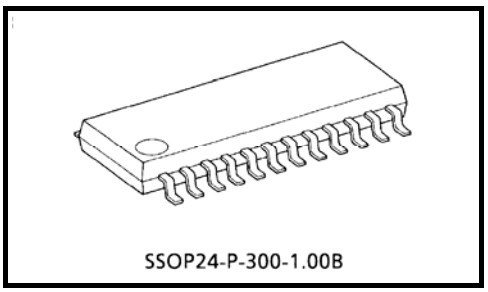
TOSHIBA Bi-CMOS Integrated Circuit Silicon Monolithic

# TB6586FG, TB6586AFG

Three-Phase Full-Wave Brushless Motor Controller

The TB6586FG/AFG is a three-phase full-wave brushless motor controller developed for use in motor fans.




Weight: 0.27 g (typ.)

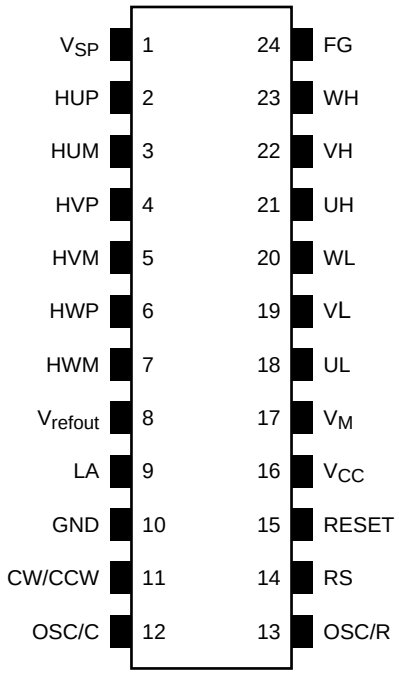
## Features

- Upper-phase PWM control
- Built-in triangular-wave generator
- Support of a bootstrap circuit
- Built-in Hall amplifier (support of a Hall element)
- Selectable 120°/150° energization
- Built-in lead angle control function
- Overcurrent protection signal input pin ($V_{RS}$ = 0.5 V (typ.))
- Built-in regulator ($V_{refout}$ = 5 V (typ.), 35 mA (max))
- Operating supply voltage range: $V_{CC}$ = 6.5 to 16.5 V, $V_M$ = 4.5 to 16.5 V
- The TB6586FG and TB6586AFG differ in the number of pulses per revolution:
  TB6586FG: 1 pulse / electrical angle: 360°
  TB6586AFG: 3 pulses / electrical angle: 360°

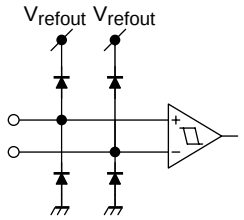
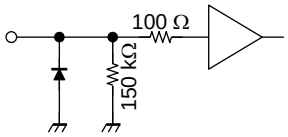
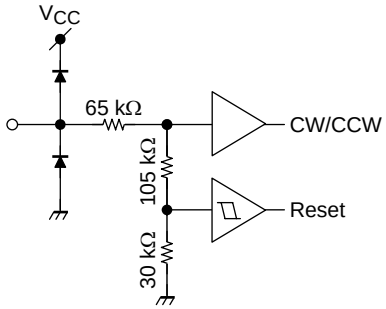
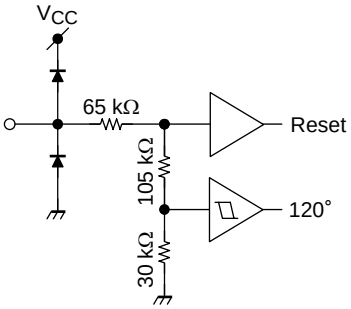
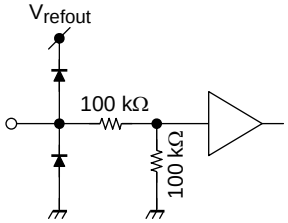
## Pin Description

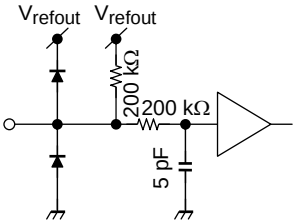
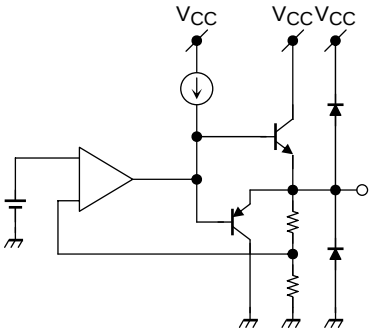
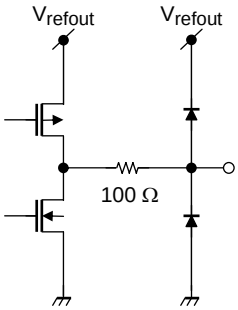
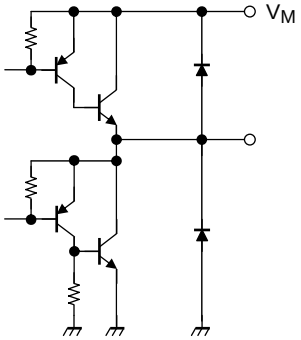
| Pin No. | Symbol | Description |
|---|---|---|
| 1 | $V_{SP}$ | Speed control |
| 2 | HUP | U-phase Hall signal input (+) pin |
| 3 | HUM | U-phase Hall signal input (–) pin |
| 4 | HVP | V-phase Hall signal input (+) pin |
| 5 | HVM | V-phase Hall signal input (–) pin |
| 6 | HWP | W-phase Hall signal input (+) pin |
| 7 | HWM | W-phase Hall signal input (–) pin |
| 8 | $V_{refout}$ | Outputs reference voltage signal (5 V / 35 mA) |
| 9 | LA | Lead angle setting signal input pin (30° / 4 bits) |
| 10 | GND | Ground pin |
| 11 | CW/CCW | Rotation direction signal input pin |
| 12 | OSC/C | Connect to condenser for PWM oscillator |
| 13 | OSC/R | Connect to resistor for PWM oscillator |
| 14 | RS | Overcurrent protection (0.5 V) |
| 15 | RESET | Energization width toggle pin (Low: 150°, High; Reset, 6.35 V: 120°) |
| 16 | $V_{CC}$ | Power supply |
| 17 | $V_M$ | Input for output power |
| 18 | UL | U-phase output pin (Low) |
| 19 | VL | V-phase output pin (Low) |
| 20 | WL | W-phase output pin (Low) |
| 21 | UH | U-phase output pin (Low) |
| 22 | VH | V-phase output pin (Low) |
| 23 | WH | W-phase output pin (Low) |
| 24 | FG | Output of number of pulses per revolution<br>(FG: 1 pulse / electrical angle; AFG: 3 pulses / electrical angle) |

## Pin Layout

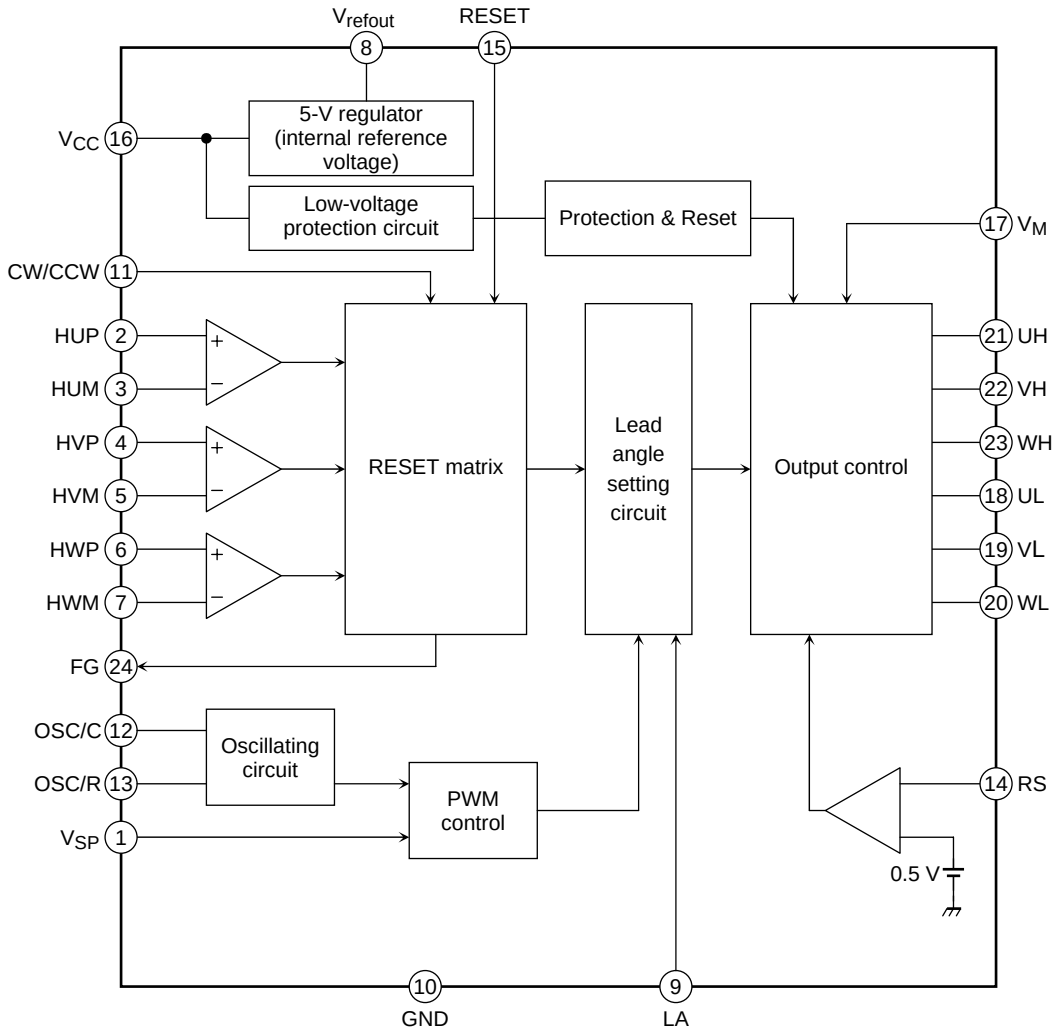


## Input/Output Equivalent Circuits

| Pin Description | Symbol | Input/Output Signal | Input/Output Internal Circuit |
|---|---|---|---|
| Positional signal input pin | HUP<br>HUM<br>HVP<br>HVM<br>HWP<br>HWM | Analog/Digital<br>Hysteresis ± 7.5 mV (typ.) |  |
| Speed control signal input pin | $V_{SP}$ | Analog<br>Input range 0 to 7 V |  |
| Rotation direction signal input pin<br>L: Forward (CW)<br>H: Reverse (CCW) | CW/CCW | Digital<br>L: 0.8 V (max)<br>H: $V_{refout}$ − 1 V (min)<br>(Test input<br>If CW/CCW = 6.35 V (typ.) or higher, the system resets)<br>Hysteresis 150 mV (typ.) |  |
| Reset input<br>L: 150° turn-on mode<br>H: Reset | RESET | Digital<br>L: 0.8 V (max)<br>H: $V_{refout}$ − 1 V (min)<br>If RESET = 6.35 V (typ.) or higher, then 120° energization drive is selected<br>Hysteresis 150 mV (typ.)<br>During a reset: Output OFF (all phases Low). The internal counter continues to operate. |  |
| Lead angle setting signal input | LA | Analog<br>Input range 0 to 5.0 V ($V_{refout}$)<br>Electrical angle 0°~28° can be divided into 16 by 4-bit data.<br>Lead angle 0°: LA = 0 V (GND)<br>Lead angle 28°: LA = 5 V ($V_{refout}$) |  |

| Pin Description | Symbol | Input/Output Signal | Input/Output Internal Circuit |
|---|---|---|---|
| Overcurrent protection signal input | RS | Analog<br>Analog filter 0.5 μs (typ.)<br>If RS = 0.5 V (typ.) or higher, UL, VL and WL pin goes low (released at carrier cycle) |  |
| Reference voltage signal output pin | $V_{refout}$ | 5.0 ± 0.5 V (35 mA)<br>5.0 ± 0.3 V (15 mA) |  |
| Rotational frequency output | FG | Digital<br>Push-pull output<br>(± 2 mA (max))<br>TB6586FG:<br>1 pulse / electrical angle of 360°<br>TB6586AFG:<br>3 pulses / electrical angle of 360° |  |
| Energization signal input | UH<br>UL<br>VH<br>VL<br>WH<br>WL | Push-pull output (± 3 mA (max)) |  |

## Block Diagram



## Maximum Ratings (Ta = 25°C)

| Characteristic | Symbol | Rating | Unit |
|---|---|---|---|
| Supply voltage | $V_{CC}$ | 18 | V |
| | $V_M$ | 18 | |
| Input voltage | $V_{IN1}$ | −0.3 to 8 (Note 1) | V |
| | $V_{IN2}$ | −0.3 to 8.5 (Note 2) | |
| | LA | −0.3 to $V_{refout}$ + 0.3 | |
| Turn-on signal output current | $I_{OUT}$ | 3 | mA |
| Supply voltage | $P_D$ | 0.8 (Note3) | W |
| | | 1.0 (Note 4) | |
| Operating temperature | $T_{opr}$ | −30 to 85 | °C |
| Storage temperature | $T_{stg}$ | −55 to 150 | |

Note 1: CW/CCW, RESET

Note 2: $V_{SP}$

Note 3: No heatsink

Note 4: When mounted on a PCB (50 × 50 × 1.6 mm, Cu 10%)

## Recommended Operation Conditions (Ta = 25°C)

| Characteristic | Symbol | Min | Typ. | Max | Unit |
|---|---|---|---|---|---|
| Supply voltage | $V_{CC}$ | 6.5 | 15 | 16.5 | V |
| | $V_M$ | 4.5 | — | 16.5 | V |
| Oscillation frequency | $F_{osc}$ | 2 | 5 | 8 | MHz |

## Electrical Characteristics (Unless otherwise specified Ta = 25°C, $V_{CC}$ = 15 V, $V_M$ = 5 V)

| Characteristic | | Symbol | | Test Circuit | Test Condition | Min | Typ. | Max | Unit |
|---|---|---|---|---|---|---|---|---|---|
| Supply current | | $I_{CC}$ | | — | $V_{refout}$ = OPEN, OSC/C = 560 pF, OSC/R = 6.2 kΩ | — | 5.5 | 10 | mA |
| Output current | | $I_M$ | | — | Drive output (UH, UL, VH, VL, WH, WL) = OPEN | — | 0.5 | 1 | mA |
| Input current | | $I_{IN\ (LA)}$ | | — | $V_{IN}$ = 5 V LA | — | 25 | 50 | μA |
| | | $I_{IN\ (SP)}$ | | | $V_{IN}$ = 5 V $V_{SP}$ | — | 35 | 70 | |
| | | $I_{IN\ (RESET)}$ | | | $V_{IN}$ = 5 V RESET | — | 25 | 50 | |
| | | $I_{IN\ (CW)}$ | | | $V_{IN}$ = 5 V CW/CCW | — | 25 | 50 | |
| | | $I_{IN\ (RS)}$ | | | $V_{IN}$ = 0 V RS | — | –25 | –50 | |
| Input voltage | | $V_{IN1}$ | High | — | CW/CCW, RESET | $V_{refout}$ – 1 | — | $V_{refout}$ | V |
| | | | Low | | | 0 | — | 0.8 | |
| | | $V_{IN2}$ | | — | RESET: 120° turn-on mode | 6.0 | 6.35 | 6.7 | |
| | | $V_{RST1}$ | | — | CW/CCW: System reset | 6.0 | 6.35 | 6.7 | V |
| | | $V_{RST2}$ | | — | RESET: Power off reset | 2.2 | — | $V_{refout}$ | |
| | | $V_{SP}$ | H | — | PWM ON duty 95% | 5.1 | 5.4 | 5.7 | V |
| | | | M | | Refresh → Start motor operation | 1.8 | 2.1 | 2.4 | |
| | | | L | | Energization OFF → Refresh | 0.7 | 1.0 | 1.3 | |
| Hall element input | Input sensitivity | $V_S$ | | — | Differential input | 40 | — | — | mVpp |
| | Common mode | $V_W$ | | | | 1.5 | — | 3.5 | V |
| | Input hysteresis | $V_{H\ (1)}$ | | | (Note) | ±4.5 | ±7.5 | ±10.5 | mV |
| Input hysteresis voltage | | $V_{H\ (2)}$ | | — | RESET: Reset ↔ 120° energization (Note) | — | 0.15 | — | V |
| | | $V_{H\ (3)}$ | | | CW/CCW: CCW ↔ Reset (Note) | — | 0.15 | — | |
| Input delay | | $T_{RS}$ | | — | RS → Output OFF | — | 2.2 | — | μs |
| Output voltage | | $V_{OUT\ (15)-H}$ | | — | $I_{OUT}$ = 3 mA, $V_M$ = 15 V | 13 | 14.2 | — | V |
| | | $V_{OUT\ (15)-L}$ | | | $I_{OUT}$ = 3 mA, $V_M$ = 15 V | — | 0.8 | 1.2 | |
| | | $V_{OUT\ (5)-H}$ | | | $I_{OUT}$ = 2 mA, $V_M$ = 5 V | 4.0 | 4.2 | — | |
| | | $V_{OUT\ (5)-L}$ | | | $I_{OUT}$ = 2 mA, $V_M$ = 5 V | — | 0.8 | 1.0 | |
| | | $V_{FG\ (H)}$ | | | $I_{OUT}$ = 2 mA FG | 4 | — | — | |
| | | $V_{FG\ (L)}$ | | | $I_{OUT}$ = 2 mA FG | — | — | 1.0 | |
| | | $V_{refout1}$ | | | $I_{OUT}$ = 15 mA $V_{refout}$ | 4.7 | 5.0 | 5.3 | |
| | | $V_{refout2}$ | | | $I_{OUT}$ = 35 mA $V_{refout}$ | 4.5 | 5.0 | 5.5 | |
| Output leakage current | | $I_{L\ (H)}$ | | — | $V_{OUT}$ = 0 V | — | 0 | 1 | μA |
| | | $I_{L\ (L)}$ | | | $V_{OUT}$ = 15 V | — | 0 | 1 | |
| Electrical current detector | | $V_{RS}$ | | — | RS | 0.46 | 0.5 | 0.54 | V |
| Lead angle correction | | $T_{LA\ (0)}$ | | — | LA = 0 V or open, Hall IN = 100 Hz | — | 0 | — | ° |
| | | $T_{LA\ (2.5)}$ | | — | LA = 2.5 V, Hall IN = 100 Hz | — | 17 | — | |
| | | $T_{LA\ (5)}$ | | — | LA = 5 V, Hall IN = 100 Hz | — | 28 | — | |
| $V_{CC}$ monitor | | $V_{CC}$ (H) | | — | Output start operation point | 5.7 | 6.0 | 6.3 | V |
| | | $V_{CC}$ (L) | | — | No output operation point | 4.7 | 5.0 | 5.3 | |
| | | $V_{H\ (4)}$ | | — | Input hysteresis width (Note) | — | 1.0 | — | |

| Characteristic | Symbol | Test Circuit | Test Condition | Min | Typ. | Max | Unit |
|---|---|---|---|---|---|---|---|
| PWM oscillator frequency (carrier frequency) | $F_{C\ (20)}$ | — | OSC/C = 560 pF, OSC/R = 6.2 kΩ | 18 | 20 | 22 | kHz |
| | $F_{C\ (18)}$ | — | OSC/C = 470 pF, OSC/R = 8.2 kΩ | 16.2 | 18 | 19.8 | |
| Output duty (max) | $T_{on}$ (max) | — | OSC/C = 560 pF, OSC/R = 6.2 kΩ, $V_{SP}$ = 5.7 V | 92 | 95 | 98 | % |

Note: Pre-shipment testing is not performed.

## Functional Description

### 1. Basic operation

At startup, the motor runs at 120° energization. When the position detection signal reaches a revolution count of fs = 5 Hz or higher, the rotor position is extrapolated from the position detection signal and output is activated using the lead angle based on the LA signal.

Startup - 5 Hz: 120° energization $fs = f_{osc} / (120 \times 2^5 \times 2^8)$

5 Hz or higher: 120° energization or 150° energization * Approximately 5 Hz if $f_{osc}$ = 5 MHz.

*: At 5 Hz or higher, operation is performed in accordance with commands from RESET and LA pins. When the motor is running at 5 Hz or lower and in reverse (in accordance with the timing chart), it will be driven at 120° energization for a lead angle of 0°.

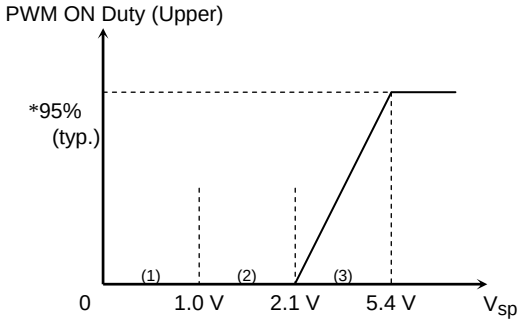
### 2. $V_{SP}$ voltage command signal function

(1) When voltage instruction is input at $V_{SP} \leqq 1.0$ V:
Output is turned off (gate block protection).

(2) When voltage instruction is input at 1.0 V < $V_{SP} \leqq 2.1$ V (refresh operation):
The lower transistor is turned on at a regular (carrier) cycle. (ON duty: $T_{on} = 18/f_{osc}$)

(3) When a voltage instruction is input at $V_{SP}$ > 2.1 V:
The drive signal is output using the energization method configured using the RESET pin.

Note: At startup, to charge the upper transistor gate power supply, turn the lower transistor on for a fixed time with 1.0 V < $V_{SP} \leqq 2.1$ V.

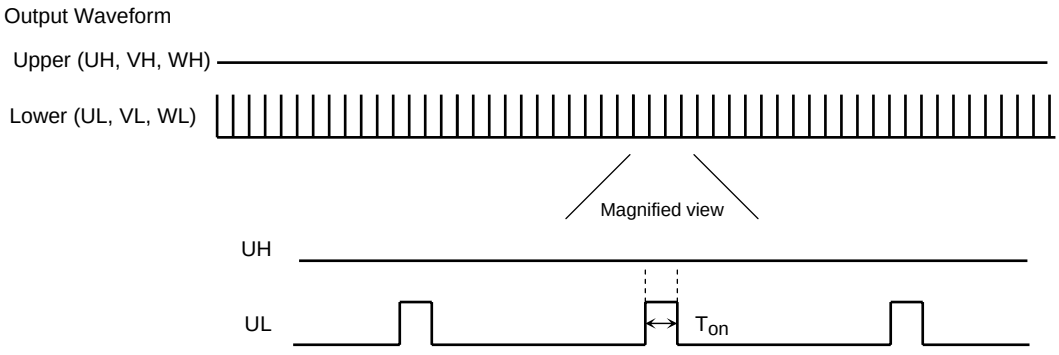



*: The maximum ON duty is $T_{on}$ = 95% (typ.) when $V_{SP}$ = 5.4 V (typ.).
Example: If $f_{osc}$ = 5 MHz, then ON time = 48 μs (typ.) ($f_c$ = 19.8 kHz)
If $f_{osc}$ = 4 MHz, then ON time = 60 μs (typ.) ($f_c$ = 15.9 kHz)

### 3. Function to stabilize the bootstrap voltage

The product is equipped with a bootstrap capacitor charging function that supports the output level of the bootstrap method.

(1) If the $V_{SP}$ input current is 1.0 V < $V_{SP} \leqq 2.1$ V, the ON signal is output to the lower phase (UL, VL, WH) based on the carrier cycle. If the output waveform is upper phase (UH, VH, WH), the OFF signal (Low) is output.

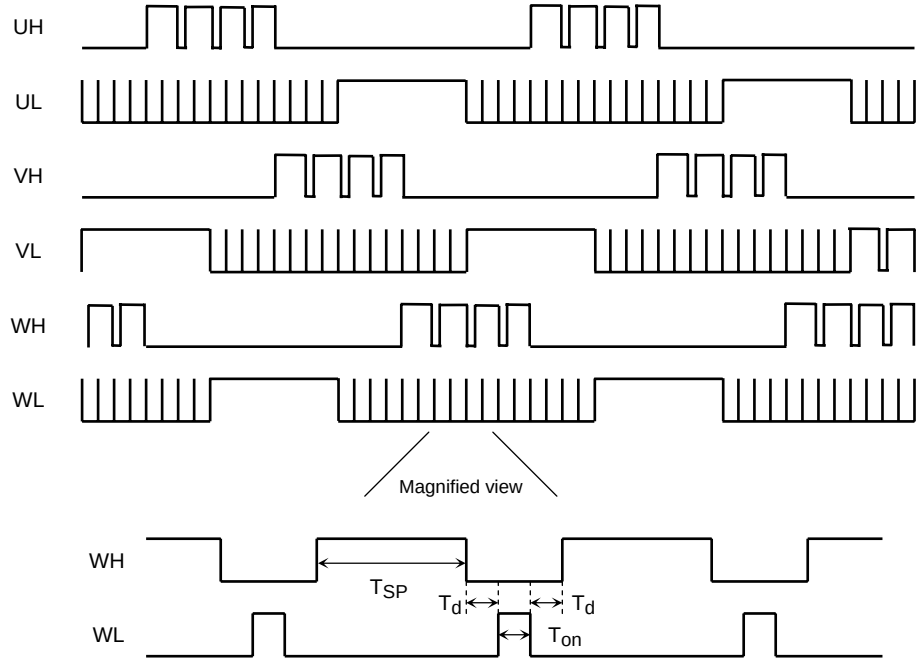



$T_{on} = 18/f_{osc}$

Example: $f_{osc}$ = 5 MHz $T_{on}$ = 3.6 μs

(2) If the $V_{SP}$ input current is 2.1 V < $V_{SP}$ and the Hall signal is 5 Hz or less, the upper phase (UH, VH, WH) will perform 120° energization at a PWM that complies with the $V_{SP}$; and the lower phase (UL, VL, WL) will operate at 120° energization, performing refresh operation based on the OFF timing. (The same drive is executed during "headwind" operation as well.)

Example Output Waveform




$T_{SP}$: Variable depending on the $V_{SP}$ (the figure above being applicable when $V_{SP}$ = 5.4 V (typ.)); $T_{on}$ = $18/f_{osc}$; Td = $18/f_{osc}$

*: The lead angle correction (LA pin) function does not operate when the Hall signal is 5 Hz or less. The lead angle correction function also does not operate when in a reverse detection state.

## 4. Correcting the lead angle

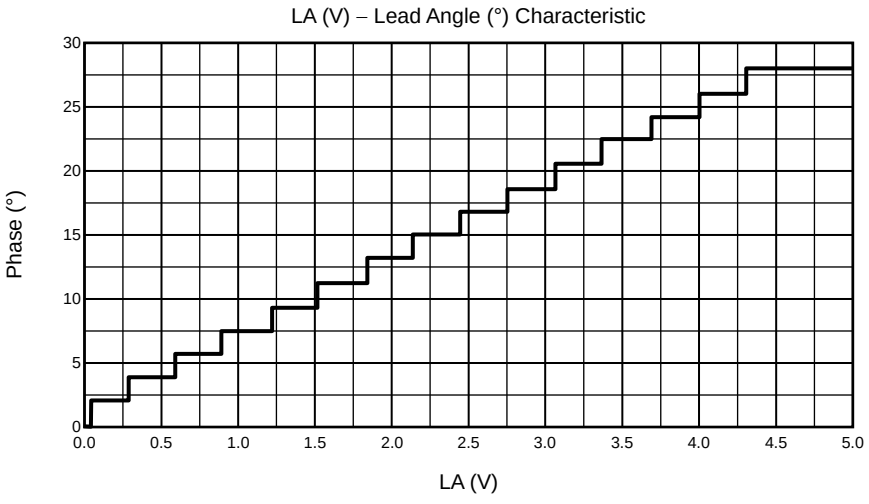
The lead angle can be corrected in the turn-on signal range from 0 to 28° in relation to the induced voltage. Analog input from the LA pin (0 V to 4.3 V divided by 16):

0 V = 0°

4.3 V or higher = 28°

Sample Evaluation Results

| Steps | LA (V) | Lead Angle (°) |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.05 | 1.93 |
| 3 | 0.28 | 3.79 |
| 4 | 0.59 | 5.65 |
| 5 | 0.89 | 7.54 |
| 6 | 1.21 | 9.43 |
| 7 | 1.52 | 11.29 |
| 8 | 1.83 | 13.15 |
| 9 | 2.14 | 15.08 |
| 10 | 2.45 | 16.87 |
| 11 | 2.75 | 18.73 |
| 12 | 3.06 | 20.66 |
| 13 | 3.37 | 22.55 |
| 14 | 3.68 | 24.37 |
| 15 | 3.99 | 26.16 |
| 16 | 4.30 | 28.09 |



## 5. Setting the carrier frequency

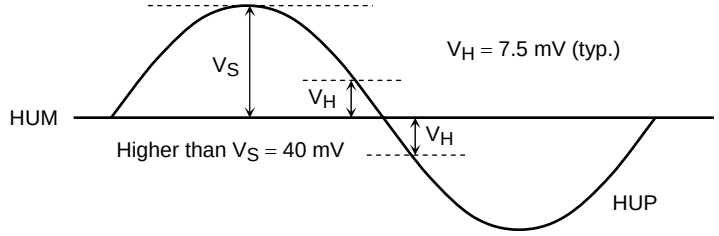
This function involves setting the triangular wave cycle (carrier cycle) necessary for generating PWM signals.

Carrier frequency: $f_c = f_{osc}/252$ (Hz) $f_{osc}$ = reference clock (crystal oscillation)

Example: If $f_{osc}$ = 5 MHz, then $f_c$ = 19.8 kHz
If $f_{osc}$ = 4 MHz, then $f_c$ = 15.9 kHz

## 6. Position detection pin

The common-mode voltage range is $V_W$ = 1.5 to 3.5 V. The input hysteresis is $V_H$ = 7.5 mV (typ.).

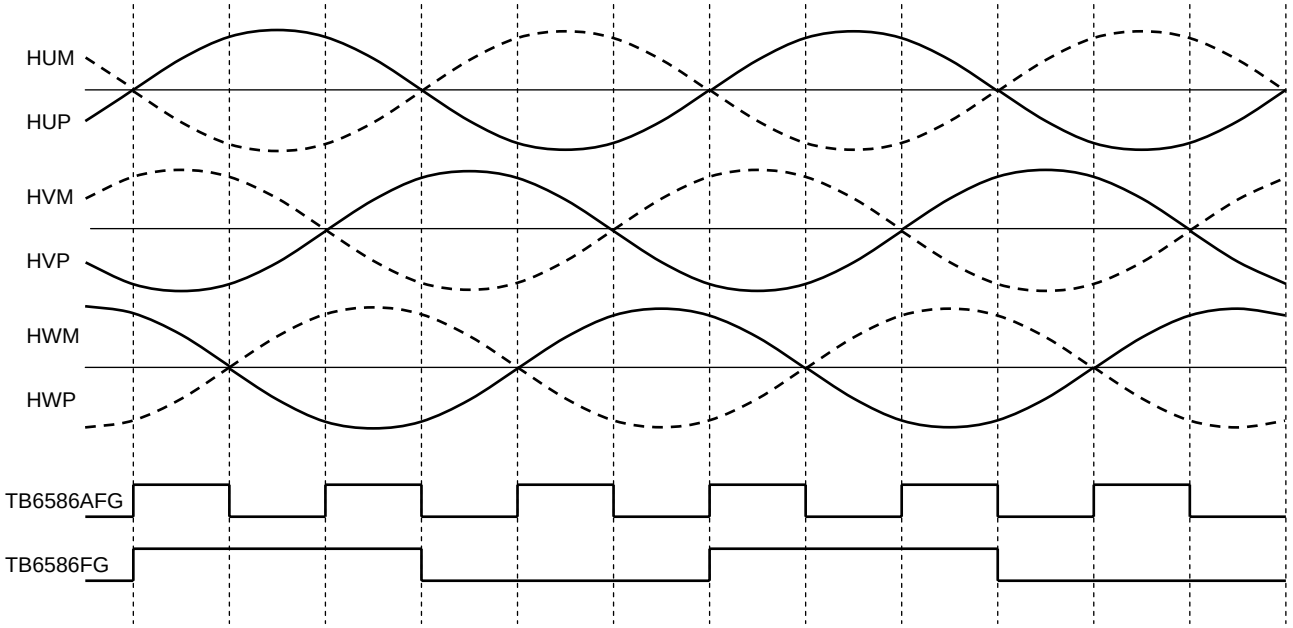



## 7. Revolution pulse output pin (the difference between TB6586FG and TB6586AFG)

This pin outputs the revolution pulses based on the Hall signal. The TB6586FG outputs one (1) pulse / electrical angle and the TB6586AFG outputs three (3) pulses / electrical angle. In the case of the TB6586FG, this pulse is generated via the U phase Hall signal. For a Hall element, the pulse is converted to digital and then output. For a Hall IC, it is output in the equivalent waveform. In the case of the TB6586AFG, the up-down edges of the U, V and W phase (respectively) are combined and then generated.

Example: Number of FG pulses for an 8-pole motor:
- TB6586FG: 4 pulses per revolution (4 ppr)
- TB6586AFG: 12 pulses per revolution (12 ppr)

### FG Signal Timing Chart

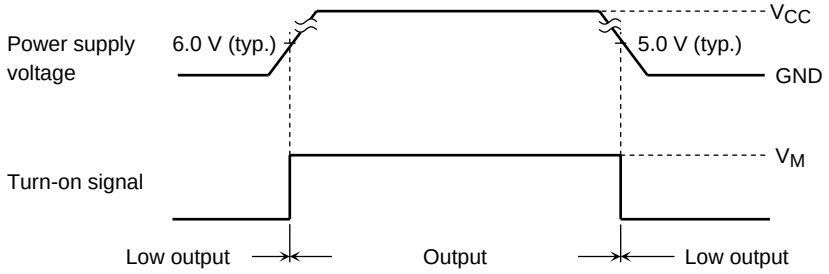


## 8. Protecting input pin

(1) Overcurrent protection (Pin RS)
When the DC link current exceeds the internal reference voltage, this pin performs gate block protection. Overcurrent protection is restored for each carrier frequency.
The pin is equipped with a filter (analog filter = 0.5 μs (typ.)) that prevents malfunctioning due to external noise.

(2) Position detection signal error protection
When the position detection signals are either all High, Low or Open, all the output is turned OFF (all phases Low). Anything else results in a restart.

(3) Low power voltage protection ($V_{CC}$ power monitor)
If the operation voltage range is exceeded when the power is being turned on or off, all the output is turned Low to prevent short circuit damage to the power element. Also, if 2.1 V or higher is input via the $V_{SP}$ pin, and if the motor is not rotating (Hall signal = 5 Hz or less), then normal drive is restored after a refresh operation (1.5 ms (typ.)) is performed. However, operations cannot be guaranteed during a power restoration as the circuitry will be unstable when the power is turned on.



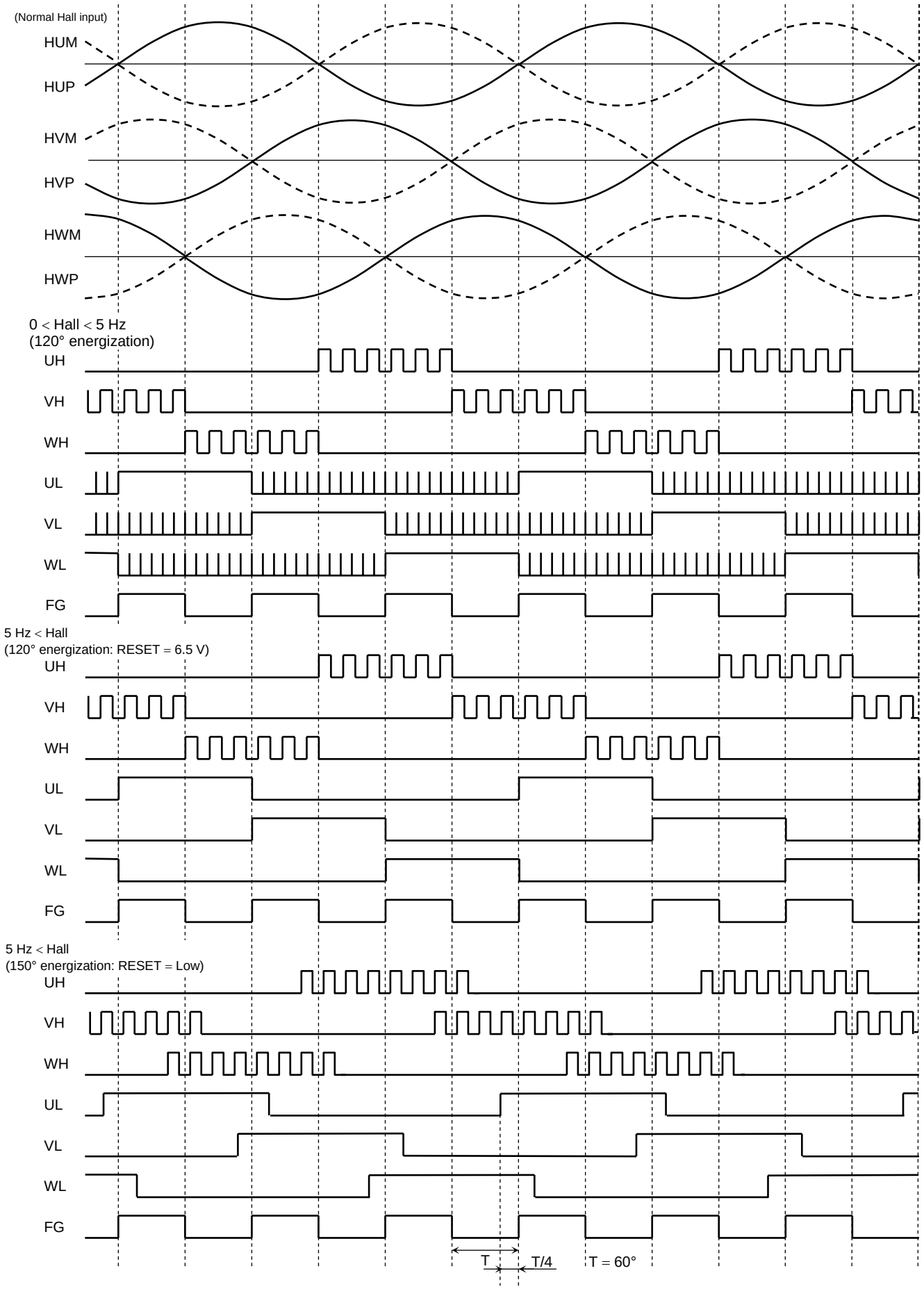

(4) Output pulse width restriction
To prevent damage to the output driver (externally attached), the drive output signals (UH, VH, WH, UL, VL, WL) are restricted from being output at a pulse width of 1 μs or less.

(5) Reset circuit
When 1.7 V (typ.) or more is input to the RESET pin, a reset will be performed with all output phases being turned off (i.e., all phases Low). Output is also turned off if 6.35 V (typ.) or more is supplied to the CW/CCW pin. However, do not use this method as the restoration obtained from it is unstable.

- RESET pin: Output off reset
  All output phases are turned Low and the externally connected power element is stopped. When 1.7 V or less is input, the power is restored. During the restoration, if 2.1 V or more is not input to the $V_{SP}$ pin, and if the motor is not rotating (Hall signal = 5 Hz or less), a refresh operation will be performed (1.5 ms (typ.)). Normal drive will then be restored.
  During the reset, the internal counter continues to operate and the FG signal continues to be output.
- CW/CCW pin: System reset
  All output phases are turned Low and the externally connected power element is stopped. Restoration takes place at an input of 6.35 V (typ.). However, operation after this kind of system reset is unstable.
  TB6586FG: During a system reset, the FG signal is output in compliance with the U-phase Hall signal.
  TB6586AFG: The FG signal is not output during a system reset.

## Timing Chart (CW/CCW = Low, LA = GND)

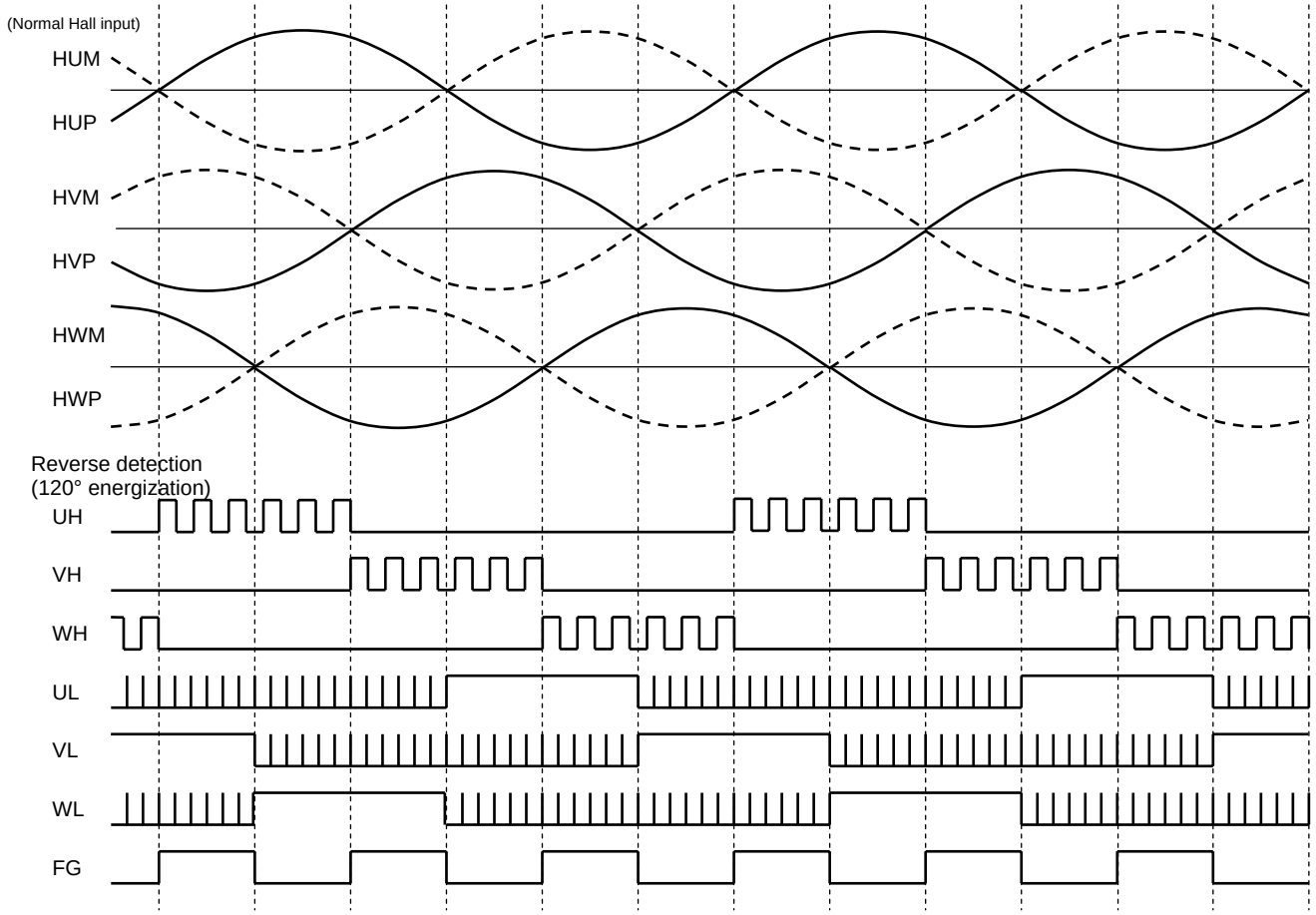
(The FG signal shown here is for the TB6586AFG.)




*: When the Hall signal is 5 Hz or higher, the lead angle function operates in accordance with the LA pin. signal.

## Timing Chart (CW/CCW = High, LA = GND)

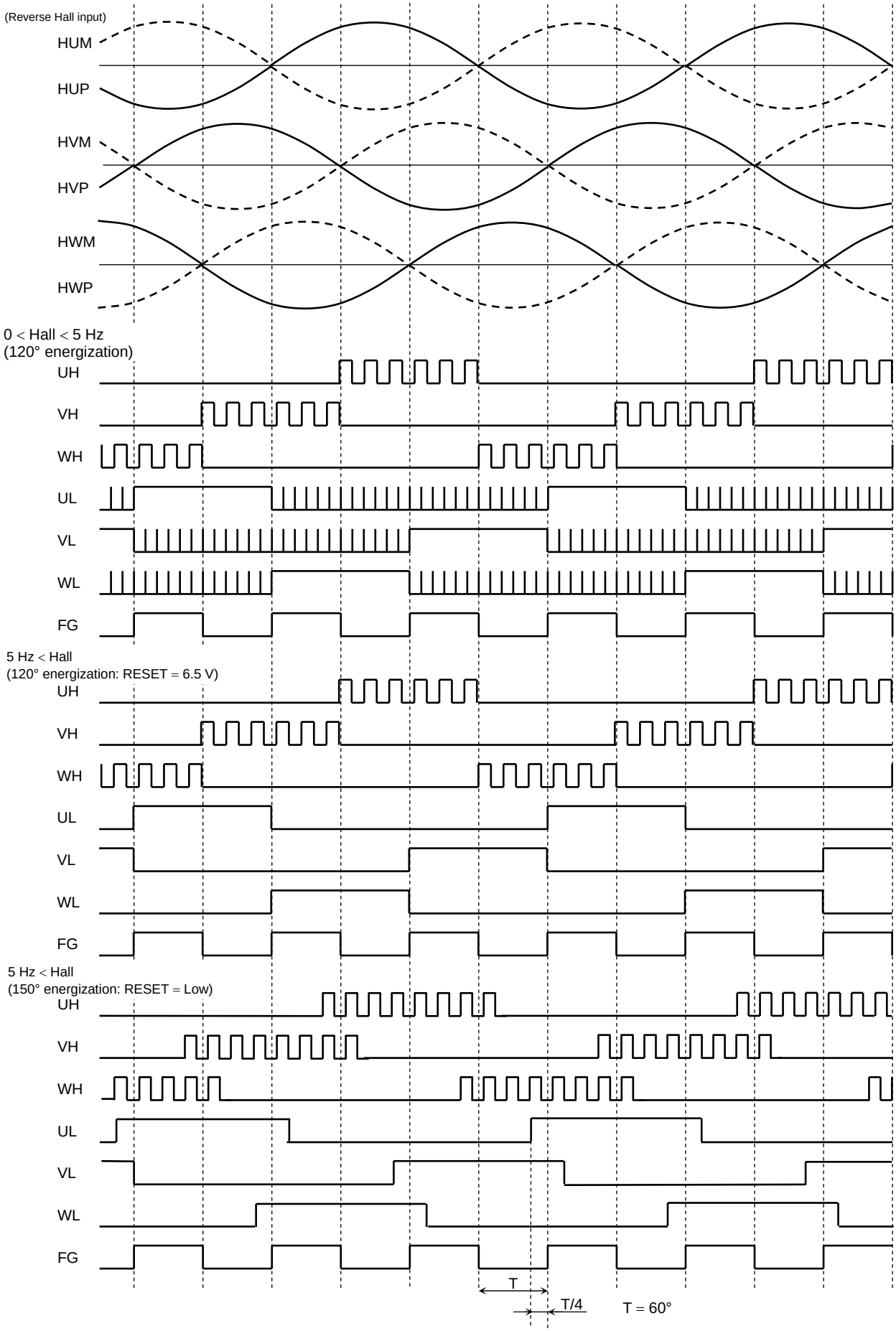
(The FG signal shown here is for the TB6586AFG.)




*: When CW/CCW = Low and a reverse Hall signal is input, it runs at 120° energization for a lead angle of 0° (“headwind” operation).

## Timing Chart (CW/CCW = High, LA = GND)

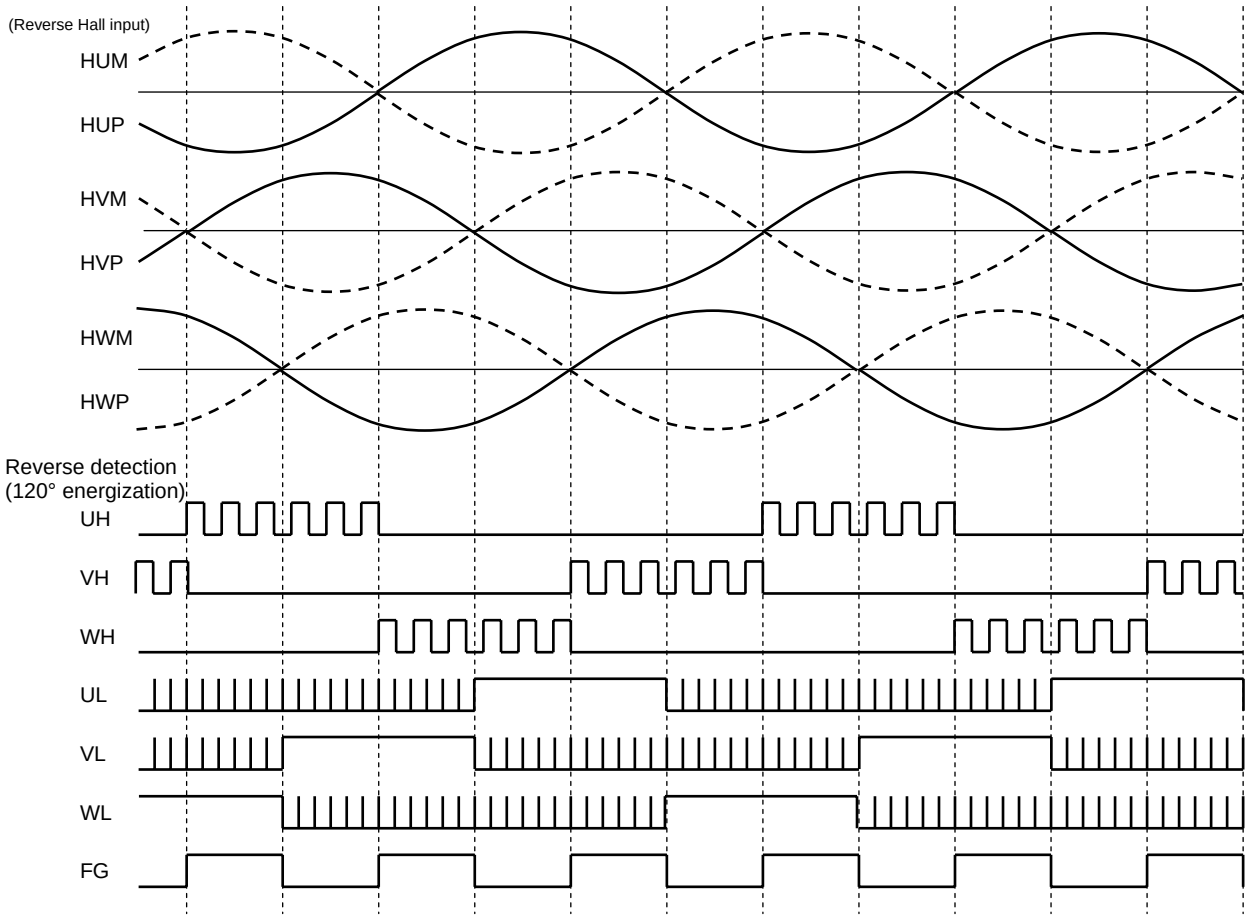
(The FG signal shown here is for the TB6586AFG.)




*: When the Hall signal is 5 Hz or higher, the lead angle function operates in accordance with the LA pin signal.

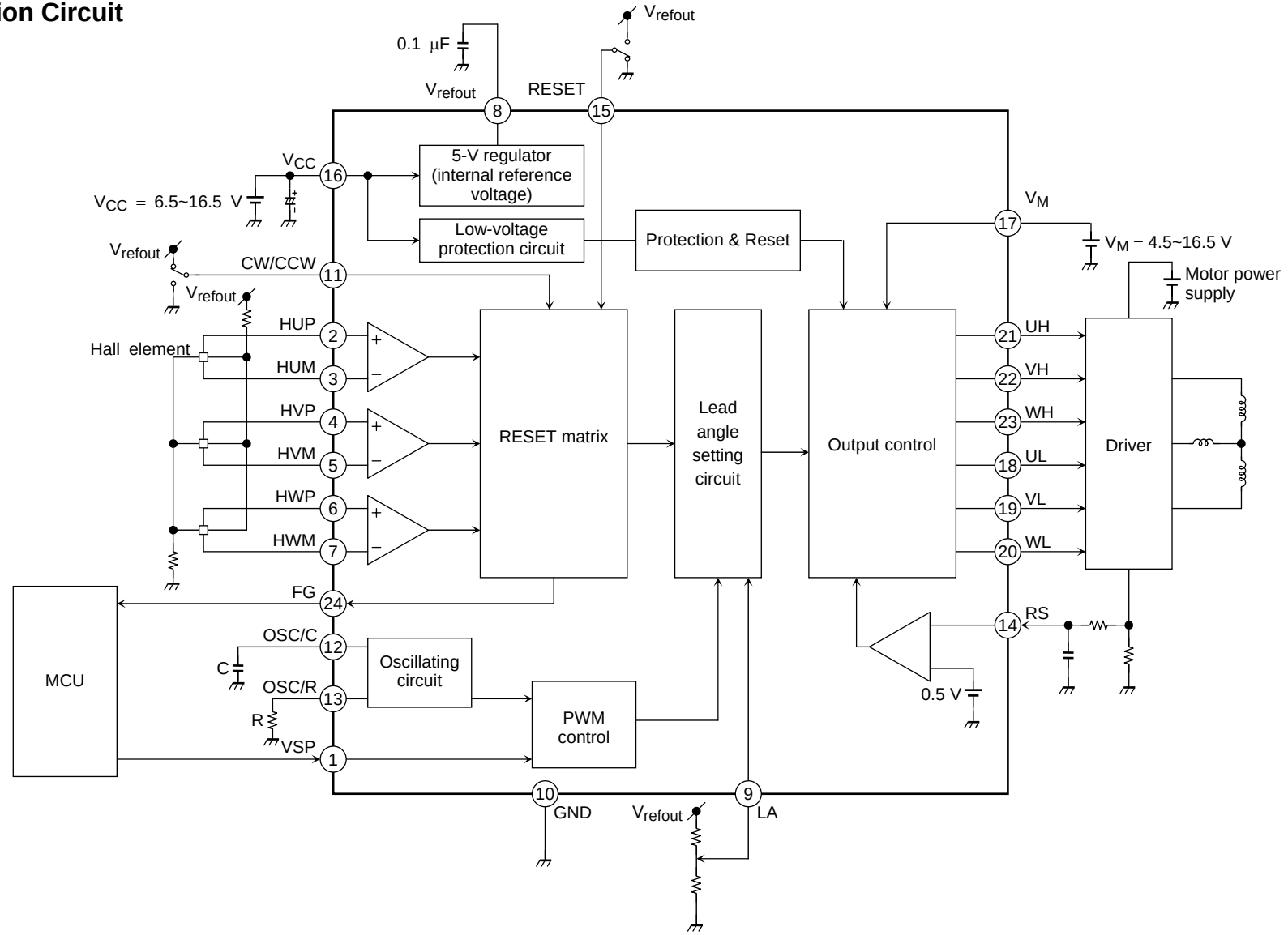
## Timing Chart (CW/CCW = Low, LA = GND)

(The FG signal shown here is for the TB6586AFG.)




*: When CW/CCW = Low and a reverse Hall signal is input, the motor runs at 120° energization for a lead angle of 0° (“headwind” operation)

## Example Application Circuit

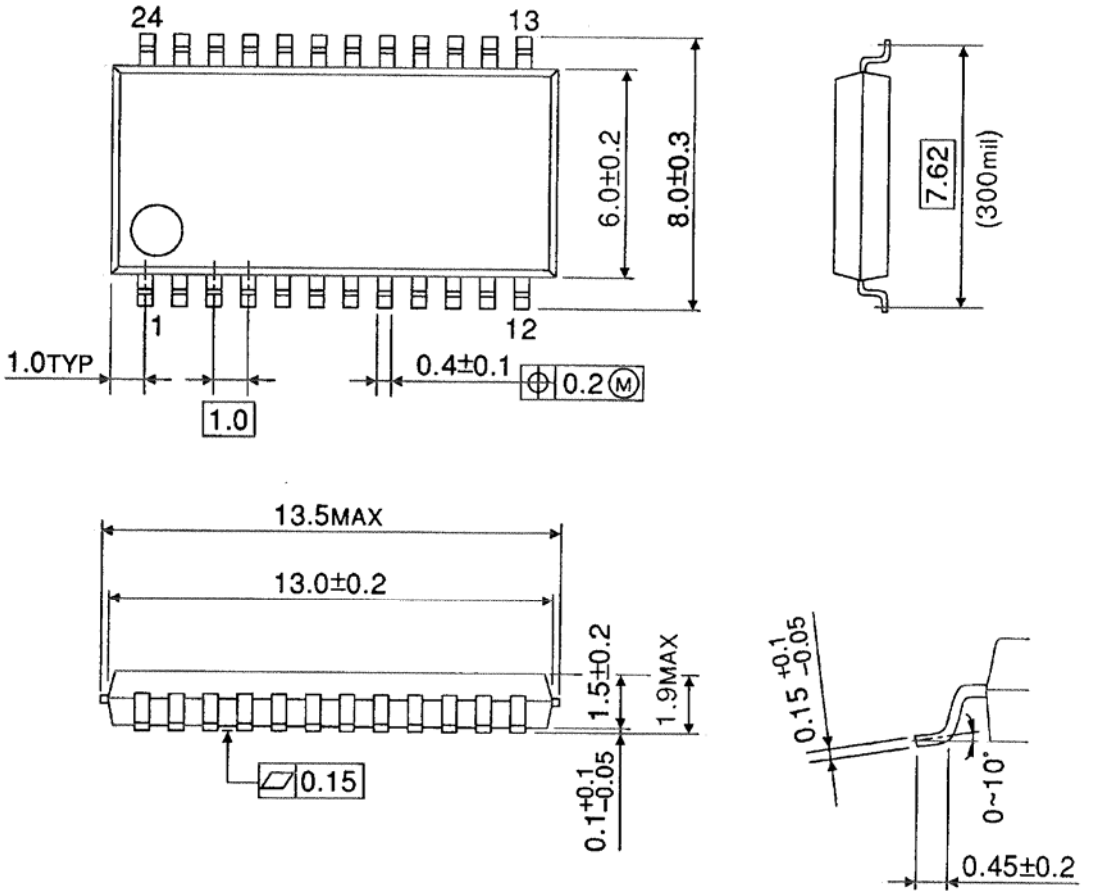



Any short circuit between the outputs, or between output and supply or ground, may damage the device. Peripheral parts may also be damaged by overvoltage and overcurrent. Design the output lines, $V_{CC}$, $V_M$ and GND lines so that short circuits do not occur.

Be careful also not to insert the IC in the wrong direction as this could destroy the IC.

## Package Dimensions

SSOP24-P-300-1.00B Unit : mm




Weight: 0.27 g (typ.)

About solderability, following conditions were confirmed

- Solderability

  (1) Use of Sn-63Pb 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

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