TB67S279FTG
TB67S289FTG
TB67S249FTG
Usage considerations

Main Specifications

Product number	TB67S279FTG / TB67S289FTG / TB67S249FTG
Control I/F	CLOCK-IN
Absolute maximum ratings	50 V, 2 A (TB67S279FTG), 3 A (TB67S289FTG), 4.5 A (TB67S249FTG)
Package	QFN48
Step resolution	Full, Half (a)/(b), Quarter, 1/8, 1/16, and 1/32 step resolution
Other features	Adoption of AGC, ADMD, and ACDS architectures Built-in error detection functions (thermal shutdown, over current protection, under voltage lock out, and motor load open detection) Built-in error detection signal output function Support the power-on sequence by the single power drive Automation oscillation circuit which does not require components

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

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Table of Contents

Main Specifications 1
Table of Contents 2
Overview 6
1. Power Supply Voltage 6
1.1. Power supply voltage and operation range 6
2. Power Supply Sequence 7
3. Output Current 8
4. Control Logic Input 8
5. Constant Current Control 8
5.1. Setting Constant current threshold 8
5.2. Setting internal oscillation frequency (f_{OSCM}) and constant current PWM (chopping) frequency (f_{chop}) 9
5.2.1. Function of internal oscillation circuit: Elimination of external components 10
5.2.2. Notes in using the component-elimination drive function of the OSCM pin 10
5.3. Constant current waveform when chopping frequency changes 11
6. Output Switching Characteristics 12
7. Function Explanation 13
7.1. CLK function 13
7.2. ENABLE function 13
7.3. CW/CCW function 13
7.4. RESET function 14
7.5. MO (Monitor Output: electrical angle output) function 15
7.6. Step resolution setting 15
7.7. AGC (Active Gain Control) 16
7.7.1. AGC0 and AGC1 functions 16
7.7.2. CLIM (AGC bottom current limit) function 17
7.7.3. BOOST (current boost) function 18
7.7.4. FLIM (AGC frequency limit) function 19
7.7.5. LTH (AGC detection threshold) function 19
8. IC Signal Output Function 20
8.1. LO1, LO2 (Error Output: Error detect flag output) function 20
9. Application Circuit Example 21
10. External Component Description 22
10.1. Capacitors for power supply pins 22
10.2. Internal oscillation frequency 23
10.3. Resistor for monitor pins 25
10.4. Layout pattern for power supply and GND 25
10.5. Fuse 25
10.6. Error detection function 26

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10.6.1. Thermal shutdown circuit (TSD) 26
10.6.1.1. Deadband time of thermal shutdown circuit 26
10.6.2. Over current protection (ISD) 26
10.6.2.1. Deadband time of over current protection 26
11. Power Consumption of the IC 27
12. Power dissipation 28
13. Foot Pattern Example 29
14. Board dimensions (Toshiba Evaluation board) 30
14.1. Input/Output 30
14.2. Main parts 31
14.3. Options 32
14.4. Board circuit diagram 33
14.5. SVF pin 34
Notes on Contents 35
IC Usage Considerations 36
Notes on handling of ICs 36
Points to remember on handling of ICs 37
RESTRICTIONS ON PRODUCT USE 38

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Figures

Figure 2.1 Power supply voltage and operation range 7
Figure 5.1 Relation of OSCM pin oscillation waveform and internal OSCM oscillation waveform 9
Figure 5.2 Chopping frequency (100 kHz) 11
Figure 5.3 Chopping frequency (72 kHz) 11
Figure 6.1 Switching characteristics 12
Figure 7.1 MO function Equivalent Circuit 15
Figure 8.1 LO function Equivalent Circuit 20
Figure 9.1 Application Circuit Example 21
Figure 10.1 Graph of R_{OSC} and f_{OSCM} (reference data/measurement data example) 24
Figure 10.2 Graph of R_{OSC} and f_{chop} (reference data/measurement data example) 24
Figure 12.1 Power dissipation 28
Figure 13.1 QFN48 foot pattern example 29
Figure 14.1 Input /Output 30
Figure 14.2 Main parts 31
Figure 14.3 Options 32
Figure 14.4 Board circuit diagram 33
Figure 14.5 Circuit diagram of SVF pin 34

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Tables

Table 1.1 Operation ranges of power supply voltage (Ta=-20 to 85°C) 6
Table 6.1 Switching characteristics 12
Table 7.1 CLK function 13
Table 7.2 ENABLE function 13
Table 7.3 CW/CCW function 13
Table 7.4 RESET function 14
Table 7.5 Phase current at RESET 14
Table 7.6 MO function 15
Table 7.7 DMODE function 15
Table 7.8 AGC0 and AGC1 functions 16
Table 7.9 CLIM function 17
Table 7.10 BOOST function 18
Table 7.11 FLIM function 19
Table 7.12 Frequency limit threshold 19
Table 7.13 LTH function 19
Table 8.1 LO function 20
Table 10.1 Recommended capacitor values for power supply pins 22
Table 10.2 Relation of external resistor (ROSC) and internal oscillation frequency (f_{OSCM}), chopping frequency (f_{chop}) (for reference only) 23
Table 10.3 Recommended resistor values for monitor pins 25

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Overview

TB67S279FTG, TB67S289FTG, and TB67S249FTG can control a single 2-phase bipolar stepping motor. This series supports from 12 V to 42 V power supply and large-current drive for motors by adopting 50 V monolithic analog process (BiCD: Bipolar CMOS DMOS).
The specification differences between TB67S279FTG, TB67S289FTG, and TB67S289FTG are output capabilities (Ron and Iout capability), Gain (VREF (gain)) that determines the constant current level, and over current detection (ISD) threshold. Pin assignments are same.
CLK-In Decoder for micro stepping drive is incorporated, allowing motors to drive with sine-wave current by inputting CLK signals. It realizes fast and accurate current following with ADMD (Advanced Mixed Decay Mode).
Also, external components can be eliminated by adopting ACDS (Advanced Current Detection System) and the component-elimination mode of the internal oscillation circuit. The key feature of the ICs is AGC (Active Gain Control: anti-stall function) technology. enabling high-efficiency motor drive while preventing motor stalls.
Usage methods and notes in using the IC are described from the next section.

1. Power Supply Voltage

1.1. Power supply voltage and operation range

In using TB67S279FTG, TB67S289FTG, and TB67S249FTG, the voltage should be applied to the pins of VM (VMA, VMB) and VREF (VREFA, VREFB).
Built-in VCC regulator for internal logic power supply enables the IC to operate with a single power supply. Applying an external voltage is unnecessary. The maximum rating of the motor supply voltage is 50 V. Its operation voltage range is 10 V to 47 V.
The maximum voltage rating, which is applied to VREF pin for constant current value, is 5 V. Its operation range is 0 to 3.6 V.
VREF is configured by voltage of VCC regulator and can be set by dividing voltage in necessary. However, if the current value exceeds the capability of the VCC regulator, the output voltage may not be maintained.
Therefore, when VREF is applied by dividing VCC, the voltage-dividing resistance (combined resistance of VCC and GND) should be in the range of 10 kΩ to 100 kΩ.

Table 1.1 Operation ranges of power supply voltage (Ta=-20 to 85°C)

Item	Symbol	Absolute maximum ratings	Operation range	Unit	Remarks
Motor power supply voltage	VM	50	10 to 47	V	—
Constant current threshold setting voltage	VREF	5.0	0 to 3.6	V	—
Voltage for internal logic power supply	VCC	6.0	4.75 to 5.25	V	Supplied by internal regulator

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2. Power Supply Sequence

There are no special procedures between power sources in powering on and shutdown because TB67S279FTG, TB67S289FTG, and TB67S249FTG can operate with a single power supply by the VCC regulator. Moreover, built-in under voltage detections (UVLO and power on reset function (POR)) avoid malfunction, which occurs at the UVLO/POR detection threshold or less. While POR is activated, the internal logic is initialized. The UVLO/POR detection threshold is as follows; in startup = 7.5 V±1.0 V, in shutdown = 7.0 V±1.0 V, and the hysteresis = 0.5 V (typ.).

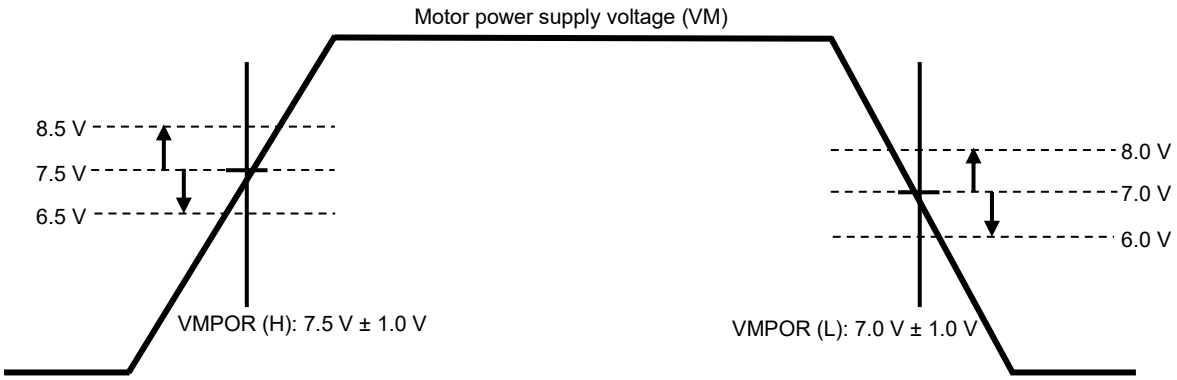


Figure 2.1 Power supply voltage and operation range

3. Output Current

Output current value for the motor depends on the power consumption that refers to the voltage drop at the on resistance of the output circuit. From the above, the absolute maximum current rating of each IC is as follows; 2 A (TB67S279FTG), 3 A (TB67S289FTG), and 4.5 A (TBS249FTG). These ratings must not be exceeded, even for a moment.
The actual-usage maximum current is limited depending on the usage conditions (the ambient temperature, the layout pattern of the board, the radiation path, the exciting design, etc.). Therefore, configure the most appropriate current value after calculating the heat and evaluating the board under the operating environment.
Moreover, the IC drives the motor with constant-current control by ACDS technology. Recommended lower current limit for appropriate motor operation is as follows; TB67S279FTG: 0.5 to 1.0 A, TB67S289FTG: 1.0 to 1.5 A, and TB67S249FTG: 1.5 to 2.0 A. When the configured current is too small in using large-current drive devices, malfunctions such as offset may occur.

4. Control Logic Input

The IC can avoid malfunctions occurred by the electromotive force, which generates when the control logic signal is input without VM voltage.
However, it is recommended to set the control logic input signals to low level while VM is not supplied. Configure the control logic signal low level during powering on and shutdown (refer to “2.1 Power supply voltage and operation range”) and input the operation signal after VM and VREF reach the operation voltage range.

5. Constant Current Control

5.1. Setting Constant current threshold

TB67S279FTG, TB67S289FTG, and TB67S249FTG can configure the constant current PWM threshold only by the applied voltage to the VREF pin. External current detection resistor is not required. (ACDS technology)
The current value (I_{out}) of TB67S279FTG, TB67S289FTG, and TB67S249FTG can be approximated from below formulas.

$I_{out} = V_{REF} \times 0.556$ (TB67S279FTG)
$I_{out} = V_{REF} \times 0.833$ (TB67S289FTG)
$I_{out} = V_{REF} \times 1.250$ (TB67S249FTG)

VREF gain of each IC is as follows;
TB67S279FTG: 0.556 (typ.)
TB67S289FTG: 0.833 (typ.)
TB67S249FTG: 1.25 (typ.)

Then, when the voltage of 2 V is input to VREF pin in using TB67S289FTG, setting current is as follows;

$I_{out} = 2\ V \times 0.833 = 1.67\ A$ (typ.)

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5.2. Setting internal oscillation frequency (f_{OSCM}) and constant current PWM (chopping) frequency (f_{chop})

TB67S279FTG, TB67S289FTG, and TB67S249FTG can set the internal oscillation frequency (f_{OSCM}) and the PWM (chopping) frequency (f_{chop}) with the constant numbers of the external components (resistor and capacitor), which are connected to OSCM pin.
The internal oscillation frequency can be set by connecting the resistor (ROSC) between VCC and OSCM pin, and connecting the capacitor (COSC) between OSCM pin and GND. Please set it by changing the ROSC value, while fixing the COSC value to 270 pF.
The relational expression of the internal oscillation frequency (f_{OSCM}) and the external resistance (ROSC) are as follows (COSC = 270 pF);

$$f_{OSCM} = 4.0 \times ROSC^{-0.8}$$

Note: Unit: f_{OSCM} (MHz) and ROSC (kΩ)

Refer to the following graph for the relation of the external component and the measured data of the internal oscillation frequency (reference data).

The relational expression of the internal oscillation frequency (f_{OSCM}) and the constant current PWM (chopping) frequency (f_{chop}) is as follows;

$$f_{chop} = f_{OSCM} / 16$$

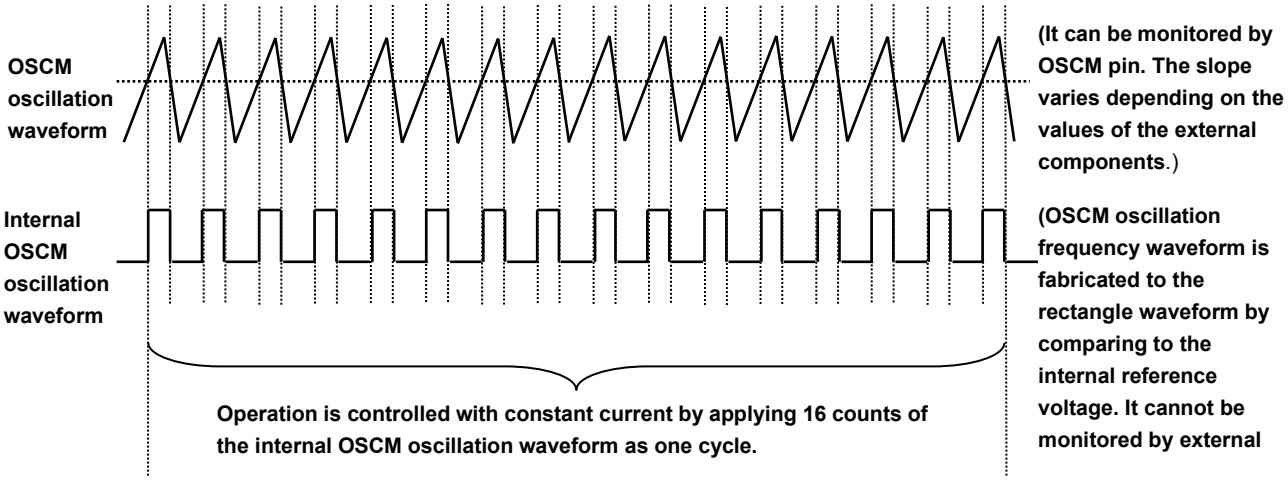


Figure 5.1 Relation of OSCM pin oscillation waveform and internal OSCM oscillation waveform

5.2.1. Function of internal oscillation circuit: Elimination of external components

The internal oscillation circuits of TB67S279FTG, TB67S289FTG, and TB67S249FTG have the function of eliminating external components.

As mentioned previously, the oscillation frequency can be changed arbitrarily by connecting external components (resistor and capacitor) to the OSCM pin and adjusting their constant numbers. Also, the motor can be controlled by internal fixed frequency without using external components.

When using this function, remove both resistor and capacitor and connect the OSCM pin to GND.

When the IC recognizes that the OSCM pin is short-circuited, the internal oscillation circuit switches to use the external component eliminating mode.

In this mode, configuration of the internal oscillation frequency (f_{OSCM}) is about 930 kHz and of the constant current PWM (chopping) frequency (f_{chop}) is about 60 kHz that is 1/16 of f_{OSCM}.

5.2.2. Notes in using the component-elimination drive function of the OSCM pin

This function is activated when judging period of 20 μs (typ.) has passed after both POR and STANDBY are released.

If the signal is input during this judging period, it may not be reflected correctly.

Therefore, do not input control signals during this period.

Moreover, while the motor is operating, be sure to fix OSCM mode to either the normal drive mode or the external-component elimination mode. Switching the OSCM mode during motor operation is prohibited.

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5.3. Constant current waveform when chopping frequency changes

The chopping frequency (f_{chop}) is recommended to be set to approximately 67 kHz when using the IC. Increasing the chopping frequency reduces motor current ripple and improves waveform quality. However, it also increases switching losses, resulting in higher heat generation.
Select a higher chopping frequency to prioritize waveform quality, or a lower frequency to reduce heat generation.

Example 1: When chopping frequency (f_{chop}) = 100 kHz,

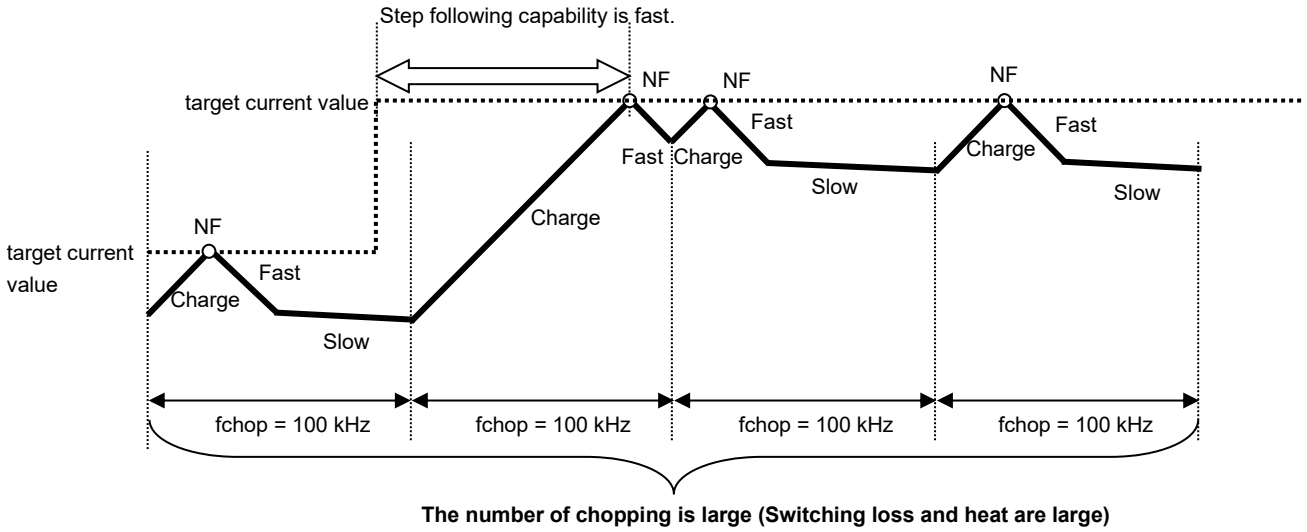


Figure 5.2 Chopping frequency (100 kHz)

Example 2: When chopping frequency (f_{chop}) = 72 kHz,

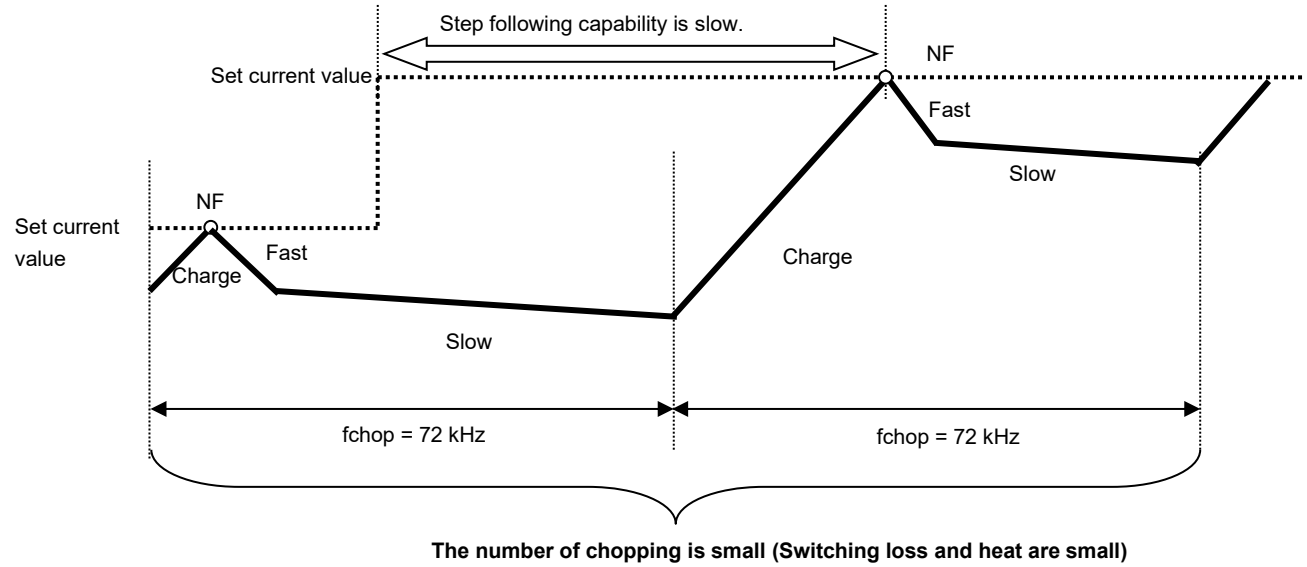


Figure 5.3 Chopping frequency (72 kHz)

Generally, it is recommended to use the IC with the frequency range of 50 kHz to 120 kHz based on 67 kHz as a typical value.

6. Output Switching Characteristics

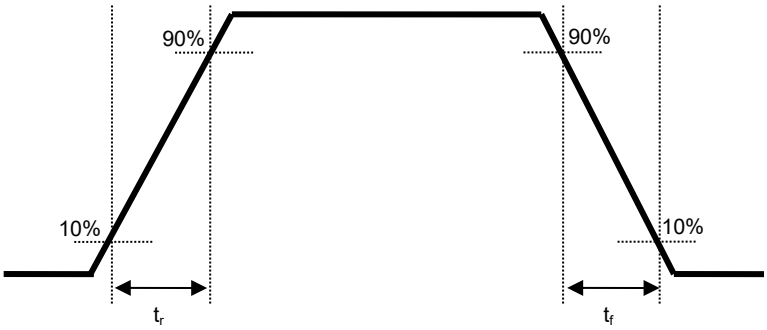


Figure 6.1 Switching characteristics

Table 6.1 Switching characteristics

Ta = 25°C, VM = 24 V, No load (Example of TB67S249FTG)

Item	Typ.	Unit
t_r	80	ns
t_f	90	ns

Note: Confirm the electrical characteristics of the data sheet for each value.

7. Function Explanation

This chapter describes the basic functions of stepping motors.

7.1. CLK function

An electrical angle advances one unit according to the driving mode, which is configured by each pulse of CLK signal. Each signal is reflected at upper edge of CLK signal.
The analog filter of 200 ns (±20%) is implemented for CLK pin to avoid malfunction due to noise.
Duty of CLK signal is not necessary to set 50 %. However, pay attention to configure the maximum frequency of the CLK signal in considering this analog filter of 200 ns.
When the state of inputting upper edge signal continues due to noise, upper edge signal is reflected after the filtering period. In this case, the motor may stall because the electrical angle advances according to the below function regardless of the signal reflecting state. Pay attention to design the wiring layout for CLK pin not to be influenced by noise.

Table 7.1 CLK function

CLK	Function
Rising edge	Shifts the electrical angle and current step on each rising edge.
Falling edge	— (no change, maintain former state)

7.2. ENABLE function

This function switches the ON/OFF state of the output circuits of the IC. When set to ON, motor operation (current output) starts; when set to OFF, motor operation stops. In the OFF state, all output MOSFETs are turned off and the outputs become high impedance. To prevent motor operation outside the VM operating voltage range, it is recommended to keep ENABLE set to low during power on and shunt down sequences, and to switch it to high after the VM voltage is stabilized at the intended operating voltage.

Table 7.2 ENABLE function

ENABLE	Function
High	Motor operation: ON (Normal operation)
Low	Motor operation: OFF (Hi-Z)

7.3. CW/CCW function

This function controls the rotation direction of the stepping motor. When CW/CCW pin is set to high level, the current of Ach leads the current of Bch by 90-degree phase difference. resulting in clockwise rotation. When CW/CCW pin is set to low level, the current of Bch leads the current of Ach by 90-degree phase difference. resulting in counterclockwise rotation.

Table 7.3 CW/CCW function

CW/CCW	Function
High	Clock-wise: The current of Ach leads the current of Bch by 90-degree phase difference.
Low	Counter clock-wise: The current of Bch leads the current of Ach by 90-degree phase difference.

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7.4. RESET function

This function initializes the internal electrical angle.

Note: Built-in digital filter of 0.625 μs (±20 %) is adopted to RESET pin.

Table 7.4 RESET function

RESET	Function
High	Initializes the internal electrical angle
Low	Normal operation

When the electrical angle is initialized by setting RESET pin to high level, the relation of the current setting for each H-bridge (Ach and Bch) and the electrical angle is shown below. In the case the MO pin level is pulled up, it shows low level (internal open-drain MOSFET turns on) when the electrical angle is initialized.

Table 7.5 Phase current at RESET

Step resolution	Ach current	Bch current	Electrical angle
1/32 step setting	71%	71%	45°
1/16 step setting	71%	71%	45°
1/8 step setting	71%	71%	45°
Half (b) step setting	71%	71%	45°
Quarter step setting	71%	71%	45°
Half (a) step setting	100%	100%	45°
Full step setting	100%	100%	45°

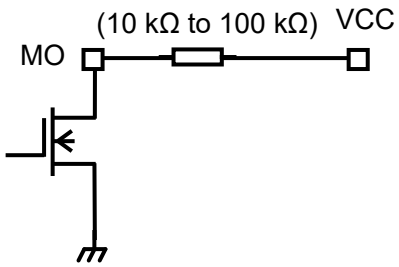
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7.5. MO (Monitor Output: electrical angle output) function

MO pin outputs an internal initial electrical angle as a signal. Since MO pin is an open drain type pin, please pull up this pin to the power supply such as VCC to enable this function. (The pull-up resistor value should be set between 10 kΩ and 100 kΩ.)
MO pin outputs high level with the pulled-up state because it is in high impedance (Hi-Z) state during the normal operation. When the internal electrical angle corresponds to the initial angle, the pin level becomes low (internal open-drain MOSFET turns on) as shown below.
In case MO pin is not used, leave the pin open state or connect it to GND.

Table 7.6 MO function

MO	Function
High (Hi-Z)	Electrical angle is not at the initial position
Low	Electrical angle is at the initial position



If the electrical angle is equal to the initial angle, the internal MOSFET is turned on and the pin voltage level is Low.

If the electrical angle is not equal to the initial angle, the internal MOSFET is turned off and the pin voltage level is High (VCC).

Figure 7.1 MO function Equivalent Circuit

Note: The equivalent circuit diagrams may be simplified or some parts of them may be omitted for explanatory purposes.

7.6. Step resolution setting

Table 7.7 DMODE function

DMODE0	DMODE1	DMODE2	Function
Low	Low	Low	Standby mode (Internal oscillator circuit (OSCM) and output MOSFETs turn off.)
Low	Low	High	Full step resolution
Low	High	Low	Half (a) step resolution
Low	High	High	Quarter step resolution
High	Low	Low	Half (b) step resolution
High	Low	High	1/8 step resolution
High	High	Low	1/16 step resolution
High	High	High	1/32 step resolution

Note: After the standby mode is released, do not input a motor driving signal until the internal circuit becomes stable. (Indication time is 1 ms after the release of the standby mode.)
It is recommended to switch the DMODE0, DMODE 1, and DMODE 2 after the RESET signal is set to low level in the initial state (MO = Low).

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7.7. AGC (Active Gain Control)

AGC is an abbreviation for Active Gain Control that is our original driving technology. When required motor torque is lower than the configured constant current value, the motor can drive efficiently by decreasing driving current. When higher torque is required, motor stall can be prevented by increasing the constant current value.

7.7.1. AGC0 and AGC1 functions

AGC0 pin and AGC1 pin switch ON/OFF of the Active Gain Control (AGC).
When both pins are set to high level, AGC turns on. The motor current is decreased according to the load torque. Upper current limit is determined by VREF.
When pin configuration is (AGC0, AGC1) = (Low, Don't Care), AGC is turned off. The IC can be used as a constant current driver because it operates with the current, which is set by VREF.
The difference between the configurations of (AGC0, AGC1) = (Low, Don't Care) and (AGC0, AGC1) = (High, Low) is waveforms in full step resolution.
AGC monitors the state of each output pin where the current value continues to be zero, and use this monitoring result for internal signal detection. However, in full step resolution drive, continuous period of zero-level current does not exist in principle. Therefore, the IC generates the judging period by controlling a certain period of zero-level current. This period is automatically generated by the IC, so users do not need to control the period externally.
In the case of switching AGC (e.g., fixing AGC0 pin high level and switching AGC1 pin from high to low level.) (Note), zero-level current duration is always provided also in the full step resolution. This reduces the change of current waveforms occurred by turning on or off AGC.
On the other hand, in the case that AGC0 pin is set to low level and AGC1 pin is set 'Don't care', this zero-level current duration is not configured because it is not necessary. In this mode, the IC can be used as a general CLK-In type driver.
Built-in digital filter of 0.625 μs (±20%) is adopted to AGC0 and AGC1 pins.

Table 7.8 AGC0 and AGC1 functions

AGC0	AGC1	Mode	Function	Existence of zero-level current period in full step resolution
High	High	AGC ON mode	Anti-stall function (AGC): ON	Exist
High	Low	AGC Active OFF mode	Anti-stall function (AGC): OFF	Exist
Low	(Don't care)	AGC OFF mode	Anti-stall function (AGC): OFF	No exist

Note: Generally, when using this IC, fix the pin configuration in either (AGC0, AGC1) = (High, High) (i.e., AGC ON mode) or (AGC0, AGC1) = (Low, Don't care) (i.e., AGC OFF mode). When it is necessary to switch the anti-stall function (AGC) on or off during motor driving, use the 'AGC Active OFF mode' by switching the AGC1 pin level.
Do not switch the AGC0 pin level during motor operation.

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7.7.2. CLIM (AGC bottom current limit) function

AGC judges the required torque value and decreases the current value from the constant current, which is set by VREF.
In order to avoid stalls including motor-system stalls, this constant current value should have enough margins.
Since actual required current value for motor driving is generally lower than this set current value, the motor driving current is reduced to the minimum required value (torque value) when AGC is enabled.
However, in the case that the load torque is very small, the set current itself becomes very small. And when the required torque becomes high due to the load fluctuates, its current difference may be very big.
In such cases, when torque is required, it may take time for the current to rise to the required level
As a result, depending on the motor characteristics, a delay in torque response may lead to motor stalling. As a counter measure for above problems, CLIM (Current limit) function prevents the current value from falling too much compared to the set constant current value.
CLIM0 and CLIM1 pins can set the lower current limit in 8 levels. CLIM0 is a 2-state logic input, and CLIM1 is a 4-state logic input.
Usually, it is effective to start the evaluation from the 'Iout × 80%' condition and lower the current limit to determine the margin limit that allows the system operation. This evaluation can be performed by using CLIM0 and CLIM1 setting combinations.
Even when operating the IC with 'Iout × 80%' condition, the power consumption can be saved greatly because it is proportional to the square of Iout.
Built-in digital filter of 0.625 μs (±20%) is adopted to CLIM0 and CLIM1 pins.
This function is disabled when AGC is not used.

Table 7.9 CLIM function

CLIM0	CLIM1	Function
High	Connected to VCC	AGC bottom current limit: Iout × 80%
	Pulled up to VCC with100 kΩ-resistor	AGC bottom current limit: Iout × 75%
	Pulled down to GND with100 kΩ-resistor	AGC bottom current limit: Iout × 70%
	Connected to GND	AGC bottom current limit: Iout × 65%
Low	Connected to VCC	AGC bottom current limit: Iout × 60%
	Pulled up to VCC with100 kΩ-resistor	AGC bottom current limit: Iout × 55%
	Pulled down to GND with100 kΩ-resistor	AGC bottom current limit: Iout × 50%
	Connected to GND	AGC bottom current limit: Iout × 45%

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7.7.3. BOOST (current boost) function

BOOST pin sets the current boost level (i.e., return to the initial constant current setting value) when the load torque increases. BOOST pin is a 4-state logic input pin, setting the compensation value in accordance with the existence of the 100 kΩ-resistor.

In the following table, Mode 1 has the fastest current recovery, and Mode 4 has the slowest one. The "step" of the function in the table means the number of divisions of the current change, indicating that the smaller this value is, the faster the current boosts (i.e., recovers).

Determination of the mode depends on the load torque change of the target system. For example, in using the system with rapid torque fluctuations, Mode 1 is suitable. In using the system with slow torque fluctuations, Mode 3 or Mode 4 can be adopted. In general, it is recommended to evaluate the operation by using Mode 1 as the standard and shift to Mode 2 and Mode 3 to verify whether the torque-following is possible or not.

Built-in digital filter of 0.625 μs (±20%) is adopted to BOOST pin.

Table 7.10 BOOST function

Mode	BOOST	Function	Recovery speed
1	Connected to VCC	Takes 5 steps in maximum to reach 100 % current (design value)	Fast
2	Pulled up to VCC with100 kΩ-resistor	Takes 7 steps in maximum to reach 100 % current (design value)	Slightly fast
3	Pulled down to GND with100 kΩ-resistor	Takes 9 steps in maximum to reach 100 % current (design value)	Slightly slow
4	Connected to GND	Takes 11 steps in maximum to reach 100 % current (design value)	Slow

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7.7.4. FLIM (AGC frequency limit) function

The FLIM pin sets the lower frequency limit at which AGC become active. Since AGC operates using the induced voltage, some motors may have unstable AGC operation at very low rotational speed. In addition, the motor's inherent resonance frequencies can also affect AGC operation. Therefore, to avoid these issues, the lower frequency limit for AGC activation is provided and can be set using the FLIM pin.
FLIM pin is a 4-state logic input. Built-in digital filter of 0.625 μs (±20%) is adopted to FLIM pin.

Table 7.11 FLIM function

Mode	FLIM	Function
1	Connected to VCC	Frequency limit: ON, AGC is invalid when f_{CLK} is less than 675 Hz
2	Pulled up to VCC with100 kΩ-resistor	Frequency limit: ON, AGC is invalid when f_{CLK} is less than 450 Hz
3	Pulled down to GND with100 kΩ-resistor	Frequency limit: ON, AGC is invalid when f_{CLK} is less than 225 Hz
4	Connected to GND	Frequency limit: OFF

When connected to GND, the operation is not limited by the limiter circuit of the IC. The induced voltage of the motor, which is used in AGC, is generated by the rotation of the motor.
Therefore, the frequency threshold for AGC activation is corresponding to the motor.

The frequency threshold for AGC activation shown in the above table is the case of full step resolution. When using other step resolutions (micro step resolution), the thresholds are different. In micro stepping, the thresholds are roughly equivalent to conversion of the full step resolution. Please refer to the table below.

Table 7.12 Frequency limit threshold

FLIM	Full step resolution	Half (a) step resolution	Half (b) step resolution	Quarter step resolution	1/8 step resolution	1/16 step resolution	1/32 step resolution
Connected to VCC	675 Hz	1.35 kHz	1.35 kHz	2.7 kHz	5.4 kHz	10.8 kHz	21.6 kHz
Pulled up to VCC with100 kΩ-resistor	450 Hz	900 Hz	900 Hz	1.8 kHz	3.6 kHz	7.2 kHz	14.4 kHz
Pulled down to GND with100 kΩ-resistor	225 Hz	450 Hz	450 Hz	900 Hz	1.8 kHz	3.6 kHz	7.2 kHz
Connected to GND	Frequency limit: OFF						

7.7.5. LTH (AGC detection threshold) function

LTH pin sets AGC detection threshold.
Torque detection sensitivity can be set by changing the connected resistor value. When lowering the resistor value, the detection sensitivity increases but the constant current value may become unstable for some motors. Therefore, caution should be exercised.
The resistor can be lowered to about 10 k Ω. Connect a 100 kΩ-resistor in the normal usage.

Table 7.13 LTH function

LTH	Function
Pulled down with100 kΩ-resistor	Standard configuration for AGC detection threshold
Pulled down with10 kΩ-resistor	Upper limit configuration for AGC detection threshold

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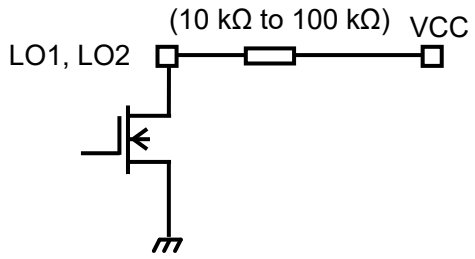
8. IC Signal Output Function

8.1. LO1, LO2 (Error Output: Error detect flag output) function

LO1 pin and LO2 pin output signals when the error state of the IC or its environment is detected. Both pins are open drain type like MO pin, therefore to use the function properly, they should be pulled up to the power supply (3.3 V/5 V) such as VCC.
Use the pull-up resistor in the range of 10 kΩ to 100 kΩ.
During normal operation, they are high-impedance (Internal open-drain MOSFETs turn off and pin voltage is VCC). Once the error detect function (thermal shutdown (TSD), over current protection (ISD), or motor load open (OPD)) operates, pin voltage becomes low level (Internal open-drain MOSFETs turn ON).
When the error detection is released by reasserting the VM power supply or using the standby mode, LO1 pin and LO2 pin show “normal operation” status again. If this function is not used, leave the pins open or connect them to GND.

Table 8.1 LO function

LO1	LO2	Function
High (Hi-Z)	High (Hi-Z)	Normal state (Normal operation)
High (Hi-Z)	Low	Detects motor load open (OPD)
Low	High (Hi-Z)	Detects over current (ISD)
Low	Low	Detects over thermal (TSD)



Once the error detection operates, internal MOSFETs of both or either LO1 or LO2 are turned on. (Pin voltage is low level.)

During normal state, internal MOSFETs of both LO1 and LO2 are turned off. (The pin voltage is high level (VCC).

Figure 8.1 LO function Equivalent Circuit

Note: The equivalent circuit diagrams may be simplified or omitted for explanatory purposes.

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9. Application Circuit Example

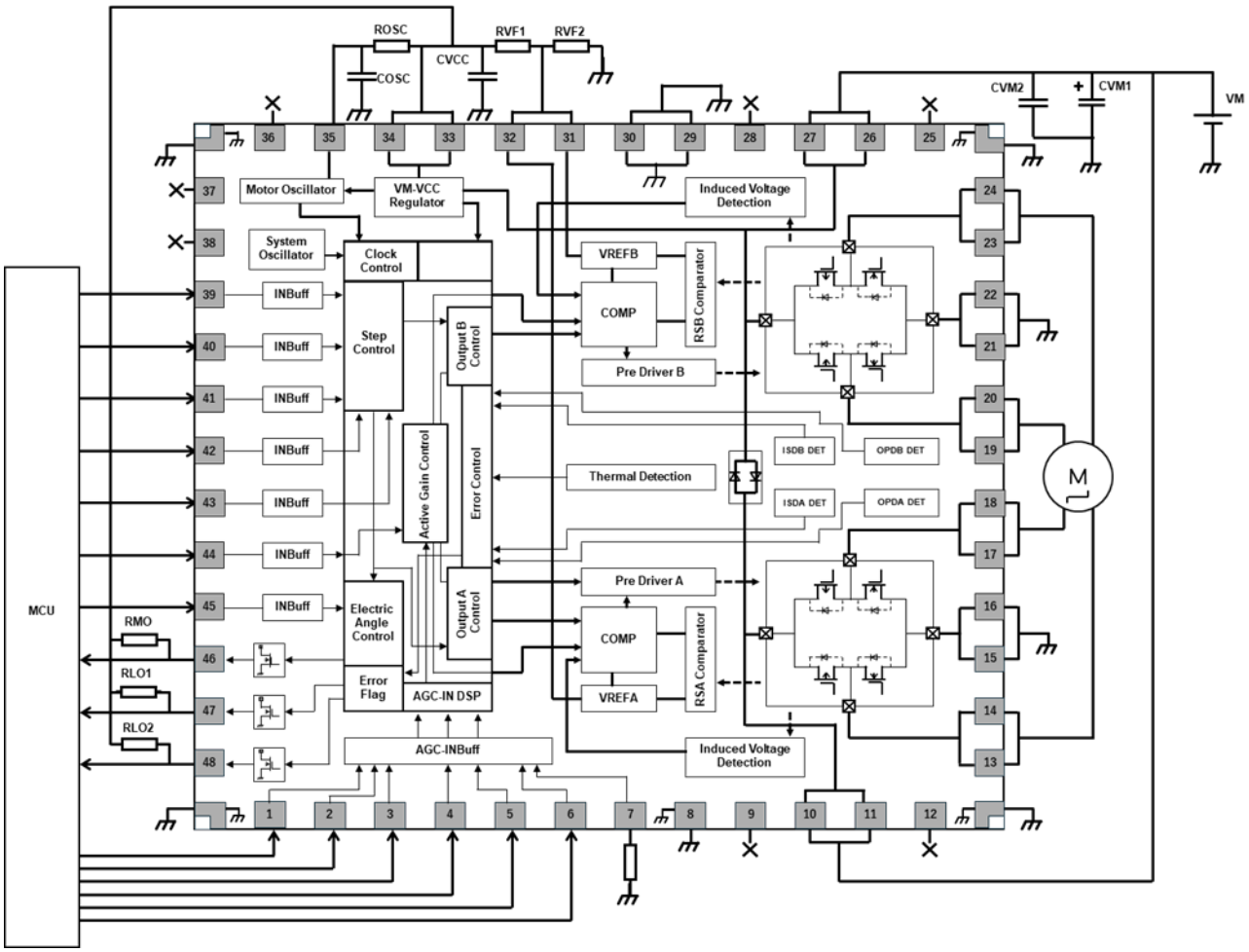


Figure 9.1 Application Circuit Example

Note: Some of the functional blocks, circuits, or constants in the block diagram may be omitted or simplified for explanatory purposes.

Note: Above application circuit example is provided for reference purposes only, and is not guaranteed for mass production.

10. External Component Description

10.1. Capacitors for power supply pins

To stabilize the power supply voltage of the IC and reduce the noise, connect an appropriate capacitor to each pin.
It is effective and recommended to connect capacitors as close to the IC as possible.
However, be sure to consider the influence of the IC's heat generation.
Also, connecting the small-capacity ceramic capacitor (bypass capacitor) near the IC is effective to reduce power supply fluctuations and noise especially at the high frequency range. Generally, this can be adopted to dealing of CMOS LOGIC IC board.

Table 10.1 Recommended capacitor values for power supply pins

Item	Components	Typ.	Recommended range
Between VM pin and GND	Decoupling capacitor (CVM1)	100 µF	22 to 100 µF
Between VCC pin and GND	Bypass capacitor (CVCC)	0.1 µF	0.01 to 1 µF
Between VREF pin and GND	Bypass capacitor (CVF)	0.1 µF	0.01 to 1 µF

Connect the capacitor in necessary between VREF pin and GND in accordance with the usage environment.
It is possible to remove the capacitor and use other than the recommended one depending on the motor load condition and the designed pattern of the board. For example, in case of using two or more motors (the same number of driver ICs as the motors are used), the capacitor between VM pin and GND can be reduced. Comprehensively, ensure the capacitor not to increase the ripple of the power supply.

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10.2. Internal oscillation frequency

OSCM oscillation frequency can be adjusted by changing the values of external capacitor and resistor. In adjusting, it is recommended to change the resistor, while fixing the capacitor to 270 pF. Chopping frequency can be also changed by adjusting OSCM frequency. To the below table in adjusting the chopping frequency.

Product name:	TB67S279FTG, TB67S289FTG, and TB67S249FTG
Board:	Toshiba evaluation board
Power supply voltage:	24 V
COSC:	270 pF

Table 10.2 Relation of external resistor (ROSC) and internal oscillation frequency (f_{OSCM}), chopping frequency (f_{chop}) (for reference only)

ROSC	f_{OSCM}	f_{chop}
kΩ	MHz	kHz
1.5	2.63	164.38
1.8	2.37	148.13
2.0	2.23	139.38
2.2	2.08	130.00
2.7	1.80	112.50
3.0	1.67	104.38
3.3	1.55	96.88
3.9	1.34	83.75
4.7	1.15	71.88
5.1	1.07	66.88
5.6	0.98	61.25
6.8	0.83	51.88
8.2	0.70	43.75
10.0	0.58	36.25

Setting chopping frequency range 40 kΩ to 150 kHz

←Typical value

Note: Values in above table are reference data. They are not guaranteed.

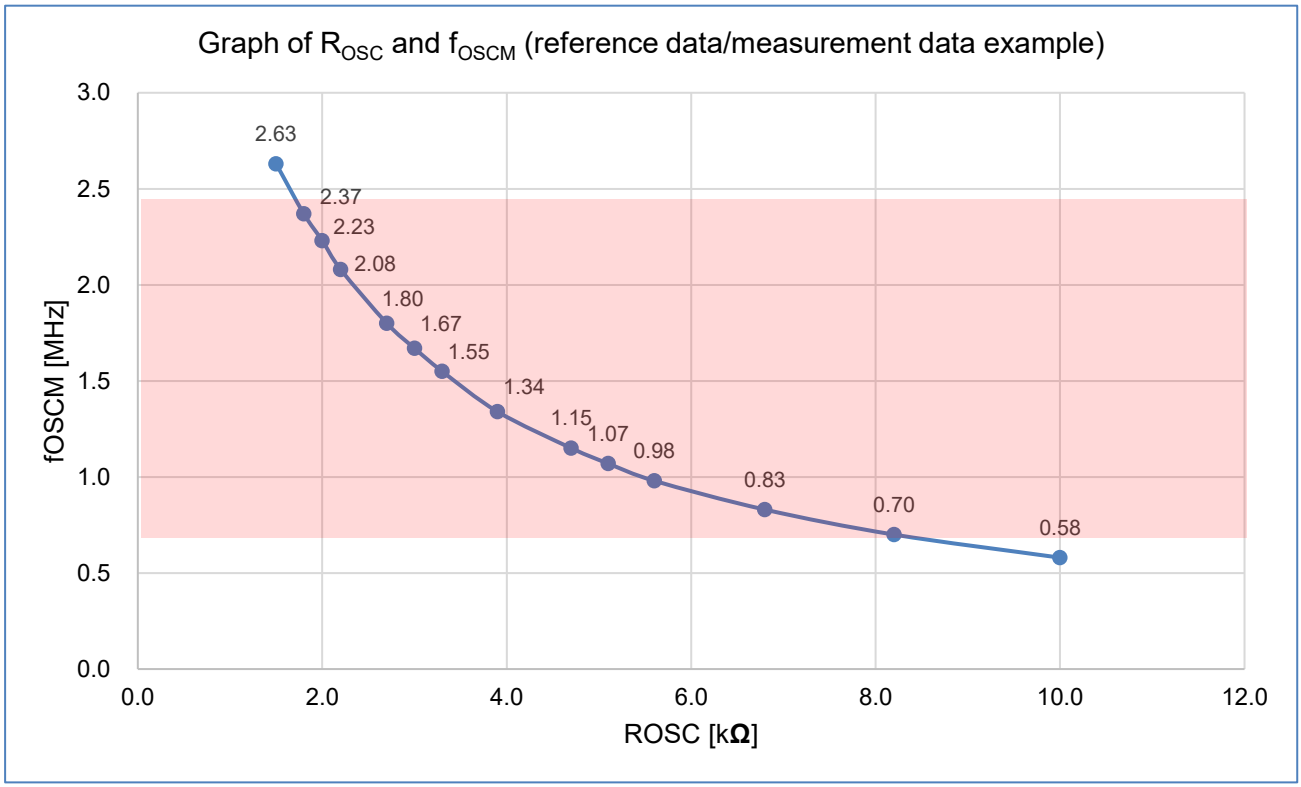


Figure 10.1 Graph of R_{OSC} and f_{OSCM} (reference data/measurement data example)

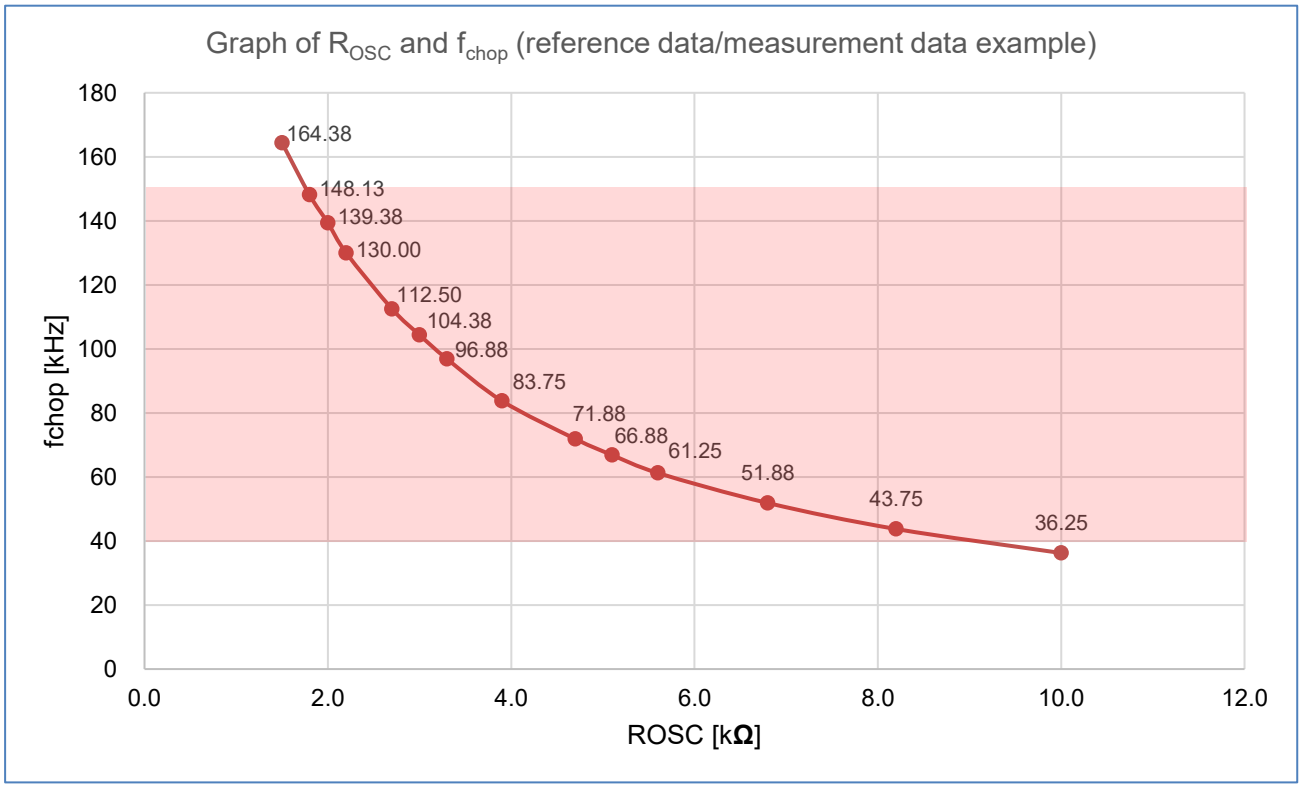


Figure 10.2 Graph of R_{OSC} and f_{chop} (reference data/measurement data example)

Note: Values in the graphs are reference data. They are not guaranteed.

10.3. Resistor for monitor pins

The IC has MO, LO1, and LO2 open-drain type pins to output some of the internal status of the IC. When internal open-drain MOSFETs turn off, these pins show high impedance. In using this function, they should be pulled up to the power supply (3.3 V/5 V) such as VCC. If this function is not used, leave the pins open or connect them to GND.

Table 10.3 Recommended resistor values for monitor pins

Item	Components	Typ.	Recommended range
Between (MO/LO1/LO2 pin) and power supply	Chip/Lead resistor	10 kΩ	10 kΩ to 100 kΩ

10.4. Layout pattern for power supply and GND

Since large current is assumed to flow in the pattern connected to VM, OUT, and GND pins in particular, design the appropriate board in order to avoid the influence of wiring impedance. It is very important for surface mounting packages such as QFN type to radiate the heat from the IC back side (the corner pad and the heat sink) to the GND (i.e., heat sink mounting area). So, design the pattern by considering the heat design.

10.5. 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 deadband time. So, it is concerned that the over current detection circuit may not operate depending on the output load conditions because of the deadband time. Therefore, in order to avoid continuing this over current state, use the fuse for the power supply line.

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10.6. Error detection function

This IC incorporates a thermal shutdown circuit (TSD) and an over current protection (ISD), which are unique error detections to power ICs, in addition to a general UVLO function. Each function is described below.

10.6.1. Thermal shutdown circuit (TSD)

When the junction temperature of the IC reaches a preset specified value, the internal detection circuit operates to turn off the output block. The deadband time is provided to avoid a false detection, which is caused by switching and so on. While TSD is activated, the operation of the IC is in the standby mode continuously. To release this function, apply the power supply again or configure the standby mode by DMODE0, DMODE, and DMODE pins. TSD function is activated when the IC is overheated irregularly. Therefore, do not use the TSD function often.

10.6.1.1. Deadband time of thermal shutdown circuit

This IC has a system clock (f_{OSCS} = 6.4 MHz (typ.)) to count up a deadband time for the error detection. Thermal shutdown circuit can avoid a false detection by the deadband time, which is counted by the system clock.

t_{TSD} = 5 µs (typ.)

10.6.2. Over current protection (ISD)

When the motor output current exceeds a specified value, over current protection circuit, which is implemented in the output block, operates to turn off the output block. The deadband time is provided to avoid a false detection, which is caused by switching and so on. While ISD is activated, the operation of the IC is in the standby mode continuously. To release this function, apply the power supply again or configure the standby mode by DMODE0, DMODE1, and DMODE2 pins.

10.6.2.1. Deadband time of over current protection

This IC has a system clock (f_{OSCS}=6.4 MHz (typ.)) to count up the deadband time for the error detection. Over current protection can avoid a false detection by the deadband time, which is counted by the system clock.

t_{ISD} = 1.25 µs (typ.)

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11. Power Consumption of the IC

Power of the IC is consumed mainly by the transistor of the output block and by the internal circuit, which includes the logic block.

P(total) = Power consumption of the IC
P(out) = Power consumption of the motor output block (MOSFET)
P(bias) = Power consumption of the internal circuit

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

(1) Power consumption of the motor output block

The motor output block consumes the power (P (out)) when the motor current flows in the output MOSFET. In case of driving stepping motors, two channels of H-SW (A-ch and B-ch) are controlled in parallel. Therefore, P (out) can be gained from below formula.

P(out) = Number of H-SW (= 2ch) × Motor current × Motor current × On resistance
(∵P = V × I = R(on) × I(out)^2) ……. (1)

The power consumption above is gained under the condition that the motor current reaches the configured peak value. Actually, since the IC performs PWM constant current control, the peak current does not flow continuously. Hence, the average motor current is lower than the configured value due to the current ripple (in the constant PWM drive) and the current decay (in switching step resolution). Therefore, the power consumption above is only for reference.

Example) When motor current is 1 A, and the operation mode is full step resolution,
P(out) = 2 (ch) × 1.0 (A) × 1.0 (A) × 0.41 (Ω) = 0.82 (W)

(2) Power consumption of the internal circuit

The power for the internal circuit (P(bias)) including the logic block is continuously consumed by applying VM voltage for the motor operation (standby release mode). It is calculated from below formula.

P(bias) = Motor power supply voltage × Current consumption = VM × IM ……. (2)

Example) When motor power supply voltage of 24 V is applied,

P(bias) = VM × IM3, then 24 (V) × 0.006(A) = 0.144 (W)

From above formula, the rough value of this IC power consumption is as follows;

P(total) = P(out) + P(bias) = 0.82 + 0.144 = 0.964 (W)

The power consumption of the standby mode, which reduces bias current of the internal circuit, can be calculated from the formula (2) by substituting IM1 (standby mode) for IM current consumption.

P(bias) = 24 (V) × 0.002 (A) = 0.048 (W)

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12. Power dissipation

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

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

The IC adopts a surface mounting package, QFN48. QFN48 package radiates the heat mainly from the heat sink of the IC back side to the mounting board. So, $R_{th(j-a)}$ depends on the board design pattern, GND area, etc.
Electrode part (corner pad) for disabled pins of QFN package is connected to the heat sink in the IC. Connect this part to the board by soldering because heat can be radiated from the board surface.

Example of thermal calculation: If $R_{th(j-a)}$ is 25 °C/W when the IC is mounted on glass-epoxy 4-layer board, the junction temperature at ambient temperature (Ta = 25 °C) can be calculated from below formula. Conditions of the power consumption are as the same as the prior section 'Power Consumption of the IC'.

$$T_j = 25\ (°C) + 0.964\ (W) \times 25\ (°C/W) = 49.1\ °C$$

Reference) Relation of power dissipation and ambient temperature

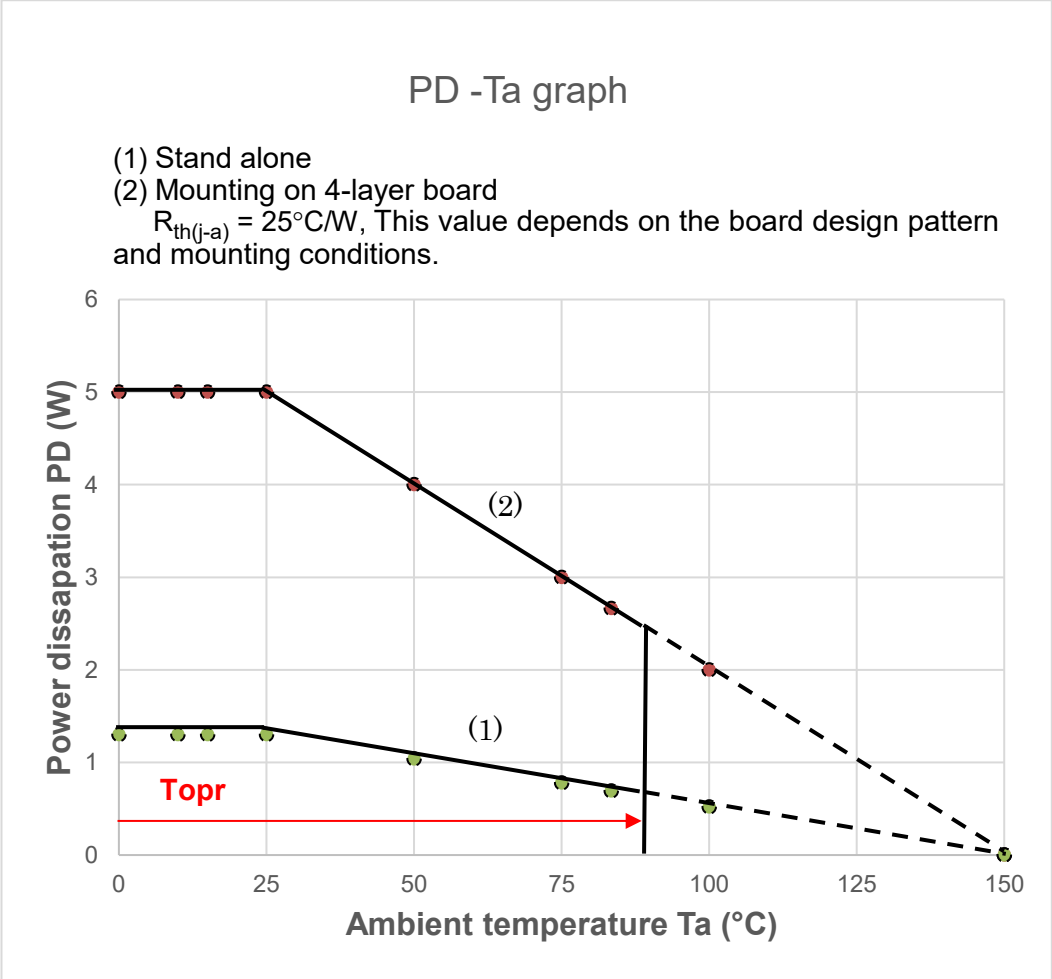


Figure 12.1 Power dissipation

Note: T_a, $R_{th(j-a)}$, and P(total) depend on the environment, in which the board and motor are used. If the ambient temperature is high, the allowable power consumption is reduced accordingly.

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13. Foot Pattern Example

QFN48 foot pattern example (unit: mm)

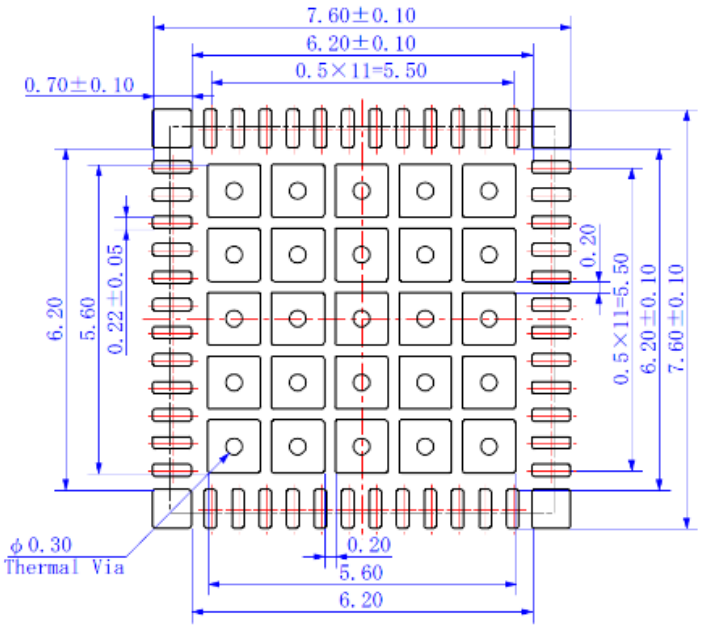


Figure 13.1 QFN48 foot pattern example

Note: The data is for reference only and not guaranteed for mass production. In designing the size of mounting board, determine the foot pattern by considering the solder bridge, the solder connecting strength, the pattern accuracy in making board, and the mounting accuracy of the IC board.

14. Board dimensions (Toshiba Evaluation board)

14.1. Input/Output

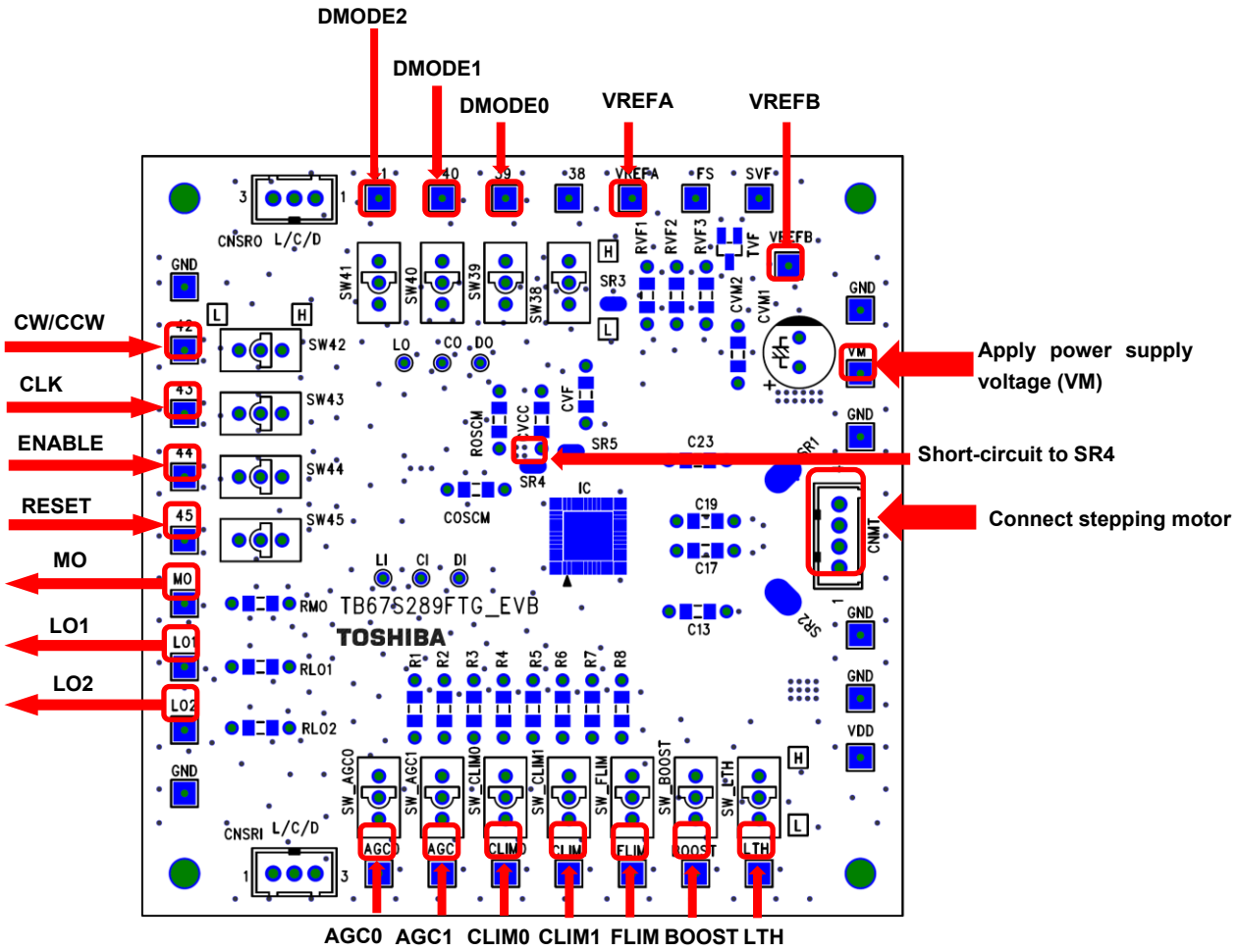


Figure 14.1 Input /Output

As for each power supply and control signal, refer to above figure.

14.2. Main parts

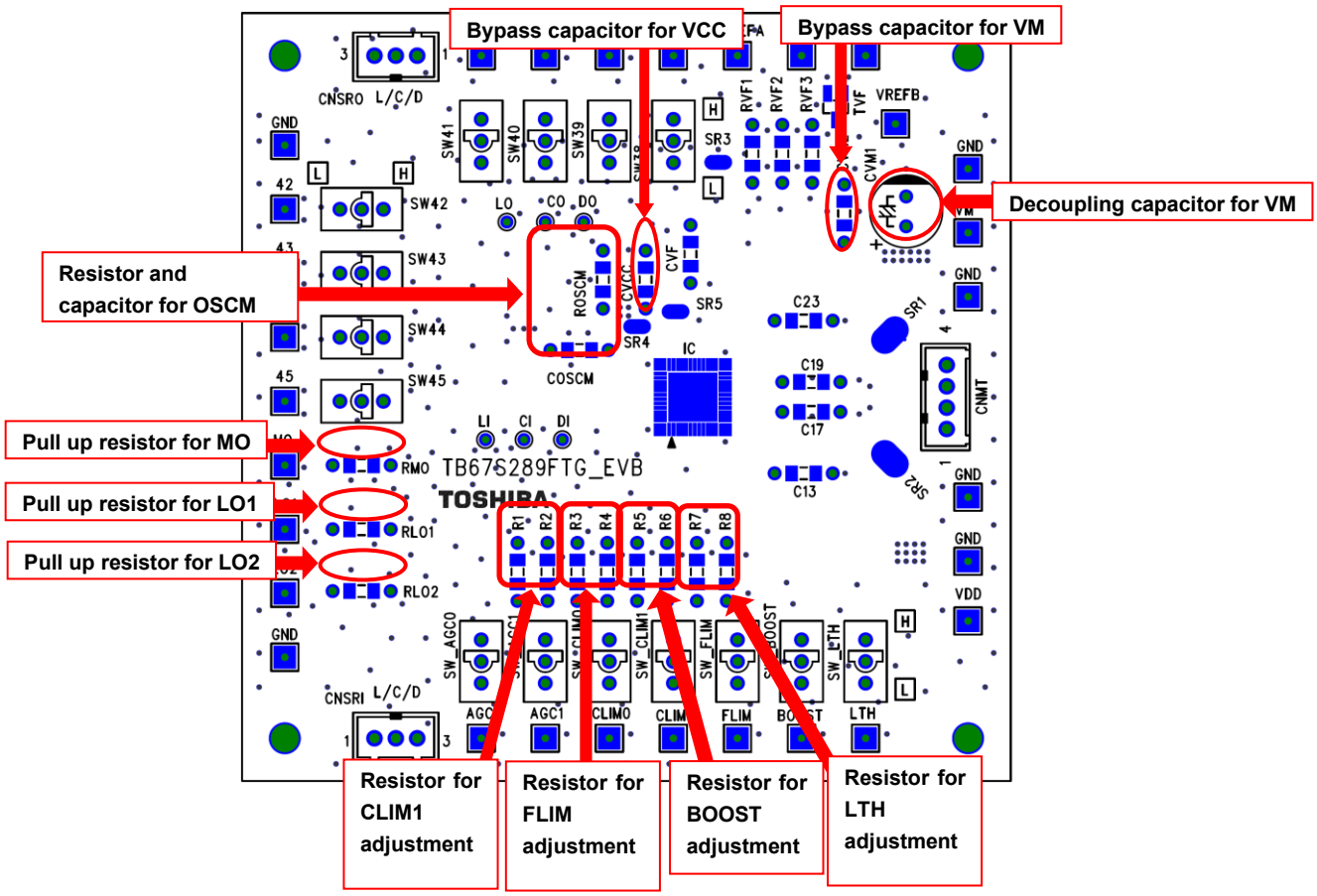


Figure 14.2 Main parts

Connect each external components referring to ’9. Application Circuit Example’.

14.3. Options

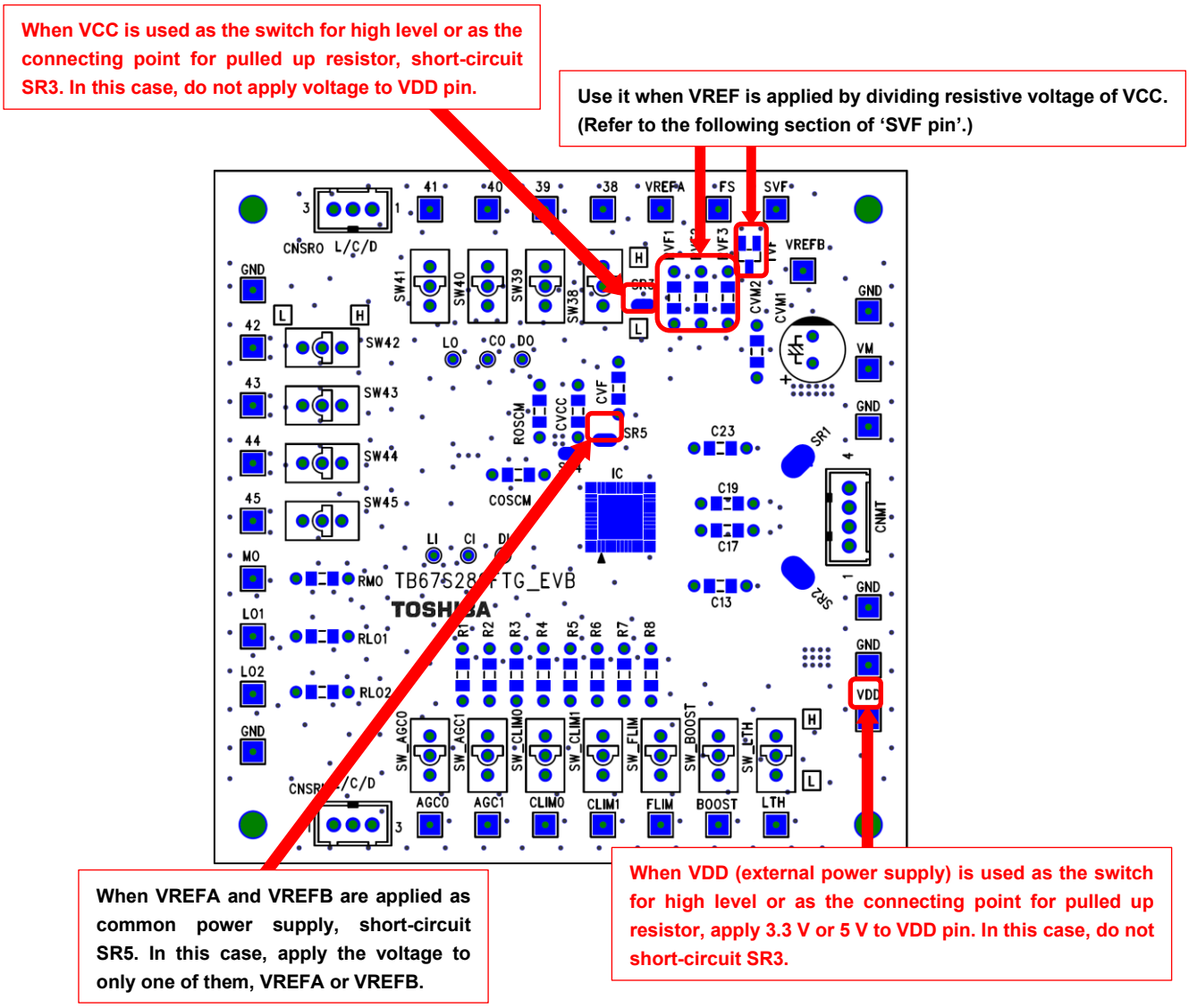


Figure 14.3 Options

14.4. Board circuit diagram

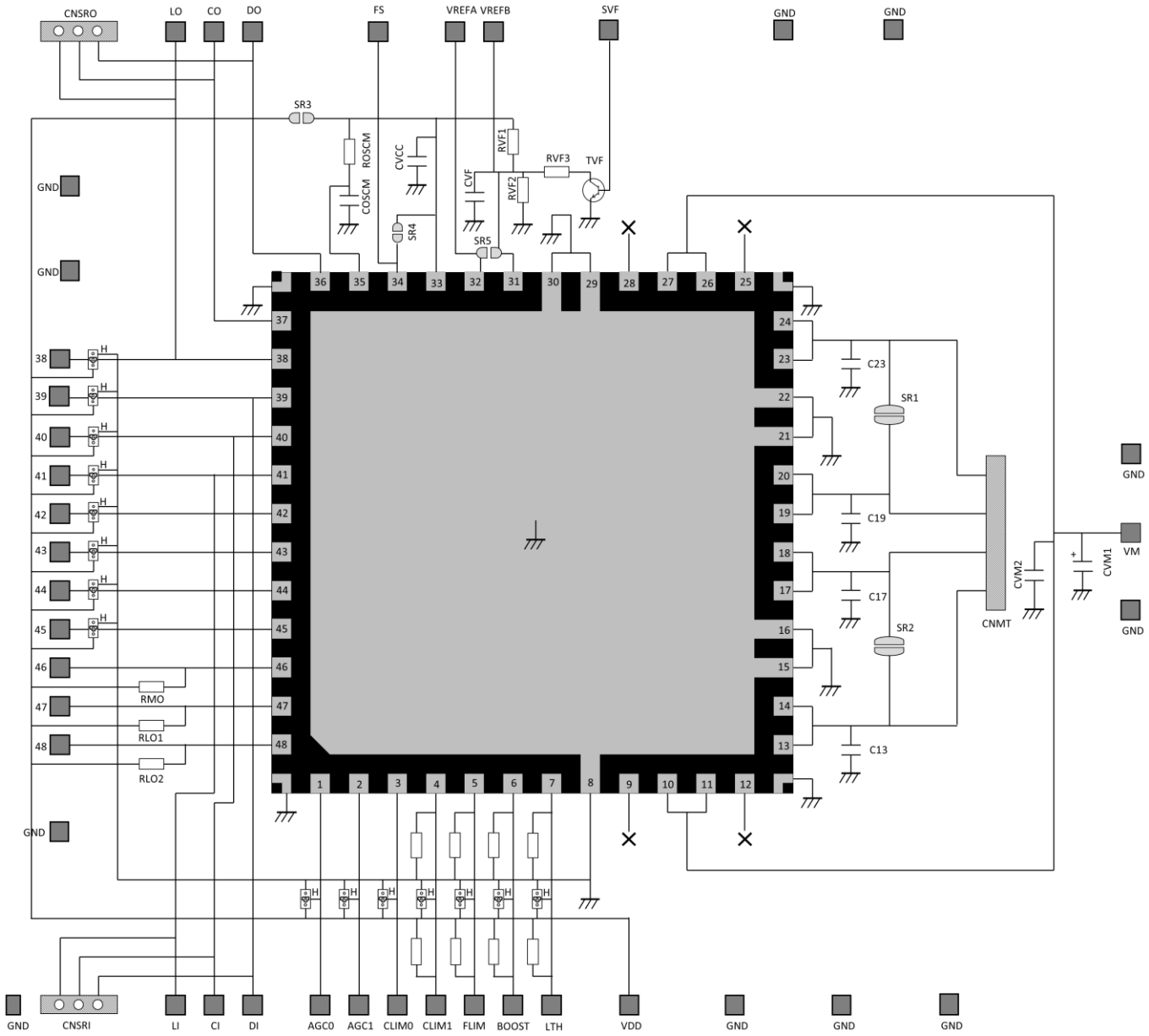


Figure 14.4 Board circuit diagram

14.5. SVF pin

The motor current and the torque can be changed during operation by using our optional pattern on the board. (Please refer to below circuit diagram.) The applied voltage for VREF can be adjusted by switching the voltage-dividing ratio with the transistor. Use an appropriate resistor for the SVF input (i.e., the base of the transistor) in accordance with the capability of the transistor.

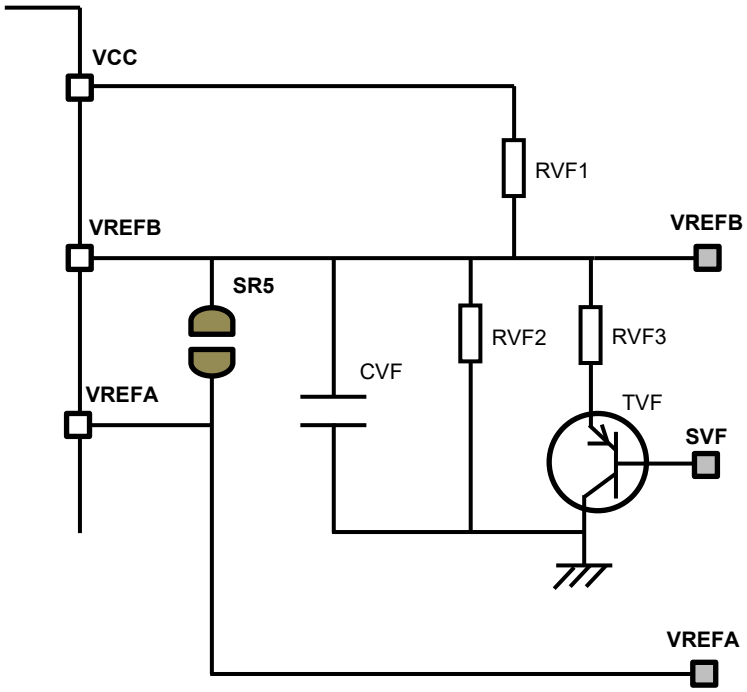


Figure 14.5 Circuit diagram of SVF pin

Note: Total value of the resistance, which is connected between VCC and GND, should be 10 kΩ to 50 kΩ regardless of the transistor's switching state.

Recommended TVF: Toshiba NPN transistor RN1401

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.

Any license to any industrial property rights is not granted by provision of these application circuit examples.

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.

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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 pins 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 in 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 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.

(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 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, over current or IC failure may cause smoke or ignition. (The over current 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.

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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, exceeding absolute maximum ratings may cause the over current protection circuit to operate improperly or IC breakdown may occur 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, 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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