

DC Brushless Fan Motor Driver Series

5 V Single-phase Full-wave Fan Motor Driver

BD69060GFT

General Description

The BD69060GFT is a 5 V single-phase full-wave Fan Motor Driver with the built-in hall element. It is part of the DC brushless Fan Motor Driver series. The BD69060GFT has a compact package. It has the silent drive by soft switching and the low battery consumption via its stand-by function. The BD69060GFT is best used for notebook PC cooling fans.

Key Specifications

- Supply Voltage Range: 1.8 V to 5.5 V
- Operating Temperature Range: -40 °C to +105 °C
- Output Voltage (Upper and Lower Total): 0.16 V(Typ) at 0.2 A

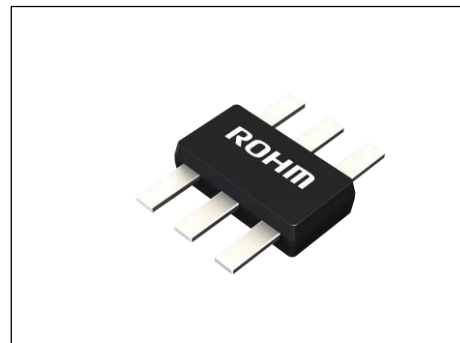
Features

- Built-in Hall Element
- PWM Speed Control
- Soft Switching Drive (PWM type)
- Start Duty Assist
- Stand-by Mode
- Quick Start
- Lock Protection and Automatic Restart
- Rotating Speed Pulse Signal (FG) Output
- Compact Package (Flat Lead Package)

Package

TSSOP6

W(Typ) x D(Typ) x H(Max)
2.90 mm x 3.80 mm x 0.8 mm



Application

- For Compact 5 V Fan Such as Notebook PC Cooling Fan

Typical Application Circuit

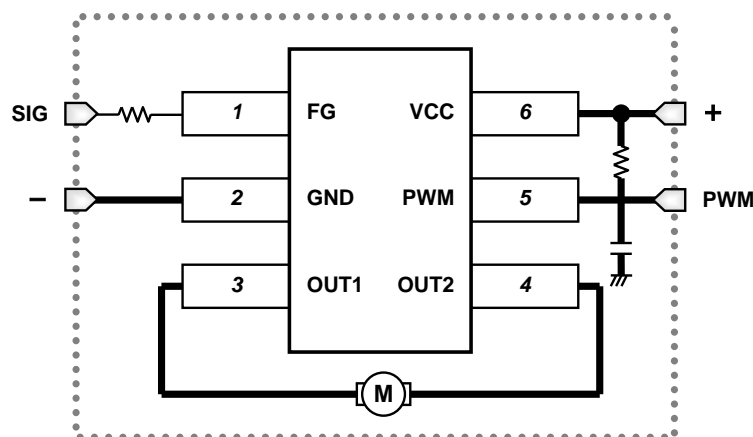
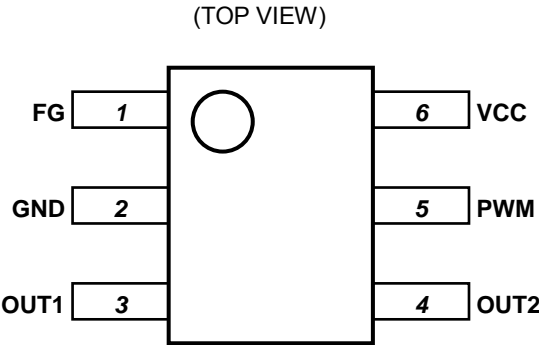


Figure 1. Application Circuit

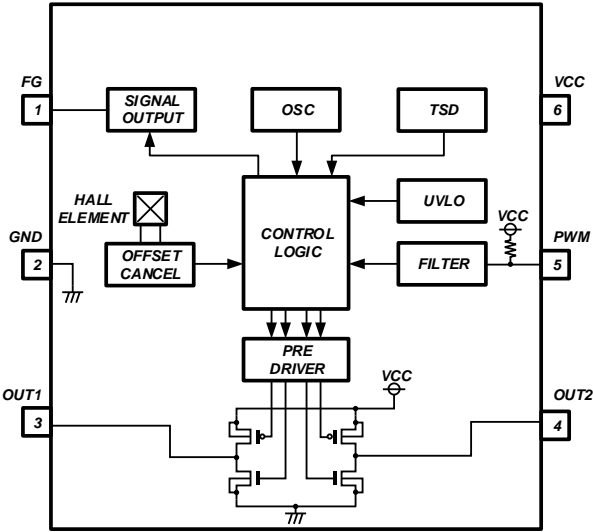
Pin Configuration



Pin Description

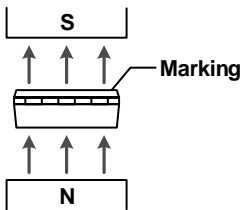
Pin No.	Pin Name	Function
1	FG	FG output
2	GND	Ground
3	OUT1	Motor output 1
4	OUT2	Motor output 2
5	PWM	PWM input
6	VCC	Power supply

Block Diagram



I/O Truth Table

Supply magnetic direction (forward)



Output operation

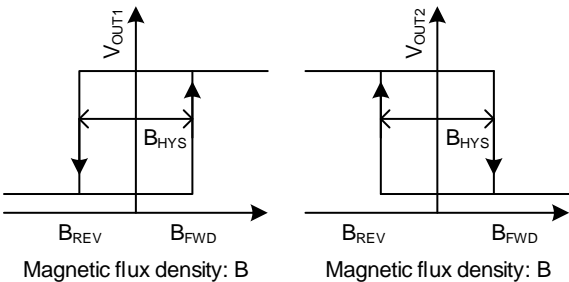


Figure 2. Relationship Magnetic Density and Output Operation

Supply Magnetic Direction	PWM	OUT1	OUT2	FG
S	H (OPEN)	H	L	L
N	H (OPEN)	L	H	Hi-Z
S	L	L	L	L
N	L	L	L	Hi-Z

H; High, L; Low, Hi-Z; High impedance
FG output is open drain type.

Motor State	FG
Rotating	-
Locking	-
Stand-by	Hi-Z

Hi-Z; High impedance

Absolute Maximum Ratings

Parameter	Symbol	Rating	Unit
Supply Voltage	V_{CC}	7	V
Storage Temperature Range	Tstg	-55 to +150	°C
Junction Temperature	T_j	150	°C
Motor Output Voltage	V_O	7	V
Motor Output Current	I_O	1.0	A
FG Output Voltage	V_{FG}	7	V
FG Output Current	I_{FG}	10	mA

Caution 1: Operating the IC over the absolute maximum ratings may damage the IC. The damage can either be a short circuit between pins or an open circuit between pins and the internal circuitry. Therefore, it is important to consider circuit protection measures, such as adding a fuse, in case the IC is operated over the absolute maximum ratings.

Caution 2: Should by any chance the maximum junction temperature rating be exceeded the rise in temperature of the chip may result in deterioration of the properties of the chip. In case of exceeding this absolute maximum rating, design a PCB boards with thermal resistance taken into consideration by increasing board size and copper area so as not to exceed the maximum junction temperature rating.

Thermal Resistance^(Note 1)

Parameter	Symbol	Thermal Resistance (Typ)		Unit
		1s ^(Note 3)	2s2p ^(Note 4)	
TSSOF6				
Junction to Ambient	θ _{JA}	357.1	188.7	°C/W
Junction to Top Characterization Parameter ^(Note 2)	Ψ _{JT}	54	42	°C/W

(Note 1) Based on JESD51-2A(Still-Air).

(Note 2) The thermal characterization parameter to report the difference between junction temperature and the temperature at the top center of the outside surface of the component package.

(Note 3) Using a PCB board based on JESD51-3.

(Note 4) Using a PCB board based on JESD51-7.

Layer Number of Measurement Board	Material	Board Size
Single	FR-4	114.3 mm x 76.2 mm x 1.57 mmt

Top	
Copper Pattern	Thickness
Footprints and Traces	70 μ m

Layer Number of Measurement Board	Material	Board Size
4 Layers	FR-4	114.3 mm x 76.2 mm x 1.6 mmt

Top		2 Internal Layers		Bottom	
Copper Pattern	Thickness	Copper Pattern	Thickness	Copper Pattern	Thickness
Footprints and Traces	70 μ m	74.2 mm x 74.2 mm	35 μ m	74.2 mm x 74.2 mm	70 μ m

Recommended Operating Conditions

Parameter	Symbol	Min	Typ	Max	Unit
Supply Voltage	V_{CC}	1.8	5.0	5.5	V
PWM Input Voltage	V_{PWM}	0	-	5.5	V
PWM Input Frequency	f_{PWM}	5	25	50	kHz
Operating Temperature Range	T_{opr}	-40	-	+105	°C

Electrical Characteristics (Unless otherwise specified $V_{CC}=5\text{ V}$ $T_a=25\text{ °C}$)

Parameter	Symbol	Min	Typ	Max	Unit	Conditions	Typical Performance Curves
Circuit Current 1	I_{CC1}	-	3	5	mA	PWM=OPEN	Figure 3
Circuit Current 2 (Stand-by Mode)	I_{CC2}	-	25	50	μA	PWM=GND	Figure 4
Magnetic Switch Point (Forward)	B_{FWD}	-	+1.5	-	mT		Figure 5
Magnetic Switch Point (Reverse)	B_{REV}	-	-1.5	-	mT		Figure 6
Magnetic Hysteresis	B_{HYS}	-	3.0	5.0	mT		Figure 7
PWM Input High Level	V_{PWMH}	2.5	-	V_{CC}	V		-
PWM Input Low Level	V_{PWML}	0	-	0.8	V		-
Motor Output Voltage	V_O	-	0.16	0.24	V	$I_o=200\text{ mA}$ (Upper and Lower total)	Figure 8 to 13
FG Output Low Voltage	V_{FGL}	-	-	0.4	V	$I_{FG}=5\text{ mA}$	Figure 14,15
FG Output Leak Current	I_{FGL}	-	-	5	μA	$V_{FG}=7\text{ V}$	Figure 16
Lock Detection ON Time	t_{ON}	0.35	0.50	0.65	s		Figure 17
Lock Detection OFF Time	t_{OFF}	3.5	5.0	6.5	s		Figure 18

About current items, define the inflow current to the IC as a positive notation.

Typical Performance Curves

(Reference Data)

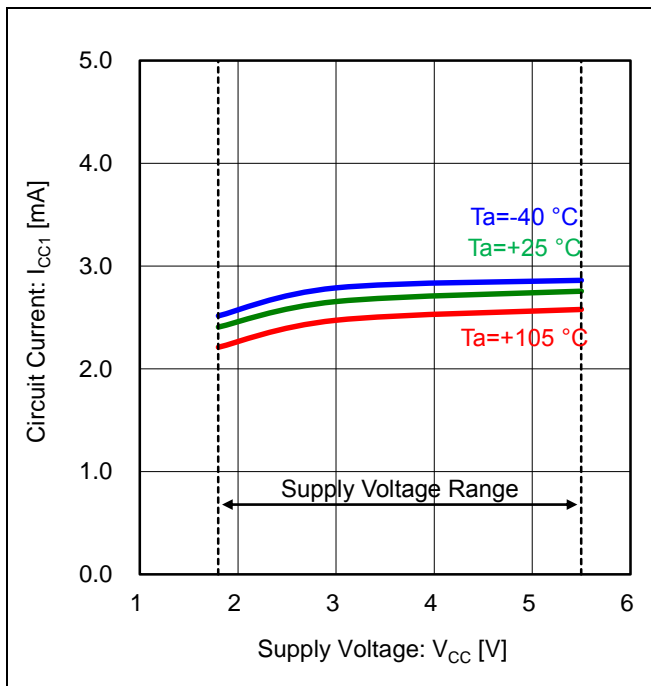


Figure 3. Circuit Current vs Supply Voltage

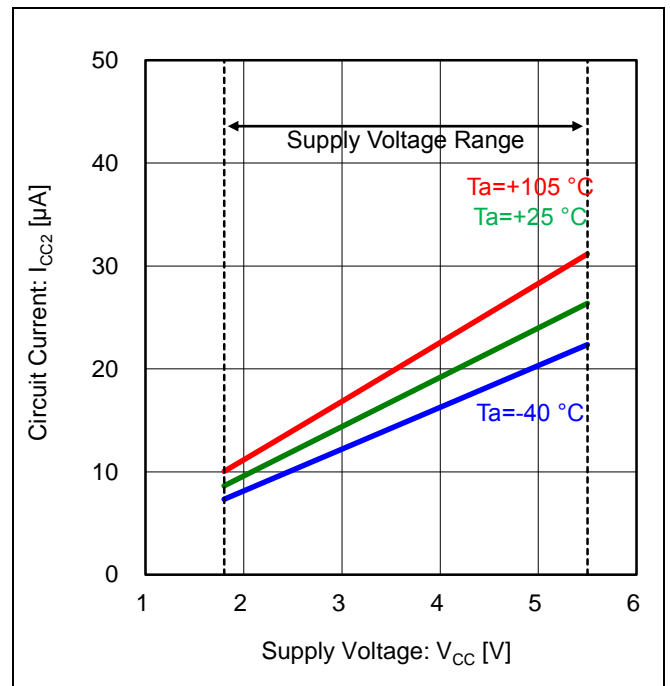


Figure 4. Circuit Current vs Supply Voltage (Stand-by Mode)

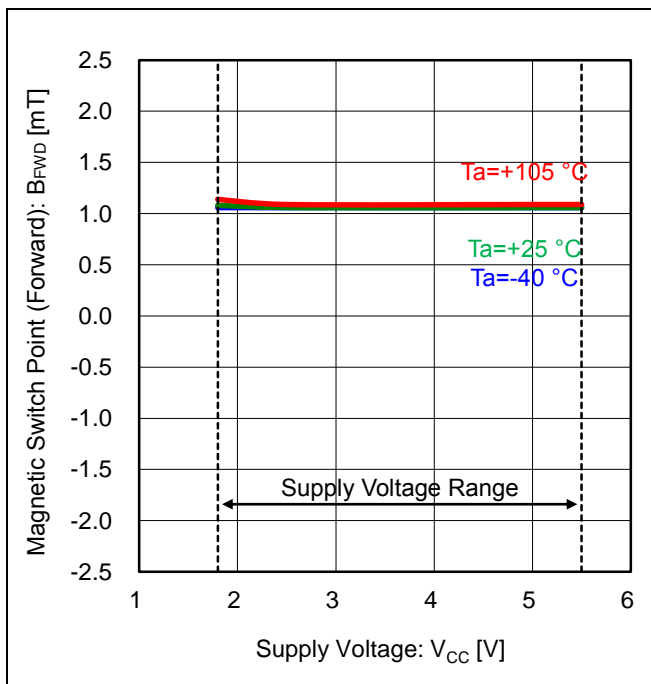


Figure 5. Magnetic Switch Point (Forward) vs Supply Voltage

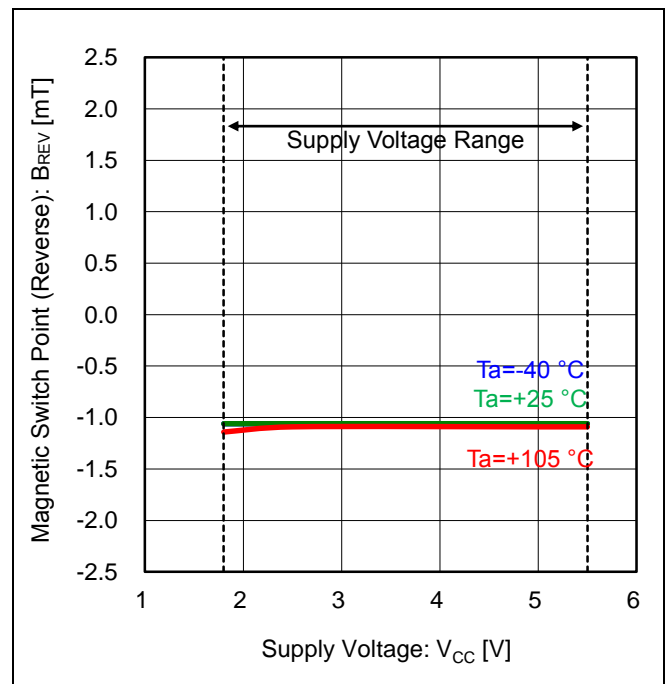


Figure 6. Magnetic Switch Point (Reverse) vs Supply Voltage

Typical Performance Curves - continued

(Reference Data)

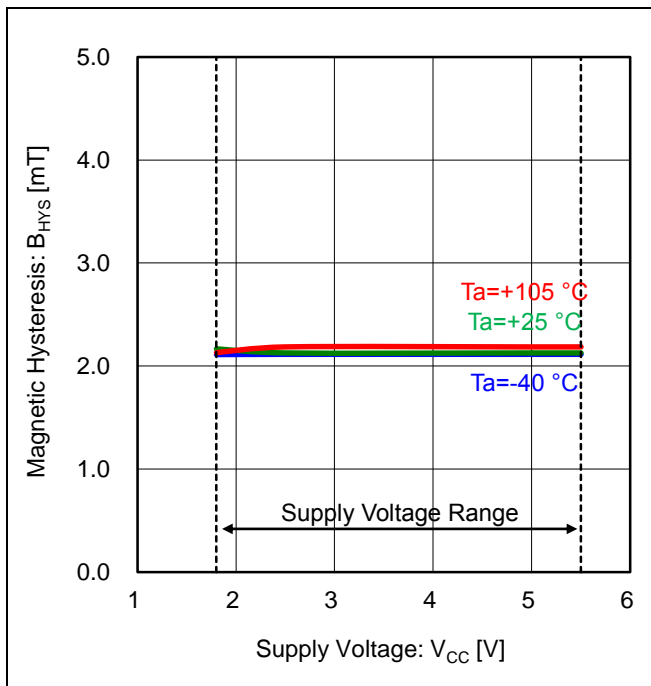


Figure 7. Magnetic Hysteresis vs Supply Voltage

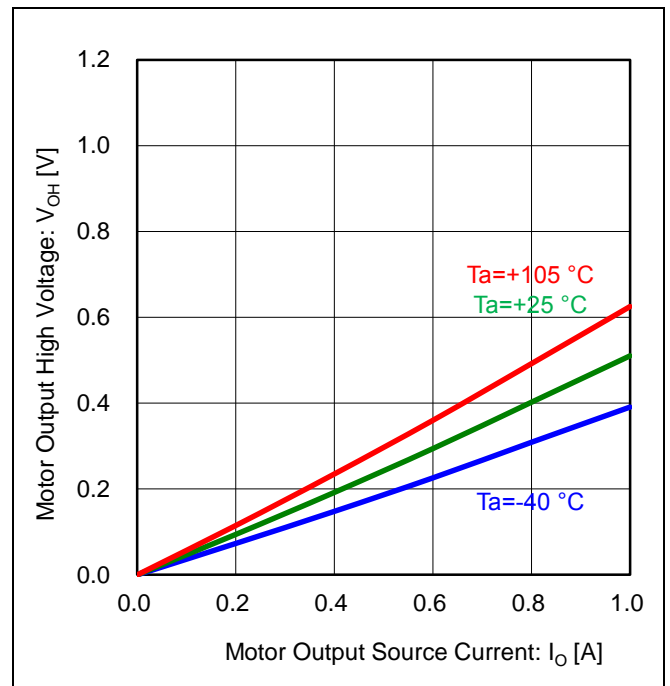


Figure 8. Motor Output High Voltage vs Motor Output Source Current
($V_{CC}=5.0\text{ V}$)

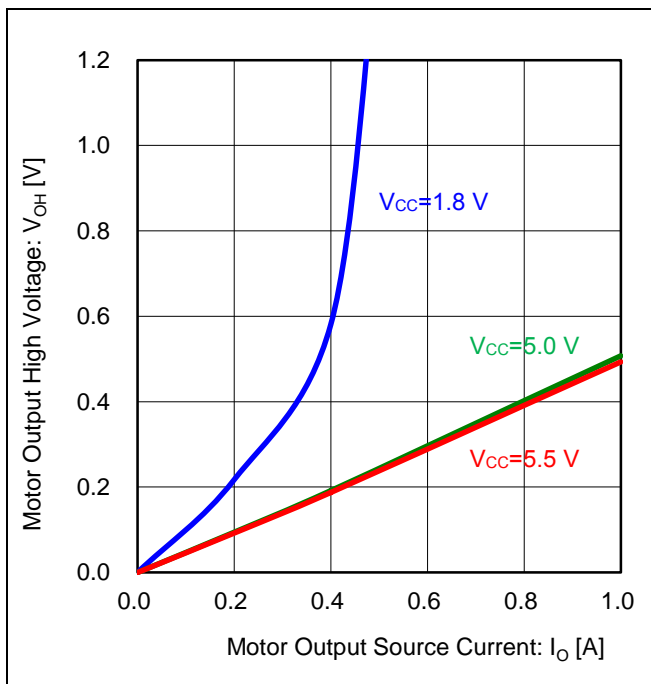


Figure 9. Motor Output High Voltage vs Motor Output Source Current
($T_a=25\text{ °C}$)

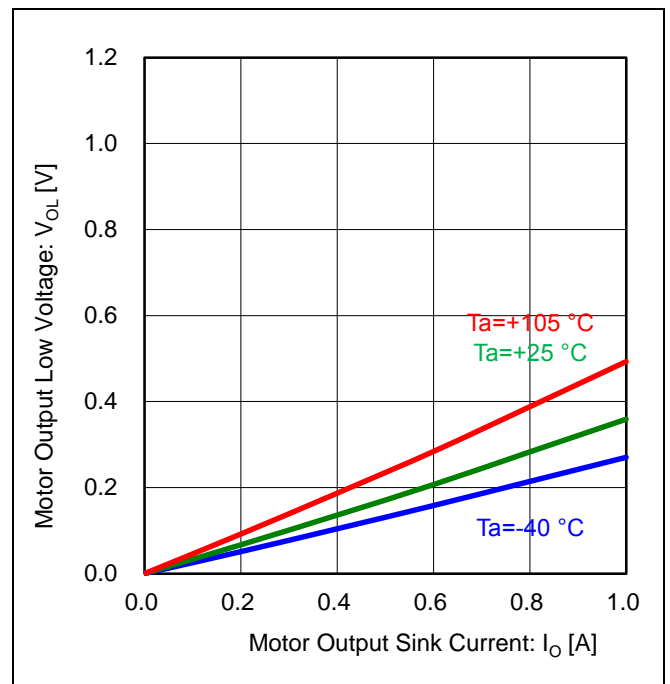


Figure 10. Motor Output Low Voltage vs Motor Output Sink Current
($V_{CC}=5.0\text{ V}$)

Typical Performance Curves - continued
(Reference Data)

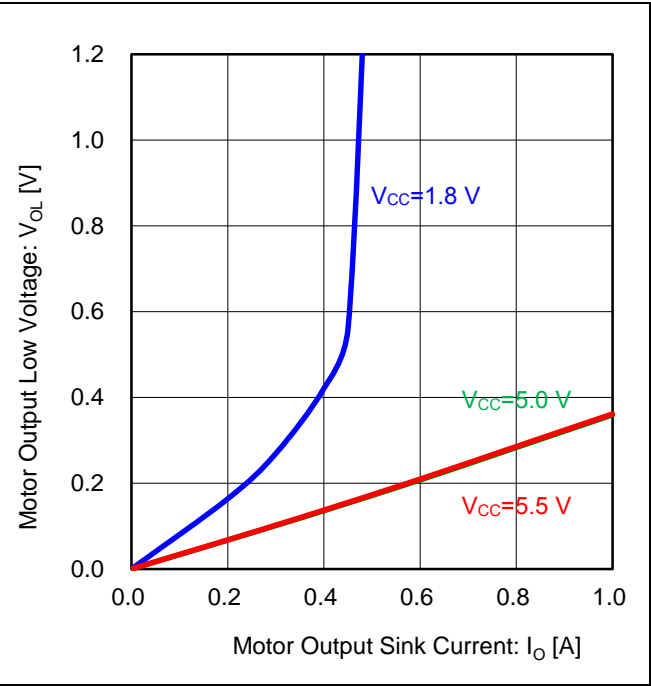


Figure 11. Motor Output Low Voltage vs Motor Output Sink Current (Ta=25 °C)

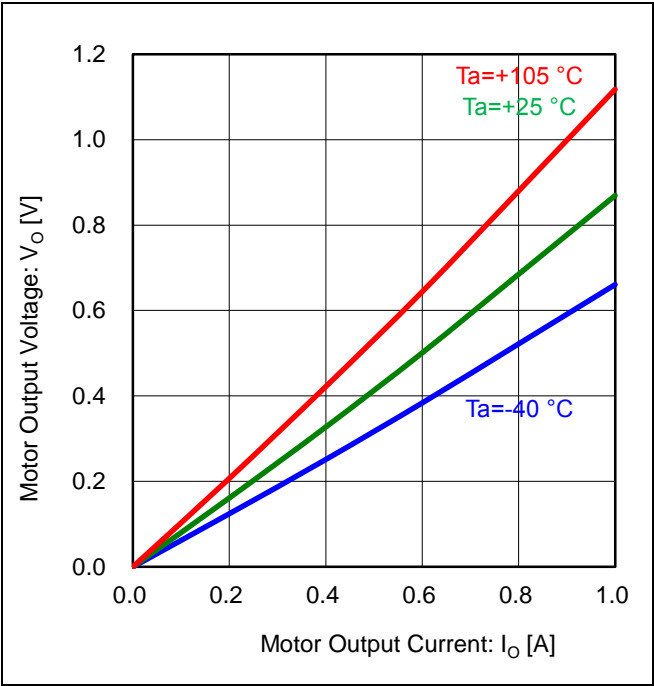


Figure 12. Motor Output Voltage vs Motor Output Current (Upper and Lower total) (V_{CC}=5.0 V)

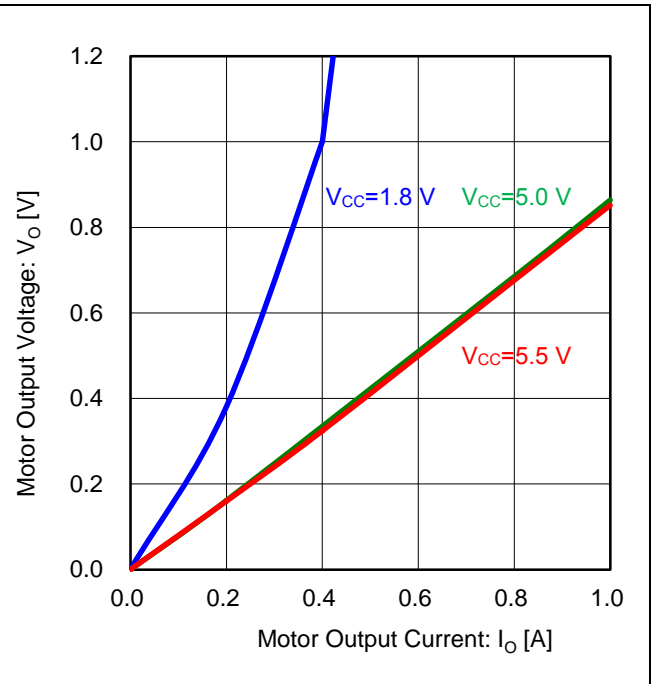


Figure 13. Motor Output Voltage vs Motor Output Current (Upper and Lower total)(Ta=25 °C)

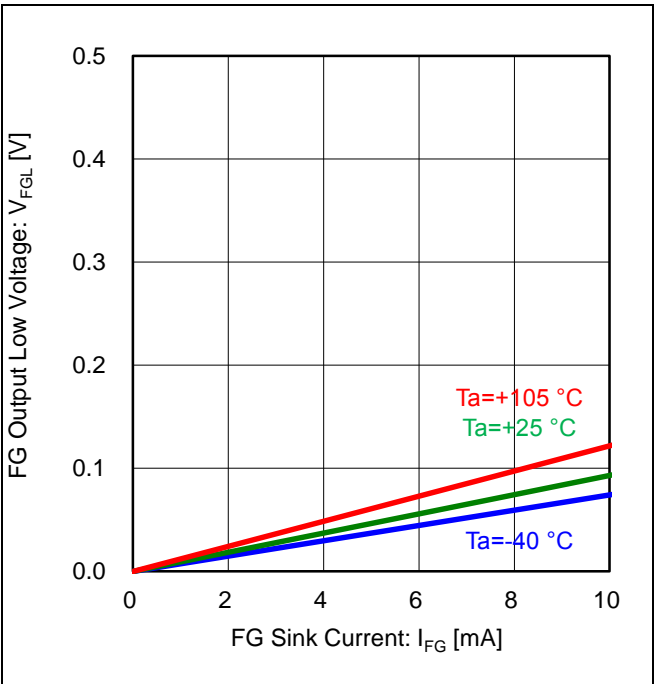


Figure 14. FG Output Low Voltage vs FG Sink Current (V_{CC}=5.0 V)

Typical Performance Curves - continued

(Reference Data)

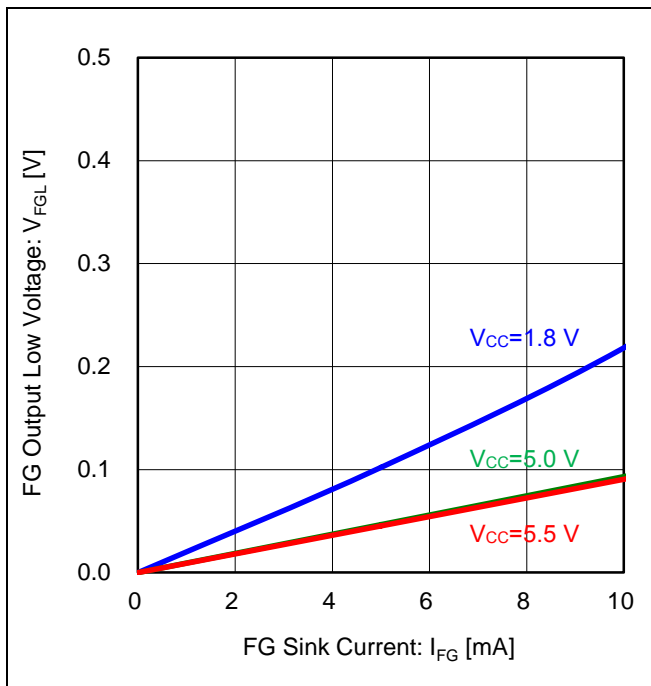


Figure 15. FG Output Low Voltage vs FG Sink Current
($T_a=25\text{ }^{\circ}\text{C}$)

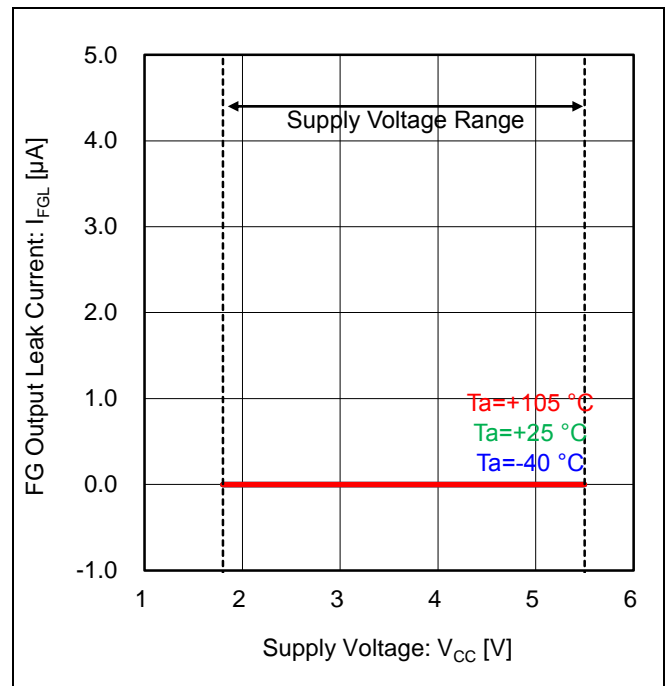


Figure 16. FG Output Leak Current vs Supply Voltage
($V_{FG}=7.0\text{ V}$)

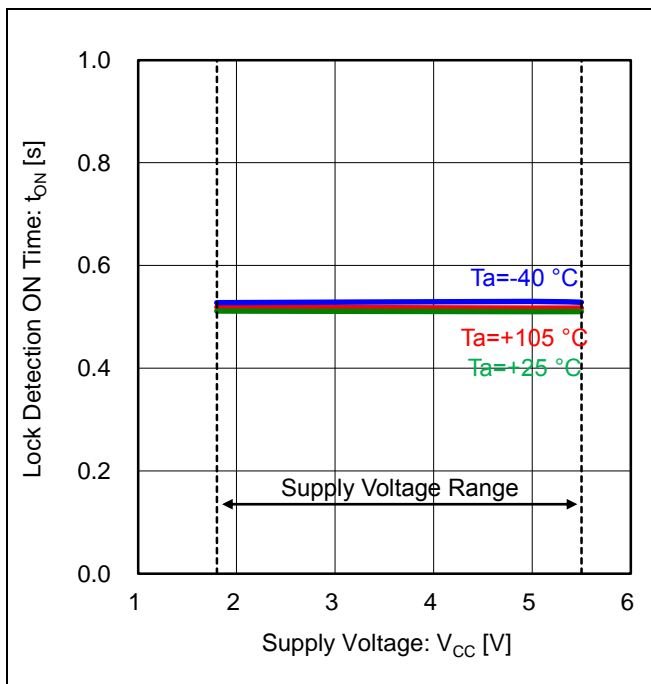


Figure 17. Lock Detection ON Time vs Supply Voltage

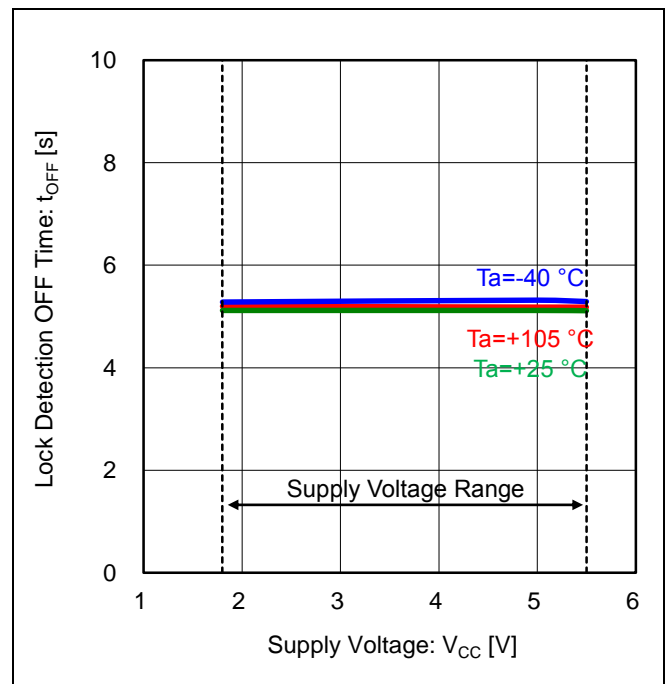


Figure 18. Lock Detection OFF Time vs Supply Voltage

Application Information Example (Constant Values for Reference)

1. PWM Input Application

This is an example of the application to control the rotational speed by the external PWM input.

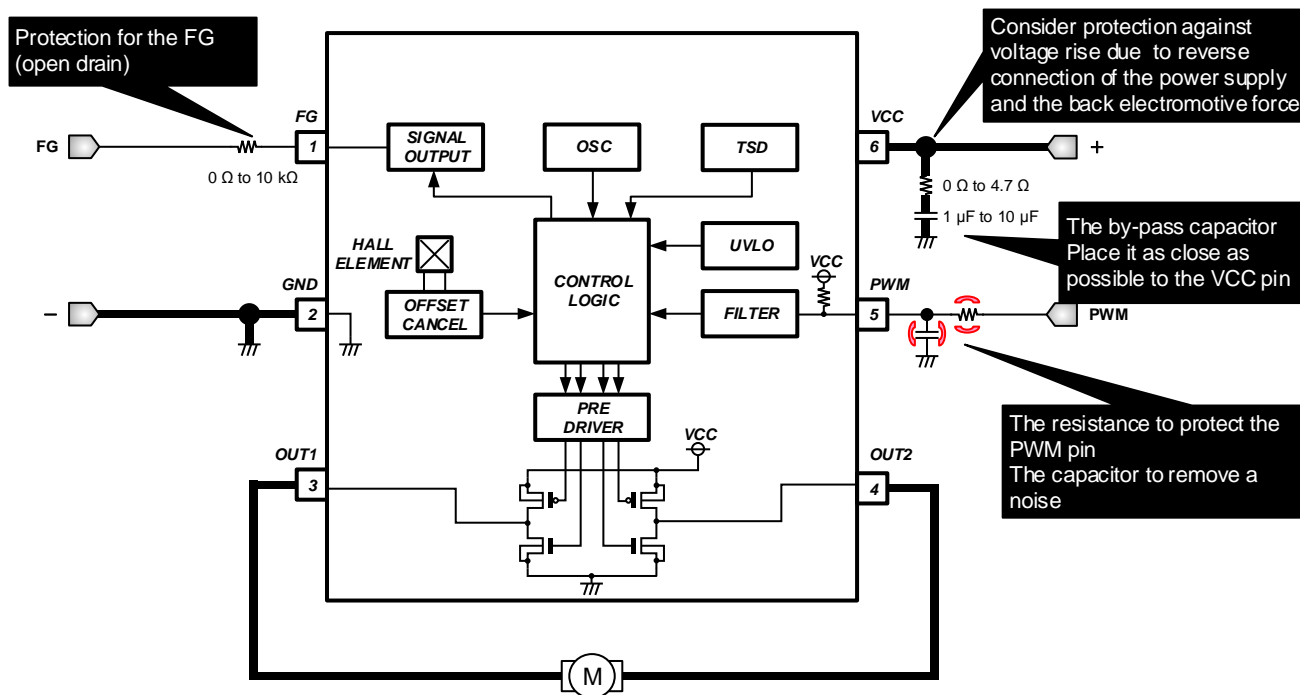


Figure 19. PWM Input Application

Substrate Design Note

- The IC power, motor outputs and the ground lines are wired as thick as possible.
- The by-pass capacitor and the Zener diode are placed as close as possible to the VCC pin.

Functional Descriptions

1. PWM Speed Control

The rotation speed of the motor can be changed depending on the PWM input duty to the PWM pin. When the PWM pin is open, the PWM input duty becomes 100 % (the PWM pin is pulled up to the VCC pin with the internal resistor of 200 k Ω (Typ)). But the PWM controls by the open collector/drain which use only the internal resistor is prohibited. Because the resistor value is big, the PWM input signal becomes dull and cannot input the expected PWM duty into the IC. The characteristic of the PWM input/output duty is shown as Figure 20.

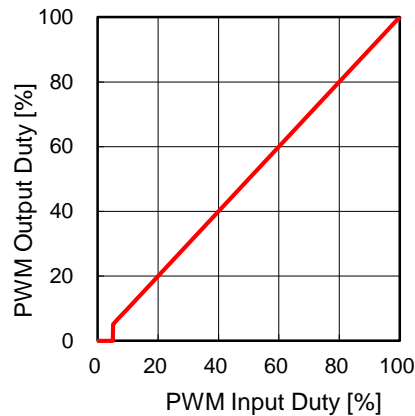


Figure 20. PWM Output Duty vs PWM Input Duty

2. Soft Switching Drive(PWM type)

The soft switching drive is a function that the output duty changes between 0 % and the PWM output duty at the timing of the output phase change. To smooth off the current waveform, the coefficient table that the output duty gradually changes is set inside the IC. When one period of the FG signal is assumed 360°, the section of the soft switching is about 60° (Typ). As shown in Figure 21, this IC is controlled same the section of the soft switching with various magnetic waveforms, such as the rectangular wave, the trapezoidal wave and the sine wave. The output PWM frequency is 50 kHz (Typ). Hence, the input PWM frequency is not equal to the output PWM frequency.

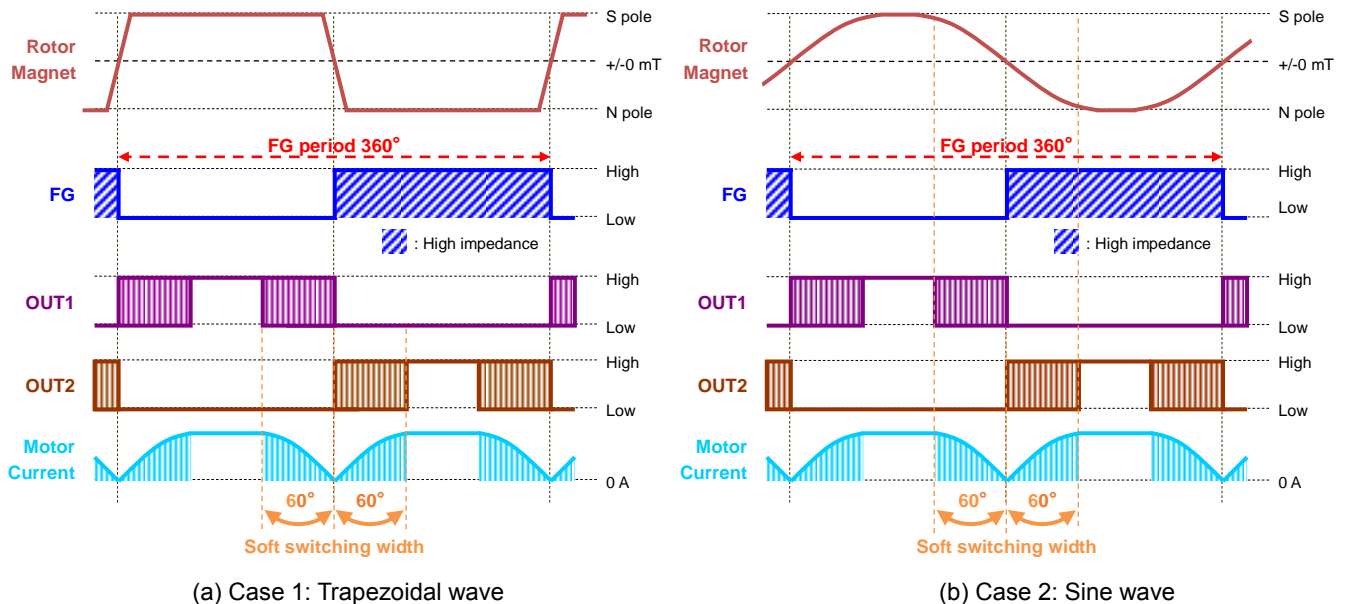


Figure 21. PWM Soft-switching Drive Waveform

Functional Descriptions - continued

3. Start Duty Assist

The start duty assist can secure a constant starting torque even at the low input duty.

The IC is driven by a constant output duty (D_{OHL} ; Typ 50 %) until detection of motor rotation from startup.

When the output ON duty is less than 50 % (Typ), the start duty assist function operates under the following conditions:

- (1) Power ON
- (2) Automatic Restart after Lock Protection
- (3) Quick Start

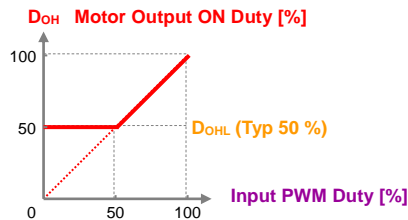


Figure 22. I/O Duty Characteristic at Start Duty Assist

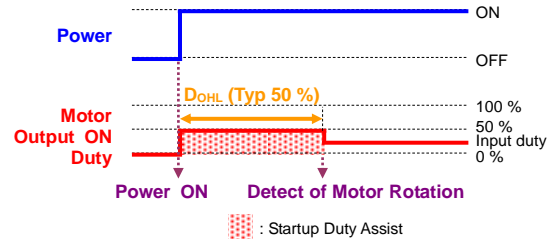


Figure 23. Timing Chart of Power ON

4. Stand-by Mode and Quick Start

When the BD69060GFT detects that the input PWM duty is 0 %, the internal state changes to the stand-by mode. The circuit current during the stand-by mode is specified at the parameter of the Circuit Current 2 in the electrical characteristics. And when the PWM signal is input while the stand-by mode, the motor can restart immediately after 10 ms (Typ) of startup time without being affected by the lock protection function. (Quick Start)

Timing chart of the stand-by mode and the quick start is shown as Figure 24.

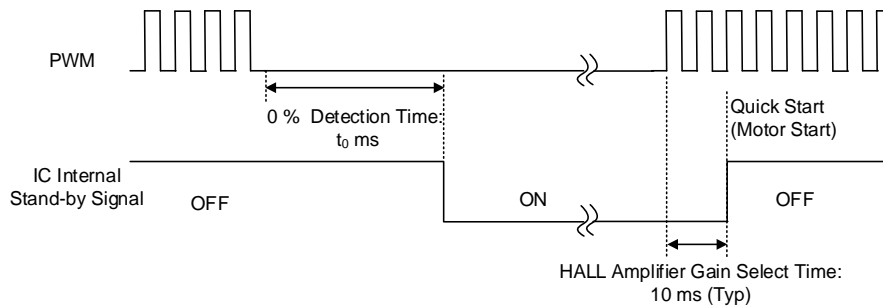


Figure 24. Timing Chart of Stand-by Mode and Quick Start

The PWM pin has a built-in digital low pass filter. The detection time of the input PWM duty 0 % (t_0) varies depending on the input PWM duty just before input 0 %. Relationship between the input PWM duty (frequency is 25 kHz) just before input 0 % and 0 % detection time is shown as Figure 25.

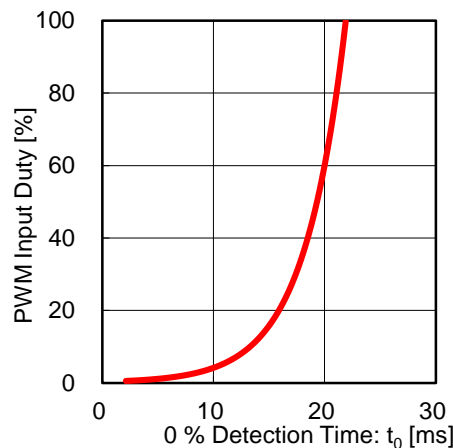


Figure 25. PWM Input Duty (25 kHz) vs 0 % Detection Time

Functional Descriptions - continued

5. Lock Protection and Automatic Restart

The motor rotation is detected by the hall signal, while the lock detection ON time (t_{ON}) and the lock detection OFF time (t_{OFF}) are set by the IC internal counter. Timing chart is shown as Figure 26.

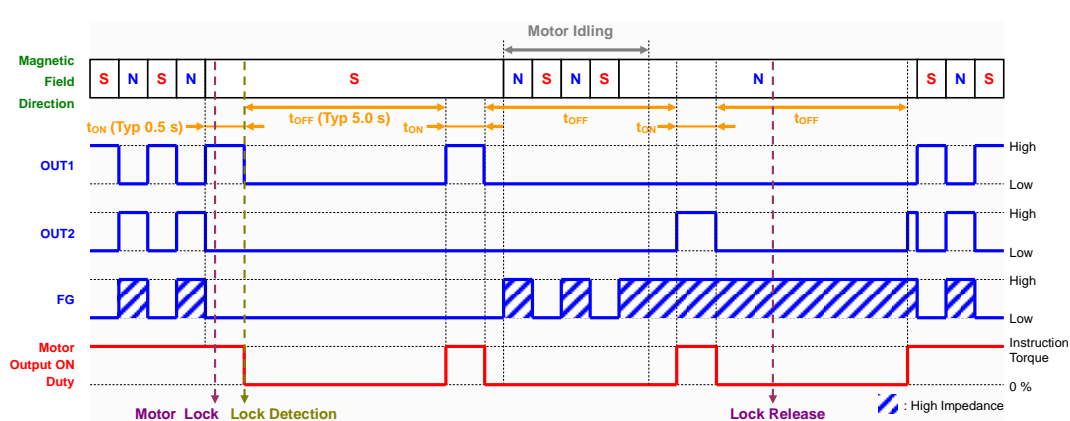


Figure 26. Timing Chart of Lock Protection

Safety Measures

1. Reverse Connection Protection Diode

The reverse connection of the power results in the IC destruction as shown in Figure 27. When the reverse connection is possible, the reverse connection protection diode must be added between the power supply and the VCC pin.

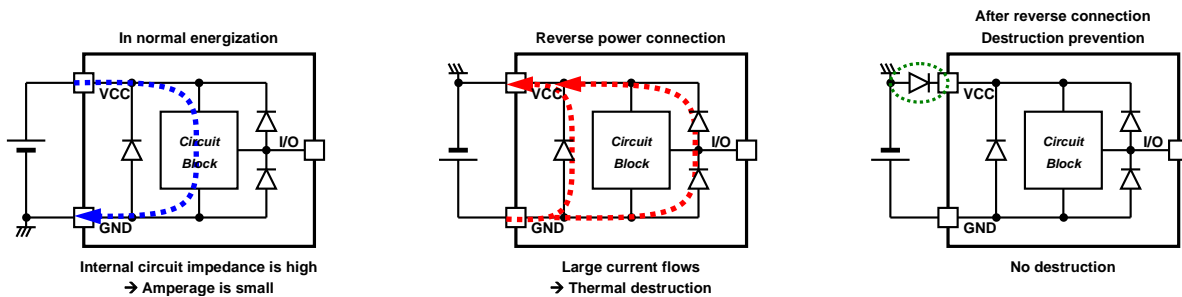


Figure 27. Flow of Current When the Power is Connected Reversely

2. Protection against V_{CC} Voltage Rise by Back Electromotive Force

The back electromotive force (Back EMF) generates regenerative current to the power supply. However, when the reverse connection protection diode is connected to the power supply line as shown in Figure 28, the V_{CC} voltage rises because the diode prevents current flow to the power supply.

When the absolute maximum rated voltage may be exceeded due to the voltage rise by the back electromotive force, place a (A) capacitor or (B) Zener diode between the VCC pin and the GND pin for regenerative current path as shown in Figure 29. If further measures are necessary, use measures of (A) and (B) together like as (C). The capacitor and the resistor can be used to have better voltage surge protection like as (D).

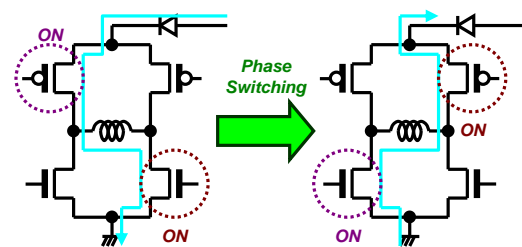


Figure 28. V_{CC} Voltage Rise by Back Electromotive

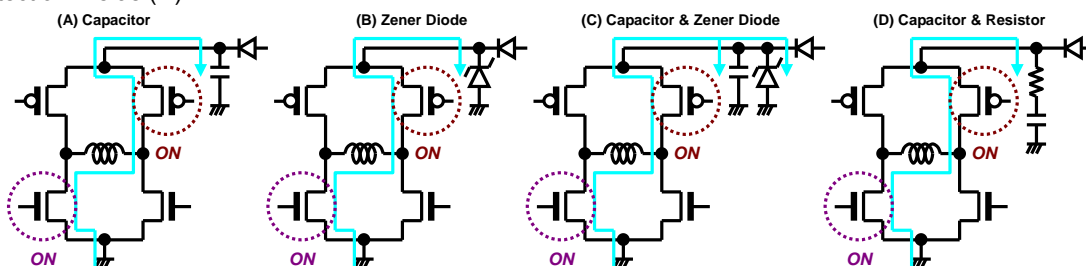


Figure 29. Measure Against V_{CC} and Motor Driving Outputs Voltage

3. PWM Switching of GND Line

Do not perform the PWM switching of the GND line because the GND pin potential cannot be kept to a minimum.

4. Protection of Input Pin and Output Pin

Misconnecting of the external connector from the motor PCB or plugging and unplugging the hot connector may cause damage to the IC by the rush current or the over voltage surge.

About the input pin and the output pin except the VCC pin and the GND pin, please take measures such as using the protection resistor so that the IC is not affected by the over voltage or the over current as shown in Figure 31.

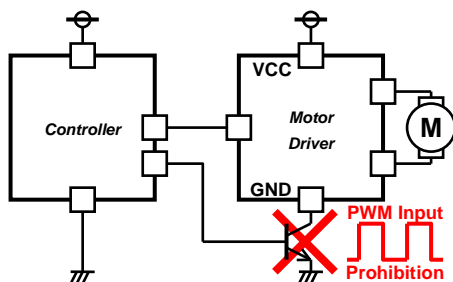


Figure 30. Prohibition of the GND Line PWM Switching

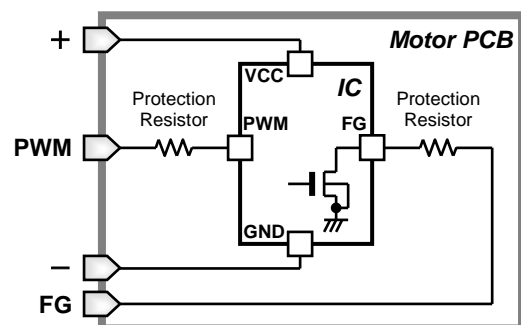


Figure 31. Protection of the PWM Pin and the FG pin

Power Consumption

1 Current Path

The current pathways that relates to the driver IC are following, and shown as Figure 32.

- (1) Circuit Current (I_{CC})
- (2) Motor Current (I_M)
- (3) FG Output Sink Current (I_{FG})

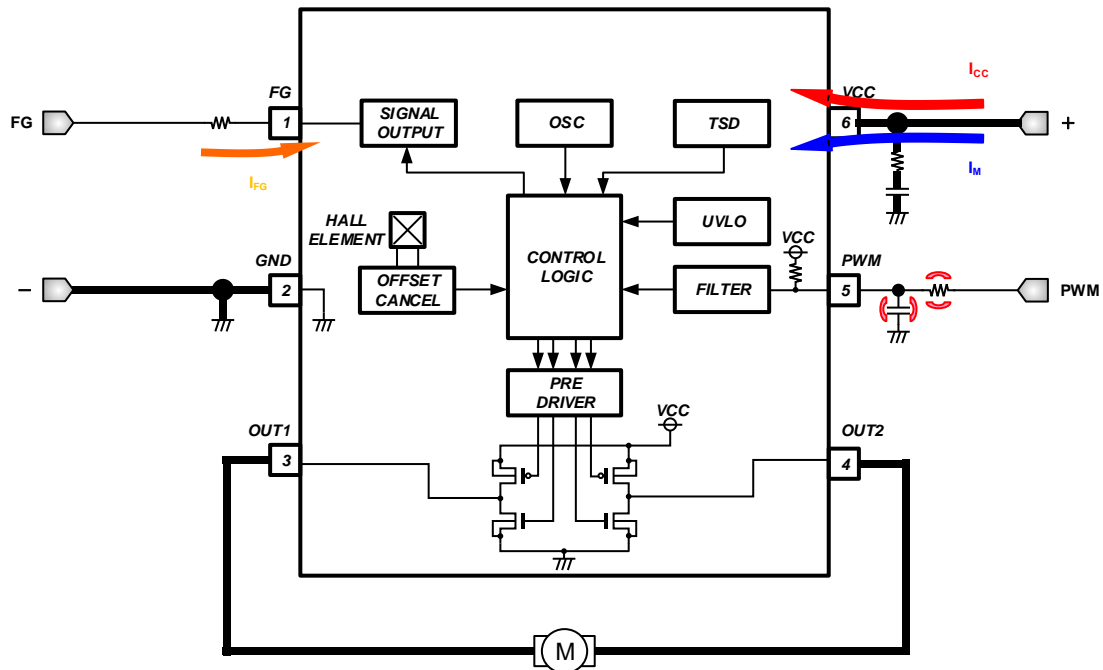


Figure 32. Current Paths of the IC

2 Calculation of Power Consumption

- (1) Circuit Current (I_{CC})

$$P_{WA} = V_{CC}[V] \times I_{CC}[A] \quad [W] \quad (I_{CC} \text{ Current does not include } I_M)$$

$$(\text{ex.}) \quad V_{CC} = 5.0 \text{ V}, \quad I_{CC} = 2.5 \text{ mA}$$

$$P_{WA} = 5.0 \times 2.5 = 12.5 \text{ mW}$$

- (2) Motor Driving Current (I_M)

The V_{OH} is the output saturation voltage of the OUT1 or the OUT2 high side, the V_{OL} is the other low side voltage,

$$P_{WB} = (V_{OH}[V] + V_{OL}[V]) \times I_M[A] \quad [W]$$

$$(\text{ex.}) \quad V_{OH} = 0.08 \text{ V}, \quad V_{OL} = 0.08 \text{ V}, \quad I_M = 200 \text{ mA}$$

$$P_{WB} = (0.08 + 0.08) \times 200 = 32.0 \text{ mW}$$

- (3) FG Output Sink Current (I_{FG})

$$P_{WC} = V_{FG}[V] \times I_{FG}[A] \quad [W]$$

$$(\text{ex.}) \quad V_{FG} = 0.05 \text{ V}, \quad I_{FG} = 5.0 \text{ mA}$$

$$P_{WC} = 0.05 \times 5.0 = 0.25 \text{ mW}$$

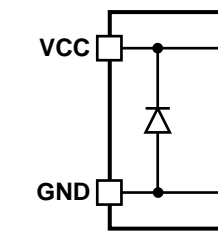
The power consumption of the driver IC totaled the above (1) to (3) is the following.

$$P = P_{WA} + P_{WB} + P_{WC} \quad [W]$$

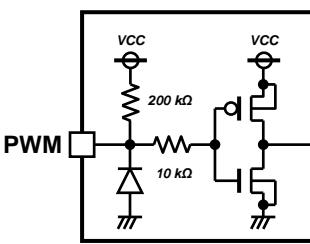
$$(\text{ex.}) \quad P = 12.5 + 32.0 + 0.25 = 44.75 \text{ mW}$$

I/O Equivalence Circuit (Resistance Values are Typical)

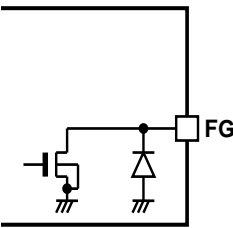
1. Supply voltage, Ground



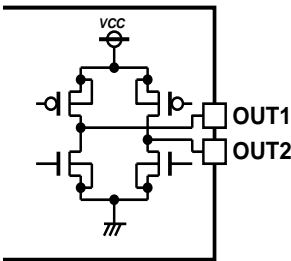
2. PWM signal input



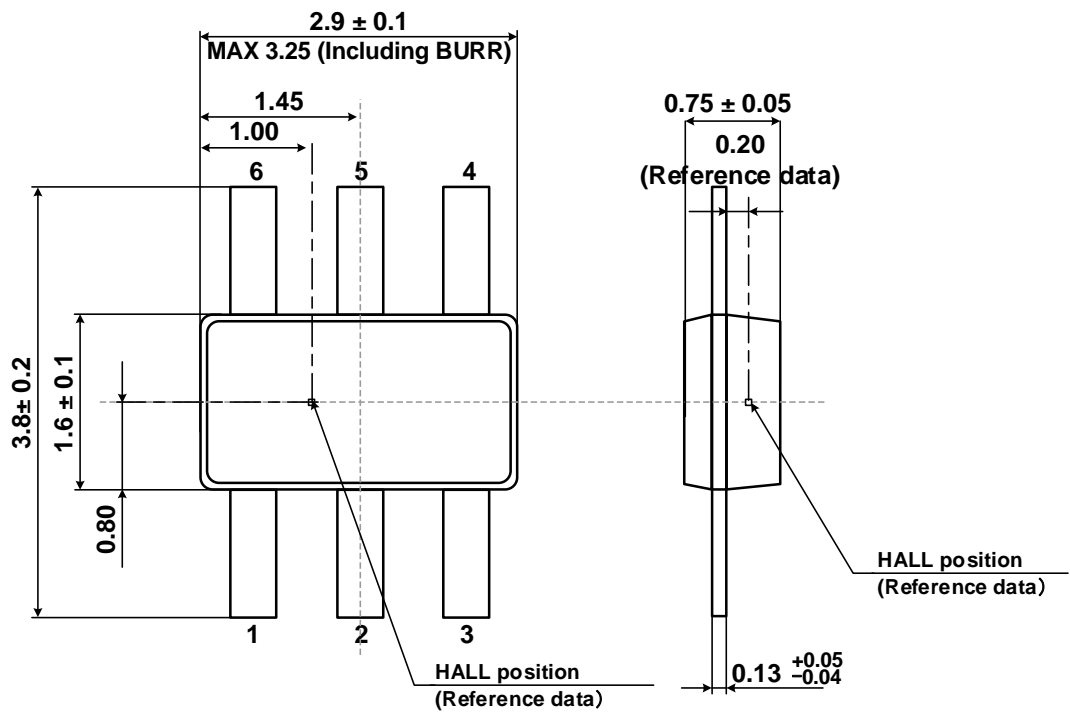
3. FG output



4. Motor outputs



Hall Position (Reference data)



Operational Notes

1. Reverse Connection of Power Supply

Connecting the power supply in reverse polarity can damage the IC. Take precautions against reverse polarity when connecting the power supply, such as mounting an external diode between the power supply and the IC's power supply pins.

2. Power Supply Lines

Design the PCB layout pattern to provide low impedance supply lines. Furthermore, connect a capacitor to ground at all power supply pins. Consider the effect of temperature and aging on the capacitance value when using electrolytic capacitors.

3. Ground Voltage

Ensure that no pins are at a voltage below that of the ground pin at any time, even during transient condition. However, pins that drive inductive loads (e.g. motor driver outputs, DC-DC converter outputs) may inevitably go below ground due to back EMF or electromotive force. In such cases, the user should make sure that such voltages going below ground will not cause the IC and the system to malfunction by examining carefully all relevant factors and conditions such as motor characteristics, supply voltage, operating frequency and PCB wiring to name a few.

4. Ground Wiring Pattern

When using both small-signal and large-current ground traces, the two ground traces should be routed separately but connected to a single ground at the reference point of the application board to avoid fluctuations in the small-signal ground caused by large currents. Also ensure that the ground traces of external components do not cause variations on the ground voltage. The ground lines must be as short and thick as possible to reduce line impedance.

5. Recommended Operating Conditions

The function and operation of the IC are guaranteed within the range specified by the recommended operating conditions. The characteristic values are guaranteed only under the conditions of each item specified by the electrical characteristics.

6. Inrush Current

When power is first supplied to the IC, it is possible that the internal logic may be unstable and inrush current may flow instantaneously due to the internal powering sequence and delays, especially if the IC has more than one power supply. Therefore, give special consideration to power coupling capacitance, power wiring, width of ground wiring, and routing of connections.

7. Operation Under Strong Electromagnetic Field

Operating the IC in the presence of a strong electromagnetic field may cause the IC to malfunction.

8. Testing on Application Boards

When testing the IC on an application board, connecting a capacitor directly to a low-impedance output pin may subject the IC to stress. Always discharge capacitors completely after each process or step. The IC's power supply should always be turned off completely before connecting or removing it from the test setup during the inspection process. To prevent damage from static discharge, ground the IC during assembly and use similar precautions during transport and storage.

9. Inter-pin Short and Mounting Errors

Ensure that the direction and position are correct when mounting the IC on the PCB. Incorrect mounting may result in damaging the IC. Avoid nearby pins being shorted to each other especially to ground, power supply and output pin. Inter-pin shorts could be due to many reasons such as metal particles, water droplets (in very humid environment) and unintentional solder bridge deposited in between pins during assembly to name a few.

10. Unused Input Pins

Input pins of an IC are often connected to the gate of a MOS transistor. The gate has extremely high impedance and extremely low capacitance. If left unconnected, the electric field from the outside can easily charge it. The small charge acquired in this way is enough to produce a significant effect on the conduction through the transistor and cause unexpected operation of the IC. So unless otherwise specified, unused input pins should be connected to the power supply or ground line.

Operational Notes – continued

11. Regarding the Input Pin of the IC

This monolithic IC contains P⁺ isolation and P substrate layers between adjacent elements in order to keep them isolated. P-N junctions are formed at the intersection of the P layers with the N layers of other elements, creating a parasitic diode or transistor. For example (refer to figure below):

When GND > Pin A and GND > Pin B, the P-N junction operates as a parasitic diode.

When GND > Pin B, the P-N junction operates as a parasitic transistor.

Parasitic diodes inevitably occur in the structure of the IC. The operation of parasitic diodes can result in mutual interference among circuits, operational faults, or physical damage. Therefore, conditions that cause these diodes to operate, such as applying a voltage lower than the GND voltage to an input pin (and thus to the P substrate) should be avoided.

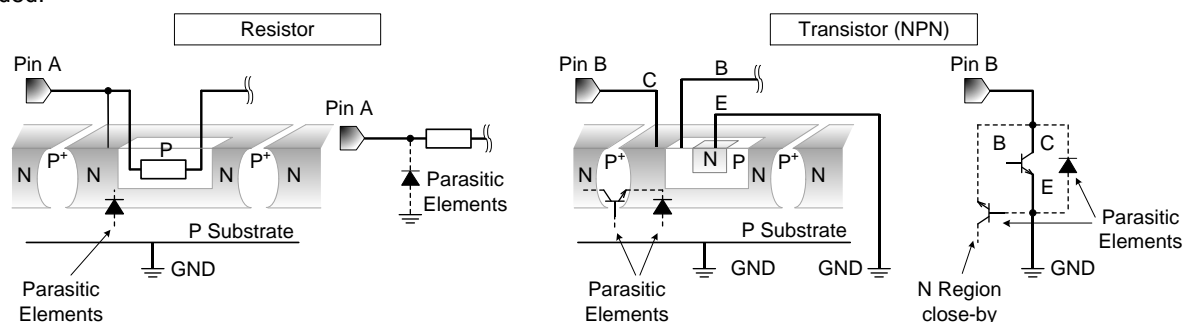


Figure 33. Example of Monolithic IC Structure

12. Ceramic Capacitor

When using a ceramic capacitor, determine a capacitance value considering the change of capacitance with temperature and the decrease in nominal capacitance due to DC bias and others.

13. Area of Safe Operation (ASO)

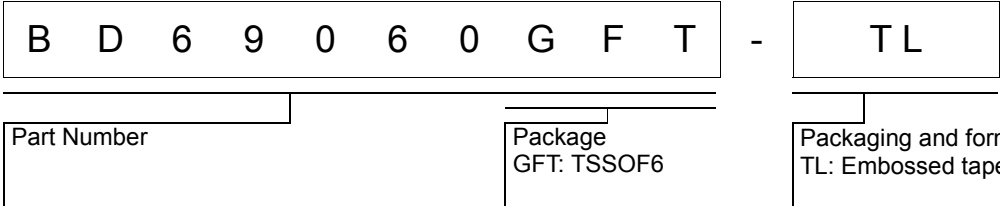
Operate the IC such that the output voltage, output current, and the maximum junction temperature rating are all within the Area of Safe Operation (ASO).

14. Thermal Shutdown Circuit (TSD)

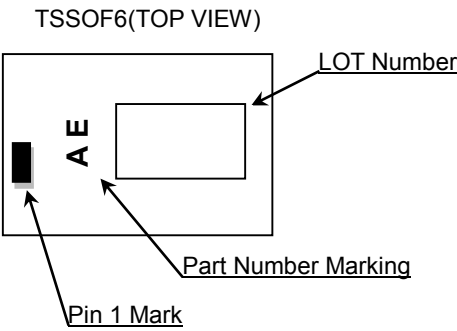
This IC has a built-in thermal shutdown circuit that prevents heat damage to the IC. Normal operation should always be within the IC's maximum junction temperature rating. If however the rating is exceeded for a continued period, the junction temperature (T_j) will rise which will activate the TSD circuit that will turn OFF power output pins. When the T_j falls below the TSD threshold, the circuits are automatically restored to normal operation.

Note that the TSD circuit operates in a situation that exceeds the absolute maximum ratings and therefore, under no circumstances, should the TSD circuit be used in a set design or for any purpose other than protecting the IC from heat damage.

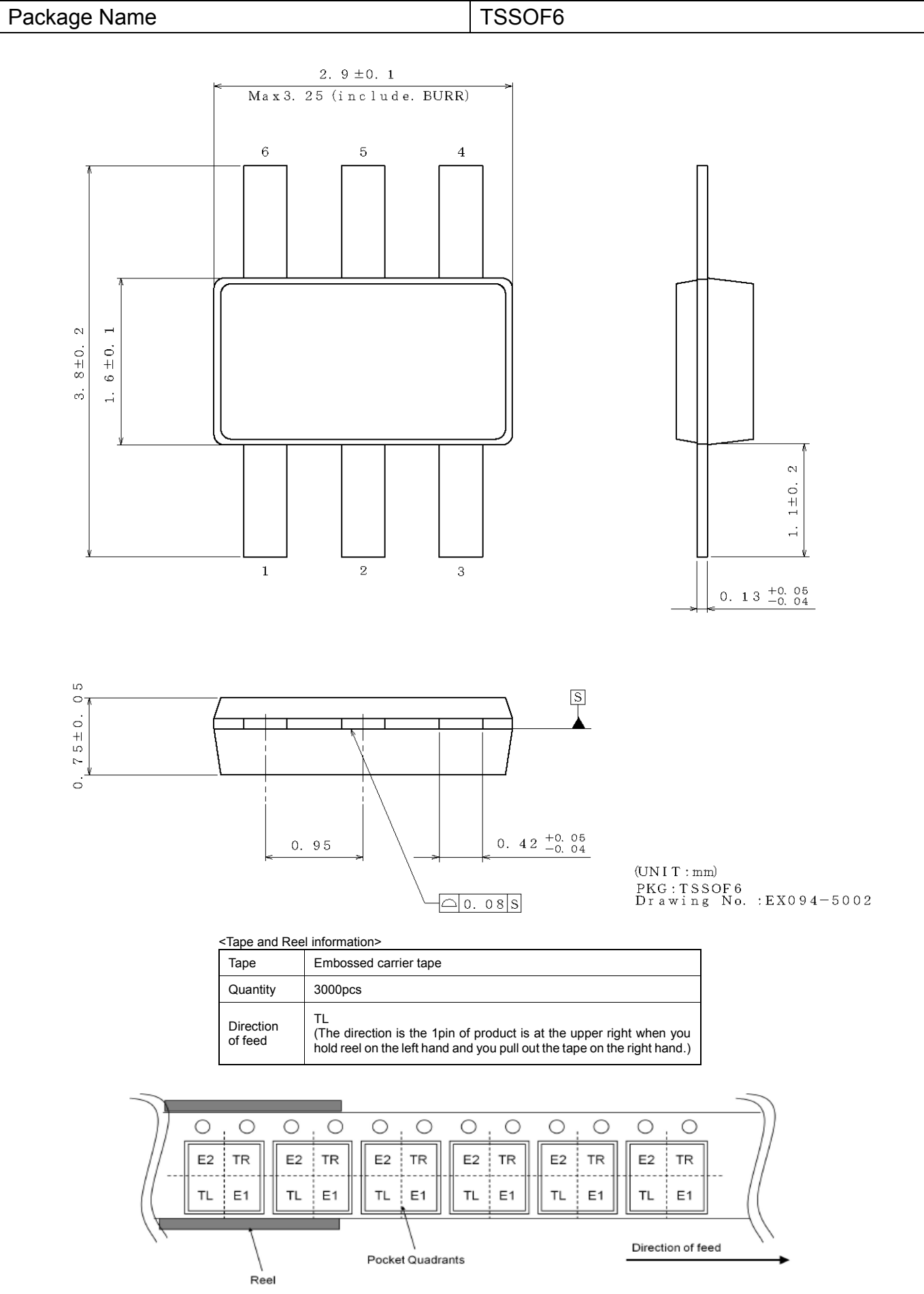
Ordering Information



Marking Diagram



Physical Dimension and Packing Information



Revision History

Date	Revision	Changes
18.Apr.2018	001	New Release

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JAPAN	USA	EU	CHINA
CLASS III	CLASS III	CLASS II b	CLASS III
CLASS IV		CLASS III	

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 - Use of our Products in proximity to heat-producing components, plastic cords, or other flammable items
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 - Use of the Products in places subject to dew condensation
- The Products are not subject to radiation-proof design.
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- Confirm that operation temperature is within the specified range described in the product specification.
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 - [c] the Products are exposed to direct sunshine or condensation
 - [d] the Products are exposed to high Electrostatic
2. Even under ROHM recommended storage condition, solderability of products out of recommended storage time period may be degraded. It is strongly recommended to confirm solderability before using Products of which storage time is exceeding the recommended storage time period.
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4. Use Products within the specified time after opening a humidity barrier bag. Baking is required before using Products of which storage time is exceeding the recommended storage time period.

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