TB67S111PG
Usage considerations

Summary

The TB67S111PG is a solenoid driver /unipolar motor driver for full parallel input.
Using the BiCD process, the power supply voltage of 45 V, the output voltage of 80 V, and the output current of 1.5 A/ch (absolute maximum rating) are realized.

Main specifications

Product name		TB67S111PG
Function		Multi-channel solenoid / unipolar driver
Package		DIP16-P-300-2.54A
Input	Control I/F	Full parallel input (TTL)
	VM power supply voltage	45 V (max)
Output	Output rating (voltage)	80 V (max)
	Output rating (current)	1.5 A per channel (max)
	Output ON resistance	0.25 Ω (typ.)
	Common diode	Built in
Other features		Built-in error detection circuits (thermal shutdown circuit and over current shutdown circuit) Built-in automatically returned function after error detection Built-in output function of thermal shutdown flag Sequence-free of power supply by single power drive

Note:The contents of this application note are provided for reference purposes only to evaluate products. Therefore, Toshiba does not guarantee about the indicated contents. Please confirm a data sheet about detailed data.

Contents

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1. Power supply voltage

1.1. Power supply voltage and usage range

In using the TB67S111, the voltage should be applied to the VM pin.
The maximum rating of VM supply voltage is 80 V. Operating range of the power supply voltage is 10 to 60 V.

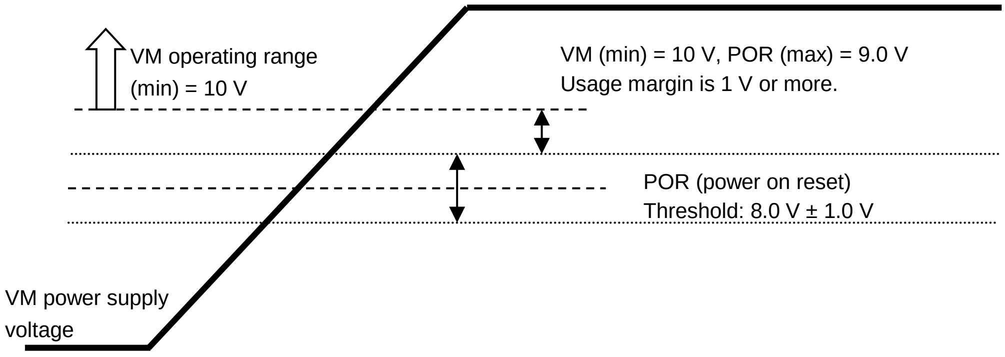


Figure 1.1 Power supply voltage and usage range

1.2. Power supply sequence

There are no special procedures of inputting a power supply and shutdown because the TB67S111 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 1.5 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 input signal low level before the power supply is applied by referring to the description of "1.2 Power supply sequence."

4. Function descriptions

4.1. Relation of logic inputs and output MOSFET

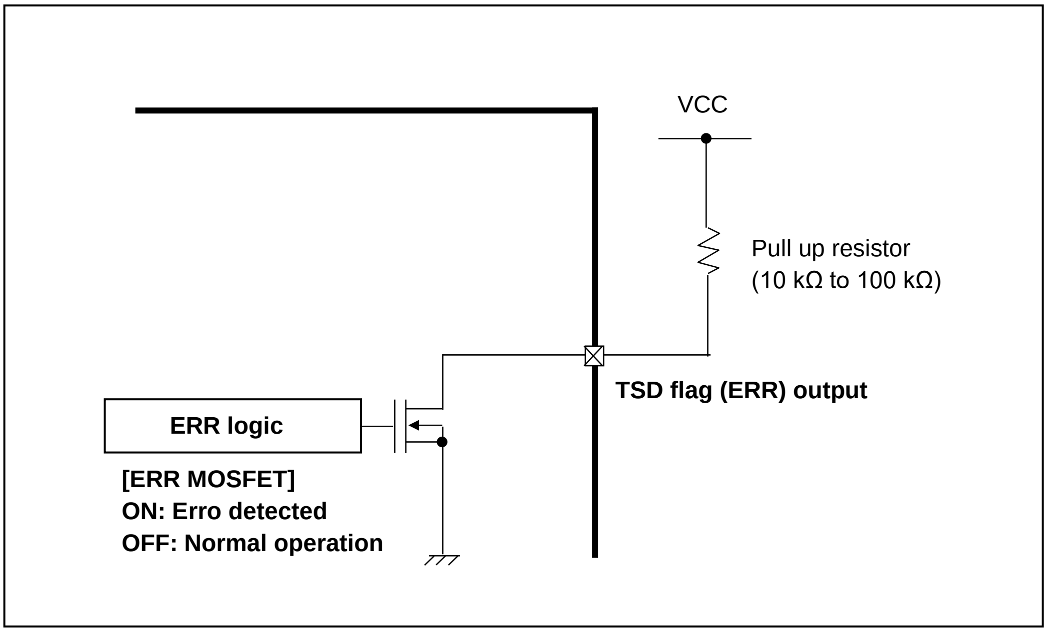
Logic input				Output MOSFET			
IN1	IN2	IN3	IN4	OUT1	OUT2	OUT3	OUT4
L	L	L	L	Off	Off	Off	Off
H	L	L	L	On	Off	Off	Off
L	**H**	L	L	Off	On	Off	Off
L	L	**H**	L	Off	Off	On	Off
L	L	L	**H**	Off	Off	Off	On
H	**H**	**H**	**H**	On	On	On	On

Each output MOSFET can be controlled between ON and OFF individually.

4.2. ERR (output function of thermal shutdown flag) function

ERR output	Function
H	Normal operation
L	Error detected (TSD)

Note: ERR pin is open drain type for Nch MOS output. In using this function, please pull up the ERR pin to VCC. In the normal operation, this pin outputs high (High impedance: internal MOS = OFF). When the TSD operates, this pin outputs low (internal MOS = ON). When the TSD is released, it outputs high again (internal MOS = OFF).
When ERR pin is not used, please leave this pin open.



5. Dead band time of error detection circuits

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

5.1. Dead band time of over current detection circuit

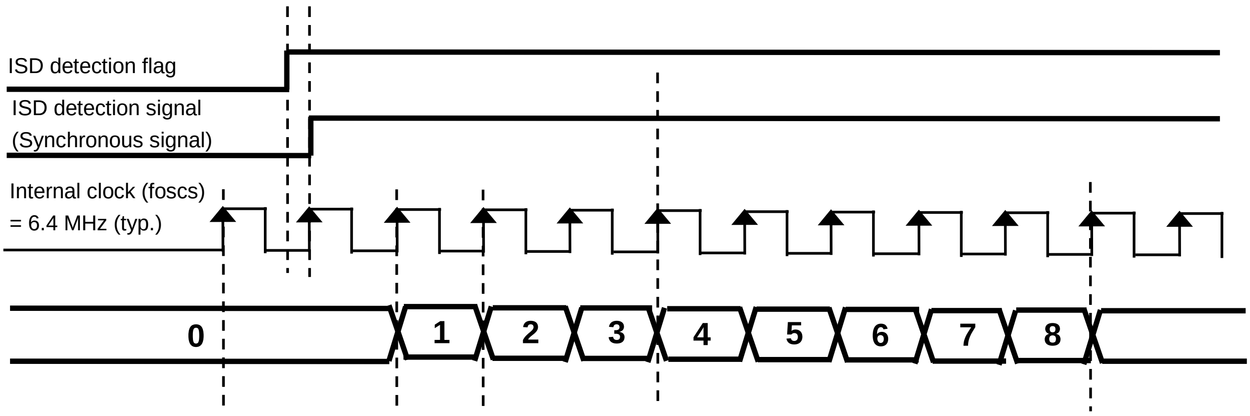


Figure 5.1 Dead band time of over current detection circuit

The over current detection circuit has a dead band time to avoid miss detection due to the spike current, which is occurred in switching. This dead band time is configured by the internal counter controlled by the fixed frequency of the IC (foscs=6.4 MHz (typ.)). Internal automatic returning function returns the IC operation 320 μs (typ.) after the over current is detected.

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

Note that this detection sequence is an example when the overcurrent flows expectedly through the motor, meaning the over current detection may not operate depending on the timing of the output control mode. Therefore, to avoid secondary damage of the device, it is recommended to use a protection fuse for the VM power line. The proper value of the fuse depends on the usage conditions. Therefore, please select the appropriate fuse whose capacity does not exceed the IC power dissipation.

5.2. Dead band time of thermal shutdown detection

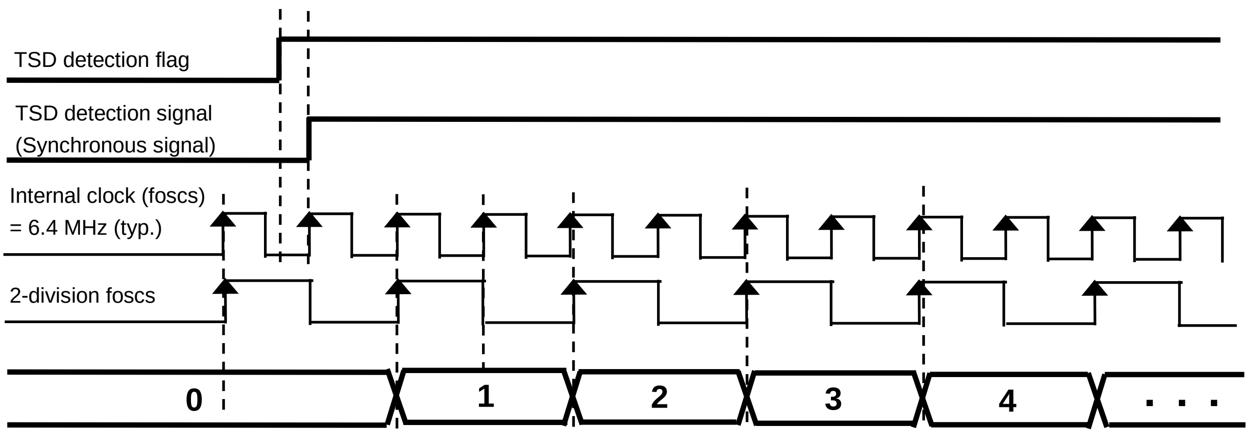


Figure 5.2 Dead band time of thermal shutdown detection

The thermal shutdown circuit has a dead band time to avoid miss detection. The dead band time is configured by the internal counter controlled by the fixed frequency of the IC (foscs=6.4 MHz (typ.)). Internal automatic returning function returns the IC operation 320 μs (typ.) after the over temperature is detected.

* foscs = 6.4 MHz (typ.) internal clock
Corresponding to foscs×32 clk to 33 clk (5.0 μs to 5.15 μs)

6. OFF time after error detections

6.1. OFF time after over current detection

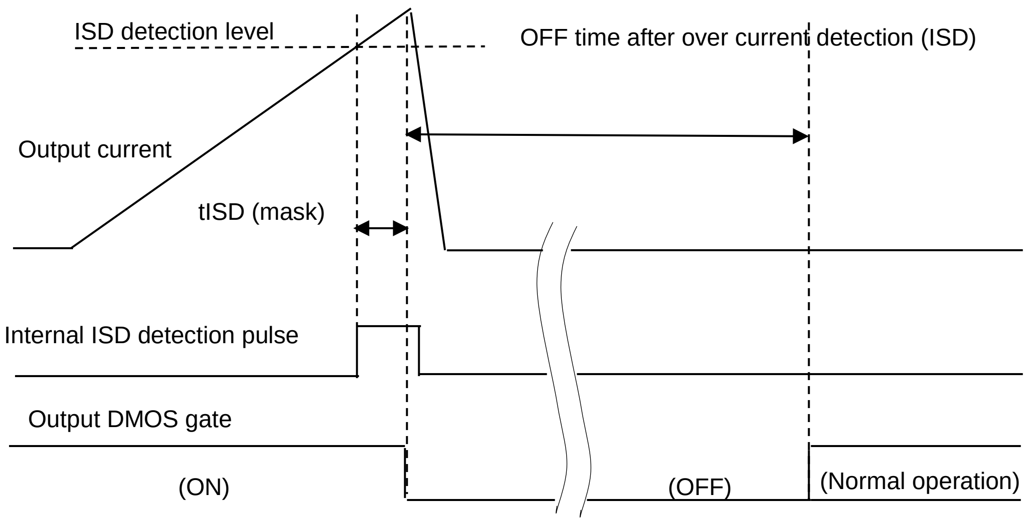


Figure 6.1 OFF time after over current detection

6.2. OFF time after thermal shutdown detection

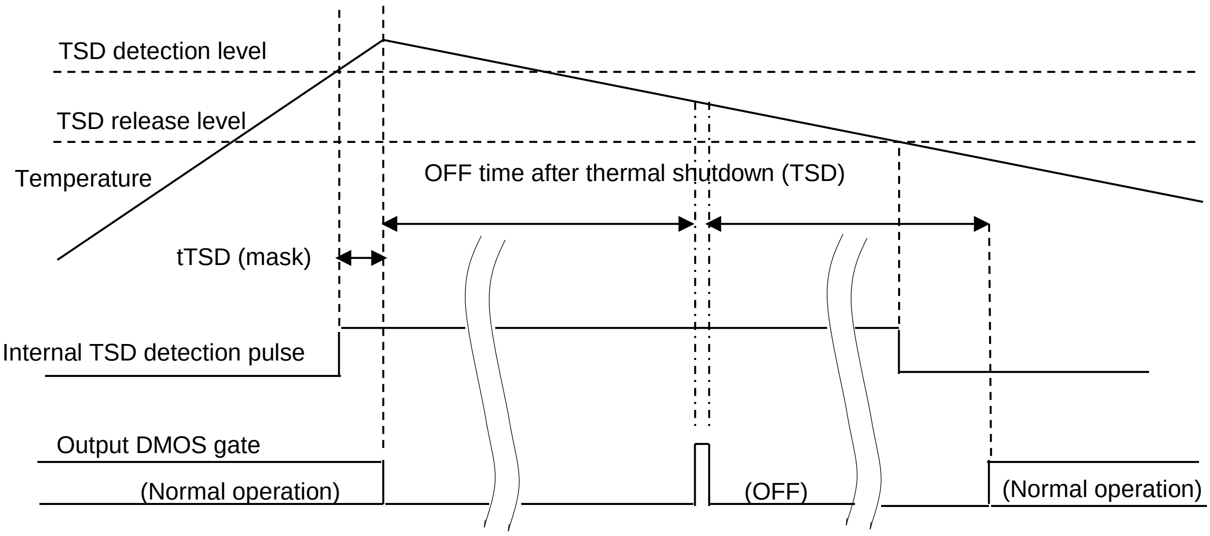


Figure 6.2 OFF time after thermal shutdown detection

After the thermal shutdown detection (TSD), if the IC temperature is still above the TSD threshold during the OFF time, output DMOS is turned off continually. (TSD detection state continues.)

7. IC loss calculation

Please configure the usage IC with sufficient margin by calculating the IC loss from below formulas and by referring to PD-Ta graph.

●Loss calculations

- **Output**
  Pout (W) = IOUT (A) × IOUT (A) × RON (Ω) × ONDuty × Ch
- **Input**
  Pin (W) = IIN (A) × VIN (V) × ONDuty × Ch
- **VCC**
  Pvcc (W) = ICC (A) × VCC (V) × ONDuty × Ch
- **Total (whole IC)**
  PD (W) = Pout (W) + Pin (W) + Pvcc (W)

* RON: Refer to 'Electrical characteristic' in the data sheet.
* ONDuty: Adopt ON term / frequency.
However, when ON term is 25 ms or more, please adopt the value of 1 to ONDuty
* Ch: Number of driving channels

●PD-Ta graph

Conditions: Absolute maxim rating of the junction temperature (Tj = 150 °C).

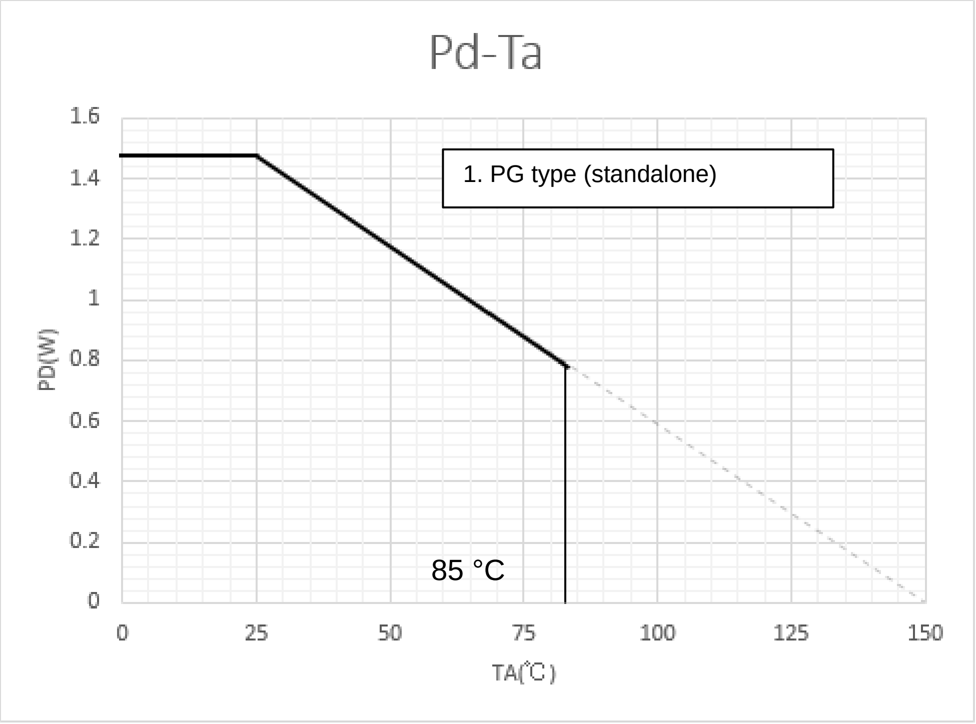
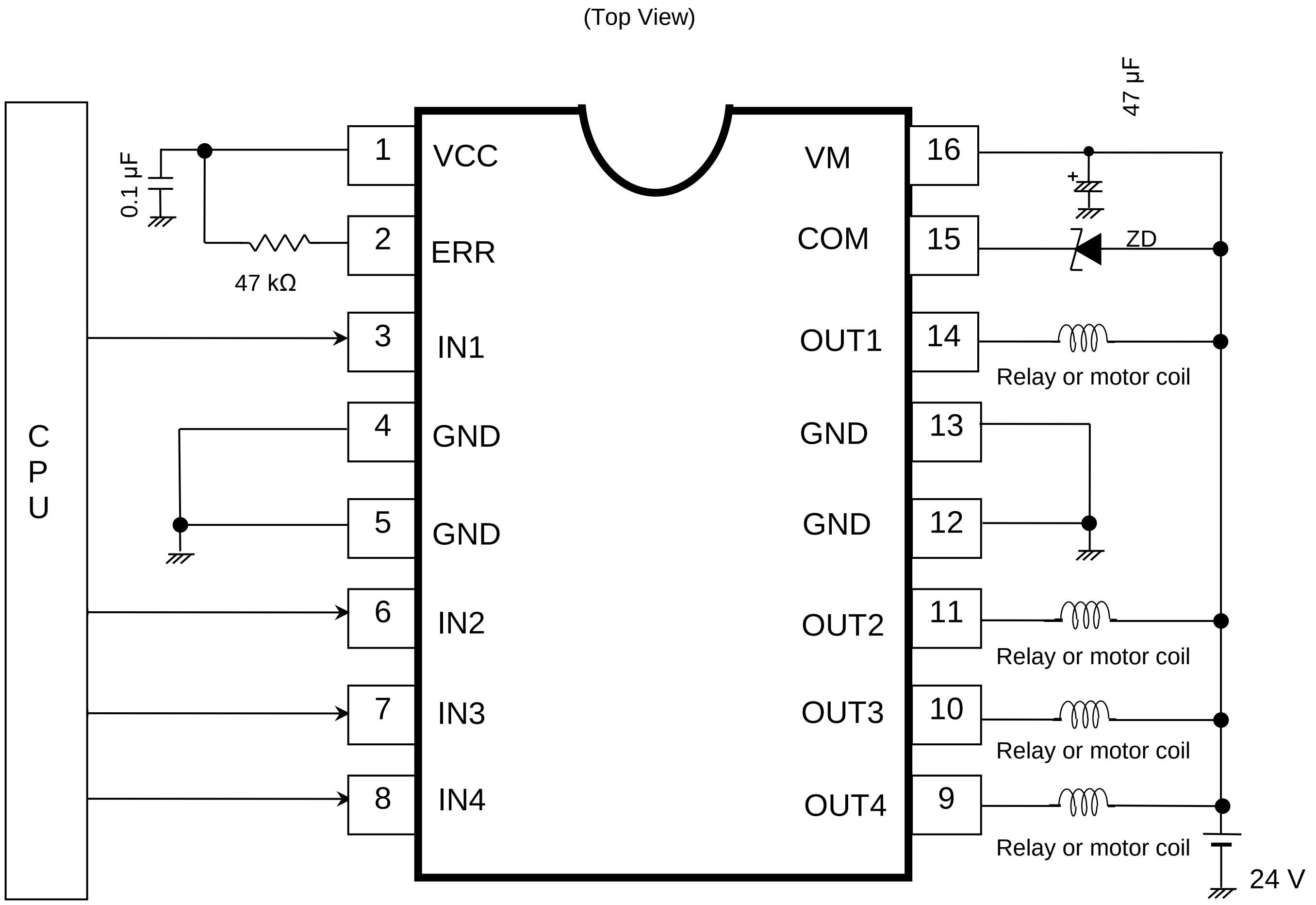


Figure 7.1 Power dissipation

●Thermal resistance of a package

PG type: Rth (j-a) = 85 °C/W (standalone)

8. Application circuit example



The application circuit shown in this document is provided for reference purposes only. Toshiba does not guarantee the data for mass production. As for zener diodes, recommended zener voltage is higher than VM.

Figure 8.1 Application circuit example

(1) Capacitor for the VM power supply

To stabilize the power supply voltage for the IC and reduce the noise, connect the appropriate capacitor to each pin. It is recommended to connect the capacitor as close to the IC as possible. Especially, by connecting the ceramic capacitor near the IC, the power supply fluctuations at the high frequency range and the noise can be reduced.

Table 8.1 Recommended capacitor values for power supply

Item	Parts	Symbol	Typ.	Recommended range
VM-GND	Electrolytic capacitor	CVM1	100 μF	47 to 100 μF
	Stacked ceramic capacitor	CVM2	0.1 μF	0.01 to 1 μF
VCC-GND	Stacked ceramic capacitor	CVCC	0.1 μF	0.01 to 1 μF

* The voltage for VREF can be set by using a resistance divider from VCC pin. In this case, please adopt the total resistance between VCC pin and GND in the range of 10 kΩ to 30 kΩ.
* The values shown in the above table is for reference only. Therefore, capacitors outside of the recommended range can also be used depending on the motor load conditions and the design pattern of the PCB.

(2) Zener diode

By connecting the zener diode between VM and VCOM, the peak voltage during output off period and the current decay during fixed off period can be adjusted. The zener diode should be placed near the IC.

Table 8.2 Recommended zener diode connected between VM and VCOM

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

* As for zener diodes, recommended zener voltage is higher than VM.

* The values shown in the table above are for reference only. Therefore, please decide the final constant numbers with evaluation under the usage environment.

(3) Resistor for ERR pin

This IC has an open-drain type logic output pin (ERR pin). When the internal MOSFET is turned off, the pin voltage level becomes high impedance. In order to use this function properly, please pull-up the pin to 3.3 V or 5.0 V power line (or VCC) with a pull-up resistance.

Table 8.3 Recommended resistance for ERR pin

Item	Parts	Symbol	Typ.	Recommended range
ERR pull-up resistance	Chip or lead type resistance	RERR	10 kΩ	10 to 100 kΩ

(4) Wiring pattern for power supply, GND, and outputs

Since large current may flow in VM, OUT, RSGND, and GND patterns especially, design the appropriate wiring patterns to avoid the influence of wiring impedance. It is very important for a 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.

9. Board dimensions

9.1. Inputs

Red characters indicate IC pin names.

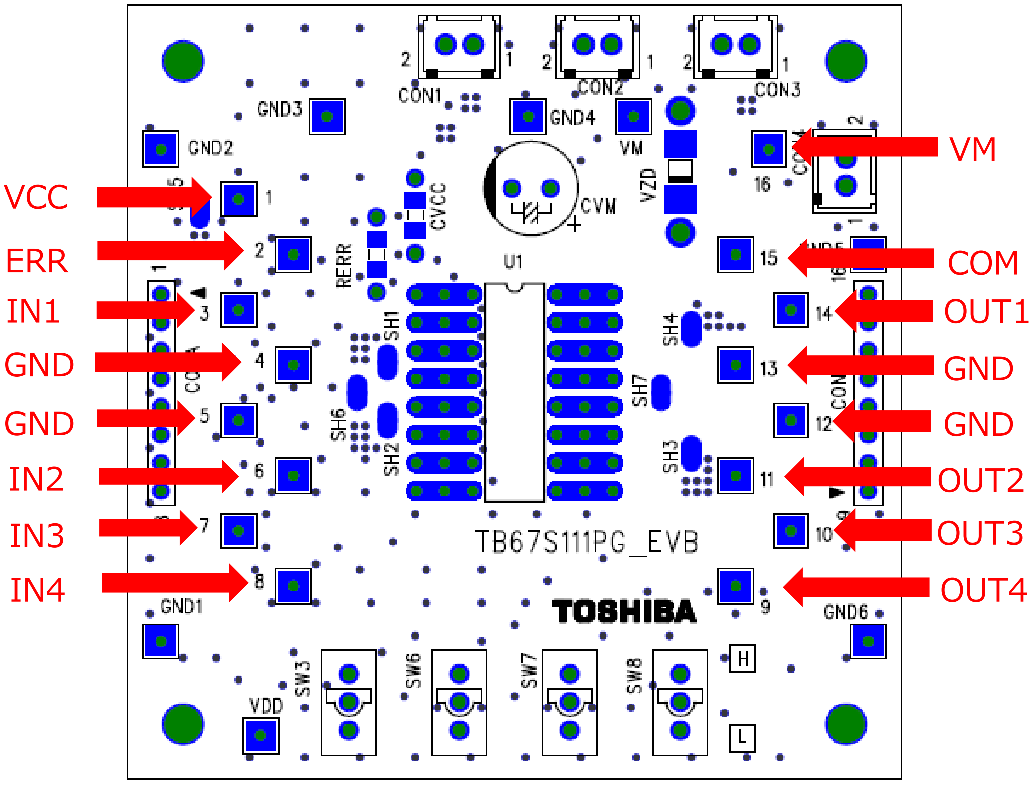


Figure 9.1 Inputs

The figure above indicates the standard evaluation board.
Input each power supply and control signal according to the figure shown above.

9.2. Main parts

Red circles indicate external components except switches.

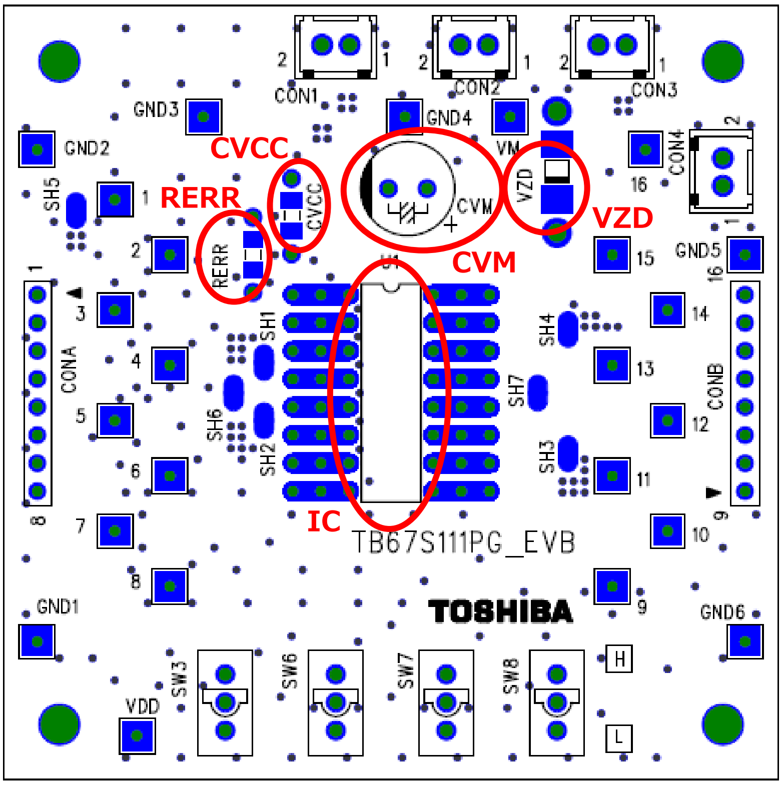


Figure 9.2 Main parts

Connect each external component referring to the descriptions of “8. Application circuit example”.

9.3. Notes in using board

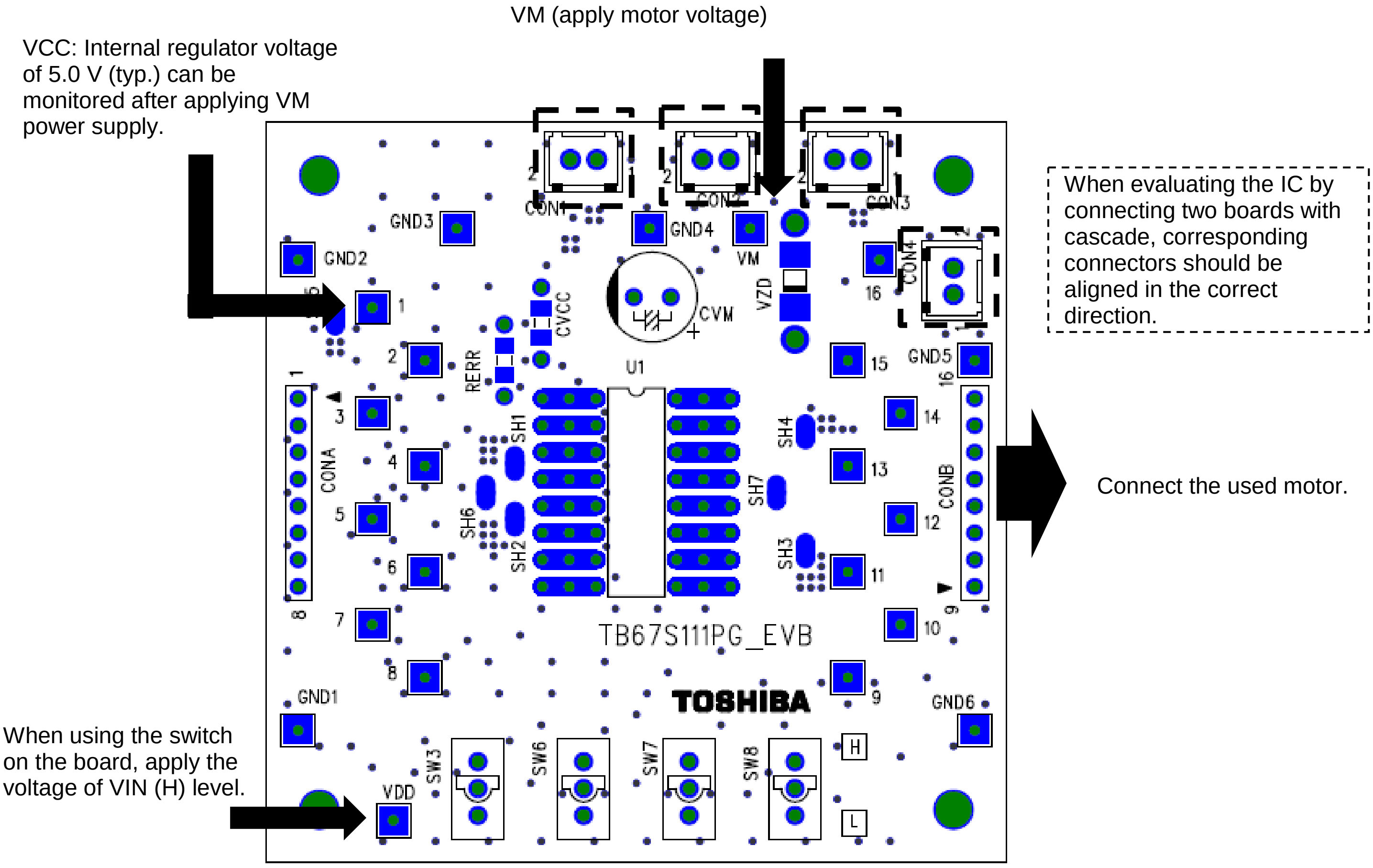


Figure 9.3 PCB options

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.
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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 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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