

# TB67H451FNG

## Usage Considerations

### **Description**

The TB67H451FNG is a PWM chopper type brushed DC motor driver.

This product includes one channel of motor output block.

Low ON-resistance MOSFETs and a PWM control provide efficient motor drive to the TB67H451FNG by accomplishing lower heat generation.

Furthermore, the TB67H451FNG has two inputs, IN1 and IN2, which are capable of selecting of the four operation modes; forward (clockwise), reverse (counter-clockwise), short brake, and stop modes.

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### 1. Power Supply Voltage

#### 1.1. Operating Power Supply Voltage Range

In using TB67H451FNG, the voltage should be applied to the pins of VM and VREF. The absolute maximum rating of VM supply voltage is 50V (no active). The usage range is 4.5 to 44V. The absolute maximum rating of VREF supply voltage is 5.5V. The usage range is 0 to 4V.

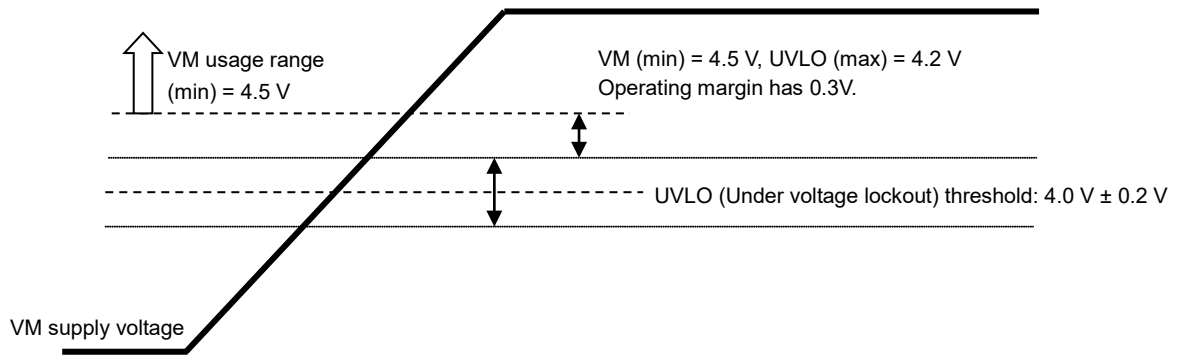


Figure 1.1 Operating power supply voltage range

#### 1.2. Power Supply Sequence

There are no special procedures of inputting a power supply and shutdown because the TB67H451FNG incorporates the under voltage lockout (UVLO). However, under the unstable state of inputting the power supply (VM) and shutdown (transient area), setting the motor operation to OFF state is recommended. After the power supply is in the stable state, the motor should be operated by switching the input signal.

### 2. Output Current

The absolute maximum rating of motor output current is 3.5A (Peak current is 6.2A (tw≤500ns)). Its operating range is 3A 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). Configures the most appropriate current value after calculating the heat and evaluating the board under the operating environment.

### 3. Control Inputs

When the logic signal is input under the condition that the voltage of VM is not supplied, the electromotive force by an input signal is not generated. However, configures the input signal to low level before the power supply is applied, referring to the description of the “1.2 Power Supply Sequence”.

## 4. Direct PWM Control

### 4.1. Input and Output Functions

A speed of the motor can be controlled by Inputting PWM signal to pins IN1 and IN2, and operating them with PWM control. It is recommended to control the input pulse width to be at least 600ns in consideration of output followability.

In order to disable the constant current function, RS pin should be connected to GND, and the voltage of 1 to 5V should be applied to VREF pin.

**Table 4.1 Input and output functions**

IN1	IN2	OUT1	OUT2	Mode
L	L	OFF (Hi-Z)	OFF (Hi-Z)	Stop
				Standby mode after elapsing 1 ms
H	L	H	L	Forward
L	H	L	H	Reverse
H	H	L	L	Short brake

Current path: Forward: OUT1 to OUT2, Reverse: OUT2 to OUT1

### 4.2. Standby Mode

When both IN1 and IN2 pins are set to L for 1 ms (typ.), the operation mode translates to the standby mode.

**Table 4.2 Time to standby**

Item	Min	Typ.	Max	Unit
Time to standby	0.7	1	1.5	ms

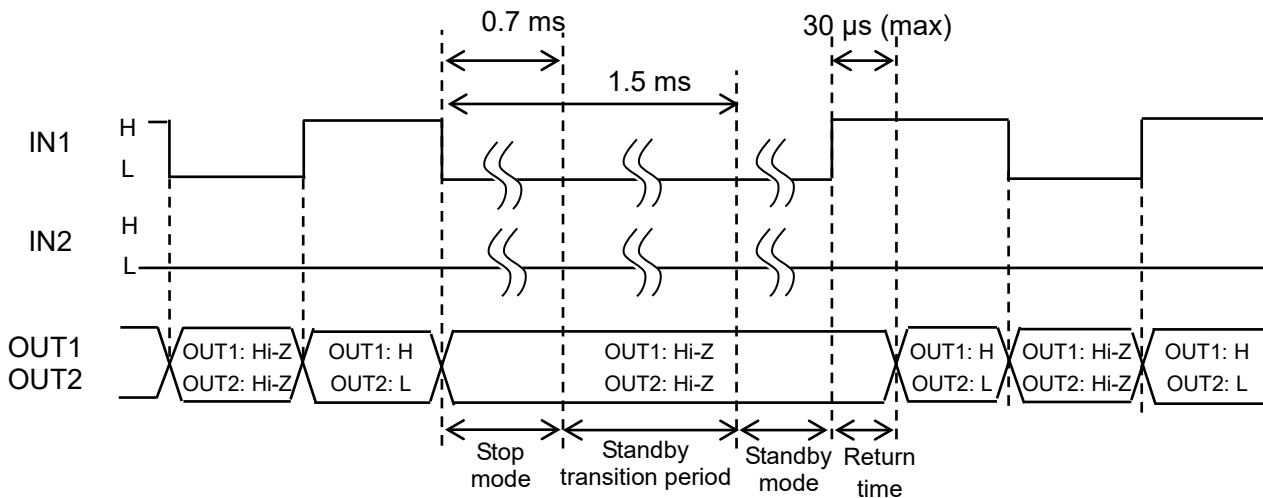
The following period in which both IN1 and IN2 pins are set to L is the standby transition period. Do not change the input states during this period since the IC becomes unstable.

- If [STOP] mode is used, set period of IN1 =L and IN2 =L to 0.7 ms or less.
- If [Standby] mode is used, set period of IN1 =L and IN2 =L to 1.5 ms or more.

In standby mode, when IN1 or IN2 is set to H, the mode returns from the standby mode, and enters to the operation mode.

Maximum 30  $\mu$ s is required for the return time from the standby release.

The OUT1 and OUT2 outputs operate after 30  $\mu$ s (max) from the standby release.



**Figure 4.1 Standby mode operation**

## 5. Constant Current PWM Control

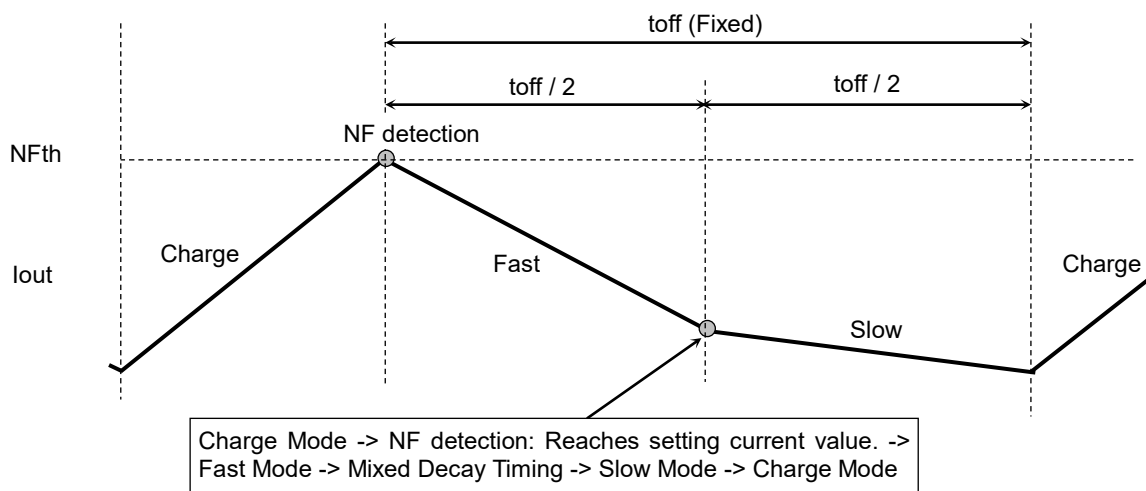
### 5.1. Constant Current Control Type (Mixed Decay)

In this product, a constant current threshold (NFth) is set by the current detection resistor between RS and GND, and VREF input voltage.

When the output current reaches the threshold due to forward rotation and reverse rotation, the constant current control is performed in Mixed Decay mode.

In case of the constant current control, the OFF time (toff) is fixed to 25  $\mu$ s (typ.) to determine the pulse width of the current (current pulsating flow). The percentage of Mixed Decay Mode is as follows; Fast Mode: 50% to Slow Mode: 50%.

For the constant current setting, refer to Section 7.4



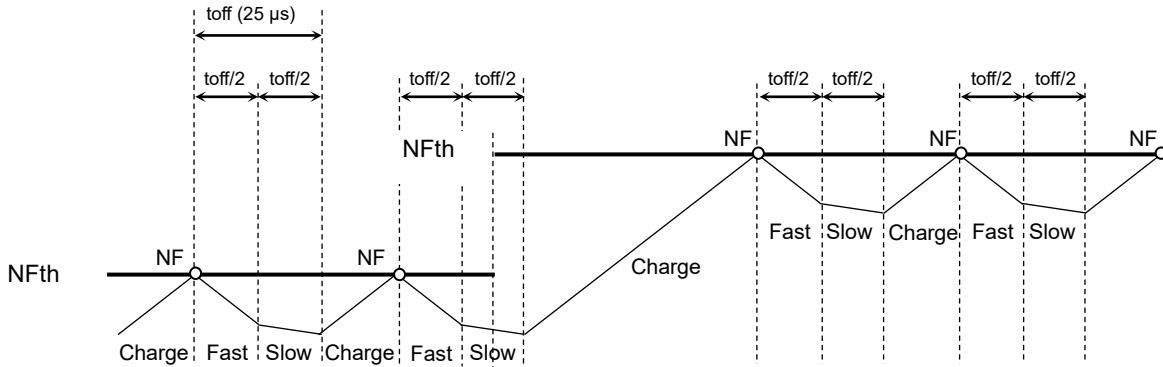
**Figure 5.1 Current waveform of Mixed Decay Mode**

If the output current is zero-detected in Fast Mode, the outputs are in High impedance.

Timing charts may be simplified for explanatory purposes.

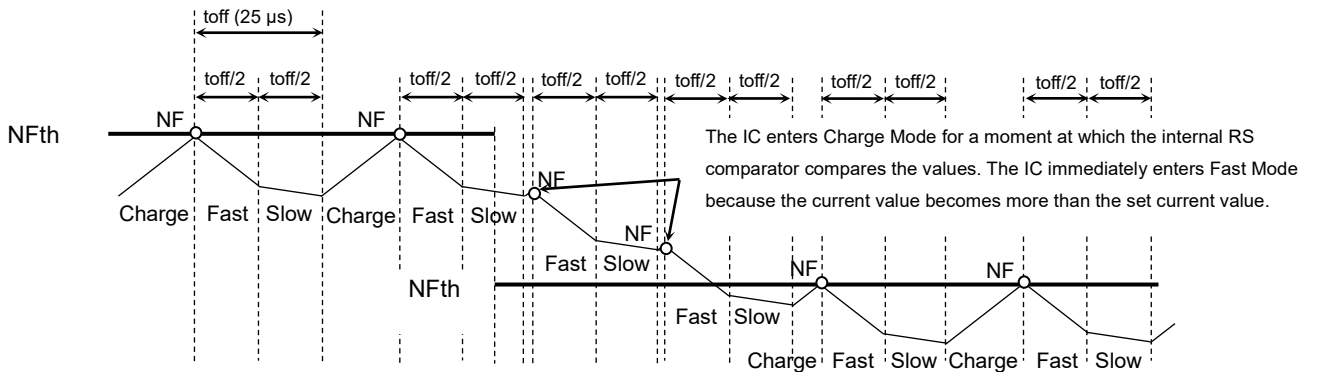
**5.2. Waveform of Mixed Decay Mode**

- When the set current value increases  
(Mixed Decay timing: OFF time is fixed, Fast: 50%/Slow: 50%)



**Figure 5.2 Current waveform of Mixed Decay Mode (when the set current value increases)**

- When the set current value decreases  
(Mixed Decay timing: OFF time is fixed, Fast: 50%/Slow: 50%)



**Figure 5.3 Current waveform of Mixed Decay Mode (when the set current value decreases)**

When the Charge period starts and the output current reaches the set value, the RS comparator detects the set current value (NF), and the IC enters to the Fast Mode. Then, the IC transmits from Fast Mode to Slow Mode at the timing of 50% of the fixed OFF time, toff=25 μs (typ.). Moreover, after 50% of the time elapses, the Slow Mode ends, and the Charge period starts again. Even if the set current is changed during Decay operation, the Decay operation continues until completion of toff operation period.

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

Timing charts may be simplified for explanatory purposes.

## 6. Switching Characteristics

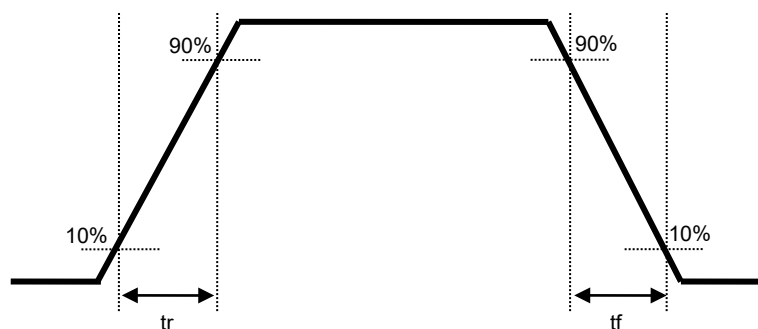


Figure 6.1 Switching characteristics

Table 6.1 Switching characteristics

Ta = 25°C, VM = 24 V, output load condition 6.8mH/5.7Ω

Item	Typ.	Unit
tr	60	ns
tf	80	ns



## 7. Application Circuit Example

### 7.1. Application Circuit Example brushed DC motor drive

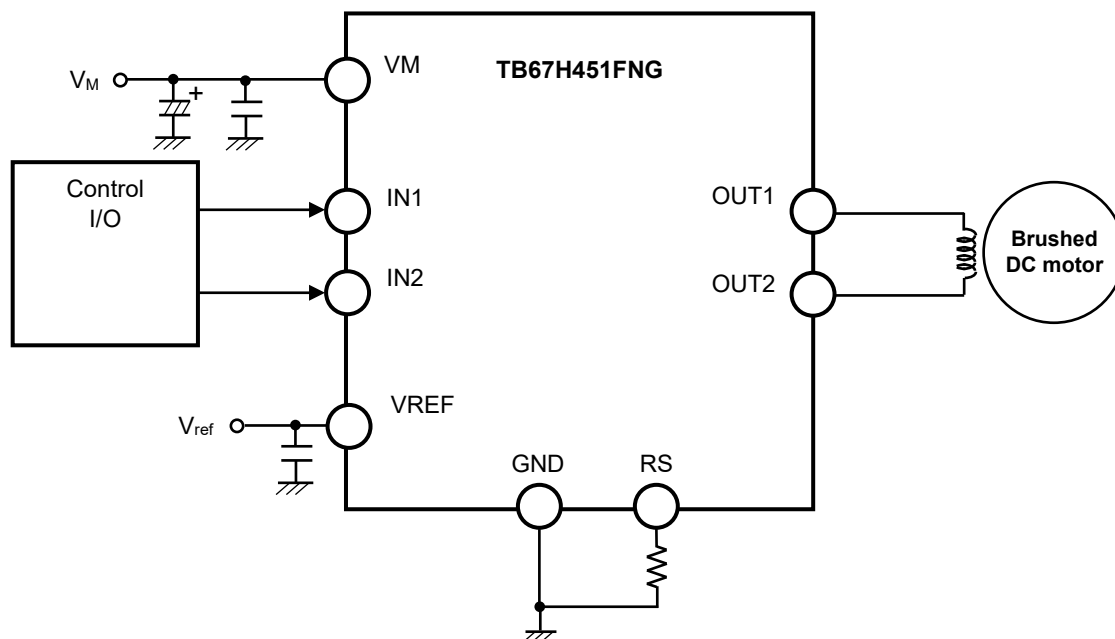


Figure 7.1 Application circuit example (Brushed DC motor)

### 7.2. Stepping motor drive

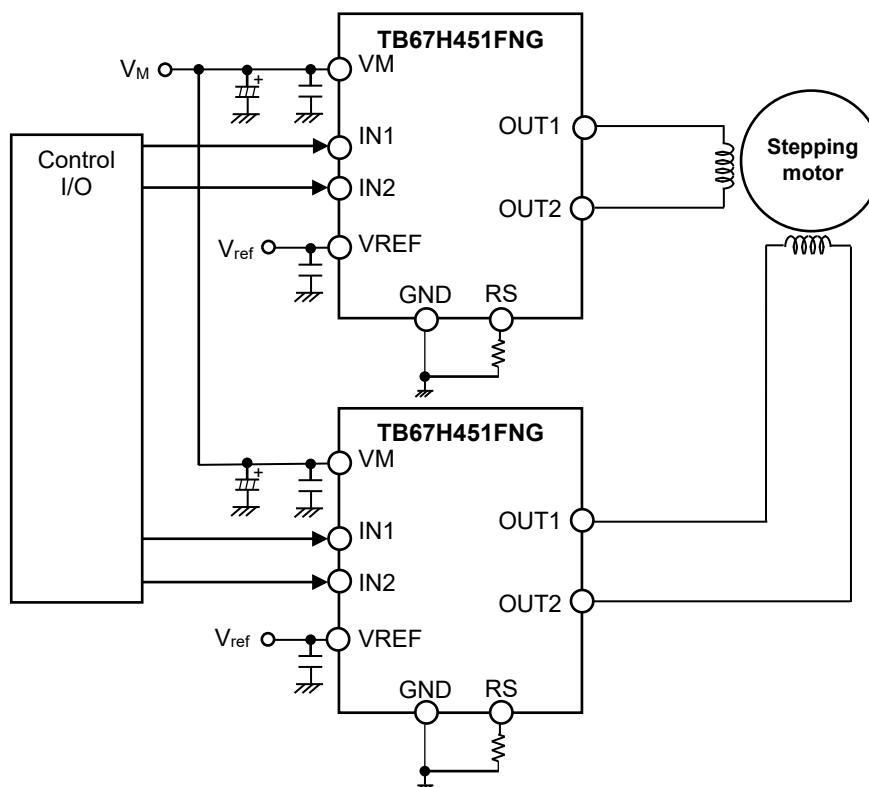


Figure 7.2 Application circuit example (stepping motor)

All the grounding wires of the TB67H451FNG must run on the solder within the mask of the PCB. It must also be externally terminated at a single point. The application circuits shown in this document are provided for reference purposes only. Thorough evaluation is required, especially at the mass production design stage.

**7.3. Capacitor for Power Supply Pin**

To stabilize the power supply voltage of 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 voltage fluctuation at the high frequency range and the noise can be reduced.

**Table 7.1 Recommended capacitor values for power supply pin**

Connection	Components	Typ.	Recommended range
Between VM and GND	Electrolytic capacitor	100 μF	47 to 100 μF
	Ceramic capacitor	0.1 μF	0.01 to 1 μF
(Between VREF and GND)	Ceramic capacitor	0.1 μF	0.01 to 1 μF

- \* Between VREF and GND: Connect the capacitor by necessity depending on the usage environment.
- \* It is possible to reduce each component and use the capacitor with other than the recommended value, depending on the motor load condition and the board design pattern.

**7.4. Current Detection Resistor**

This IC configures the threshold of the constant current detection by connecting the current detection resistor between RS pin and GND pin. The detection resistor 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 7.2 Recommended values for current detection resistor**

Connection	Parts	Typ.	Recommended range
Between RS and GND	Chip / Lead resistor	0.22 Ω (1.5 to 3.0 A)	0.22 to 1.0 Ω
Between RS and GND	Chip / Lead resistor	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 RS detection resistor is as follows;

$$I_{out(max)} = V_{ref(gain)} \times \frac{V_{ref(V)}}{R_{RS}(\Omega)}$$

Vref(gain): Vref decay ratio is 1 / 10.0 (typ.).

Vref(V): The operation range of Vref is 0 to 4V.

The Vref voltage can also be used from 4 to 5V, however, the threshold of the constant current detection is the same values as Vref = 4V setting. (Design guarantee at VM = 24V)

As for the current detection resistor, the constant number which is out of recommended range can be adopted. In this case, please pay attentions to the followings when the used resistor value is high and low.

- \* When the detection resistance is low, the difference voltage between RS and GND 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 ( $P=I^2 \times R$ ). So, in comparison with the same current flows in low resistance, the power dissipation should be larger.

### **7.5. Wiring Pattern for Power Supply and GND**

Since large current may flow in VM, RS, and GND pattern especially, design the appropriate wiring pattern in order 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 IC's back side to the GND. So, design the pattern by considering the heat design.

### **7.6. 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.

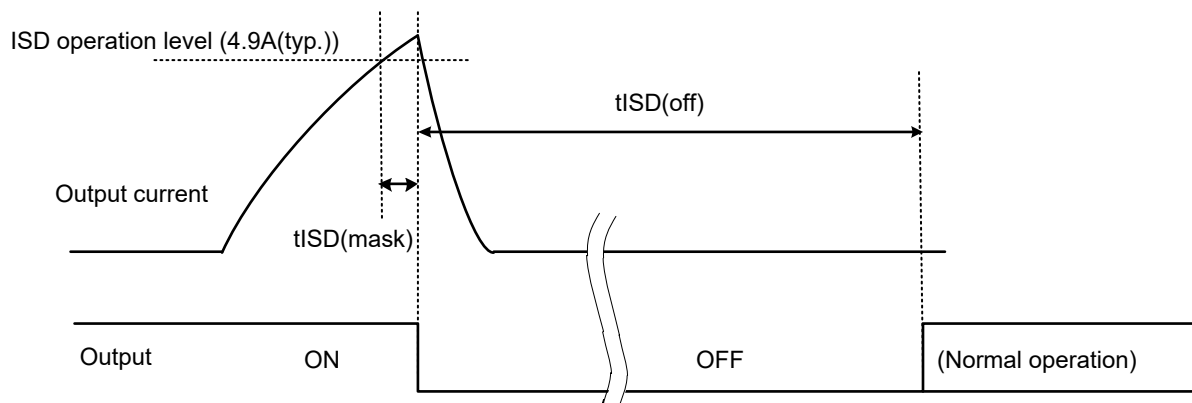
## 8. Fault Detection

- Thermal shutdown (TSD)**  
 When the junction temperature of the IC reaches the TSD threshold, the TSD circuit is triggered; the internal reset circuit then turns off the output transistors. In order to avoid malfunctions by switching etc., detection mask time ( $t_{TSD(mask)}$ ) is prepared inside IC. Since the operating temperature of TSD circuit has a hysteresis width, the IC reruns automatically when the junction temperature become lower the return-temperature.  
 The TSD circuit is a backup function to detect a thermal error, therefore is not recommended to be used aggressively.

Mask time of TSD ( $t_{TSD(mask)}$ ): 2 to 8  $\mu s$

- Over current detection (ISD)**  
 When the output current reaches the threshold, the ISD circuit is triggered; the internal reset circuit then turns off the output transistors. In order to avoid malfunction by switching etc., detection mask time ( $t_{ISD(mask)}$ ) is prepared inside IC. The IC operation recovers automatically after specified OFF time ( $t_{ISD(off)}$ ) passes.

Mask time of ISD ( $t_{ISD(mask)}$ ): 1.5  $\mu s$  (typ.)  
 OFF time of ISD ( $t_{ISD(off)}$ ): 3 ms (typ.)



**Figure 8.1 Operation of over current detection**

- Under voltage Lock out (UVLO)**  
 The under voltage detection circuit operates when the applied voltage of VM pin falls 3.8V (typ.) or less. All output power transistors are turned off. The UVLO operation is released when the voltage applied to VM pin rises 4.0V (typ.) or more.

\* The operation thresholds and mask time of the fault detection shown above are reference values.

### 9. Power consumption of IC

Power consumption of the IC is consumed by the transistor of the output block and that of the logic block mainly.

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

- Power consumption of the motor output block  
Power of the output block (P(out)) is consumed by MOSFET of upper and lower H-Bridge.

$$P(\text{out}) = I_{\text{out}} (\text{A}) \times V_{\text{DS}} (\text{V}) = I_{\text{out}} (\text{A}) \times I_{\text{out}} (\text{A}) \times R_{\text{on}} (\Omega) \dots\dots\dots (1)$$

When the current waveform of the motor output corresponds to the ideal waveform, the average power of the output block can be provided as follows;

When  $R_{\text{on}} = 0.60\Omega$ ,  $I_{\text{out}} (\text{peak: max}) = 1.5 \text{ A}$ ,  $V_{\text{M}} = 24 \text{ V}$

$$P(\text{out}) = 1.5 (\text{A}) \times 1.5 (\text{A}) \times 0.60 (\Omega) \dots\dots\dots (2)$$

$$= 1.35 (\text{W})$$

- Power consumption of logic and IM systems  
Power consumption of logic and IM systems are calculated separately by the state of operating and stopping.

$$I (\text{IM3}) = 3.5 \text{ mA (typ.): Operating (fPWM=30 kHz)}$$

$$I (\text{IM2}) = 3.0 \text{ mA (typ.): Stopping (Brake Mode)}$$

The outputs are connected to VM (24V). (Outputs: Current consumed by the circuit connected to VM + Current consumed by switching output stages)

Power consumption is calculated as follows;

$$P(\text{bias}) = 24 (\text{V}) \times 0.0035 (\text{A}) \dots\dots\dots (3)$$
$$= 0.084 (\text{W})$$

- Power consumption  
Total power consumption P (total) is calculated from the values of equation (2) and (3).

$$P(\text{total}) = P(\text{out}) + P(\text{bias}) = 1.35 + 0.084 = 1.434 (\text{W})$$

The power consumption in non-operation mode (stopping) of the motor is calculated as follows;

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

Additionally, the power consumption can be reduced by stopping the operation with the standby mode. (IM1=1µA (max))

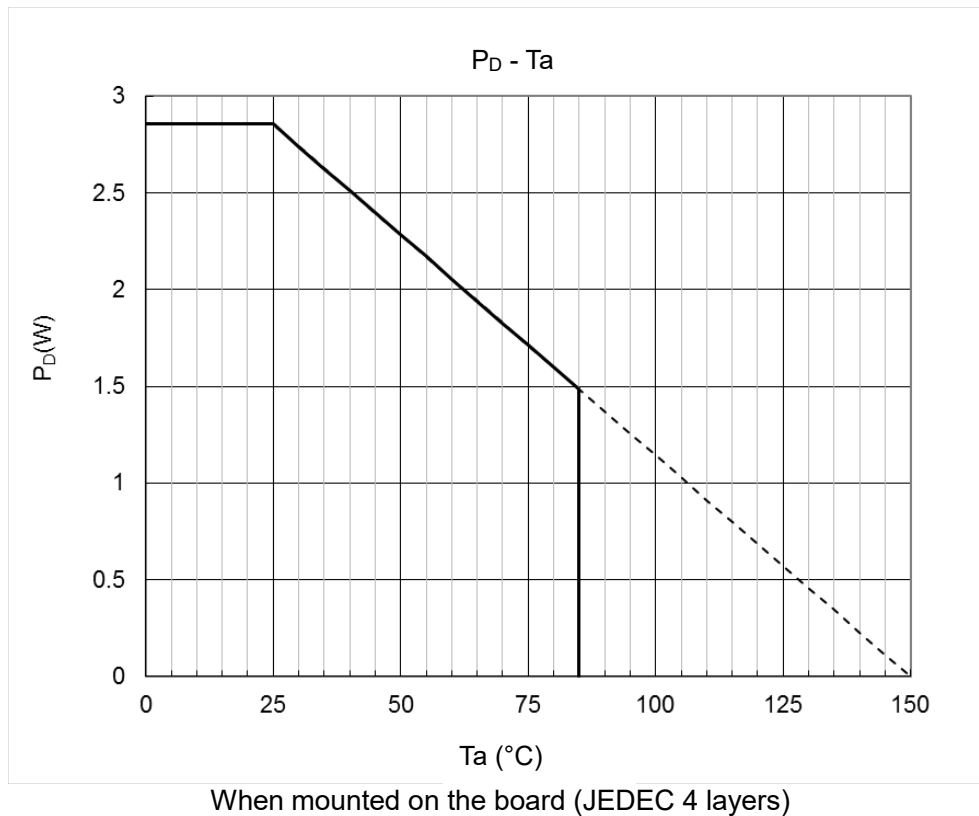
In actual motor operation, the average current becomes lower than the calculated value because of transition time of the current steps and the ripple of the constant current PWM. Refer to the above equations, evaluate the heat design of the board by the actual board enough, and configure the appropriate margin.

## 10. Power Dissipation

Relation equation of the ambient temperature ( $T_a$ ), junction temperature ( $T_j$ ), and the thermal resistance ( $R_{th(j-a)}$ ) between junction temperature to ambient temperature is as follows;

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

(Reference) Relation between power dissipation and ambient temperature

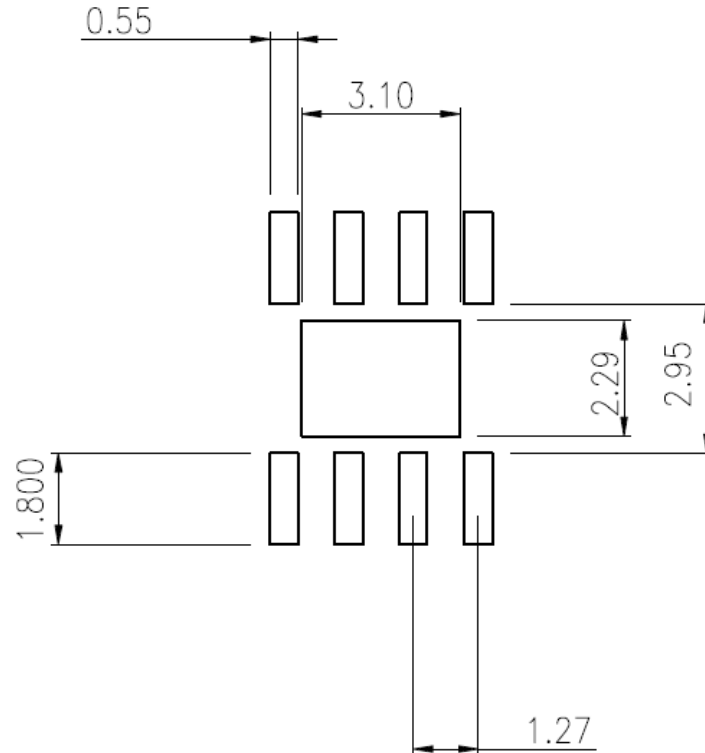


Pay attention that  $T_a$ ,  $R_{th(j-a)}$ , and  $P$  (total) depend on the usage environment. When ambient temperature is high, the allowable power consumption decreases.

## 11. Reference Land Pattern

P-HSOP8-0405-1.27-002

“Unit: mm”



### Notes

- All linear dimensions are given in millimeters unless otherwise specified.
- This drawing is based on JEITA ET-7501 Level3 and should be treated as a reference only. TOSHIBA is not responsible for any incorrect or incomplete drawings and information.
- You are solely responsible for all aspects of your own land pattern, including but not limited to soldering processes.
- The drawing shown may not accurately represent the actual shape or dimensions.
- Before creating and producing designs and using, customers must also refer to and comply with the latest versions of all relevant TOSHIBA information and the instructions for the application that Product will be used with or for.

## 12. Evaluation Board (original board examples of our company)

### 12.1. Evaluation board pattern layout

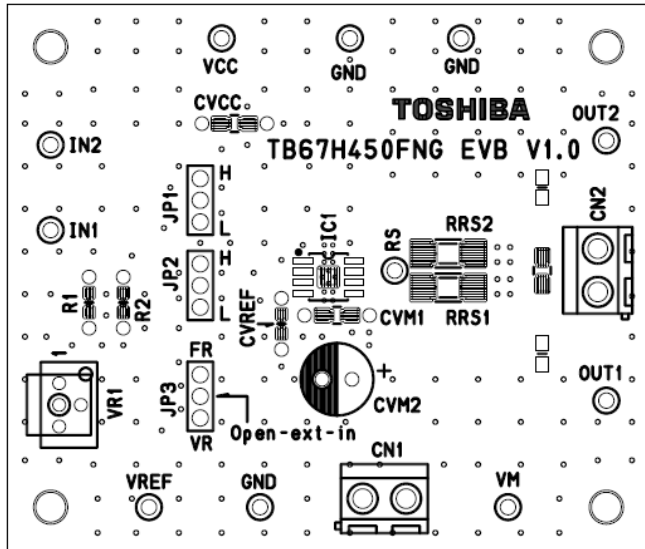


Figure 12.1 Evaluation board pattern layout (silk, resist -A)

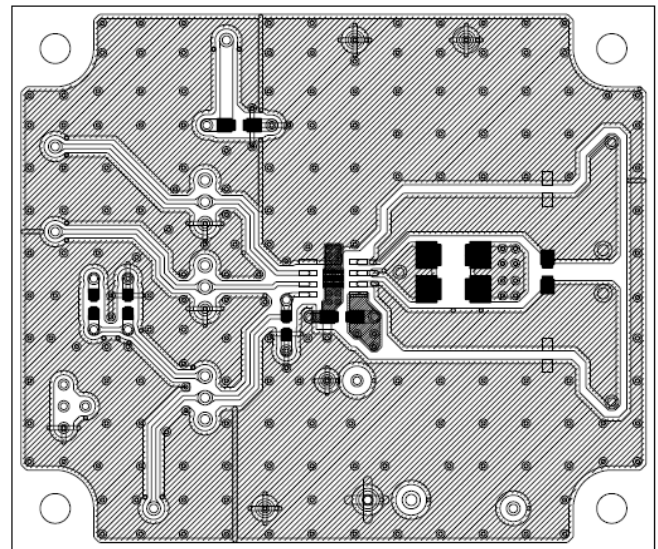


Figure 12.2 Evaluation board layout (layer -1)

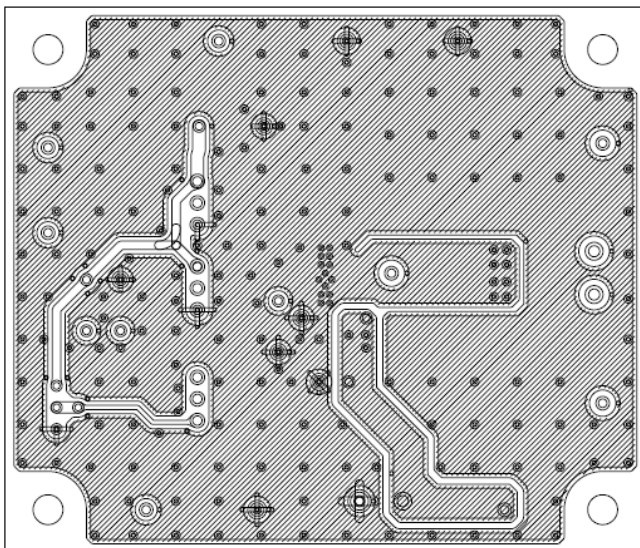


Figure 12.3 Evaluation board pattern layout (layer -2)

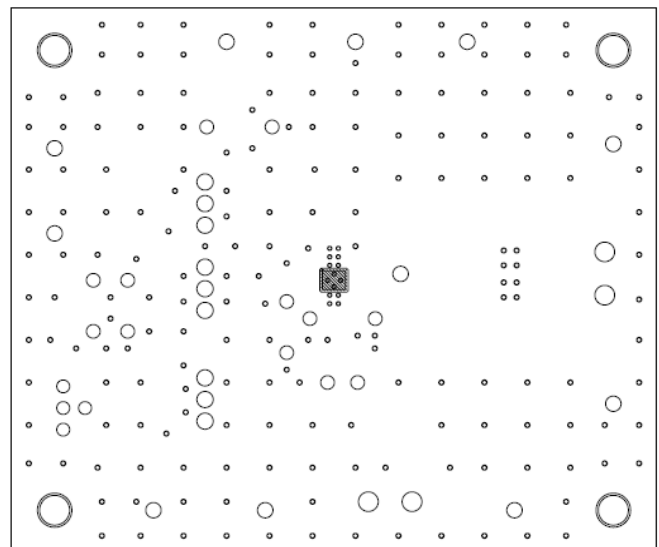
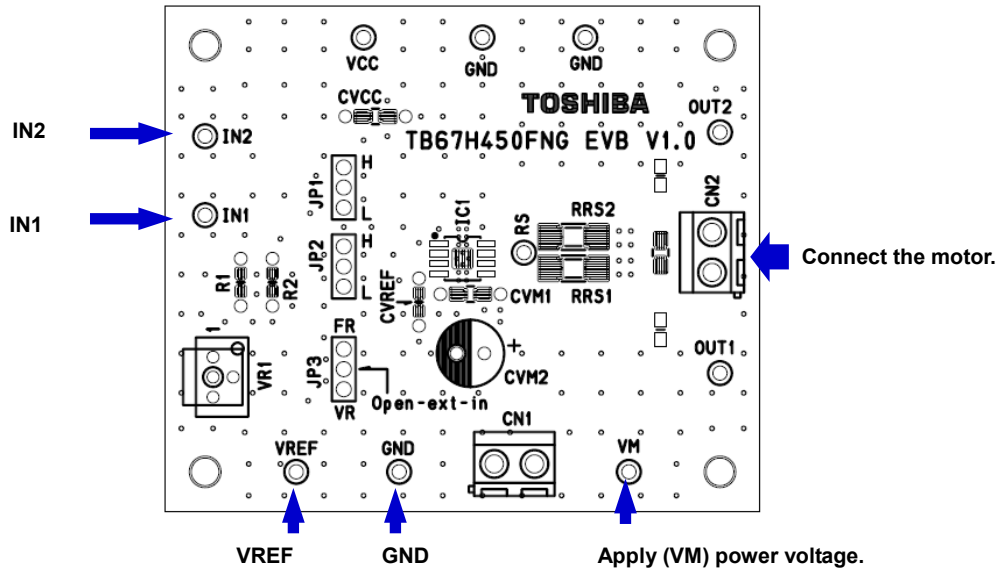


Figure 12.4 Evaluation board pattern layout (resist -B)



### 12.2. Input

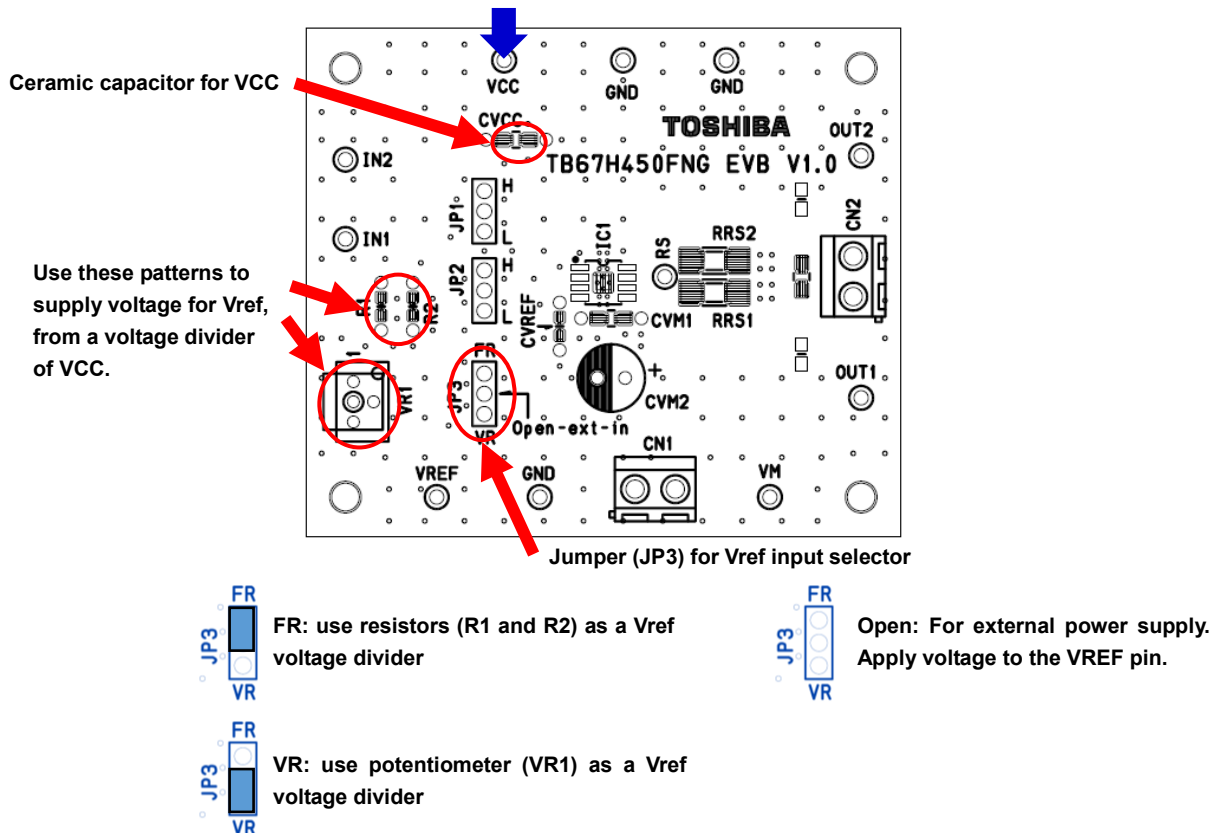


**Figure 12.5 Input**

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

### 12.3. PCB options

To use a power source for logic “High” level inputs and for VCC voltage divider for Vref, supply 5V to the VCC pin.



**Figure 12.6 PCB options**

Silk name on the board are different because the series products have the common board.

### 12.4. Board circuit diagram

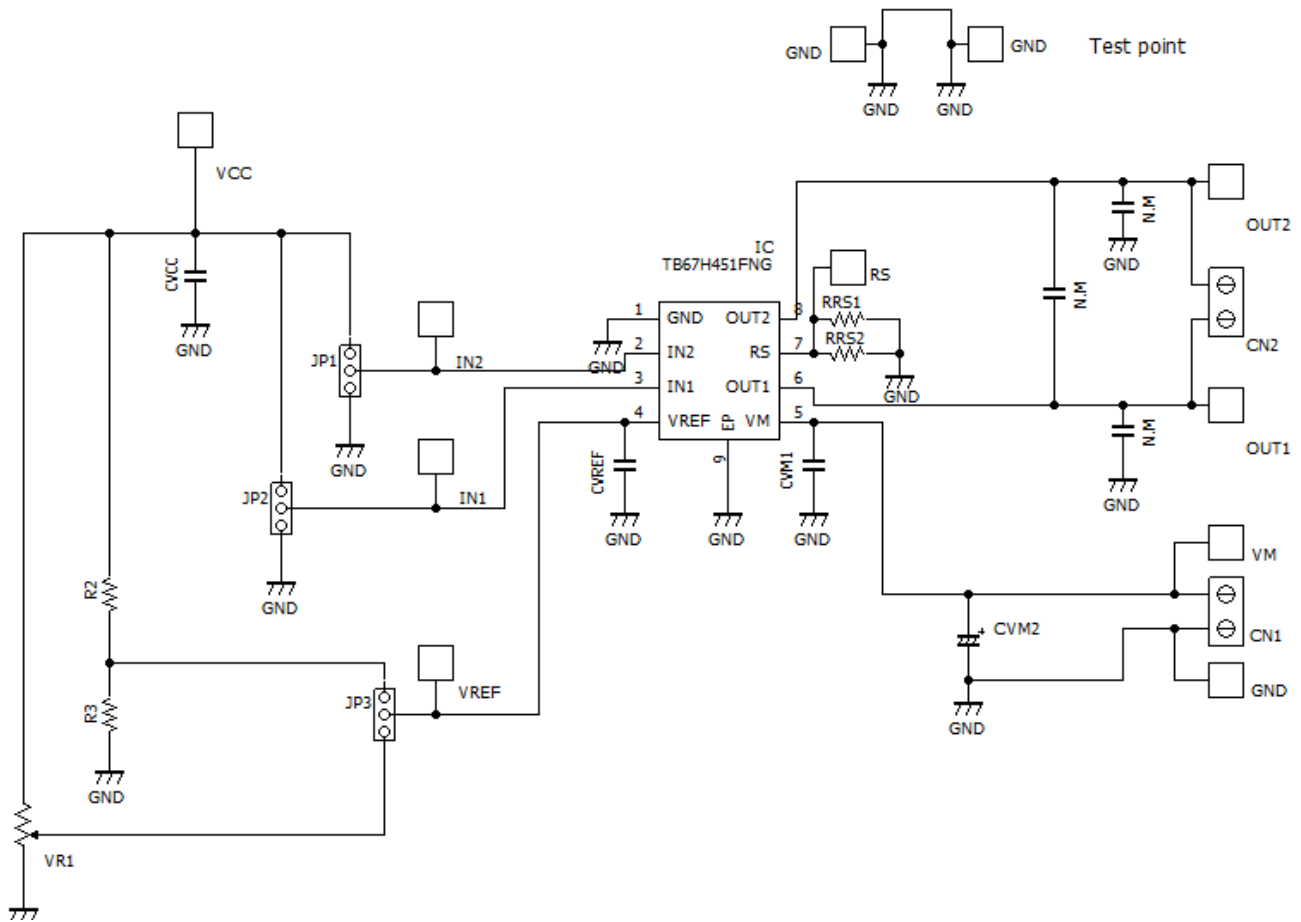


Figure 12.7 Board circuit diagram

## 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.

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, 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 consideration 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.

**Revision history**

Version	Notes	Revision date
1.0	New release	2020-03-09
2.0	Added the explanation to the standby mode	2020-11-26

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