TB67S141

Usage considerations

Summary

The TB67S141 is a two-phase unipolar stepping motor driver with phase-in PWM chopping control. Fabricated with the BiCD process, this device is rated at 84V/3.0A

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1. Power supply voltage

1.1. Power supply voltage and usage range

In using the TB67S141, 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 40V.
The maximum rating of VREF voltage is 6V. Usage range of the voltage is 0 to 4.0V 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 10kΩ to 30kΩ.

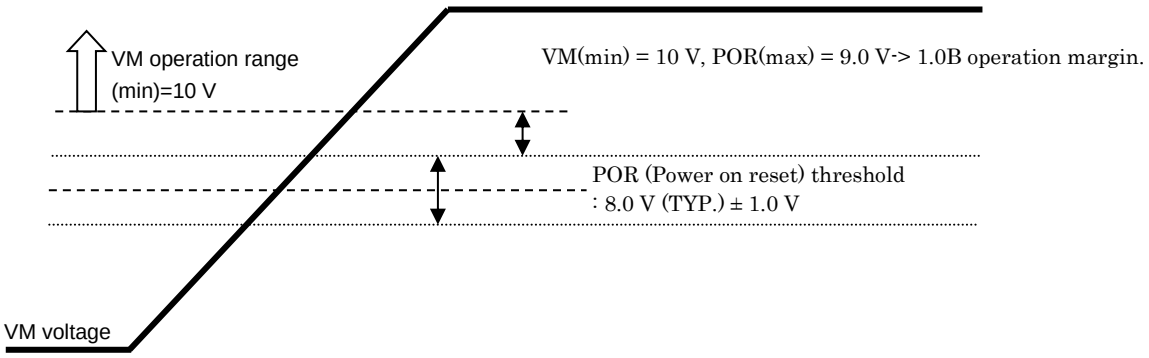

Figure 1.1 Power supply voltage and operation range

1.2. Power supply sequence

There are no special requirements for power-on and power-off sequence because the TB67S141 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 3A (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 TB67S141 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)
3.9kΩ	4.1μs
4.7kΩ	4.9μs
5.6kΩ	5.8μs
6.8kΩ	7.0μs
8.2kΩ	8.3μs
10kΩ	10μs
15kΩ	15μs
18kΩ	18μs
22kΩ	21μs
27kΩ	26μs
39kΩ	37μs

*Please connect 10kΩ during constant voltage operation also.

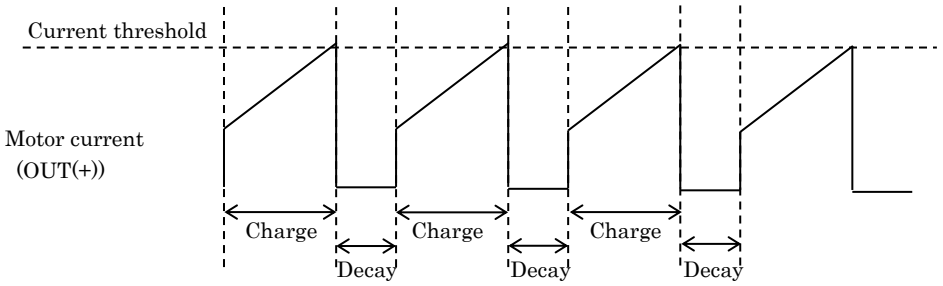

Figure 4.1 Constant current PWM timing chart 1

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

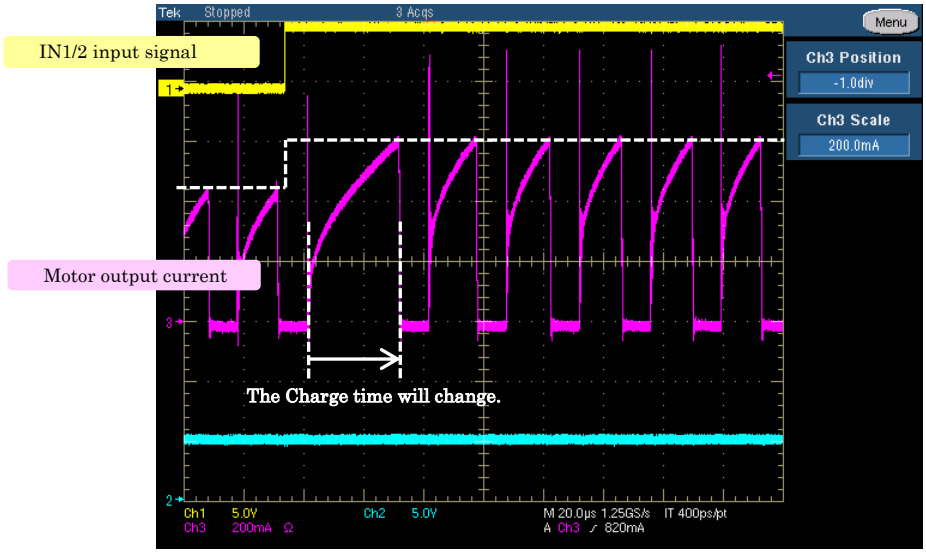

Figure 4.2 Constant current PWM waveform

(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

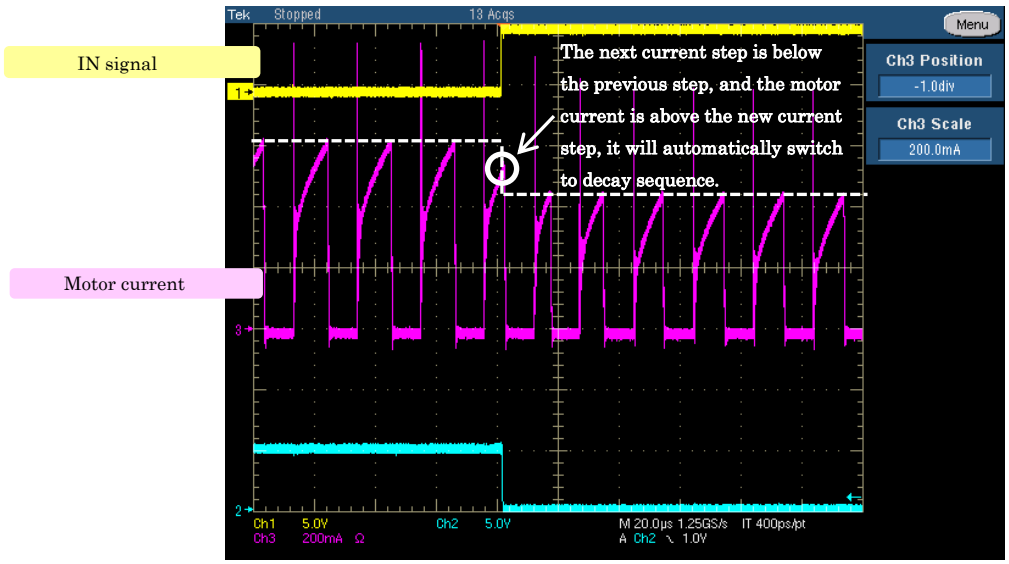

Figure 4.3 Constant current PWM waveform(next step is lower than previous)

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) IN1/IN2/PHASE function

The current is defined as 'plus' when the current flows from VM to OUT+ during charge status(OUT+ side MOSFET is turned on), and is defined as 'minus' when the current flows from VM to OUT- during charge status (OUT- side MOSFET is turned on).

Table 5.1 Current ratio table of full step resolution

Ach						Bch					
Logic signal			MOSFET		Current	Logic signal			MOSFET		Current
PHASEA	INA1	INA2	OUTA+	OUTA-	IOUT(A)	PHASEB	INB1	INB2	OUTB+	OUTB-	IOUT(B)
H	H	H	ON	OFF	+100%	H	H	H	ON	OFF	+100%
L	H	H	OFF	ON	-100%	H	H	H	ON	OFF	+100%
L	H	H	OFF	ON	-100%	L	H	H	OFF	ON	-100%
H	H	H	ON	OFF	+100%	L	H	H	OFF	ON	-100%

Note: About MOSFETs: motor output pin level will show 'Low' when 'ON', and pin level will show 'Hi-Z' when OFF.

Table 5.2 Current ratio table of half(a) step resolution

Ach						Bch					
Logic signal			MOSFET		Current	Logic signal			MOSFET		Current
PHASEA	INA1	INA2	OUTA+	OUTA-	IOUT(A)	PHASEB	INB1	INB2	OUTB+	OUTB-	IOUT(B)
H	H	H	ON	OFF	+100%	H	H	H	ON	OFF	+100%
L or H	L	L	OFF	OFF	0%	H	H	H	ON	OFF	+100%
L	H	H	OFF	ON	-100%	H	H	H	ON	OFF	+100%
L	H	H	OFF	ON	-100%	L or H	L	L	OFF	OFF	0%
L	H	H	OFF	ON	-100%	L	H	H	OFF	ON	-100%
L or H	L	L	OFF	OFF	0%	L	H	H	OFF	ON	-100%
H	H	H	ON	OFF	+100%	L	H	H	OFF	ON	-100%
H	H	H	ON	OFF	+100%	L or H	L	L	OFF	OFF	0%

Note: About MOSFETs: motor output pin level will show 'Low' when 'ON', and pin level will show 'Hi-Z' when OFF.

Table 5.3 Current ratio table of half(b) step resolution

Ach						Bch					
Logic signal			MOSFET		Current	Logic signal			MOSFET		Current
PHASEA	INA1	INA2	OUTA+	OUTA-	IOUT(A)	PHASEB	INB1	INB2	OUTB+	OUTB-	IOUT(B)
H	H	L	ON	OFF	+71%	H	H	L	ON	OFF	+71%
L or H	L	L	OFF	OFF	0%	H	H	H	ON	OFF	+100%
L	H	L	OFF	ON	-71%	H	H	L	ON	OFF	+71%
L	H	H	OFF	ON	-100%	L or H	L	L	OFF	OFF	0%
L	H	L	OFF	ON	-71%	L	H	L	OFF	ON	-71%
L or H	L	L	OFF	OFF	0%	L	H	H	OFF	ON	-100%
H	H	L	ON	OFF	+71%	L	H	L	OFF	ON	-71%
H	H	H	ON	OFF	+100%	L or H	L	L	OFF	OFF	0%

Note: About MOSFETs: motor output pin level will show 'Low' when 'ON', and pin level will show 'Hi-Z' when OFF.

Table 5.4 Current ratio table of quarter step resolution

Ach						Bch					
Logic signal			MOSFET		Current	Logic signal			MOSFET		Current
PHASEA	INA1	INA2	OUTA+	OUTA-	IOUT(A)	PHASEB	INB1	INB2	OUTB+	OUTB-	IOUT(B)
H	H	L	ON	OFF	+71%	H	H	L	ON	OFF	+71%
H	L	H	ON	OFF	+38%	H	H	H	ON	OFF	+100%
L or H	L	L	OFF	OFF	0%	H	H	H	ON	OFF	+100%
L	L	H	OFF	ON	-38%	H	H	H	ON	OFF	+100%
L	H	L	OFF	ON	-71%	H	H	L	ON	OFF	+71%
L	H	H	OFF	ON	-100%	H	L	H	ON	OFF	+38%
L	H	H	OFF	ON	-100%	L or H	L	L	OFF	OFF	0%
L	H	H	OFF	ON	-100%	L	L	H	OFF	ON	-38%
L	H	L	OFF	ON	-71%	L	H	L	OFF	ON	-71%
L	L	H	OFF	ON	-38%	L	H	H	OFF	ON	-100%
L or H	L	L	OFF	OFF	0%	L	H	H	OFF	ON	-100%
H	L	H	ON	OFF	+38%	L	H	H	OFF	ON	-100%
H	H	L	ON	OFF	+71%	L	H	L	OFF	ON	-71%
H	H	H	ON	OFF	+100%	L	L	H	OFF	ON	-38%
H	H	H	ON	OFF	+100%	L or H	L	L	OFF	OFF	0%
H	H	H	ON	OFF	+100%	H	L	H	ON	OFF	+38%

Note: About MOSFETs: motor output pin level will show 'Low' when 'ON', and pin level will show 'Hi-Z' when OFF.

(2) STBY function

Setting the STBY pin will enable the device to be set to Standby mode (=Low power mode) which will cut all unneccesary internal bais current to reduce power consumption. The ISD(Over current detection) /TSD(Thermal shutdown) status can also be reseted by STBY.

Table 5.5 STBY function table

STBY	Function
H	Standby mode: OFF(normal operation)
L	Standby mode: ON(Low power mode)

The ISD(over current)/TSD(Thermal shutdown) status will be reseted when STBY is set to Low.

Note) After STBY is set to High, the internal circuit will restart from low power mode. Therefore it is preferable not to input any logic signal for 10μs, after the STBY is set to High. (If the logic signal is input to the device during wake-up period, the device may not be able to receive the signal correctly.)

6. Dead band time of error detection circuits

Dead band time of Over current detection(ISD)

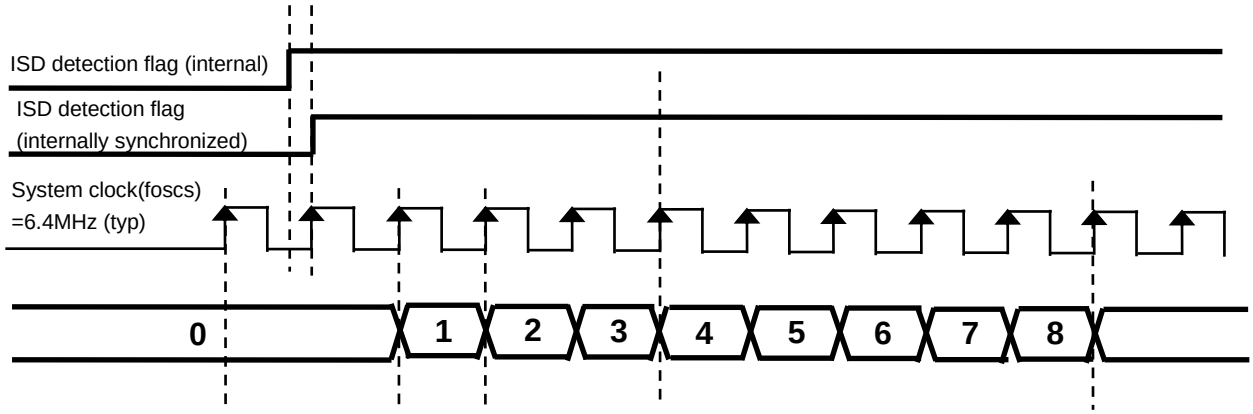

Figure 6.1 Dead band time of over current detection

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 (foscs=6.4MHz (typ)).

*foscs=6.4MHz(typ) internal clock
1/foscs × 8 to 9clk worth(1.25 μs to 1.4 μs)

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.

Dead band time of Over thermal detection(TSD)

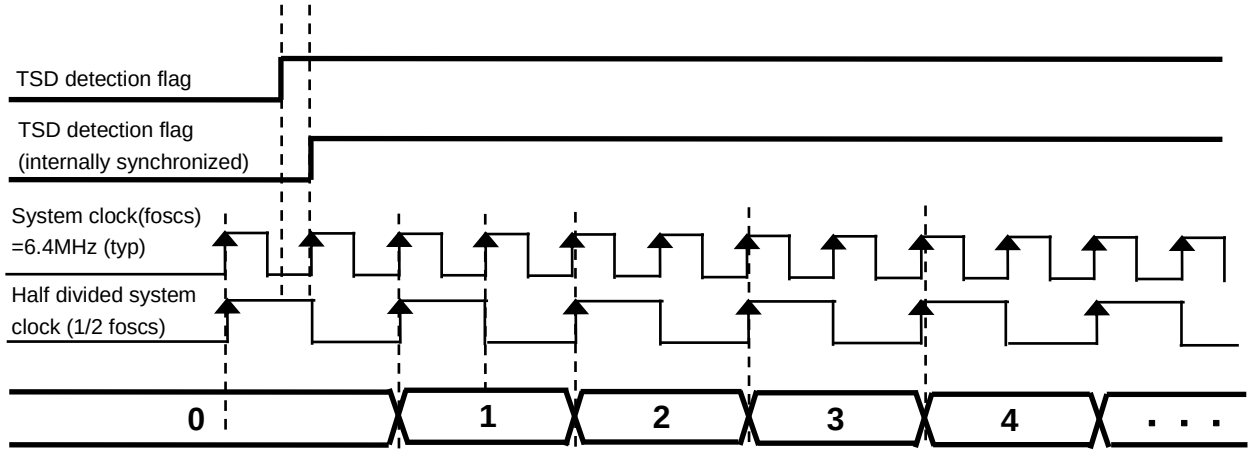

Figure 6.2 Dead band time of over thermal detection

Timing charts may be omitted for explanatory purpose.

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

*foscs=6.4MHz(typ) internal clock
1/foscs × 32 to 33clk worth(5.0 μs to 5.15 μs)

7. Power consumption

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

P(total) = P(out) + P(bias)

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

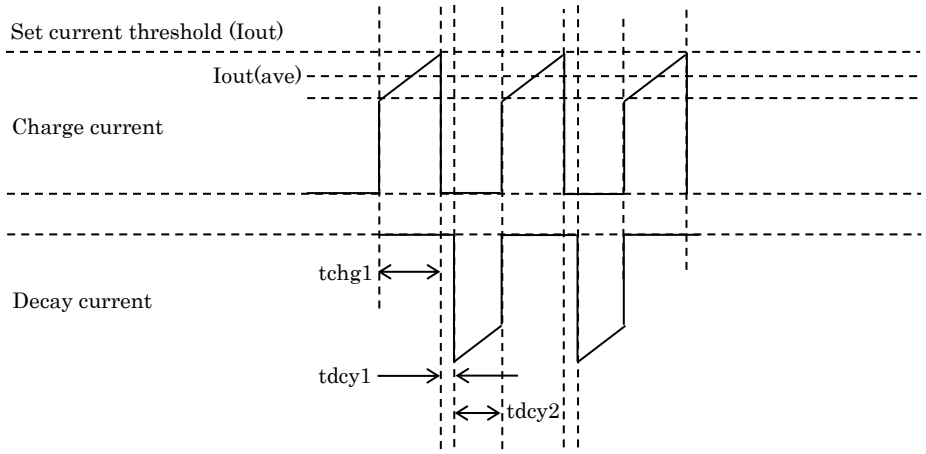

Figure 7.1 Constant current PWM waveform timing chart example 2

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(Iout(ave))＝Current setting(Iout)×0.85 (taking current ripple into consideration)
・Flow through current of the internal common diode(IZD)＝10% of Iout(ave)=Iout(ave)×0.1
・Output voltage during decay sequence(VOUT)=VM(Motor power supply)＋VZD(Zener voltage)
・Setting each sequence duty to tchg1:tdcy1:tdcy2=50%:3%:47% for reference.

From the calculation shown above; Ex: VM=24V, VZD=36V, Iout=1.5A, Full step resolution,

Pout=Pchg1+Pdcy1+Pdcy2
Pchg1=Iout(ave)×Iout(ave)×Ron×H-bridge channel×Duty,
=1.5×0.85×1.5×0.85×0.25×2×0.5=0.406 [W]
Pdcy1=Vout×(IZD)×H-bridge channel×Duty
=(VM+VZD)×(Iout(ave)×10%)×2×0.03
=60×1.5×0.85×0.1×2×0.03=0.459 [W]
Pdcy2=VF×IF×H-bridge channel×Duty,
=1.4×1.5×0.85×2×0.47=1.678 [W]
∴Pout=0.406+0.459+1.678=2.543 [W] →The power consumption of the output stage.

Note that the average running current will drop to around 71%(1/√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 power consumption can be calculated as below;

Pbias = 24 (V) × 0.003 (A)= 0.072 (W)

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

Ptotal = Pout + Pbias = 2.543 + 0.072 = 2.615 (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 (Ta), junction temperature (Tj), and junction-to-case thermal resistance (Rth(j-a)).

$$Tj = Ta + P \times Rth(j\text{-}a)$$

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

(For reference) Relationship between power dissipation and ambient temperature

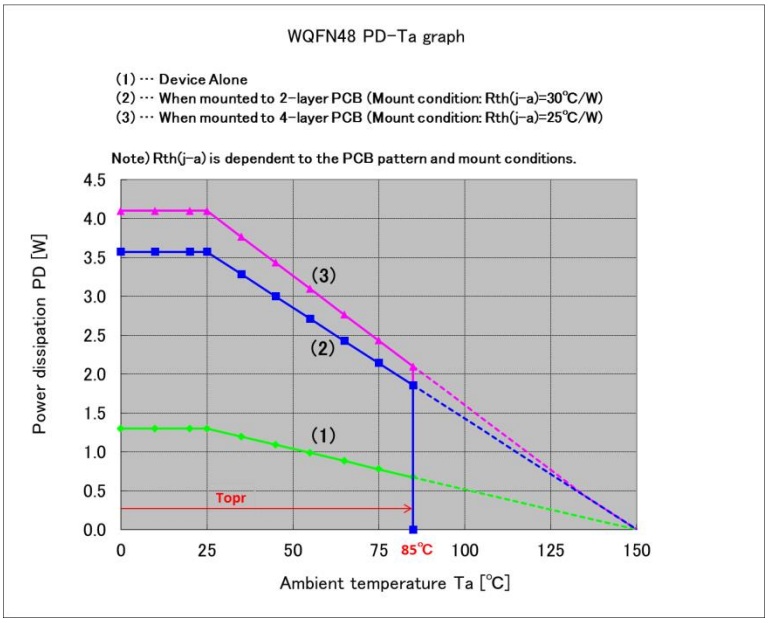

Figure 8.1 Power dissipation (WQFN48)

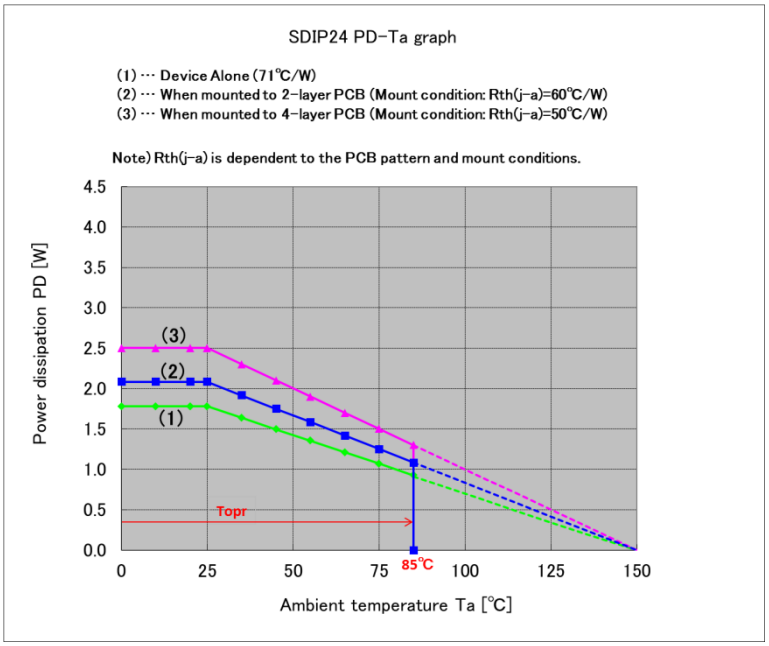

Figure 8.2 Power dissipation (SDIP24)

For reference only: WQFN48 T(j-c)=3.5°C/W

9. Application circuit example (WQFN48_Current feedback mode:ON)

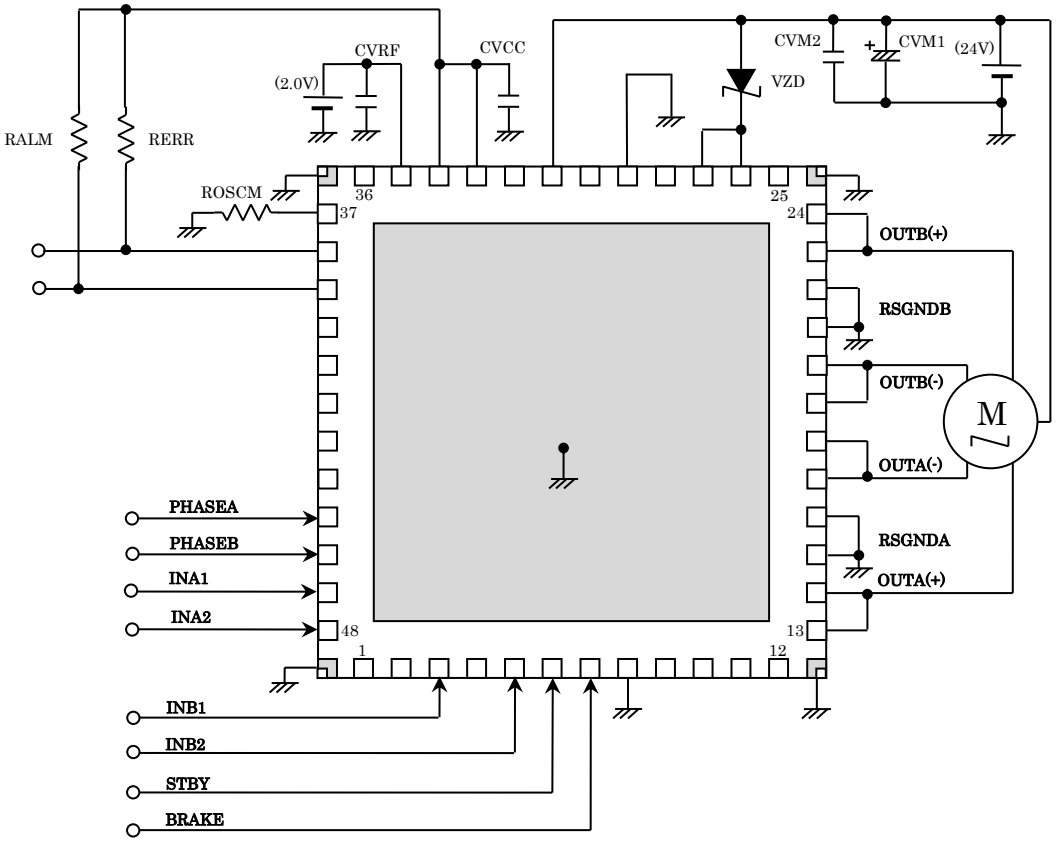

Figure 9.1 Application circuit example (Current feedback mode: ON)

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

9 Application circuit example (WQFN48_Current feedback mode:OFF)

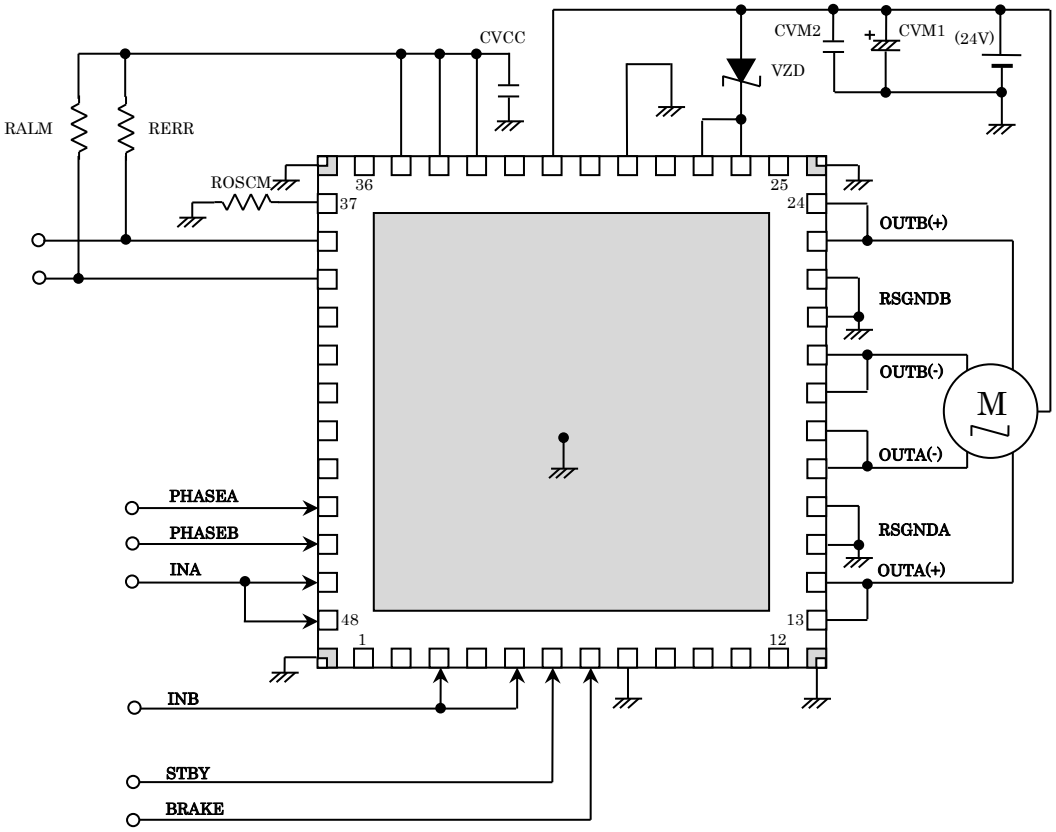

Figure 9.2 Application circuit example (WQFN48_Current feedback mode: OFF)

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

9 Application circuit example (SDIP24_Current feedback mode: ON)

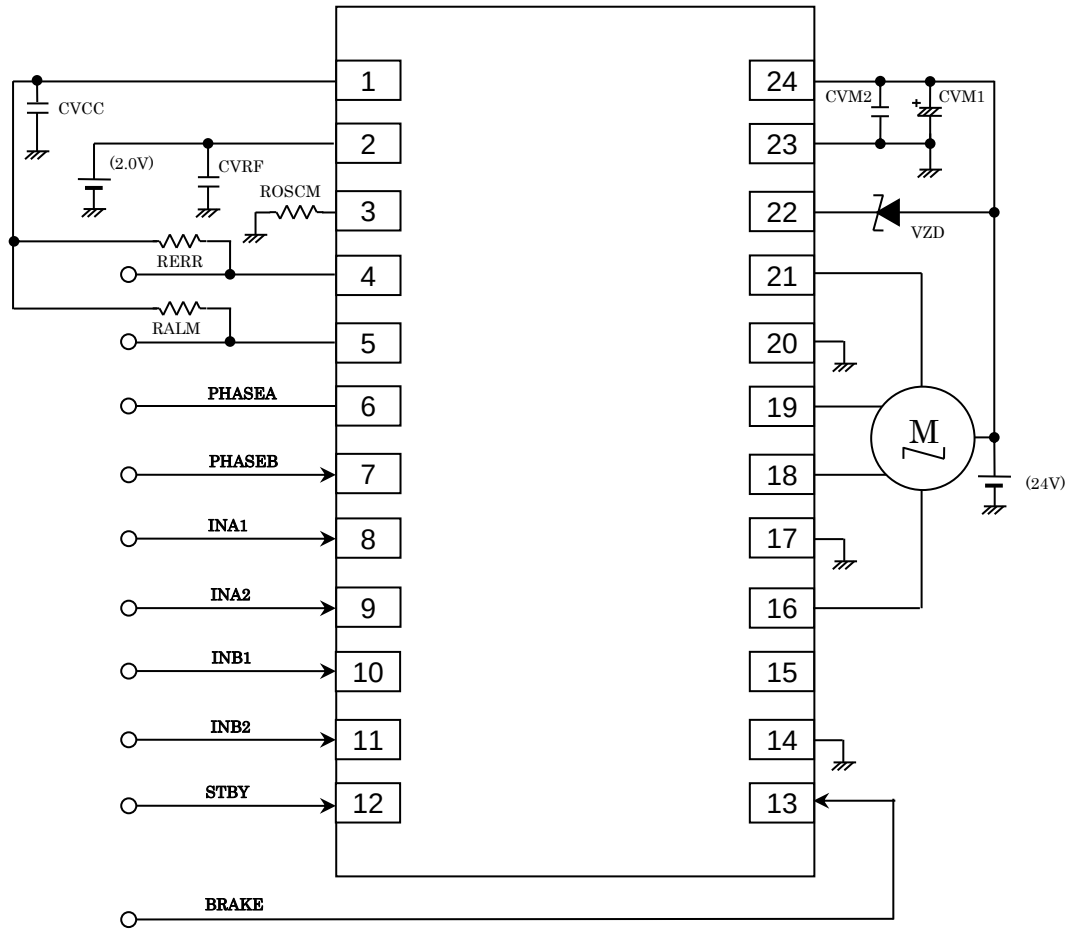

Figure 9.3 Application circuit example (SDIP24_Current feedback mode: ON)

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

9 Application circuit example (SDIP24_Current feedback mode: OFF)

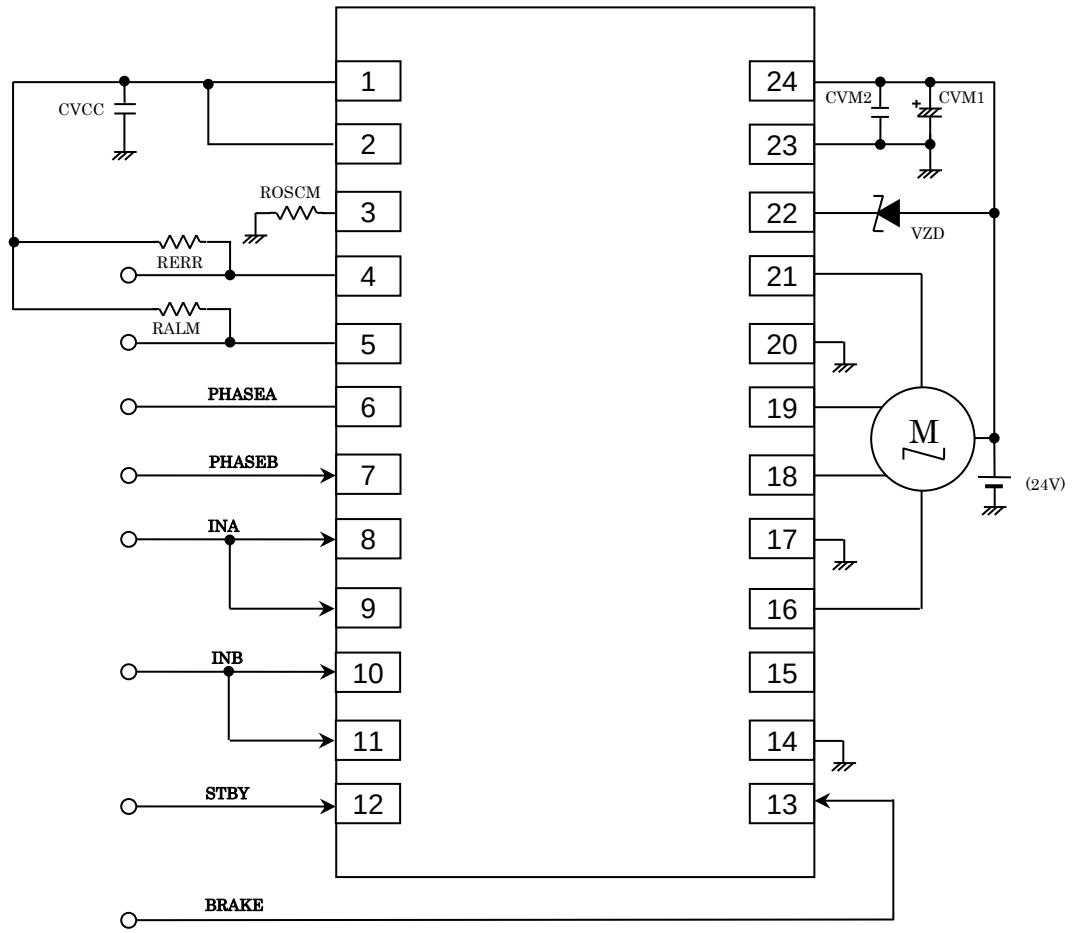

Figure 9.4 Application circuit example (SDIP24_Current feedback mode: OFF)

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 μF	47 to 100 μF
	Ceramic capacitor	CVM2	0.1 μF	0.01 to 1 μF
VCC-GND	Ceramic capacitor	CVCC	0.1 μF	0.01 to 1 μF
VREF-GND	Ceramic capacitor	CVRF	0.1 μF	0.01 to 1 μF

Note) VREF-GND: Connect the capacitor in necessary depending on the usage environment. To set the VREF voltage using a voltage divider from VCC, please set it so that the resistance between VCC and GND is in the range of 10kΩ to 30kΩ.
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. With the zener diode, the peak voltage level of the output can be clamped, also will enable the control of the current. 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 18V	24V
			19 to 27V	36V
			28 to 40V	43V

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

(3) Resistance for Logic output pins

This device has three open-drain type logic output pins (MO, ERR, and 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 3.3V or 5.0V 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
ERR pull-up resistance	Chip or lead type resistance	RERR	10 kΩ	10 to 100 kΩ
ALM pull-up resistance	Chip or lead type resistance	RALM	10 kΩ	10 to 100 kΩ

(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 diagram

10.1. Input (WQFN48)

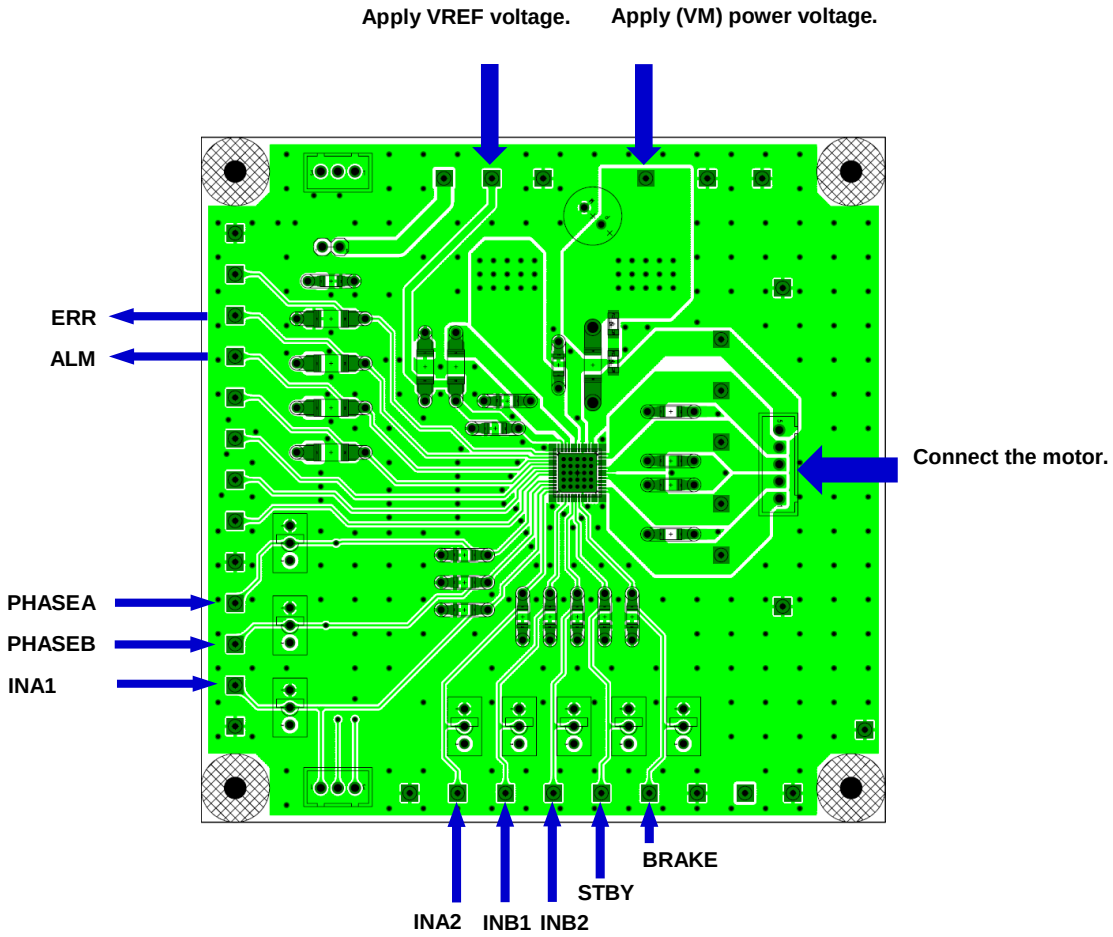

Figure 10.1 Input (WQFN48)

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

10.2. Main parts (WQFN48)

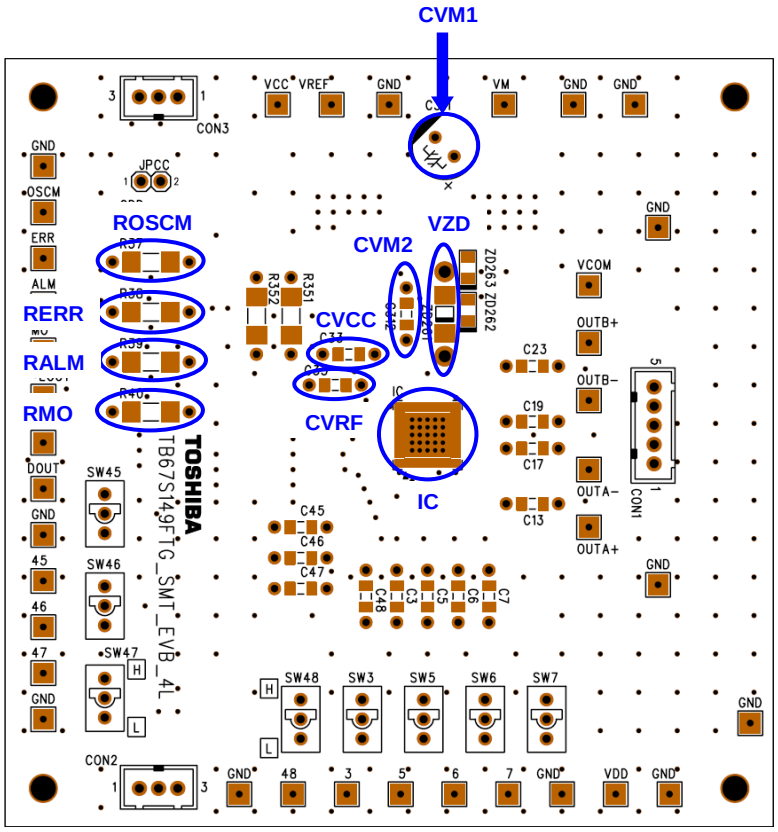

Figure 10.2 Main parts(WQFN48)

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

10.3. PCB options (WQFN48)

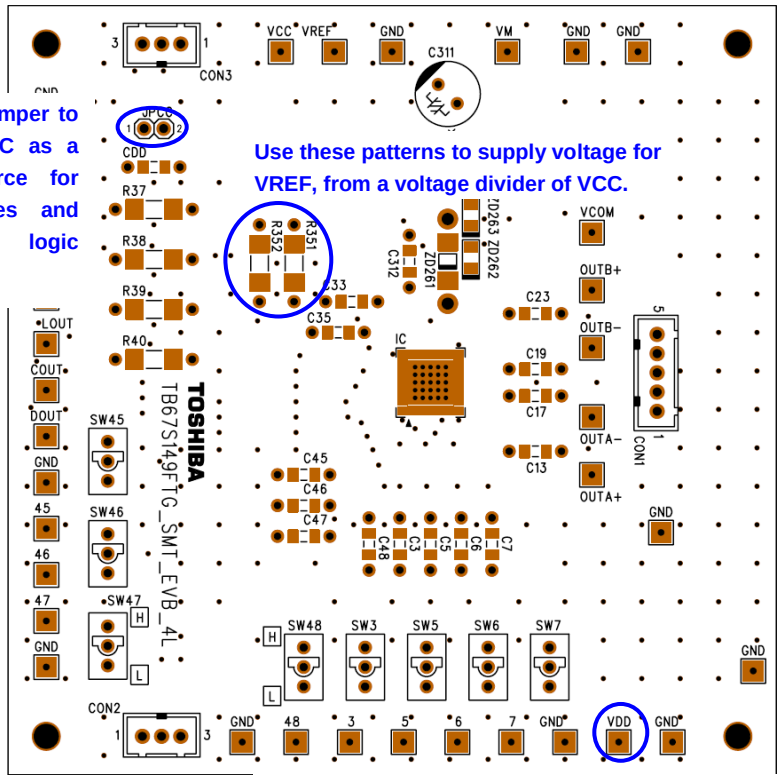

Figure 10.3 PCB options(WQFN48)

10.4. Input (SDIP24)

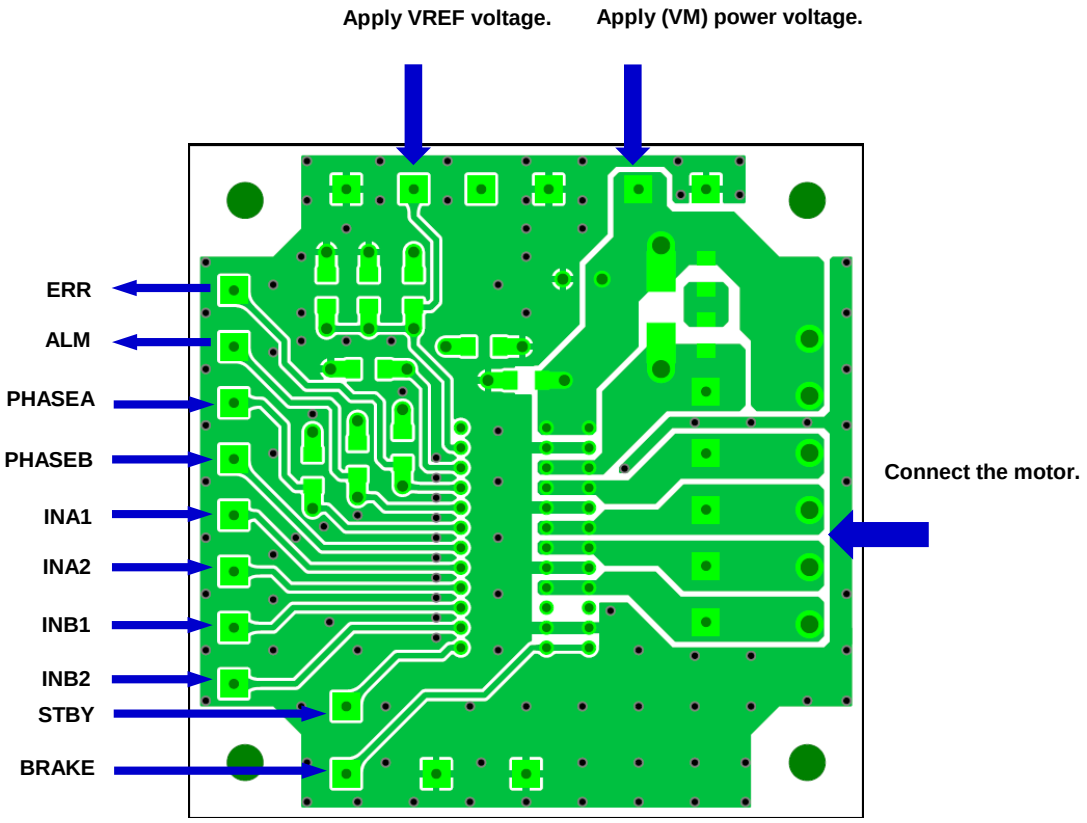

Figure 10.4 Input (SDIP24)

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

10.5. Main parts (SDIP24)

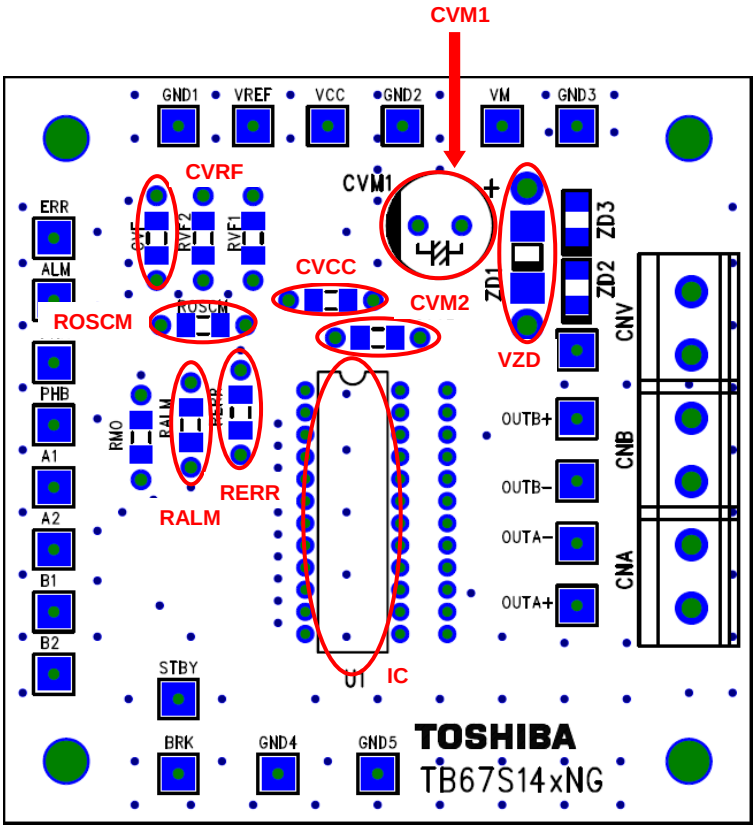

Figure 10.5 Main parts (SDIP24)

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

10.6. PCB options (SDIP24)

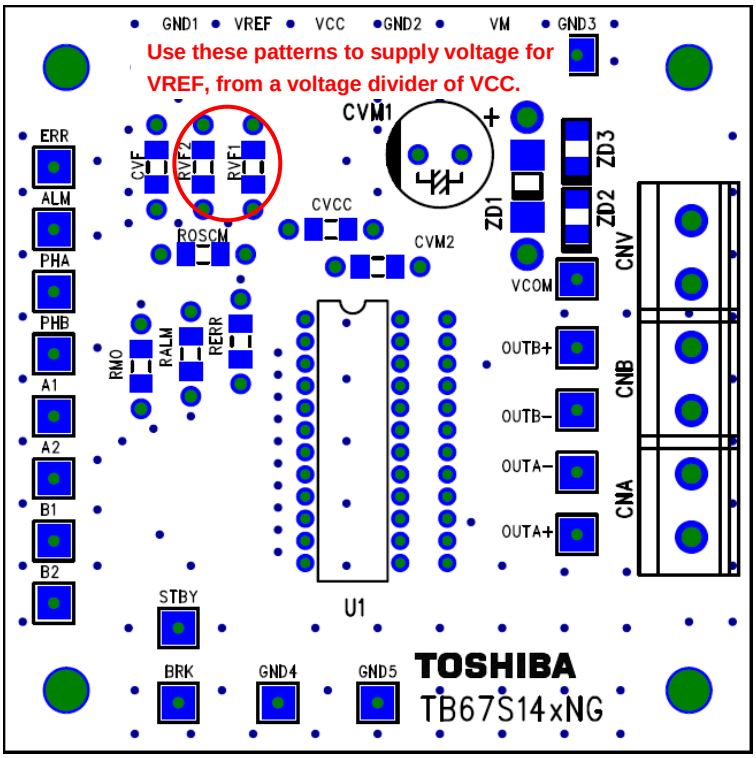

Figure 10.6 PCB options (SDIP24)

11. Example of reference foot pattern

(1) WQFN48 foot pattern (unit: mm)

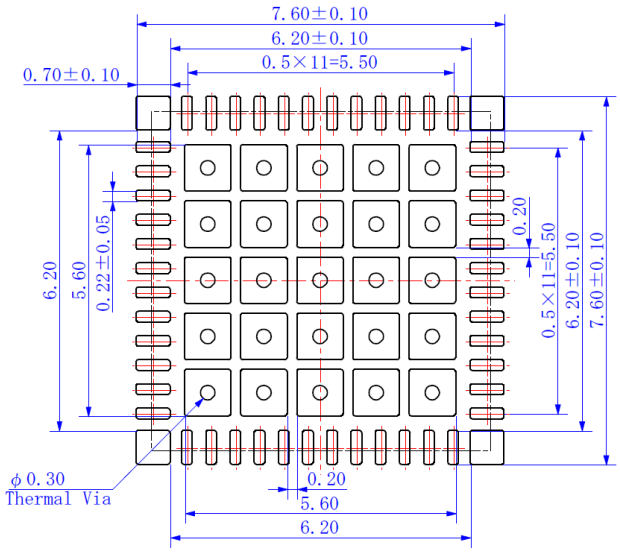

Figure 11.1 WQFN48 foot pattern

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.

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 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 the device breakdown, damage or deterioration, and may result injury by explosion or combustion.

[2] 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.

[3] If your design includes an inductive load such as a motor coil, incorporate a protection circuit into the design to prevent device malfunction or breakdown caused by the current resulting from the inrush current at power ON or the negative current resulting from the back electromotive force at power OFF. IC breakdown may cause injury, smoke or ignition.
Use a stable power supply with ICs with built-in protection functions. If the power supply is unstable, the protection function may not operate, causing IC breakdown. IC breakdown may cause injury, smoke or ignition.

[4] Do not insert devices in the wrong orientation or incorrectly.
Make sure that the positive and negative terminals of power supplies are connected properly.
Otherwise, the current or power consumption may exceed the absolute maximum rating, and exceeding the rating(s) may cause the device breakdown, damage or deterioration, and may result injury by explosion or combustion.
In addition, do not use any device that is applied the current with inserting in the wrong orientation or incorrectly even just one time.

[5] Carefully select external components (such as inputs and negative feedback capacitors) and load components (such as speakers), for example, power amp and regulator.
If there is a large amount of leakage current such as input or negative feedback condenser, the IC output DC voltage will increase. If this output voltage is connected to a speaker with low input withstand voltage, overcurrent or IC failure can cause smoke or ignition. (The over current can cause smoke or ignition from the IC itself.) In particular, please pay attention when using a Bridge Tied Load (BTL) connection type IC that inputs output DC voltage to a speaker directly.

Points to remember on handling of ICs

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

(2) Thermal Shutdown Circuit
Thermal shutdown circuits do not necessarily protect ICs under all circumstances. If the thermal shutdown circuits operate against the over temperature, clear the heat generation status immediately.
Depending on the method of use and usage conditions, such as exceeding absolute maximum ratings can cause the thermal shutdown circuit to not operate properly or IC breakdown before operation.

(3) Heat Radiation Design
In using an IC with large current flow such as power amp, regulator or driver, please design the device so that heat is appropriately radiated, not to exceed the specified junction temperature (T_j) at any time and condition. These ICs generate heat even during normal use. An inadequate IC heat radiation design can lead to decrease in IC life, deterioration of IC characteristics or IC breakdown. In addition, please design the device taking into 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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