

**Preliminary**

Toshiba Bi-CMOS Integrated Circuit Silicon Monolithic

# TB6549F, TB6549P

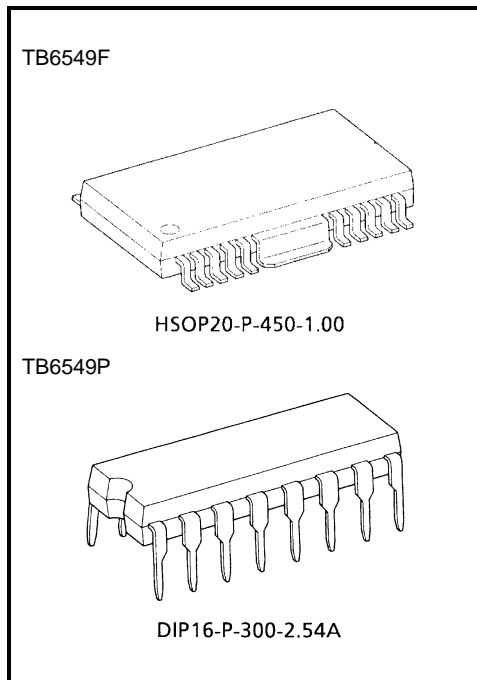
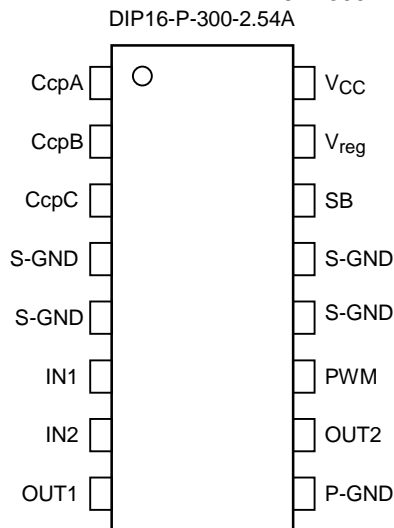
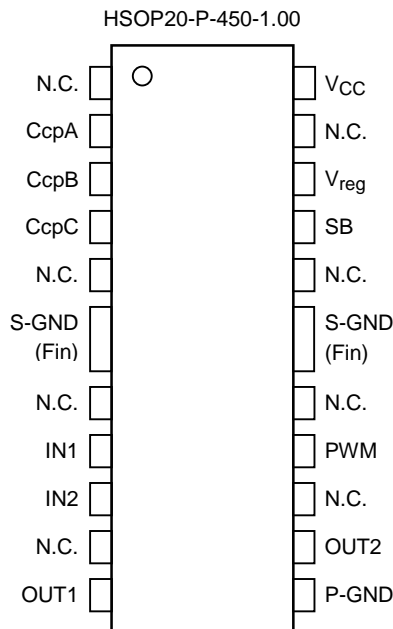
Full-Bridge Driver IC for DC motor

TB6549F/P is a full-bridge driver IC for DC motor which uses LDMOS for output transistors. High efficient drive is possible by MOS process with low ON-resistor and PWM drive system. Four modes such as CW, CCW, short brake, and stop can be chosen by IN1 and IN2.

## Features

- Power supply voltage: 30 V (max)
- Output current: 3.5 A (max)
- Low ON resistor: 0.5 Ω (typ.)
- Capable of PWM controlling
- Standby system
- CW/CCW/short brake/stop function modes.
- Built-in overcurrent protection
- Built-in thermal shutdown circuit
- Package: HSOP-20/DIP-16

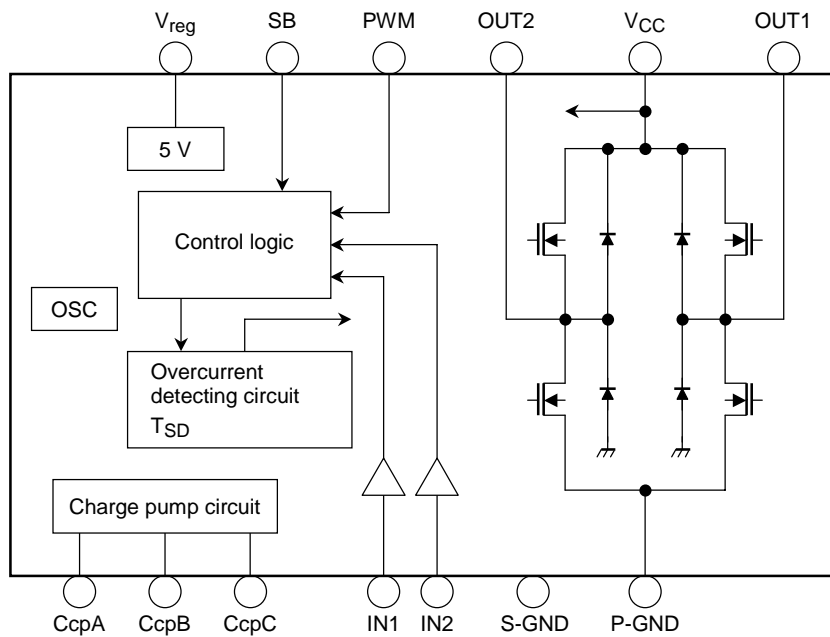
## Pin Assigment



Weight  
 HSOP20-P-450-1.00: 0.79 g (typ.)  
 DIP16-P-300-2.54A: 1.11 g (typ.)

Note: This product has a MOS structure and is sensitive to electrostatic discharge. When handling this product, ensure that the environment is protected against electrostatic discharge by using an earth strap, a conductive mat and an ionizer. Ensure also that the ambient temperature and relative humidity are maintained at reasonable levels.

## Block Diagram



## Pin Functions

Pin No.		Pin Name	Functional Description	Remarks
F	P			
1	—	(NC)	No Connection	—
2	1	CcpA	Capacitor connection pin for charge pump A	Connect a capacitor for charge pump
3	2	CcpB	Capacitor connection pin for charge pump B	Connect a capacitor for charge pump
4	3	CcpC	Capacitor connection pin for charge pump C	Connect a capacitor for charge pump
5	—	(NC)	No Connection	—
6	—	(NC)	No Connection	—
7	6	IN1	Control signal input 1	Input 0/5-V signal
8	7	IN2	Control signal input 2	Input 0/5-V signal
9	—	(NC)	No Connection	—
10	8	OUT1	Output pin 1	Connect to motor coil pin
11	9	P-GND	Power GND	—
12	10	OUT2	Output pin 2	Connect to motor coil pin
13	—	(NC)	No Connection	—
14	11	PWM	PWM control signal input pin	Input 0/5-V PWM signal
15	—	(NC)	No Connection	—
16	—	(NC)	No Connection	—
17	14	SB	Standby pin	H: Start, L: Standby
18	15	V <sub>reg</sub>	5 V output pin	Connect a capacitor to S-GND
19	—	(NC)	No Connection	—
20	16	V <sub>CC</sub>	Power supply input pin	V <sub>CC (ope)</sub> = 10 to 27 V
FIN	4, 5, 12, 13	S-GND	GND pin	—

## Maximum Ratings (Ta = 25°C)

Characteristics		Symbol	Rating	Unit
Supply voltage		V <sub>CC</sub>	30	V
Output current		I <sub>O</sub> (Peak)	3.5 (Note 1)	A
		I <sub>O</sub> (Ave)	2.0	
Power dissipation	F	P <sub>D</sub>	2.5 (Note 2)	W
	P		2.5 (Note 3)	
Operating temperature		T <sub>opr</sub>	-20 to 85	°C
Storage temperature		T <sub>stg</sub>	-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.

Note 3: This value is obtained by 50 × 50 × 1.6 mm PCB mounting occupied 50% of copper area.

## Operating Range (Ta = 25°C)

Characteristics	Symbol	Rating	Unit
Supply voltage	V <sub>CC</sub>	10 to 27	V
PWM frequency	f <sub>CLK</sub>	100	kHz

**Electrical Characteristics (V<sub>CC</sub> = 24 V, Ta = 25°C)**

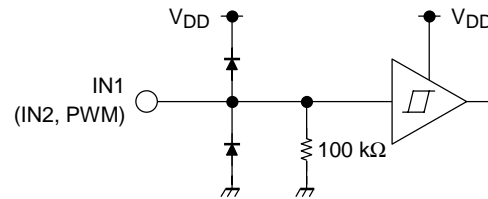
Characteristics		Symbol	Test Circuit	Test Condition	Min	Typ.	Max	Unit	
Supply current		I <sub>CC1</sub>	1	Stop mode	—	4	8	mA	
		I <sub>CC2</sub>		CW/CCW mode	—	6	10		
		I <sub>CC3</sub>		Short break mode	—	4	8		
		I <sub>CC4</sub>		(Standby mode)	—	1	2		
Control circuit		V <sub>INH</sub>	2		2	—	5.5	V	
		V <sub>INL</sub>			—	—	0.8		
		Hysteresis voltage	V <sub>IN (HYS)</sub>	—	(Not tested)	—	0.2	—	μA
		Input current	I <sub>INH</sub>	1	V <sub>IN</sub> = 5 V	—	50	75	
I <sub>INL</sub>	V <sub>IN</sub> = 0 V		—		—	5			
PWM input circuit		Input voltage	3		2	—	5.5	V	
					V <sub>PWML</sub>	—	—		0.8
		Hysteresis voltage	V <sub>PWM(HYS)</sub>	—	(Not tested)	—	0.2	—	μA
		Input current	I <sub>PWMH</sub>	3	V <sub>PWM</sub> = 5 V	—	50	75	
			I <sub>PWML</sub>		V <sub>PWM</sub> = 0 V	—	—	5	
PWM frequency	f <sub>PWM</sub>	3	Duty = 50%	—	—	100	kHz		
Minimum clock pulse width	tw(PWM)			2	—	—	μs		
Standby circuit		Input voltage	2		2	—	5.5	V	
					V <sub>INSL</sub>	—	—		0.8
		Hysteresis voltage	V <sub>IN (HYS)</sub>	—	(Not tested)	—	0.2	—	μA
		Input current	I <sub>INSH</sub>	1	V <sub>IN</sub> = 5 V	—	50	75	
I <sub>INSL</sub>	V <sub>IN</sub> = 0 V		—		—	5			
Output ON resistance		R <sub>on (U + L)</sub>	4		I <sub>o</sub> = 0.2 A	—	1.0	1.75	Ω
					I <sub>o</sub> = 1.5 A	—	1.0	1.75	
Output leakage current		I <sub>L (U)</sub>	5	V <sub>CC</sub> = 30 V (Note 1)	—	—	150	μA	
		I <sub>L (L)</sub>			V <sub>CC</sub> = 30 V	—	—		10
Diode forward voltage		V <sub>F (U)</sub>	6	I <sub>o</sub> = 1.5 A		1.3	1.7	V	
		V <sub>F (L)</sub>			I <sub>o</sub> = 1.5 A		1.3		1.7
Internal reference voltage		V <sub>reg</sub>	4	No load	4.5	5	5.5	V	
Overcurrent detection offset time		I <sub>SD (OFF)</sub>	—	(Not tested)	—	50	—	μs	
Charge pump rising time		t <sub>ONG</sub>	7	C <sub>1</sub> = 0.22 μF, C <sub>2</sub> = 0.01 μF (Note 2)	—	1	3	ms	
Thermal shutdown circuit operating temperature		T <sub>SD</sub>	—	(Not tested)	—	160	—	°C	

Note 1: Include the current in the circuit.

Note 2: C<sub>1</sub> is a capacitor between CcpA and GND. C<sub>2</sub> is a capacitor between CcpB and CcpC.

**Component Description**

**1. Control Input/PWM Input Circuit**

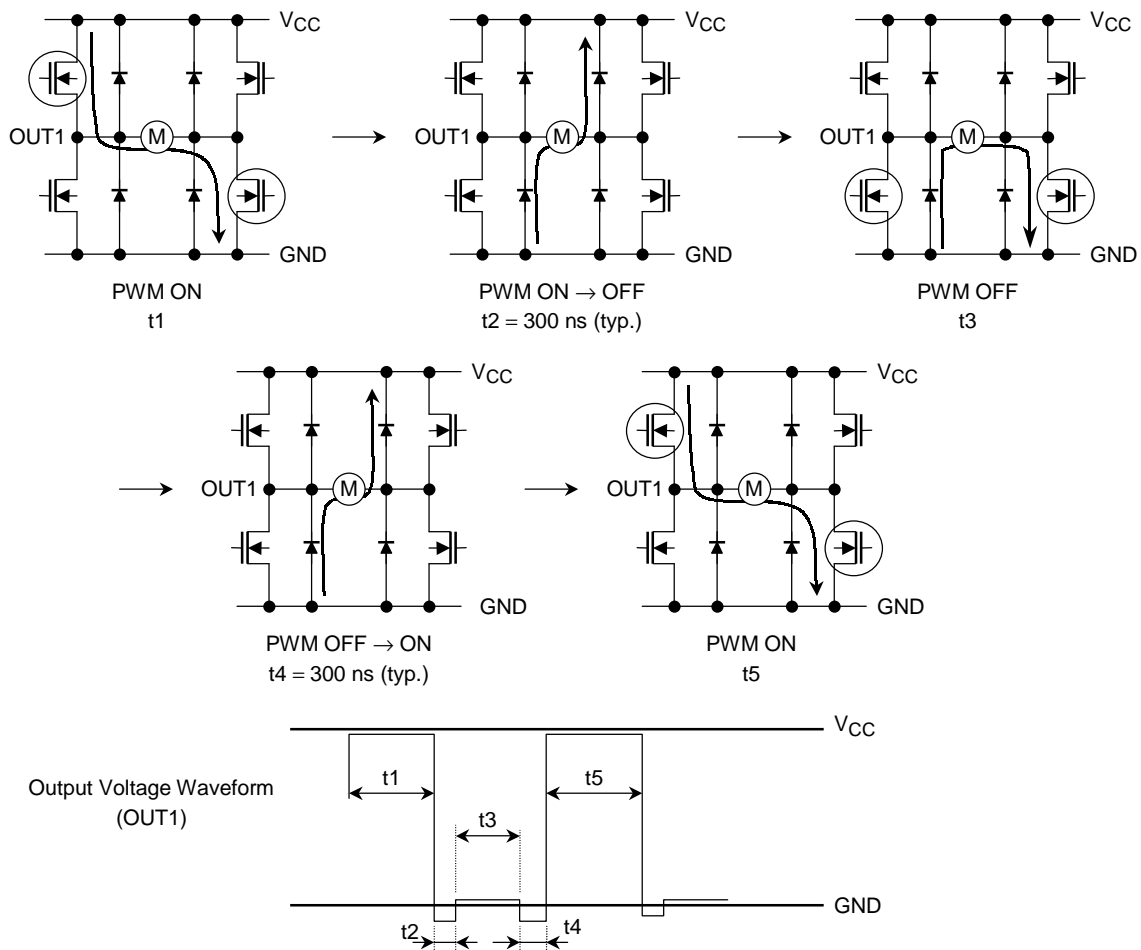


- The input signals are shown below. Input at the CMOS and TTL levels can be provided. Note that the input signals have a hysteresis of 0.2 V (typ.).  
 $V_{INH}$ : 2 to  $V_{reg}$  V  
 $V_{INL}$ : GND to 0.8 V
- The PWM input frequency should be 100 kHz or less.

**Input/Output Function**

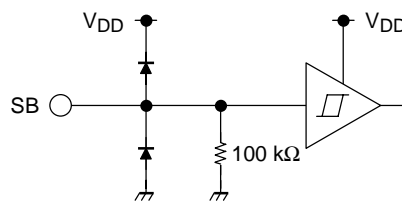
Input				Output		
IN1	IN2	SB	PWM	OUT1	OUT2	Mode
H	H	H	H ----- L	L	L	Short brake
L	H	H	H	L	H	CW/CCW
			L	L	L	Short brake
H	L	H	H	H	L	CCW/CW
			L	L	L	Short brake
L	L	H	H	OFF (high impedance)		Stop
			L	OFF (high impedance)		
H/L	H/L	L	H	OFF (high impedance)		Standby
			L	OFF (high impedance)		

- PWM control function  
 Motor speed can be controlled by inputting the 0/5-V PWM signal to the PWM pin.  
 When PWM control is 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.



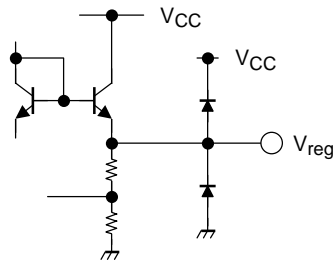
Note: Please set the pin PWM to High when PWM control function is not used.

## 2. Standby Circuit



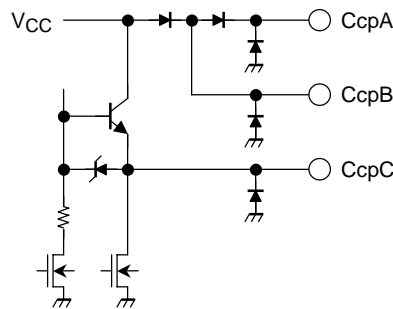
- All circuits are turned off except the standby circuit and the charge pump circuit under the standby condition.
- Input voltage range is shown below. Input at CMOS and TTL level is possible. Input signal has 0.2-V (typ.) hysteresis.  
 VINSH: 2 to Vreg V  
 VINSL: GND to 0.8 V
- Please avoid controlling the output by inputting PWM signal to the standby pin. The output signal becomes unstable and it may cause the destruction of the IC.
- The charge pump circuit is turned On/Off by the switch of the input signal from the standby pin. If the switching cycle is shorter than 50 ms, the charge pump circuit will not operate with precise timing. Therefore, switching cycle of the standby pin should be longer than 50 ms.
- When the Standby condition is changed to the Operation Mode, set IN1 and IN2 to Low level (Stop Mode) at first. Then switch IN1 and IN2 to High level when the charge pump circuit reaches the stable condition, VcpA is about VCC + 5 V.

**3. 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 V<sub>reg</sub>. No other loads should be connected to pin V<sub>reg</sub>.
- This IC has a power monitoring function and turns the output OFF when V<sub>reg</sub> 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 V<sub>reg</sub> reaches 3.3 V (design target value) again .

**4. Charge Pump Circuit**



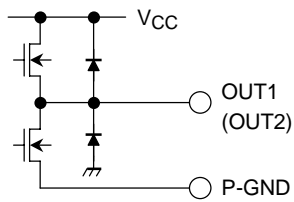
- This IC has a charge pump circuit for driving the gate for the upper power transistor in the output circuit. A voltage of V<sub>CC</sub> + 5 V (typ.) is generated by connecting an external capacitor to this IC. It takes about 2 ms to boost V<sub>CPA</sub> up V<sub>CC</sub> + 5 V (typ.) after the switch of the input signal from the standby pin. (while C<sub>cpA</sub> = 0.22 μF, and C<sub>cpB</sub> and C<sub>cpC</sub> are connected through 0.01 μF).
- The proper capacitance of the external capacitor varies depending on the V<sub>CC</sub> value. Thus, determine the constant by referring to the following data. The value of the capacitor between C<sub>cpB</sub> and C<sub>cpC</sub> should be such that, while the motor is being driven, the voltage on the C<sub>cpA</sub> pin will be kept constant, typically at V<sub>CC</sub> + 5 V. (If a reduced V<sub>CC</sub> level causes the voltage on C<sub>cpA</sub> to start to fall, please adjust this capacitance value accordingly.)

<External capacitor>

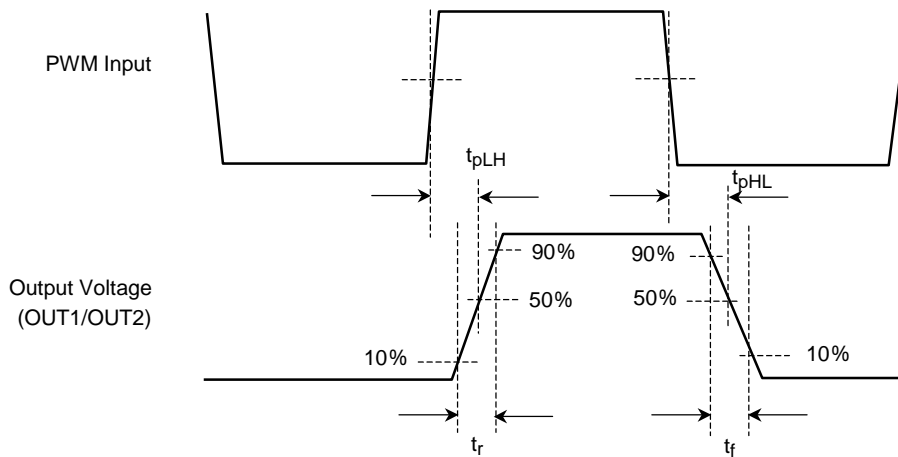
V <sub>CC</sub>	Between C <sub>cpB</sub> and C <sub>cpC</sub>	Between C <sub>cpA</sub> and GND
10 V~15 V	0.01 μF~0.047 μF	0.22 μF
15 V~27 V	0.01 μF	0.22 μF

- Reference oscillation is performed by using the internal capacitor.

**5. Output Circuit**



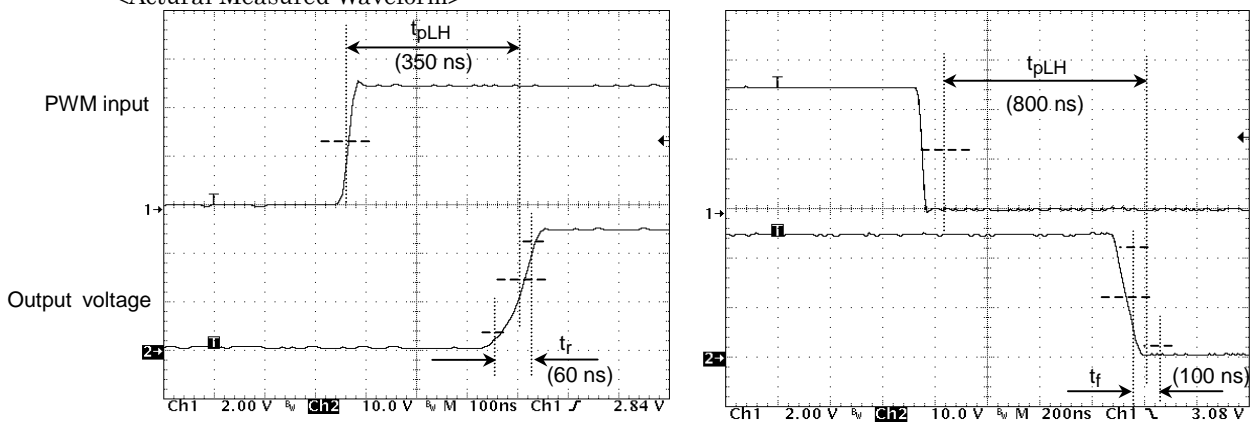
- This IC uses Nch MOS transistors as the upper and lower transistors in the output circuit.
- As output  $R_{on}$  is  $1\ \Omega$  (sum for the upper and lower parts/typ.), this IC is a device of the low  $R_{on}$  type.
- The switching characteristics of the output transistors are shown below.



<Typical Value>

Item	Typical Value	Unit
$t_{pLH}$	350	ns
$t_{pHL}$	800	
$t_r$	60	
$t_f$	100	

<Actual Measured Waveform>



\*: OUT 1, OUT 2; open



**6. V<sub>CC</sub> Power Supply Section**

- The V<sub>CC</sub> power supply delivers a voltage to the output circuit, charge pump circuit, and internal 5-V circuit.
- The operating voltage range is shown below.  
 $V_{CC (opr.)} = 10 \text{ to } 27 \text{ V}$
- 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.

**7. GND Sections**

- This IC includes two separate GND sections: S-GND for controlling and P-GND for outputting. Be sure to short-circuit these two GNDs as close to TB6549 as possible.

**8. Power Monitoring Circuit**

- This circuit turns the output OFF when V<sub>reg</sub> becomes 3.0 V (design target value) or less. At this time, V<sub>CC</sub> = 4.6 V (typ.)
- With a hysteresis of 0.3 V (design target value), the output turns back ON when V<sub>reg</sub> exceeds 3.3 V (design target value) after this circuit starts operating.

**9. Thermal Shutdown (T<sub>SD</sub>) Circuit**

This IC includes a thermal shutdown circuit which turns the output OFF when the junction temperature (T<sub>j</sub>) exceeds 160°C (typ.). The output turns back ON automatically. The thermal hysteresis is 20°C.

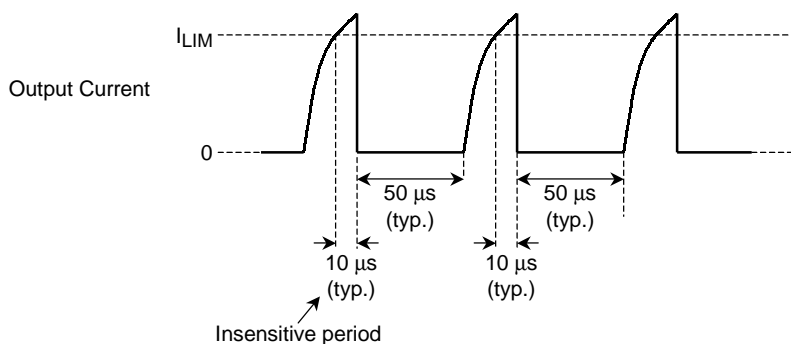
$$T_{SD} = 160^{\circ}\text{C (design target value)}$$

$$\Delta T_{SD} = 20^{\circ}\text{C (design target value)}$$

**10. Overcurrent Detection (I<sub>SD</sub>) Circuit**

This IC includes a circuit which detects a current flowing through the output power transistors. The current limit is set to 5 A (typ.). The circuit detects a current flowing through each of the four output power transistors. If the current in any one output power transistor exceeds the set limit, this circuit turns all the outputs OFF.

This circuit includes a timer which causes the outputs to be OFF for 50 μs (typ.) after detection of an overcurrent and then turn back ON automatically. If the overcurrent continues to flow, this ON-OFF operation is repeated. Note that to prevent a malfunction due to a glitch, an insensitive period of 10 μs (typ.) is provided.

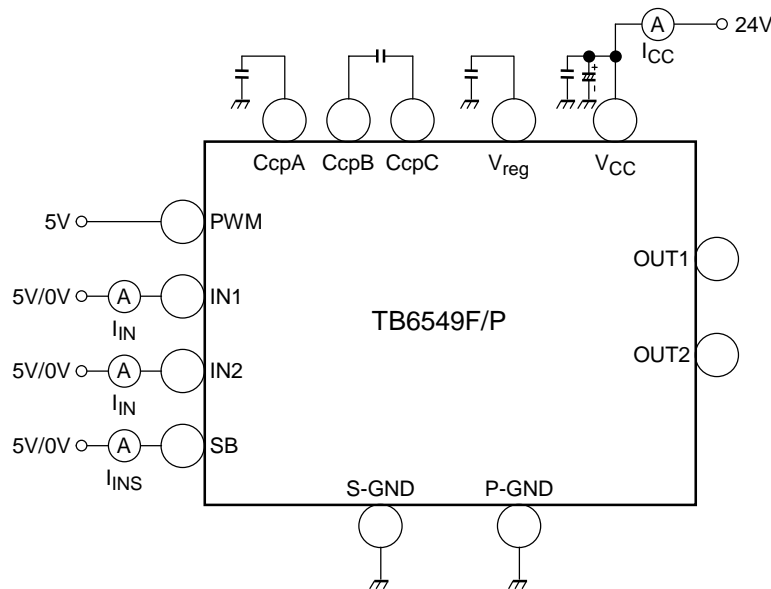


The set limit is 5 A (typ.) as a design target value. The distributions shown below exist because of the variations in thermal characteristics of different ICs. These distributions should be fully considered in the motor torque design.

Also, output peak current should be less than 3 A because of the variations below,  
 Detected current: Approximately from 3.5 to 6.5 A

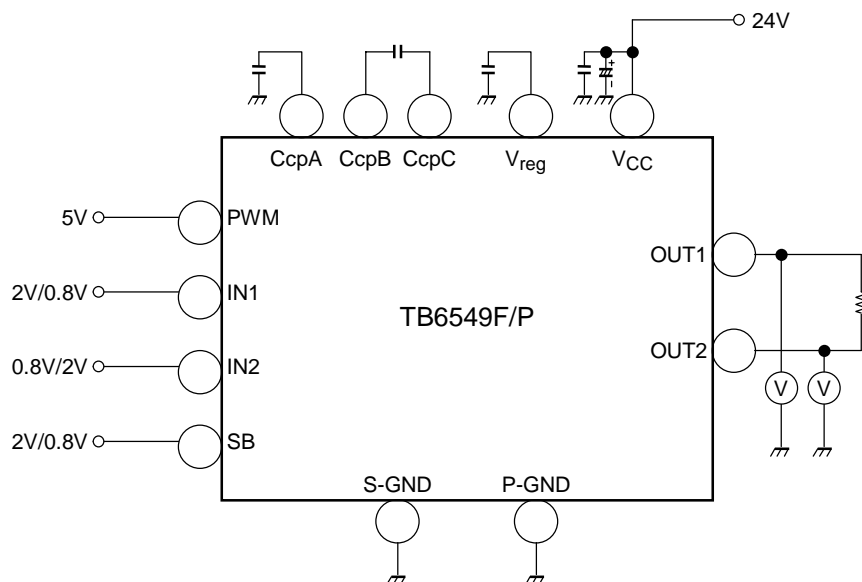
## Test Circuit

### 1. $I_{cc1}$ , $I_{cc2}$ , $I_{cc3}$ , $I_{cc4}$ , $I_{INH}$ , $I_{INL}$ , $I_{INSH}$ , $I_{INSL}$



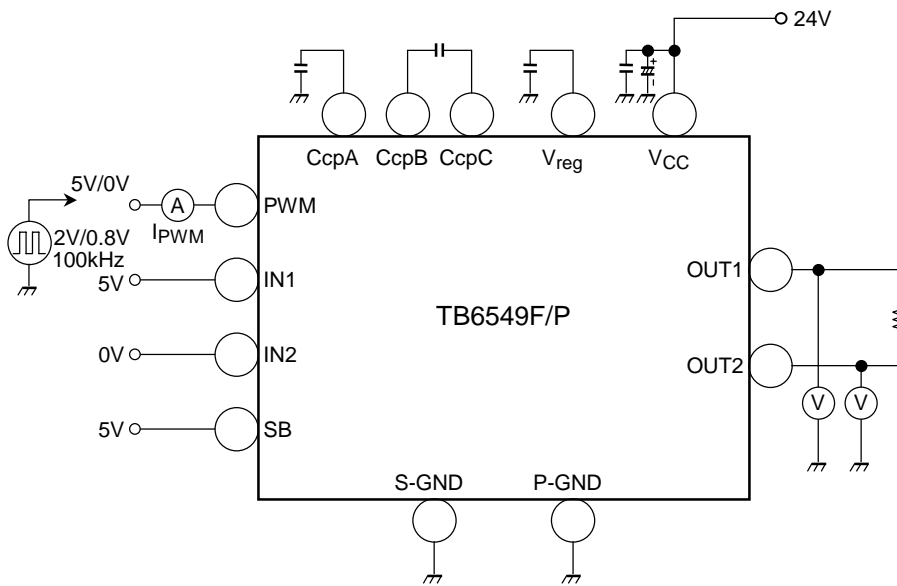
- $I_{cc1}$ :  $IN1 = 0\text{ V}$ ,  $IN2 = 0\text{ V}$ ,  $SB = 5\text{ V}$
- $I_{cc2}$ :  $IN1 = 5\text{ V}$ ,  $IN2 = 5\text{ V}$ ,  $SB = 5\text{ V}$  or  $IN1 = 0\text{ V}$ ,  $IN2 = 5\text{ V}$ ,  $SB = 5\text{ V}$
- $I_{cc3}$ :  $IN1 = 5\text{ V}$ ,  $IN2 = 5\text{ V}$ ,  $SB = 5\text{ V}$
- $I_{cc4}$ :  $IN1 = 5\text{ V}/0\text{ V}$ ,  $IN2 = 5\text{ V}/0\text{ V}$ ,  $SB = 0\text{ V}$
- $I_{INH}$ :  $IN1 = 5\text{ V}$ , and  $IN2 = 5\text{ V}$
- $I_{INL}$ :  $IN2 = 0\text{ V}$ , and  $IN2 = 0\text{ V}$
- $I_{INSH}$ :  $SB = 5\text{ V}$
- $I_{INSL}$ :  $SB = 0\text{ V}$

### 2. $V_{INH}$ , $V_{INL}$ , $V_{INSH}$ , $V_{INSL}$



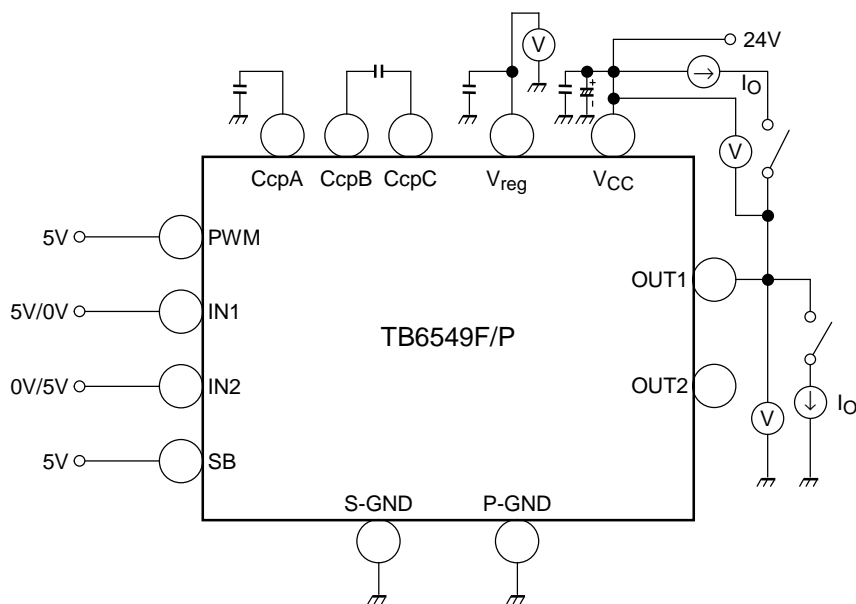
- $V_{INH}$ ,  $V_{INSH}$ :  $IN1 = IN2 = SB = 2\text{ V}$ , Verify that  $OUT1 = OUT2 = L$ .
- $V_{INL}$ :  $IN1 = 0.8\text{ V}$ ,  $IN2 = SB = 2\text{ V}$ , Verify that  $OUT1 = L$ ,  $OUT2 = H$ .  $IN1 = SB = 2\text{ V}$ ,  $IN2 = 0.8\text{ V}$ , Verify that  $OUT1 = OUT2 = L$ .
- $V_{INSL}$ :  $IN1 = IN2 = 2\text{ V}$ ,  $SB = 0.8\text{ V}$ , Verify that output function is high impedance.

### 3. VPWMH, VPWML, IPWMH, IPWML, fPWM, tw (PWM)



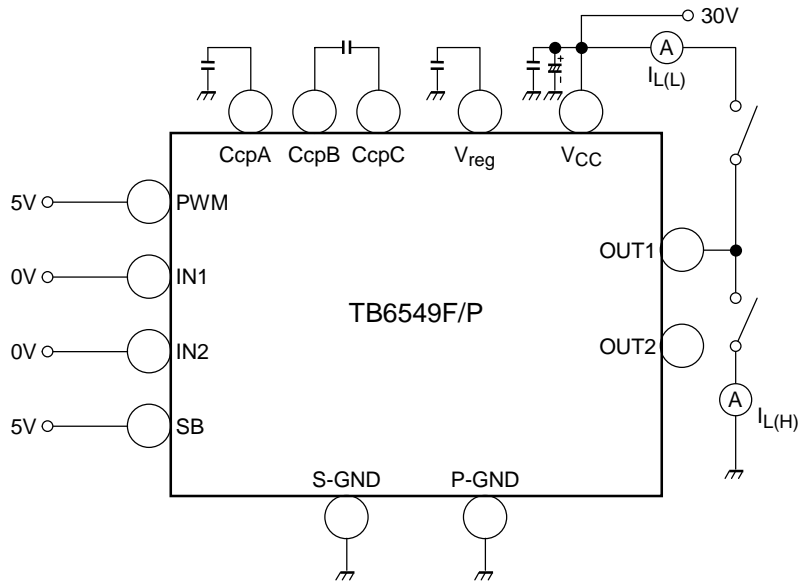
- VPWMH, VPWML, fPWM: PWM = 2 V/0.8 V, 100 kHz, duty: 50 % (rectangle wave), Verify out1
- VPWMH, VPWML: PWM = 5 V or PWM = 0 V.
- tw(PWM): PWM = 2 V/0.8 V, 100 kHz, duty: 20 % (2  $\mu$ s) (2  $\mu$ s/rectangle wave), Verify out1

### 4. Ron (H + L), Vreg

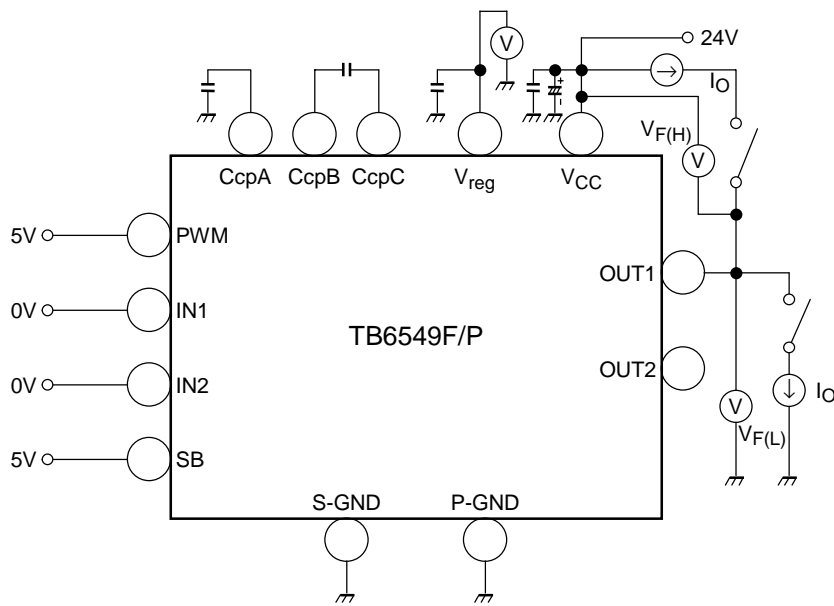


- Ron (H + L): Measure Vds (Sum of upper and lower side) at Io = 0.2 A, and change it to resistor. Same as at Io = 1.5 A.
- Vreg: Vreg pin Voltage.

5.  $I_L(U)$ ,  $I_L(L)$

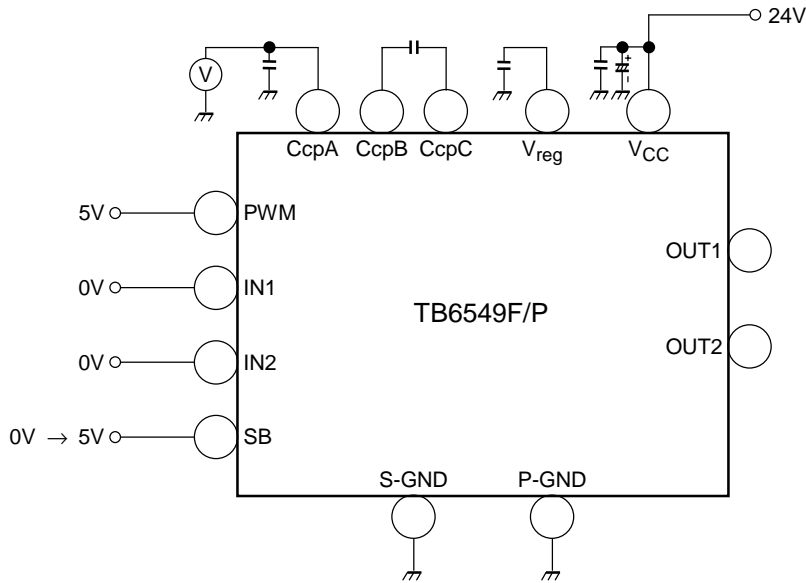


6.  $V_F(U)$ ,  $V_F(L)$

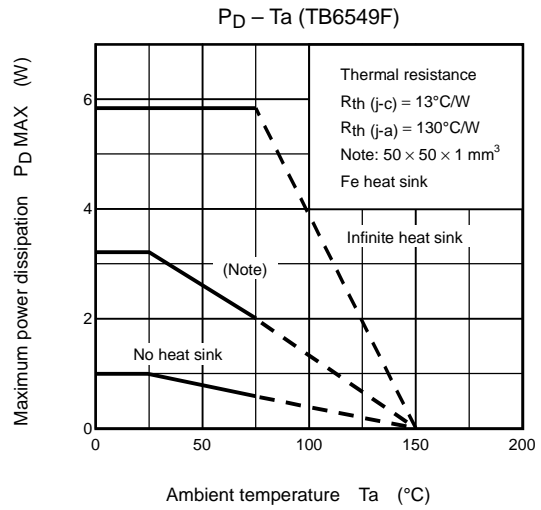
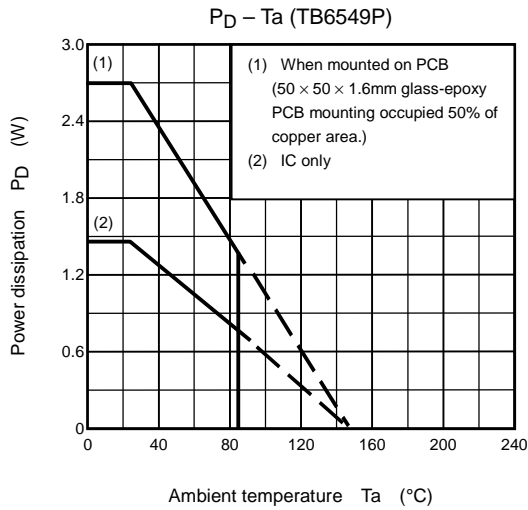


- $V_F(U)$ ,  $V_F(L)$ :  $I_o = 1.5 A$ .

7. tONG



- tONG: SB = 0 V → 5 V. Measure the time to boost CcpA voltage up about 29 V (24 V + 5 V)

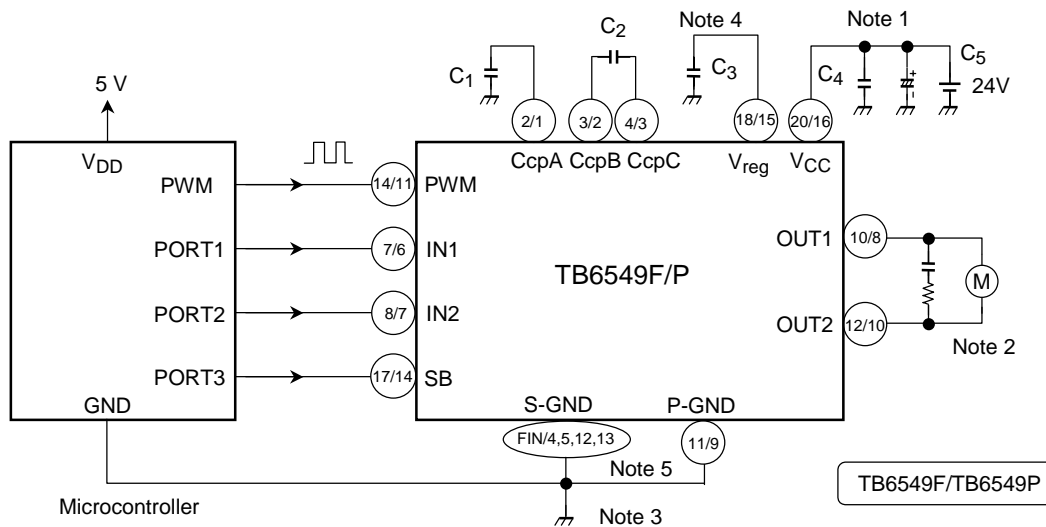


**External Attachments**

Symbol	Use	Recommended Value	Remarks
C <sub>1</sub>	Charge pump	0.22 μF	—
C <sub>2</sub>	Charge pump	0.01 μF	V <sub>CC</sub> = 24 V (Note)
		0.033 μF	V <sub>CC</sub> = 12 V (Note)
C <sub>3</sub>	Prevention of V <sub>reg</sub> oscillation	0.1 μF to 1.0 μF	—
C <sub>4</sub>	Absorption of power noise	0.001 μF to 1 μF	—
C <sub>5</sub>	Absorption of power noise	50 μF to 100 μF	—

Note: The recommended values for charge pumps depend on the V<sub>CC</sub> value. Please refer to the Component Description 4, Charge Pump Circuit.

## Typical Application Diagram



TB6549F: Pins 1, 5, 6, 9, 13, 15, 16, and 19 are not connected.

- 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.
- Note 5: Connect the capacitors  $C_1$  and  $C_2$  as close to TB6549 as possible, and the capacitor  $C_1$  as close to S-GND.
- Note 6: Pins 4, 5, 12, and 13 of the P type are connected to the chip's bed. Therefore, expanding their round area produces a better heat radiation effect.

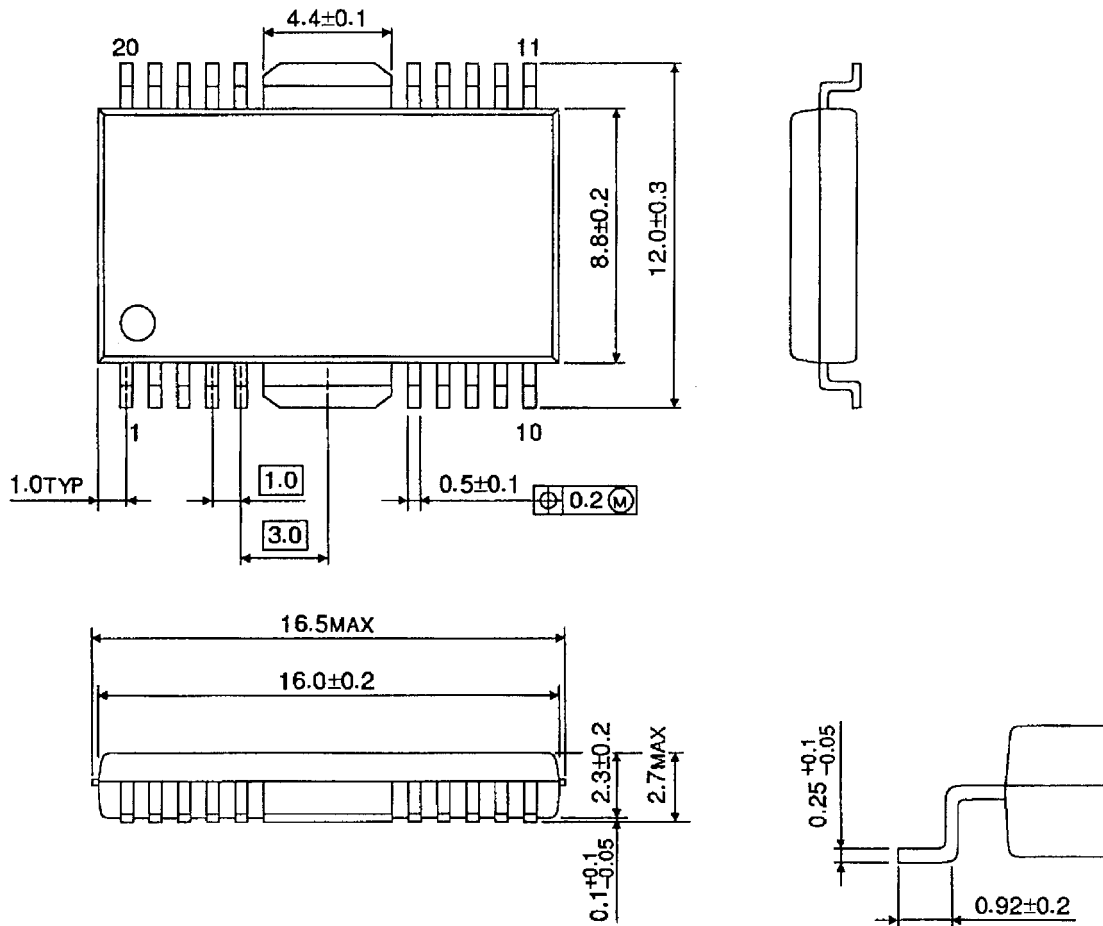
## Usage Precautions

- 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, VCC 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**

HSOP20-P-450-1.00

Unit : mm



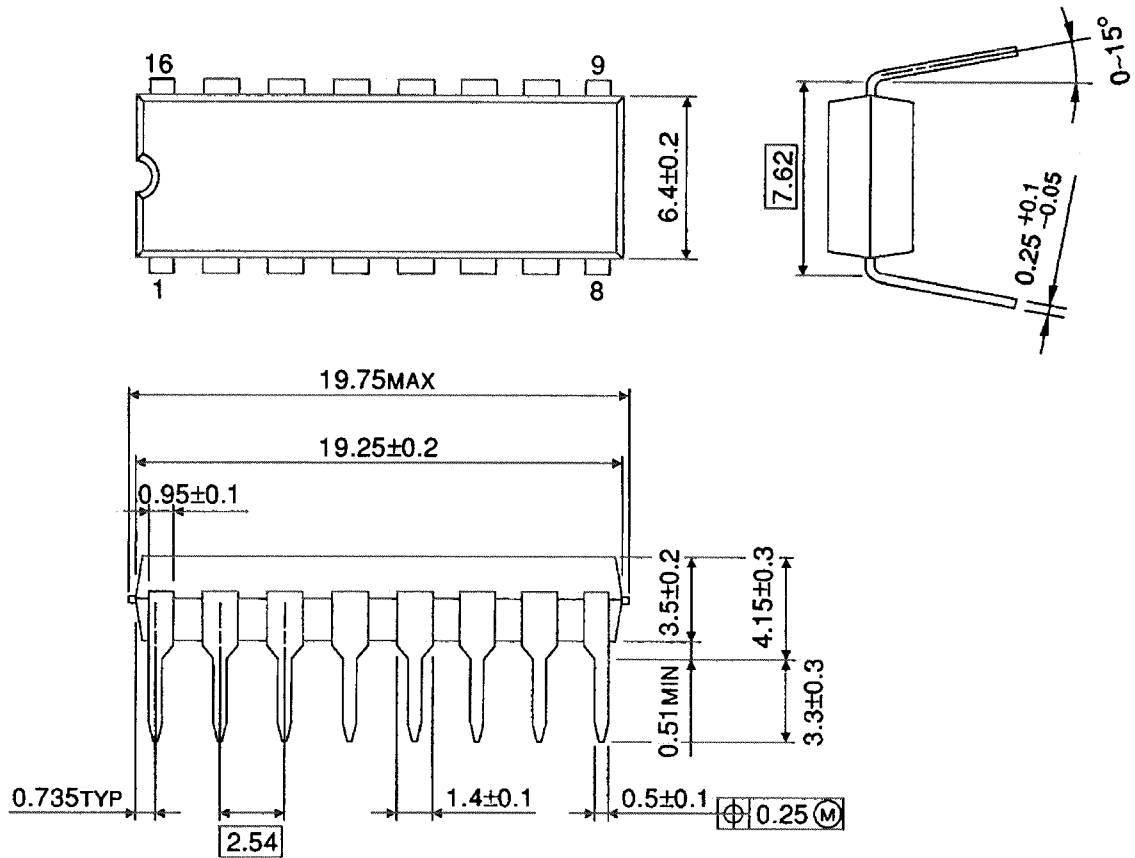
Weight: 0.79 g (typ.)



## Package Dimensions

DIP16-P-300-2.54A

Unit : mm



Weight: 1.11 g (typ.)

**RESTRICTIONS ON PRODUCT USE**

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In developing your designs, please ensure that TOSHIBA products are used within specified operating ranges as set forth in the most recent TOSHIBA products specifications. Also, please keep in mind the precautions and conditions set forth in the "Handling Guide for Semiconductor Devices," or "TOSHIBA Semiconductor Reliability Handbook" etc..
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