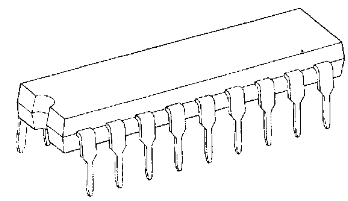
TOSHIBA CMOS Integrated Circuit Silicon Monolithic

TB6537P/PG,TB6537F/FG

3-PHASE FULL-WAVE SENSORLESS CONTROLLER FOR BRUSHLESS DC MOTORS

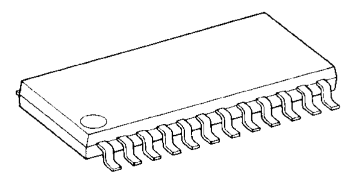
The TB6537P/PG/F/FG is a 3-phase full-wave sensorless controller for brushless DC motors. It is capable of controlling voltage through PWM signal input. When combined with various drive circuits, it can be used for various types of motors.

TB6537P/PG



DIP18-P-300-2.54D

TB6537F/FG



SSOP24-P-300-1.00

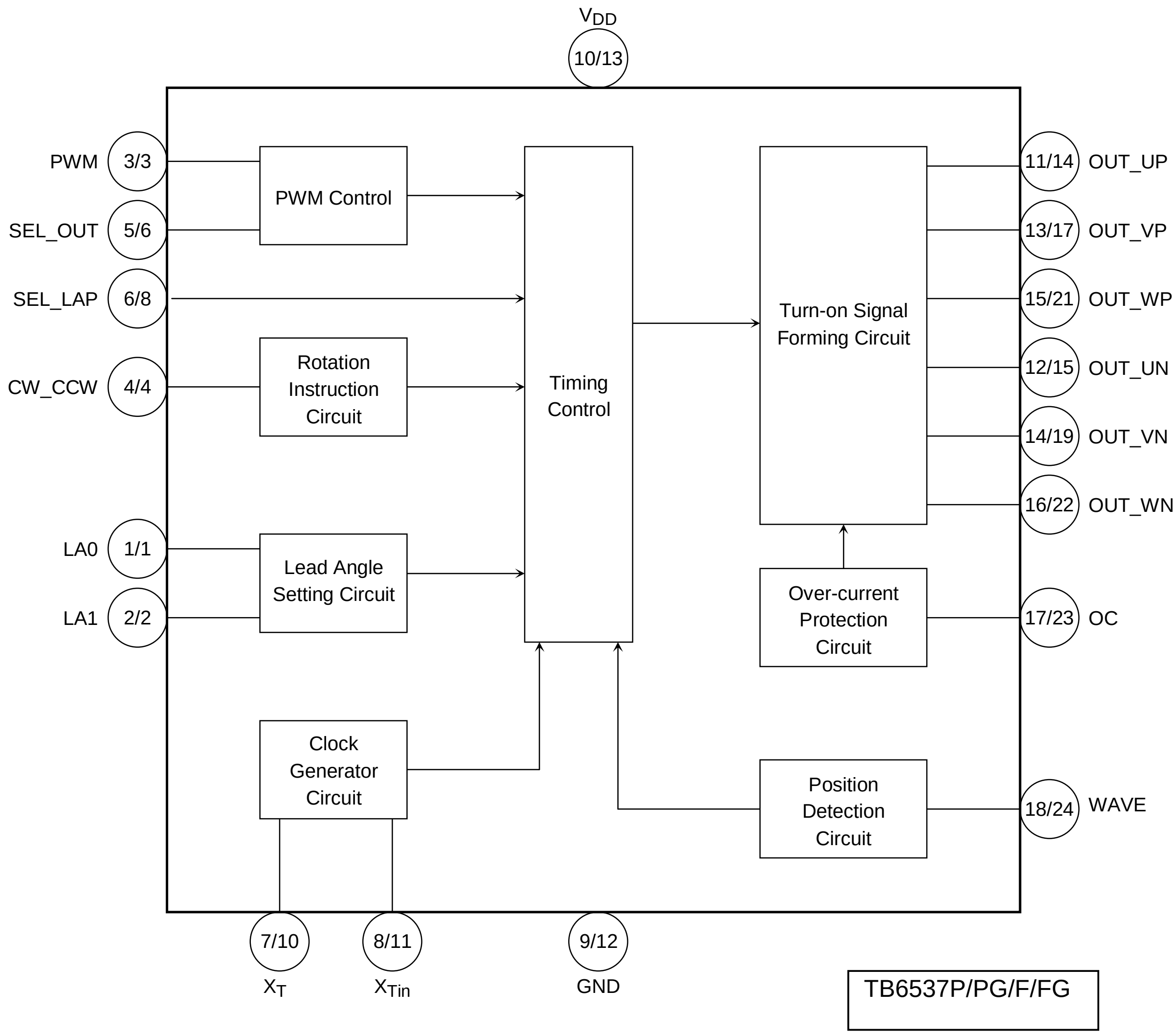
Weight
DIP18-P-300-2.54D: 1.47 g (typ.)
SSOP24-P-300-1.00: 0.32 g (typ.)

Features

- 3-phase full-wave sensorless drive
- PWM control (PWM signal is supplied from external sources.)
- Turn-on signal output current: 20 mA
- Over-current protection function
- Forward/reverse modes
- Lead angle control function (0°, 7.5°, 15° and 30°)
- Built-in lap turn-on function
- Two types of PWM output (upper PWM and upper/lower alternate PWM)

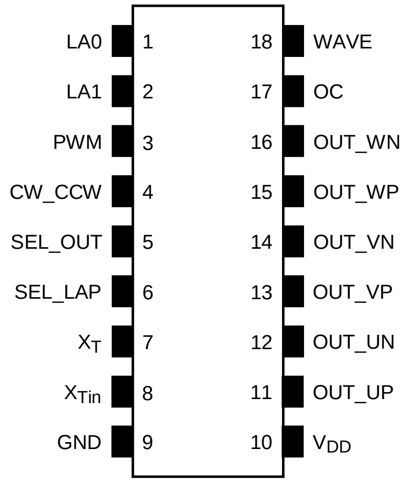
TB6537PG/FG:
The TB6537PG/FG is a Pb-free product.
The following conditions apply to solderability:
*Solderability
1. Use of Sn-63Pb solder bath
   *solder bath temperature = 230°C
   *dipping time = 5 seconds
   *number of times = once
   *use of R-type flux
2. Use of Sn-3.0Ag-0.5Cu solder bath
   *solder bath temperature = 245°C
   *dipping time = 5 seconds
   *number of times = once
   *use of R-type flux

Block Diagram

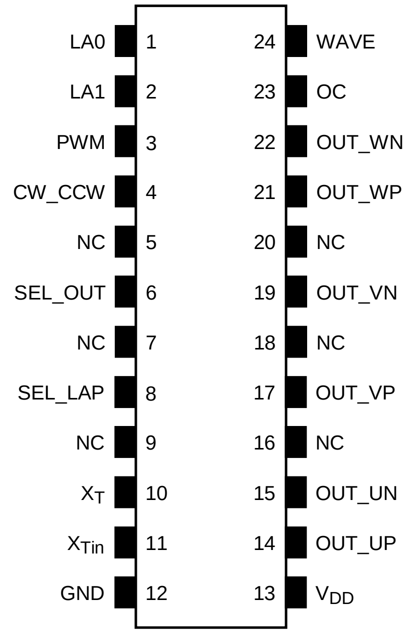


Pin Assignment

TB6537P/PG



TB6537F/FG



Pin Description

Pin No. TB6537P/PG	Pin No. TB6537F/FG	Symbol	I/O	Description
1	1	LA0	I	Lead angle setting signal input pin • LA0 = Low, LA1 = Low: Lead angle 0° • LA0 = High, LA1 = Low: Lead angle 7.5° • LA0 = Low, LA1 = High: Lead angle 15° • LA0 = High, LA1 = High: Lead angle 30° • Built-in pull-down resistor
2	2	LA1	I	
3	3	PWM	I	PWM signal input pin • Inputs Low-active PWM signal • Built-in pull-up resistor • Disables input of duty-100% (Low) signal High for 250 ns or longer is required.
4	4	CW_CCW	I	Rotation direction signal input pin • High: Reverse (U → W → V) • Low, Open: Forward (U → V → W) • Built-in pull-down resistor
—	5	NC	—	Not connected
5	6	SEL_OUT	I	Pin to select the synthesis method of the burn-in signal and PWM signal • Low: Upper PWM • High: Upper/Lower alternate PWM • Built-in pull-down resistor
—	7	NC	—	Not connected
6	8	SEL_LAP	I	Lap turn-on select pin • Low: Lap turn-on • High: 120° turn-on • Built-in pull-up resistor
—	9	NC	—	Not connected
7	10	X_T	—	Resonator connecting pin • Selects starting commutation frequency. Starting commutation frequency f_{st} = Resonator frequency $f_{xt}/(6 \times 2^{17})$
8	11	X_{Tin}	—	
9	12	GND	—	Connected to GND.
10	13	V_{DD}	—	Connected to 5-V power supply.
11	14	OUT_UP	O	U-phase upper turn-on signal output pin • U-phase winding wire positive ON/OFF switching pin • ON: Low, OFF: High
12	15	OUT_UN	O	U-phase lower turn-on signal output pin • U-phase winding wire negative ON/OFF switching pin • ON: High, OFF: Low
—	16	NC	—	Not connected
13	17	OUT_VP	O	V-phase upper turn-on signal output pin • V-phase winding wire positive ON/OFF switching pin • ON: Low, OFF: High
—	18	NC	—	Not connected
14	19	OUT_VN	O	V-phase lower turn-on signal output pin • V-phase winding wire negative ON/OFF switching pin • ON: High, OFF: Low

Pin No.		Symbol	I/O	Description
TB6537P/PG	TB6537F/FG			
—	20	NC	—	Not connected
15	21	OUT_WP	O	W-phase upper turn-on signal output pin • W-phase winding wire positive ON/OFF switching pin • ON: Low, OFF: High
16	22	OUT_WN	O	W-phase lower turn-on signal output pin • W-phase winding wire negative ON/OFF switching pin • ON: High, OFF: Low
17	23	OC	I	Over-current signal input pin • High on this pin can put constraints on the turn-on signal that is performing PWM control. • Built-in pull-up resistor
18	24	WAVE	I	Positional signal input pin • Inputs majority logic synthesis signal of three-phase pin voltage. • Built-in pull-up resistor

Functional Description

1. Sensorless Drive

On receipt of PWM signal start instruction turn-on signal for forcible commutation (commutation irrespective of the rotor position of the motor) is output and the motor starts to rotate. The rotation of the motor causes induced voltage on the winding wire pin for each phase.

When signals indicating positive or negative for pin voltage (including induced voltage) for each phase are input on the respective positional signal input pins, the turn-on signal for forcible commutation is automatically switched to the turn-on signal for the positional signal (induced voltage).

Thereafter the turn-on signal is formed according to the induced voltage contained in the pin voltage so as to drive the brushless DC motor.

2. Starting commutation frequency (resonator pin and counter bit select pin)

The forcible commutation frequency at the time of start is determined by the resonator frequency and the number of counter bits (within the IC).

Starting commutation frequency f_{st} = Resonator frequency $f_{xt}/(6 \times 2^{(bit + 3)})$ bit = 14.

The forcible commutation frequency at the time of start can be adjusted using the inertia of the motor and load.

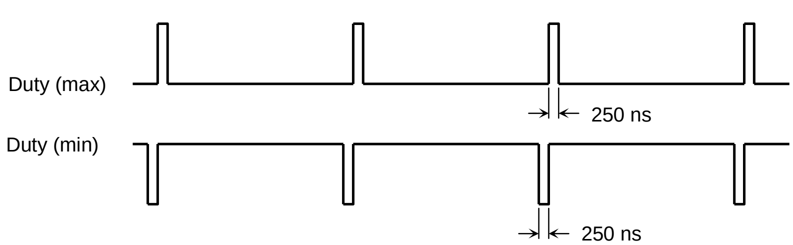
- The forcible commutation frequency should be set higher as the number of magnetic poles increases.
- The forcible commutation frequency should be set lower as the inertia of the load increases.

3. PWM Control

The PWM signal can be reflected in the turn-on signal by supplying the PWM signal from external sources.

The frequency of the PWM signal should be set sufficiently high with regard to the electrical frequency of the motor and in accordance with the switching characteristics of the drive circuit.

As positional detection is performed in synchronization with the rising edges of PWM signal, positional



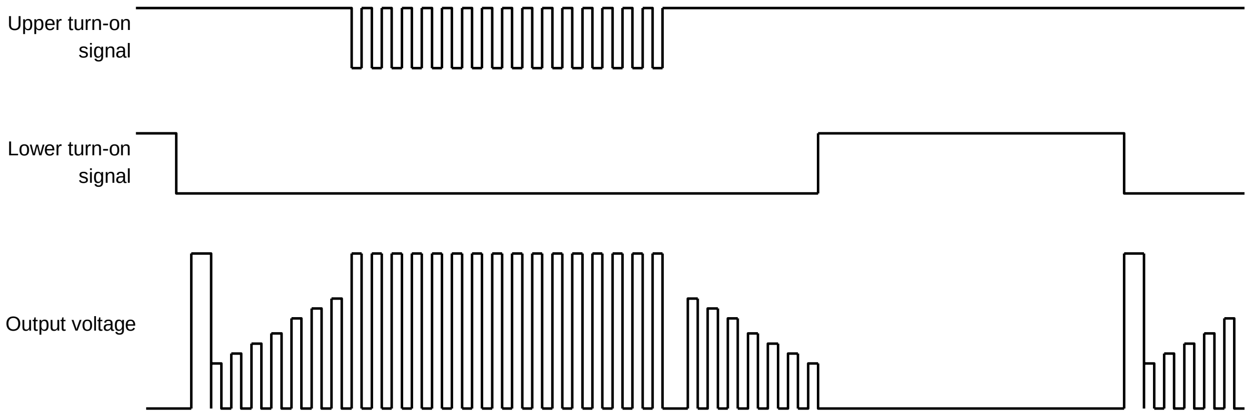
detection cannot be performed with 0% duty or 100% duty.

Even if the duty is 99%, the duty of the voltage applied to the motor is 100% owing to the storage time of the drive circuit.

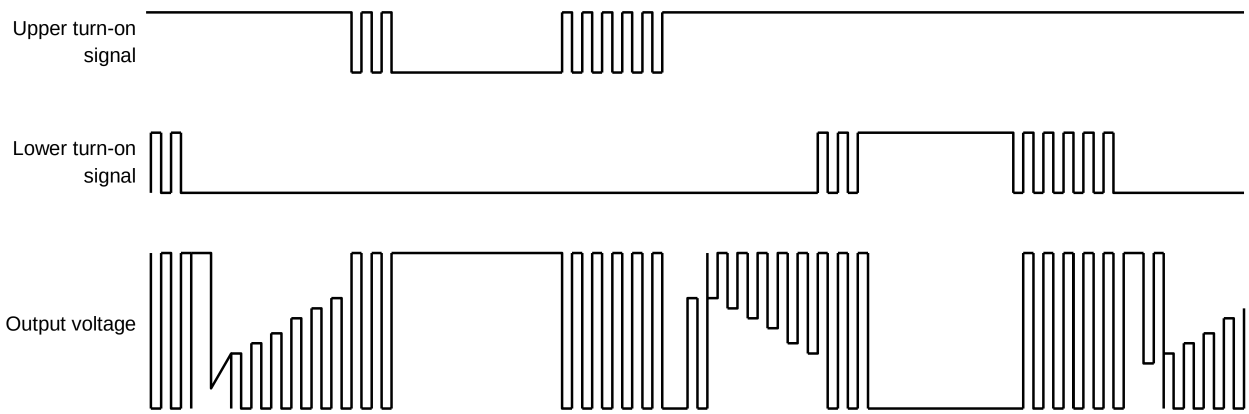
4. Selecting PWM Output Form

The PWM output form can be selected using SEL_OUT.

SEL_OUT = Low

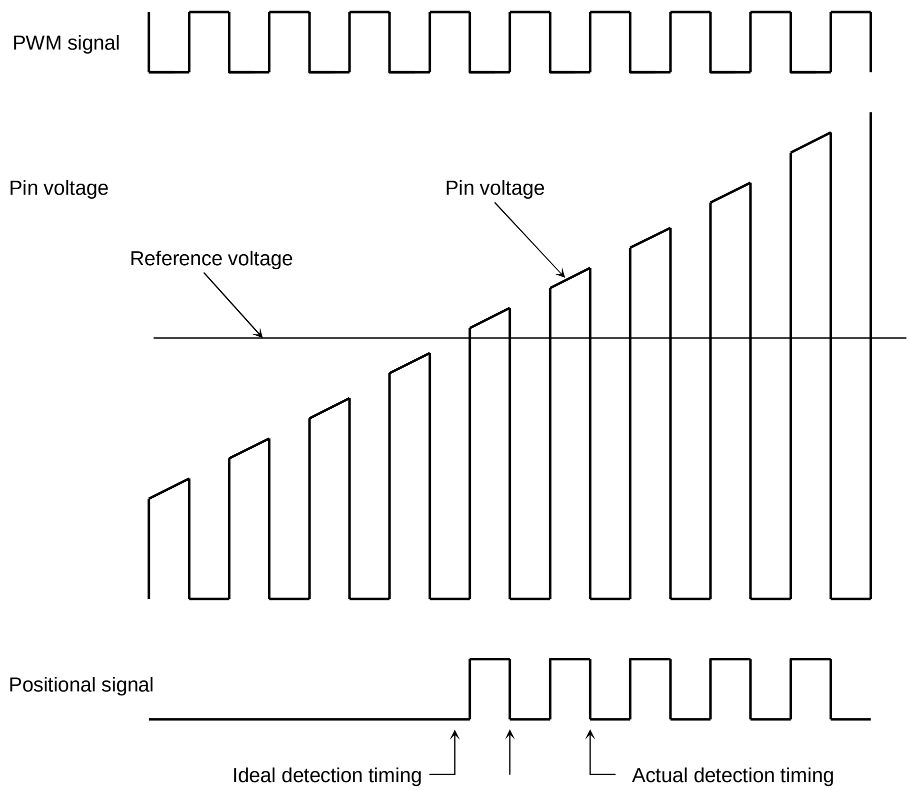


SEL_OUT = High



5. Positional Variation

Since positional detection is performed in synchronization with PWM signal, positional variation occurs in connection with the frequency of PWM signal. Be especially careful when the IC is used for high-speed motors.



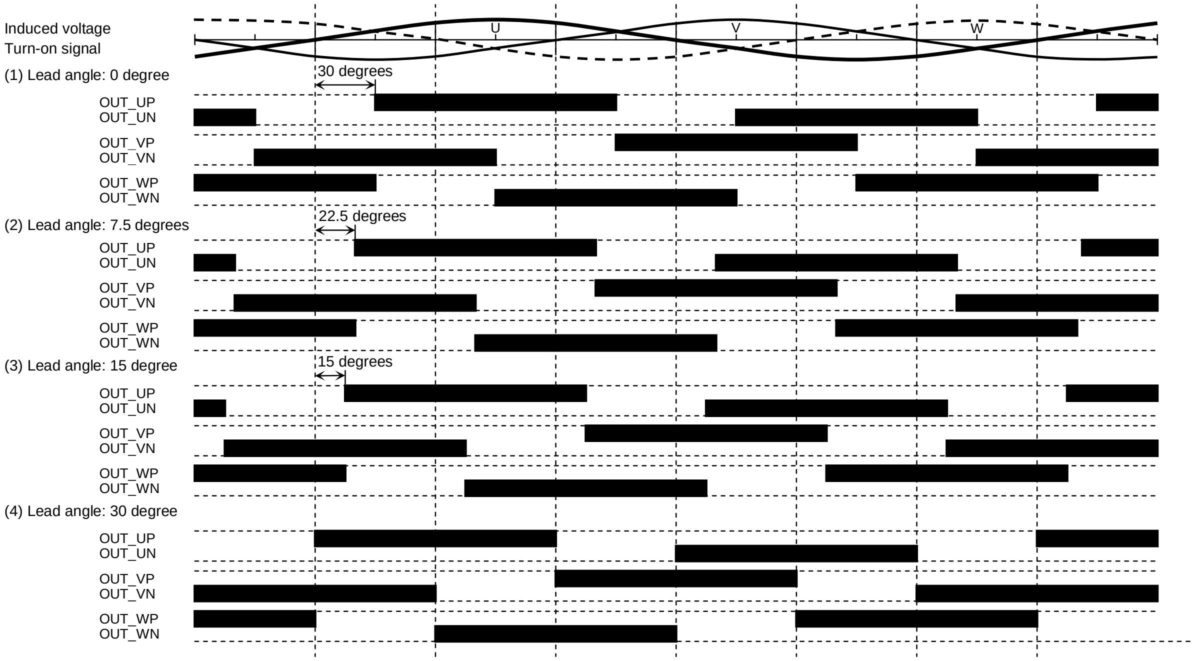
Variation is calculated through detection at two consecutive rising edges of the PWM signal.
$1/f_p$ < Detection time variation < $2/f_p$ f_p: PWM frequency.

6. Over-current protection function

The active phase that controls the PWM is turned off by the rising-edge of the OC signal. The inactive phase is turned on by the timing of the next PWM signal.

7. Lead Angle Control

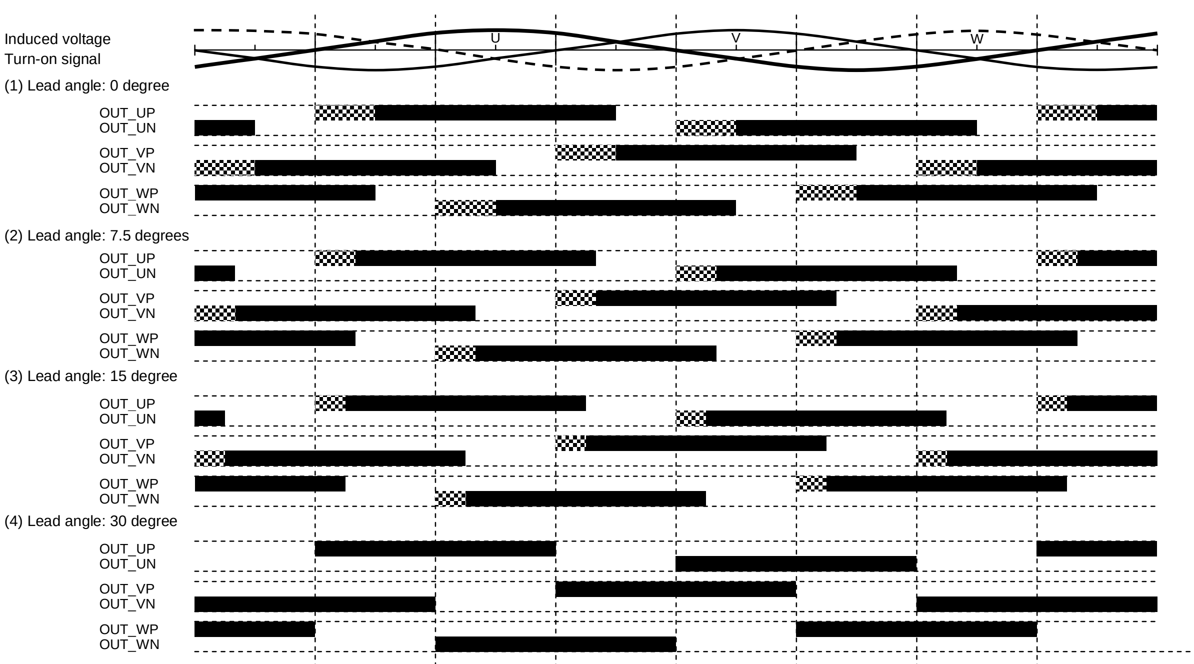
The lead angle is 0° during the starting forcible commutation and, when normal commutation is started, automatically changes to the lead angle that was set using LA0 and LA1. However, if both LA0 and LA1 are set for High, the lead angle is 30° in the starting forcible commutation as well as in normal commutation.



8. Lap Turn-on Control

When SEL_LAP = High, the turn-on angle is 120°. When SEL_LAP = Low, the Lap Turn-on Mode starts.

In Lap Turn-on Mode, the time between zero-cross point and the 120° turn-on timing becomes longer (see the shaded area in the chart below) so as to create some overlap when switching turn-on signals. The lap time differs depending on the lead angle setting.

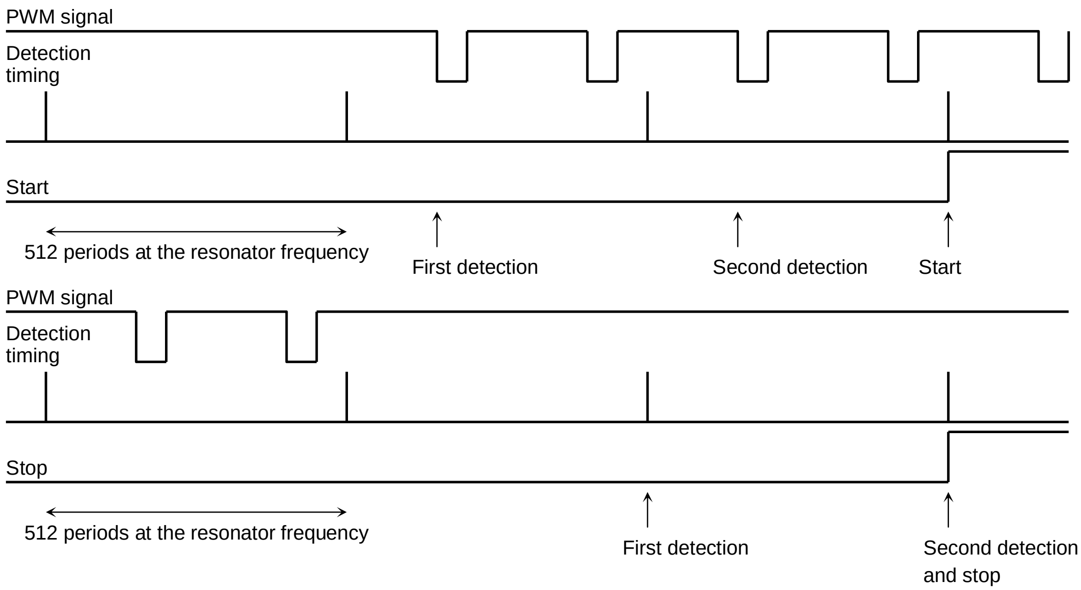


9. Start/Stop Control

Start/Stop operation is controlled using the PWM signal input pin.

A stop is acknowledged when the PWM signal duty is 0, and a start is acknowledged when the ON-signal of a frequency four times higher than the resonator frequency or greater is input continuously.

Timing chart



Note: Take sufficient care regarding noise on the PWM signal input pin.

Maximum Ratings (Ta = 25°C)

Characteristics	Symbol	Rating		Unit
Power supply voltage	V_{DD}	5.5		V
Input voltage	V_{in}	-0.3 to $V_{DD} + 0.3$		V
Turn-on signal output current	I_{OUT}	20		mA
Power dissipation	P_D	TB6537P/PG	1.25	W
		TB6537F/FG	0.59	
Operating temperature	T_{opr}	-30 to 85		°C
Storage temperature	T_{stg}	-55 to 150		°C

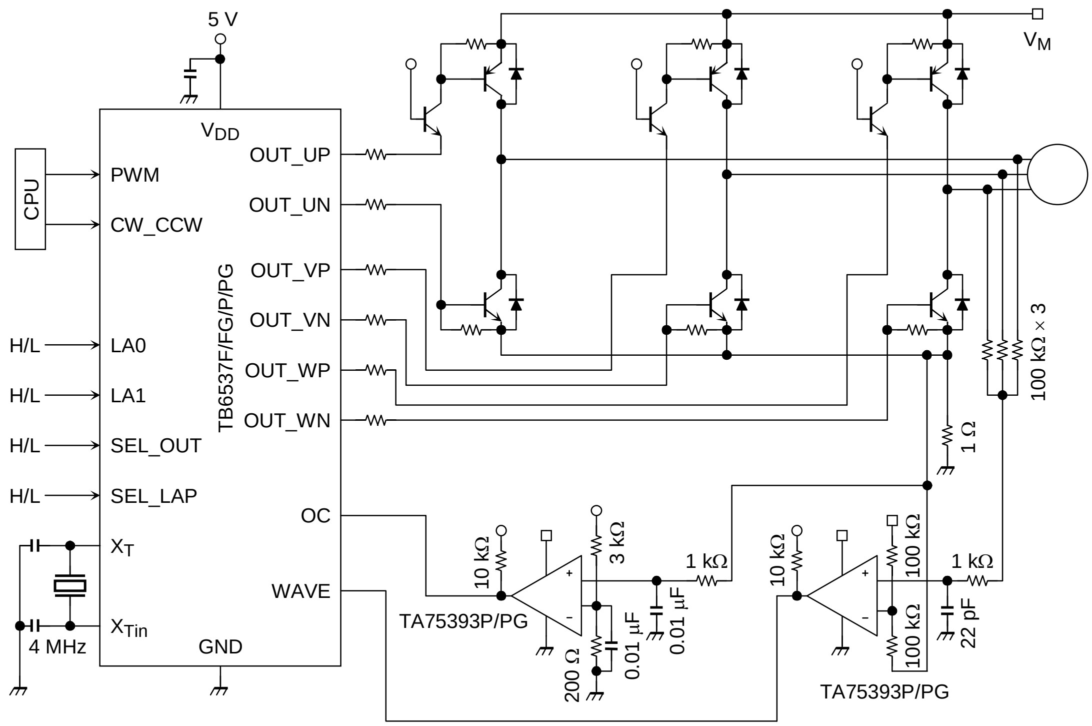
Recommended Operating Conditions (Ta = −30 to 85°C)

Characteristics	Symbol	Test Condition	Min	Typ.	Max	Unit
Power supply voltage	V_{DD}	—	4.5	5.0	5.5	V
Input voltage	V_{in}	—	-0.3	—	$V_{DD} + 0.3$	V
PWM frequency	f_{PWM}	—	—	16	—	kHz
Oscillation frequency	f_{osc}	—	1.0	—	10	MHz

Electrical Characteristics (Ta = 25°C, V_{DD} = 5 V)

Characteristics	Symbol	Test Circuit	Test Condition	Min	Typ.	Max	Unit
Static power supply current	I_{DD}	—	PWM = H, X_{Tin} = H	—	0.1	0.3	mA
Dynamic power supply current	$I_{DD\ (opr)}$	—	PWM = 50% Duty, X_{Tin} = 4 MHz	—	1	3	mA
Input current	I_{IN-1} (H)	—	V_{IN} = 5 V, PWM, OC, WAVE_U, SEL_LAP	—	0	1	μA
	I_{IN-1} (L)	—	V_{IN} = 0 V, PWM, OC, WAVE_U, SEL_LAP	−75	−50	—	
	I_{IN-2} (H)	—	V_{IN} = 5 V, CW_CCW, LA0, LA1, SEL_OUT	—	50	75	
	I_{IN-2} (L)	—	V_{IN} = 0 V, CW_CCW, LA0, LA1, SEL_OUT	−1	0	—	
Input voltage	V_{IN} (H)	—	PWM, OC, SEL_LAP, CW_CCW WAVE_U, LA0, LA1, SEL_OUT	3.5	—	5	V
	V_{IN} (L)	—	PWM, OC, SEL_LAP, CW_CCW WAVE_U, LA0, LA1, SEL_OUT	GND	—	1.5	
Input hysteresis voltage	V_H	—	PWM, OC, SEL_LAP, CW_CCW WAVE_U, LA0, LA1, SEL_OUT	—	0.6	—	V
Output voltage	V_{O-1} (H)	—	I_{OH} = −1 mA OUT_UP, OUT_VP, OUT_WP	4.3	—	V_{DD}	V
	V_{O-1} (L)	—	I_{OH} = 20 mA OUT_UP, OUT_VP, OUT_WP	GND	—	0.5	
	V_{O-2} (H)	—	I_{OH} = −20 mA OUT_UN, OUT_VN, OUT_WN	4.0	—	V_{DD}	
	V_{O-2} (L)	—	I_{OH} = 1 mA OUT_UN, OUT_VN, OUT_WN	GND	—	0.5	
Output leak current	I_L (H)	—	V_{DD} = 5.5 V, V_{OUT} = 0 V OUT_UP, OUT_VP, OUT_WP OUT_UN, OUT_VN, OUT_WN	—	0	10	μA
	I_L (L)	—	V_{DD} = 5.5 V, V_{OUT} = 5.5 V OUT_UP, OUT_VP, OUT_WP OUT_UN, OUT_VN, OUT_WN	—	0	10	
Output delay time	t_{pLH}	—	PWM-Output	—	0.5	1	μs
	t_{pHL}			—	0.5	1	

Application Circuit Example

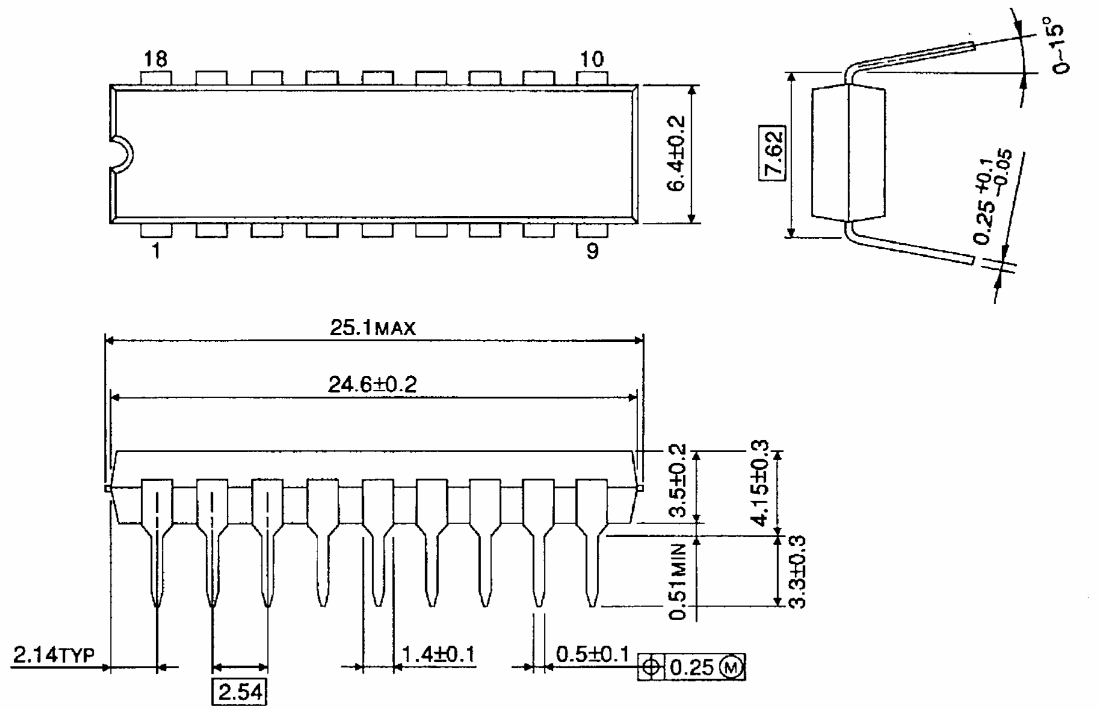


Note 1: Take particular care in designing output V_{DD} lines and GND lines to avoid short circuits between outputs, V_{DD} faults or GND faults, which may cause the IC to break down.

Note 2: The above application circuit and values mentioned are an example provided for reference purposes only. Since the values may vary depending on the motor to be used, appropriate values must be determined through experiments before the device is used.

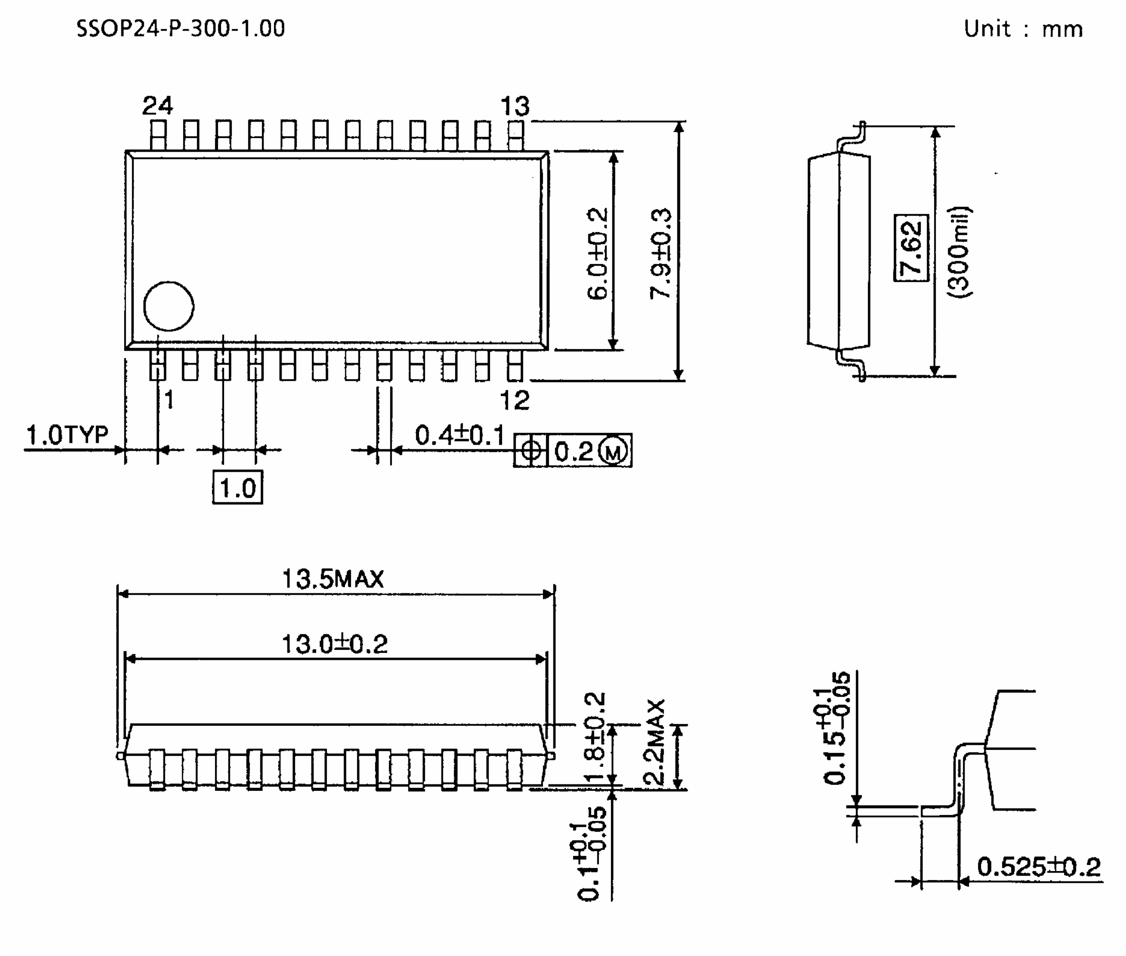
Package Dimensions

DIP18-P-300-2.54D Unit : mm



Weight: 1.47 (typ.)

Package Dimensions



Weight: 0.32 (typ.)

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. Maximum Ratings

The absolute maximum ratings of a semiconductor device are a set of specified parameter values that must not be exceeded during operation, even for an instant.

If any of these ratings are exceeded during operation, the electrical characteristics of the device may be irreparably altered, in which case the reliability and lifetime of the device can no longer be guaranteed.

Moreover, any exceeding of the ratings during operation may cause breakdown, damage and/or degradation in other equipment. Applications using the device should be designed so that no maximum rating will ever be exceeded under any operating conditions.

Before using, creating and/or producing designs, refer to and comply with the precautions and conditions set forth in this document.

5. Application Circuits

The application circuits shown in this document are provided for reference purposes only. Thorough evaluation is required in the mass production design phase.

In furnishing these examples of application circuits, Toshiba does not grant the use of any industrial property rights.

6. Test Circuits

Components in test circuits are used only to obtain and confirm device characteristics. These components and circuits are not guaranteed to prevent malfunction or failure in application equipment.

Handling of the IC

Ensure that the product is installed correctly to prevent breakdown, damage and/or degradation in the product or equipment.

Over-current protection and heat protection circuits

These protection functions are intended only as a temporary means of preventing output short circuits or other abnormal conditions and are not guaranteed to prevent damage to the IC.

If the guaranteed operating ranges of this product are exceeded, these protection features may not operate and some output short circuits may result in the IC being damaged.

The over-current protection feature is intended to protect the IC from temporary short circuits only.

Short circuits persisting over long periods may cause excessive stress and damage the IC. Systems should be configured so that any over-current condition will be eliminated as soon as possible.

Counter-electromotive force

When the motor reverses or stops, the effect of counter-electromotive force may cause the current to flow to the power source.

If the power supply is not equipped with sink capability, the power and output pins may exceed the maximum rating.

The counter-electromotive force of the motor will vary depending on the conditions of use and the features of the motor. Therefore make sure there will be no damage to or operational problem in the IC, and no damage to or operational errors in peripheral circuits caused by counter-electromotive force.

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