

# TB6640FTG

## Full-Bridge DC Motor Driver IC

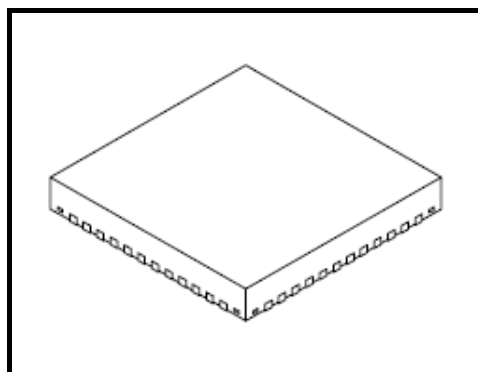
The TB6640FTG is a full-bridge DC motor driver with DMOS output transistors.

The low ON-resistance DMOS process and PWM control enables driving DC motors with high thermal efficiency.

Four operating modes are selectable via IN1 and IN2: clockwise (CW), counterclockwise (CCW), Short Brake and Stand-by.

### Features

- Power supply voltage : 40 V (max)
- Output current : 3 A (max)
- Direct PWM control
- PWM constant-current control
- CW/CCW/Short Brake/Stand-by modes
- Overcurrent shutdown circuit (ISD)
- Thermal shutdown circuit (TSD)
- Undervoltage lockout circuit (LVD)
- Dead time for preventing shoot-through current

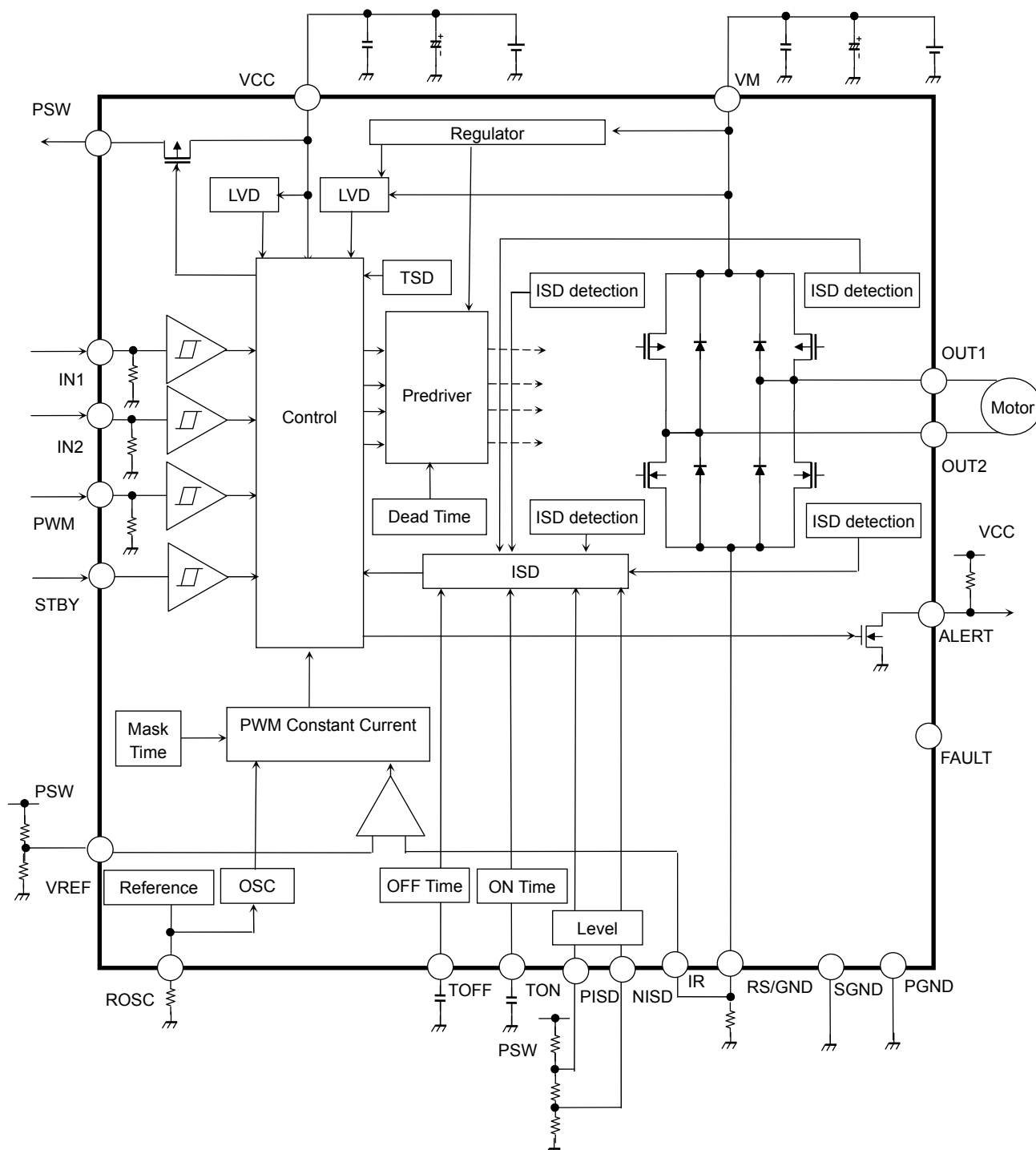


Weight: 0.1g (typ.)

## Block Diagram (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.

Toshiba does not grant any license to any industrial property rights by providing these examples of application circuits.



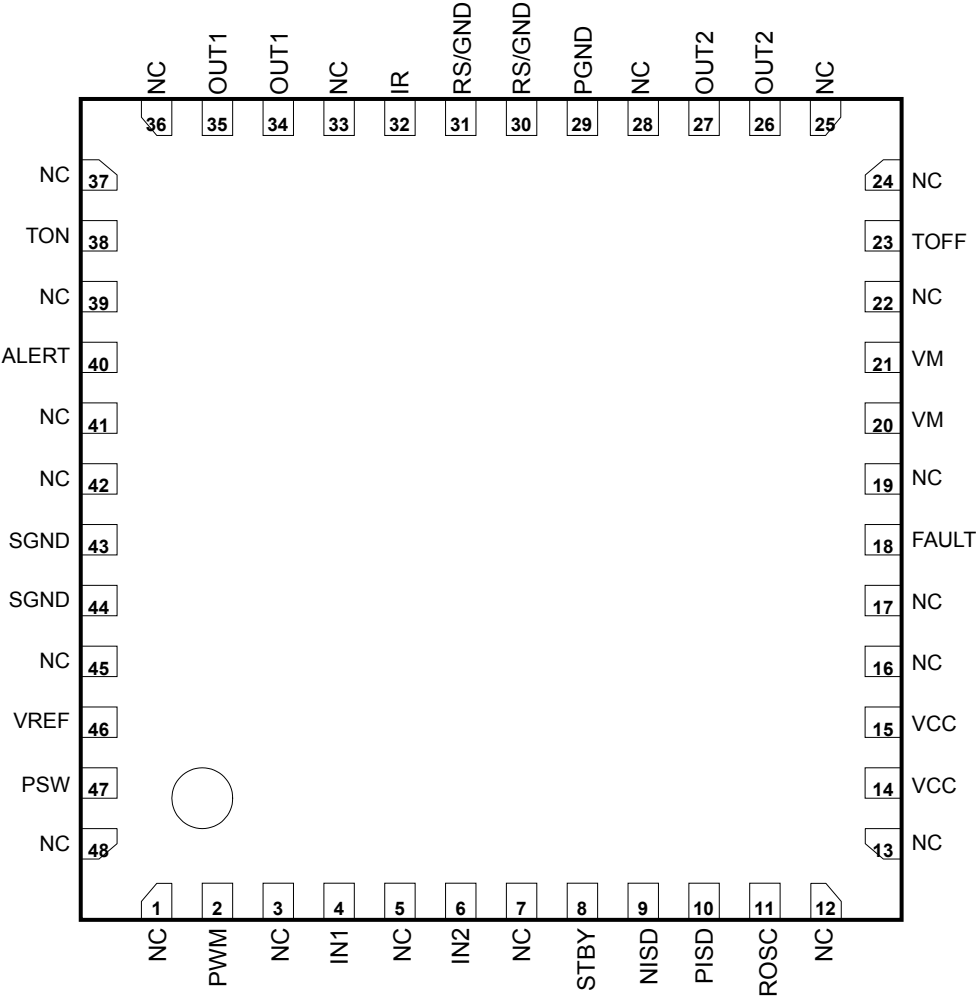
## Pin Functions

| Pin No. | Pin Name | Functional Description                                                    |
|---------|----------|---------------------------------------------------------------------------|
| 1       | N.C.     | No-connect                                                                |
| 2       | PWM      | PWM input pin                                                             |
| 3       | N.C.     | No-connect                                                                |
| 4       | IN1      | Control signal input pin 1                                                |
| 5       | N.C.     | No-connect                                                                |
| 6       | IN2      | Control signal input pin 2                                                |
| 7       | N.C.     | No-connect                                                                |
| 8       | STBY     | Standby input pin                                                         |
| 9       | NISD     | Program pin for overcurrent detection control for Nch                     |
| 10      | PISD     | Program pin for overcurrent detection control for Pch                     |
| 11      | ROSC     | Resistor control pin for reference frequency                              |
| 12      | N.C.     | No-connect                                                                |
| 13      | N.C.     | No-connect                                                                |
| 14      | VCC      | Power supply voltage pin                                                  |
| 15      | VCC      | Power supply voltage pin                                                  |
| 16      | N.C.     | No-connect                                                                |
| 17      | N.C.     | No-connect                                                                |
| 18      | FAULT    | TEST pin (The pin should be open.)                                        |
| 19      | N.C.     | No-connect                                                                |
| 20      | VM       | Power supply voltage pin for motor                                        |
| 21      | VM       | Power supply voltage pin for motor                                        |
| 22      | N.C.     | No-connect                                                                |
| 23      | TOFF     | Program pin for OFF time of overcurrent detection                         |
| 24      | N.C.     | No-connect                                                                |
| 25      | N.C.     | No-connect                                                                |
| 26      | OUT2     | Output pin 2                                                              |
| 27      | OUT2     | Output pin 2                                                              |
| 28      | N.C.     | No-connect                                                                |
| 29      | PGND     | Connect pin for power ground                                              |
| 30      | RS/GND   | Detection resistor pin for PWM constant-current control/ Power ground pin |
| 31      | RS/GND   | Detection resistor pin for PWM constant-current control/ Power ground pin |
| 32      | IR       | Detection pin for constant current                                        |
| 33      | N.C.     | No-connect                                                                |
| 34      | OUT1     | Output pin 1                                                              |
| 35      | OUT1     | Output pin 1                                                              |
| 36      | N.C.     | No-connect                                                                |
| 37      | N.C.     | No-connect                                                                |
| 38      | TON      | Program pin for ON time of overcurrent detection                          |
| 39      | N.C.     | No-connect                                                                |
| 40      | ALERT    | Error detection output pin                                                |
| 41      | N.C.     | No-connect                                                                |

|    |      |                                                     |
|----|------|-----------------------------------------------------|
| 42 | N.C. | No-connect                                          |
| 43 | SGND | Small signal ground pin                             |
| 44 | SGND | Small signal ground pin                             |
| 45 | N.C. | No-connect                                          |
| 46 | VREF | Supply voltage pin for PWM constant-current control |
| 47 | PSW  | Output pin for VCC                                  |
| 48 | N.C. | No-connect                                          |

Pin Assignment (top view)

Note: Design the pattern in consideration of the heat design because the back side has the role of heat radiation.  
(The back side should be connected to GND because it is connected to the back of the chip electrically.)



## Absolute Maximum Ratings (Ta = 25°C)

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.

| Characteristics       | Symbol   | Rating  | Unit | Appropriate pin       | Remarks                                                                                           |
|-----------------------|----------|---------|------|-----------------------|---------------------------------------------------------------------------------------------------|
| Power supply voltage  | VM       | 40      | V    | VM                    |                                                                                                   |
|                       | VCC      | 6       | V    | VCC                   |                                                                                                   |
| Output voltage        | VO1      | 40      | V    | OUT1,OUT2             |                                                                                                   |
|                       | VO2      | 6       | V    | ALERT,PSW             |                                                                                                   |
| Output current        | IO1 peak | 3       | A    | OUT1,OUT2             | Use the IC not to exceed 3A (Rating value) including parasitic diode of output transistor (DMOS). |
|                       | IO2 peak | 1       | mA   | ALERT,PSW             |                                                                                                   |
| Input voltage         | VIN      | -0.3~6  | V    | IN1,IN2,PWM,STBY,VREF |                                                                                                   |
| Power dissipation     | PD       | 2.5     | W    | —                     | 35 mm × 50 mm × 1.6 mm<br>CEM-3 double-sided,<br>Cu dimension: 50%                                |
| Operating temperature | Topr     | -40~85  | °C   | —                     |                                                                                                   |
| Storage temperature   | Tstg     | -55~150 | °C   | —                     |                                                                                                   |

## Operating Ranges

| Characteristics              | Symbol   | Min. | Typ. | Max. | Unit | Appropriate pin | Remarks                                                                                                                                                                                                                                                                                                            |
|------------------------------|----------|------|------|------|------|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Power supply voltage         | VMopr    | 4.5  | 24   | 38   | V    | VM              |                                                                                                                                                                                                                                                                                                                    |
|                              | VCCopr1  | 4.5  | 5    | 5.5  | V    | VCC             | In case of using constant current PWM control.                                                                                                                                                                                                                                                                     |
|                              | VCCopr2  | 3.0  | 5    | 5.5  | V    | VCC             | In case of not using constant current PWM control.                                                                                                                                                                                                                                                                 |
| Input voltage of VREF and IR | VREFopr  | 0    | —    | 0.5  | V    | VREF,IR         |                                                                                                                                                                                                                                                                                                                    |
| PWM frequency                | fPWMopr  | —    | 100  | —    | kHz  | PWM, IN1, IN2   | Reference value<br>The switching characteristic of the output transistor strains the frequency.                                                                                                                                                                                                                    |
| Output current               | IO (Ave) | —    | 1    | —    | A    | —               | Reference value<br>The average output current shall be increased or decreased depending on usage conditions such as ambient temperature and IC mounting method).<br>Use the average output current so that the junction temperature of 150°C (Tj) and the absolute maximum output current rating are not exceeded. |

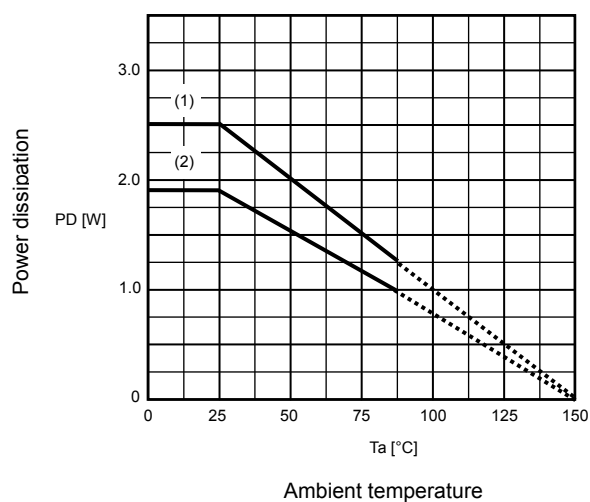
## Electrical Characteristics (unless otherwise specified, Ta = 25°C, VM = 24 V, and VCC = 5 V)

| Characteristics                                   |                                           | Symbol  | Test Condition                                 | Min  | Typ. | Max | Unit |
|---------------------------------------------------|-------------------------------------------|---------|------------------------------------------------|------|------|-----|------|
| Power supply voltage                              |                                           | IM      | VM operation mode                              | —    | 1.3  | 5   | mA   |
|                                                   |                                           | ICC     | VCC operation mode                             | —    | 3    | 7   | mA   |
|                                                   |                                           | IMSTBY  | VM standby mode                                | —    | —    | 1   | μA   |
|                                                   |                                           | ICCSTBY | VCC standby mode                               | —    | —    | 1   | μA   |
| IN1 pin<br>IN2 pin<br>PWM pin                     | Input voltage                             | VINH    | —                                              | 2    | —    | 5.5 | V    |
|                                                   |                                           | VINL    | —                                              | 0    | —    | 0.7 |      |
|                                                   | Hysteresis voltage                        | VINHYS  | —                                              | —    | 0.2  | —   | μA   |
|                                                   |                                           | IINH    | VIN = 5 V                                      | —    | 20   | 30  |      |
| STBY pin                                          | Input voltage                             | VINHSB  | —                                              | 2    | —    | 5.5 | V    |
|                                                   |                                           | VINLSB  | —                                              | 0    | —    | 0.7 |      |
|                                                   | Hysteresis voltage                        | VSBHYS  | —                                              | —    | 0.2  | —   | V    |
|                                                   |                                           | IINSB   | —                                              | —    | —    | 1   |      |
|                                                   | Output response time 1                    | TSTBY1  | STBY = H → L (Reference value *)               | —    | 0.1  | —   | μs   |
|                                                   | Output response time 2                    | TSTBY2  | STBY = L → H (Reference value *)               | —    | 16   | 30  | μs   |
| OUT1 pin<br>OUT2 pin                              | Output ON resistance                      | RONU    | Io = -2.5 A                                    | —    | 0.6  | 0.9 | Ω    |
|                                                   |                                           | RONL    | Io = 2.5 A                                     | —    | 0.4  | 0.6 | Ω    |
|                                                   | Output leakage current                    | ILU     | VM = 40 V, VOUT = 0 V                          | -1   | 0    | —   | μA   |
|                                                   |                                           | ILL     | VM = VOUT = 40 V                               | —    | 0    | 1   |      |
|                                                   | Diode forward voltage                     | VFU     | Io = 2.5 A                                     | —    | 1.3  | 1.7 | V    |
|                                                   |                                           | VFL     | Io = -2.5 A                                    | —    | 1.15 | 1.5 |      |
| ALERT pin                                         | Output LOW voltage                        | VALLO   | IALERT = 1 mA                                  | —    | 0.02 | 0.4 | V    |
|                                                   | Output leakage current                    | IALLE   | VALERT = 5.5 V                                 | —    | 0    | 1   | μA   |
| TON pin                                           | TON voltage                               | VTON    | —                                              | 1.1  | 1.25 | 1.4 | V    |
|                                                   | TON charge current                        | ITON    | —                                              | 30   | 110  | 200 | μA   |
|                                                   | TON time                                  | TTON    | TON: 470 pF (Reference value *)                | 2.3  | 5.35 | 9.4 | μs   |
| TOFF pin                                          | TOFF voltage                              | VTOFF   | —                                              | 1.1  | 1.25 | 1.4 | V    |
|                                                   | TOFF charge current                       | ITOFF   | —                                              | 0.3  | 1.25 | 2.5 | μA   |
|                                                   | TOFF time                                 | TTOFF   | TOFF: 1000 pF (Reference value *)              | 0.4  | 1    | 1.6 | ms   |
| PISD pin                                          | PISD over current set                     | IPISD   | PISD = 3 V (Reference value *)                 | 4    | 5    | 7   | A    |
| NISD pin                                          | NISD over current set                     | INISD   | NISD = 3 V (Reference value *)                 | 4    | 5    | 6   | A    |
| ROSC pin                                          | OSC frequency                             | fOSC    | ROSC = 24 kΩ (Reference value *)               | 8    | 10   | 12  | MHz  |
|                                                   | Constant current PWM short brake time     | TSHB    | ROSC = 24 kΩ                                   | 13.3 | 16   | 20  | μs   |
|                                                   | Constant current PWM minimum charge width | TMIN    | ROSC = 24 kΩ (Reference value *)<br>VREF=0.25V | 1.2  | 1.7  | 2.2 | μs   |
| VREF pin                                          | Input current                             | IVREF   | —                                              | -0.5 | —    | 0.5 | μA   |
| IR pin                                            | Constant current PWM offset voltage       | VIROFS  | VREF = 0 V IR (Reference value *)              | -10  | 0    | 10  | mV   |
| PSW pin                                           | Output ON resistance                      | PSWRON  | IPSW = -1 mA                                   | —    | 25   | 75  | Ω    |
|                                                   | Output leakage current                    | PSWIL   | VPSW = 0 V, VCC = 5.5 V                        | —    | 0    | 1   | μA   |
| Operation temperature of thermal shutdown circuit |                                           | TSDON   | (Reference value *)                            | —    | 170  | —   | °C   |

| Characteristics                                          | Symbol | Test Condition      | Min | Typ. | Max | Unit |
|----------------------------------------------------------|--------|---------------------|-----|------|-----|------|
| Recover temperature of thermal shutdown circuit          | TSDOFF | (Reference value *) | —   | 130  | —   | °C   |
| Hysteresis temperature width of thermal shutdown circuit | TSDHYS | (Reference value *) | —   | 40   | —   | °C   |
| Detect voltage for VM decreasing                         | VMD    | —                   | —   | 4.0  | —   | V    |
| Recover voltage for VM decreasing                        | VMR    | —                   | —   | 4.2  | —   | V    |
| Hysteresis voltage width for VM decreasing               | VMHYS  | (Reference value *) | —   | 0.2  | —   | V    |
| Detect voltage for VCC decreasing                        | VCCD   | —                   | —   | 2.7  | —   | V    |
| Recover voltage for VCC decreasing                       | VCCR   | —                   | —   | 2.8  | —   | V    |
| Hysteresis voltage width for VCC decreasing              | VCCHYS | (Reference value *) | —   | 0.1  | —   | V    |

\*: Toshiba does not implement testing before shipping.

## Characteristics of Power Dissipation (Reference value)



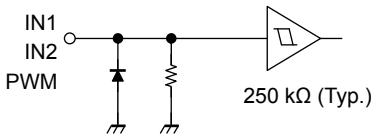
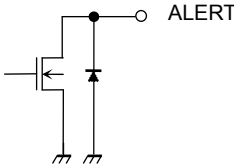
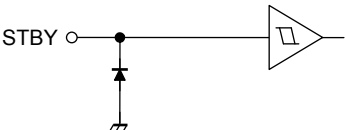
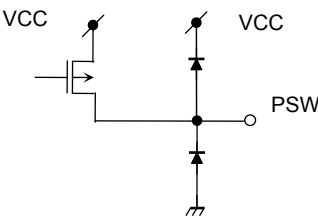
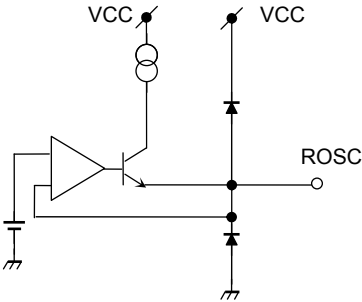
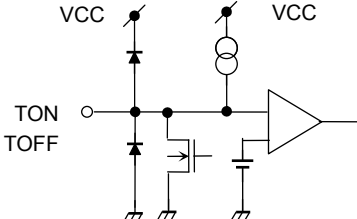
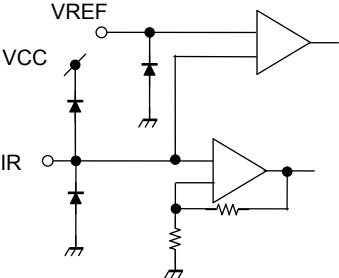
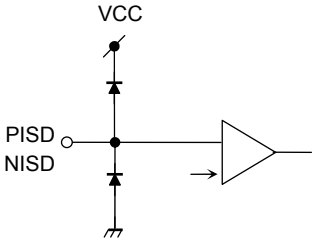
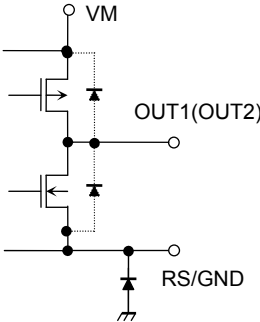
1) When mounted on the board:  $\theta_{ja} = 49.3^{\circ}\text{C/W}$  (35 mm × 50 mm × 1.6 mm CEM-3(thermal conductivity; 1.0 W/m·K) Double-sided Cu dimension: 50%)

2) When mounted on the board:  $\theta_{ja} = 65.7^{\circ}\text{C/W}$  (35 mm × 50 mm × 1.6 mm CEM-3(thermal conductivity; 1.0 W/m·K) Double-sided Cu dimension: 25%)



I/O Equivalent Circuits

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

| Pin name               | I/O Internal Circuit                                                                | Pin name     | I/O Internal Circuit                                                                 |
|------------------------|-------------------------------------------------------------------------------------|--------------|--------------------------------------------------------------------------------------|
| IN1<br>IN2<br>PWM      |    | ALERT        |   |
| STBY                   |    | PSW          |    |
| ROSC                   |   | TON<br>TOFF  |   |
| IR<br>VREF             |  | PISD<br>NISD |  |
| OUT1<br>OUT2<br>RS/GND |  |              |                                                                                      |

## Functional Description

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

Timing charts may be simplified for explanatory purposes.

### 1. Input/Output Functions

| Input |     |     |     | Output     |            | Mode        |
|-------|-----|-----|-----|------------|------------|-------------|
| STBY  | IN1 | IN2 | PWM | OUT1       | OUT2       |             |
| H     | H   | H   | H   | L          | L          | Short brake |
|       |     |     | L   | L          | L          | Short brake |
|       | L   | H   | H   | L          | L          | Short brake |
|       |     |     | L   | L          | H          | CCW/CW      |
|       | H   | L   | H   | L          | L          | Short brake |
|       |     |     | L   | H          | L          | CW/CCW      |
|       | L   | L   | —   | OFF (Hi-Z) | OFF (Hi-Z) | Standby     |
|       |     |     | —   | OFF (Hi-Z) | OFF (Hi-Z) | Standby     |
| L     | —   | —   | —   | OFF (Hi-Z) | OFF (Hi-Z) | Standby     |

### 2. Protective Operation Alert Output (ALERT pin)

The ALERT pin behaves as an open-drain output and provides a high-impedance state on output being pulled up by a resistor externally wired.

The output is Low when the TB6640FTG performs a normal operation. The output is High when the operation is in the states of the standby mode, the thermal shutdown circuit (TSD), the overcurrent detection circuit (ISD), and the under voltage lockout (LVD).

### 3. VCC Output (PSW pin)

PSW pin behaves as an open-drain output and provides VCC in the normal operation.

The output is High when the operation is in the states of standby mode and the under voltage lockout (LVD).

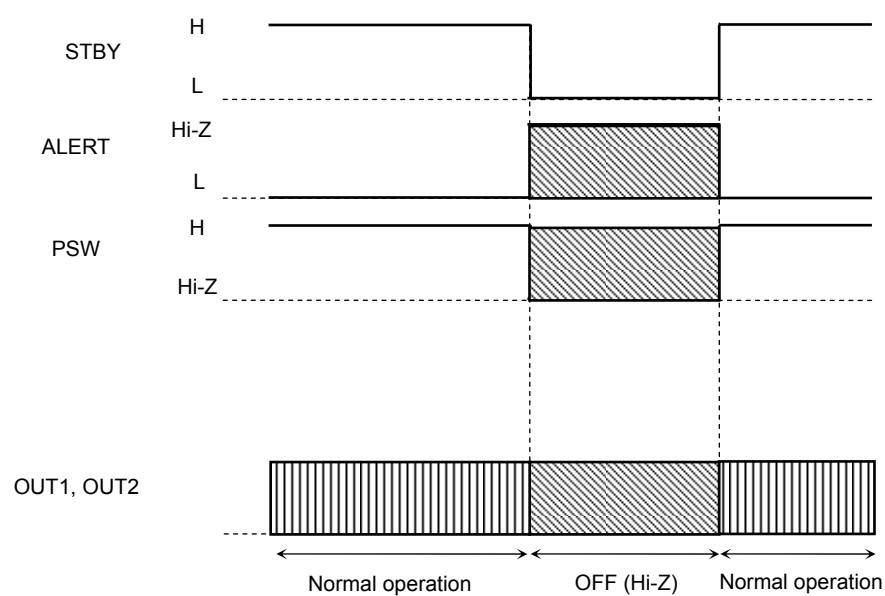
The standby power requirement can be reduced by using it as a set voltage of the external part because it synchronizes with the standby mode.

#### 4. Standby Mode

The operation state moves to the standby mode when STBY pin outputs Low or both of IN1 pin and IN2 pin output Low. The power consumption can be reduced in this mode.

Standby mode can also release the thermal shutdown circuit (TSD) and the overcurrent detection circuit (ISD) forcibly.

<Standby mode>



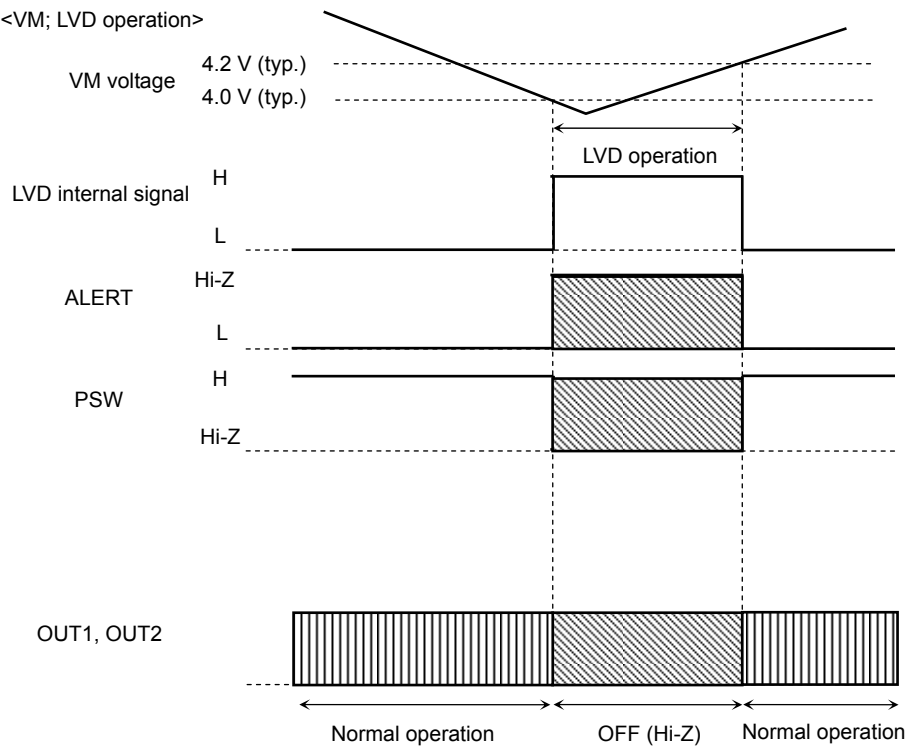
## 5. Undervoltage Lockout Circuit (LVD)

The TB6640FTG incorporates an undervoltage lockout circuit for VM and VCC.

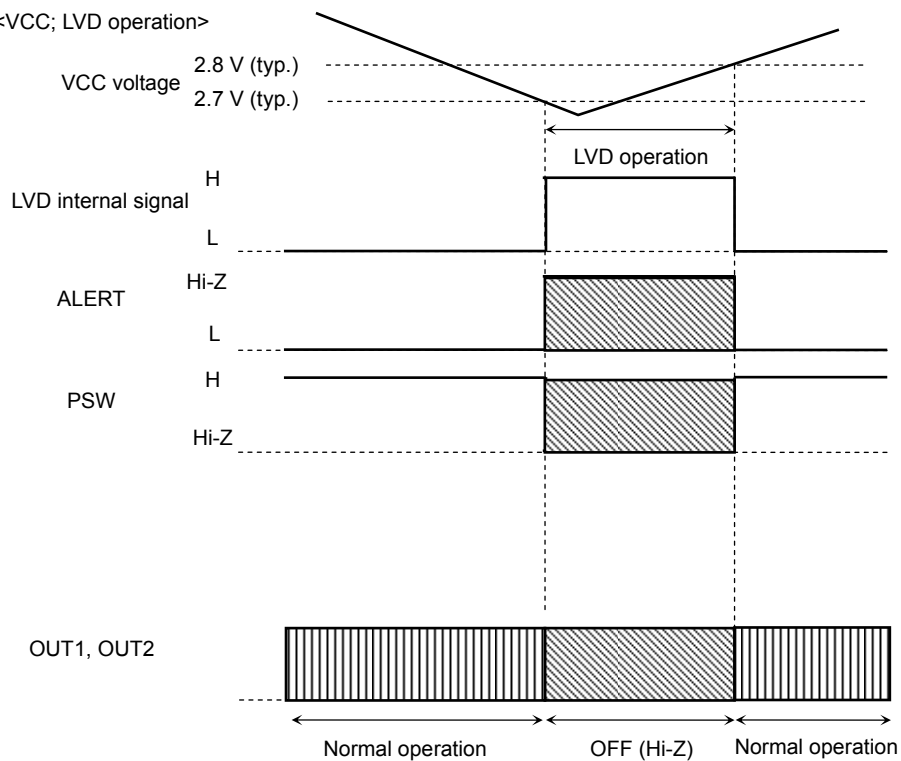
When VM drops under 4.0 V (typ.), all the outputs are turned off (Hi-Z). The LVD circuit has a hysteresis of 0.2 V (typ.); the TB6640FTG resumes the normal operation at 4.2 V (typ.).

When VCC drops under 2.7 V (typ.), all the outputs are turned off (Hi-Z). The LVD circuit has a hysteresis of 0.1 V (typ.); the TB6640FTG resumes the normal operation at 2.8 V (typ.).

<VM; LVD operation>



<VCC; LVD operation>



## 6. Thermal Shutdown Circuit (TSD)

The TB6640FTG incorporates a thermal shutdown circuit. If the junction temperature ( $T_j$ ) exceeds 170°C (typ.), all the outputs are turned off (Hi-Z).

The TB6640FTG has a hysteresis of 40°C (typ.); the TB6640FTG resumes the normal operation automatically when both of the following conditions are provided; the temperature is 130°C (typ.) or less. The operation stops for more than toff.

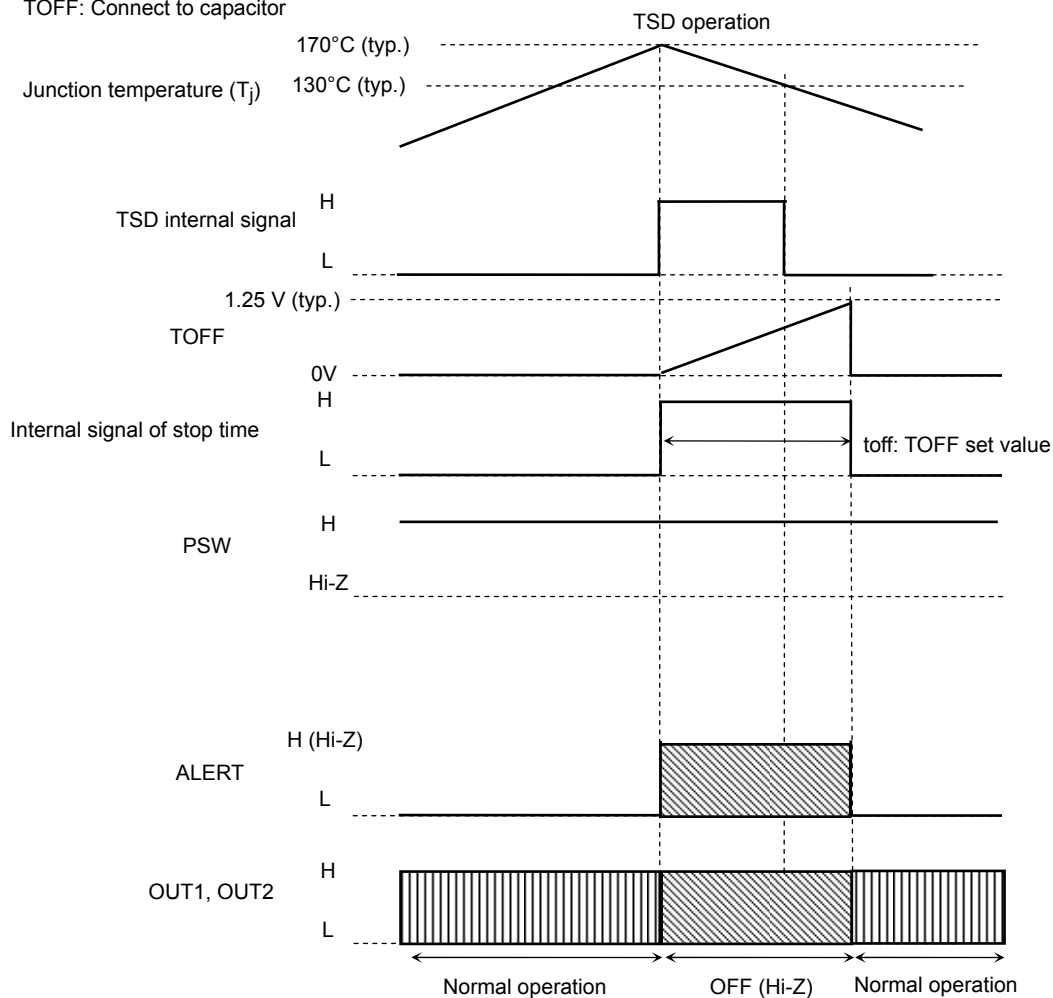
Stop time (toff) can be programmed by the capacitor of TOFF pin.

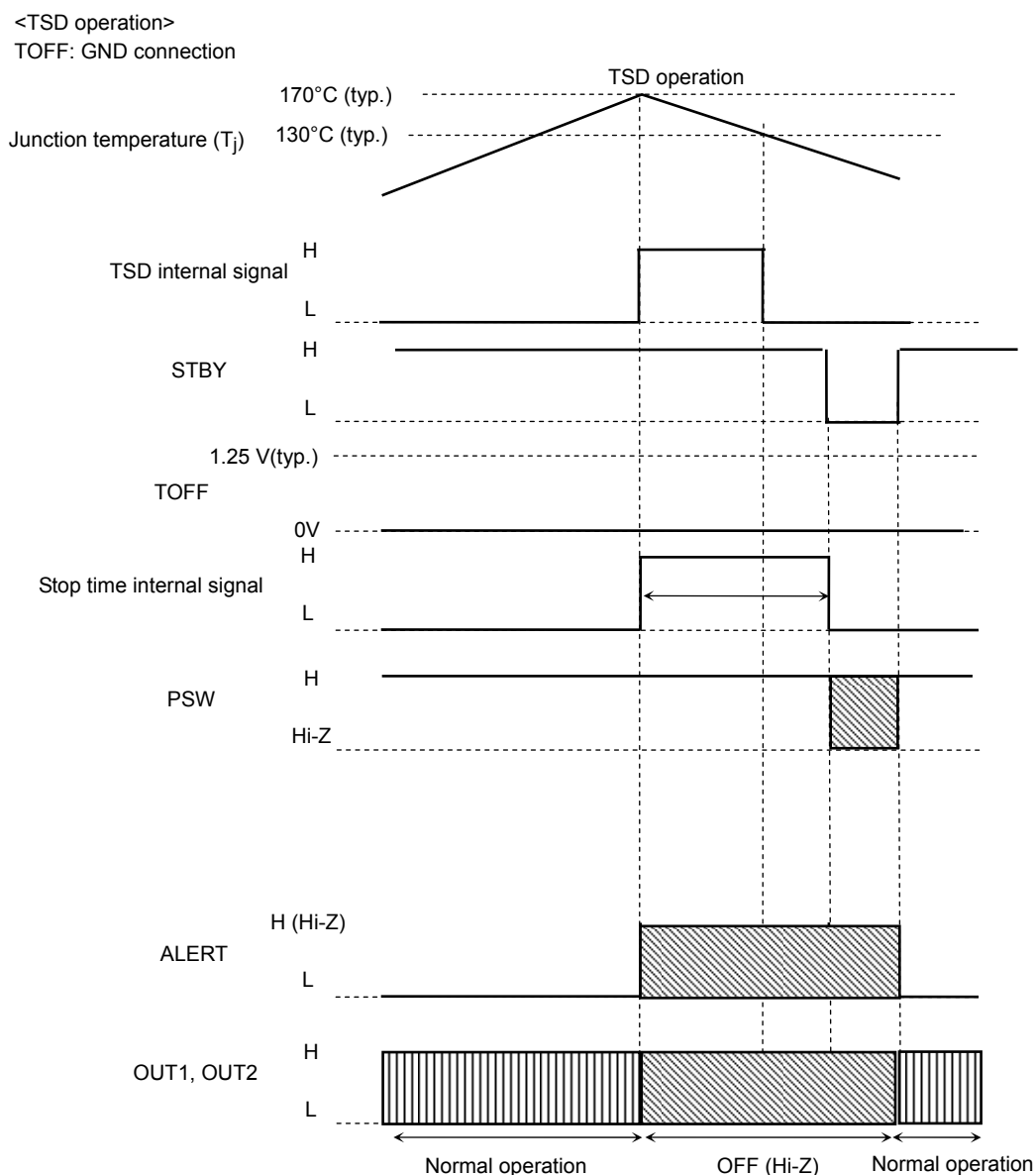
In order not to resume the normal operation automatically after the thermal shutdown mode, connect TOFF pin to the GND.

The TB6640FTG resumes the normal operation by transferring to the standby mode (STBY pin = Low or IN1 pin = IN2 pin = Low).

<TSD operation>

TOFF: Connect to capacitor





Note: The TSD circuit is activated if the absolute maximum junction temperature rating ( $T_j$ ) of 150°C is violated. Note that the circuit is provided as an auxiliary only and does not necessarily provide the IC with a perfect protection from any kind of damages.

## 7. Overcurrent Shutdown Circuit (ISD)

The TB6640FTG incorporates overcurrent detection (ISD) circuits monitoring the current that flows through each of all the four output power transistors.

The detection current is programmable by setting input voltage of NISD pin and PISD pin. If the overcurrent flowing through any one of the ISD circuit flows beyond the detected time threshold, outputs of OUT1 and OUT2 are turned off (Hi-Z) and that of ALERT is programmed High (Hi-Z).

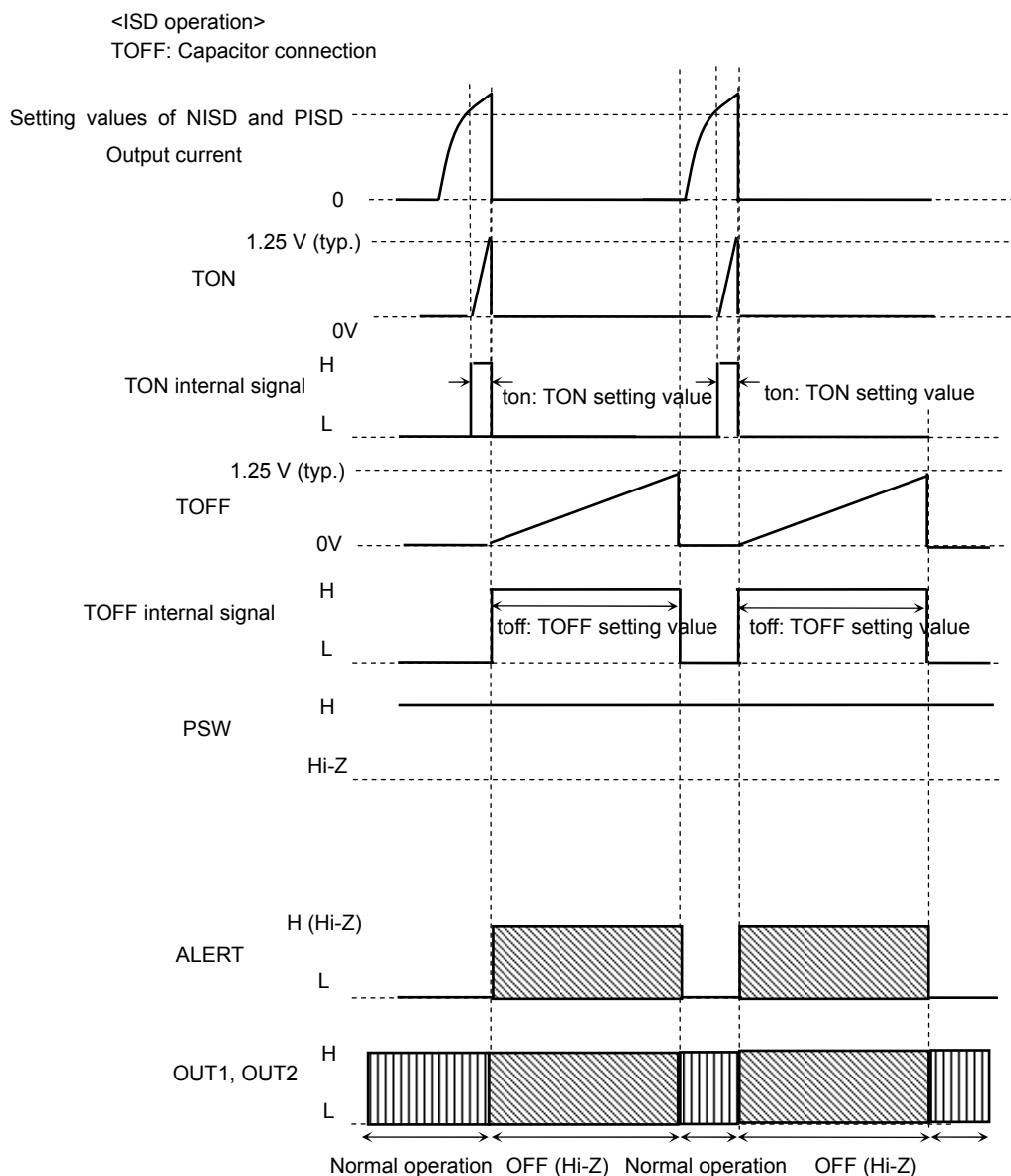
Then, the TB6640FTG resumes the normal operation automatically after stop time (toff) has passed.

The detection time (ton) is controllable through the external resistor of the TON pin.

The stop time (toff) is controllable through the capacitor of the TOFF pin.

In order not to resume the normal operation automatically after detection of overcurrent, connect TOFF pin to the GND.

The TB6640FTG resumes the normal operation by transferring to the standby mode (STBY pin = Low or IN1 pin = IN2 pin = Low).



Note: The ISD circuit is activated if the absolute maximum current rating is violated. Note that the circuit is provided as an auxiliary only and does not necessarily provide the IC with a perfect protection from damages due to overcurrent caused by power fault, ground fault, load-short and the like.

## 8. Direct PWM Control

The motor rotation speed is controllable by the PWM input sent through the PWM pin.

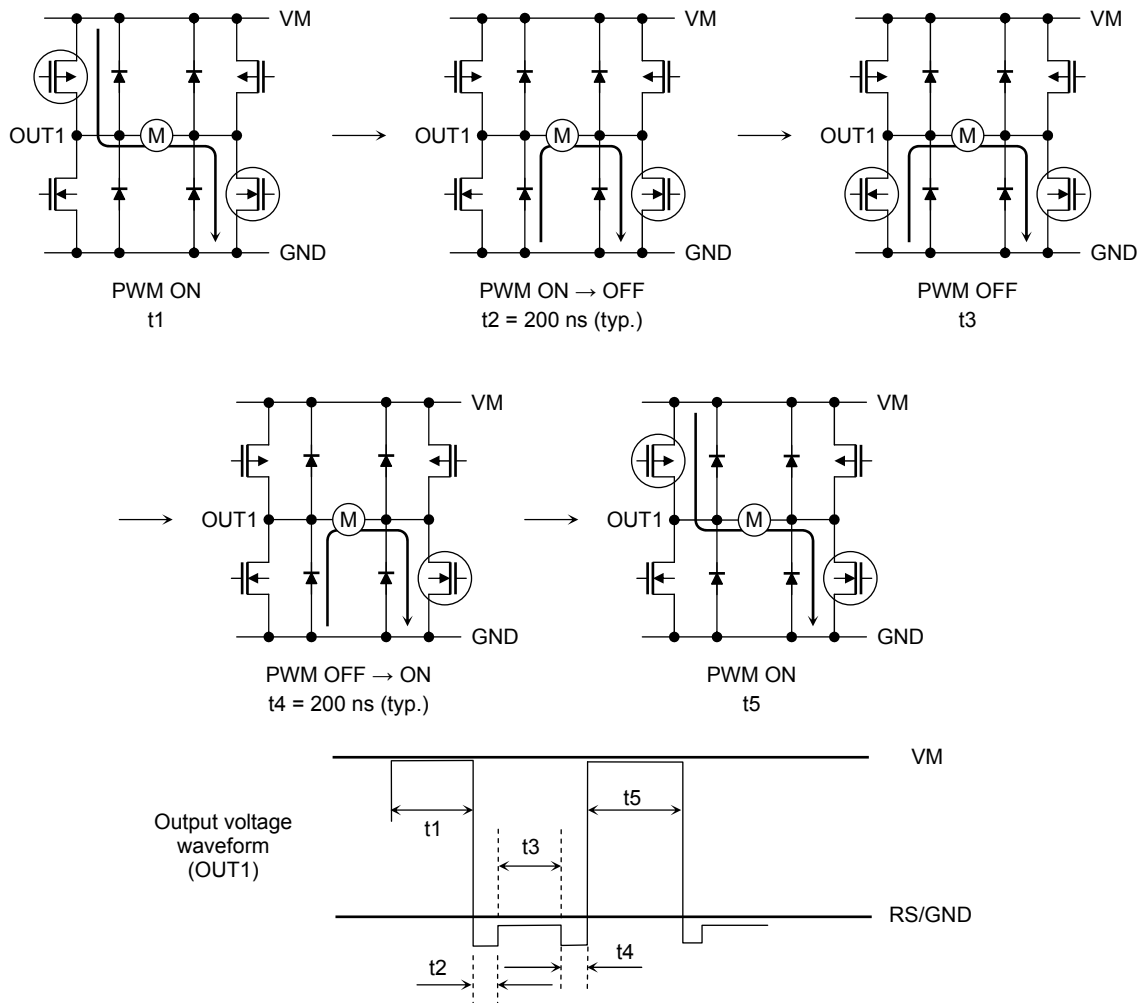
It is also possible to control the motor rotation speed by sending in the PWM signal through not the PWM pin but the IN1 and IN2 pins.

When the motor drive is controlled by the PWM input, the TB6640FTG repeats operating in Normal Operation mode and Short Brake mode alternately.

For preventing the shoot-through current in the output circuit caused by the upper and lower power transistors being turned on simultaneously, the dead time is internally generated at the time the upper and lower power transistors switches between on and off.

This eliminates the need of inserting Off time externally; thus the PWM control with synchronous rectification is enabled.

Note that inserting Off time externally is not required on operation mode changes between CW and CCW, and CW (CCW) and Short Brake, again, because of the dead time generated internally.





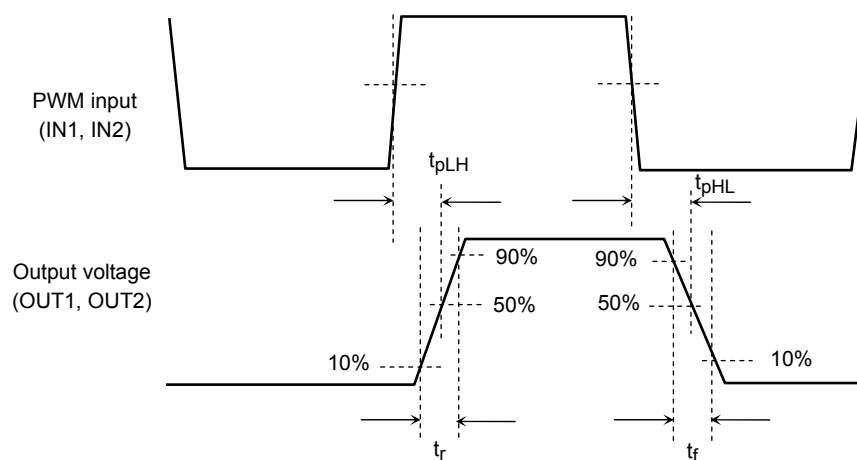
## 9. Output Circuit

The switching characteristics of the output transistors of the OUT1 and OUT2 pins are as shown below:

Ta = 25°C, VM = 24 V, VCC= 5V, No load

| Characteristic   | Typ. (Reference value*) | Max. (Reference value ) | Unit |
|------------------|-------------------------|-------------------------|------|
| t <sub>pLH</sub> | 260                     | 500                     | ns   |
| t <sub>pHL</sub> | 260                     | 500                     |      |
| t <sub>r</sub>   | 50                      | 100                     |      |
| t <sub>f</sub>   | 50                      | 100                     |      |

\*In case of switching in the short- brake mode. When it switches in the standby mode, it delays according to the output response time.



## 10. PWM Constant-Current Control

The TB6640FTG uses a peak current detection technique to keep the output current constant by applying constant voltage through the VREF pin. When running in Discharge mode, the TB6640FTG powers the motor to operate in Short-brake mode (OUT1 = OUT2 = Low).

### (1) PWM constant-current control programming

The peak current upon the constant-current operation is determined by applying voltage on the VREF pin. The peak current value is calculated by the following equation:

$$I_O = V_{REF}/R \quad [A]$$

### (2) PWM constant-current programming time

Reference oscillation frequency is determined by connecting the resistance to the ROSC pin.

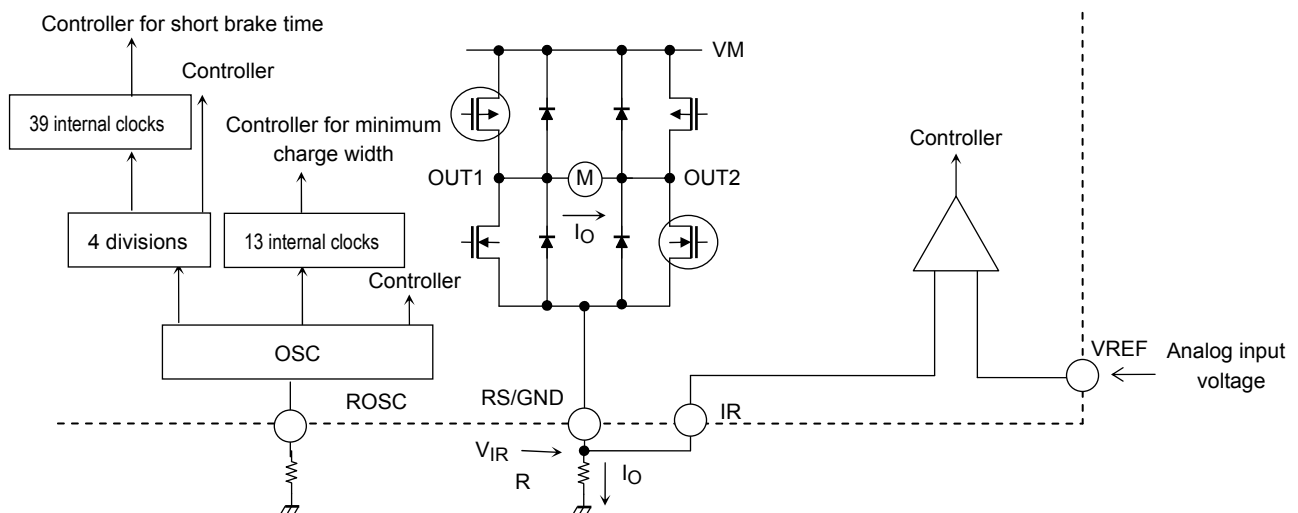
Short brake time (discharging time) corresponds to 39 internal clocks of four cycles of OSC signal and adding analog delay time.

Minimum charge width corresponds to 13 internal clocks of OSC signal and adding analog delay time.

Short brake time =  $4/f_{OSC} \times 39$  internal clocks + A      A: Analog delay time (400 ns (typ.))

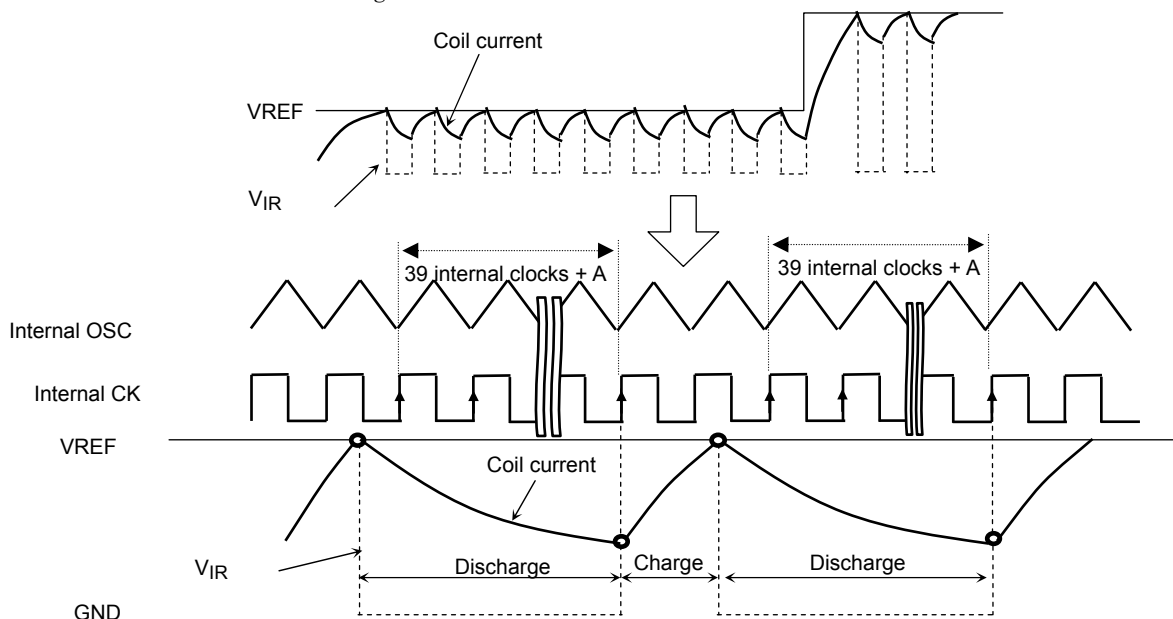
Minimum charge width =  $1/f_{OSC} \times 13$  internal clocks + B      B: Analog delay time (350 ns (typ.))

Ex.:  $f_{OSC} = 10$  MHz; Short brake time = 16  $\mu$ s (typ.)      Minimum charge width = 1.7  $\mu$ s (typ.)



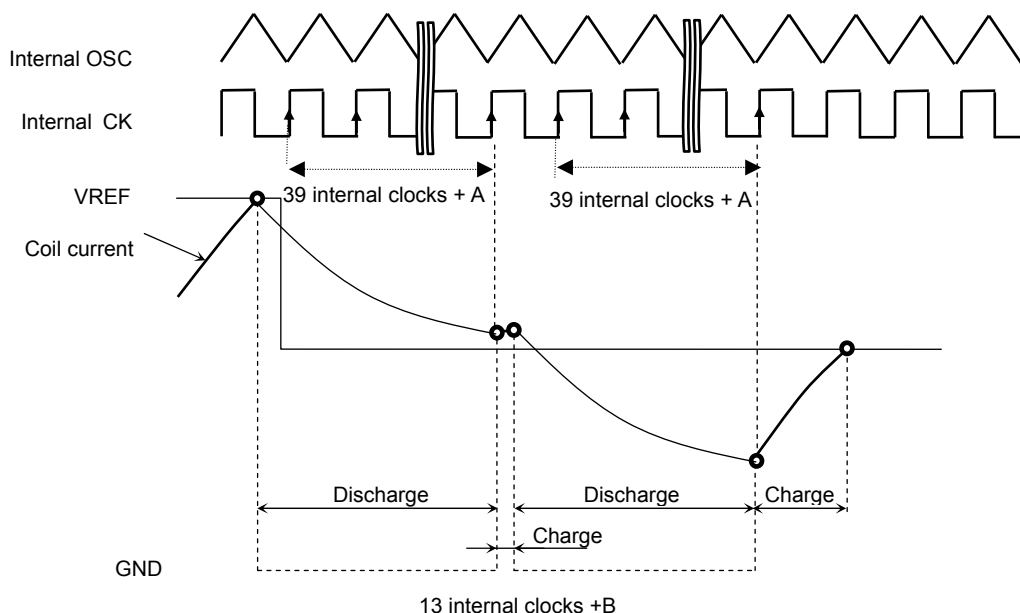
### (3) Constant-current chopping

The TB6640FTG enters Discharge mode when  $V_{IR}$  reaches the predetermined voltage ( $V_{REF}$ ). After a lapse of 39 internal clocks + A which is generated by the 4 cycles of OSC signal, the TB6640FTG shifts to Charge mode.



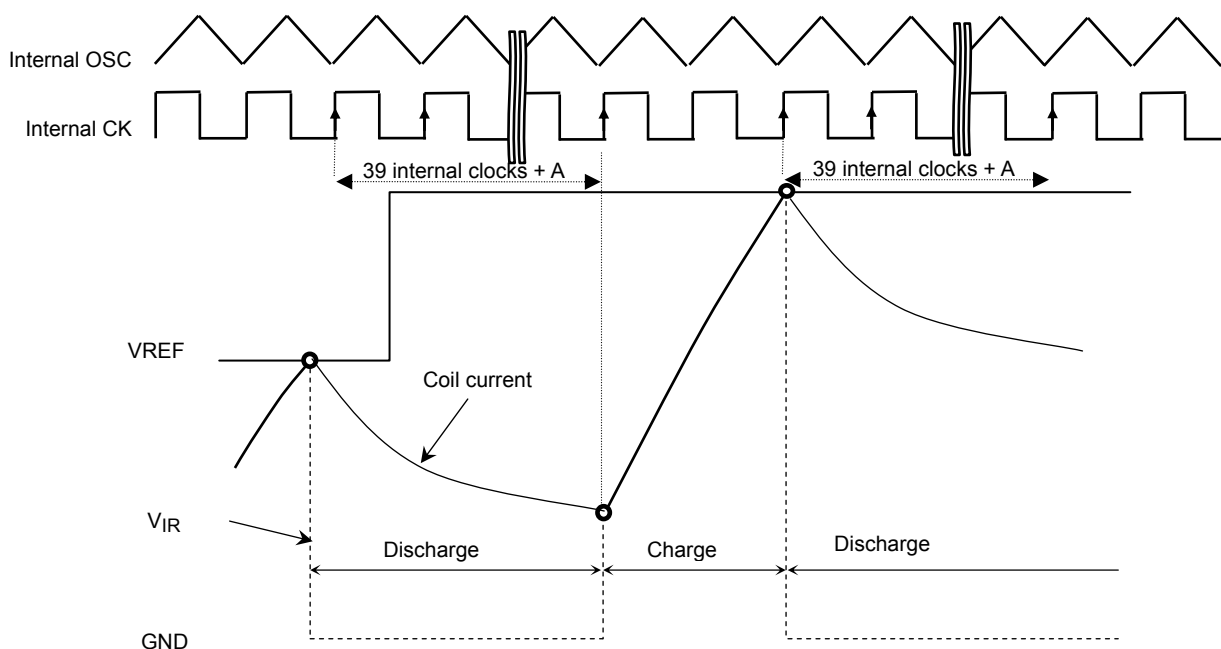
(4) Operation on change of predetermined current value (when in Discharge mode)

The TB6640FTG enters Discharge mode as  $V_{IR}$  reaches the predetermined voltage ( $V_{REF}$ ) and then transits to Charge mode after 39 internal clocks + A. However, if  $V_{IR} > V_{REF}$  at the time, the TB6640FTG goes back to Discharge mode. If  $V_{IR} < V_{REF}$  after another 39 internal clocks + A, then the TB6640FTG enters Charge mode and stays until  $V_{IR}$  reaches  $V_{REF}$ .



(5) Operation on change of predetermined current value (when in Charge mode)

Even though  $V_{REF}$  reaches the predetermined current value, Discharge mode continues for 39 internal clocks + A after that. And then Charge mode is entered.



Due to the peak current detection technique, the average current value of the constant-current operation shall be smaller than the predetermined value. Because this depends on characteristics of used motor coils, precise identification of the used motor coils must be performed when determining the current value.

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2013-08-13

## 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.

Toshiba does not grant any license to any industrial property rights by providing these examples of application circuits.

### 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 the device breakdown, damage or deterioration, and may result injury by explosion or combustion.
- [2] 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.
- [3] If your design includes an inductive load such as a motor coil, incorporate a protection circuit into the design to prevent device malfunction or breakdown caused by the current resulting from the inrush current at power ON or the negative current resulting from the back electromotive force at power OFF. IC breakdown may cause injury, smoke or ignition.  
Use a stable power supply with ICs with built-in protection functions. If the power supply is unstable, the protection function may not operate, causing IC breakdown. IC breakdown may cause injury, smoke or ignition.
- [4] Do not insert devices in the wrong orientation or incorrectly.  
Make sure that the positive and negative terminals of power supplies are connected properly.  
Otherwise, the current or power consumption may exceed the absolute maximum rating, and exceeding the rating(s) may cause the device breakdown, damage or deterioration, and may result injury by explosion or combustion.  
In addition, do not use any device that is applied the current with inserting in the wrong orientation or incorrectly even just one time.

**Points to remember on handling of ICs****(1) Over current Protection Circuit**

Over current protection circuits (referred to as current limiter circuits) do not necessarily protect ICs under all circumstances. If the over current protection circuits operate against the over current, clear the over current status immediately.

Depending on the method of use and usage conditions, such as exceeding absolute maximum ratings can cause the over current protection circuit to not operate properly or IC breakdown before operation. In addition, depending on the method of use and usage conditions, if over current continues to flow for a long time after operation, the IC may generate heat resulting in breakdown.

**(2) Thermal Shutdown Circuit**

Thermal shutdown circuits do not necessarily protect ICs under all circumstances. If the thermal shutdown circuits operate against the over temperature, clear the heat generation status immediately.

Depending on the method of use and usage conditions, such as exceeding absolute maximum ratings can cause the thermal shutdown circuit to not operate properly or IC breakdown before operation.

**(3) Heat Radiation Design**

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

**(4) Back-EMF**

When a motor rotates in the reverse 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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