TB67H452FTG

Usage considerations

Summary

The TB67H452FTG is a 4 ch H-bridge motor driver. Rating is 40 V and 3.5 A. Built-in interface is not only for DC brushed motors but for stepping motors. Therefore, motors can operate with various combinations such as 2 channels of DC brushed motors and 1 channel of stepping motor. The TB67H452FTG can be used for wide applications.
This application note describes usage methods based on brushed DC motor modes.

Main specifications

Product name	TB67H452FTG
Control I/F	CLK-IN
Absolute maximum ratings	• Brushed DC motor mode 40 V, 3.5 A (Small mode) 40 V, 5.0 A (Large mode) • Stepping motor mode 40 V, 3.5 A (Small mode) 40 V, 5.0 A (Large mode)
Number of drive channels	Stepping motor: maximum 2 channels Brushed motor: maximum 4 channels
Package	QFN48-P-0707-0.50
Step resolution	Full step, half step, and quarter step resolution
Other features	The consumption current at standby is reduced by the built-in sleep function. Built-in error detection functions (thermal shutdown, over current detection, and under voltage lockout) Error detection signal output function (ERR output) Supports the power-on sequence by the single power drive

* Contents in this application note are only for reference to evaluate products. Therefore, they are not guaranteed. As for details, please refer to the data sheet.

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1. Power supply voltage

1.1. Power supply voltage and usage range

In using the TB67H452FTG, the voltage should be applied to the pins of VM, VREFA, and VREFB. The maximum rating of VM supply voltage is 40 V. Usage range of the power supply voltage is 6.3 to 38 V.
The maximum rating of VREF voltage is 5 V. Usage range of the voltage is 0 to 3.6 V.
As for the voltage of VREF, the voltage of the internal regulator of the IC (VCC) can be also used. (However, if the current is pulled up exceeding the capability of the internal regulator, the regulation of VCC may not be kept. When the voltage of VREF is applied by dividing the voltage of VCC, the total of the voltage-dividing resistance should not be less than 10 kΩ.

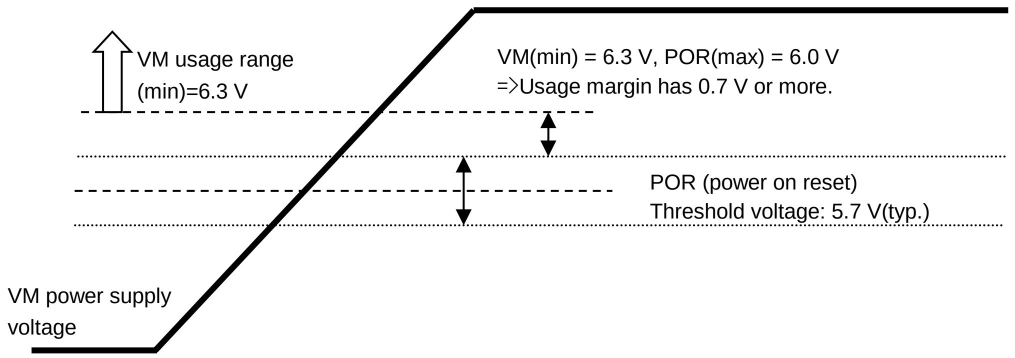


Figure 1.1 Power supply voltage and usage range

1.2. Power supply sequence

There are no special procedures of inputting a power supply and shutdown because the TB67H452FTG 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 3.5 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 voltage of VM is not supplied, the electromotive force by inputting signal is not generated. However, configure the input signal low level before the power supply is applied by referring to the description of the "1.2. Power supply sequence".

4. PWM control

The TB67H452FTG can adjust the internal oscillation frequency (fOSCM) and the chopping frequency (fchop) with the constant number of the external parts connecting to OSCM pin.

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

Chopping [kHz]	C [pF]	R [kΩ]
150	150	180
140	180	100
130	180	150
120	220	100
110	180	220
100	270	120
90	330	68
80	330	130
70	390	130
60	470	120
50	560	180
40	820	68

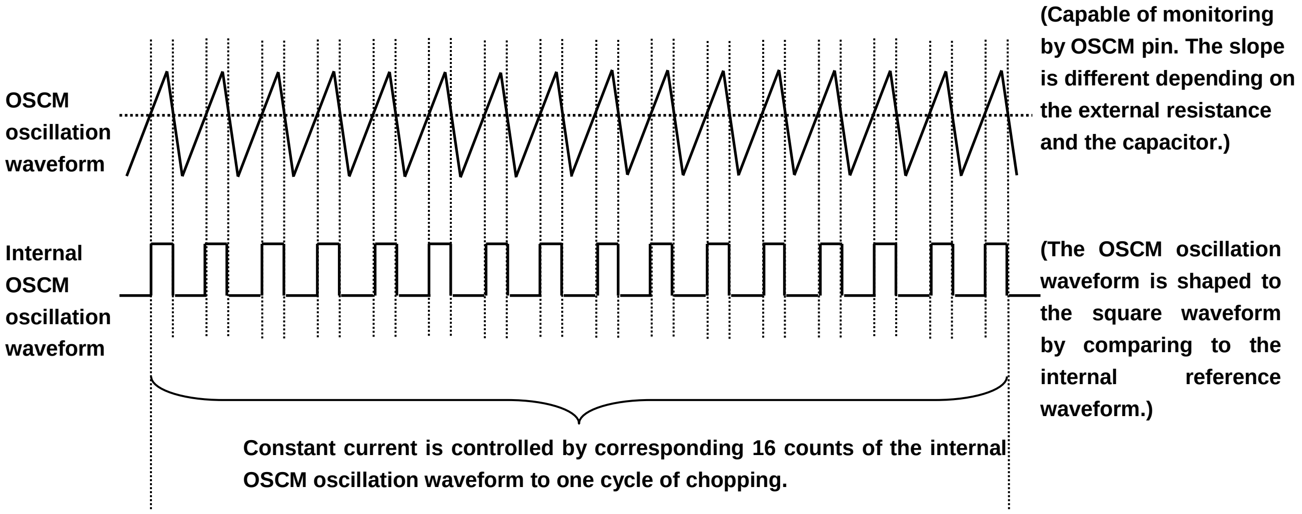


Figure 4.1 OSCM oscillation frequency

When the chopping frequency is increased, the motor can rotate faster because the following capability of the current steps increases. However, switching loss and heat increase may occur because the number of switching of output MOSFET is larger than the case of low frequency of the chopping.

(Example 1) Chopping frequency (fchop) = 100 kHz

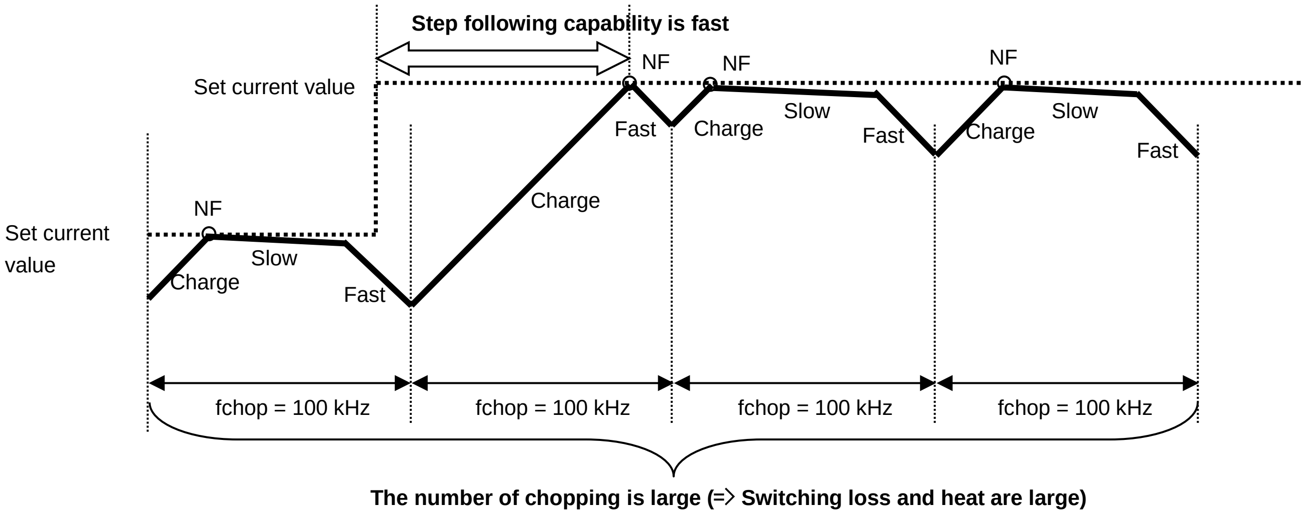


Figure 4.2 Chopping frequency (100 kHz)

(Example 2) Chopping frequency (fchop) = 50 kHz

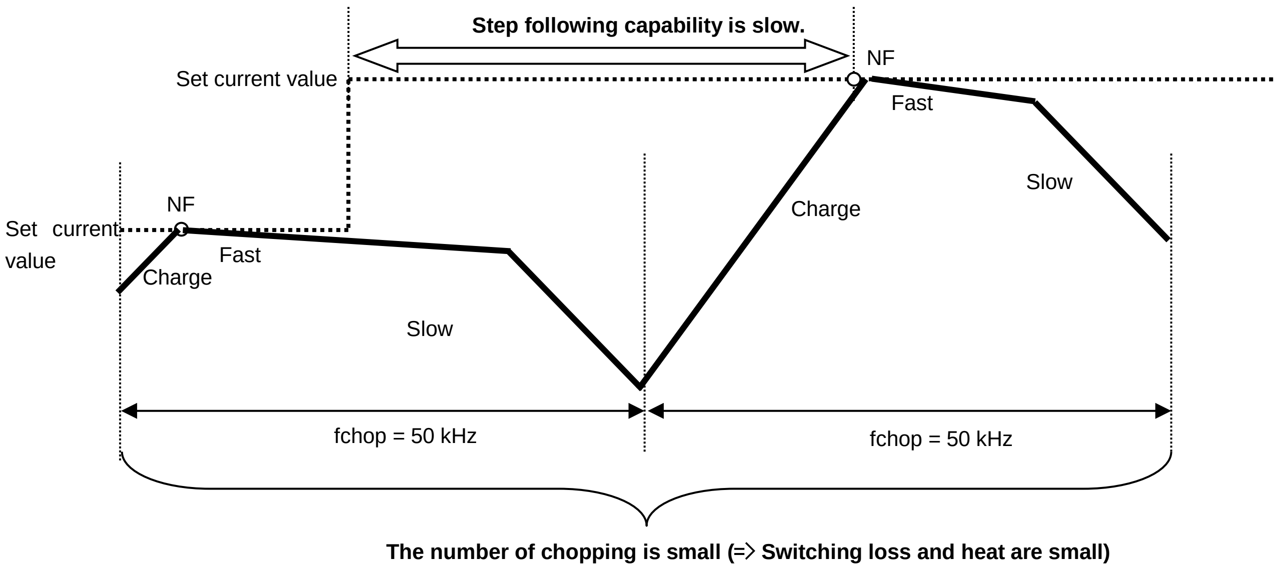


Figure 4.3 Chopping frequency (50 kHz)

Generally, it is recommended to configure the frequency in the range of 50 kHz to 100 kHz on the basis of 70 kHz.

5. Mixed Decay Mode / zero point detection operation

In the case of the constant current control, a period of drawing current (Fast) is fixed to OSCM= 6 CLK.

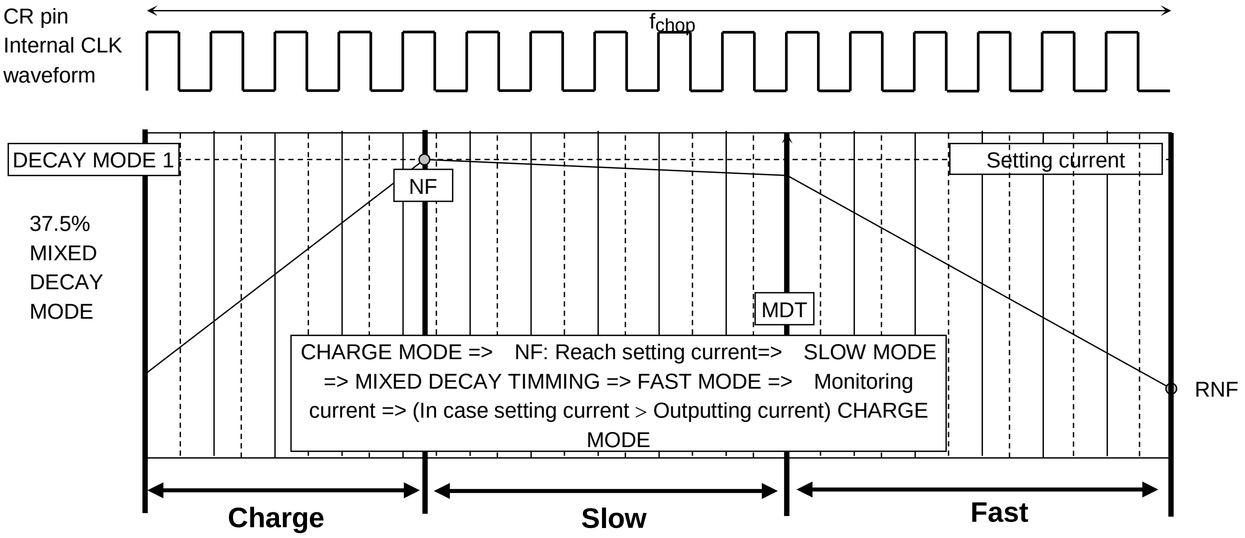


Figure 5.1 Mixed Decay waveform

6. Switching characteristics

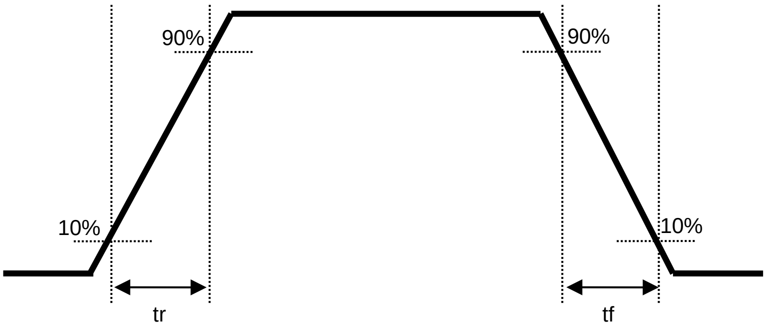


Figure 6.1 Switching characteristics

Table 6.1 Switching characteristics

T_a = 25°C, VM = 24 V, No load

Item	Typ.	Unit
tr	120	ns
tf	70	ns

7. Function explanation

7.1. Function of motor drive mode selection

Motor drive modes can be selected depending on the type of motors to be driven.

The configuration of H-bridge drivers and control category are changed according to the selected mode.

There is basically no need to change drive modes during motor operation. Thus, the TB67H452FTG does not support dynamic mode switching.

Changing the settings of these pins changes the functions and timing of control pins.

The setting of mode select pins must not be changed after the TB67H452FTG is powered on.

MODE0 pin	MODE1 pin	MODE2 pin	Drive Mode
H	H	H	Stepping Motor (S) × 2
L	H	H	DC Motor (L) (Combination) × 2
H	L	H	Stepping Motor (L) (Combination) × 1
L	L	H	DC Motor (S) × 4
H	H	L	DC Motor (L) (Combination) × 1 + Stepping Motor (S)
L	H	L	DC Motor (S) × 2 + Stepping Motor (S)
H	L	L	Inhibited (For Toshiba testing only)
L	L	L	Standby mode

- **Brushed DC motor mode**
  This mode is used to drive brushed DC motors.
  The tBLANK time can be specified as a fixed analog value, or as four OSC cycles in digital tBLANK mode, where OSC is a reference signal for chopper circuit.
  When DC motors are driven under PWM control, a discharge current spike can occur due to a varistor. To prevent this current spike from erroneously tripping the constant-current sensor, the constant-current sensor is digitally blanked for a period of time that is determined by tBLANK, which is derived from the OSC signal.
  Using this blanking function enables constant-current limiter control, as well as external PWM control. An over-current can be observed only during blank times.

- **Stepping motor mode**
  This mode is used to drive stepping motors.
  The tBLANK time is specified as a fixed analog value (about 550 ns).

- **Combination mode**
  The Combination mode, such as DC Motor (L) and Stepping Motor (L) modes, can be selected when two units of H-bridges with the same characteristics are operated in parallel.
  In this mode, the actual ON-resistance is reduced by half while the current capability is doubled. (Specifications actually include the thermal capacitance as well. See electrical characteristics for more details.)
  To use this mode, the power supply, ground, and output pins that have identical names should be shorted together on the board.
  At the same time, the wirings of a board should be routed to balance the impedance at each pin. Otherwise, the shorted pins may experience a current imbalance and more current may flow into either one of them than the other.

7.2. Control signal functions in brushed DC motor mode

Control Input			State of the output stage		
X ch IN1	**X ch IN2**	**X ch PWM**	**OUT_X+**	**OUT_X-**	**Mode**
H	H	H	L	L	Short brake
		L			
L	H	H	L	H	Forward/reverse
		L	L	L	Short brake
H	L	H	H	L	Reverse/forward
		L	L	L	Short brake
L	L	H	OFF (Hi-Z)	OFF (Hi-Z)	Stop
		L			

Note: "X" means the ellipsis of A, B, C, and D of each channel (X ch IN1, X ch IN2, X ch PWM, OUT_X+, and OUT_X-).

Note: When X ch PWM function is not used, fix this pin to high level.

- **External PWM control function**
  The motor speed can be controlled by applying 0 V and 5 V (higher than TTL level) PWM signals to the PWM pin.
  In PWM mode, the PWM chopper circuit alternates between on and short brake.

  When the PWM speed control is not required, the PWM pin (short brake pin) should be held High.

  When the constant-current limiter is used, the TB67H452FTG enters 37.5% Mixed Decay mode after an output current reaches the predefined current value. Since the dead band time is internally inserted to prevent a shoot-through current eliminating, the special arrangement is not required.

The short brake function is disabled in Stepping Motor mode (Large or Small).

Stepping motors can also be driven in Brushed DC motor mode.
To perform such operation, the short brake function should not be used and the D_tBLANK pin should be set Low.
At the same time, input signal functions should also be confirmed.

7.3. D_tBLANK function (DC motor MODE only)

D_tBLANK_AB D_tBLANK_CD	Motor drive mode
L	OFF: Digital tBLANK Time = OSC × 0
H	ON: Digital tBLANK Time = OSC × 4

* If it is set to “L”, only analog tBLANK width can be available.

7.4. Stepping motor mode function

(1)CLK function

The electrical angle leads one by one in the manner of the clocks. The clock signal is reflected to the electrical angle on the rising edge.

CLK_AB CLK_CD	Function
Rise	The electrical angle leads one by one on the rising edge.
Fall	— (Remains at the same position.)

(2)ENABLE function

The ENABLE pin controls whether the current is allowed to flow through a given phase for a stepper motor drive. This pin selects whether the motor is stopped in Off mode or activated. The pin should be fixed to Low at power-on or power-down of the TB67H452FTG.

ENABLE_AB ENABLE_CD	Function
H	Output transistors are enabled (normal operation mode).
L	Output transistors are disabled (high impedance: Hi-Z).

(3)CW/CCW function and output pin function (Output logic at charge starting)

The CW/CCW pin switches rotation direction of stepping motors.

CW_CCW_AB CW_CCW_CD	Input function	OUT (+)	OUT (-)
X	L	OFF	OFF
H	Clock-wise	H	L
L	Counter clock-wise	L	H

X: Don't care

(4)Function of setting step resolution

AB_MODE1 CD_MODE1	AB_MODE2 CD_MODE2	Function
L	L	Fixed electrical angle (Initial setting of Full step: 45°)
L	H	Half step
H	L	Full step
H	H	Quarter step

In the case of AB/CD_MODE1=L, and AB/CD_MODE2=L, the electrical angle is reset and fixed to 45°, which is the initial value in the full step mode.

7.5. Decay switching function (Stepping motor MODE only)

D_tBLANK_AB D_tBLANK_CD	Constant current control mode
L	Mixed Decay:37.5% fixed
H	Mixed Decay:12.5% (During the current decay is 37.5%)

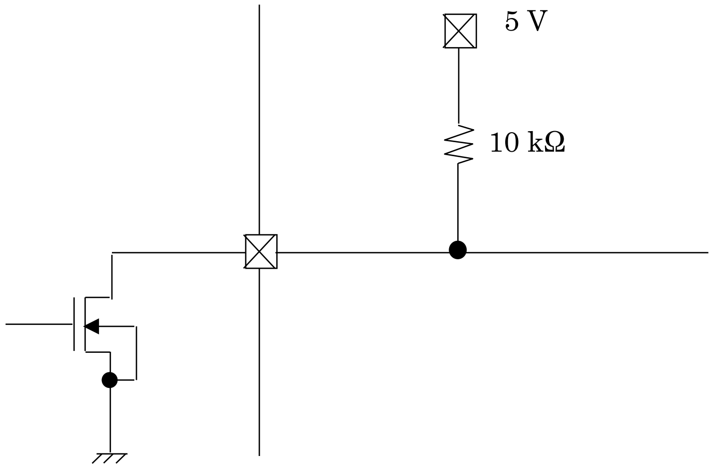
7.6. SLEEP function

To control the SLEEP pin, you can control a low power consumption mode (VCC OFF) and the normal operation mode (VCC ON).
When SLEEP pin is Low, VCC regulator is turned OFF, completely logic will stop.
SLEEP pin is High after the input, it can return to the normal operation mode in 1 ms.

SLEEP	Function
L	low power consumption mode (VCC OFF)
H	normal operation mode (VCC ON)

7.7. ALERT function

The ALERT pin outputs "Low" level when an error state is detected (TSD/ISD operation).



The ALERT is an open drain output pin. When the output pin is pulled up to the VCC with resistance, the Low is output (MOSFET ON) at the Reset, and the High (internal Hi-Z) is output at the non-reset.

Please connect with pull-up to the VCC.

8. Application circuit example

Block diagram (brushed DC motor (S) × 4-channel mode)

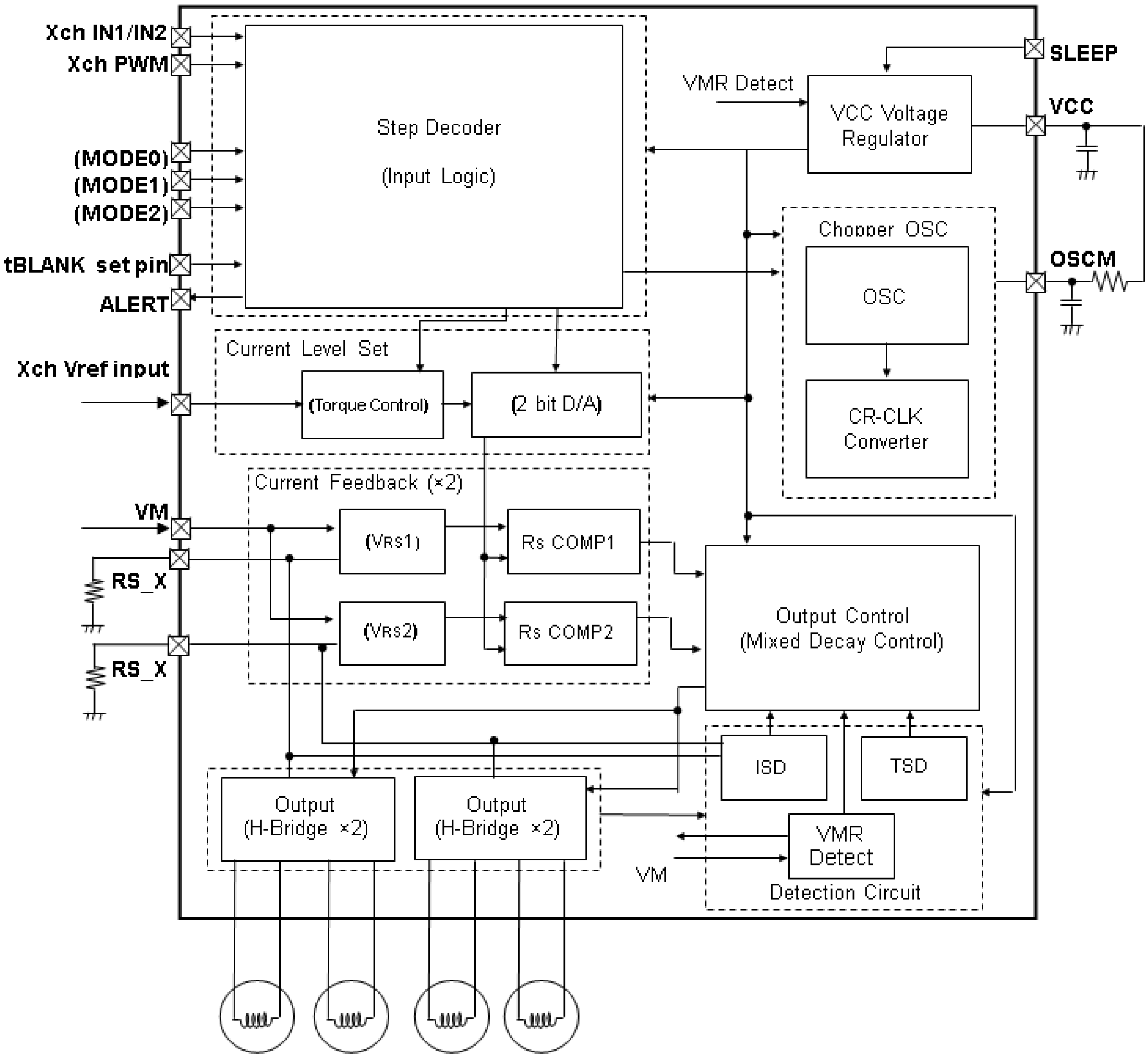


Figure 8.1 Application circuit example

Note: Though pin functions are different depending on the used mode, they are indicated according to the DC(S) ×4 mode in this document.

Note: "X" means the ellipsis of A, B, C, or D of each Ch. (Xch IN1/IN2, Xch PWM, Xch Vref input, and RS_X)

Note: Number of RS pins is 8 in total.

Note: GND wiring: All the grounding wires of the TB67H452FTG should run on the solder mask on the PCB and be externally terminated at only one point. Also, a grounding method should be considered for efficient heat dissipation.

In controlling the setting pins for each mode by SW, those pins should be pulled up to power supply like VCC or pulled down to GND not to go into a high-impedance (Hi-Z) state. Careful attention should be paid to the layout of the output, VM and GND traces, to avoid short circuits across output pins or to the power supply or ground. If such a short circuit occurs, the device may be permanently damaged.
Also, the utmost care should be taken for pattern designing and implementation of the device since it has power supply pins (VM, RS, OUT, GND, etc.) through which a particularly large current may run. If these pins are wired incorrectly, an operation error may occur or the device may be destroyed.
The logic input pins must also be wired correctly. Otherwise, the device may be damaged owing to a current running through the IC that is larger than the specified current.
Careful attention should be paid to design patterns and mountings.

Pin assignment

PIN No.	Pin name	(1) Stepper(S)×2	(2) DC(L)×2	(3) Stepper(L)	(4) DC(S)×4	(5) DC(L)+Stepper(S)	(6) DC(S)×2 + Stepper(S)
1	MO_CD	CDch MO pin	CDch IN 1 Pin	-	Cch IN 1 pin	CDch MO pin	
2	CD_MODE2	CDch step resolution mode setting	-	-	Dch IN 2 pin	CDch step resolution mode setting	
3	OUT_C-	Cch output pin(-)	CDch output pin(-)		Cch output pin(-)		
4	RS_C	Cch sensing Rs connection pin	CDch sensing Rs Connection pin		Cch sensing Rs connection pin		
5	RS_C	Cch sensing Rs connection pin	CDch sensing Rs Connection pin		Cch sensing Rs connection pin		
6	OUT_C+	Cch output pin(+)	CDch output pin(+)		Cch output pin(+)		
7	OUT_D+	Dch output pin(+)	CDch output pin(+)		Dch output pin(+)		
8	RS_D	Dch sensing Rs connection pin	CDch sensing Rs Connection pin		Dch sensing Rs connection pin		
9	RS_D	Dch sensing Rs connection pin	CDch sensing Rs Connection pin		Dch sensing Rs connection pin		
10	OUT_D-	Dch output pin(-)	CDch output pin(-)		Dch output pin(-)		
11	CD_MODE1	CDch step resolution mode setting	-	-	Dch IN 1 pin	CDch step resolution mode setting	
12	VREF_A	Ach Vref input	ABch Vref input		Ach Vref input	ABch Vref input	Ach Vref input
13	VREF_B	Bch Vref input	-		Bch Vref input	-	Bch Vref input
14	VREF_C	Cch Vref input	CDch Vref input		Cch Vref input	Cch Vref input	Cch Vref input
15	VREF_D	Dch Vref input	-		Dch Vref input	Dch Vref input	Dch Vref input
16	OSCM	Setting pin of oscillation circuit frequency for chopping					
17	VCC	Monitoring pin for internal generated 5V bias					
18	GND	GND					
19	VM	VM power input pin					
20	VM	VM power input pin					
21	SLEEP	Sleep pin					
22	ALERT	Alert pin					
23	CLK_AB	ABch CLK input	ABch PWM pin	CLK input	Ach PWM pin	ABch PWM pin	Ach PWM pin
24	ENABLE_AB	ABch ENABLE input	-	ENABLE input	Bch PWM pin	-	Bch PWM pin
25	CLK_CD	CDch CLK input	CDch PWM pin	-	Cch PWM pin	CDch CLK input	CDch CLK input
26	ENABLE_CD	CDch ENABLE input	-	-	Dch PWM pin	CDch ENABLE input	CDch ENABLE input
27	OUT_A-	Ach output pin(-)	ABch output pin(-)		Ach output pin(-)	ABch output pin(-)	Ach output pin(-)
28	RS_A	Ach sensing Rs connection pin	ABch sensing Rs connection pin		Ach sensing Rs connection pin	ABch sensing Rs connection pin	Ach sensing Rs connection pin
29	RS_A	Ach sensing Rs connection pin	ABch sensing Rs connection pin		Ach sensing Rs connection pin	ABch sensing Rs connection pin	Ach sensing Rs connection pin
30	OUT_A+	Ach output pin(+)	ABch output pin(+)		Ach output pin(+)	ABch output pin(+)	Ach output pin(+)
31	OUT_B+	Bch output pin(+)	ABch output pin(+)		Bch output pin(+)	ABch output pin(+)	Bch output pin(+)
32	RS_B	Bch sensing Rs connection pin	ABch sensing Rs connection pin		Bch sensing Rs connection pin	ABch sensing Rs connection pin	Bch sensing Rs connection pin
33	RS_B	Bch sensing Rs connection pin	ABch sensing Rs connection pin		Bch sensing Rs connection pin	ABch sensing Rs connection pin	Bch sensing Rs connection pin
34	OUT_B-	Bch output pin(-)	ABch output pin(-)		Bch output pin(-)	ABch output pin(-)	Bch output pin(-)
35	D_tBLANK_AB	ABch Decay setting pin	tBLANK setting pin	-	tBLANK setting pin	tBLANK setting pin	
36	NC	NC					
37	D_tBLANK_CD	CDch Decay setting pin	tBLANK setting pin	CDch Decay setting pin	tBLANK setting pin	CDch Decay setting pin	
38	MODE2	"H" input fixed	"H" input fixed	"H" input fixed	"H" input fixed	"L" input fixed	"L" input fixed
39	MODE1	"H" input fixed	"H" input fixed	"L" input fixed	"L" input fixed	"H" input fixed	"H" input fixed
40	MODE0	"H" input fixed	"L" input fixed	"H" input fixed	"L" input fixed	"H" input fixed	"L" input fixed
41	VM	VM power input pin					
42	VM	VM power input pin					
43	NC	NC					
44	CW_CCW_AB	ABch CW/CCW pin	ABch IN2 pin	CW/CCW pin	Ach IN2 pin	ABch IN2 pin	Ach IN2 pin
45	MO_AB	ABch MO pin	ABch IN1 pin	MO pin	Ach IN1 pin	ABch IN1 pin	Ach IN1 pin
46	AB_MODE2	ABch step resolution mode setting	-	Mode setting	Bch IN2 pin	-	Bch IN2 pin
47	AB_MODE1	ABch step resolution mode setting	-	Mode setting	Bch IN1 pin	-	Bch IN1 pin
48	CW_CCW_CD	CDch CW/CCW pin	CDch IN2 pin	-	Cch IN2 pin	CDch CW/CCW pin	

* In Large mode, please connect the corresponding pins to each other.

(1) 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 change of the power supply at the high frequency range and the noise can be reduced.

Table 8.1 Recommended capacitor values for power supply pin

Item	Parts	Typ.	Recommended range
VM-GND	Electrolytic capacitor	100 μF	47 to 100 μF
	Ceramic capacitor	0.1 μF	0.01 to 1 μF
VCC-GND	Ceramic / Electrolytic capacitor	1 μF	1 μF
(VREF-GND)	Ceramic capacitor	0.1 μF	0.01 to 1 μF

＊VREF-GND: Connect the capacitor in necessary depending on the usage environment.
＊It is possible to use the capacitor, which is not the recommended capacitor, depending on the motor load condition and the design pattern of the board.

(2) Resistance of current detection

This IC configures the threshold of the constant current detection by connecting the resistance of current detection between VM and RS pins. The detection resistance is recommended to connect near the IC. (The motor can be controlled with the accurate current because the influence of the wire resistance of the board can be reduced.)

Table 8.2 Recommended resistance values for current detection

Item	Parts	Typ.	Recommended range
VM-RS	Chip / Lead resistance	0.22 Ω (0 to 2.0 A)	0.22 to 1.0 Ω

The relation equation of the threshold of the constant current detection, Vref voltage, and the resistance of RS detection is as follows;

$$Iout(max) = Vref(gain) \times \frac{Vref(V)}{R_{RS}(\Omega)}$$

Vref(gain): Vref decay ratio is 1 / 5.0(typ.).

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

- When the detection resistance is low, the difference voltage between VM and RS comparing to the internal reference voltage becomes small. So, the current may be largely different from the configured current value.
- When the detection resistance is high, the power applied to the detection resistance increases in motor operation (P=I^2×R). So, in case the same current flows as the case of low resistance, the power dissipation should be larger.

(3) Resistance for monitor pin

This IC has two open-drain pins of MO_X and ALERT. When internal MOSFET is turned off, it is high impedance as a pin level. In order to operate the IC with accurate high and low levels, connect the pull-up resistance to the power supply of 3.3 V or 5 V in using.

Table 8.3 Recommended resistance for monitor pin

Item	Parts	Typ.	Recommended range
MO_X, ALERT (3.3 V or VCC)	Chip / Lead resistance	10 kΩ	10 to 100 kΩ

Note: "X" means the ellipsis of AB and CD of each channel (MO_X).

(4) Wiring pattern for power supply and GND

Since large current may flow in VM, RS, and GND pattern especially, design the appropriate wiring pattern to avoid the influence of wiring impedance. It is very important for surface mounting package to radiate the heat from the heat sink of the back side of the IC to the GND. So, design the pattern by considering the heat design.

(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 detection circuit to not operate properly or IC breakdown before operation. In addition, depending on the method of use and usage conditions, if over current continues to flow for a long time after operation, the IC may generate heat resulting in breakdown.
To avoid above IC destruction and malfunctions caused by noise, the over current detection circuit has a dead band time. So, it is concerned that the over current detection circuit may not operate depending on the output load conditions because of the dead band time. Therefore, in order to avoid continuing this abnormal state, use the fuse for the power supply line.

(6) Abnormality detection function

- Thermal shutdown circuit (TSD)
  When the IC detects an over temperature, the internal circuit turns off the output MOSFETs. It has a dead band time to avoid TSD misdetection, which may be triggered by external noise. Reassert the VM power supply or use the standby mode by MODE pin to release this function. The TSD is triggered when the device is over heated irregularly. Make sure not to use the TSD function aggressively.

- Over current detection (ISD)
  When the IC detects an over current, the internal circuits turns off the output MOSFETs. It has a dead band time to avoid ISD misdetection, which may be triggered by external noise. Reassert the VM power supply or use the standby mode by MODE pin to release this function.

Dead band time of ISD

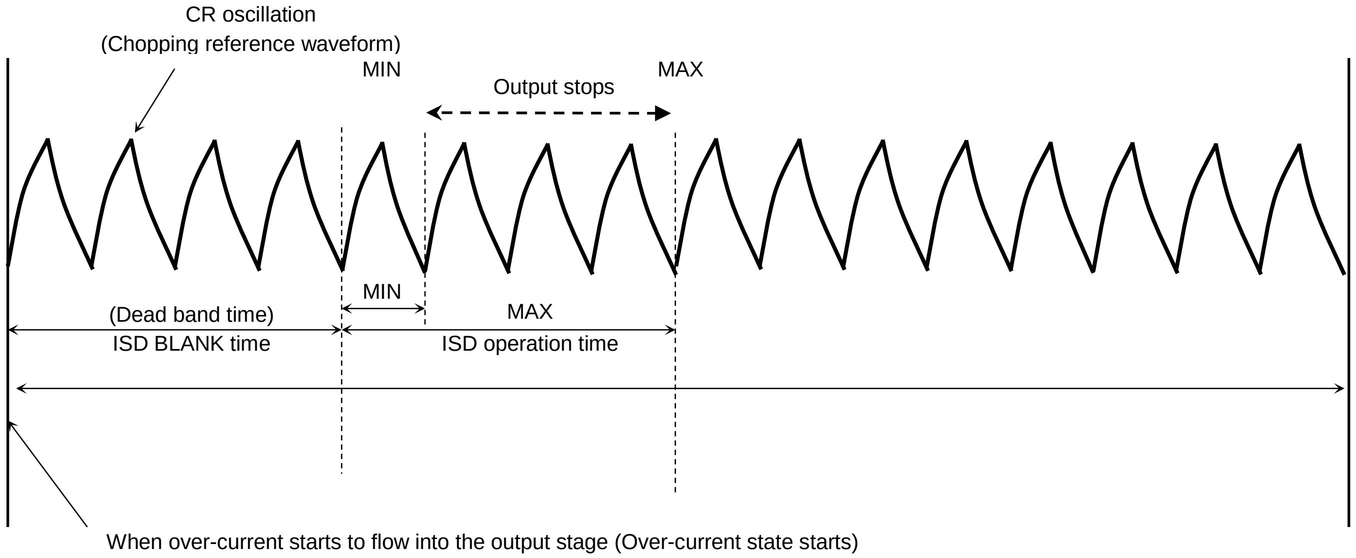


Figure 8.2 Dead band time of ISD

Timing charts may be simplified for explanatory purposes.

The over-current detection circuit has a dead band time to prevent erroneous detection of I_{RR} or spike current at switching. The dead band time being synchronized with the frequency of the OSC for setting chopping frequency is expressed as follows.

Dead band time =4 × CR time

Time required to stop the output after over-current flows into the output stage is expressed as follows.

Minimum time: 4 × CR time

Maximum time: 8 × CR time

Note that the above-mentioned operating times are achieved only when over-current flows as it is expected. Depending on the timing of output control mode, the circuit may not be triggered.

Thus, to ensure safe operation, please insert a fuse in the motor power supply.

The capacity of the fuse is determined according to the usage conditions. Please select one whose capacity does not exceed the power dissipation for the IC to avoid any operating problems.

9. Power consumption of the IC

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

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

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

P(out) =Number of H-Bridge × Iout (A) × VDS (V) = 2 (ch) × Iout (A) × Iout (A) × Ron (Ω)............(1)

When the current waveform of the motor output corresponds to the ideal waveform (2-phase excitation / square wave), average power of output block can be provided as follows;

When Ron = 0.6 Ω, Iout (peak: Max) = 1.5 A, VM = 24 V
P(out) = 2 (ch) × 1.5 (A) × 1.5 (A) × 0.6(Ω)...(2)
= 2.7 (W)

When the maximum resolution capability of the TB67H452FTG (W1-2 phase, 4 steps) is configured by using μ-stepping function, the average power is about 71% (= 1/√2) and P(out) is 1.35 (W).

- Power consumption of logic and IM systems.
  Power consumptions of logic and IM systems are calculated by separating the states (operating and stopping).

I (IM3) = 8.0 mA (typ.) : Operating
I (IM2) = 3.5 mA (typ.) : Stopping

Output system is connected to VM (24 V). (Output system: Current consumed by the circuit connected to VM + Current consumed by switching output steps)

Power consumption is calculated as follows;

P(bias) = 24 (V) × 0.008 (A)...(3)
= 0.192 (W)

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

P(total) = P(out) + P(bias) = 2.7 + 0.192 = 2.892 (W)

Standby mode is released. The power consumption in non-operation mode of the motor (waiting mode) is calculated as follows;

P = 24 (V) × 0.0035 (A) = 0.0840 (W)

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

10. Power dissipation

Relation equation of the ambient temperature (Ta), junction temperature (Tj), and the heat resistance (Rth(j-a)) between junction temperature to ambient temperature is as follows;

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

(Example)
When 4-layer mounting board (Rth(j-a) = 25°C/W), Ta = 25°C, P(total) = 2.892 W (Iout = 1.5 A, 2-phase excitation) T_j = 25 (°C) + 25 (°C/W) × 2.892 (W) = 97.3°C

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

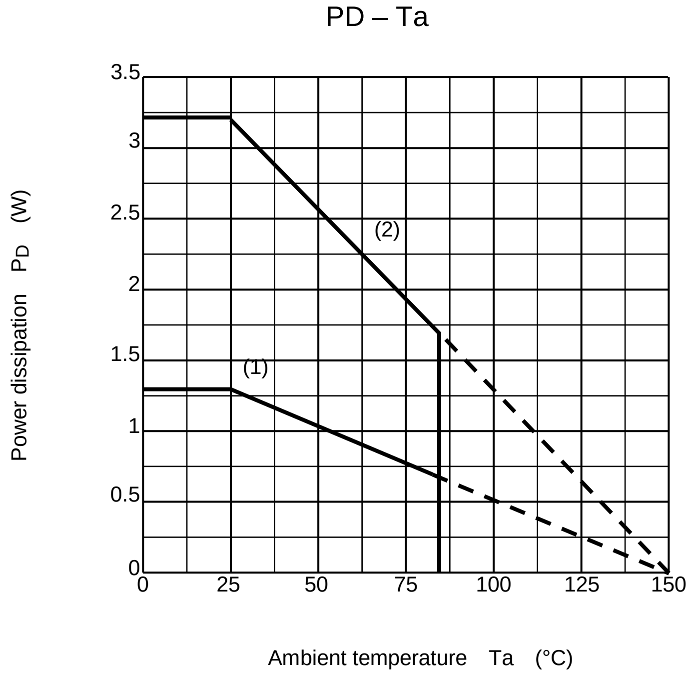


Figure 10.1 Power dissipation

(1) Rth(j-a) IC only (113°C /W)
(2) When dedicated board is mounted (100 mm × 200 mm × 1.6 mm 2 layer: 37°C /W (typ.))

* 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.

11. Board dimensions

Brushed DC motor (S)×4-channel mode

11.1. Input/ Main part

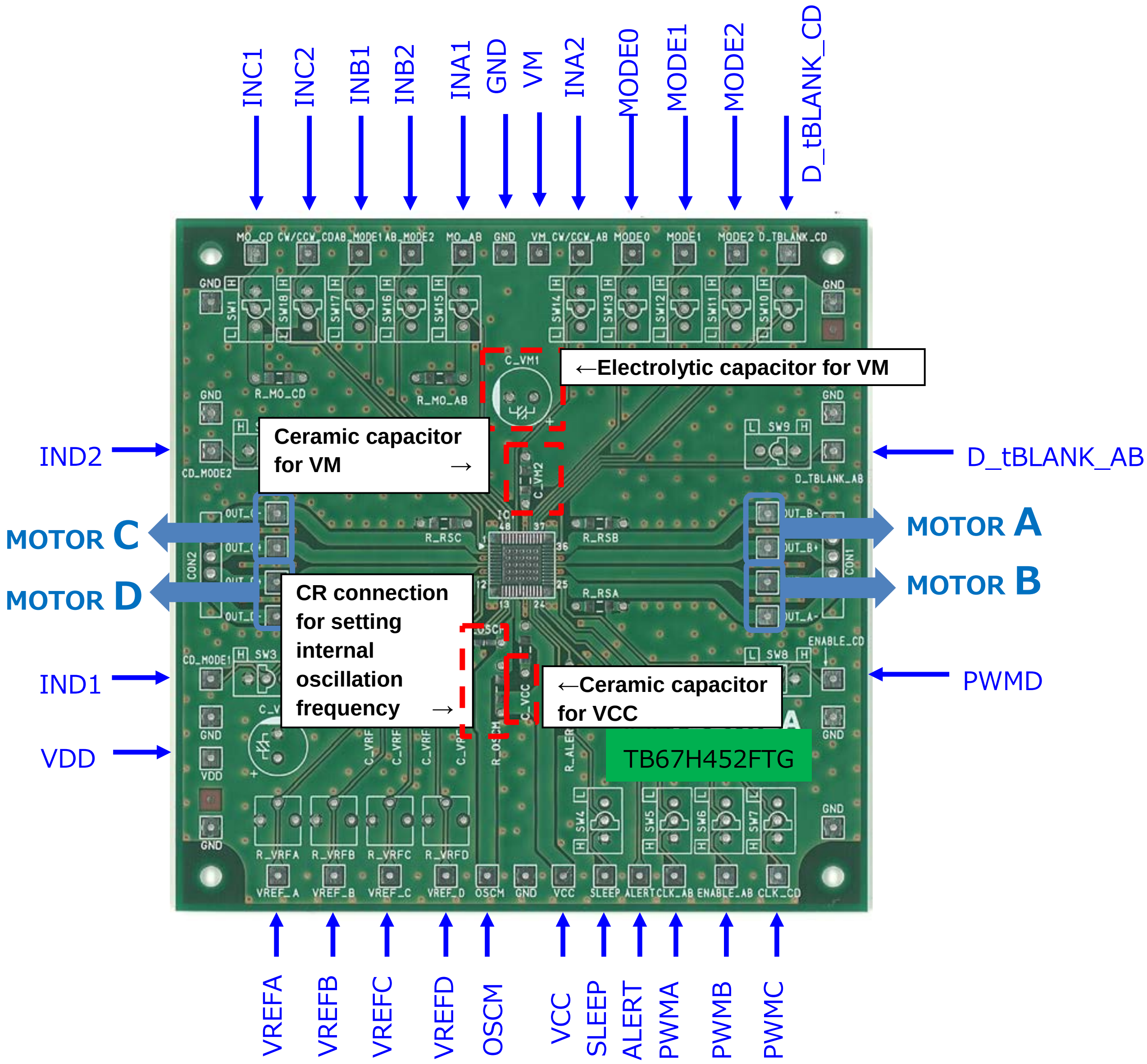


Figure 11.1 Input / Main part

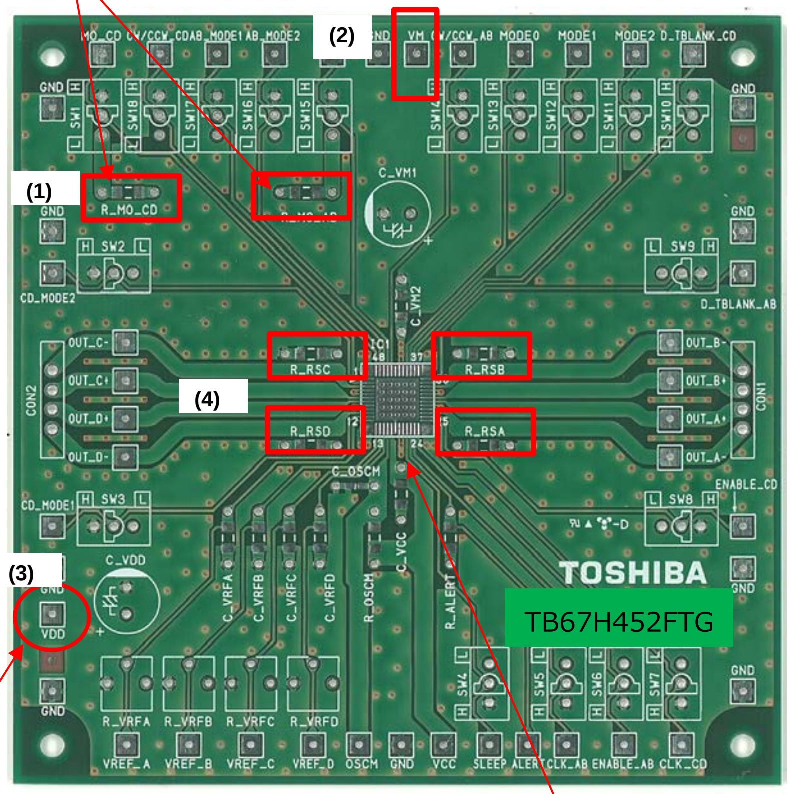
Input each power supply and control signal according to above figure.
Please connect each component by referring to "8. Application circuit example".

11.2. Notes in assembling board

When using Toshiba's evaluation board, pay attention to the followings.

(1) In using DC motor mode, connect them directly. In using as MO monitoring pin in the stepping motor mode, connect a pull-up resistor.

(2) VM single-power drive is possible because 5-V regulator is incorporated. (Applying 5 V to VCC is unnecessary.)



(3)Power supply of a control pin for switching.
When VCC is not used for the switch and the resistor, apply voltage of 5 V.

(4)Connect RS resistor in case of using constant current PWM mode.
Otherwise, short circuit and connect them to GND.

12. Foot patter example (for reference only)

(1) QFN48 foot pattern example (unit: mm)

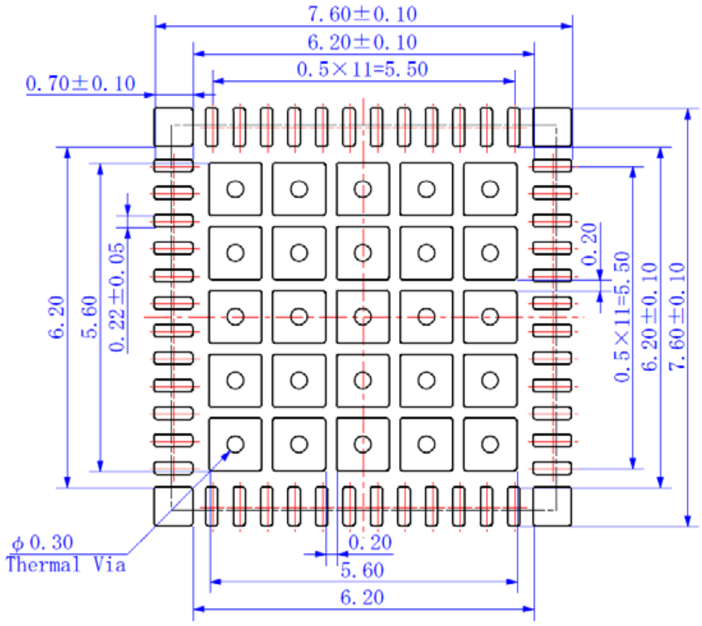


Figure 12.1 QFN48 foot pattern example

Toshiba does not guarantee the data for mass production. Please use the data as reference data for customer's application.
In determining the size of mounting board, design the most appropriate pattern by considering the solder bridge, the solder connecting strength, the pattern accuracy in making board, and tpinhe 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.
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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 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 device breakdown, damage or deterioration, and may result in injury by explosion or combustion.
In addition, do not use any device inserted in the wrong orientation or incorrectly to which current is applied even just once.

(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 from 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 may cause smoke or ignition. (The overcurrent may 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) Overcurrent detection Circuit
Overcurrent detection circuits (referred to as current limiter circuits) do not necessarily protect ICs under all circumstances. If the overcurrent detection circuits operate against the overcurrent, clear the overcurrent status immediately.
Depending on the method of use and usage conditions, exceeding absolute maximum ratings may cause the overcurrent detection circuit to operate improperly or IC breakdown may occur before operation. In addition, depending on the method of use and usage conditions, if overcurrent 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, exceeding absolute maximum ratings may cause the thermal shutdown circuit to operate improperly or IC breakdown to occur before operation.

(3) Heat Radiation Design
When using an IC with large current flow such as power amp, regulator or driver, design the device so that heat is appropriately radiated, in order not to exceed the specified junction temperature (TJ) at any time or under any 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, when designing the device, take into consideration the effect of IC heat radiation with peripheral components.

(4) Back-EMF
When a motor rotates in the reverse direction, stops or slows abruptly, current flows back to the motor's power supply owing 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 the absolute maximum ratings. To avoid this problem, take the effect of back-EMF into consideration in system design.

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