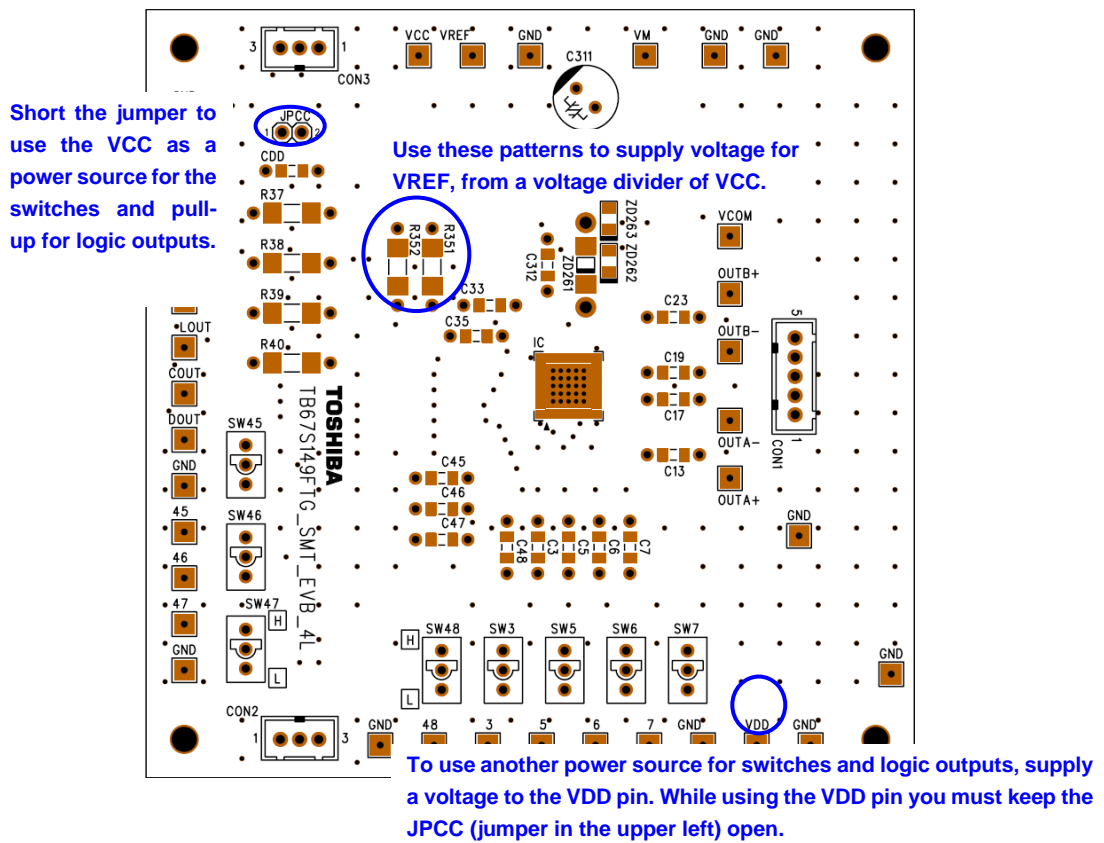


Figure 10.3 PCB options

11. Example of reference foot pattern

(1) WQFN48 foot pattern (unit: mm)

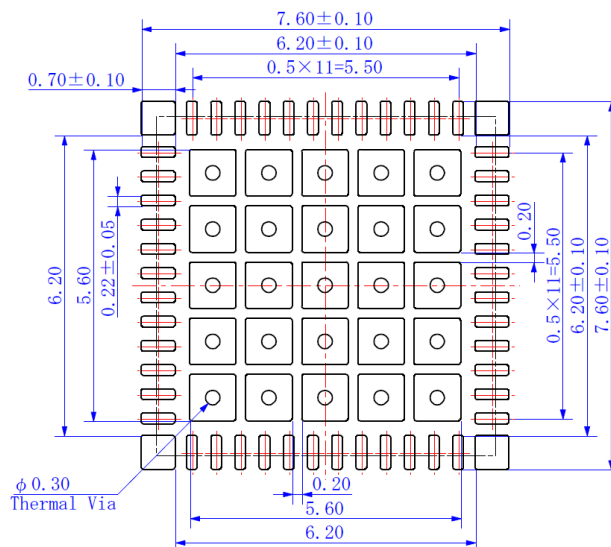


Figure 11.1 WQFN48 foot pattern

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

Note: 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.

Note 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 Circuit

The equivalent circuit may be partially omitted or simplified to explain the circuit.

3. Timing Charts

Timing charts may be simplified for explanatory purposes.

4. Application Circuit Example

The application circuits shown in this document are provided for reference purposes only. Thorough evaluation is required, especially at the mass production design stage.

Providing these application circuit examples does not grant a license for industrial property rights.

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, over-current 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

Over-current detection circuit

Over-current detection 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.

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.

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.

Back-EMF

When a motor reverses the rotation 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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