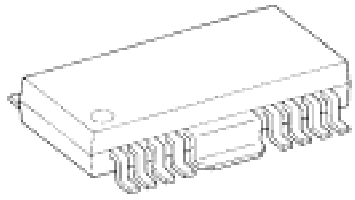
TOSHIBA Bi-CD Integrated Circuit Silicon Monolithic

TB6559FG

Full-Bridge Driver IC for DC Motor

TB6559FG is a full-bridge driver IC for DC motor which uses LDMOS for output transistors. It adopts MOS processes for upper Pch and lower Nch transistors, and introduces a constant-current or direct PWM drive system. Owing to the MOS processes and the PWM drive system, it can enable high thermal efficiency drive without using a charge pump.

Four modes such as CW, CCW, short brake, and stop can be chosen by IN1 and IN2.



Weight: 0.50 g (typ.)

Features

- Power supply voltage: 50 V (max)
- Output current: 2.5 A (max)
- Low ON resistor (U + L): 1.5 Ω (typ.)
- Average current controlling or PWM controlling
- Standby system
- CW/CCW/short brake/stop function modes.
- Built-in overcurrent protection
- Built-in thermal shutdown circuit

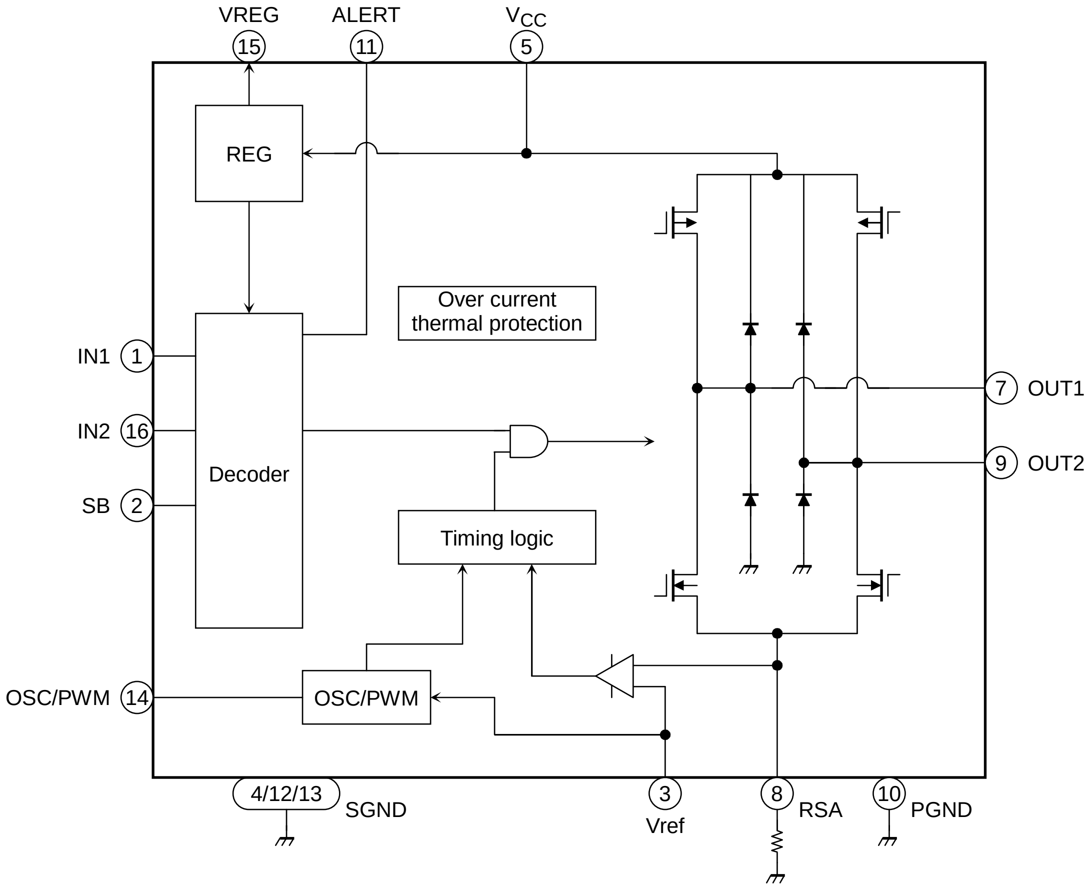
The TB6559FG uses Sn-Ag plating free of lead.

About solderability, following conditions were confirmed

(1) Use of Sn-37Pb solder Bath
- solder bath temperature = 230°C
- dipping time = 5 seconds
- the number of times = once
- use of R-type flux

(2) Use of Sn-3.0Ag-0.5Cu solder Bath
- solder bath temperature = 245°C
- dipping time = 5 seconds
- the number of times = once
- use of R-type flux

Block Diagram



Pin Functions

Pin No	Pin Name	Functional Description	Remarks
1	IN1	Control signal input 1	Input 0-/5-V signal
2	SB	Standby pin	H: Start, L: Standby
3	Vref	Supply voltage pin for control	0 to 3 V/constant-current control, 4.5 V to VREG/PWM control
4	S-GND	GND pin	—
5	V_{CC}	Power supply input pin	$V_{CC\ (ope)}$ = 10 to 27 V
6	(NC)	No Connection	—
7	OUT1	Output pin 1	Connect to motor coil pin
8	RSA	Output current detection resistor connection pin	—
9	OUT2	Output pin 2	Connect to motor coil pin
10	P-GND	Power GND	—
11	ALERT	Protective operation detection output	In Protection mode, output (VREG)
12	S-GND	GND pin	—
13	S-GND	GND pin	—
14	OSC/PWM	Capacitor connection/PWM input	Set an internal clock. PWM input by Vref
15	VREG	5 V output pin	Connect a capacitor to S-GND
16	IN2	Control signal input 2	Input 0-/5-V signal

Maximum Ratings (Ta = 25°C)

Characteristics	Symbol	Rating	Unit
Supply voltage	V_{CC}	50	V
Output current	I_O (Peak)	2.5 (Note 1)	A
	I_O (Ave)	1.5	
Power dissipation	P_D	1.4 (Note 2)	W
Operating temperature	T_{opr}	–30 to 85	°C
Storage temperature	T_{stg}	–55 to 150	°C

Note 1: The maximum ratings must be observed strictly. Make sure that all the characteristics listed above never exceed the maximum ratings.

Note 2: This value is obtained by 115 × 75 × 1.6 mm, PCB mounting occupied 30% of copper area.

Operating Range (Ta = 25°C)

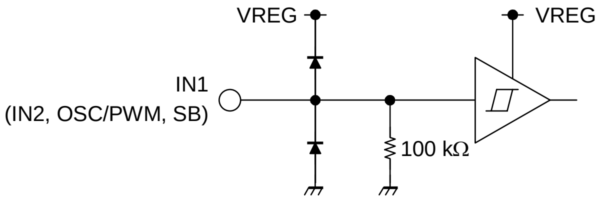
Characteristics	Symbol	Rating	Unit
Supply voltage	V_{CC}	10 to 27	V
PWM frequency	f_{CLK}	up to 100	kHz
VREG output current	VREGout	up to 1	mA

Electrical Characteristics (V_{CC} = 24 V, Ta = 25°C)

Characteristics		Symbol	Test Circuit	Test Condition	Min	Typ.	Max	Unit
Supply current		I_{CC1}	1	Stop mode	—	4	8	mA
		I_{CC2}		CW/CCW mode	—	6	10	
		I_{CC3}		Short break mode	—	4	8	
		I_{CC4}		Standby mode	—	1	2	
Control circuit	Input voltage	V_{INH}	2		2	—	VREG	V
		V_{INL}			–0.2	—	0.8	
	Hysteresis voltage	$V_{IN\ (HYS)}$	—	(Not tested)	—	0.2	—	
	Input current	I_{INH}	1	V_{IN} = 5 V	—	50	75	μA
		I_{INL}		V_{IN} = 0 V	—	—	5	
OSC/PWM input circuit	Input voltage	V_{PWMH}	3		2	—	VREG	V
		V_{PWML}			–0.2	—	0.8	
	Hysteresis voltage	$V_{PWM(HYS)}$	—	(Not tested)	—	0.2	—	
	Input current	I_{PWMH}	3	V_{PWM} = 5 V	—	55	75	μA
		I_{PWML}		V_{PWM} = 0 V	—	—	5	
	PWM frequency	f_{PWM}	3	Duty = 50%	—	—	100	kHz
	Minimum clock pulse width	$t_{w(PWM)}$			2	—	—	μs
Standby circuit	Input voltage	V_{INSH}	2		2	—	VREG	V
		V_{INSL}			–0.2	—	0.8	
	Hysteresis voltage	$V_{IN\ (HYS)}$	—	(Not tested)		0.2	—	
	Input current	I_{INSH}	1	V_{IN} = 5 V	—	50	75	μA
		I_{INSL}		V_{IN} = 0 V	—	—	5	
Output ON resistance		$R_{on\ (U + L)}$	4	I_o = 0.2 A	—	1.5	1.8	Ω
				I_o = 1.5 A	—	1.5	1.8	
Output leakage current		$I_{L\ (U)}$	5	V_{CC} = 30 V	—	—	10	μA
		$I_{L\ (L)}$		V_{CC} = 30 V	—	—	10	
Diode forward voltage		$V_{F\ (U)}$	6	I_o = 1.5 A		1.3	1.7	V
		$V_{F\ (L)}$		I_o = 1.5 A		1.3	1.7	
Internal reference voltage		VREG	4	VREGout = 1 mA	4.5	5	5.5	V
Overcurrent detection offset time		$I_{SD\ (OFF)}$	—	(Not tested)	—	50	—	μs
Overcurrent detection current		I_{SD}		(Not tested)	2.5	—	—	A
Thermal shutdown circuit operating temperature		T_{SD}	—	(Not tested)	150	170	—	°C
Thermal shutdown circuit histeresis				(Not tested)		20		°C
OSC frequency				C_{osc} = 0.89 nF		500		kHz
ALERT voltage		$V_{ALERT}(H)$		I_{ALERT} = –1 mA	VREG – 1			V
		$V_{ALERT}(L)$		I_{ALERT} = 1 mA			0.5	

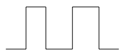
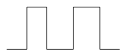
Component Description

1. Control Input/PWM Input Circuit



- The input signals are shown below. Input at the CMOS and TTL levels can be provided. Note that the input signals have a hysteresis of 0.2 V (typ.).
  V_{INH}: 2 to VREG V
  V_{INL}: GND to 0.8 V
- The PWM input frequency should be 100 kHz or less.
- All the circuits other than the standby circuit and the internal 5-V circuit are turned off when in standby mode.
- You should not apply PWM or other signals to the standby pin to control output. Otherwise, the output may become unstable, with the IC damaged. (The recommended period is 50 ms or higher.)
- To switch standby mode to operation mode, you have to preset IN1 and IN2 to the "L" level (stop mode), waiting for the power supply to be stabilized.
- OSC control function (0 V < Vref < 3 V)
  You can set up constant-current operation by connecting a capacitor to the OSC/PWM pin to start CR oscillations.
- PWM control function (4.5 V < Vref < VREG)
  You can control the speed by applying a 0/5-V PWM signal to the OSC/PWM pin. Normal operation and short braking operation are repeated when in PWM control mode.

Input/Output Function

	Input					Output			
	Vref	IN1	IN2	SB	PWM/OSC	IO (100%) (typ.)	OUT1	OUT2	Mode
OSC	0 to 3 V	H	H	H	Condenser	—	L	L	Short break
		L	H	H	Condenser	$\frac{Vref}{6 \cdot RS}$	L L	Constant current chopping 	CCW Short break
		H	L	H	Condenser	$\frac{Vref}{6 \cdot RS}$	Constant current chopping 	L L	CW Short break
		L	L	H	Condenser	—	OFF (Hi-Z)		Stop
		X	X	L	Condenser	—	OFF (Hi-Z)		Standby
PWM	4.5 V to VREG	H	H	H	H L		L	L	Short break
		L	H	H	H L		L L	H L	CCW Short break
		H	L	H	H L		H L	L L	CW Short break
		L	L	H	H L		OFF (Hi-Z)		Stop
		X	X	L	H L		OFF (Hi-Z)		Standby

Note: X = Don't care

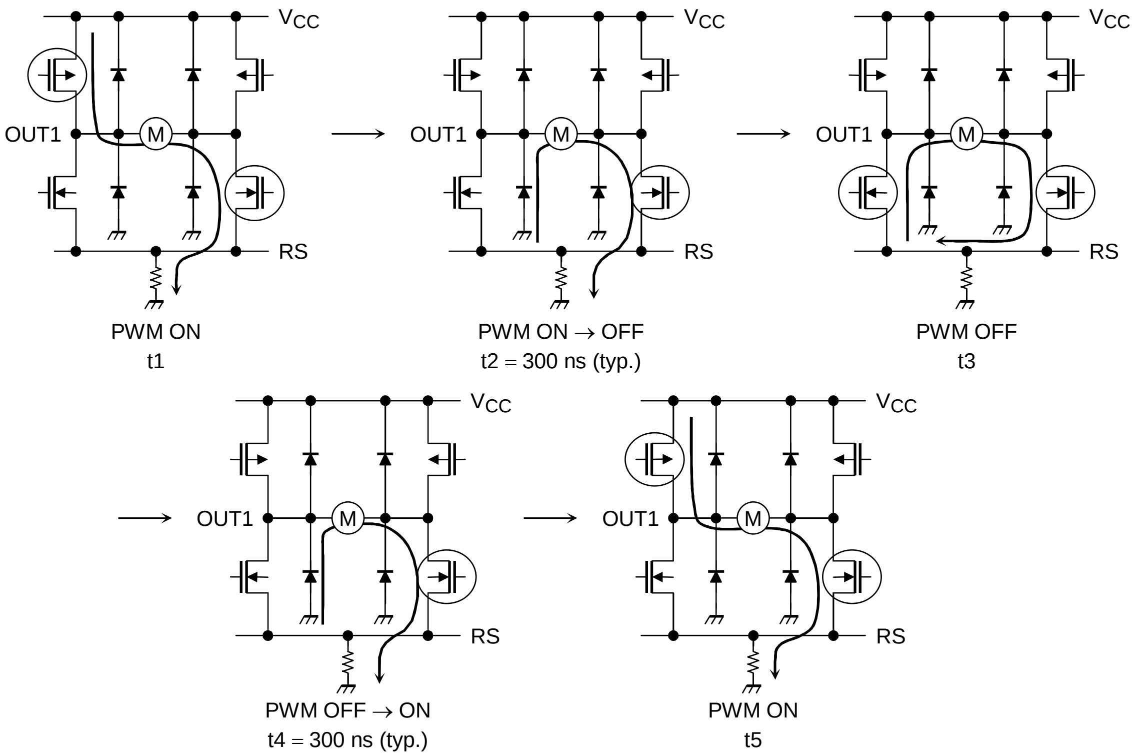
Output Operation

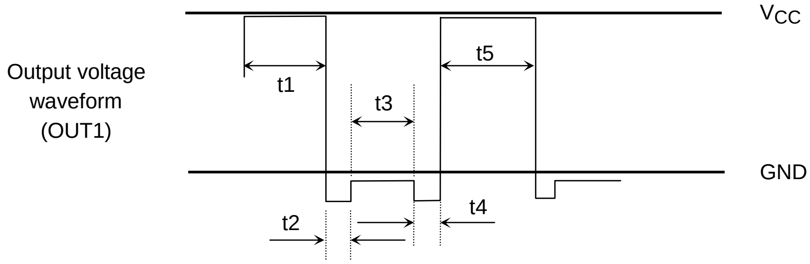
- Control mode selection
  Use of Vref enables selection of constant-current control based on a current sensing resistor or of PWM control under which external PWM is entered directly. The following gives the ranges you can select.
  Constant-current control: 0 < Vref < 3 V
  PWM control: 4.5 V < Vref < VREG
  The constant-current function is inactive when in PWM control mode.

When constant current control and PWM control are provided, normal operation and short brake operation are repeated.

If the upper and lower power transistors in the output circuit were ON at the same time, a penetrating current would be produced. To prevent this current from being produced, a dead time of 300 ns (design target value) is provided in the IC when either of the transistors changes from ON to OFF, or vice versa.

Therefore, PWM control by synchronous rectification is enabled without an OFF time being inserted by external input. Note that a dead time is also provided in the IC at the time of transition between CW and CCW or between CW (CCW) and short brake mode, thereby eliminating the need for an OFF time.

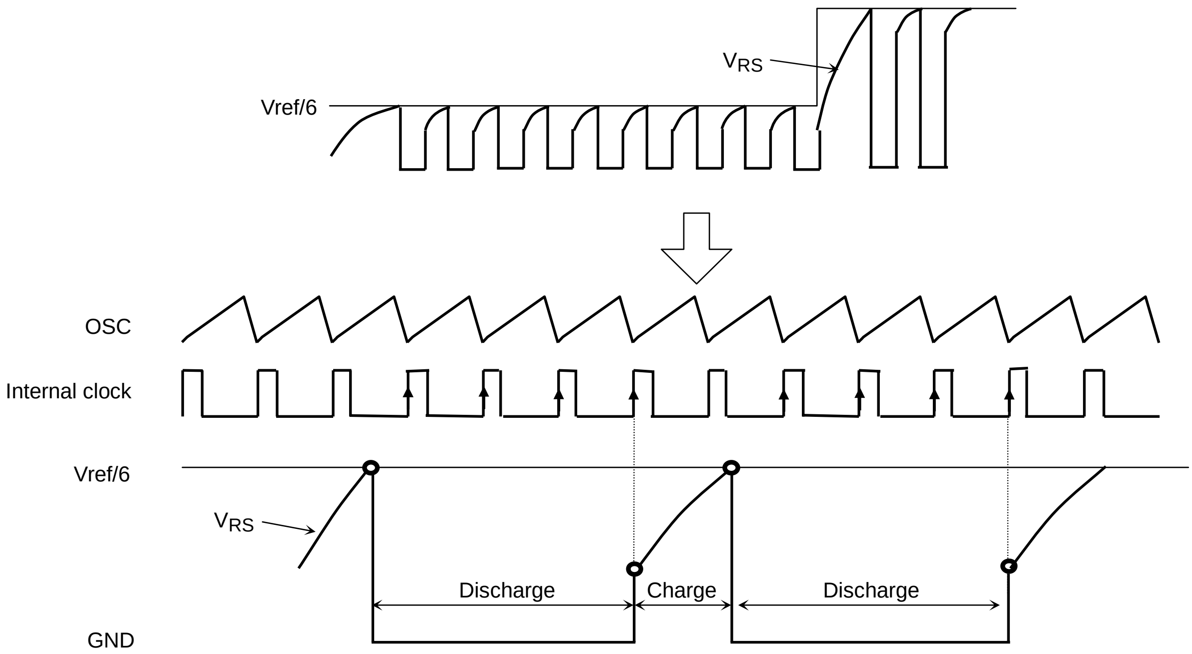




Constant Current Regulation

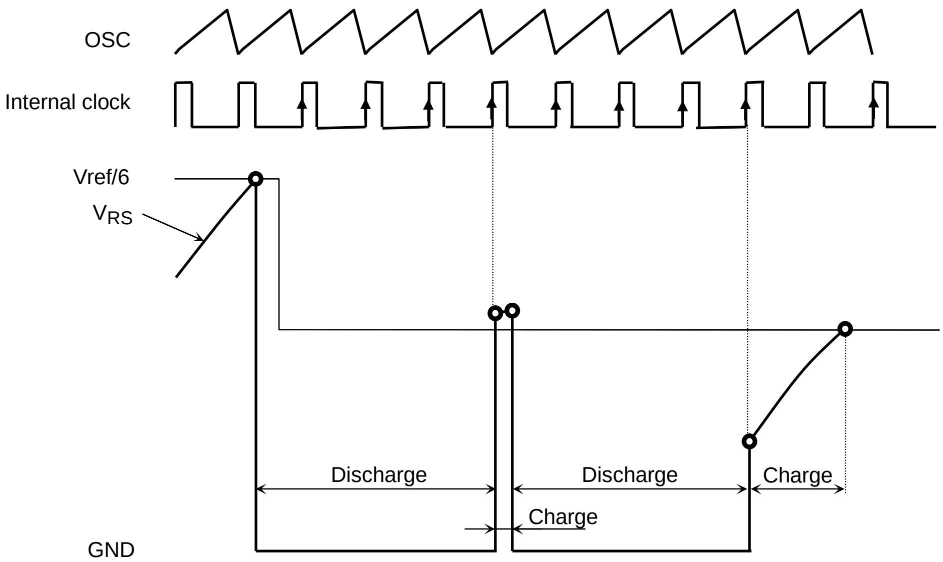
(1) Constant-current chopping mode

When V_{RS} reaches a reference voltage (Vref), the IC enters discharge mode.
After 4 clocks generated from an oscillator, the IC moves from discharge mode to charge mode.

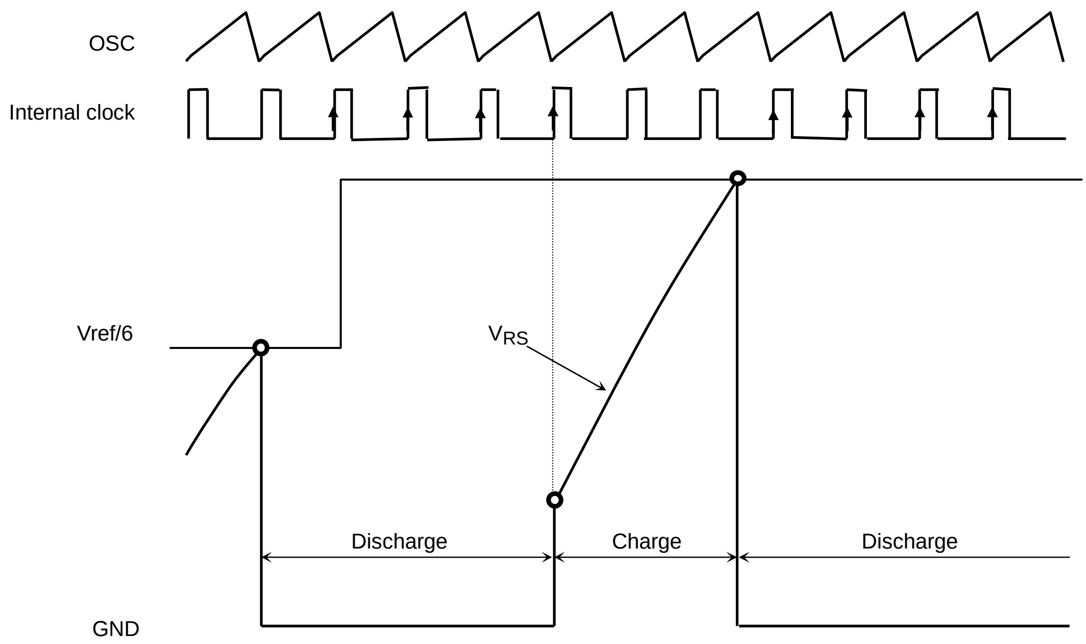


(2) Operation when changing the set current (during deceleration)

When VRS reaches the reference voltage (Vref/6), the IC enters discharge mode. After 4 clock pulses the IC exits from discharge mode and enters charge mode. If VRS > Vref/6 when it enters charge mode, however, it then reenters discharge mode. After 4 clock pulses, VRS is again compared with Vref/6. If VRS < Vref/6, the IC enters and stays in charge mode until VRS reaches Vref/6.



(3) Transition from discharge mode to charge mode (for acceleration)
Even when the reference voltage becomes higher, discharge mode lasts for 4 clocks and then it is toggled to charge mode.



Calculation of Internal Oscillation Frequency

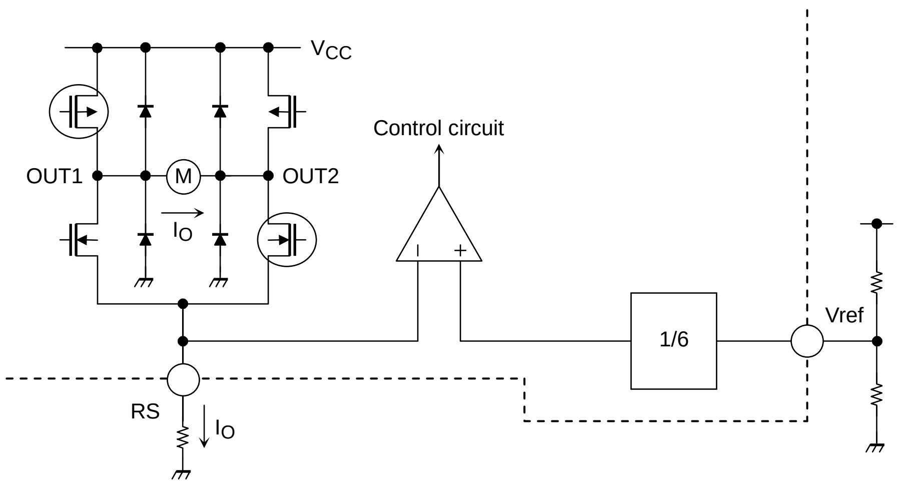
The OSC oscillation frequency can be calcurated by the following formulas:

$$f_{osc} = 1/(0.523 \times (C_{osc} \times 3700 + C_{osc} \times 600))$$

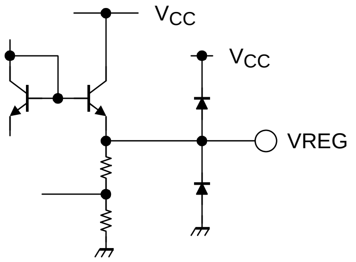
Reference Voltage Generator

Current value at 100% is determined by applying voltage at Vref pin.
The value can be calculated as:

$$I_O\ (100\%) = \mathrm{Vref}/\mathrm{RS} \times 1/6\ [\mathrm{A}]$$

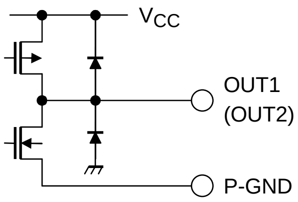


2. Internal Constant-Voltage (5 V) Circuit

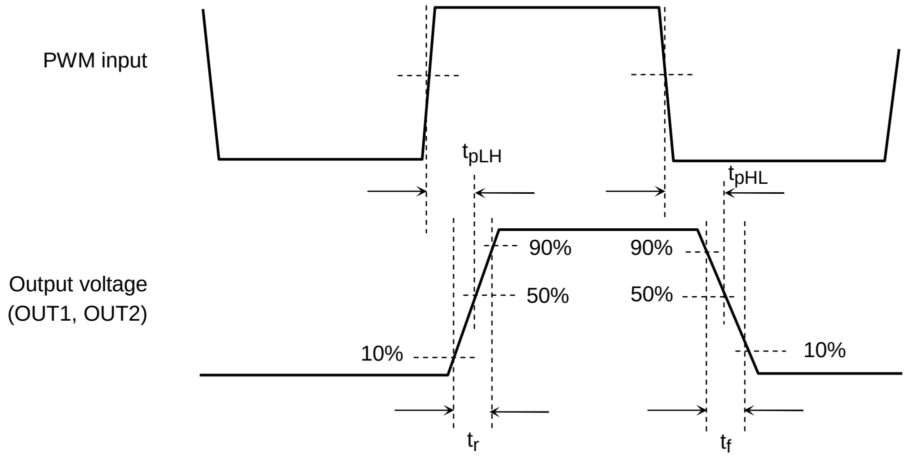


- This IC includes a 5-V power supply for control circuit.
- A capacitor for prevention of oscillation should be connected to S-GND associated with the pin VREG. No other loads should be connected to pin VREG. Although the pin can be used to control input pins of the IC, note that any variation in voltage on this pin causes the IC operation to be unstable. (1 mA (max))
- This IC has a power monitoring function and turns the output OFF when VREG goes down to 3.0 V (design target value) or less. With a hysteresis of 0.3 V (design target value), the output are turned ON when VREG reaches 3.3 V (design target value) again.

3. Output Circuit



- This IC adopts a Pch MOS transistor for the upper output part, and an Nch MOS transistor for the lower output part.
- As output R_{on} is 1 Ω (sum for the upper and lower parts/typ.)
- The switching characteristics of the output transistors are shown below.



<Typical value>

Item	Typical Value	Unit
t_{pLH}	700	ns
t_{pHL}	1000	
t_r	150	
t_f	200	
Dead time	800	

4. V_{CC} Power Supply Section

- The V_{CC} power supply delivers a voltage to the output circuit and internal 5-V circuit.
  The operating voltage range is shown below.
  $V_{CC\ (opr.)}$ = 10 to 27 V
- This IC has a power monitoring function for preventing an output malfunction on power-up. However, Toshiba recommends that IN1, IN2, and SB be set to the Low level at power-on.

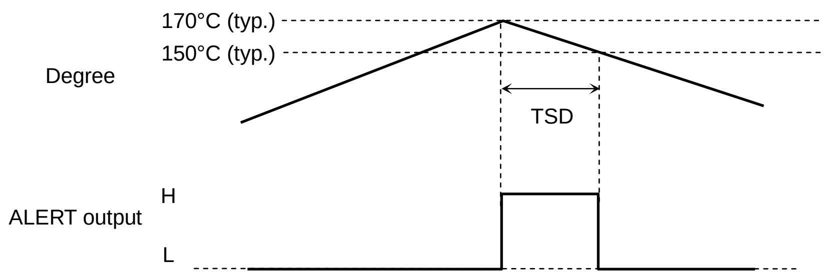
5. GND Sections

- This IC includes two separates GND sections: S-GND for controlling P-GND for outputting. Be sure to short-circuit these two GNDs as close to TB6559F/P as possible.

6. Thermal Shutdown Circuit (TSD)

The IC incorporates a thermal shutdown circuit. When the junction temperature (T_j) reaches 170°C (typ.), the output transistors are turned off.
After 50 μs (typ.), the output transistors are turned on automatically.
The IC has 20°C of temperature hysteresis.
TSD = 170°C (target spec)
ΔTSD = 20°C (target spec)

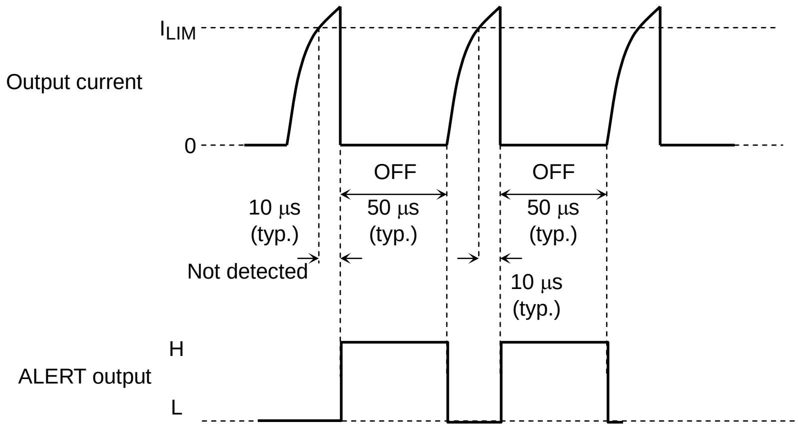
<TSD operating>



7. Overcurrent Protection Circuit (ISD)

The IC incorporates an overcurrent protection circuit to detect voltage that flows through the output transistors. The overcurrent threshold is 3.5 A (typ.).
Currents that flow through the output transistors are monitored individually. If overcurrent is detected in at least one of the transistors, all transistors are turned off.
The IC incorporates a timer to count 50 μs (typ.) for which the transistors are off. After 50 μs, they are turned on automatically. If an overcurrent occurs again, the same operation is repeated. To prevent false detection due to glitch, the circuit turns off the transistors only when current that exceeds the overcurrent threshold flows for 10 μs or longer.

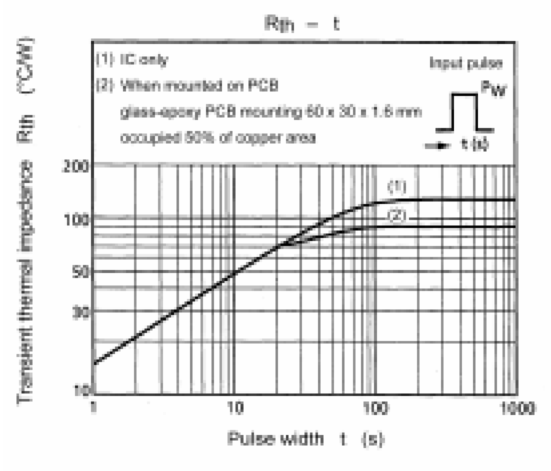
<ISD operating>



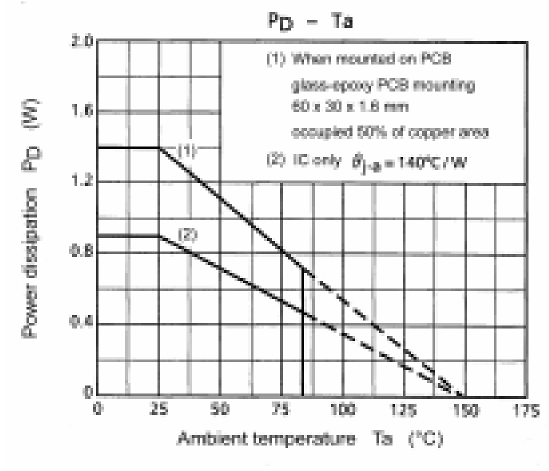
The design target value of a limiter value is 3.5 A (typ.), and has the variation in 2.5 to 4.5 A.

Characteristics Charts

TB6559FG



TB6559FG

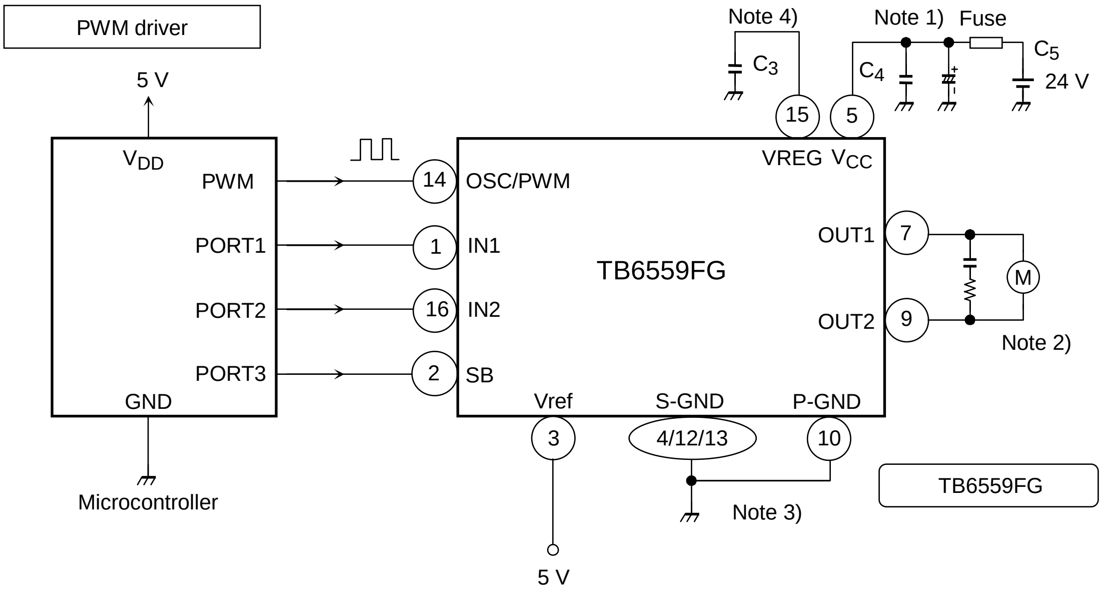


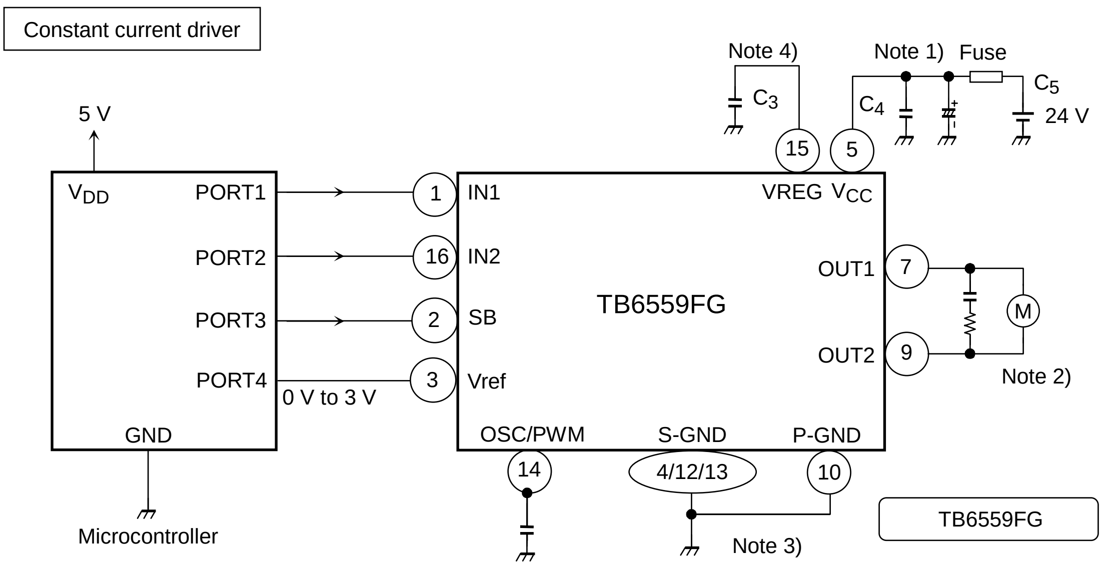
External Components

Symbol	Use	Recommended Value	Remarks
C_3	Prevention of VREG oscillation	0.1 μF to 1.0 μF	—
C_4	Absorption of power noise	0.1 μF to 1 μF	—
C_5	Absorption of power noise	50 μF to 100 μF	—

Note: The recommended values for charge pumps depend on the V_{CC} value.

Typical Application Diagram





Note 1: Connect V_{CC} and P-GND through the power supply capacitor. This capacitor should be as close as possible to the IC.

Note 2: When connecting the motor pins through the capacitor for reducing noise, connect a resistor to the capacitor for limiting the charge current. The switching loss increases for PWM control. Therefore, whenever practicable, avoid connecting the capacitor if PWM control is required.

Note 3: Short-circuit S-GND and P-GND as close to TB6549 as possible.

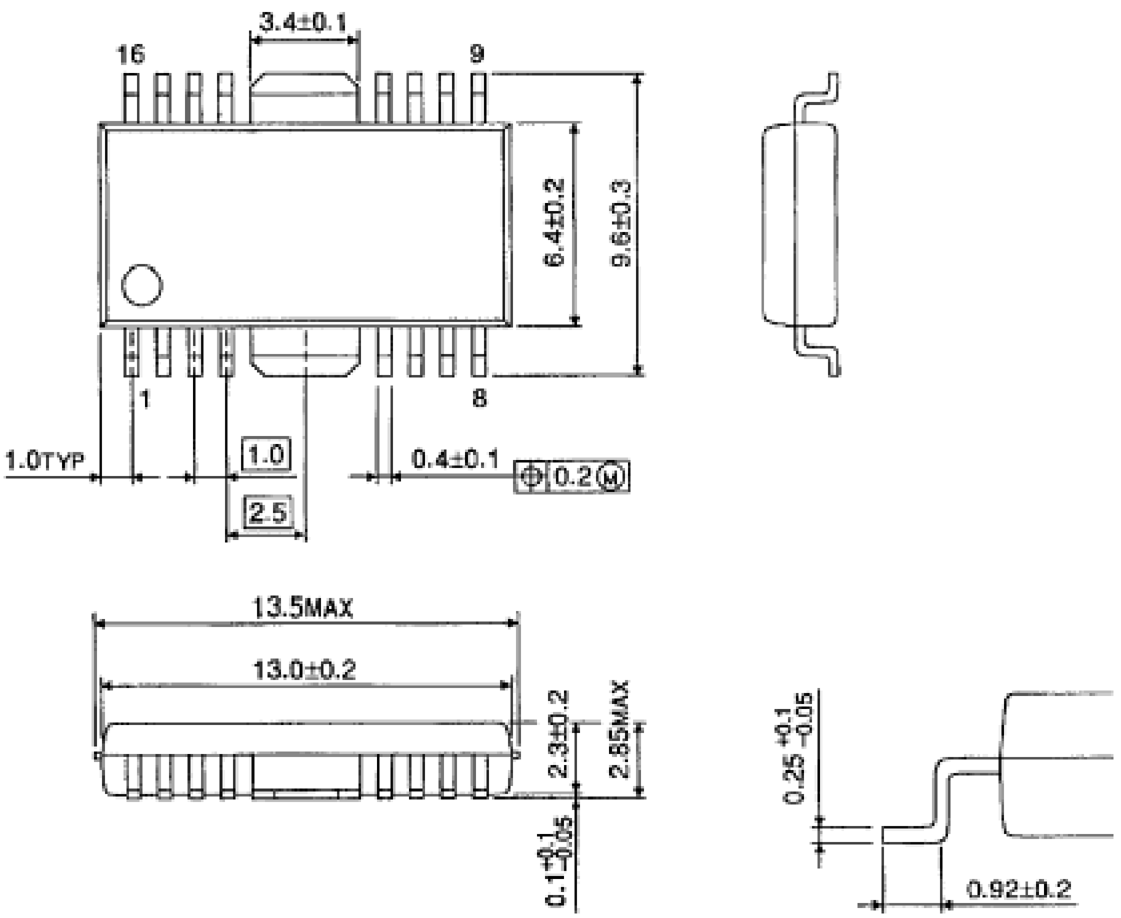
Note 4: Connect the capacitor C_3 to S-GND.

Usage Precautions

- This IC includes an overcurrent detection circuit. However, if a short circuit takes place between output pins or if an output pin is connected to the voltage source or ground, a heavy current temporarily flows through the IC. It might destroy the IC. This possibility should be fully considered in the design of the output line, V_{CC} line, and GND line. If the IC is destroyed, a heavy current might continuously flow through it as a secondary effect. Therefore, Toshiba recommends that a fuse be connected to the power supply line.
- Install this IC properly. If not, (e.g., installing it in the wrong position), the IC might be destroyed.

Package Dimensions

HSOP16-P-300-1.00 Unit : mm



Weight: 0.50 g (typ.)

Notes on Described Items

1. Block Diagrams

Some function blocks, circuits, constants and other items in block diagrams are omitted or simplified for convenience of function descriptions.

2. Equivalent Circuits

Some equivalent circuits are omitted or simplified for convenience of circuit descriptions.

3. Timing Chart

Some timing charts are simplified for convenience of function and operation descriptions.

4. Maximum Ratings

Do not use devices under conditions in which their absolute maximum ratings (e.g. current, voltage, power dissipation or temperature) will be exceeded. A device may break down or its performance may be degraded, causing it to catch fire or explode resulting in injury to the user.
The absolute maximum ratings are rated values which must not be exceeded during operation, even for an instant. Although absolute maximum ratings differ from product to product, they essentially concern the voltage and current at each pin, the allowable power dissipation, and the junction and storage temperatures.
If the voltage or current on any pin exceeds the absolute maximum rating, the device's internal circuitry can become degraded. In the worst case, heat generated in internal circuitry can fuse wiring or cause the semiconductor chip to break down.
If storage or operating temperatures exceed rated values, the package seal can deteriorate or the wires can become disconnected due to the differences between the thermal expansion coefficients of the materials from which the device is constructed.

5. Examples of Applications Circuits

The examples of applications circuits are offered for your reference. You should fully evaluate those examples for commercial production design. We do not intend to grant use of any industrial property rights.

6. Test Circuit

Component parts in measuring circuits are used to check characteristics. We do not warrant that applications equipment neither malfunction nor become out of order.

Caution for Using

Installing this IC properly. If not, (e.g., installing it in the wrong position), the IC might be destroyed.

Overcurrent and Thermal Protectors

- These protectors temporarily prevent output shorting and other abnormal operation, but do not ensure that the IC is not destroyed.
- Out of the guaranteed operation range, the protectors do not function and the IC may be damaged when output is shorted.
- The overcurrent protection function aims to protect the IC against temporary short-circuit. With short-circuit continued for an extended period, the IC may be damaged owing to overstress.
  You have to so configure your system that overcurrent may be reset rapidly.

Counter Electromotive Force

- When you reversely revolve or stop the motor, current may flow from the motor into the power supply owing to its counter electromotive force. If the power supply lacks sink capability, the IC's power supply pin and output pin may provide voltages exceeding the rated ones. The motor's counter electromotive force depends on usage conditions and its characteristics. You must fully verify that the IC neither is destroyed nor malfunctions by counter electromotive force, and that the peripheral and other circuits neither malfunction nor are damaged.

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