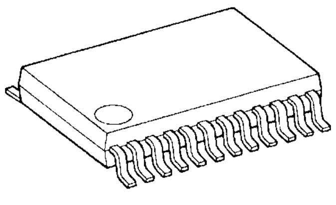
Preliminary TOSHIBA CMOS Digital Integrated Circuit Silicon Monolithic

TB9060FN

3-Phase Full-Wave Sensorless Controller for Brushless DC Motors

The TB9060FN is a 3-phase full-wave sensorless controller for brushless DC motors. It is capable of controlling voltage by PWM signal input. When combined with various drive circuits, it can be used for various types of motors.

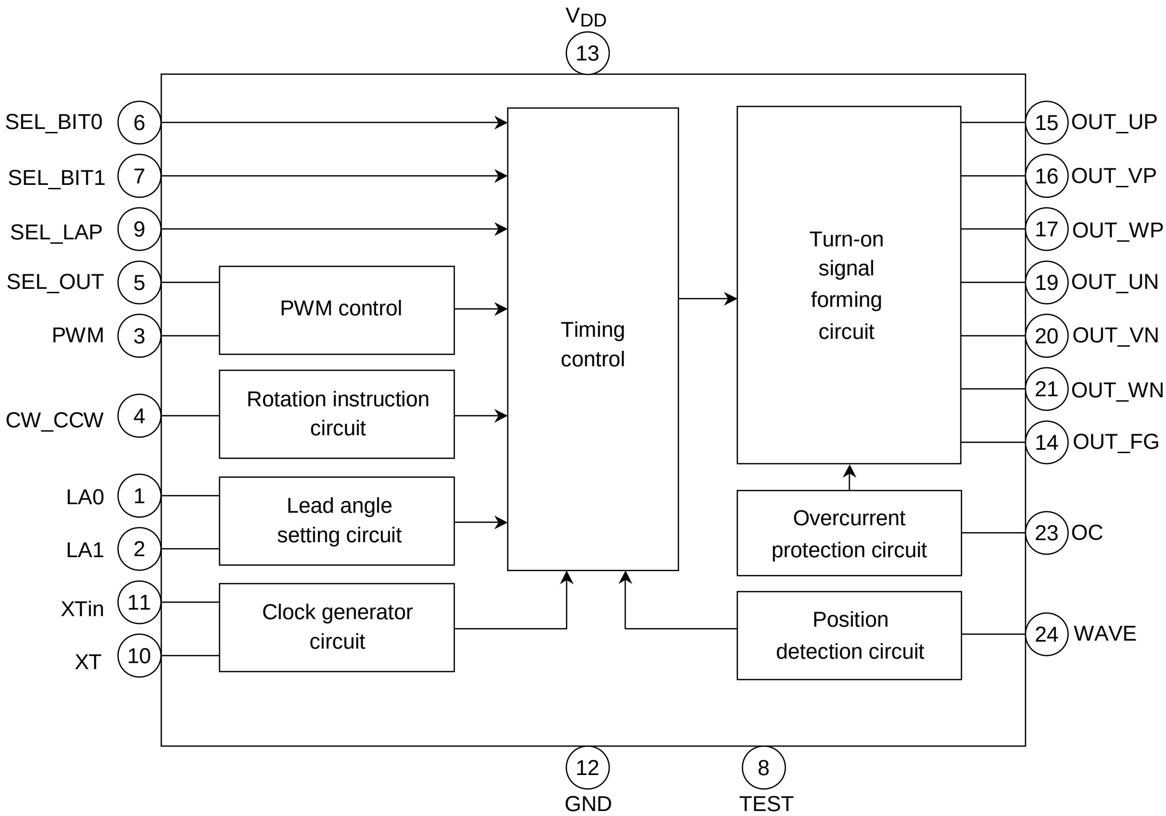


Weight: 0.10 g (typ.)

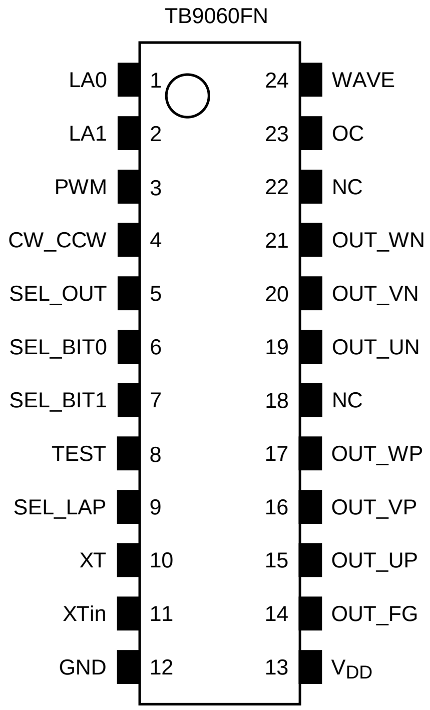
Features

- 3-phase full-wave sensorless drive
- PWM control (PWM signal is applied externally.)
- Turn-on signal output current: 20 mA
- Overcurrent protection function
- Forward/reverse modes
- Lead angle control function (0°, 7.5°, 15° and 30°)
- Lap turn-on function
- Two types of PWM output (upper PWM and upper/lower alternate PWM)
- Rotational speed sensing function

Block Diagram



Pin Assignment



Pin Description

Pin No.	Symbol	I/O	Description
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 (100 kΩ)
2	LA1	I	
3	PWM	I	PWM signal input pin ・ Applies active low PWM signal ・ Built-in pull-up resistor (100 kΩ) ・ Disables input of duty-100% (low) signal High for 250 ns or longer is required.
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 (100 kΩ)
5	SEL_OUT	I	Pin to select the synthesis method of turn-on signal and PWM signal ・ Low: Upper PWM ・ High: Upper/Lower alternate PWM ・ Built-in pull-down resistor (100 kΩ)
6	SEL_BIT0	I	The number of counter bit (within the IC) select pin The forced commutation frequency at the time of start is determined by the resonator's frequency and the number of counter bit. ・ SEL_BIT0 = High, SEL_BIT1 = High: 16 bits ・ SEL_BIT0 = Low, SEL_BIT1 = High: 14 bits ・ SEL_BIT0 = High, SEL_BIT1 = Low: 12 bits ・ SEL_BIT0: Built-in pull-down resistor (100 kΩ), SEL_BIT1: Built-in pull-up resistor (100 kΩ)
7	SEL_BIT1	I	
8	TEST	I	Test pin ・ Built-in pull down resistor (10 kΩ) Please connect this pin to GND in your application.
9	SEL_LAP	I	Lap turn-on select pin ・ Low: Lap turn-on ・ High: 120° turn-on ・ Built-in pull-up resistor (100 kΩ)
10	XT	—	Resonator connecting pin ・ Selects starting commutation frequency. Starting commutation frequency f_{st} = Resonator frequency $f_{xt}/(6 \times 2^{(BIT + 3)})$ BIT: The number of counter bit which is decided by SEL_BIT0 and SEL_BIT1.
11	XTin	—	
12	GND	—	Connected to ground.

Pin No.	Symbol	I/O	Description
13	V_{DD}	—	Connected to 5-V power supply.
14	OUT_FG	O	Rotation signal output pin ・ Motor is stopped or starting: Low ・ Motor is in operation: The level is changed by electrical frequency of the motor.
15	OUT_UP	O	U-phase upper turn-on signal output pin ・ U-phase winding wire positive ON/OFF switching pin ・ ON: Low, OFF: High
16	OUT_VP	O	V-phase upper turn-on signal output pin ・ V-phase winding wire positive ON/OFF switching pin ・ ON: Low, OFF: High
17	OUT_WP	O	W-phase upper turn-on signal output pin ・ W-phase winding wire positive ON/OFF switching pin ・ ON: Low, OFF: High
18	NC	—	Not connected
19	OUT_UN	O	U-phase lower turn-on signal output pin ・ U-phase winding wire negative ON/OFF switching pin ・ ON: High, OFF: Low
20	OUT_VN	O	V-phase lower turn-on signal output pin ・ V-phase winding wire negative ON/OFF switching pin ・ ON: High, OFF: Low
21	OUT_WN	O	W-phase lower turn-on signal output pin ・ W-phase winding wire negative ON/OFF switching pin ・ ON: High, OFF: Low
22	NC	—	Not connected
23	OC	I	Overcurrent signal input pin ・ High on this pin can put constraints on the turn-on signal which is performing PWM control. ・ Built-in pull-up resistor (100 kΩ)
24	WAVE	I	Position signal input pin ・ Applies majority logic synthesis signal of three-phase pin voltage. ・ Built-in pull-up resistor (100 kΩ)

Functional Description

1. Sensorless Drive

On receipt of PWM signal start instruction, turn-on signal for forced commutation (commutation irrespective of the motor's rotor position) is driven onto pins 15 to 17 and pins 19 to 21, and the motor starts to rotate. The motor's rotation causes induced voltage on winding wire pin for each phase.

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

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

Sensorless drive timing charts (lead angles: 0°, 7.5°, 15° and 30°) are shown below.

Figure 1 Sensorless drive timing chart (lead angle: 0°)

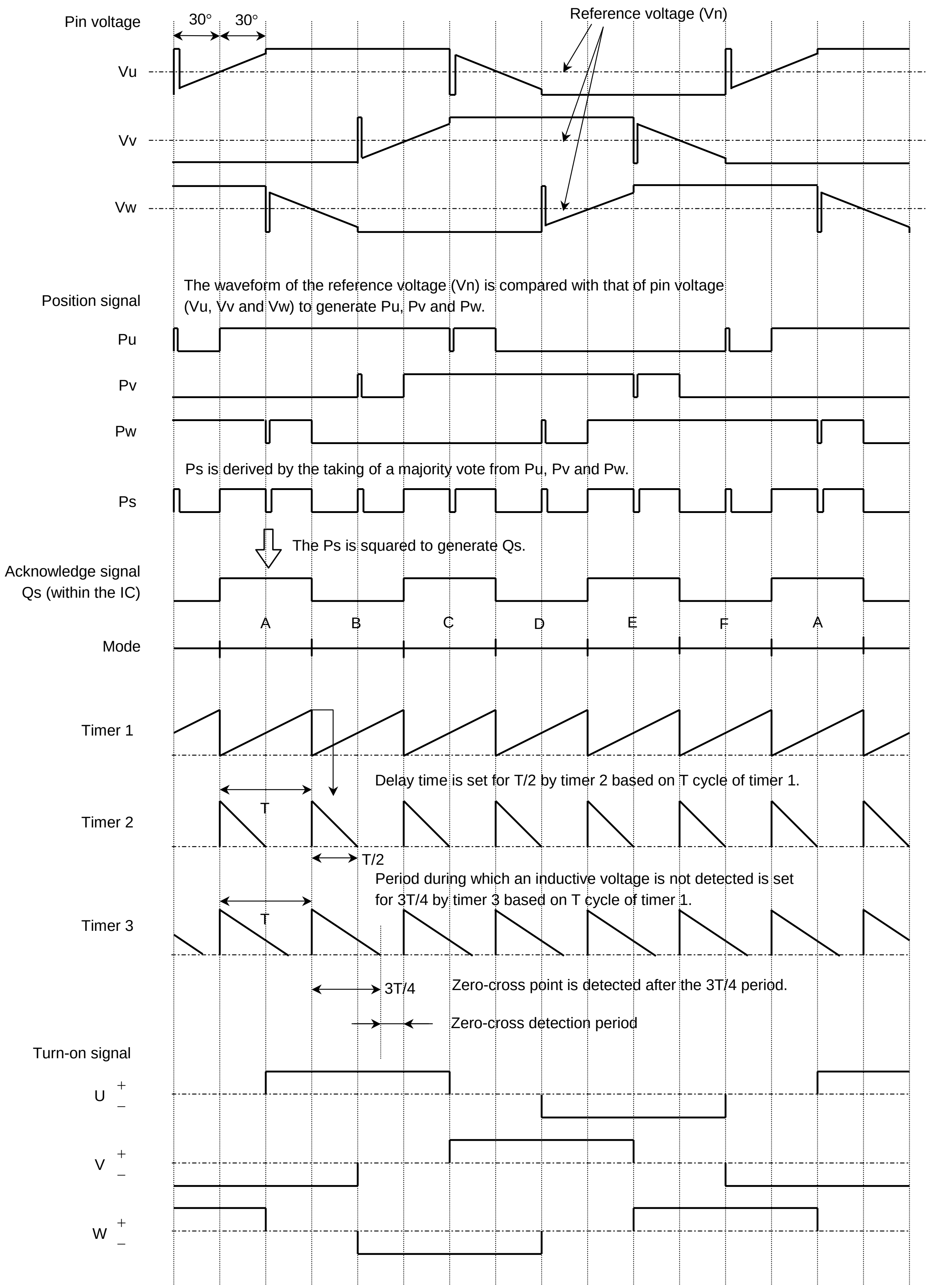


Figure 2 Sensorless drive timing chart (lead angle: 7.5°)

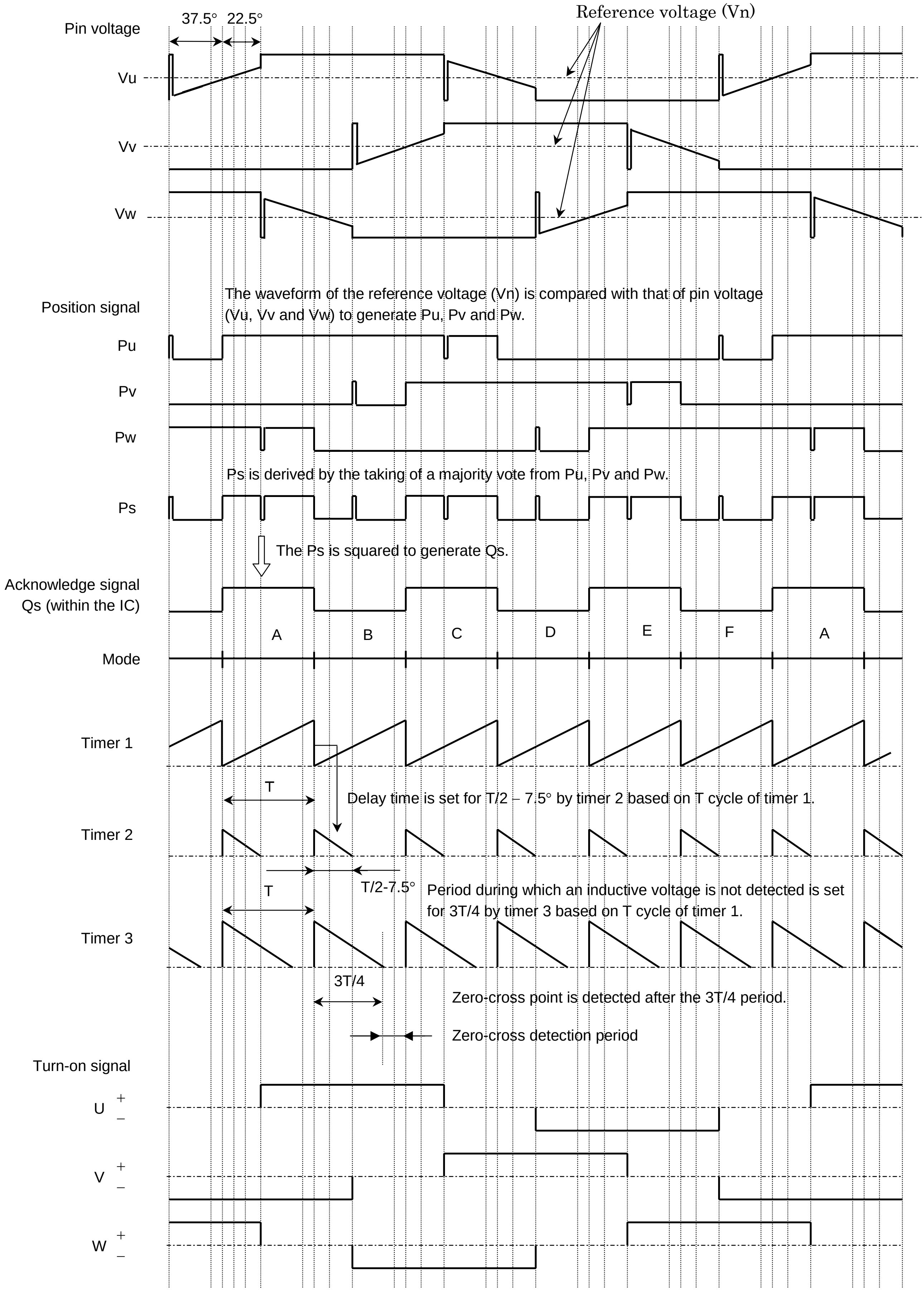


Figure 3 Sensorless drive timing chart (lead angle: 15°)

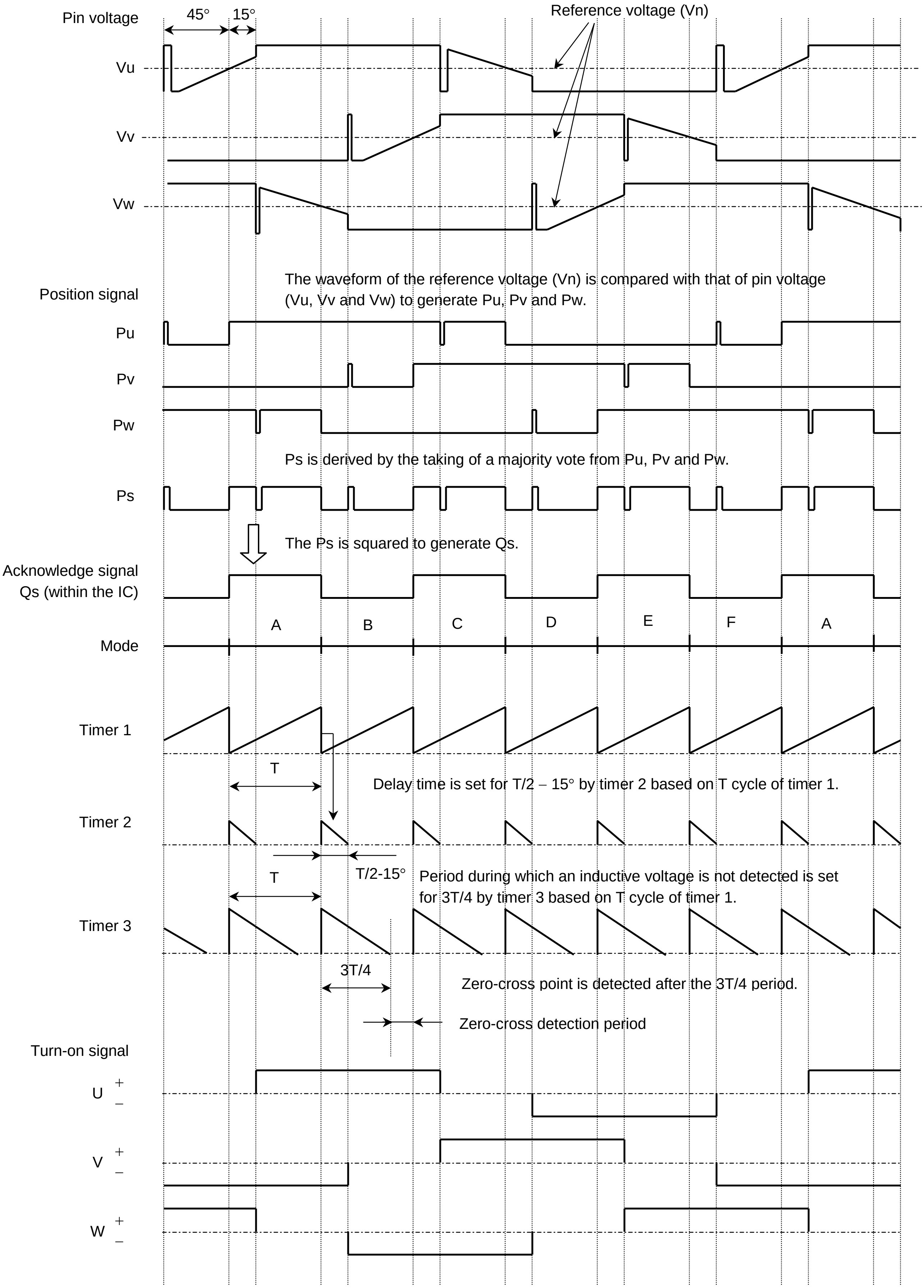
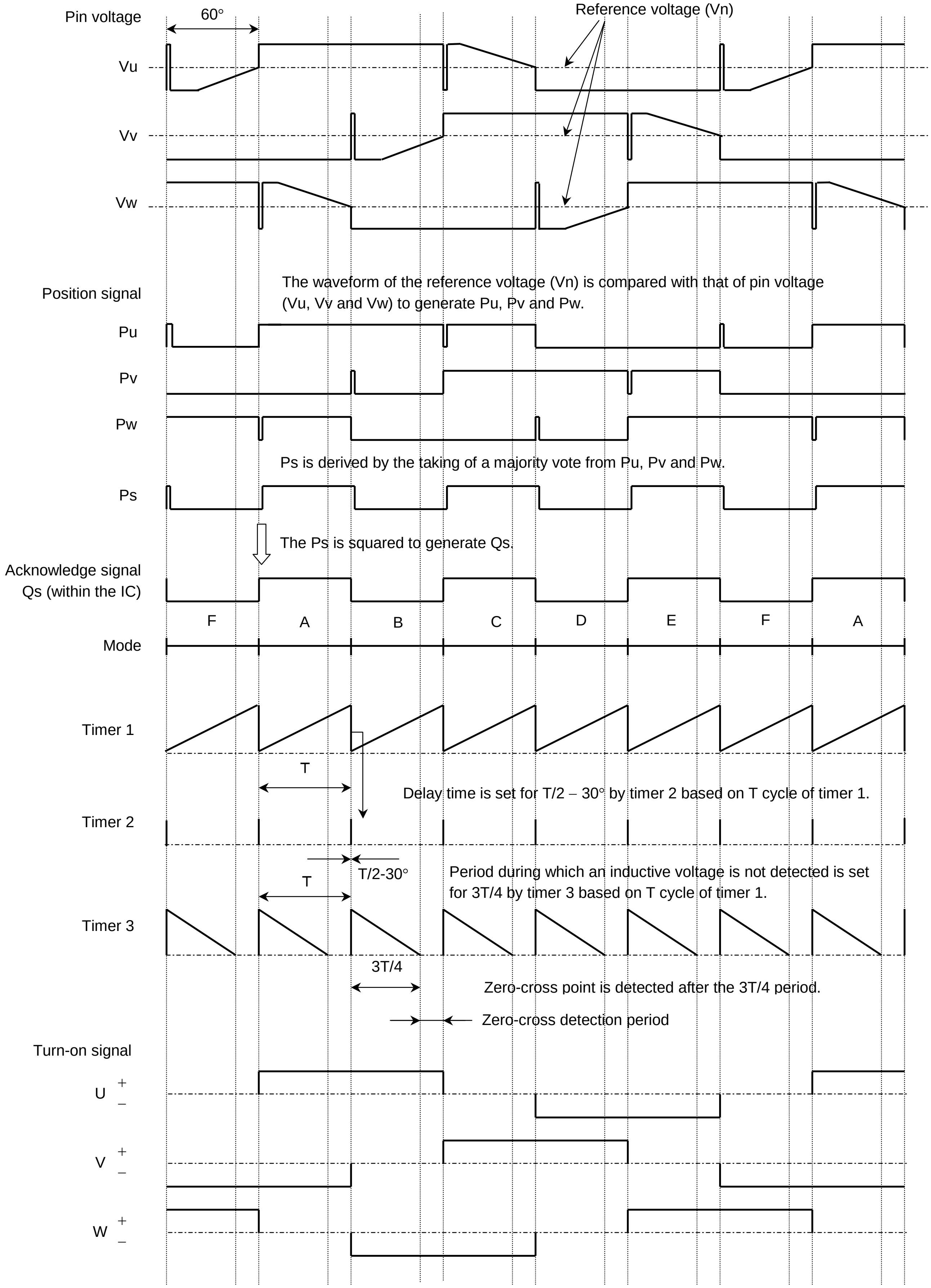


Figure 4 Sensorless drive timing chart (lead angle: 30°)



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

The forced commutation frequency at the time of start is determined by the resonator's frequency and the number of counter bit (within the IC).

SEL_BIT0 = High, SEL_BIT1 = High: Bit = 16
SEL_BIT0 = Low, SEL_BIT1 = High: Bit = 14
SEL_BIT0 = High, SEL_BIT1 = Low: Bit = 12

Starting commutation frequency f_{st} = Resonator frequency $f_{xt}/(6 \times 2^{(BIT + 3)})$
(BIT: The number of counter bit which is decided by SEL_BIT0 and SEL_BIT1.)

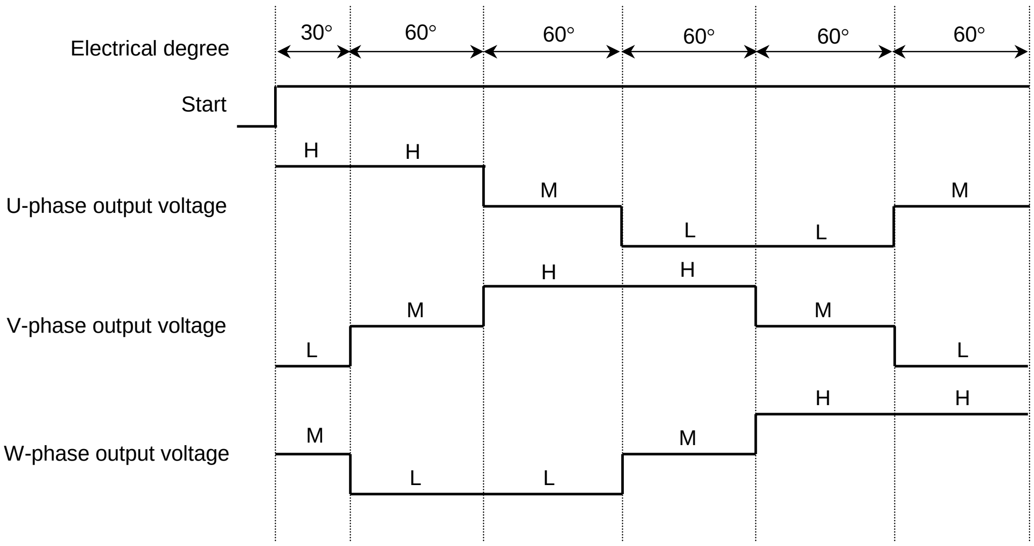
The forced commutation frequency at the time of start can be adjusted using inertia of the motor and load.

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

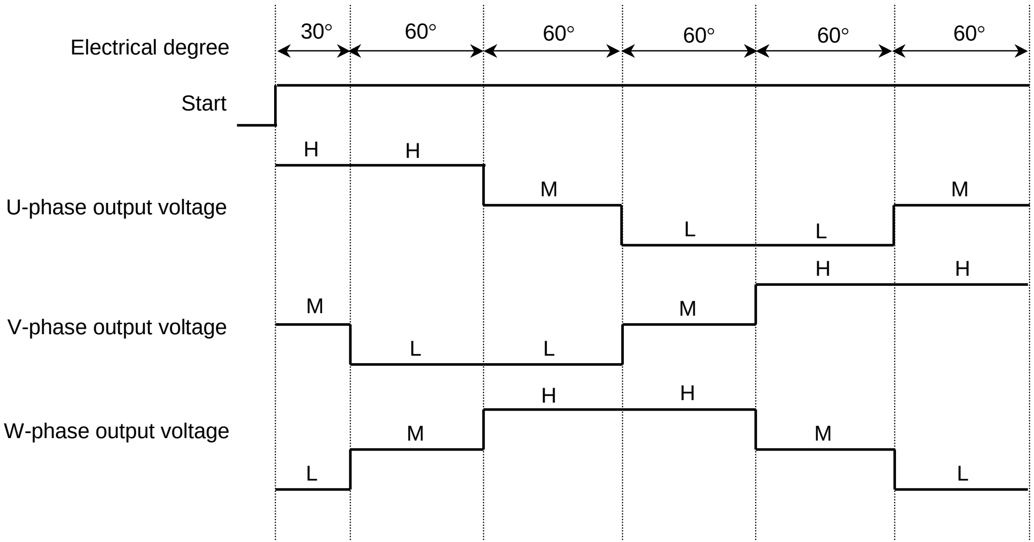
2.1 Forced commutation pattern

Forced commutation is performed at the timings as shown below according to the state of CW_CCW. The commutation pattern immediately after the motor starts is always the same.

(1) Forward rotation (CW_CCW = Low)



(2) Reverse rotation (CW_CCW = High)

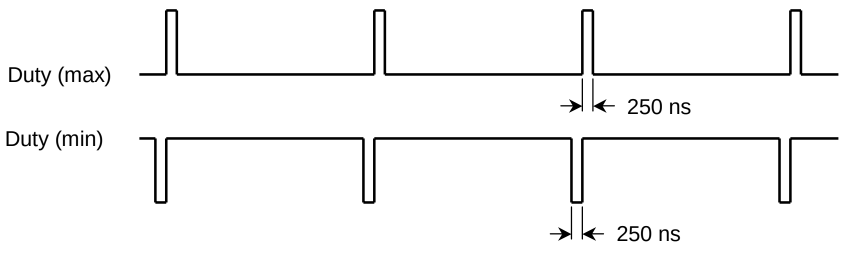


3. PWM Control

PWM signal can be reflected in turn-on signal by applying PWM signal externally.

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

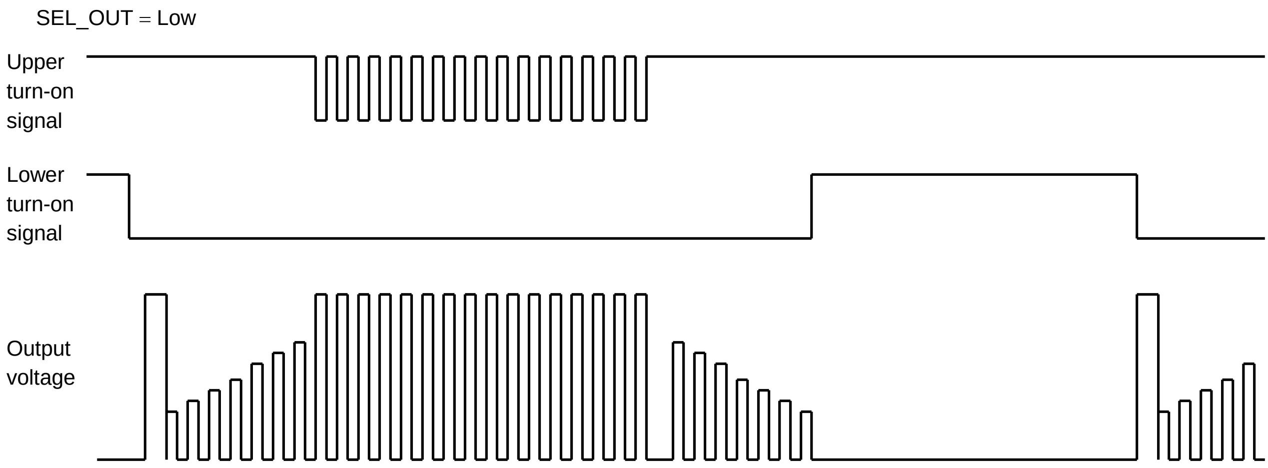
Because positional detection is performed on the falling edges of PWM signal, positional detection cannot be performed with 0% duty or 100% duty.

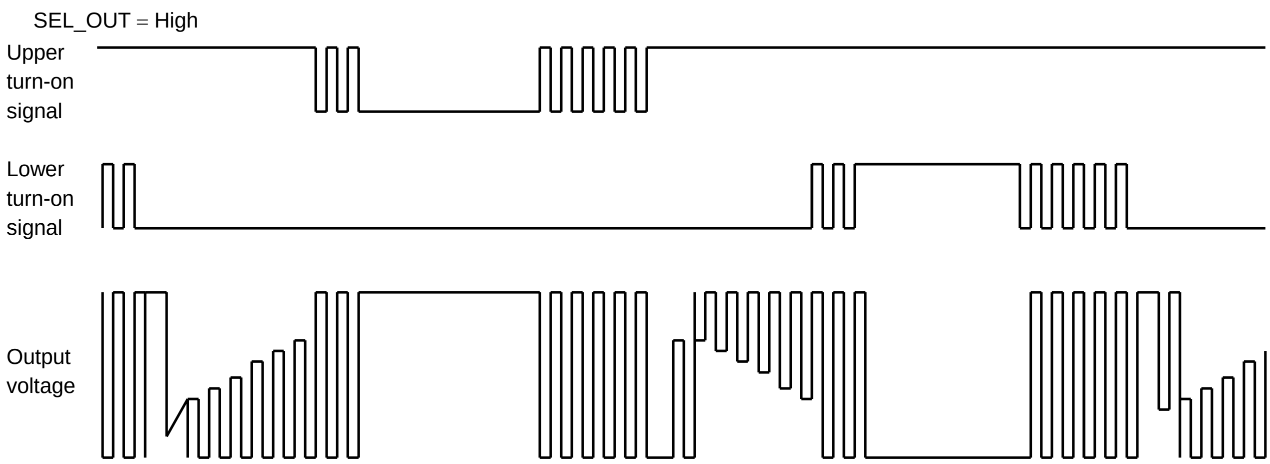


The voltage applied to the motor is duty 100% because of the storage time of the drive circuit even if the duty is 99%.

4. Selecting PWM Output Form

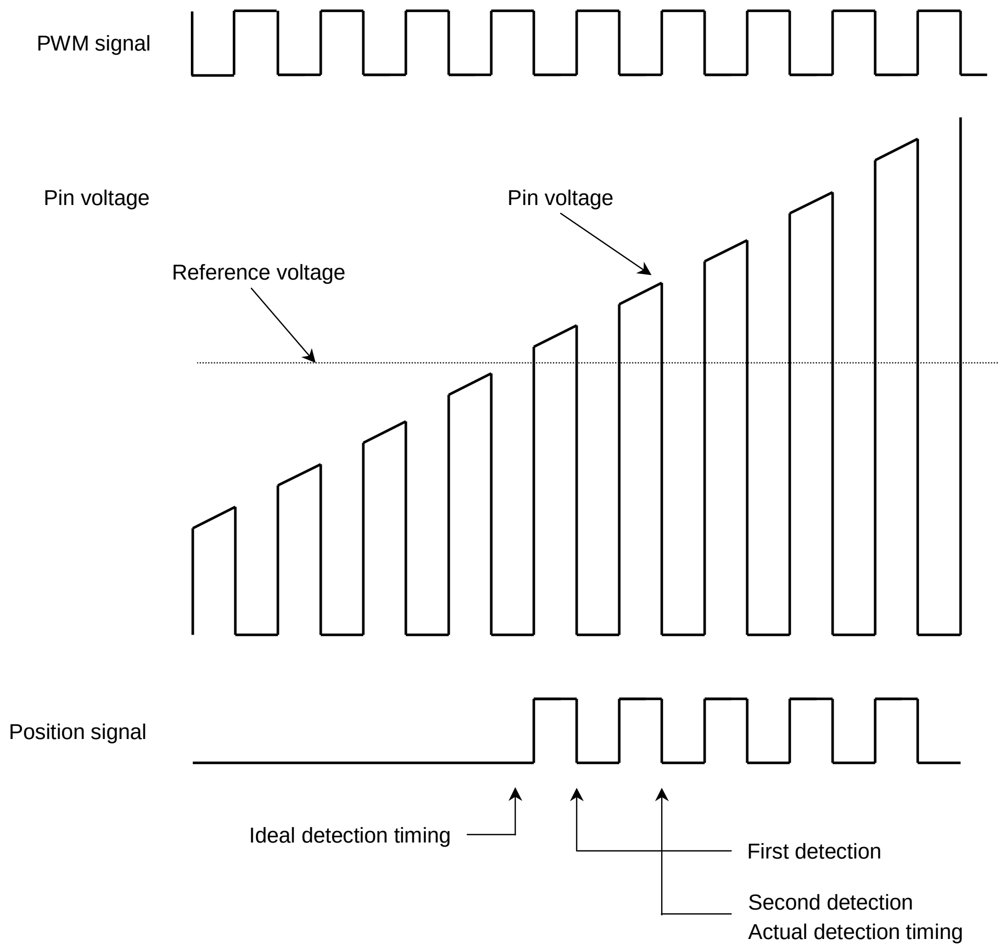
PWM output form can be selected using SEL_OUT.





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.

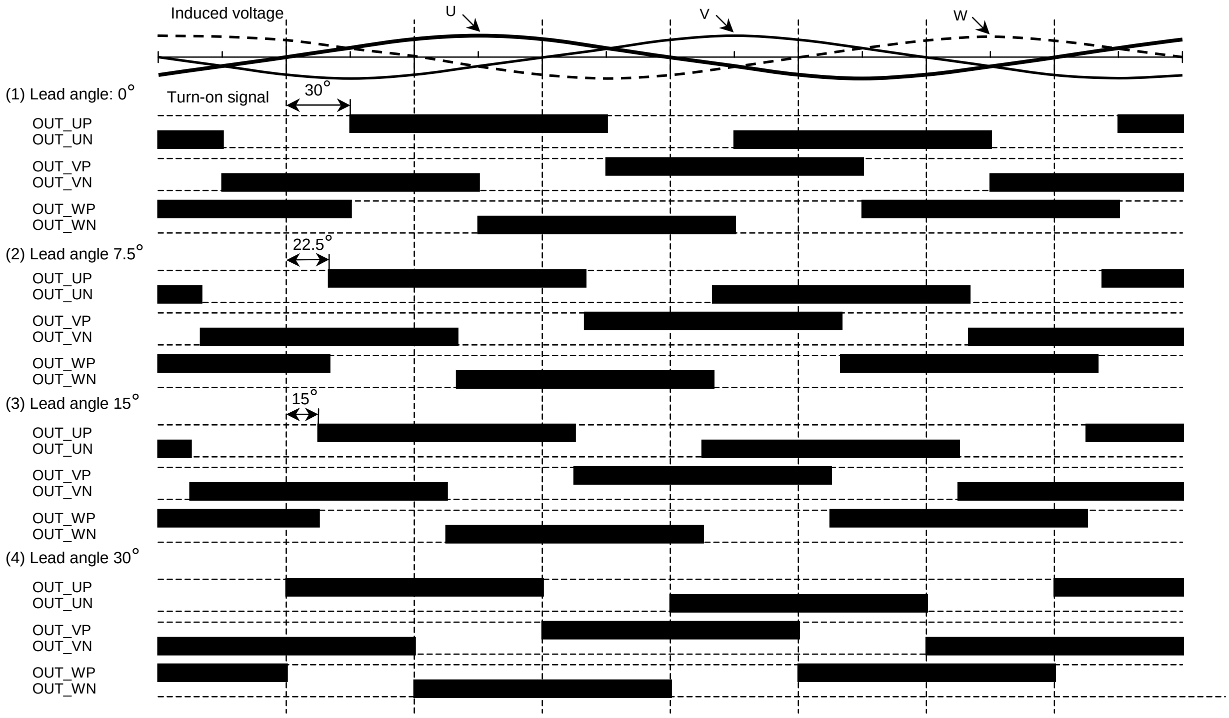


Variation is calculated by detecting at two consecutive rising edges of PWM signal.

$1/f_p$ < Detection time variation < $2/f_p$ f_p: PWM frequency

6. Lead Angle Control

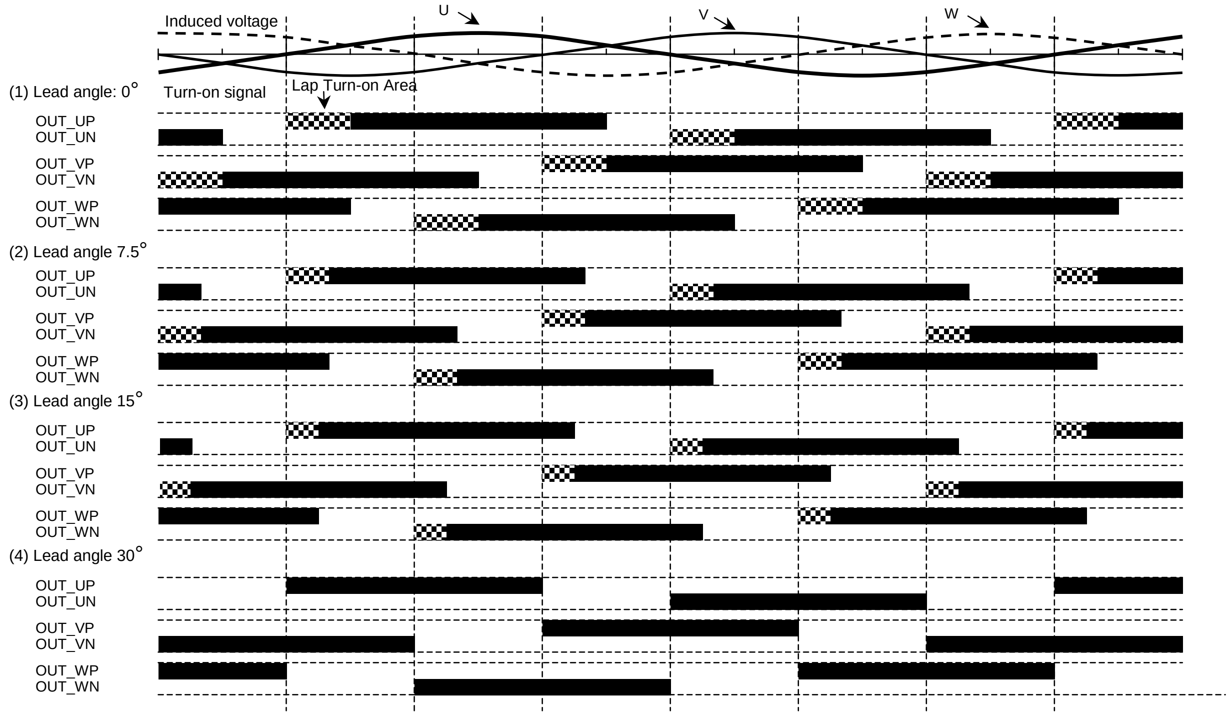
The lead angle is 0° during the starting forced commutation and when normal commutation is started, automatically changes to the lead angle which has been set using LA0 and LA1. However, if both LA0 and LA1 are set high, the lead angle is 30° in the starting forced commutation as well as in natural commutation.



7. Lap Turn-on Control

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

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

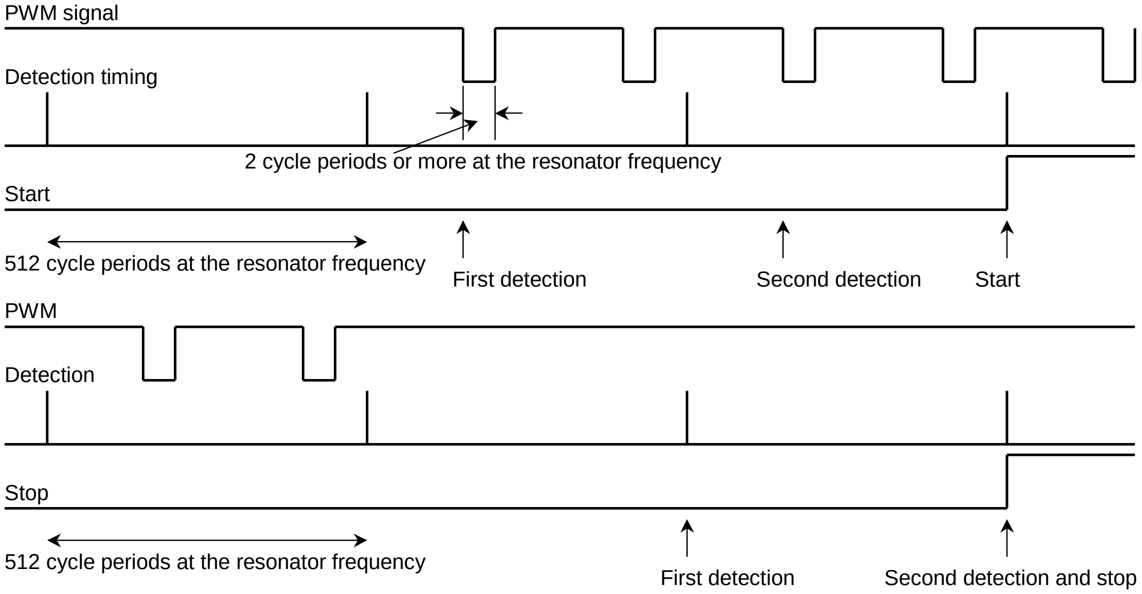


8. Start/Stop Control

Start/Stop is controlled using PWM signal input pin.

A stop is acknowledged when PWM signal duty is 0, and a start is acknowledged when ON-signal of a frequency 2 times higher than the resonator frequency or even higher is applied successively.

Timing chart

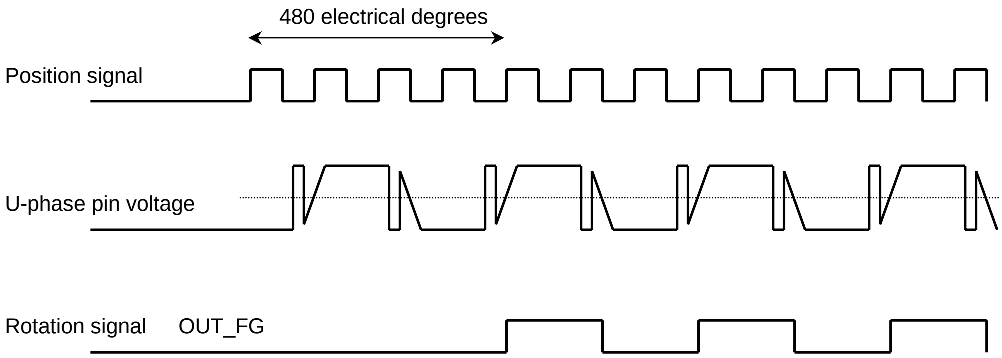


Note: Take sufficient care for noise on PWM signal input pin.

9. Rotation Signal Monitor Function

The rotation signal that senses rotational speed and indicates errors including motor lock is driven onto the OUT_FG pin. Low voltage is driven onto the pin at forced commutation of starting and stopping the motor. After natural commutation (position signal is detected) is performed for 480 electrical degrees, the rotation signal in synchronization with the U-phase position detection result is driven onto the pin. If motor lock occurs due to overload during rotation, the forced commutation of starting the motor is performed and low voltage is driven onto the pin.

It is possible to determine an error from the relationship between duty cycle of PWM signal and rotation frequency.



10. Pull-out of Synchronism

If you do not receive the OUT_FG output at the specified frequency while monitoring the rotation signal (OUT_FG output), please restart the TB9060FN.

Maximum Ratings (Ta = 25°C)

Characteristics	Symbol	Rating	Unit
Power supply voltage	V_{DD}	6.0	V
Input voltage	V_{IN}	−0.2~V_{DD} + 0.2	V
Turn-on signal output current	I_{OUT}	20	mA
Power dissipation	P_D	850	mW
Operating temperature	T_{opr}	−40~125	°C
Storage temperature	T_{stg}	−55~150	°C
Lead Temperature−Time	T_{sol}	260(10s)	°C

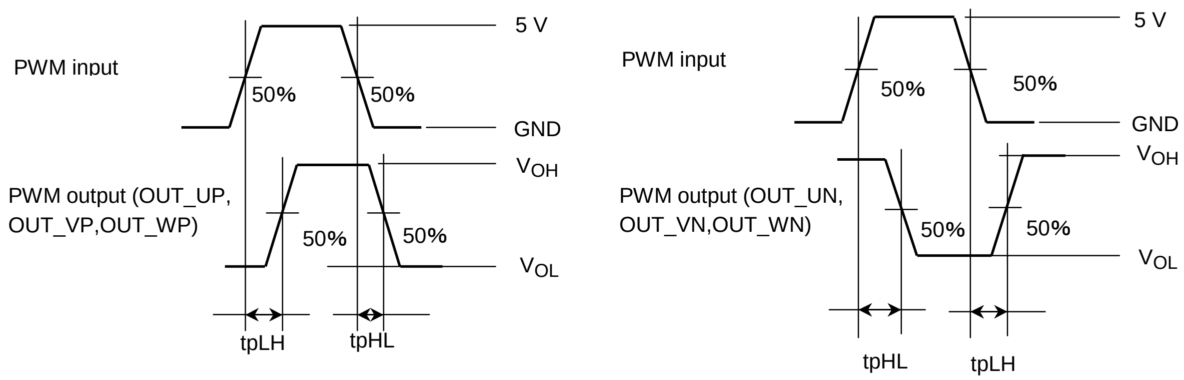
Recommended Operating Conditions (Ta = −40~125°C)

Characteristics	Symbol	Test Condition	Min	Typ.	Max	Unit
Power supply voltage	V_{DD}	—	4.5	5.0	5.5	V
Input voltage	V_{IN}	—	−0.2	—	V_{DD} + 0.2	V
PWM frequency	f_{PWM}	—	—	16	—	kHz
Oscillation frequency	f_{osc}	—	1.0	—	10	MHz

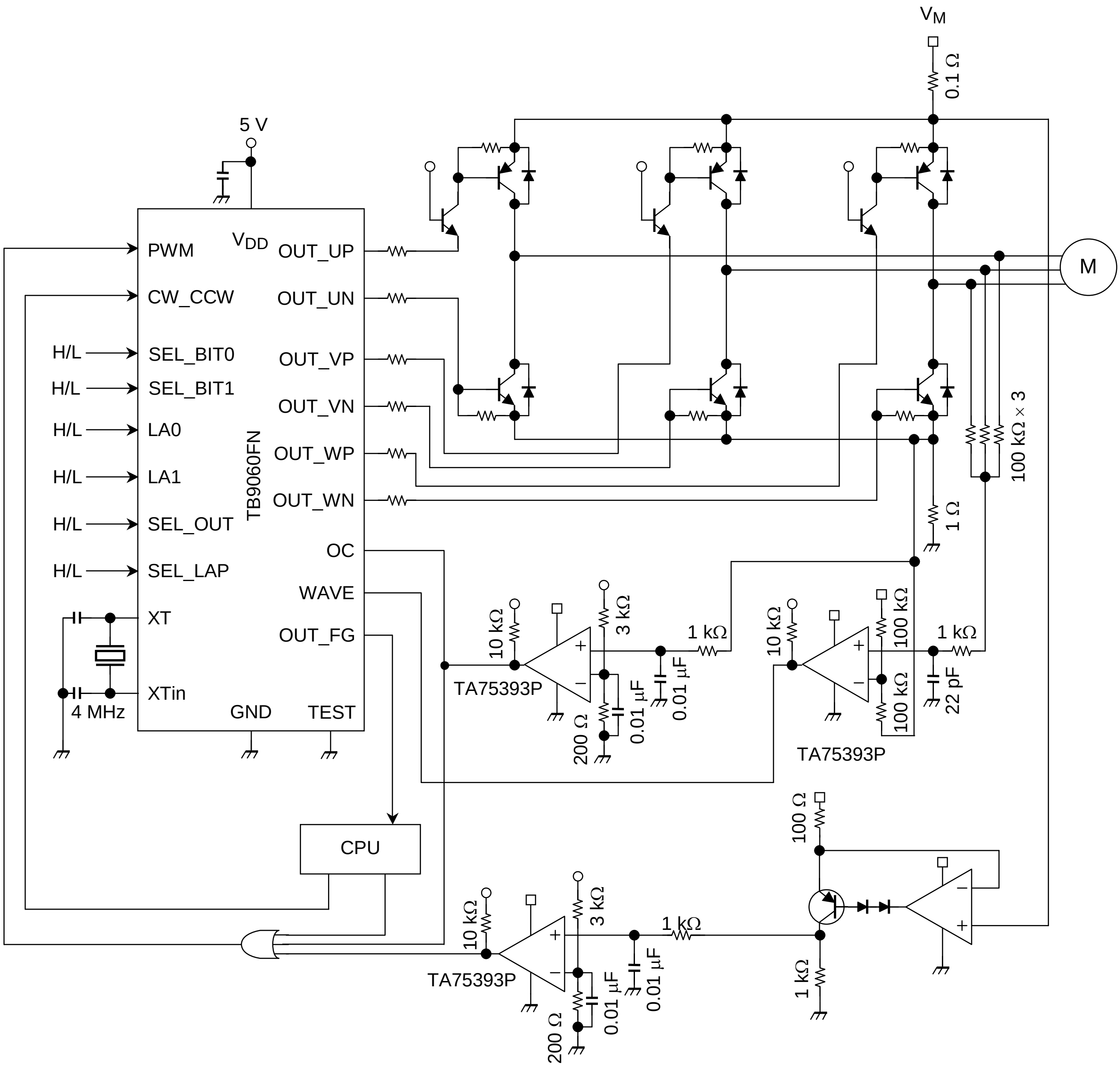
Electrical Characteristics (V_{DD} = 5 V, Ta = –40 to 125°C)

Characteristics	Symbol	Test Circuit	Test Condition	Min	Typ.	Max	Unit
Static power supply current	I_{DD}	—	PWM = H, XTin = H	—	0.1	0.3	mA
Dynamic power supply current	$I_{DD\ (opr)}$	—	PWM = 50%Duty, XTin = 4 MHz	—	1	3	mA
Input current	$I_{IN\text{-}1\ (H)}$	—	V_{IN} = 5 V, PWM, OC, WAVE SEL_LAP, SEL_BIT1	—	0	1	μA
	$I_{IN\text{-}1\ (L)}$	—	V_{IN} = 0 V, PWM, OC, WAVE SEL_LAP, SEL_BIT1	–100	–50	—	
	$I_{IN\text{-}2\ (H)}$	—	V_{IN} = 5 V, CW_CCW, LA0, LA1, SEL_OUT, SEL_BIT0	—	50	100	
	$I_{IN\text{-}2\ (L)}$	—	V_{IN} = 0 V, CW_CCW, LA0, LA1, SEL_OUT, SEL_BIT0	–1	0	—	
Input voltage	$V_{IN\ (H)}$	—	PWM, OC, SEL_LAP CW_CCW, WAVE, LA0 LA1, SEL_OUT SEL_BIT0, SEL_BIT1	4.0	—	V_{DD}	V
	$V_{IN\ (L)}$	—		GND	—	1.0	
Input hysteresis voltage	V_H	—		—	0.6	—	V
Output voltage	$V_{O\text{-}1\ (H)}$	—	I_{OH} = –1mA OUT_UP, OUT_VP, OUT_WP	4.0	—	V_{DD}	V
	$V_{O\text{-}1\ (L)}$	—	I_{OL} = 20 mA OUT_UP, OUT_VP, OUT_WP	GND	—	0.7	
	$V_{O\text{-}2\ (H)}$	—	I_{OH} = –20 mA OUT_UN, OUT_VN, OUT_WN	3.8	—	V_{DD}	
	$V_{O\text{-}2\ (L)}$	—	I_{OL} = 1 mA OUT_UN, OUT_VN, OUT_WN	GND	—	0.7	
	$V_{O\text{-}3\ (H)}$	—	I_{OH} = –1 mA, OUT_FG	4.0	—	V_{DD}	V
	$V_{O\text{-}3\ (L)}$	—	I_{OL} = 1 mA, OUT_FG	GND	—	0.7	
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 OUT_FG	—	0	15	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 OUT_FG	—	0	15	
Output delay time	t_{pLH}	—	PWM – Output	—	0.5	1	μS
	t_{pHL}	—		—	0.5	1	

Note1: Output delay time test waveforms



Application Circuit Example

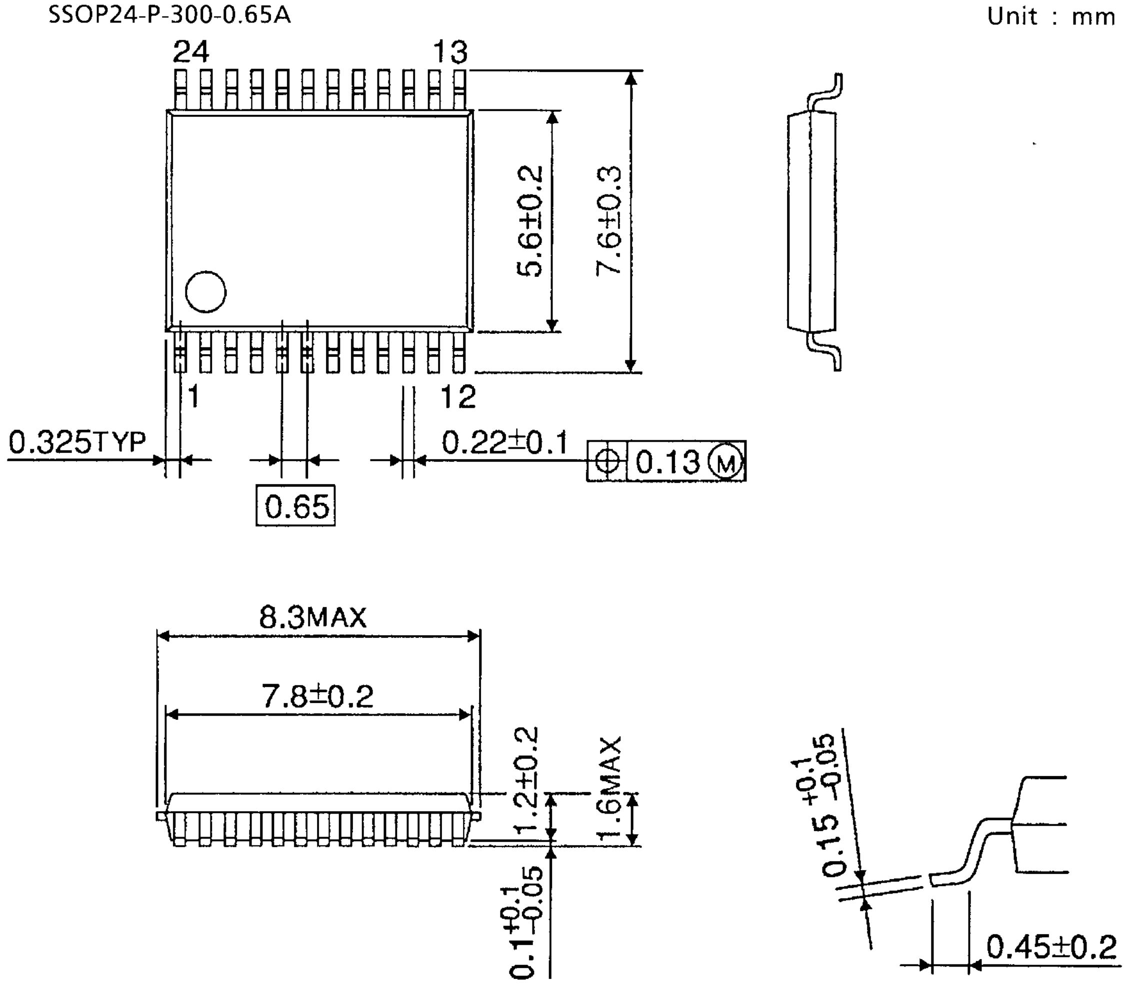


Note 2: Take enough care in designing output V_{DD} line and ground line to avoid short circuit between outputs, V_{DD} fault or ground fault which may cause the IC to break down.

Note 3: The above application circuit and values mentioned are just an example for reference. Since the values may vary depending on the motor to be used, appropriate values must be determined through experiments before using the device.

Note 4: TEST pin is only used for factory test, so connect it to ground in application.

Package Dimensions



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