Notes in use of TB67S531FTG

Description

TB67S531FTG is a PWM chopper type two-phase bipolar stepping motor driver. As full step, half step, quarter step excitation modes are selectable, the motor can be controlled only by inputting the phase signal.
And owing to the function of Advanced Current Detect System (ACDS), PWM constant current drive without external current detection resistor Is realized.

Toshiba Electronic Devices & Storage Corporation

Note: 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.

Contents

Figures

Tables

1. Power supply voltage

1.1. Operating range of Power supply voltage

In use of TB67S531FTG, voltage supply to the VM pin and the VREF pin is required. Even though the absolute maximum rating of the VM power supply voltage is 35V (in active), please use within the operating range: 4.5 to 34V. Please ensure that the slew rate from 0 V to 10 V during power turn-on is 1 ms or longer. If different conditions are used, a slew rate of 0.05 V/μs or less is recommended as a guideline. Please thoroughly evaluate the application in your product and the entire system and determine the applicability at your own responsibility.

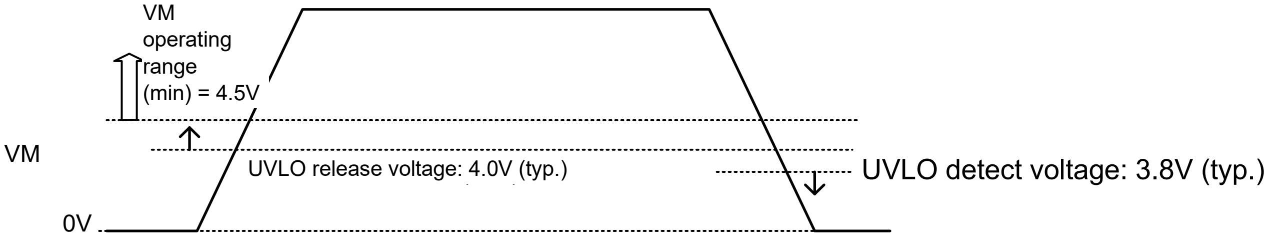


Figure 1.1 VM operating range and UVLO threshold

1.2. Sequence of power supply

Owing to the built-in regulator a single power supply drive is realized in this device. And owing to the built-in low power supply voltage detection (UVLO) malfunctions at low power supply voltage can be prevented. When the voltage of VM is unstable at turning power on / off (transient area), it is recommended to turn off the motor operation. Please start motor operation by switching the input signal after the power supply voltage becomes stable. And likewise, it is recommended to turn off the power supply after the motor has stopped completely.

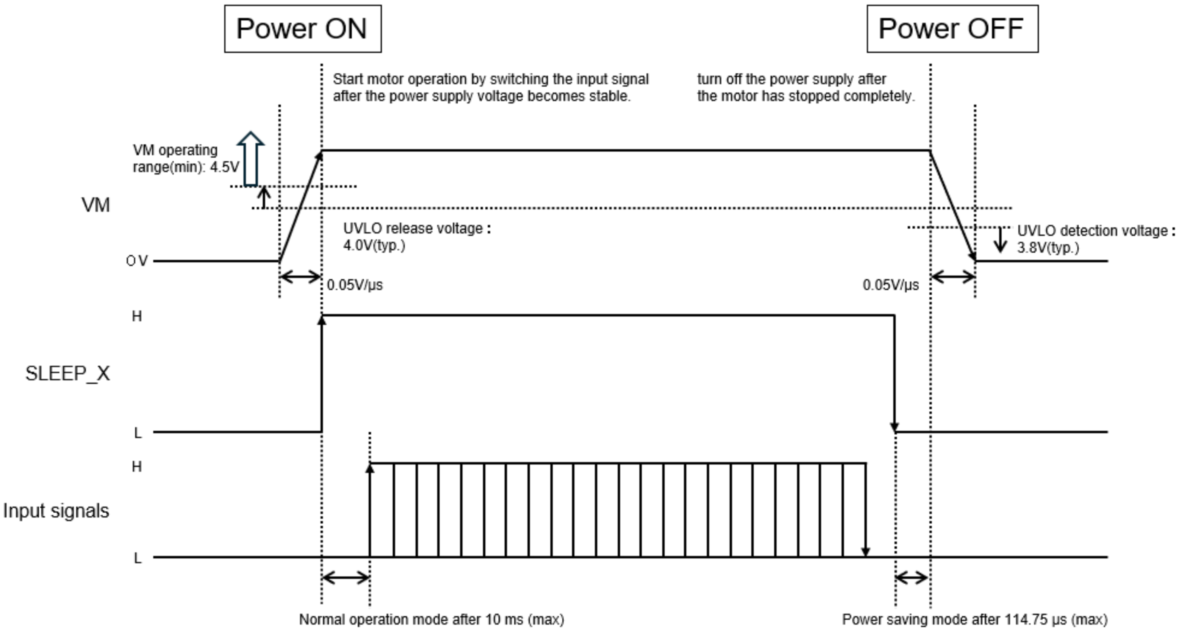


Figure 1.2 Sequence of power supply

2. Output current

Please use this device within the operating range of the motor current: 1.8A or less (per phase). And the maximum current value that can be used actually is limited by application conditions (ambient environment temperature, the board wiring, heat dissipation path, etc.). Please set the optimum current value within the range that does not exceed the allowable loss under operating environment after thermal calculation and actual evaluation.

3. Control input

This device is configured that no electromotive force by the signal input is generated, even though the logic input signal is input during the VM voltage is not supplied. However, it is recommended to set the input signal GND level before the power supply is turned on. As the logic input signal is specified as VIN (H) = 2.0V (min.) and VIN (L) = 0.8V (max.), this device can be also controlled with input signal of the 3.3V system. Pull-down resistors of 100 kΩ (typ.) are integrated.
The VREF pin should be used within the operating range: 0 to 3.6 V.

4. Function description

4.1. SLEEP_X function

The operation can resume from the output forced off state, which is configured by the thermal shutdown detection (TSD) and the over-current detection (ISD), by setting SLEEP mode once and then setting the normal operation mode again. The SLEEP_X pin is set to Low, and SLEEP mode is set after 114.75 μs(Max). The SLEEP_X pin is set to High, and normal mode resumes after 10 ms(Max).

Table 4.1 SLEEP_X functions

SLEEP_X	Function
L	Power saving mode (charge pump stopped, VCC Reg stopped)
H	Normal operation mode

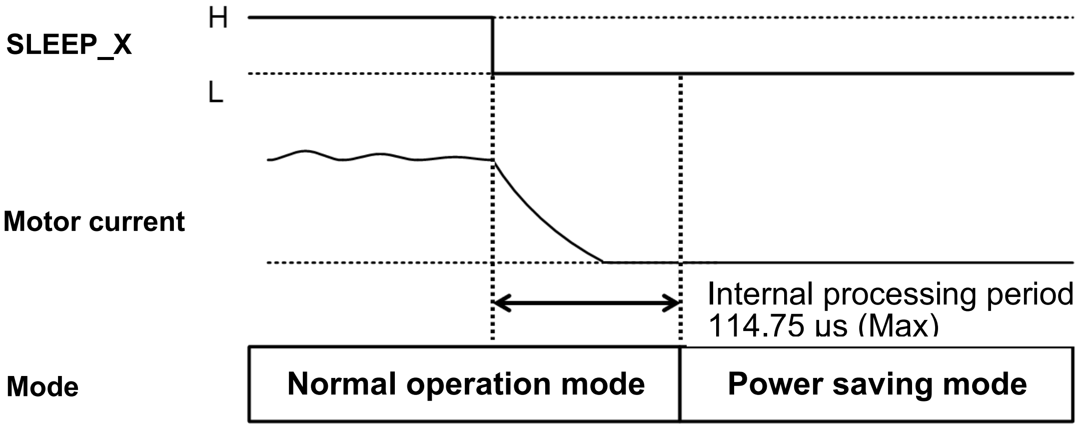


Figure 4.1 SLEEP_X Timing

Note: Please control the SLEEP_X pin from a logic signal such as the MCU. In particular, when pull up to a power supply such as 5V or 3.3V through a resistor, please adjust the rise time of the signal to less than 0.1ms.

4.2. Functions of IN_A1, IN_A2, IN_B1, IN_B2, PHASE_A, PHASE_B

Table 4.2 Functions of IN_A1, IN_A2, IN_B1, IN_B2, PHASE_A, PHASE_B

Input			Output		
PHASE_A PHASE_B	**IN_A1 IN_B1**	**IN_A2 IN_B2**	**OUTA1 OUTB1**	**OUTA2 OUTB2**	**IOUT**
H	H	H	H	L	100%
	H	L	H	L	71%
	L	H	H	L	38%
	L	L	Output OFF	Output OFF	0%
L	H	H	L	H	-100%
	H	L	L	H	-71%
	L	H	L	H	-38%
	L	L	Output OFF	Output OFF	0%

Definition of current flowing direction at IOUT:
From OUTA1(OUTB1) to OUTA2(OUTB2): Positive current
From OUTA2(OUTB2) to OUTA1(OUTB1): negative current

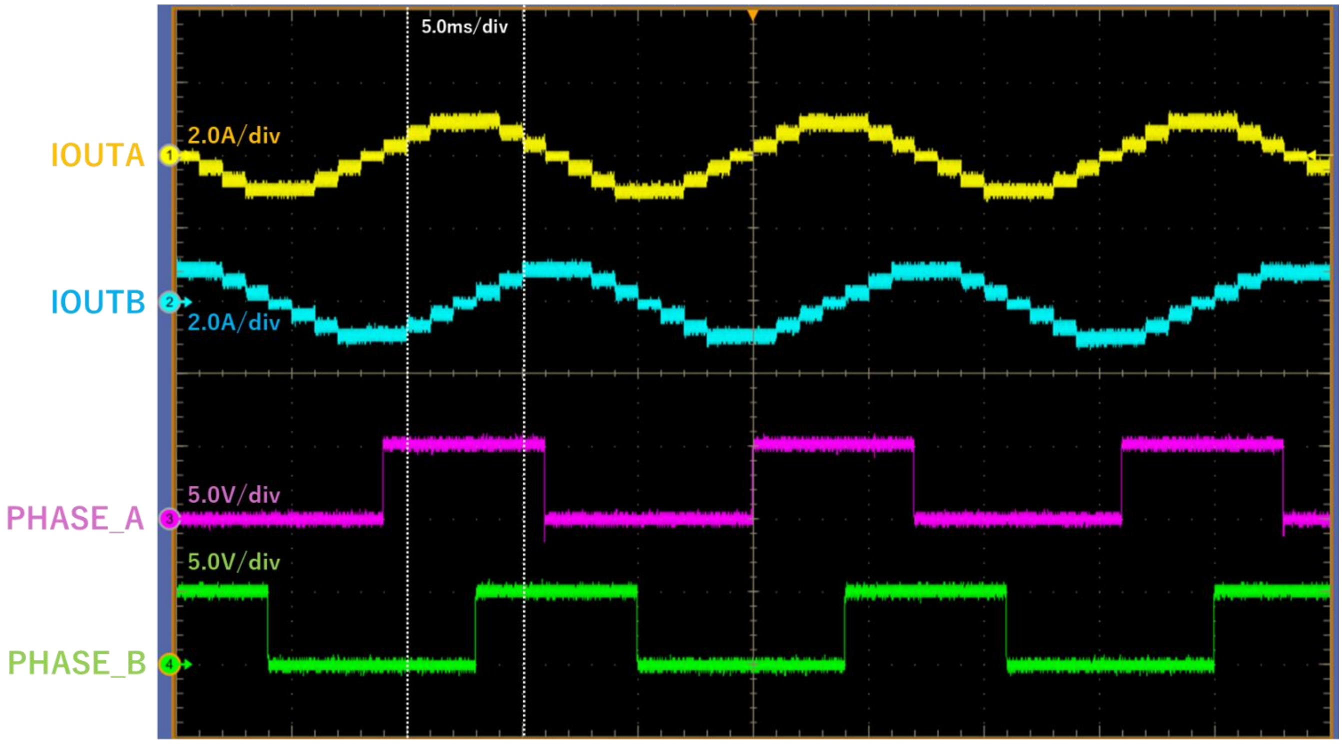


Figure 4.2 IOUTx and PHASE_x in quarter step

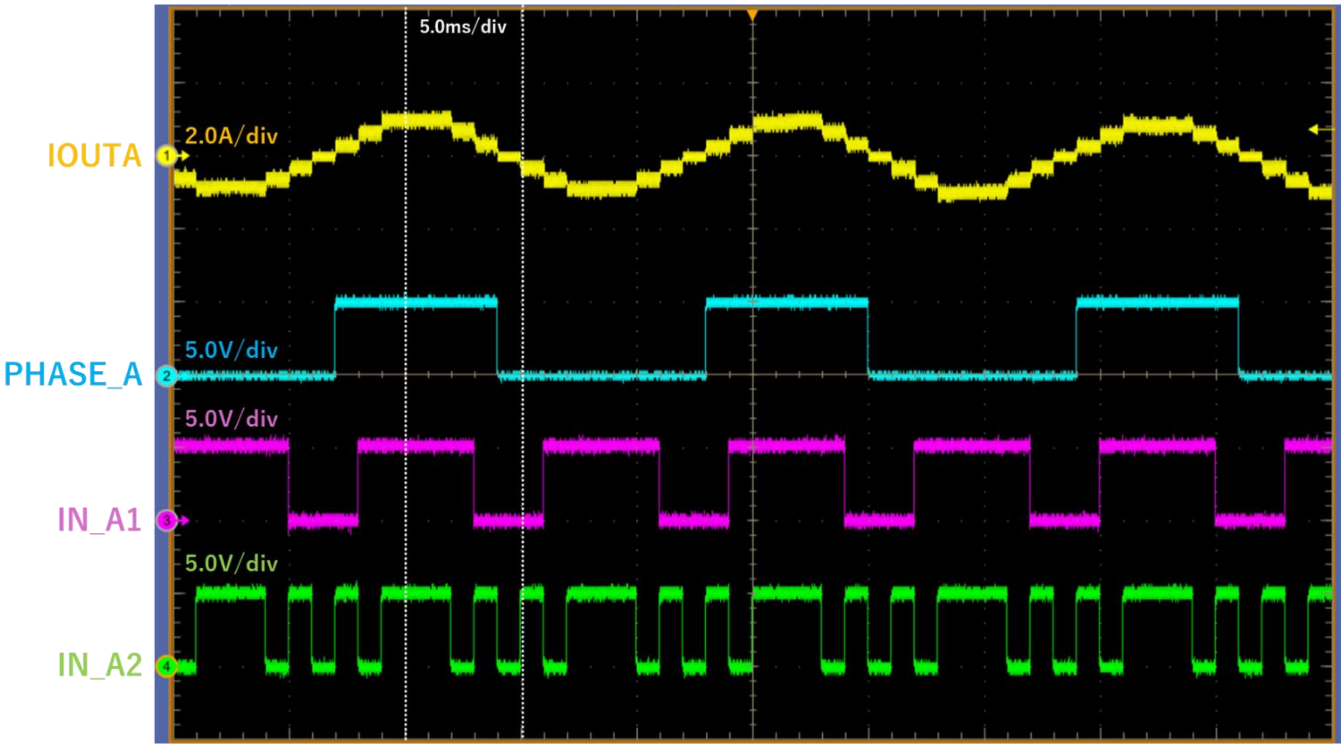


Figure 4.3　A-phase waveform in quarter step

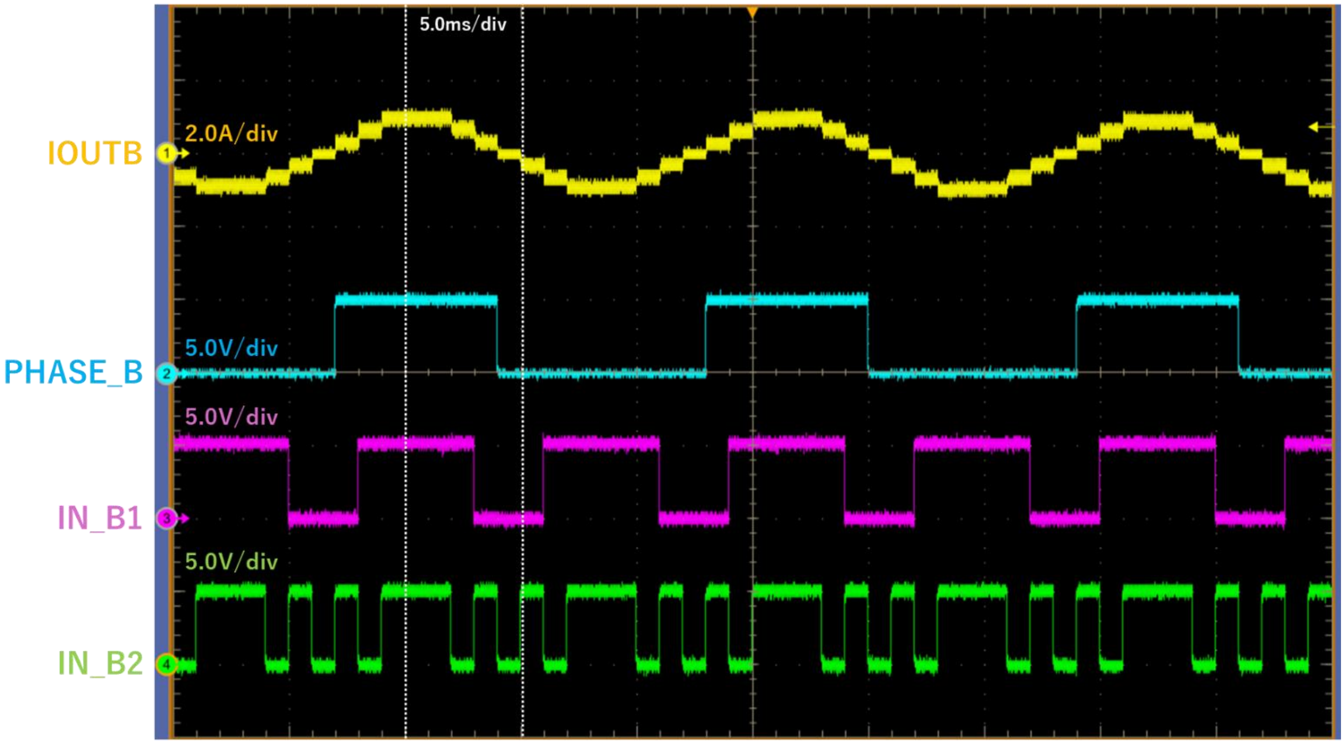


Figure 4.4　B-phase waveform in quarter step

4.3. Selectable Mixed Decay Function

Selectable Mixed Decay function can adjust the regeneration amount of the current during Decay period using the DECAY pins.
Mixed Decay control is realized by changing three controls: Charge, Slow Decay, and Fast Decay.
The constant-current control can be selected from the following four settings by DECAY pins. When this setting is changed during the constant-current operation, the changed setting is applied from next chopping cycle.

Table 4.3 Selectable Mixed Decay Function

DECAY2 pin	DECAY1 pin	Function
L	L	Mixed Decay
L	H	Slow Decay only
H	L	Fast Decay only
H	H	ADMD

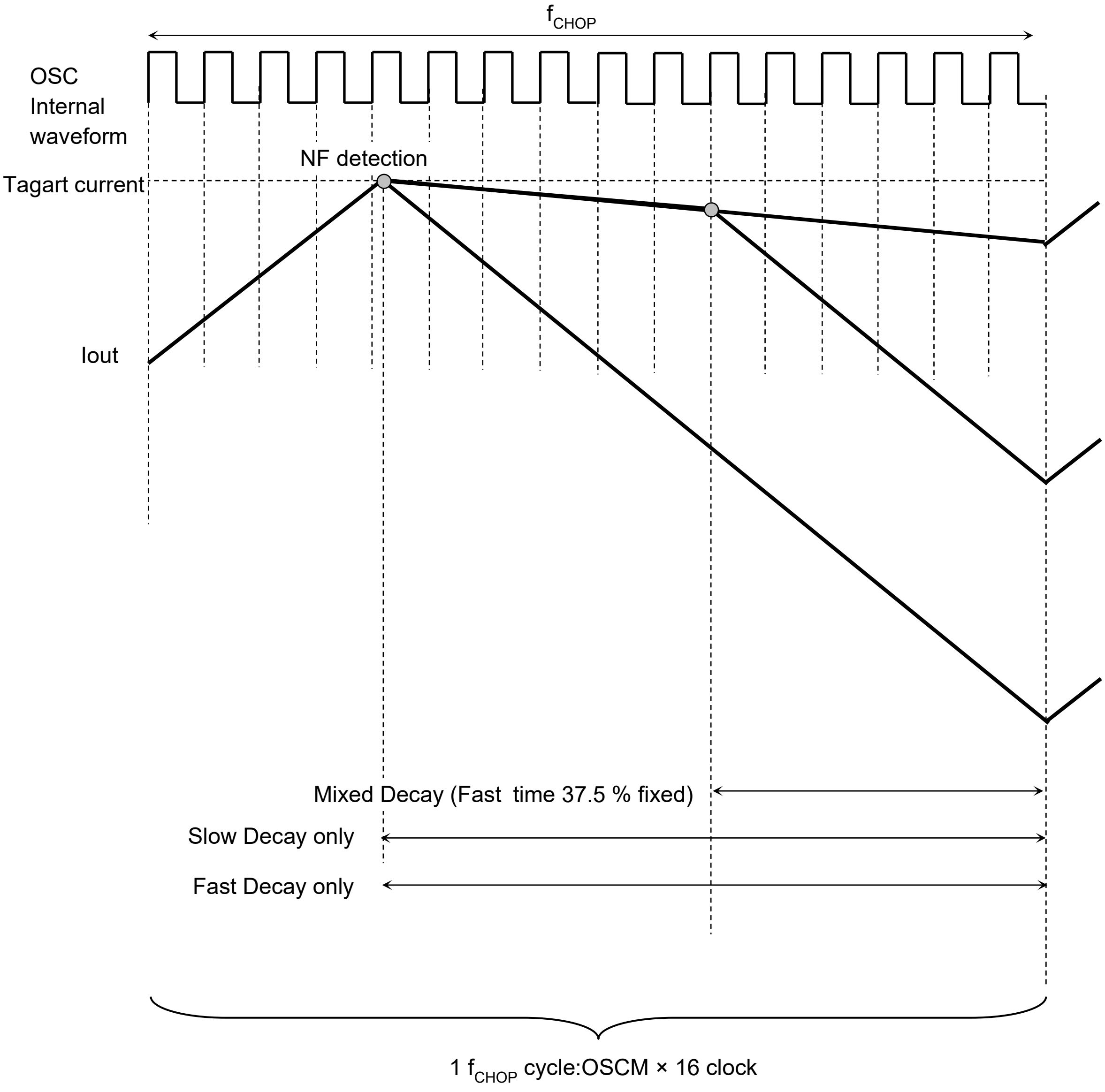


Figure 4.5 Selectable Mixed Decay Function

Note: Timing charts may be simplified for explanatory purpose.

4.4. ADMD (Advanced Dynamic Mixed Decay) Constant Current Control

ADMD monitors both the current flowing from the power supply to the motor and the current which regenerates from the motor to the power supply, and performs constant current PWM control.
The basic sequence of the ADMD is as follows.

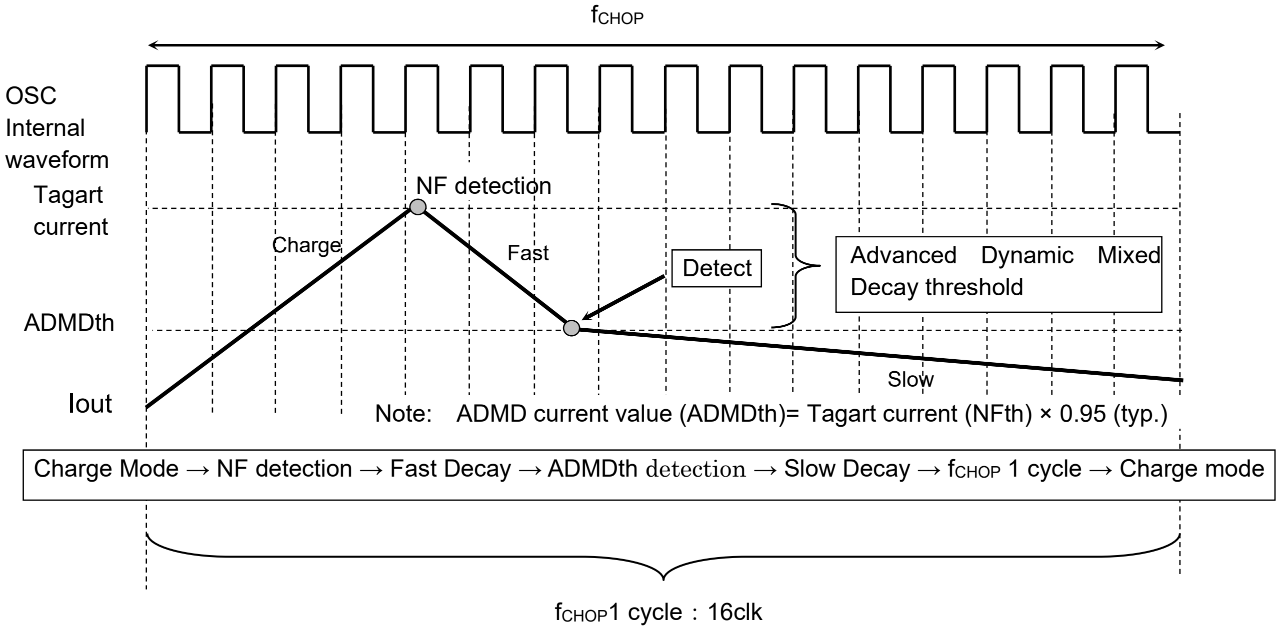


Figure 4.6 ADMD (Advanced Dynamic Mixed Decay) Constant Current Control

Note: Timing charts may be simplified for explanatory purpose. The values in the timing chart are reference values.

Each filter is attached in order to avoid current-detection error caused by the external noise, etc. (Shown in below figure.)
L value of the motor to be used is small, and when the current value reaches ADMDth (ADMD current value) within the ADMDtblank period, it changes to Slow operation after the ADMDtblank period elapsed. In this case, the ADMD current value (ADMDth) becomes smaller than ''the set current value (NFth) x 0.95 (typ.)''.

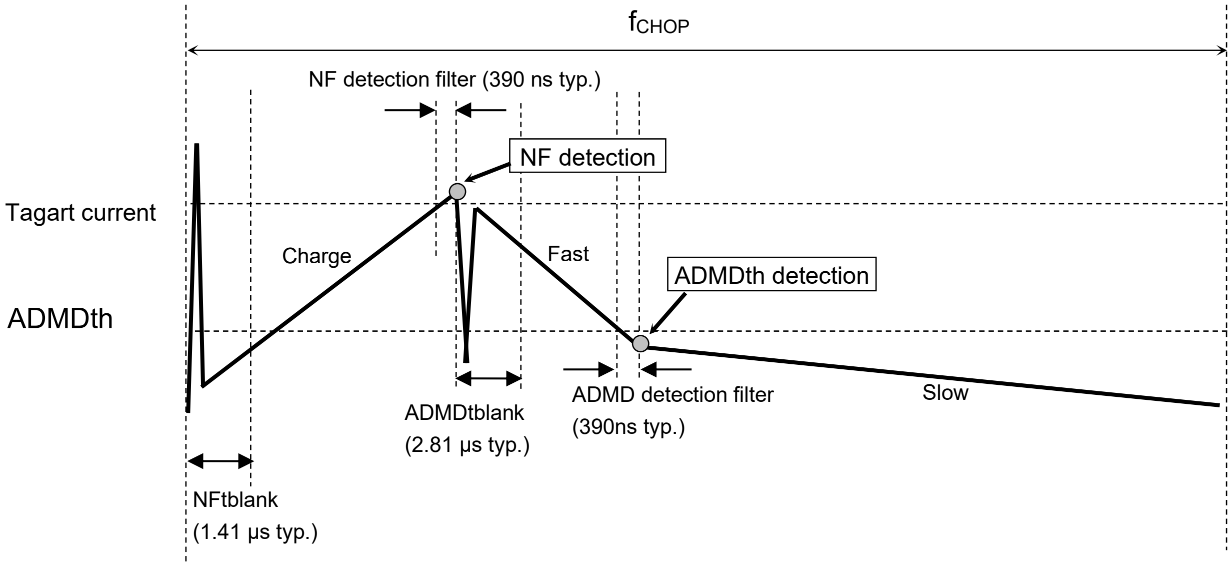


Figure 4.7 Each filter settings

Note: Timing charts may be simplified for explanatory purpose. The values in the timing chart are reference values.

4.5. Torque function

TRQ pins set the torque of the motor.

Table 4.4 Torque function

TRQ pin input	Function
L	Torque setting: 100 %
H	Torque setting: 50 %

4.6. LO (Error detection flag output) function

The LO function outputs signals when the error detection operates.
Both pins are open drain type. Therefore, to use function properly, the LO1 and LO2 pins should be connected to 3.3 V or 5 V power supply with a pull up resistor in the range of 10 k to 100 kΩ.
During normal operation, the LO1 pin is high-impedance (the internal MOSFET is OFF). When the error detections (thermal shutdown (TSD) and over-current detection (ISD)) operate, the pins output Low (the internal MOSFET is ON).
The LO2 pin outputs Low only when the TSD is detected.
When reasserting the VM power or using the SLEEP mode to release the error detection status, the LO pins return to “normal operation mode” again. When the LO pins are not used, the pins should be open.

Table 4.5 LO function

LO1 pin output	Function
H (Pull up)	Normal status (Normal operation)
L	Detected over-current (ISD) and over-temperature (TSD) status

LO2 pin output	Function
H (Pull up)	Normal status (Normal operation)
L	Detected over-temperature (TSD) status

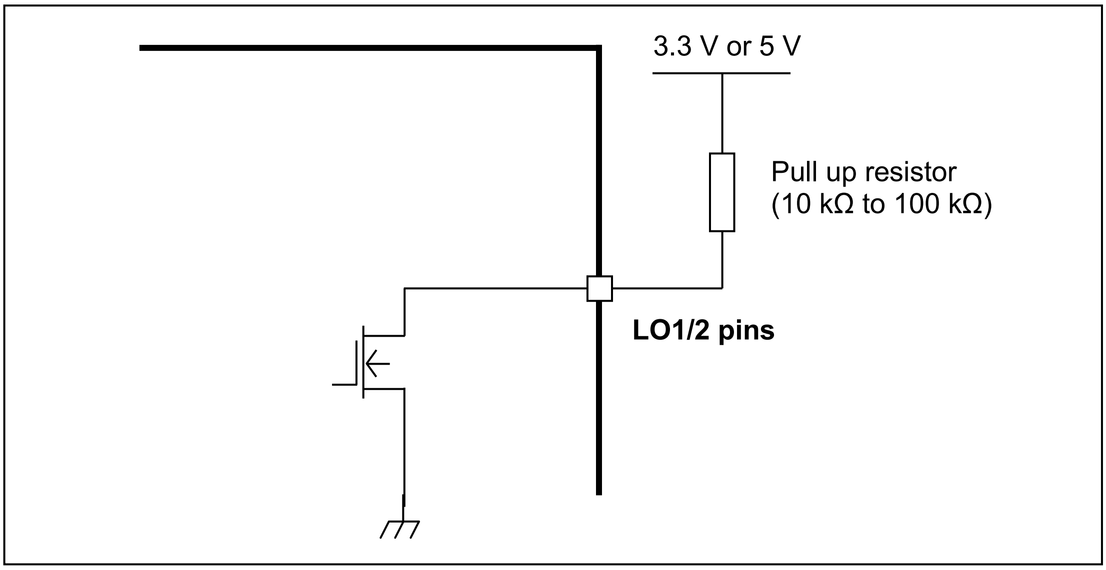


Figure 4.8 LO function Equivalent Circuit

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

Note: As a system of this device, the internal regulator is stopped for power saving when SLEEP_X = L. When SLEEP_X = H, the internal regulator is started up, but since there is an internal undefined period before rise up, the internal Logic block is initialized again for stable operation. Therefore, LO1 is Low for a moment at start-up. When the LO1 is monitored all the time, please mask the signal for 100μs (max) at switching SLEEP_X from Low to High. In addition, as the LO2 is also used as a Toshiba internal test pin, it is an input / output configuration pin. Therefore, when this pin is pulled up to an external 5V while the VM power supply is not turned on, a current inflow occurs. but it is not affected to the operation of this device.

5. Constant current control

5.1. The calculation formula of current value setting

In TB67S531FTG the constant current value is set only by the input voltage value of the VREF pin without using an external current detection resistor. Setting current value: $I_{out\ (max)}$ is calculated by the following formula.

$$I_{out\ (max)} = 0.556 \times V_{REF}\ (V)$$

5.2. Correction of output setting current

In use of this device under conditions other than $I_{OUT} = 1.0A$, an error caused by the circuit off-set can be reduced by using the correction coefficient.

$$(I_{OUT}/0.556) \times \text{correction coefficient} = V_{REF}$$

Table 5.1 VREF correction factor

I_{OUT}(A)	Correction factor
0.13	0.77
0.23	0.88
0.32	0.93
0.42	0.95
0.52	0.96
0.62	0.97
0.71	0.98
0.81	0.99
0.91	0.99
≧1	1

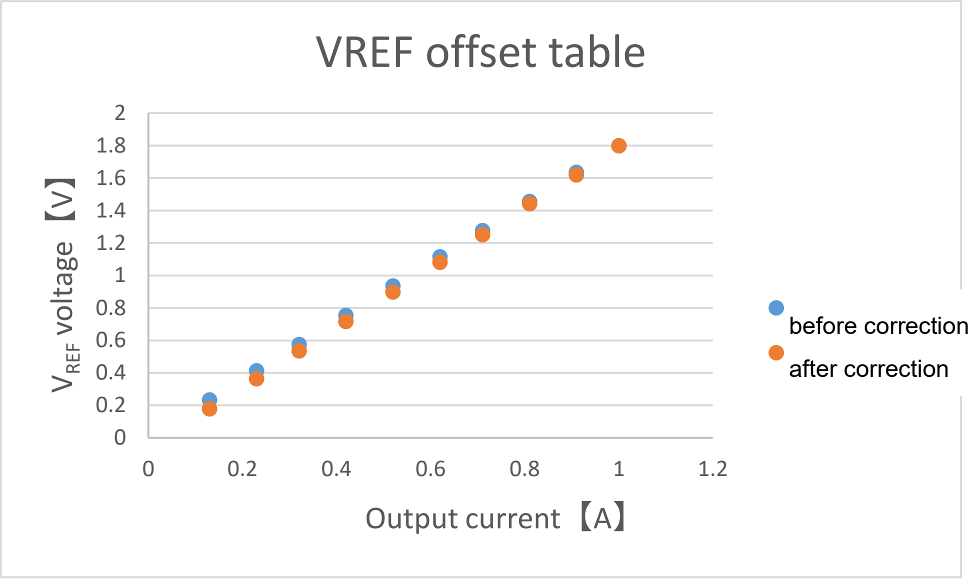


Figure 5.1 VREF offset table

Note: The graph above is not guaranteed value, but a reference one.

5.3. OSCM Oscillation Frequency and Chopping Frequency

In TB67S531FTG the internal oscillation frequency (f_{OSCM}) and the accompanying chopping frequency (f_{CHOP}) can be adjusted by the constant of an external resistor (R_{OSC}) connected to the OSCM pin. And it is also possible to use with a fixed chopping frequency without connecting external parts to the OSCM pin.

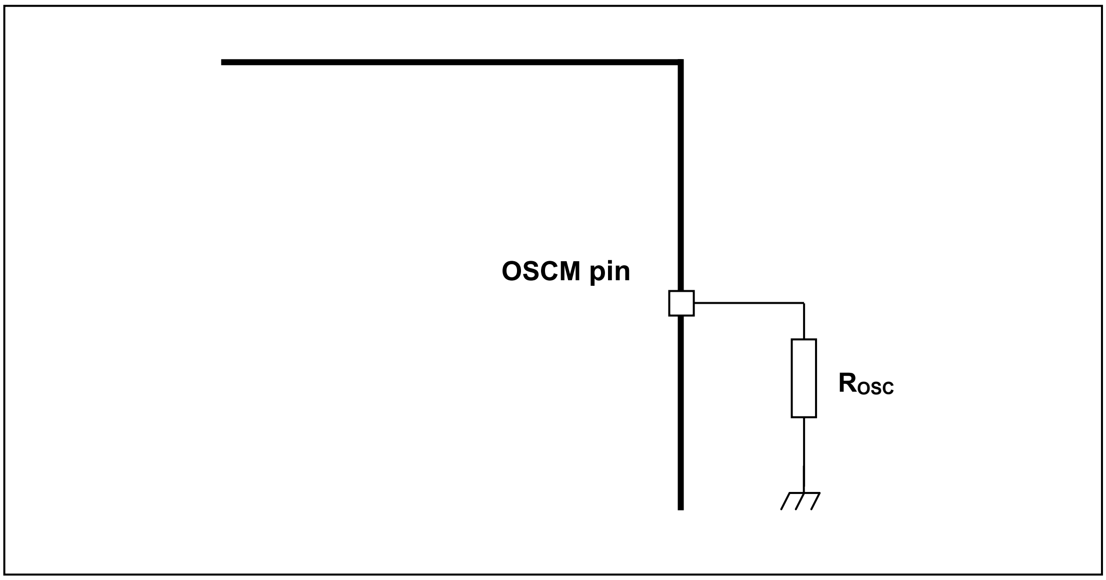


Figure 5.2 OSCM pin Equivalent Circuit

Note: The equivalent circuit may be partially omitted or simplified to explain the circuit.

The chopping frequency (f_{CHOP}) is approximately calculated from the following formula. In general, it is recommended to consider approximately 70 kHz as a typical value and set the frequency within the range of 40 kHz to 100 kHz.

$f_{CHOP} = f_{OSCM} / 16$
$f_{OSCM} = 1 / (\alpha \times R_{OSC} + \beta)$ [MHz], $\alpha = 1.7 \times 10^{-5}$, $\beta = 0.0285$
Example: When $R_{OSC} = 47\ k\Omega$, $f_{OSCM} = 1.2$ MHz (typ.), $f_{CHOP} = 75$ kHz (typ.)

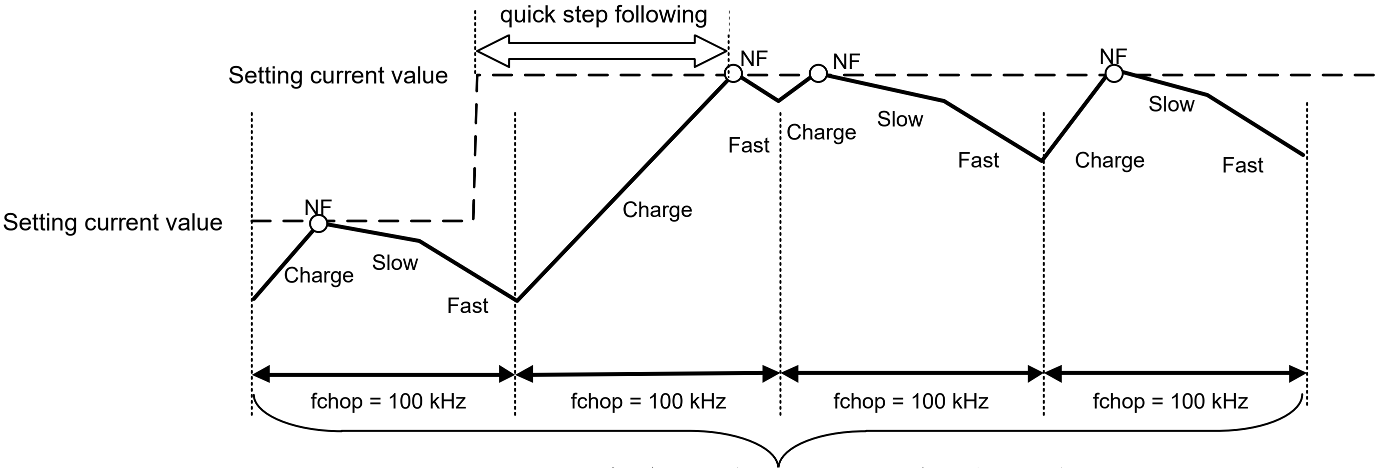
When the OSCM pin is open or shorted to the GND, TB67S531FTG operates with the frequencies that $f_{OSCM2} = 914$ kHz (typ.) and $f_{CHOP} = 57.1$ kHz (typ.) which are generated inside the device automatically.

When the chopping frequency is increased, the waveform reproducibility is improved because the current ripple is reduced, but on the other hand the heat generation is increased because the gate loss inside the device is increased. On the contrary the chopping frequency is lowered, a decrease in heat generation can be expected, but the current ripple may increase.

5.4. Constant current waveform when the chopping frequency is changed.

It is generally recommended to set and use a chopping frequency (f_{CHOP}) of approximately 70 kHz as a typical value. And when the chopping frequency is increased from the typical one, the ripple of a motor current can be reduced and the waveform quality is improved. But on the other hand, as the number of chopping is increased, switching loss also increases and heat generation increases. When the waveform quality is prioritized, increase the chopping frequency, and when the heat generation is concerned, decrease the chopping frequency.

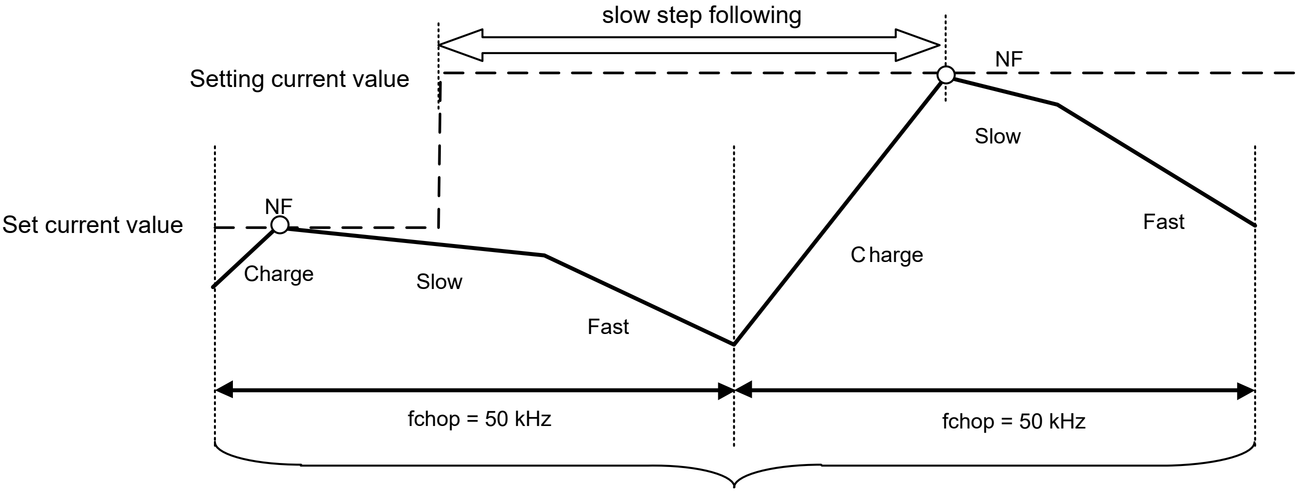
Example 1: When chopping frequency (f_{CHOP}) = 100 kHz



large number of choppings (→ switching loss / heat generation are large)

Figure 5.3 Constant current waveform (when f_{CHOP} = 100 kHz)

Example 2: When chopping frequency (f_{CHOP}) = 50kHz



small number of choppings (→ switching loss / calorific value are small)

Figure 5.4 Constant current waveform (when f_{CHOP} = 50 kHz)

6. Fault detection circuit

・Over-temperature detection circuit (TSD)

When the junction temperature of the device reaches 160 °C (typ.), the internal detection circuit starts operation and latches the output section to OFF state. A dead band time of 5 μs (typ.) is provided internally to avoid false detection caused by noise from the outside. After the TSD operation, it can be canceled by turning the power on again or setting the standby mode. As the TSD is a function that detects when the device overheats abnormally, please avoid utilizing this function aggressively.

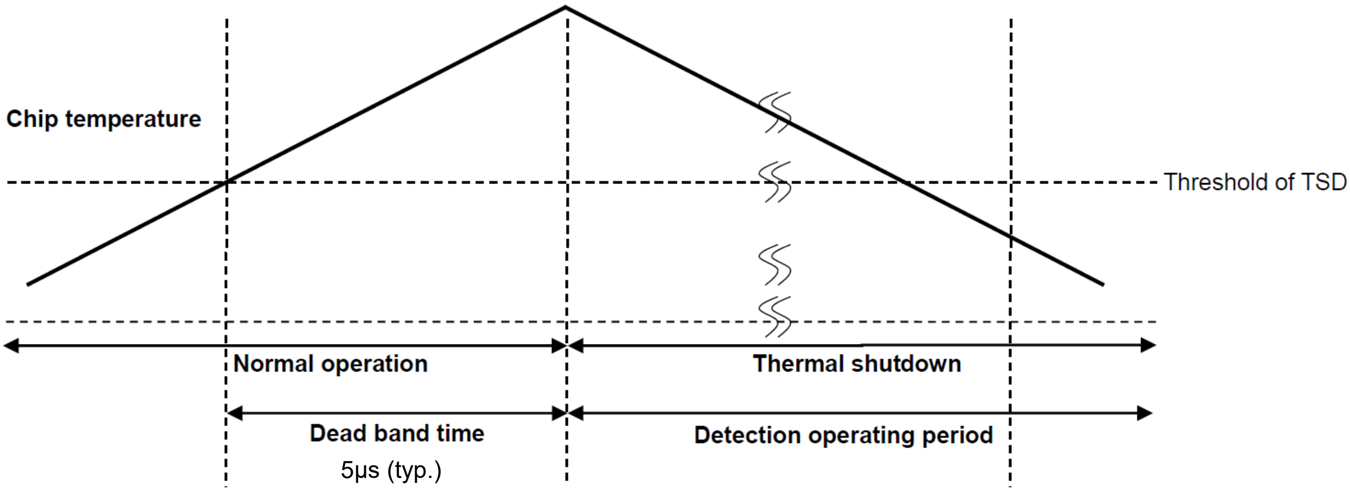


Figure 6.1 TSD operation

Note: The above time widths are not a guaranteed value, but a reference value.

・Low voltage detection circuit (UVLO)

When the voltage applied to the VM pin reaches 3.8 V (typ.) or less, the internal detection circuit starts operation and puts the output section off state. After the UVLO operation, it is canceled by setting the voltage applied to the VM pin to 4.0V (typ.) or higher.

・Over-current detection circuit (ISD)

When a current exceeding the specified value flows through the motor output, the internal detection circuit starts operation and latches the output section to OFF state. A dead zone period of 1.25 μs (typ.) is provided internally to avoid malfunctions caused by switching or ets.. After the ISD operation, it can be canceled by turning the power on again or setting the standby mode.

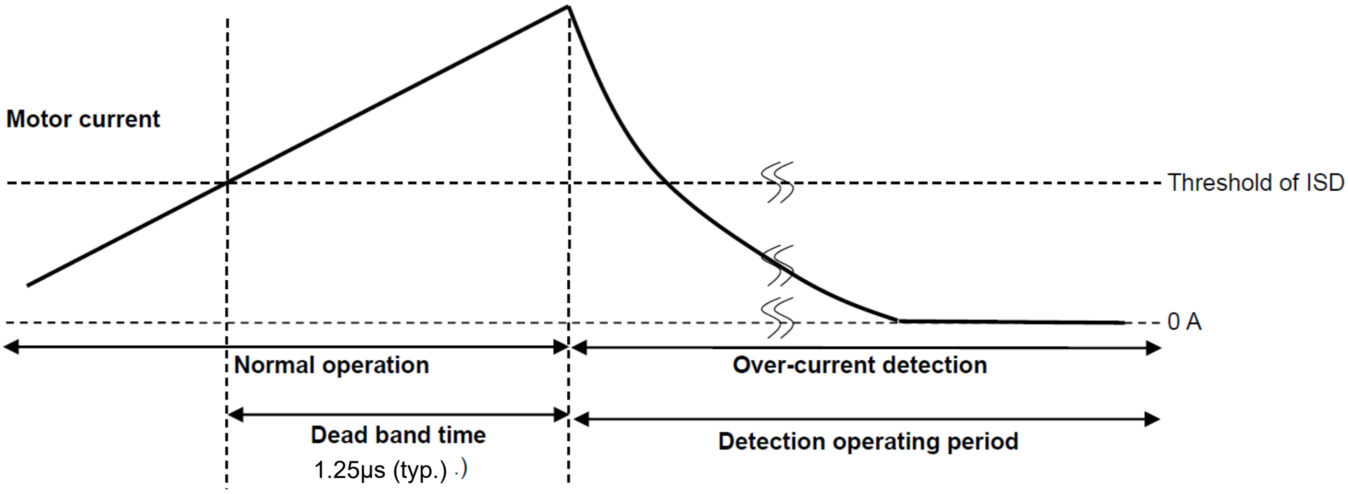


Figure 6.2 ISD operation

Note: The above time widths are not a guaranteed value, but a reference value.

7. Power consumption of the device

The power consumed in the device can be divided into the power consumed by the output transistors and the power consumed by the internal circuit including the logic section.

$P_D = P_D\,(out) + P_D\,(bias)$

- **Power consumption of output transistors**

The power consumption (P_D (out)) of the output transistor section is consumed in the high-side and low-side transistors in the H-bridge.

P_D (out) = Number of H-bridges x Iout (A) x VDS (V) = 2 (ch) x Iout (A) x Iout (A) x Ron (Ω) …… (1)

When the current waveform of the motor output is assumed as the ideal one (two-phase excitation / square wave), the average power of the output section can be calculated as follows.

When Ron = 0.8Ω, Iout (peak: Max) = 1.0 A, VM = 24V, it can be calculated as follows.

P_D (out) = 2 (ch) × 1.0 (A) × 1.0 (A) × 0.8(Ω) = 1.6 (W) ……………………………………… (2)

- **Power consumption of Logic block and IM system**

The power consumption P_D (bias) of the logic block and IM system is calculated separately during operation and stop.

I (IM3) = 5.4 mA (typ.): During operation
I (IM2) = 4.8 mA (typ.): During stopped

The output system is connected to the VM (12V). (Output system: the sum of the current consumed by the circuit connected to the VM and the current consumed by switching the output stage)

The power consumption can be calculated as follows.

P_D (bias) = 24 (V) × 0.0054 (A) = 0.13 (W)……………………………………………………… (3)

- **Power consumption**

The total power consumption P_D can be calculated from the values in formulas (2) and (3) as follows.

$P_D = P_D\,(out) + P_D\,(bias) = 1.6 + 0.13 = 1.73\ (W)$

The power consumption when the motor is not operating (when stopped) can be calculated as follows.

$P_D = 24(V) \times 0.0048\ (A) = 0.115\ (W)$

And power consumption can be reduced by stopping the operation by using the standby mode.

IM1 = 1μA (max)

In addition, in actual motor operation, the average current will be lower than the calculated value due to the transition time of the current step and the ripple caused by constant current PWM. However, referring to the above calculated values, please perform the thermal design of the board, etc. with a margin after a sufficient evaluation of the assembled board.

8. Application circuit example

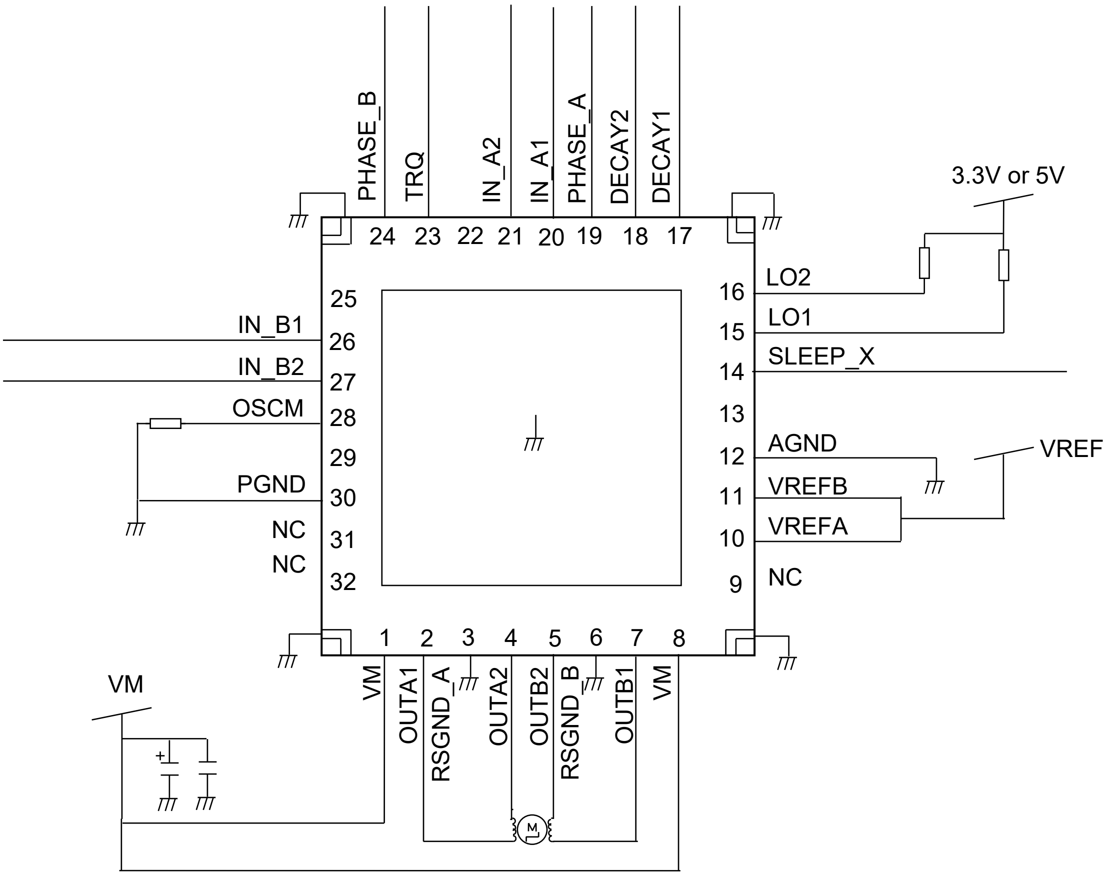


Figure 8.1 Application circuit example

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

8.1. Capacitor for power supply pins

Please connect a capacitor with an appropriate value to each pin for stabilizing the power supply voltage applied to the device and rejecting noises. And it is recommended to connect the capacitor as close to the device as possible. In particular, locating a ceramic capacitor close to the device is effective in suppressing fluctuations of high-frequency power supply and noise.

Table 8.1 Recommended values of capacitor at power supply pins

Item	Parts	Typical value	Recommended value 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

Note: Please consider connecting a capacitor between VREF and GND in accordance with application and environment.

Note: It is also possible to omit each part or use a capacitor other than the recommended value depending on the motor load conditions and PCB pattern layout.

8.2. Wiring pattern for power supply / GND

In this device, a large current is assumed to flow through PCB patterns especially of VM, AGND, PGND_x, OUT_x +, OUT_x- (x = A or B)). Please secure a sufficient wiring pattern in order not to be affected by the wiring impedance, etc.. As TB67S531FTG is surface mount package type, it is extremely important to dissipate heat from the heat sink on the back side of the package to the GND pattern of the board, therefore please design pattern in sufficient consideration of the thermal design.

8.3. Fuse

Please insert an appropriate fuse into the power supply line before use in order to prevent a continue large current flow in the event of an over-current or the device failure. The device may be destroyed caused by usage exceeding the absolute maximum rating, incorrect wiring, and abnormal pulse noise induced by wiring or load. As a result, a continues large current flow through the device might lead to smoke or ignition. Assuming a large current inflow and outflow cause by the device destruction, appropriate settings of fuse such as capacity, blow time, and insertion circuit location are required to minimize the effects.

In this device, the over-current detection circuit (ISD) that detects when an excessive current flows through the outputs and turns the outputs off is a built-in, but it is not guaranteed that the device is protected under all conditions. Please release the over-current state immediately after the fault detection circuit operates. Depending on the usage and conditions such as exceeding the absolute maximum ratings, the over-current detection circuit may not operate normally or the device may be damaged before the ISD operates. In addition, when over-current continues to flow, the device may be destroyed caused by heat generation depending on the usage and conditions. A secondary destruction is concerned when the over-current state continues, and non-operation of the ISD is concerned depending on the output load conditions because a dead zone period is provided in order to prevent malfunction caused by noise.

As a conclusion, considering the case of emergency please use a fuse in the power supply to prevent abnormal state form continuing.

9. PCBA design dimensions for reference

P-VQFN32-0505-0.50-004 (Unit: mm)

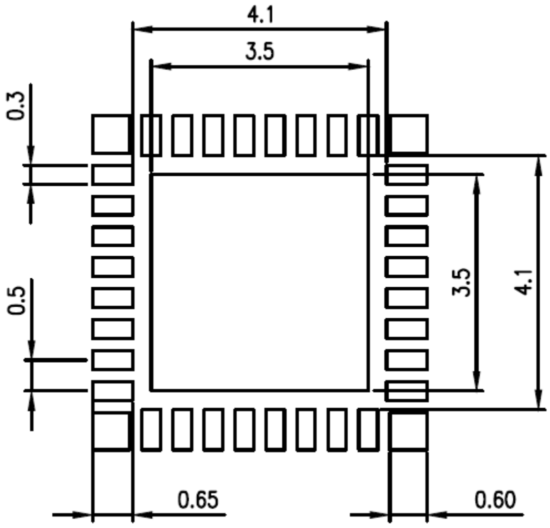


Figure 9.1 PCBA design dimensions for reference

Note: All linear dimensions are given in millimeters unless otherwise specified.

Note: 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.

Note: You are solely responsible for all aspects of your own land pattern, including but not limited to soldering processes.

Note: The drawing shown may not accurately represent the actual shape or dimensions.

Note: Before creating and producing designs and use, 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.

Note on Contents

1. **Block Diagram**
   Some of the functional blocks, circuits, or constants in the block diagram may be omitted or simplified for explanatory purposes.

2. **Equivalent Circuit**
   The equivalent circuit may be partially omitted or simplified to explain the circuit.

3. **Timing Charts**
   Timing charts may be simplified for explanatory purposes.

4. **Application Circuit Example**
   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, over-current 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

Over-current detection circuit

Over-current detection 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.

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.

Heat radiation design

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

Back-EMF

When a motor reverses the rotation direction, stops or slows down abruptly, a current flow back to the motor’s power supply due to the effect of back-EMF. If the current sink capability of the power supply is small, the device’s motor power supply and output pins might be exposed to conditions beyond absolute maximum ratings. To avoid this problem, take the effect of back-EMF into consideration in system design.

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