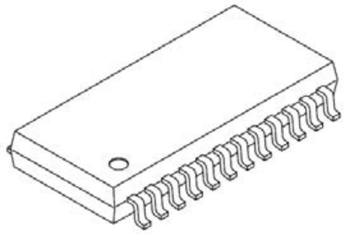
TOSHIBA Bi-CMOS Integrated Circuit Silicon Monolithic

# 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.



P-SSOP24-0613-1.00-001

Weight: 0.36 g (typ.)

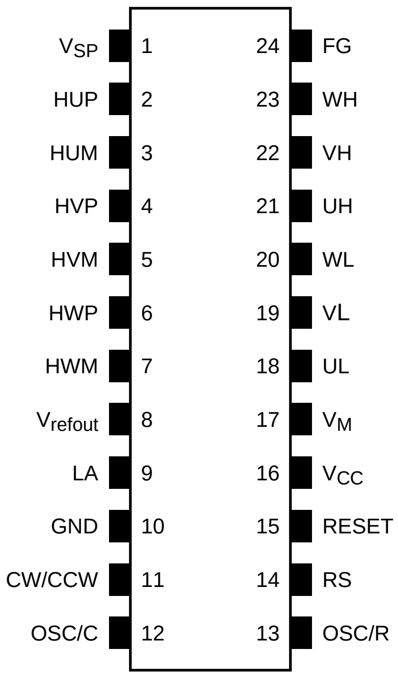
## Features

- 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

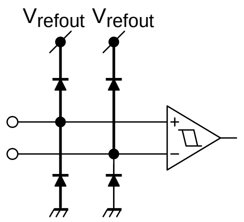
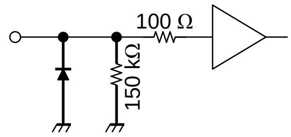
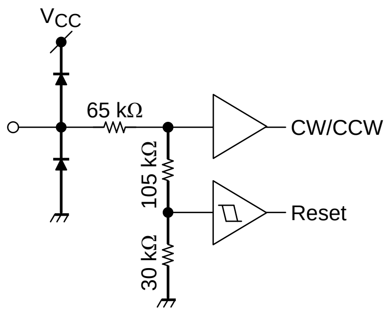
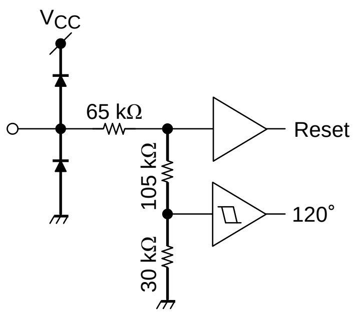
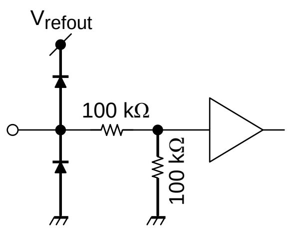
| Pin No. | Symbol | Description |
|---|---|---|
| 1 | $V_{SP}$ | Speed control input |
| 2 | HUP | U-phase Hall signal input (+) pin |
| 3 | HUM | U-phase Hall signal input (−) pin |
| 4 | HVP | V-phase Hall signal input (+) pin |
| 5 | HVM | V-phase Hall signal input (−) pin |
| 6 | HWP | W-phase Hall 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 bit) |
| 10 | GND | Ground pin |
| 11 | CW/CCW | Rotation direction signal input pin |
| 12 | OSC/C | Connect to capacitor 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 side) |
| 19 | VL | V-phase output pin (Low side) |
| 20 | WL | W-phase output pin (Low side) |
| 21 | UH | U-phase output pin (High side) |
| 22 | VH | V-phase output pin (High side) |
| 23 | WH | W-phase output pin (High side) |
| 24 | FG | Output of number of pulses per revolution<br>(FG: 1 pulse / electrical angle; AFG: 3 pulses / electrical angle) |

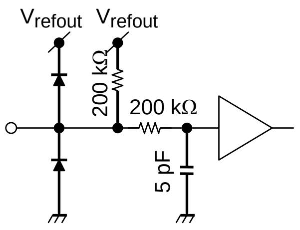
## Pin Layout

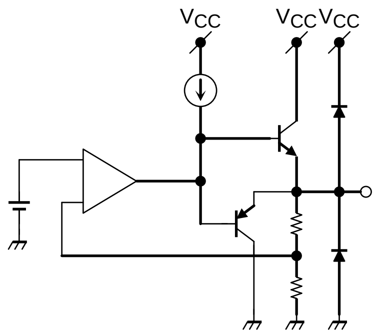


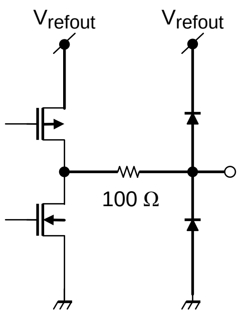
## Input/Output Equivalent Circuits

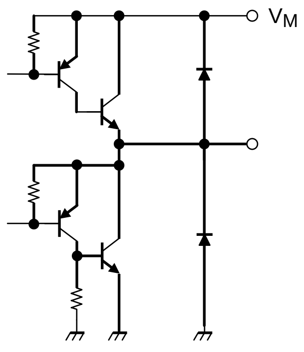
The equivalent circuit diagrams may be simplified or some parts of them may be omitted for explanatory purposes.

| 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><br>Hysteresis ± 7.5 mV (typ.) |   |
| Speed control signal input pin | $V_{SP}$ | Analog<br><br>Input range 0 to 7 V |   |
| Rotation direction signal input pin<br><br>L: Forward (CW)<br>H: Reverse (CCW) | CW/CCW | Digital<br><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><br>L: 150° turn-on mode<br>H: Reset | RESET | Digital<br><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><br>During a reset: Output OFF (all phases Low). The internal counter continues to operate. |   |
| Lead angle setting signal input | LA | Analog<br><br>Input range 0 to 5.0 V ($V_{refout}$)<br><br>Electrical angle 0° to 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 ($V_{refout}$) |   |

<table>
<tr><th>Pin Description</th><th>Symbol</th><th>Input/Output Signal</th><th>Input/Output Internal Circuit</th></tr>
<tr><td>Overcurrent protection signal input</td><td>RS</td><td>Analog<br><br>Analog filter 0.5 μs (typ.)<br><br>If RS = 0.5 V (typ.) or higher, UH, VH and WH pin goes low (released at carrier cycle)</td><td>


</td></tr>
<tr><td>Reference voltage signal output pin</td><td>$V_{refout}$</td><td>5.0 ± 0.5 V (35 mA)<br>5.0 ± 0.3 V (15 mA)</td><td>


</td></tr>
<tr><td>Rotational frequency output</td><td>FG</td><td>Digital<br><br>Push-pull output<br>(± 2 mA (max))<br><br>TB6586FG:<br>1 pulse / electrical angle of 360°<br>TB6586AFG:<br>3 pulses / electrical angle of 360°</td><td>


</td></tr>
<tr><td>Energization signal output</td><td>UH<br>UL<br>VH<br>VL<br>WH<br>WL</td><td>Push-pull output (± 3 mA (max))</td><td>


</td></tr>
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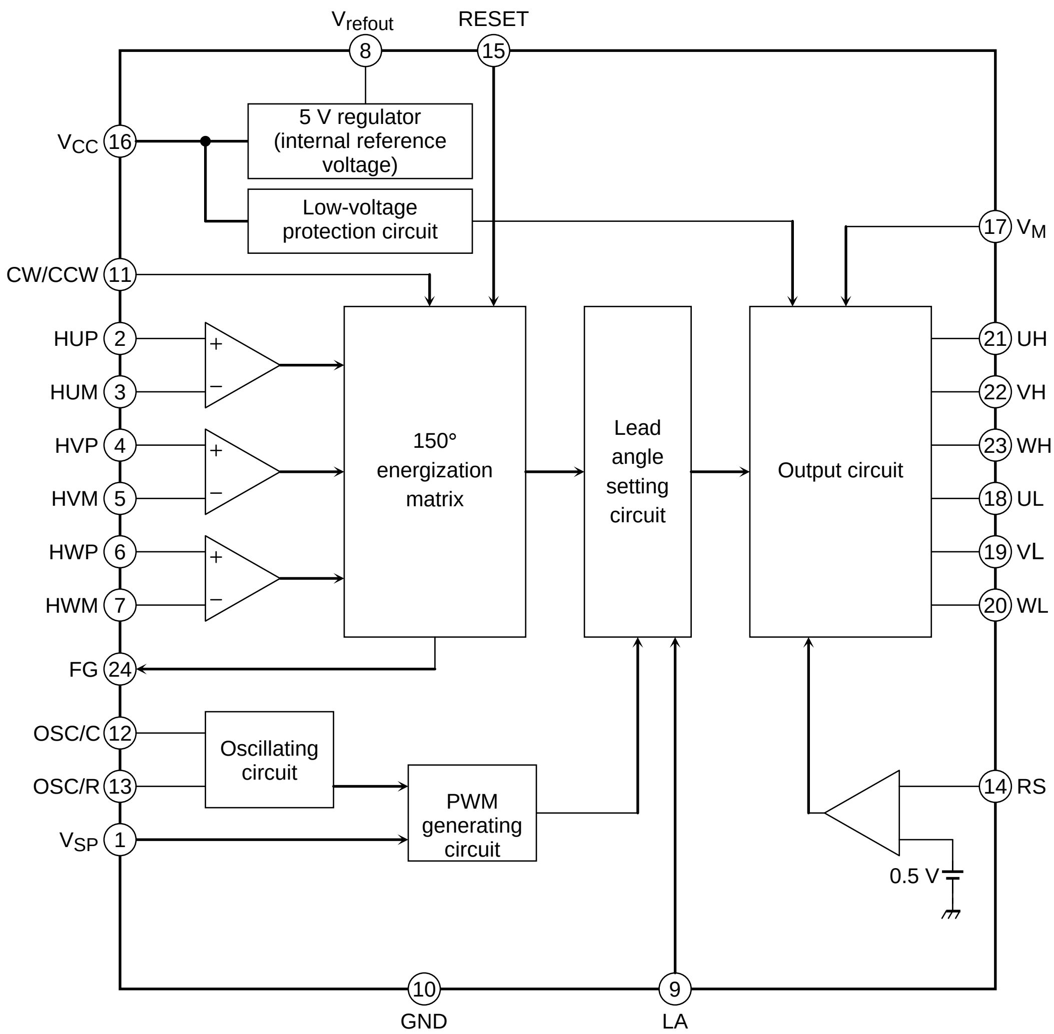
## Block Diagram

In the block diagram, part of the functional blocks or constants may be omitted or simplified for explanatory purposes.



## Absolute Maximum Ratings

| 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) | |
| | $V_{IN3}$ | −0.3 to $V_{refout}$ + 0.3 (Note 3) | |
| Turn-on signal output current | $I_{OUT}$ | 3 | mA |
| Power dissipation | $P_D$ | 0.8 (Note 4) | W |
| | | 1.0 (Note 5) | |
| Operating temperature | $T_{opr}$ | −30 to 115 | °C |
| Storage temperature | $T_{stg}$ | −55 to 150 | |

Note 1: CW/CCW, RESET

Note 2: $V_{SP}$

Note 3: LA

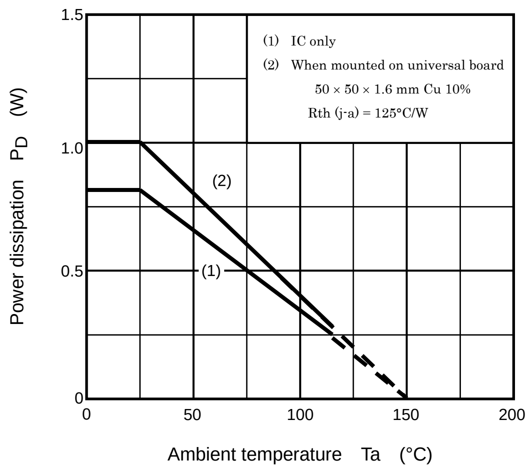
Note 4: No heatsink

Note 5: When mounted on a PCB (50 × 50 × 1.6 mm, Cu 10%)

## 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 |

$P_D$ – Ta



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

| Characteristic | | Symbol | | 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 | | $V_{IN(CW/CCW)}$ | RST | System reset | 6.0 | 6.35 | 7.1 | V |
| | | | High | CCW (Reverse) | $V_{refout}$ − 1 | — | $V_{refout}$ | |
| | | | Low | CW (Forward) | 0 | — | 0.8 | |
| | | $V_{IN(RESET)}$ | RST | 120° energization | 6.0 | 6.35 | 7.1 | V |
| | | | High | Output off reset | 2.2 | — | $V_{refout}$ | |
| | | | Low | 150° energization | 0 | — | 0.8 | |
| | | $V_{SP}$ | 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 | $VH_{(1)}$ | | (Note) | ± 4.5 | ± 7.5 | ± 10.5 | mV |
| Input hysteresis voltage | | $VH_{(2)}$ | | RESET: Reset ↔ 120° energization (Note) | — | 0.15 | — | V |
| | | $VH_{(3)}$ | | CW/CCW: CCW ↔ Reset (Note) | — | 0.15 | — | |
| Input delay | | $T_{RS}$ | | RS → Output OFF<br>RS input : 0V / 2V | — | 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 | 5.3 | |
| 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 operation start point | 5.7 | 6.0 | 6.3 | V |
| | | $V_{CC}$ (L) | | No output operation point | 4.7 | 5.0 | 5.3 | |
| | | $VH_{(4)}$ | | Input hysteresis width (Note) | — | 1.0 | — | |

Note: Pre-shipment testing is not performed.

| Characteristic | Symbol | 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 | % |

## 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°.

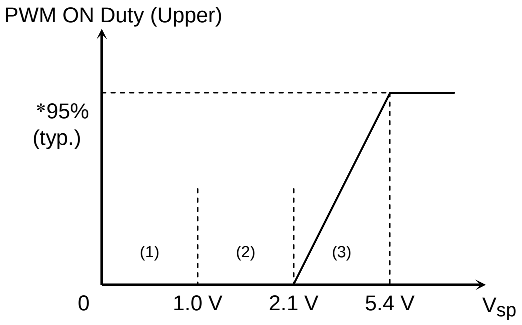
### 2. $V_{SP}$ voltage command signal function

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

(2) When voltage instruction is input at 1.0 V < $V_{SP} \le 2.1$ 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 on the lower transistor for a fixed time with 1.0 V < $V_{SP} \le 2.1$ V.

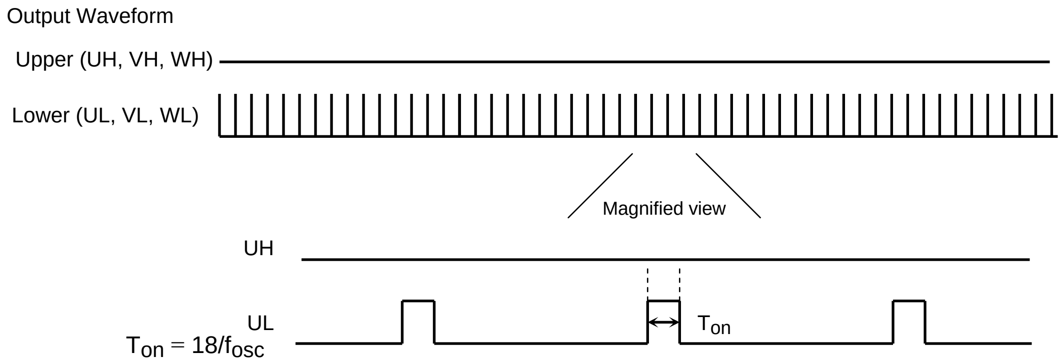



*: The maximum ON duty is $T_{on}$ = 95% (typ.) when $V_{SP}$ = 5.4 V (typ.).
Example: If $f_{osc}$ = 5 MHz, then ON time = 48 μs (typ.) ($f_c$ = 19.8 kHz)
If $f_{osc}$ = 4 MHz, then ON time = 60 μs (typ.) ($f_c$ = 15.9 kHz)

### 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 VSP input voltage is 1.0 V < VSP ≤ 2.1 V, the ON signal based on the carrier cycle is output to the lower phase (UL, VL, WL) and the OFF signal (Low) is output to the upper phase (UH, VH, WH).

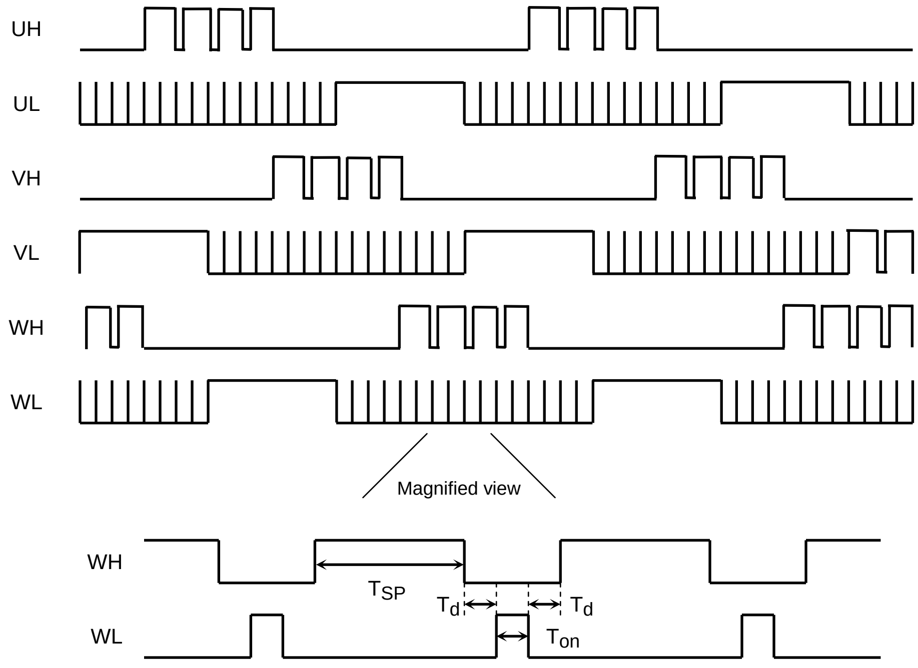



$T_{on} = 18/f_{osc}$

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

(2) If the $V_{SP}$ input voltage 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 reverse rotation 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)**:**

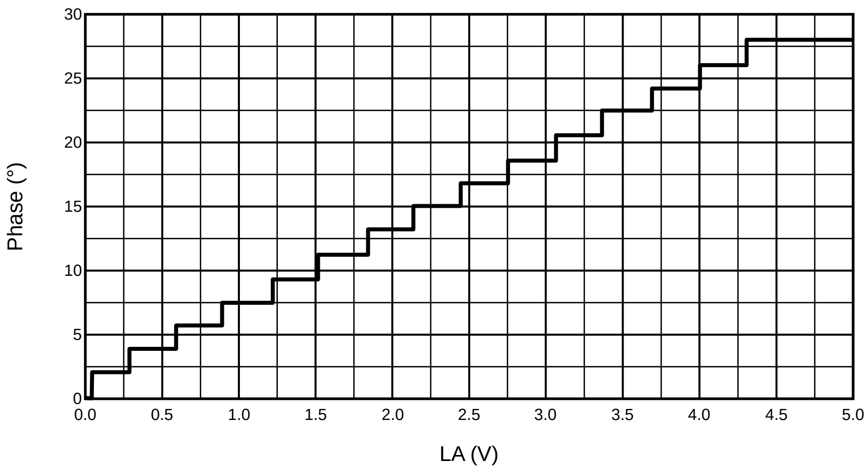
0 V = 0°

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 |

LA (V) − Lead Angle (°) Characteristic



## 5. Setting the carrier frequency

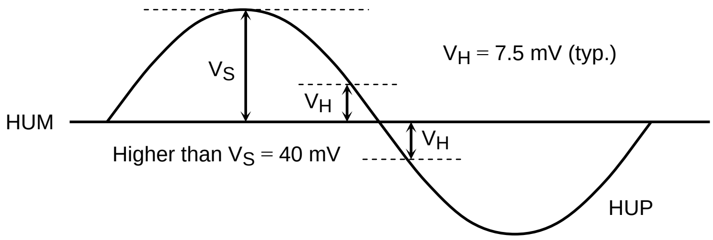
This function involves setting the triangular wave frequency (carrier frequency) necessary for generating PWM signals.

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

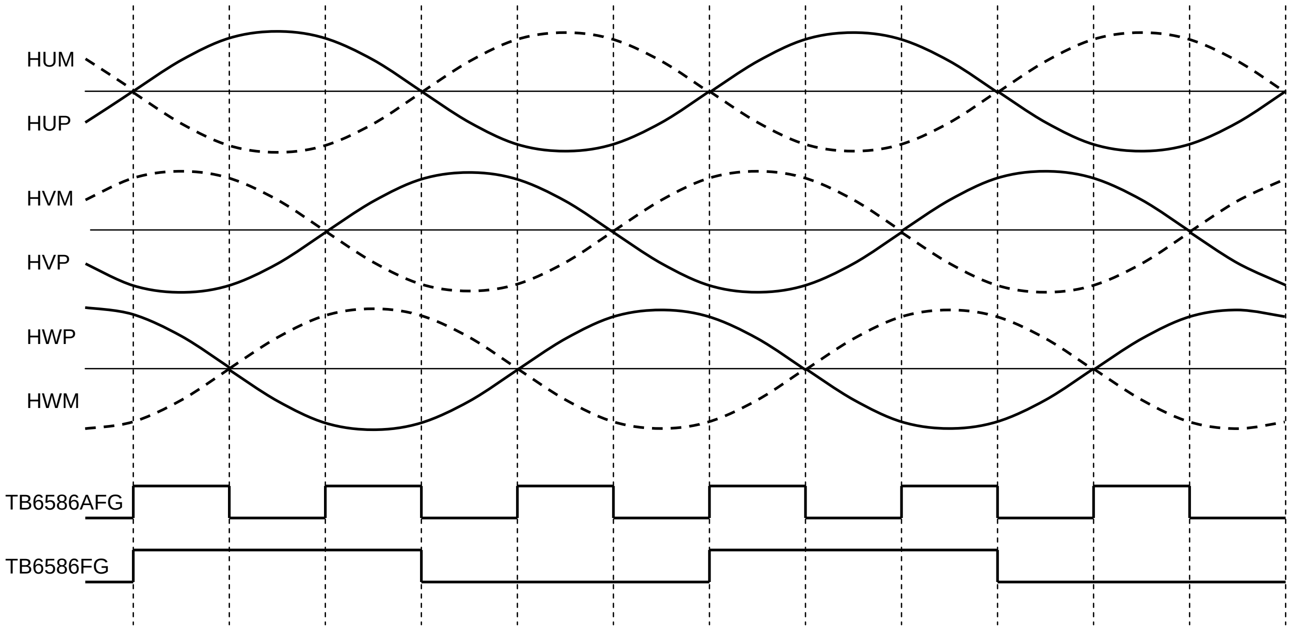



## 7. Revolution pulse output pin (the difference between TB6586FG and TB6586AFG)

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

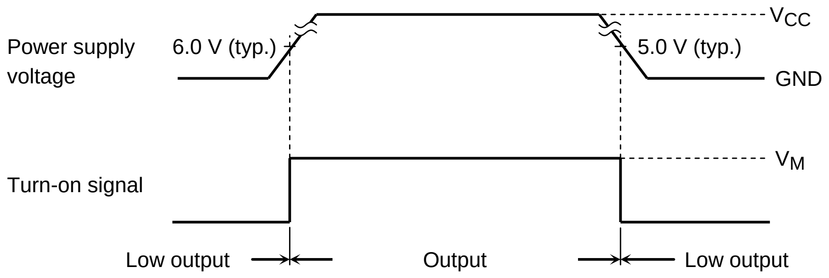


## 8. Protecting input pin

(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 cycle.
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.



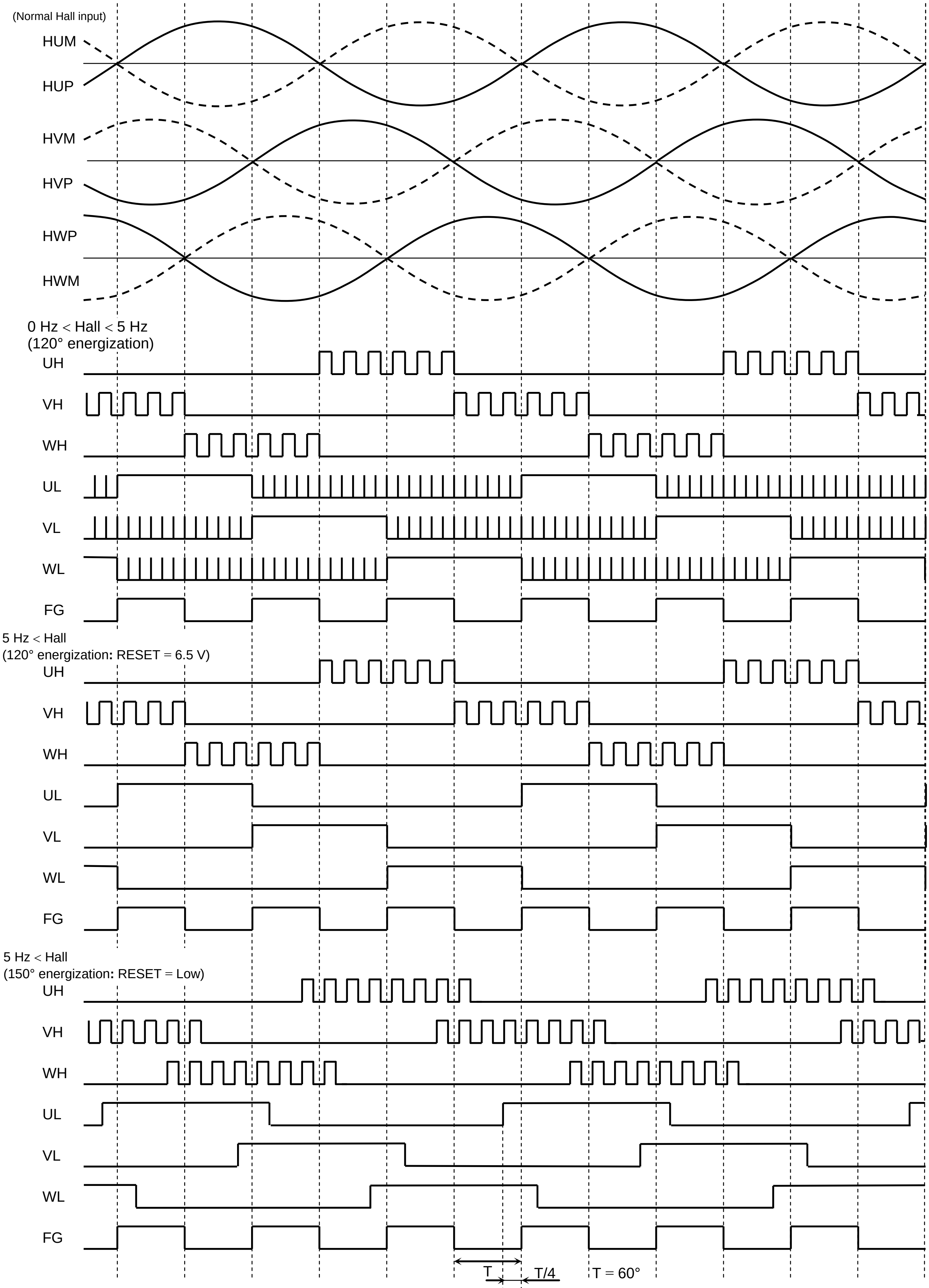

(4) Output pulse width restriction
To prevent damage to the output driver (externally attached), the drive output signals (UH, VH, WH, UL, VL, WL) are restricted from being output at a pulse width of 1 μs or less.

(5) Reset circuit
When 2.2 V (min) 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 0.8 V (max) 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.

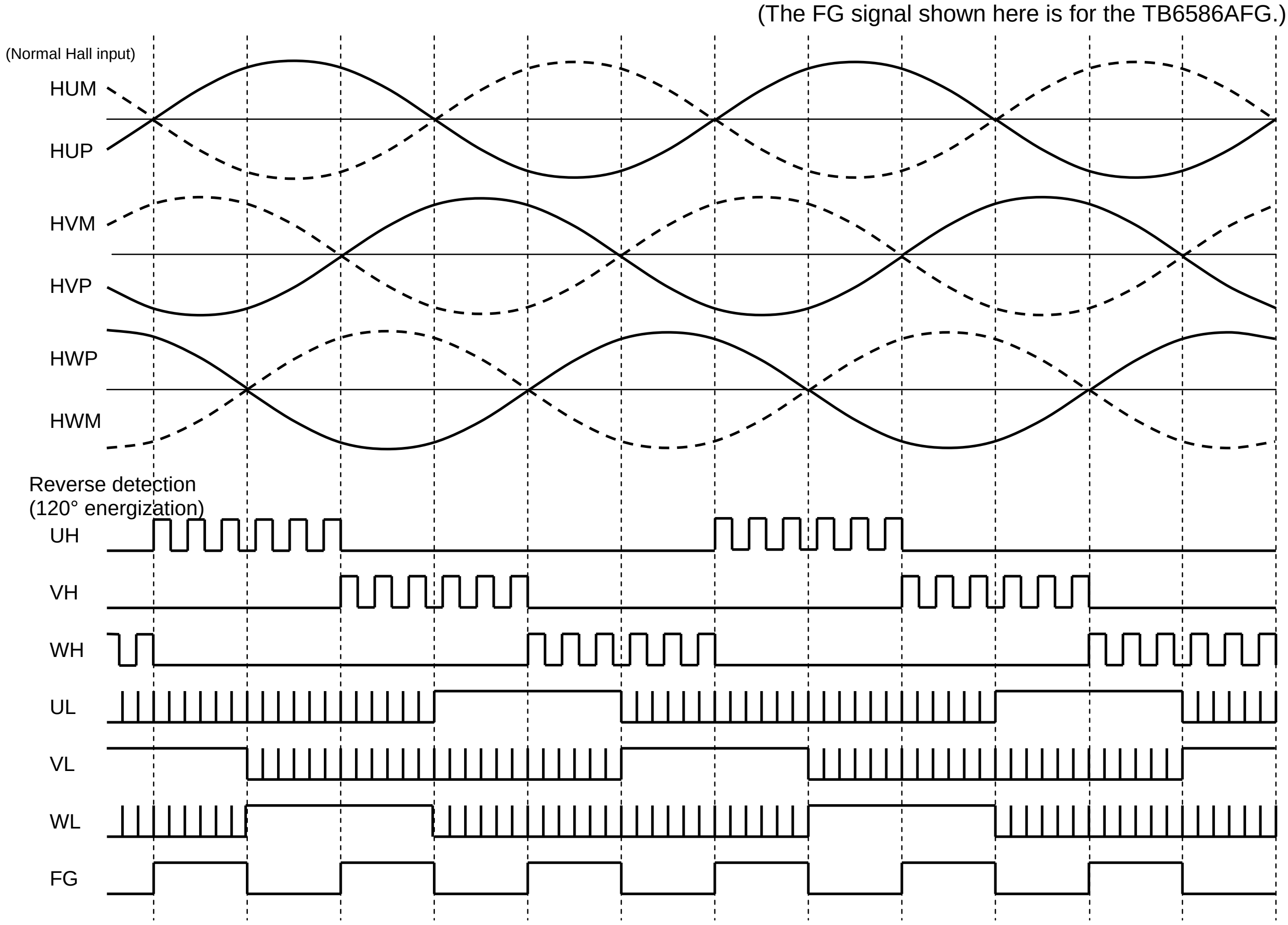
## Timing Chart (CW/CCW = Low, LA = GND)

(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.

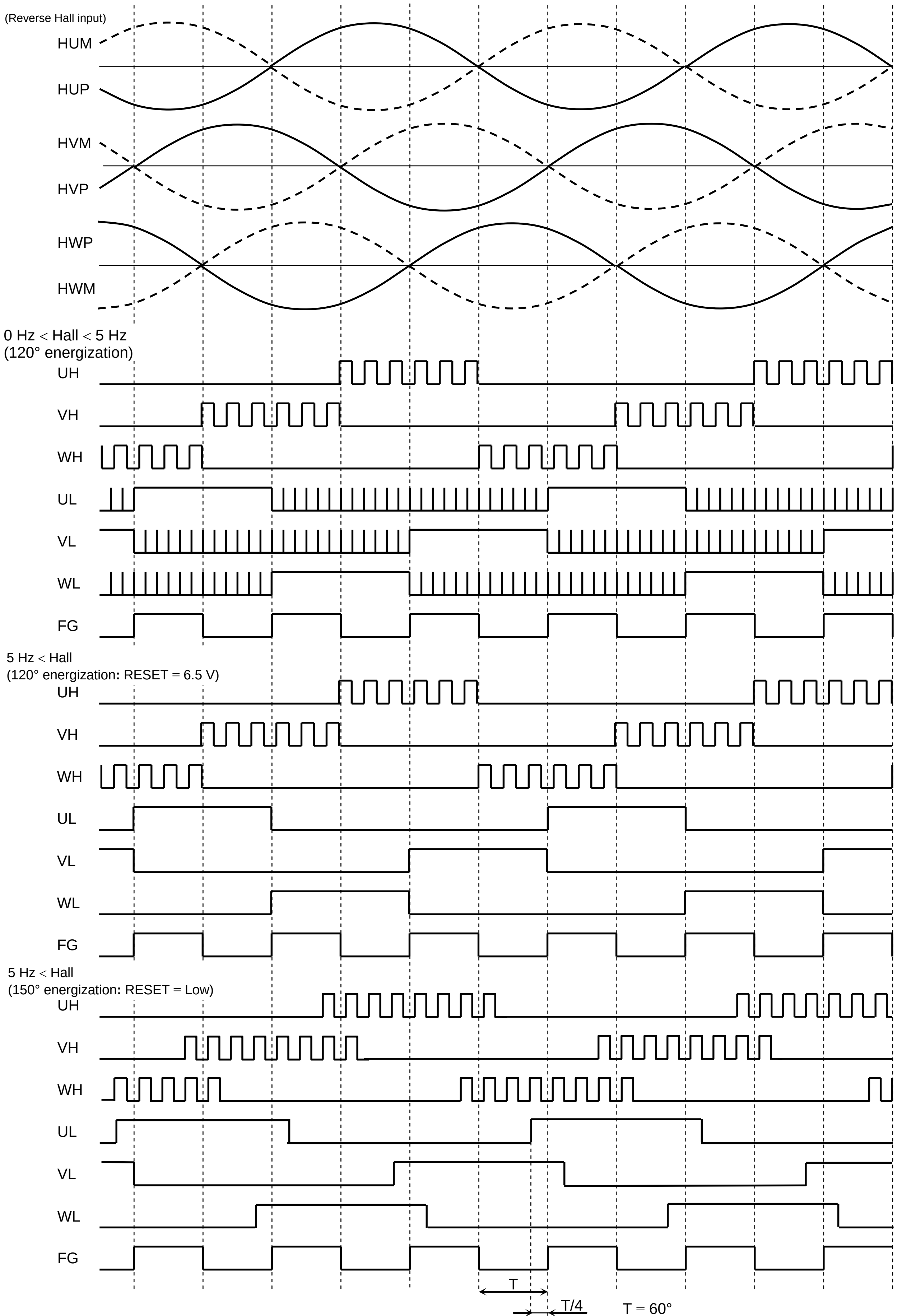
## Timing Chart (CW/CCW = High, LA = GND)




*: When CW/CCW = High and a normal Hall signal is input, it runs at 120° energization for a lead angle of 0° (reverse rotation).

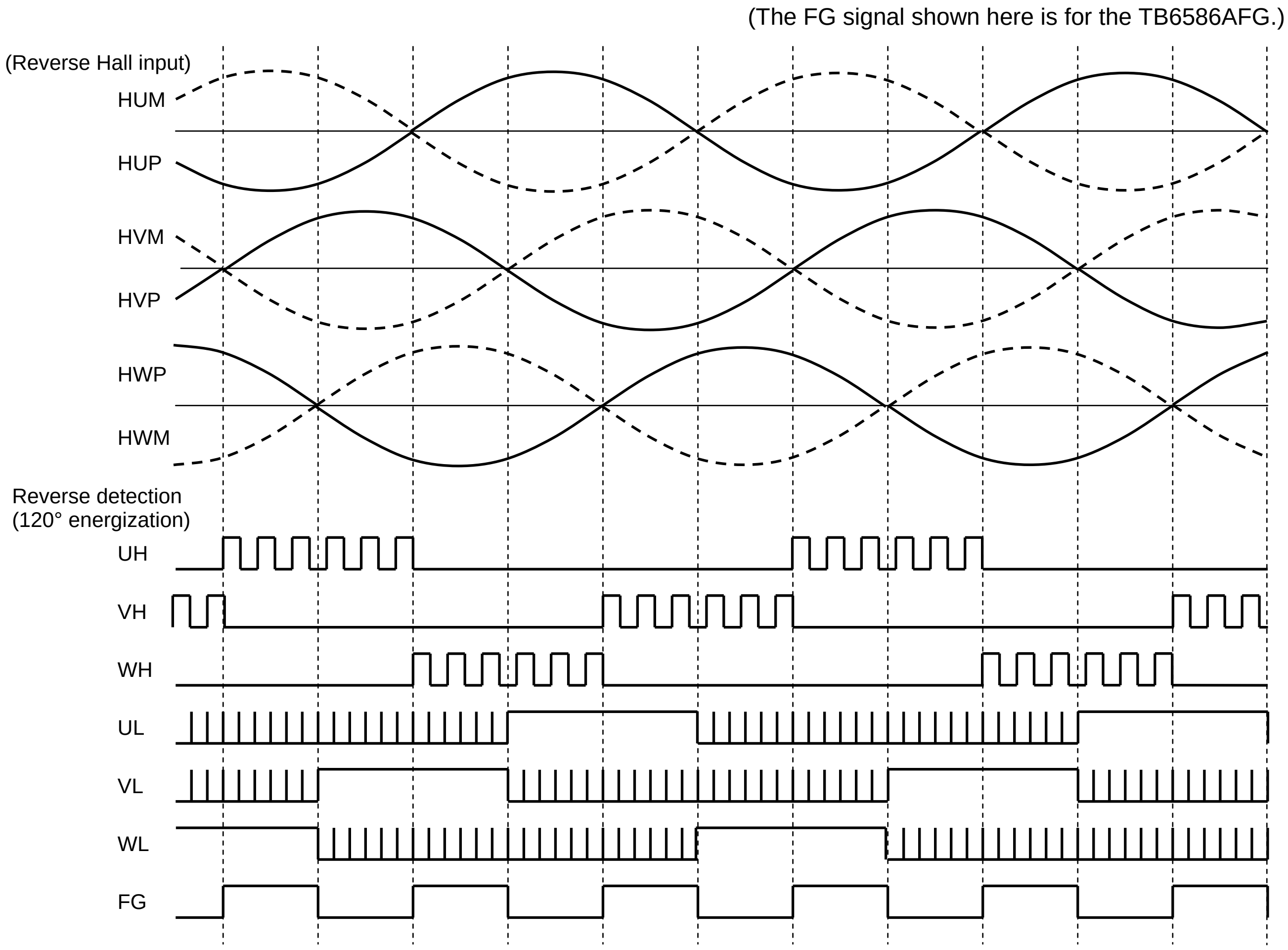
## Timing Chart (CW/CCW = High, LA = GND)

(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.

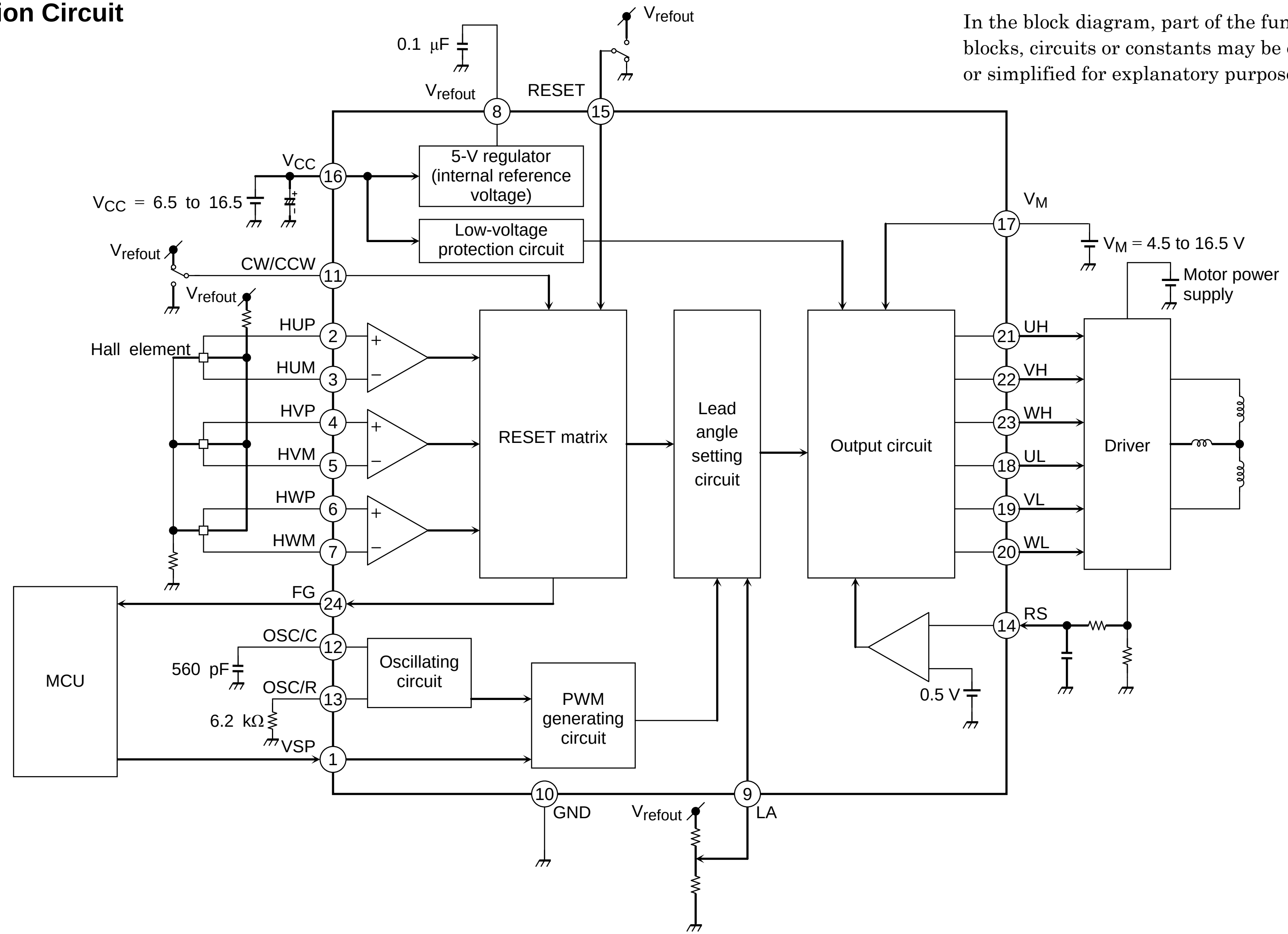
## Timing Chart (CW/CCW = Low, LA = GND)




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

## Example Application Circuit

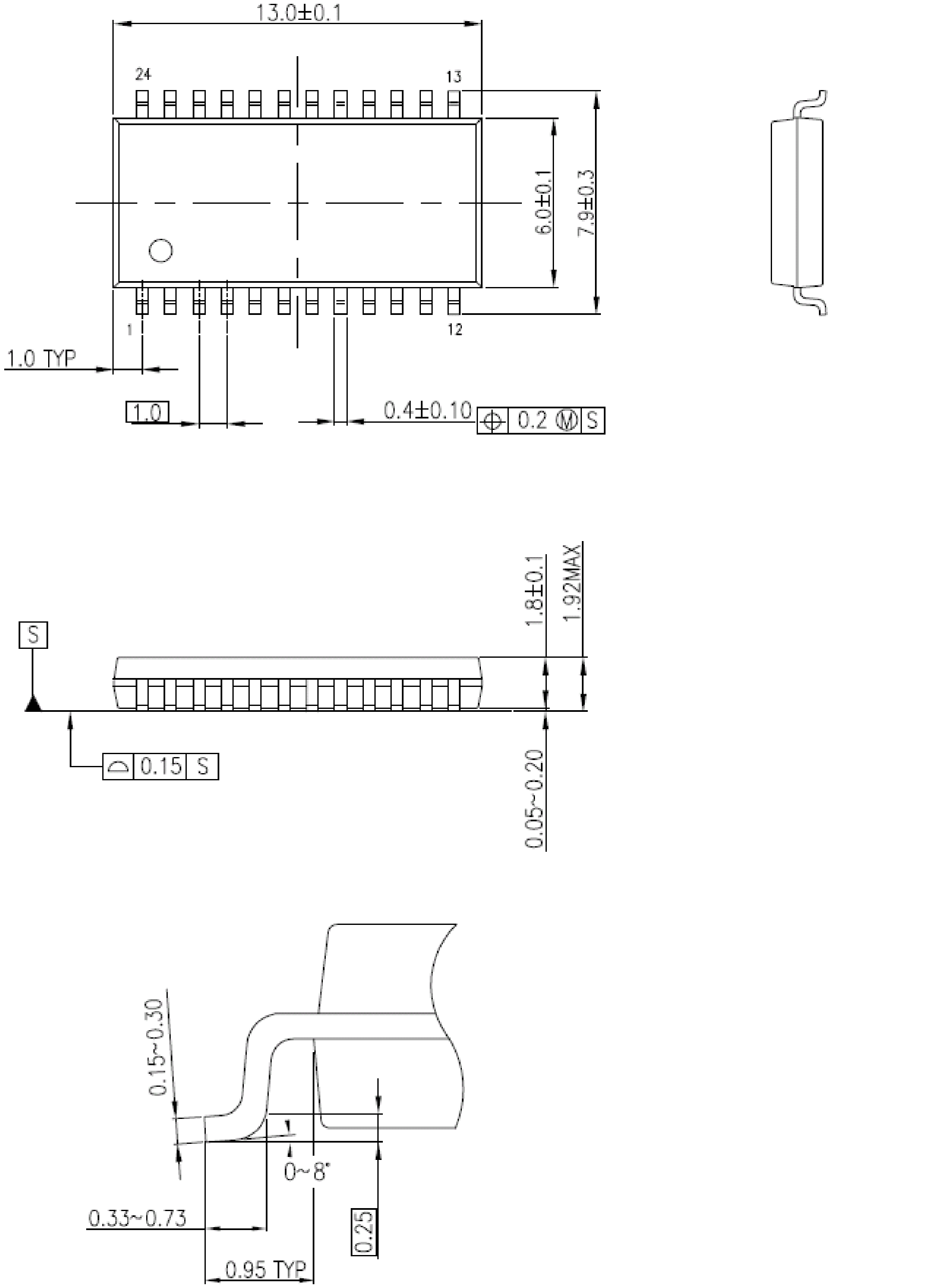
In the block diagram, part of the functional blocks, circuits or constants may be omitted or simplified for explanatory purposes.




Note: Utmost care is necessary in the design of the output, $V_{CC}$, $V_M$, and GND lines, since the IC may be destroyed by short-circuiting between outputs, short to VCC, short to VM or short to ground.
Add overcurrent protection such as a fuse to make the device drive normally should a current exceeding the maximum rating flow in the IC for any reason.

## Package Dimensions

P-SSOP24-0613-1.00-001 "Unit:mm"




Weight: 0.36 g (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. Application Circuits
The application circuits shown in this document are provided for reference purposes only. Thorough evaluation is required, especially at the mass production design stage.
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## IC Usage Considerations
### Notes on handling of ICs

[1] The absolute maximum ratings of a semiconductor device are a set of ratings that must not be exceeded, even for a moment. Do not exceed any of these ratings.
Exceeding the rating(s) may cause the device breakdown, damage or deterioration, and may result injury by explosion or combustion.

[2] Do not insert devices in the wrong orientation or incorrectly.
Make sure that the positive and negative terminals of power supplies are connected properly.
Otherwise, the current or power consumption may exceed the absolute maximum rating, and exceeding the rating(s) may cause the device breakdown, damage or deterioration, and may result injury by explosion or combustion.
In addition, do not use any device that is applied the current with inserting in the wrong orientation or incorrectly even just one time.

### Points to remember on handling of ICs

Heat Radiation Design
In using an IC with large current flow such as power amp, regulator or driver, please design the device so that heat is appropriately radiated, not to exceed the specified junction temperature ($T_J$) at any time and condition. These ICs generate heat even during normal use. An inadequate IC heat radiation design can lead to decrease in IC life, deterioration of IC characteristics or IC breakdown. In addition, please design the device taking into considerate the effect of IC heat radiation with peripheral components.

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- Консультации по применению компонента;
- Поставка образцов и прототипов;
- Техническая поддержка проекта;
- Защита от снятия компонента с производства.


## Как с нами связаться

**Телефон:** 8 (812) 309 58 32 (многоканальный)
**Факс:** 8 (812) 320-02-42
**Электронная почта:** org@eplast1.ru
**Адрес:** 198099, г. Санкт-Петербург, ул. Калинина, дом 2, корпус 4, литера А.