

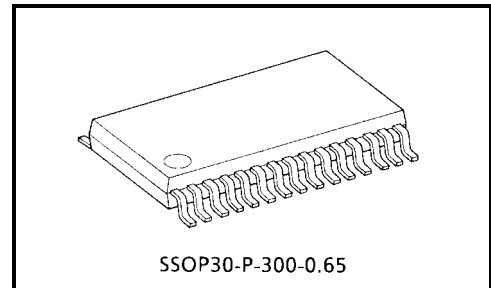
# TB6634FNG

## 3-Phase Full-Wave Sine-Wave PWM Brushless Motor Controller

The TB6634FNG is designed for motor fan applications for three-phase brushless DC (BLDC) motors.

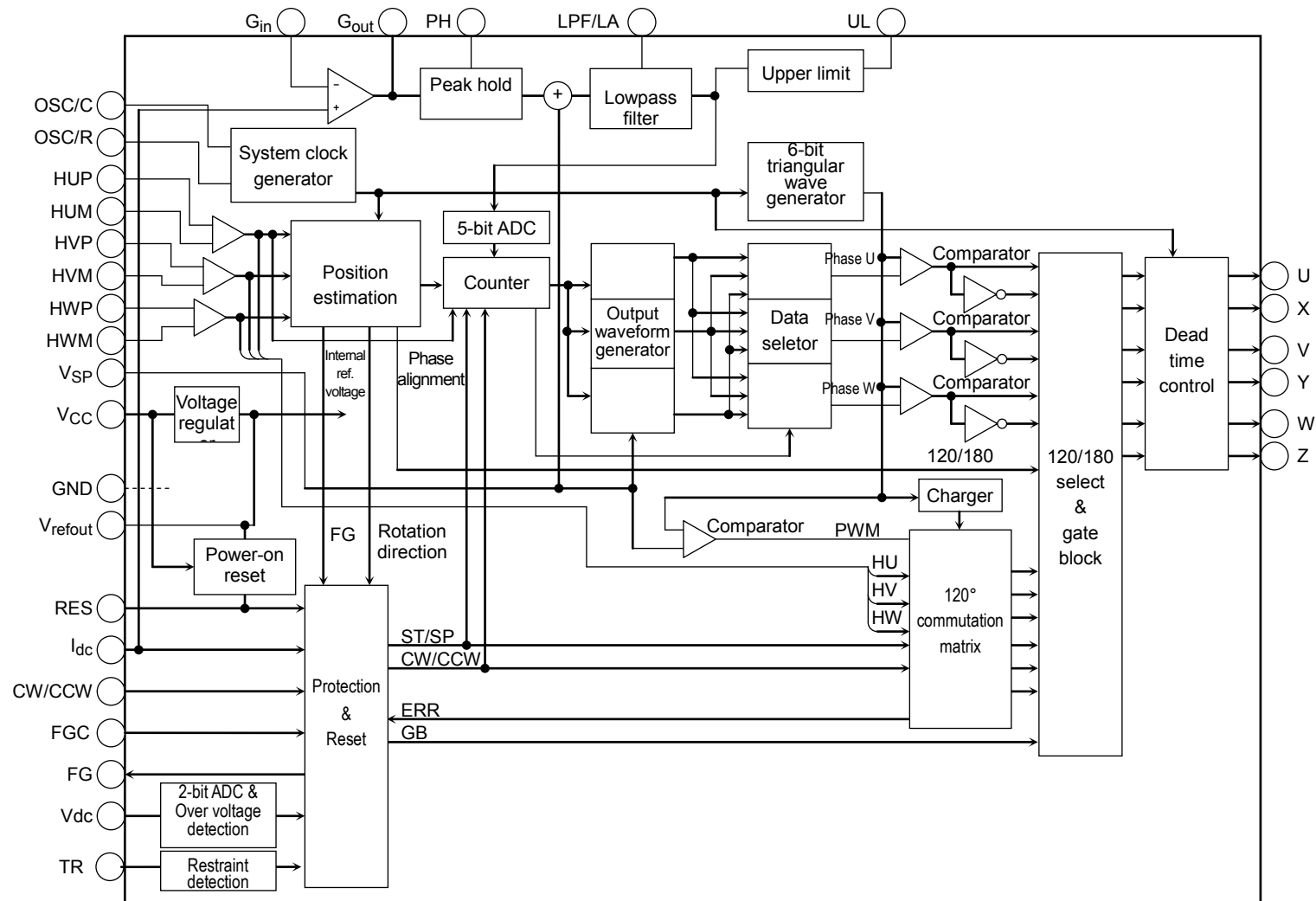
### Features

- Sine-wave PWM control
- Triangular-wave generator  
(with a carrier frequency of  $f_{OSC}/252$  Hz)
- Lead angle control ( $0^\circ$  to  $58^\circ$  in 32 separate steps)
- Lead angle external setting or automatic internal control
- Current-limiting input pin
- Voltage regulator ( $V_{refout} = 5$  V (typ.), 30 mA (max))
- Operating supply voltage range:  $V_{CC} = 6$  V to 16.5 V
- Motor restrained detection
- Motor supply voltage detection



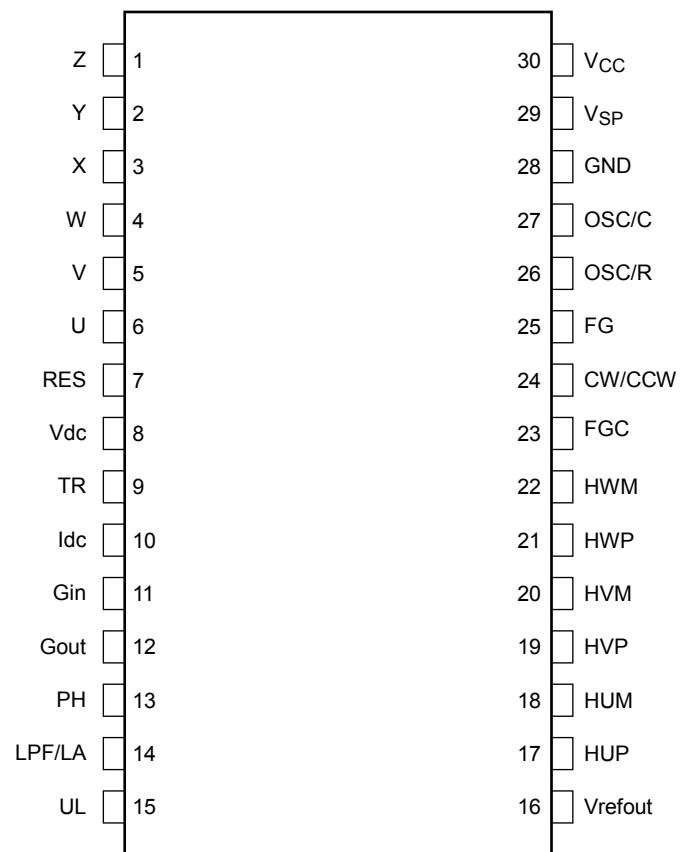
Weight: 0.17 g (typ.)

**Block Diagram**



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

**Pin Configuration**



## Pin Description

| Pin No. | Symbol          | Function  | Description   |
|---------|-----------------|---|---|
| 1       | Z               | Commutation signal output, Z (low-side of W-phase)  | High-active   |
| 2       | Y               | Commutation signal output, Y (low-side of V-phase)  |   |
| 3       | X               | Commutation signal output, X (low-side of U-phase)  |   |
| 4       | W               | Commutation signal output, W (high-side of W-phase) |   |
| 5       | V               | Commutation signal output, V (high-side of V-phase) |   |
| 6       | U               | Commutation signal output, U (high-side of U-phase) |   |
| 7       | RES             | Abnormal detection input                            | H: Runs the motor<br>L: Stops the motor. (The commutation output signals are forced Low.)<br>The RES input has an internal pull-down resistor.  |
| 8       | Vdc             | Motor supply voltage detection                      | Adjusting the number of steps addition of the lead angle by input voltage (2-bit AD)<br>Over voltage detection<br>Hysteresis: $\pm 0.1$ V (typ.)<br>3.9 V (typ.) or less: Runs the motor.<br>4.1 V (typ.) or more: Stops the motor (The commutation output signals are forced Low). |
| 9       | TR              | Motor restrained detection                          | Ratio of the driving term and the stopping term: 1:6.   |
| 10      | Idc             | Current limit control input                         | The DC-link current is applied to the Idc input. The reference voltage is 0.3 V. The Idc input has an internal RC filter and a digital filter.  |
| 11      | Gin             | Gain setting  | The G <sub>IN</sub> and G <sub>OUT</sub> pins are used to amplify the Idc level so that the lead angle will be optimal.   |
| 12      | Gout            |   |   |
| 13      | PH              | Peak hold   | A peak-hold capacitor and a discharge resistor are connected to this pin.   |
| 14      | LPF/LA          | Low pass filter/<br>Input lead angle setting        | Connecting the capacitor for RC low pass filter (Built-in resistance of 100 k $\Omega$ )<br>0° to 58° in 32 separate steps.   |
| 15      | UL              | Upper limit of lead angle                           | Setting upper limit of the lead angle (UL = 0 V to 5.0 V)   |
| 16      | Vrefout         | Reference voltage output                            | 5 V (typ.), 30 mA (max)<br>A capacitor for oscillation prevention is connected to the V <sub>refout</sub> output.   |
| 17      | HUP             | Position signal input, U                            | Gate block protection is activated when UVW = 111 or 000. These inputs have internal pull-up resistors and digital filters.   |
| 18      | HUM             |   |   |
| 19      | HVP             | Position signal input, V                            |   |
| 20      | HVM             |   |   |
| 21      | HWP             | Position signal input, W                            |   |
| 22      | HWM             |   |   |
| 23      | FGC             | FG output signal switch input                       | H or OPEN: FG = 3 ppr<br>L: FG = 1 ppr<br>The FGC input has an internal pull-up resistor.   |
| 24      | CW/CCW          | Clockwise/counterclockwise rotation                 | L: Clockwise rotation<br>H: Counterclockwise rotation<br>The CW/CCW input has an internal pull-up resistor.   |
| 25      | FG              | FG signal output                                    | FGC = H or OPEN: 3 ppr output.<br>FGC = L: 1 ppr output. <span style="float: right;">ppr: one pulse per electrical angle</span>   |
| 26      | OSC/R           | Oscillator resistor                                 | CR oscillation  |
| 27      | OSC/C           | Oscillator capacitor                                |   |
| 28      | GND             | Ground  | —   |
| 29      | V <sub>SP</sub> | Voltage command input                               | The V <sub>SP</sub> input has an internal pull down resistor.   |
| 30      | V <sub>CC</sub> | Power supply  | V <sub>CC</sub> = 6 to 16.5 V   |

**Input/Output Equivalent Circuits**

Equivalent circuit diagrams may be partially omitted or simplified for explanatory purposes.

| Pin   | Symbol                                 | Input/Output Signal   | Internal Circuit |
|---|--|---|------------------|
| Position signal input U<br>Position signal input V<br>Position signal input W | HUP<br>HUM<br>HVP<br>HVM<br>HWP<br>HWM | Analog<br>Hysteresis: $\pm 10.5$ mV (typ.)<br><br>Built-in digital filter<br>4 CLK@f <sub>OSC</sub>   |                  |
| Clockwise/counterclockwise rotation   | CW/CCW                                 | Digital<br>H: V <sub>refout</sub> - 1 V (min)<br>L: 0.8 V (max)<br><br>H/open: Counterclockwise (CCW)<br>L: Clockwise (CW)  |                  |
| Abnormal detection  | RES                                    | Hysteresis comparator<br>Hysteresis $\pm 0.1$ V (typ.)<br>Built-in digital filter 4 CLK@f <sub>OSC</sub><br><br>H: 2.6 V (typ.) or more.<br>L: 2.4 V (typ.) or less.<br>H: Runs the motor<br>L/open: Stops the motor (The commutation output signals are forced Low.)   |                  |
| FG output signal switch input   | FGC                                    | Digital<br>H: V <sub>refout</sub> - 1 V (min)<br>L: 0.8 V (max)<br><br>H/open: FG = 3 ppr<br>L: FG = 1 ppr  |                  |
| Voltage command signal  | VSP                                    | Analog<br>Input range: 0 to 10 V  |                  |
| Motor supply voltage detection  | V <sub>dc</sub>                        | Adjusting the number of steps<br>addition of the lead angle by input<br>voltage (2-bit AD)<br>Hysteresis $\pm 0.1$ V (typ.)<br>Over voltage detection<br>Hysteresis $\pm 0.1$ V (typ.)<br>Built-in digital filter 4 CLK@f <sub>OSC</sub><br>4.1 V (typ.) or more: Stops the<br>motor.<br>(Gate block protection)<br>3.9 V (typ.) or less: Runs the motor. |                  |

| Pin   | Symbol                              | Input/Output Signal   | Internal Circuit |
|---|-------------------------------------|---|------------------|
| Gain setting<br>(Lead angle control circuitry)                                | G <sub>in</sub><br>G <sub>out</sub> | Non-inverting amplifier<br>25 dB max<br>G <sub>out</sub> output voltage<br>Low: GND<br>High: V <sub>CC</sub> - 1.7 V  |                  |
| Peak hold<br>(Lead angle control circuitry)                                   | PH                                  | A peak-hold capacitor and a discharge resistor are connected to the PH pin.<br>Recommended R/C: 100 kΩ/0.1 μF   |                  |
| Lowpass filter/<br>Lead angle control input<br>(Lead angle control circuitry) | LPF/LA                              | A capacitor for the RC lowpass filter is connected to this pin.<br>A 100-kΩ (typ.) resistor is contained on-chip.<br>Recommended C value: 0.1 μF<br><br>In case lead angle is fixed externally,<br>UL is connected to V <sub>refout</sub> . Setting voltage is input to LA pin.<br>Input range 0 to 5.0 V (V <sub>refout</sub> )<br>Input voltage of V <sub>refout</sub> or more is fixed to maximum lead angle of 58°.<br><br>Lead angle (5-bit AD)<br>0 V: 0°<br>5 V: 58° |                  |
| Upper limit for LA  | UL                                  | If the voltage applied to the LA input exceeds the upper limit set by this input, it is clipped to limit the lead angle.<br>UL = 0 to 5.0 V   |                  |
| Current limit control input   | Idc                                 | Analog filter time constant 1 μs (typ.)<br>Digital filter 5 CLK@f <sub>OSC</sub><br>When the Idc voltage exceeds 0.3 V (typ.), the commutation signal outputs low. (It is deactivated after a carrier cycle)<br>If Ids is open, all the commutation outputs are disabled.   |                  |

| Pin  | Symbol                     | Input/Output Signal   | Internal Circuit |
|--|----------------------------|---|------------------|
| Reference voltage output   | V <sub>refout</sub>        | 5 ± 0.5 V (30 mA (max))   |                  |
| Motor restrained detection   | TR                         | Capacitor connection for motor restrained detection<br>0.01 μF:<br>Run: Stop (The commutation signal outputs low.)<br>= 5 s: 30 s                           |                  |
| FG signal output   | FG                         | Digital<br>Push-pull output (±1 mA (max))<br>FGC = H/open<br>3 PPR output (3 pulses/electrical angle)<br>FGC = L<br>1 PPR output (1 pulse/electrical angle) |                  |
| Commutation signal output U<br>Commutation signal output V<br>Commutation signal output W<br>Commutation signal output X<br>Commutation signal output Y<br>Commutation signal output Z | U<br>V<br>W<br>X<br>Y<br>Z | Digital<br>Push-pull output (± 2 mA (max))<br>L: 0.78 V (max)<br>H: V <sub>refout</sub> - 0.78 V (min)  |                  |

## Absolute Maximum Ratings (Ta = 25°C)

| Characteristics                    | Symbol              | Rating                                    | Unit |
|------------------------------------|---------------------|---|------|
| Supply voltage                     | V <sub>CC</sub>     | 18  | V    |
| Input voltage                      | V <sub>IN1</sub>    | -0.3 to V <sub>CC</sub> (Note 1)          | V    |
|                                    | V <sub>IN2</sub>    | -0.3 to V <sub>refout</sub> +0.3 (Note 2) |      |
| Output voltage                     | V <sub>out</sub>    | V <sub>refout</sub> +0.3 (Note 3)         | V    |
| Input/Output voltage               | V <sub>inout</sub>  | V <sub>CC</sub> (Note 4)                  |      |
| Output current                     | I <sub>OUT1</sub>   | 1 (Note 5)                                | mA   |
|                                    | I <sub>OUT2</sub>   | 2 (Note 3)                                | mA   |
| V <sub>refout</sub> output current | I <sub>refout</sub> | 30 (Note 6)                               | mA   |
| Power dissipation                  | P <sub>D</sub>      | 1.1 (Note 7)                              | W    |
| Operating temperature              | T <sub>opr</sub>    | -30 to 115 (Note 8)                       | °C   |

Note 1: V<sub>IN 1</sub> pin: V<sub>SP</sub>

Note 2: V<sub>IN 2</sub> pins:

HUP, HVP, HWP, HUM, HVM, HWM CW/CCW, RES, Idc, FGC, Gin, TR, OSC/R, OSC/C, and Vdc

Note 3: U, V, W, X, Y, and Z

Note 4: Gout, PH, LPF/LA, and UL

Note 5: FG

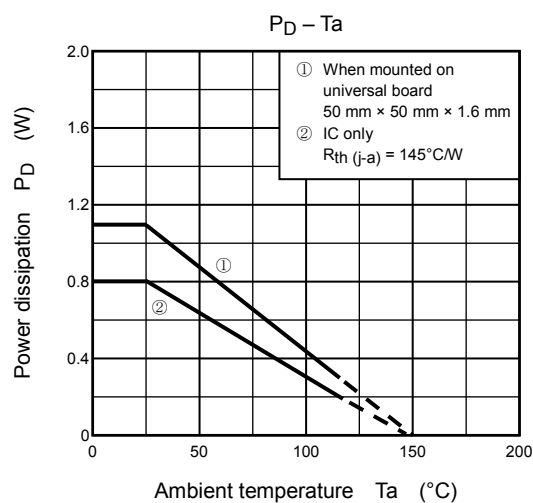
Note 6: Since the V<sub>refout</sub> pin delivers a maximum output current of 30 mA, care should be exercised to the output impedance.

Note 7: When mounted on a universal board (50 mm × 50 mm × 1.6 mm, Cu 40 %)

Note 8: The operating temperature range is determined by the P<sub>D</sub> - Ta characteristics.

## Operating Ranges (Ta = 25°C)

| Characteristics       | Symbol           | Min | Typ. | Max  | Unit |
|-----------------------|------------------|-----|------|------|------|
| Supply voltage        | V <sub>CC</sub>  | 6   | 15   | 16.5 | V    |
| Oscillation frequency | F <sub>osc</sub> | 3   | 4.5  | 6    | MHz  |





## Electrical Characteristics (Ta = 25°C, VCC = 15 V)

| Characteristics                         |                           | Symbol         | Test Condition  | Min  | Typ.               | Max              | Unit    |              |   |
|---|---------------------------|----------------|---|--|--------------------|------------------|---------|--------------|---|
| Supply current                          |                           | $I_{CC}$       | $V_{refout} = OPEN$   | —  | 6                  | 9                | mA      |              |   |
| Input current                           |                           | $I_{IN1}$      | $V_{IN} = 5 V \quad V_{SP}$   | —  | 35                 | 70               | $\mu A$ |              |   |
|   |                           | $I_{IN2}$      | $V_{IN} = 5 V \quad RES$  | —  | 50                 | 100              |         |              |   |
|   |                           | $I_{IN3}$      | $V_{IN} = 0 V \quad CW/CCW, FGC$  | -100                                       | -50                | —                |         |              |   |
| Input voltage                           |                           | $V_{IN}$       | H   | RES Stop → Drive                           | 2.4                | 2.6              | 2.8     | V            |   |
|   |                           |                | L   | RES Drive → Stop                           | 2.2                | 2.4              | 2.6     |              |   |
|   |                           |                | Hys   | RES  | —                  | ±0.1             | —       |              |   |
|   |                           | $V_{IN}$       | High  | CW/CCW, FGC                                |                    | $V_{refout} - 1$ | —       | $V_{refout}$ | V |
|   |                           |                | Low   |  |                    | —                | —       | 0.8          |   |
|   |                           | $V_{SP}$       | T   | Sine-wave commutation ON duty = 92% (typ.) | 8.2                | —                | 10      | V            |   |
|   |                           |                | H   | PWM duty 92%                               | 5.1                | 5.4              | 5.7     |              |   |
|   |                           |                | M   | Refresh → Motor startup                    | 1.8                | 2.1              | 2.4     |              |   |
| L                                       | Commutation OFF → Refresh |                | 0.7   | 1.0  | 1.3                |                  |         |              |   |
| Hall effect inputs                      | Input sensitivity         | $V_S$          | Differential inputs   | 40   | —                  | —                | mVpp    |              |   |
|   | Common-mode input voltage | $V_W$          |   | 1.5  | —                  | 3.5              | V       |              |   |
|   | Input hysteresis          | $V_H$          | Reference data (Note 1)   | 3  | 10.5               | 21               | mV      |              |   |
| Input delay time                        |                           | $T_{DT}$       | Hall sensor inputs (fOSC = 4.5 MHz)   | —  | 1.0                | —                | $\mu s$ |              |   |
|   |                           | $T_{DC}$       | $I_{dc}$ (fOSC = 4.5 MHz)   | —  | 2.0                | —                |         |              |   |
| Output voltage                          |                           | $V_{OUT(H)-1}$ | $I_{OUT} = 2 mA \quad U, V, W, X, Y, Z$   | $V_{refout} - 0.78$                        | $V_{refout} - 0.3$ | —                | V       |              |   |
|   |                           | $V_{OUT(L)-1}$ | $I_{OUT} = -2 mA \quad U, V, W, X, Y, Z$  | —  | 0.3                | 0.78             |         |              |   |
|   |                           | $V_{FG(H)}$    | $I_{OUT} = 1 mA \quad FG$   | $V_{refout} - 1.0$                         | $V_{refout} - 0.2$ | —                |         |              |   |
|   |                           | $V_{FG(L)}$    | $I_{OUT} = -1 mA \quad FG$  | —  | 0.2                | 1.0              |         |              |   |
|   |                           | $V_{refout}$   | $I_{OUT} = 30 mA \quad V_{refout}$  | 4.5  | 5.0                | 5.5              |         |              |   |
| Output leakage current                  |                           | $I_L(H)$       | $V_{OUT} = 0 V \quad U, V, W, X, Y, Z$  | —  | 0                  | 10               | $\mu A$ |              |   |
|   |                           | $I_L(L)$       | $V_{OUT} = V_{refout} \quad U, V, W, X, Y, Z$   | —  | 0                  | 10               |         |              |   |
| Dead time (cross conduction protection) |                           | $T_{OFF}$      | (fOSC = 4.5 MHz),<br>$I_{OUT} = \pm 2 mA$ ,   | 1.7  | 2.0                | 2.3              | $\mu s$ |              |   |
| Current limit detection voltage         |                           | $V_{Idc}$      | $I_{dc}$  | 0.285                                      | 0.3                | 0.315            | V       |              |   |
| LA gain setting amp                     |                           | $AMP_{OUT}$    | $G_{IN}, G_{OUT} 100 k\Omega/10 k\Omega$<br>$I_{dc} = Input 0.2 V \quad I_{OUT} = 1 mA$ | 2.0  | 2.2                | 2.4              | V       |              |   |
|   |                           | $AMP_{OFS}$    | $G_{IN}, G_{OUT} 100 k\Omega/10 k\Omega \quad I_{dc} = Input 0.2 V$                     | —  | 5                  | —                | mV      |              |   |
| LA limit setting error                  |                           | $T_{UL(2.5)}$  | UL = 2.5 V, Hall IN = 100 Hz  | 26   | 30                 | 33               | °       |              |   |
| LA peak hold output voltage             |                           | $PHOUT$        | $G_{IN}, G_{OUT} 100 k\Omega/10 k\Omega$<br>$I_{dc} = Input 0.2 V \quad I_{OUT} = 5 mA$ | 2.0  | 2.2                | 2.4              | V       |              |   |
| Lead angle correction                   |                           | $T_{LA(0)}$    | LPF/LA = 0 V, Hall IN = 100 Hz  | —  | 0                  | —                | °       |              |   |
|   |                           | $T_{LA(2.5)}$  | LPF/LA = 2.5 V, Hall IN = 100 Hz  | 26   | 30                 | 33               |         |              |   |
|   |                           | $T_{LA(5)}$    | LPF/LA = 5 V, Hall IN = 100 Hz  | 52   | 57                 | 60               |         |              |   |

| Characteristics                                  | Symbol                | Test Condition   | Min   | Typ.  | Max   | Unit |
|--|-----------------------|--|-------|-------|-------|------|
| V <sub>CC</sub> monitor                          | V <sub>CC</sub> (H)   | Output turn-on threshold                                 | 4.2   | 4.5   | 4.8   | V    |
|  | V <sub>CC</sub> (L)   | Output turn-off threshold                                | 3.7   | 4.0   | 4.3   |      |
|  | V <sub>H</sub>        | Input hysteresis width                                   | —     | 0.5   | —     |      |
| PWM oscillation frequency<br>(Carrier frequency) | F <sub>C</sub> (20)   | OSC/C = 330 pF, OSC/R = 9.1 kΩ                           | 18.45 | 20.5  | 22.55 | kHz  |
|  | F <sub>C</sub> (18)   | OSC/C = 330 pF, OSC/R = 10 kΩ                            | 16.65 | 18.5  | 20.35 |      |
| Maximum conduction duty cycle                    | T <sub>on</sub> (max) | OSC/C = 330 pF, OSC/R = 10 kΩ<br>V <sub>SP</sub> = 5.7 V | 89    | 92    | 95    | %    |
| Motor restrained detection                       | TONTR                 | TR = 0.01 μF Drive time<br>Reference data (Note 1)       | 3.33  | 4.76  | 8.33  | s    |
|  | TOFFTR                | TR = 0.01 μF Stop time<br>Reference data (Note 1)        | 20    | 28.57 | 50    | s    |
|  | FTR                   | TR = 0.01 μF Frequency                                   | 65    | 105   | 150   | Hz   |
| Motor supply voltage detection                   | V <sub>dc3H</sub>     | V <sub>dc</sub> Lead angle + 5.625° → Stop               | 3.9   | 4.1   | 4.3   | V    |
|  | V <sub>dc3L</sub>     | V <sub>dc</sub> Stop → Lead angle + 5.625°               | 3.7   | 3.9   | 4.1   | V    |
|  | V <sub>dc2H</sub>     | V <sub>dc</sub> Lead angle + 3.75° → Lead angle + 5.625° | 2.9   | 3.1   | 3.3   | V    |
|  | V <sub>dc2L</sub>     | V <sub>dc</sub> Lead angle + 5.625° → Lead angle + 3.75° | 2.7   | 2.9   | 3.1   | V    |
|  | V <sub>dc1H</sub>     | V <sub>dc</sub> Lead angle + 1.875° → Lead angle + 3.75° | 2.5   | 2.7   | 2.9   | V    |
|  | V <sub>dc1L</sub>     | V <sub>dc</sub> Lead angle + 3.75° → Lead angle + 1.875° | 2.3   | 2.5   | 2.7   | V    |
|  | V <sub>dc0H</sub>     | V <sub>dc</sub> Lead angle + 0° → Lead angle + 1.875°    | 2.1   | 2.3   | 2.5   | V    |
|  | V <sub>dc0L</sub>     | V <sub>dc</sub> Lead angle + 1.875° → Lead angle + 0°    | 1.9   | 2.1   | 2.3   | V    |
|  | V <sub>dchys</sub>    | V <sub>dc</sub> Input hysteresis width                   | —     | ±100  | —     | mV   |

Note 1: Not tested in production

## Function Description

### 1. Basic Operation

In startup, the motor is driven by square-wave commutation signals that are generated according to the position signals. When the position signals indicate a rotational speed ( $f$ ) of 1 Hz, the TB6634FNG estimates the rotor positions from the position signals and modulate them. The TB6634FNG then generates sine-wave by comparing the modulated signals against a triangular waveform.

From startup to 1 Hz: square-wave drive (120° commutation);  $f = f_{OSC}/(750000 \times 6)$

Over 1 Hz: Sine-wave PWM drive (180° commutation);  $f$  will be approximately 1 Hz when  $f_{OSC} = 4.5$  MHz

### 2. Voltage Command ( $V_{SP}$ ) Signal and Bootstrap Voltage Regulation

- (1) When  $V_{SP} \leq 1.0$  V:

The commutation signal outputs are disabled (i.e., gate protection is activated).

- (2) When  $1.0$  V  $< V_{SP} \leq 2.1$  V:

The low-side transistors are turned on at a regular (PWM carrier) frequency. (The conduction duty cycle is approx. 8 %.) (Refresh)

- (3) When  $2.1$  V  $< V_{SP} \leq 7.3$  V:

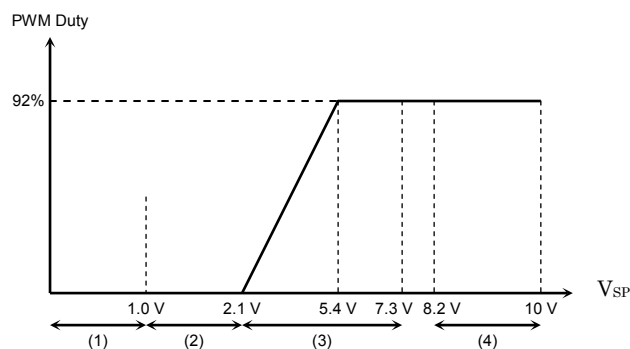
During sine-wave PWM drive, the commutation signals directly appear externally. During square-wave drive, the low-side transistors are forced on at a regular (PWM carrier) frequency. (The conduction duty cycle is approx. 8 %.)

- (4) When  $8.2$  V  $\leq V_{SP} \leq 10$  V (test mode):

The TB6634FNG operates in sine-wave mode at lead angle of zero. However, it operates in square-wave mode while it detects upwind.

The drive mode switches from square-wave drive to sine-wave PWM at a  $V_{SP}$  of 7.9 V typical.

The conduction duty cycle keeps the state as follows; 5.4 V typical  $\leq V_{SP}$ . It is calculated as PWM\_carrier\_frequency  $\times$  92 % typical.

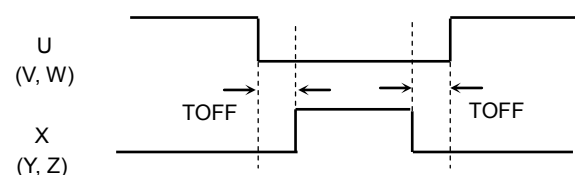


### 3. Dead Time Insertion (cross conduction protection)

To prevent a short-circuit between external low-side and high-side power elements during sine-wave PWM drive, a dead time is digitally inserted between the turn-on of one side and the turn-off of the other side. (The dead time is also implemented at the full duty cycle during square-wave drive.)

$$T_{OFF} = 9/f_{OSC}$$

$T_{OFF} \approx 2.0$   $\mu$ s when  $f_{OSC} = 4.5$  MHz, where  $f_{OSC}$  is the reference clock frequency (i.e., CR oscillator frequency).



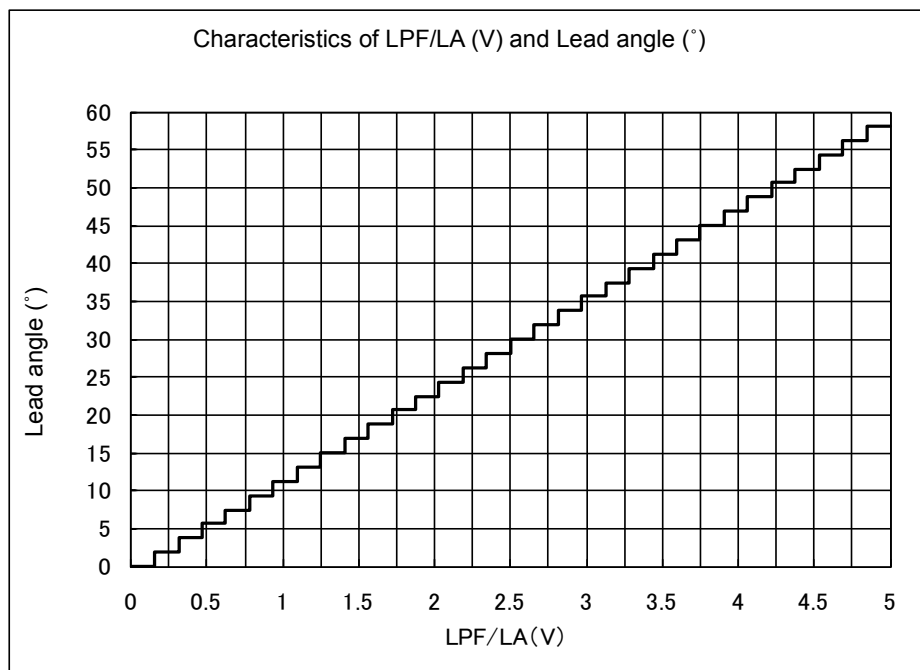
**4. Lead Angle Control**

The lead angle can be adjusted between 0° and 58° in 32 separate steps according to the induced voltage level on the LPF/LA input, which works with 0 to 5 V.

0 V = 0°

5 V = 58° (A lead angle of 58° is assumed when the LA voltage exceeds 5 V.)

| Steps | LPF/LA (V) | Lead angle (°) | Steps | LPF/LA (V) | Lead angle (°) | Steps | LPF/LA (V) | Lead angle (°) |
|-------|------------|----------------|-------|------------|----------------|-------|------------|----------------|
| 0     | 0.000      | 0.000          | 11    | 1.719      | 20.625         | 22    | 3.438      | 41.250         |
| 1     | 0.156      | 1.875          | 12    | 1.875      | 22.500         | 23    | 3.594      | 43.125         |
| 2     | 0.313      | 3.750          | 13    | 2.031      | 24.375         | 24    | 3.750      | 45.000         |
| 3     | 0.469      | 5.625          | 14    | 2.188      | 26.250         | 25    | 3.906      | 46.875         |
| 4     | 0.625      | 7.500          | 15    | 2.344      | 28.125         | 26    | 4.063      | 48.750         |
| 5     | 0.781      | 9.375          | 16    | 2.500      | 30.000         | 27    | 4.219      | 50.625         |
| 6     | 0.938      | 11.250         | 17    | 2.656      | 31.875         | 28    | 4.375      | 52.500         |
| 7     | 1.094      | 13.125         | 18    | 2.813      | 33.750         | 29    | 4.531      | 54.375         |
| 8     | 1.250      | 15.000         | 19    | 2.969      | 35.625         | 30    | 4.688      | 56.250         |
| 9     | 1.406      | 16.875         | 20    | 3.125      | 37.500         | 31    | 4.844      | 58.125         |
| 10    | 1.563      | 18.750         | 21    | 3.281      | 39.375         | 32    | 5.000      | 58.125         |



Note: Be careful in using the TB6634FNG because the upper of lead angle is limited to about 25 steps when the range of the power supply voltage  $V_{CC}$  is 6 V to 7 V.

**5. PWM Carrier Frequency**

The triangular waveform generator provides a carrier frequency of  $f_{OSC}/252$  necessary for PWM generation. (The triangular wave is also used to force the switch-on of low-side transistors during square-wave drive.)

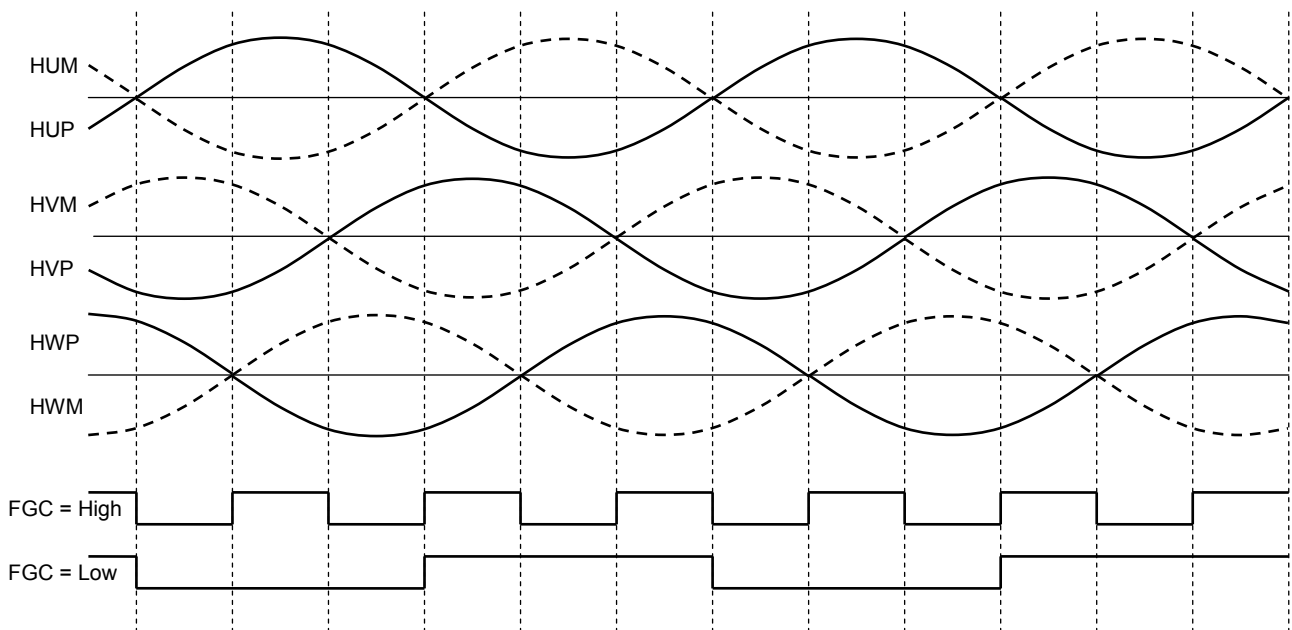
Carrier frequency:  $FC = f_{OSC}/252$  (Hz), where  $f_{OSC}$  = reference clock (crystal oscillator) frequency

**6. Rotation Pulse Output**

Rotation pulse based on the hall signal is outputted. FGC terminal switches 1 pulse/electrical angle and 3 pulses/electrical angle. One pulse/electrical angle is generated by the hall signal of U phase. Three pulses/electrical angle are generated by combined each up-down edge of U phase, V phase, and W phase.

| FGC          | FG                        |
|--------------|---------------------------|
| High or Open | 3 pulses/electrical angle |
| Low          | 1 pulse/electrical angle  |

**Timing Chart of FG Signal**



**7. Abnormal Detection Input Pins**

- (1) Overcurrent protection (Idc pin)  
 If the voltage of the DC-link current exceeds the internal reference voltage, the commutation signals are forced Low. Overcurrent protection is disabled after every carrier period.  
 Reference voltage = 0.3 V (typ.)
- (2) Abnormal detection input (RES pin)  
 When the RES input is Low, the commutation outputs are disabled. When the RES input is then set High, abnormal detection is disabled after every carrier period and the commutation outputs are re-enabled.  
 Any irregular conditions of the motor should be detected by external hardware; such indications should be presented to the RES input.

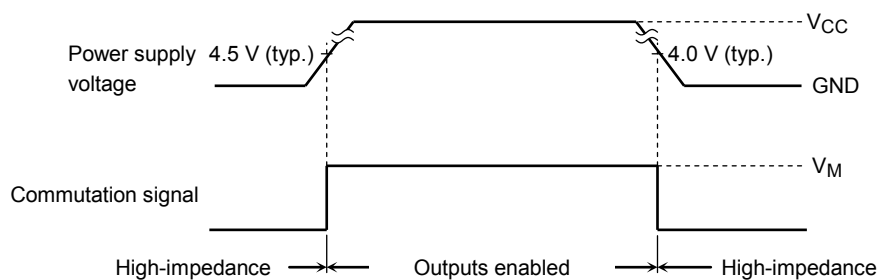
| RES Pin     | Commutation Output Signals (U, V, W, X, Y, Z) |
|-------------|---|
| High        | The motor can be driven                       |
| Low or Open | Low (Gate block protection)                   |

When RES is Low, charging of the bootstrap capacitor stops.  
 In order to charge the bootstrap capacitor in recovering, input the voltage as follows:  
 $1.0\text{ V} < V_{SP} \leq 2.1\text{ V}$

- (3) Abnormal position signal protection  
 When the position signal inputs (UVW) are all Highs or all Lows, the commutation outputs are forced off (i.e., Gate block protection). When these inputs are then set to any other combination, the commutation outputs are re-enabled. (The all-High and all-Low conditions are Hall sensor outputs.)

Position detection signal (internal hall amplifier output) in sine-wave PWM drive mode is constructed with latch circuit.  
 So, some noise or chattering do not invite errors in driving because prior mode is kept in case the position detection signal outputs different voltage from the expected one.

- (4) Undervoltage lockout (VCC monitor)  
 While the power supply voltage is outside the rated range during power-on or power-off, the commutation outputs are set to the high-impedance state to prevent external power elements from damage due to short-circuits.



8. Motor Restrained Protection

When hall signal continues to detect below state, intermittent operation (period of operation: period of halt = 1:6) is repeated.

<State of motor restrained protection>

Operation starts and the restrained protection starts counting when VSP exceeds 2.1 V. In case rotation direction of the motor is the same as the set direction (CW: 180° conduction mode), the motor restrained protection operates under the condition that the hall signal outputs with 1 Hz (f<sub>osc</sub> = 4.5 MHz) or less in the square-wave drive mode (120° conduction).

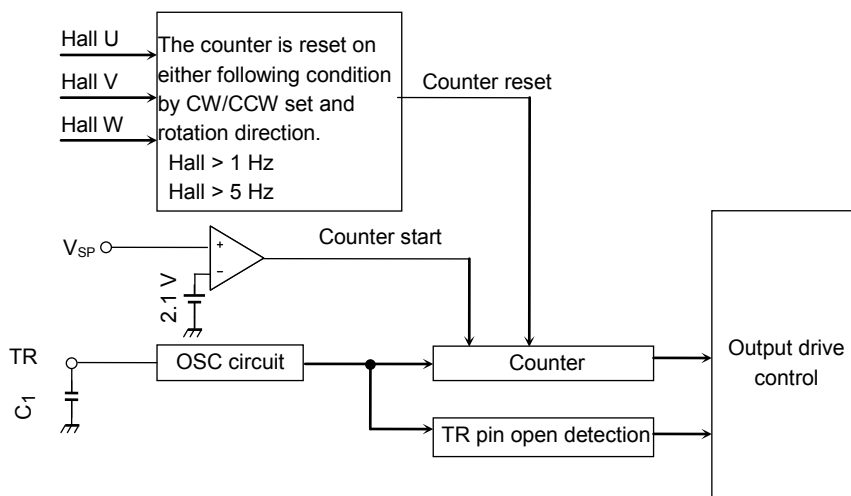
In case rotation direction of the motor is opposite of the set direction (CCW: 120° conduction mode of the inverted hall input), the motor restrained protection operates under the condition that the hall signal outputs with about 5 Hz (f<sub>osc</sub> = 4.5 MHz) or less.

When motor restrained protection operates, conducting output is set low during turning off.

In case VSP is set 2.1 V or less during operation, the counter starts from initial state after reset. However, the counter does not reset and the term of turning off continues though VSP is set 2.1 V or less during turning off.

Operation of motor restrained protection

| CW/CCW     | V <sub>SP</sub> > 2.1 V                                       |   | V <sub>SP</sub> ≤ 2.1 V |
|------------|---|---|-------------------------|
|            | Motor rotation direction                                      |   |                         |
|            | CW  | CCW   | -                       |
| Low (CW)   | Operation ≤ 1 Hz<br>(Same as set direction by CW/CCW pin)     | Operation ≤ 5 Hz<br>(Opposite of set direction by CW/CCW pin) | Non active              |
| High (CCW) | Operation ≤ 5 Hz<br>(Opposite of set direction by CW/CCW pin) | Operation ≤ 1 Hz<br>(Same as set direction by CW/CCW pin)     | Non active              |



<Setting>

Term of detection and that of turning off can be set by the external capacitor (C1) of TR terminal.

- Setting time

$$\text{Operation term } T_{on}[s] = C1 \times (VH - VL) \times 2/I \times 500 \text{ counters}$$

$$\text{Turning off term } T_{off}[s] = C1 \times (VH - VL) \times 2/I \times 3000 \text{ counters (Note 1)}$$

- Ex: When C1 is 0.01 μF, I is 3.15 μA (typ.), VH is 2 V (typ.), and VL is 0.5 V (typ.). And so, T<sub>on</sub>[s] is 4.76 s (typ.) and T<sub>off</sub>[s] is 28.57 s (typ.).

Note 1: In turning off term, the boot strap capacitor is not charged (refresh).

In order to charge the boot strap capacitor in recovering operation, input command voltage as follows; 1.0 V < V<sub>SP</sub> ≤ 2.1 V.

Note 2: Conducting output is low (turning off state) when open detection operates under the condition that TR pin is open.

Note 3: The counter is not increased any more by applying fixed voltage (GND) to TR pin. And operation state continues because the motor restrained protection stops operation.

## 9. Motor supply voltage detection

The change of the motor power supply voltage can be monitored because lead angle can be corrected (Four levels of lead angle are increased based on LPF/LA) and the operation can be halted (gate block protection) by inputting voltage to Vdc pin.

| Voltage of Vdc pin (typ.)<br>(Note 1) | Functions  |
|---------------------------------------|--|
| 4.0 V to Vref+0.3 V                   | Conducting signal output is Low(gate block protection)<br>(Note 2) |
| 3.0 V to 4.0 V                        | Lead angle (LPF/LA) + 3 levels (5.625°)                            |
| 2.6 V to 3.0 V                        | Lead angle (LPF/LA) + 2 levels (3.75°)                             |
| 2.2 V to 2.6 V                        | Lead angle (LPF/LA) + 1 level (1.875°)                             |
| 0 V to 2.2 V                          | Lead angle (LPF/LA) + 0 level                                      |

Note 1: Threshold voltage of Vdc is different between rising state and falling state because it has the hysteresis width of 100 mV (typ.).

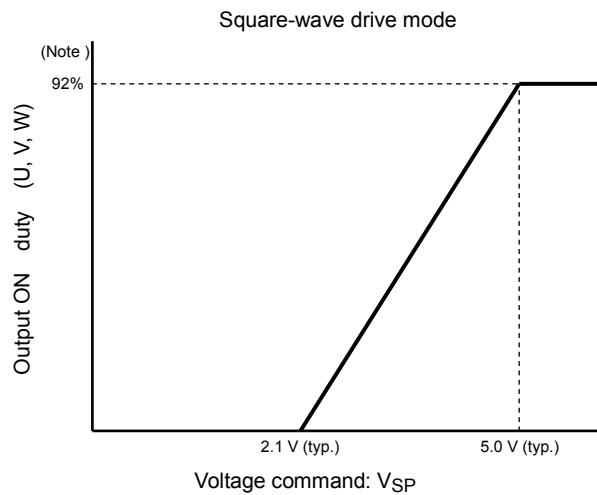
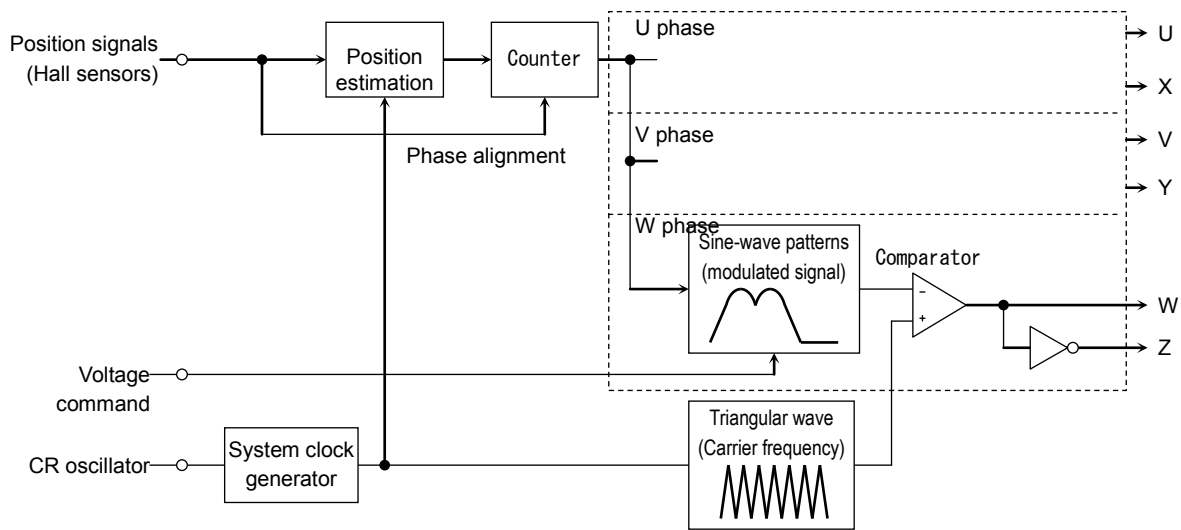
Note 2: It is released on every carrier frequency.

The boot strap capacitor is not charged (refresh) in turning off.

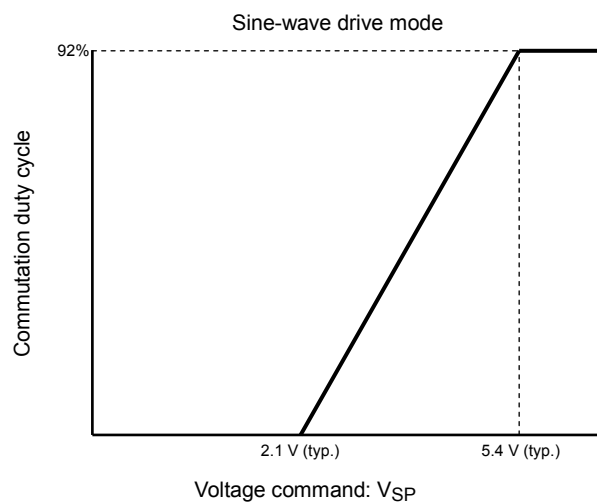
In order to charge the boost strap capacitor in recovering, input the command voltage as follows;  $1.0\text{ V} < V_{SP} \leq 2.1\text{ V}$ .



## Operation Flow



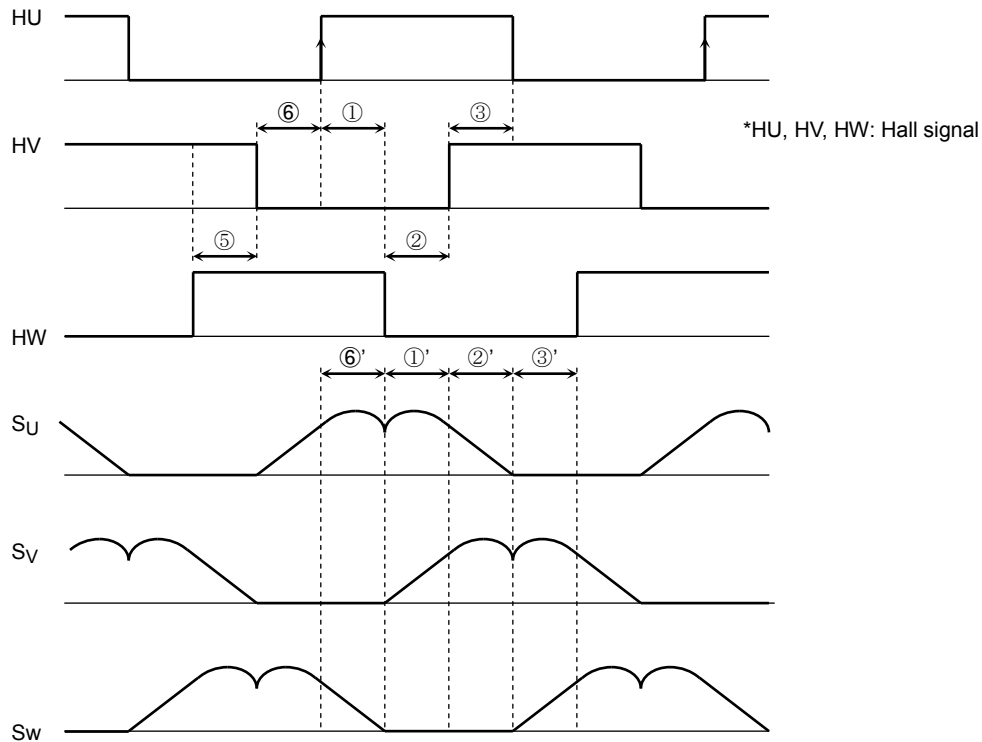
Note: The conduction period is reduced by the dead time.  $(\text{carrier\_frequency} \times 92\% - T_d \times 2)$



The position signals from Hall sensors are modulated, and the modulated signals are then compared against a triangular waveform to generate a sine-wave PWM.

The counter measures the period from given rising (or falling) edges of three hall signals to their next falling (or rising) edges (60 electrical degrees). This period is then used as 60° phase data for the next modulation.

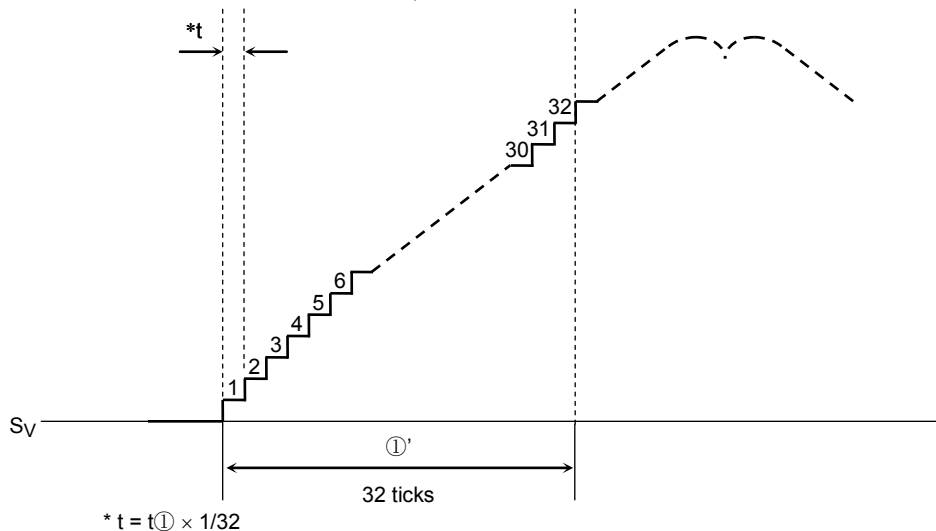
A total of 32 ticks comprise 60 electrical degrees; the length of a tick equals 1/32nds the time period of the immediately preceding 60° phase.



In the above diagram, the modulated waveforms have an interval (①') equal to 1/32nds of the interval between a rising edge of HU to a falling edge of HW (①) of the previous cycle.

Likewise, the modulated waveforms have an interval (②') equal to 1/32nds of the interval between a falling edge of HW to a rising edge of HV (②) of the previous cycle.

If 32 ticks finish modulated before ①' or ②' ends, next 32 ticks modulate with the same time width until the next falling edge.



Moreover, the phase match with the modulated waveform is done at every zero crossing of the positional detection signal.

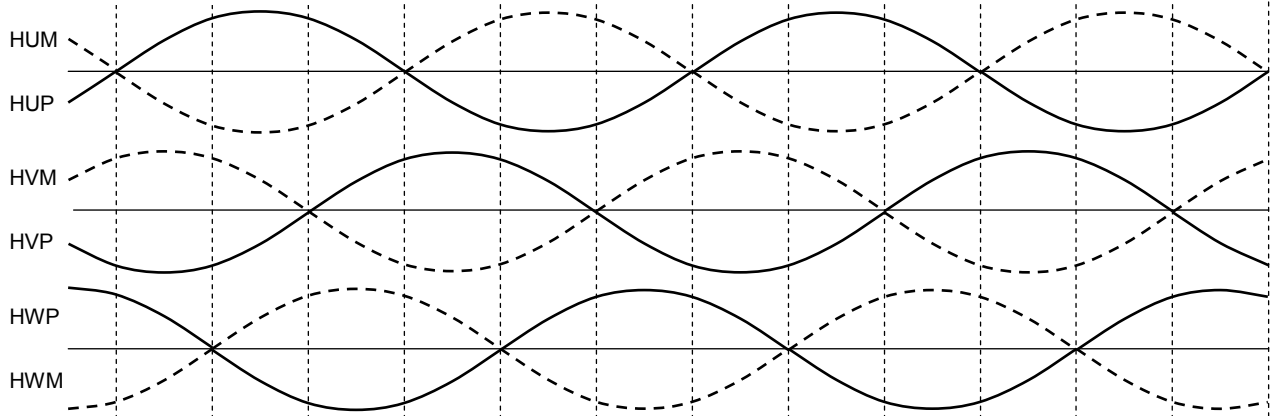
The modulated waveform is reset on each falling or rising edge of the positional detection signal, which occurs every 60° electrical degrees.

Therefore, the modulated waveform becomes discontinuous at each reset while the position of the hall signal misaligns or the motor is accelerating or decelerating.

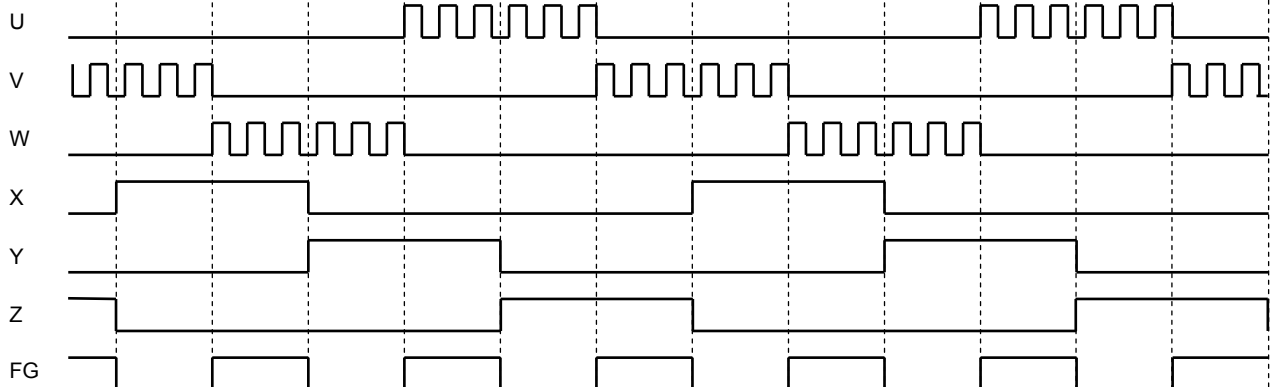
Note: In the above diagram, HU is shown as square waveforms for the sake of simplicity.

## Forward Rotation Timing Chart (CW/CCW = Low, LPF/LA = GND, FGC=High)

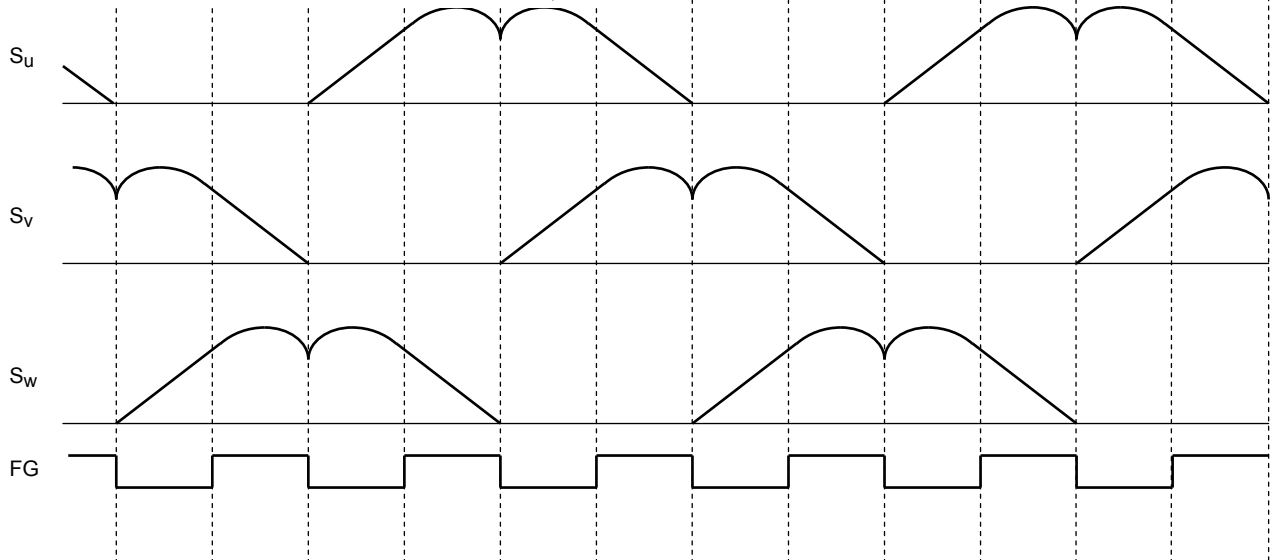
(Noninverted hall signal inputs)



0 < Hall signals < 1 Hz  
(120° commutation)



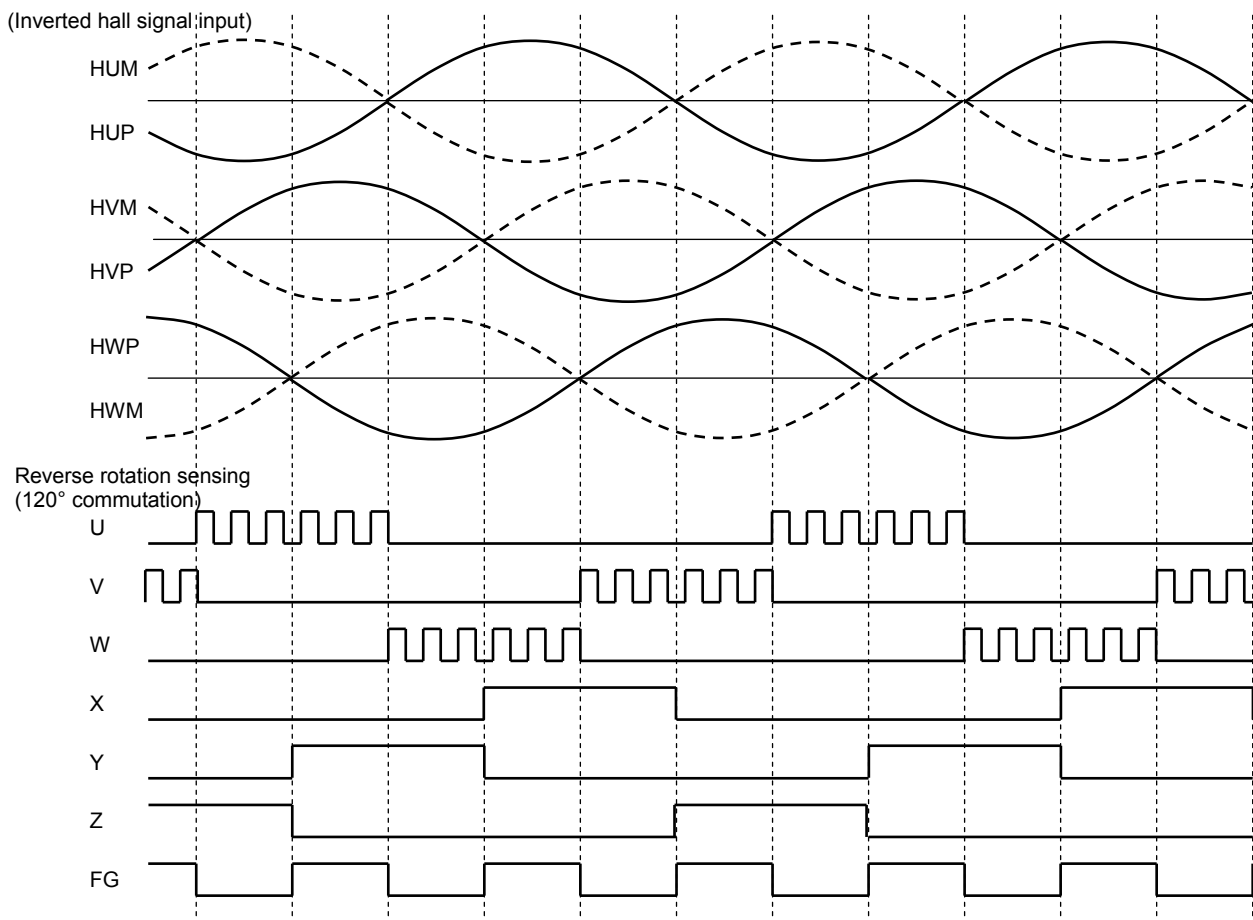
1 Hz < Hall signals  
(180° commutation: Modulated waveforms of the internal IC)



\*: When the Hall input frequency is equal to or greater than 1 Hz (@  $f_{OSC} = 4.5$  MHz), lead angle control is activated according to the LPF/LA input.

The above timing chart is simplified to illustrate the function and behavior of the device.

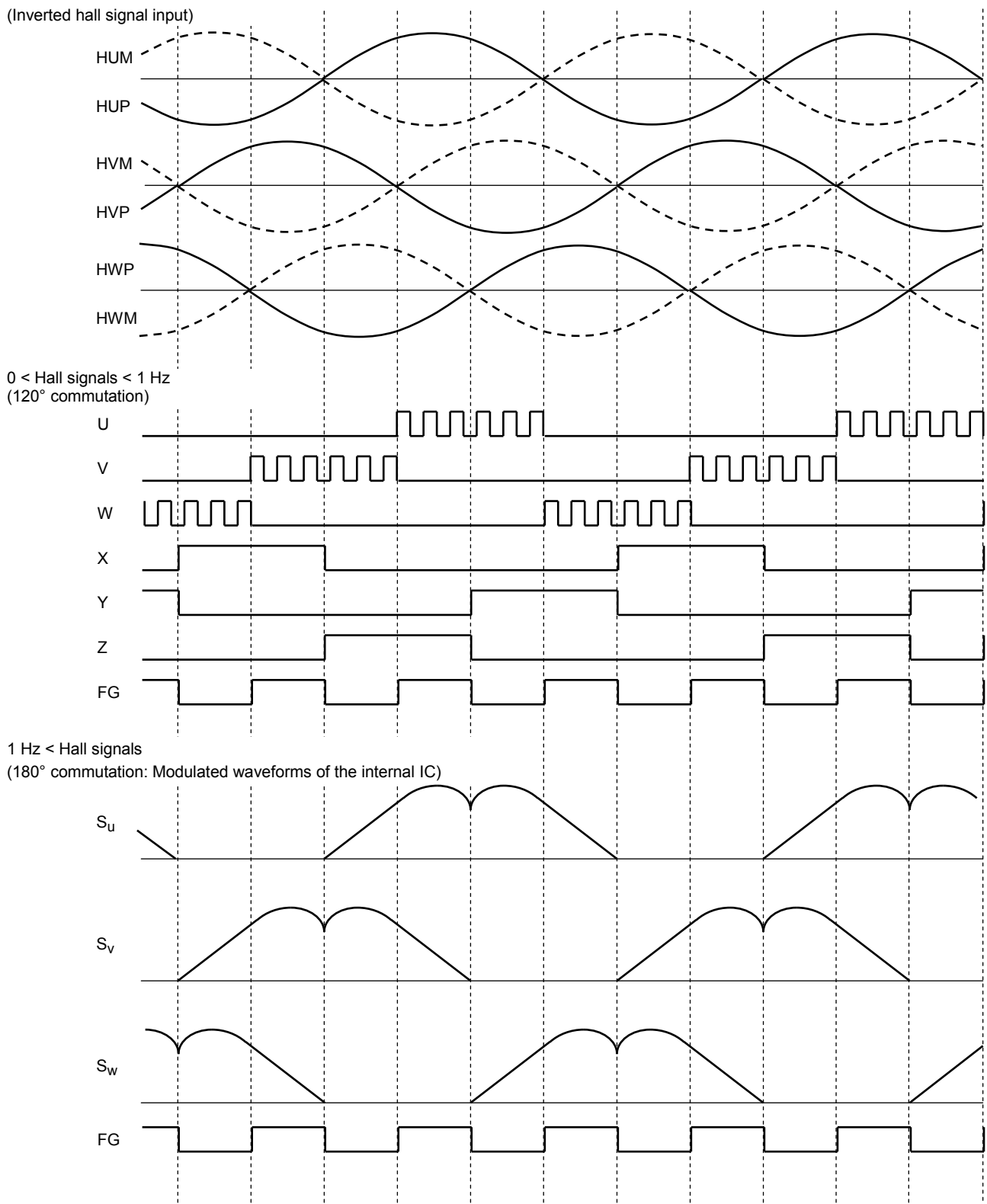
**Forward Rotation Timing Chart (CW/CCW = Low, LPF/LA = GND, FGC = High)**



\*: When the inverted Hall signal is inputted while CW/CCW is Low, The IC drives in 120° commutation mode with a lead angle of 0° (reverse rotation).

The above timing chart is simplified to illustrate the function and behavior of the device.

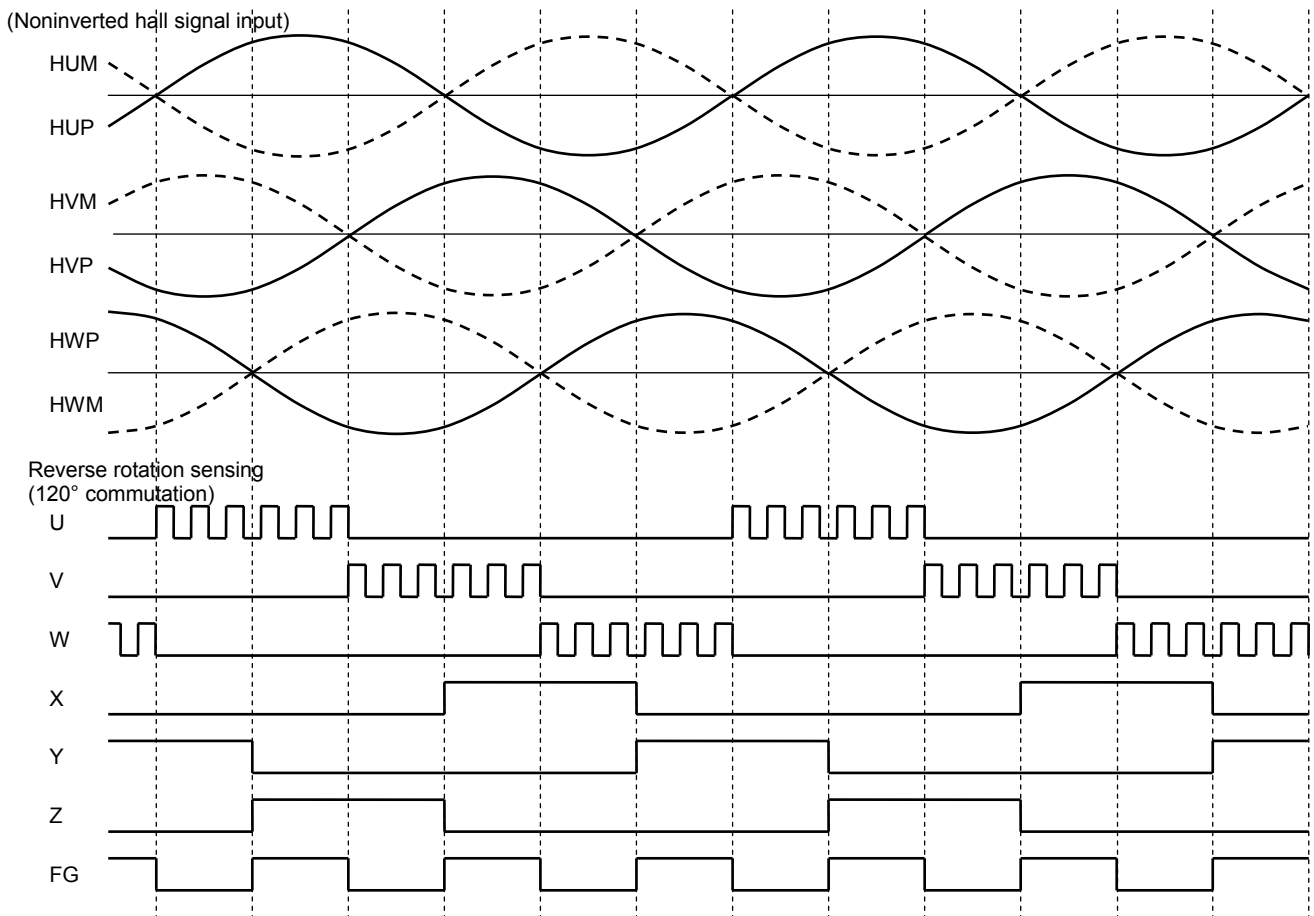
## Reverse Rotation Timing Chart (CW/CCW = High, LPF/LA = GND, FGC = High)



\*: When the Hall input frequency is equal to or greater than 1 Hz (@  $f_{osc} = 4.5$  MHz), lead angle control is activated according to the LPF/LA input.

The above timing chart is simplified to illustrate the function and behavior of the device.

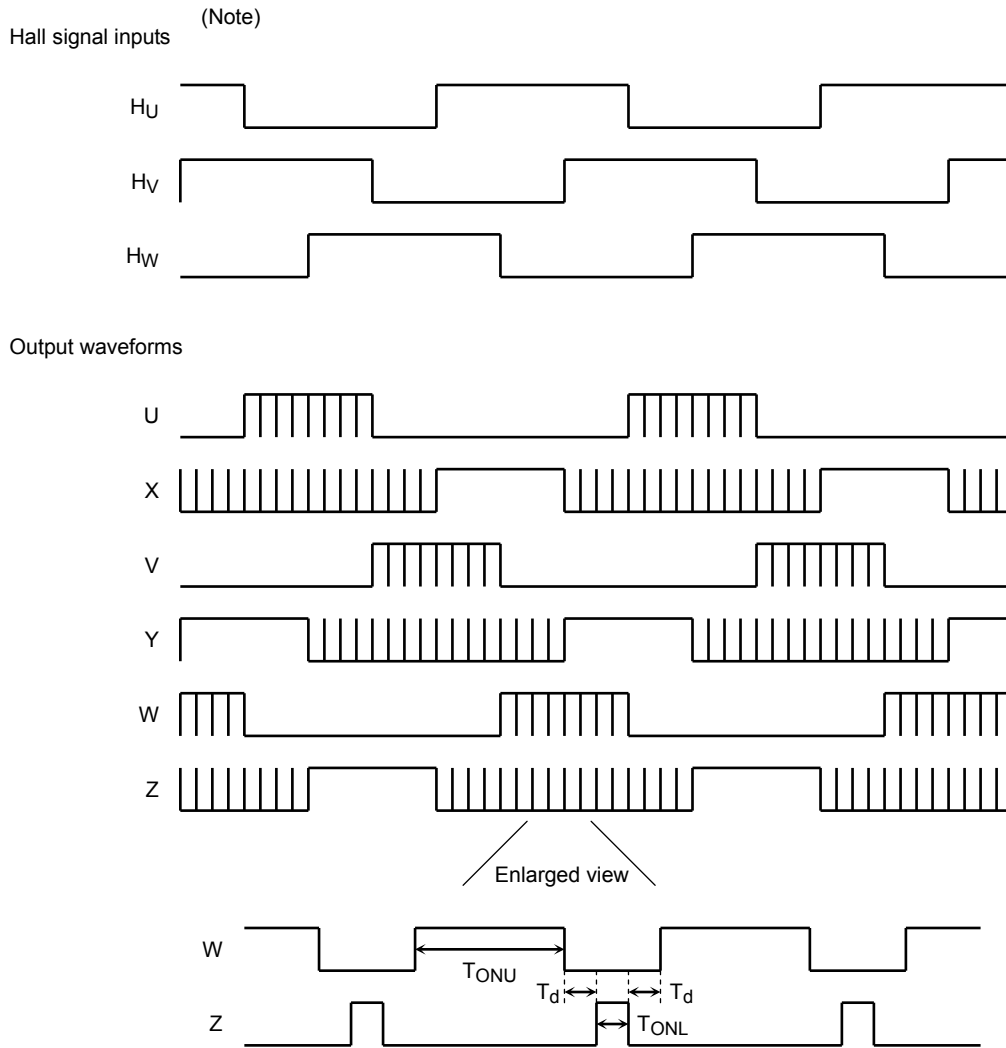
**Reverse Rotation Timing Chart (CW/CCW = High, LPF/LA = GND, FGC = High)**



\*: When the noninverted Hall signal is inputted while CW/CCW is High, the IC drives in 120° commutation mode with a lead angle of 0° (reverse rotation).

The above timing chart is simplified to illustrate the function and behavior of the device.

**Square-Wave Drive Waveform (CW/CCW = Low)**



Note: Square waveforms are used in the above diagram for the sake of simplicity.

To obtain an adequate bootstrap voltage, the low-side outputs (X, Y and Z) are always turned on for eight percent of the carrier period ( $T_{ONL}$ ) even during the off time of the low side in 120° commutation mode. As shown in the enlarged view, the high-side outputs (U, V and W) are turned off for a dead time period while the low-side outputs are on. ( $T_d$  varies with the  $V_{SP}$  input.)

Carrier frequency =  $f_{osc}/252$  (Hz)

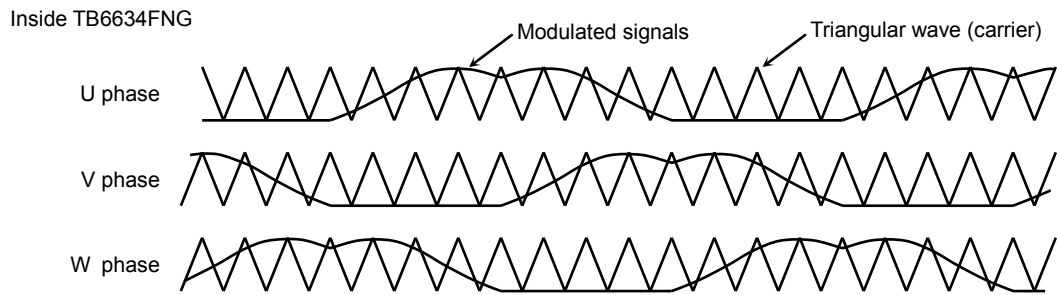
Dead time:  $T_d = 9/f_{osc}$  (s) ( $V_{SP} \geq 5.0$  V,  $T_d = \text{Low}$ )

$T_{ONL} = \text{carrier\_frequency} \times 8\%$  (s) (Constant regardless of the  $V_{SP}$  input)

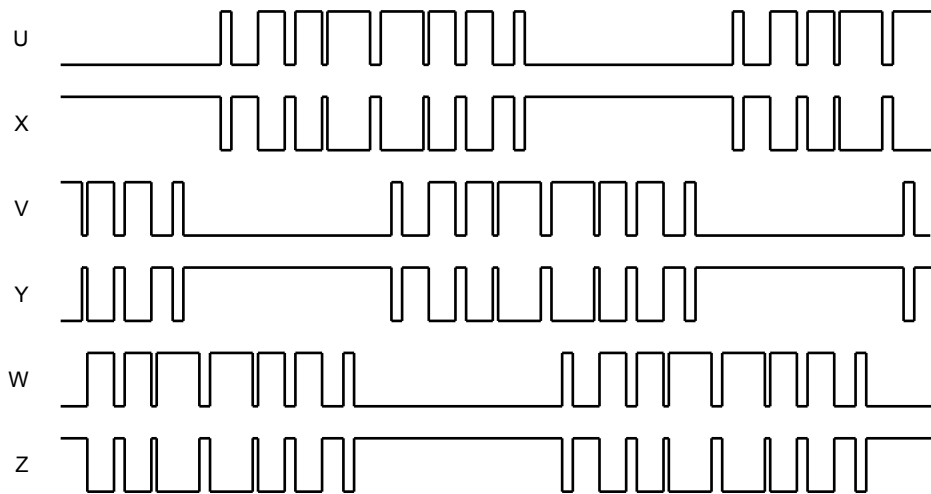
In square-wave drive mode, the changing of the motor speed is enabled, depending on the  $V_{SP}$  voltage; the motor speed is determined by the duty cycle of  $T_{ONU}$ .

Note: At startup, the motor is driven by a square wave when the Hall signal frequency is 1 Hz or lower (@  $f_{osc} = 4.5$  MHz) and when the motor is rotating in the direction reverse to the settings of the TB6634FNG.

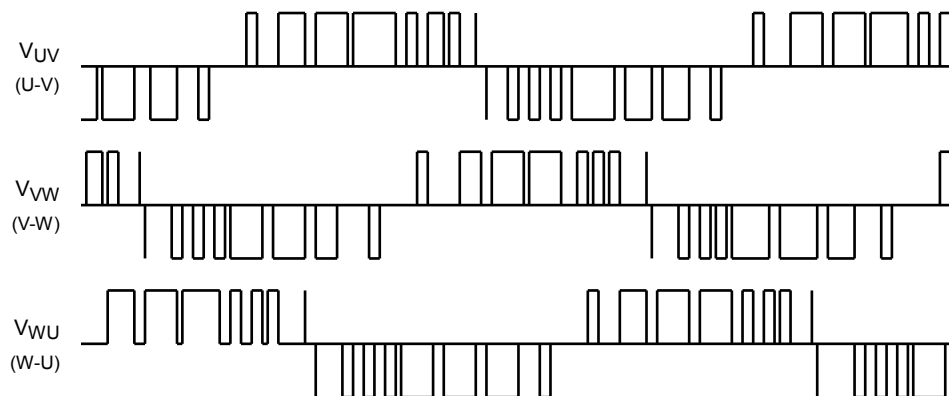
## Sine-Wave Drive Waveform (CW/CCW = Low)



Output waveforms



Phase voltage differences



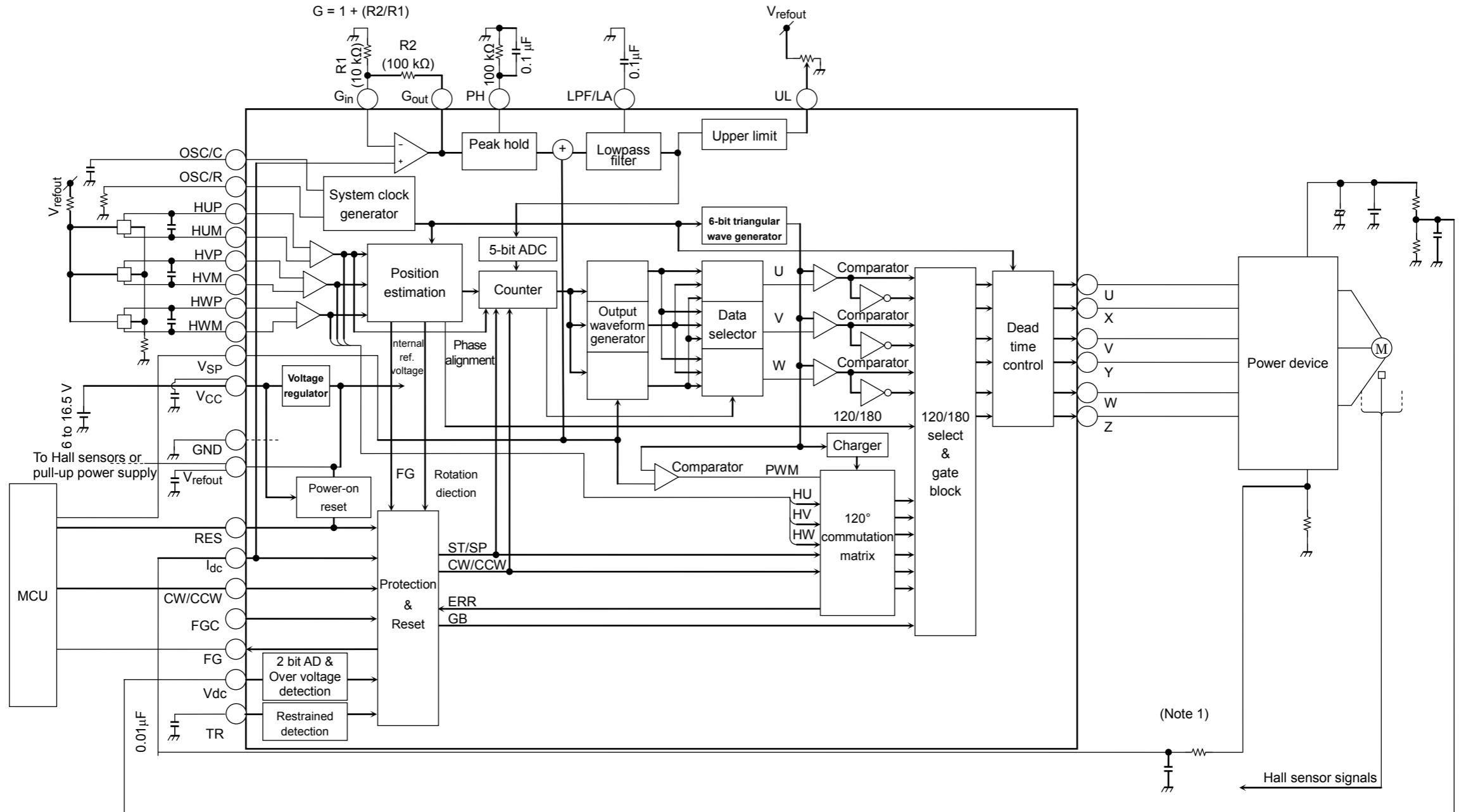
In sine-wave drive mode, the amplitude of the modulated signals varies with the VSP voltage and the motor speed changes with the conduction duty cycle of the output waveforms.

$$\text{Triangular wave frequency} = \text{carrier frequency} = f_{\text{osc}}/252 \text{ (Hz)}$$

Note: At startup, the motor is driven by a sine wave when the Hall signal frequency is 1 Hz or higher (@  $f_{\text{osc}} = 4.5$  MHz) and when the motor is rotating in the same direction as settings of the TB6634FNG.



Application Circuit Example



Note 1: Connect to ground as necessary to prevent IC malfunction due to noise.

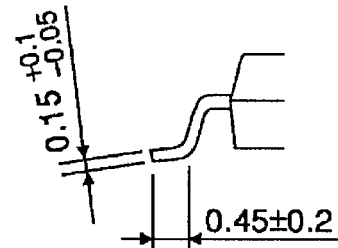
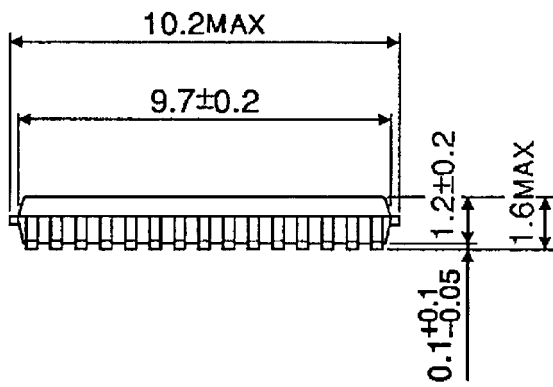
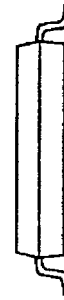
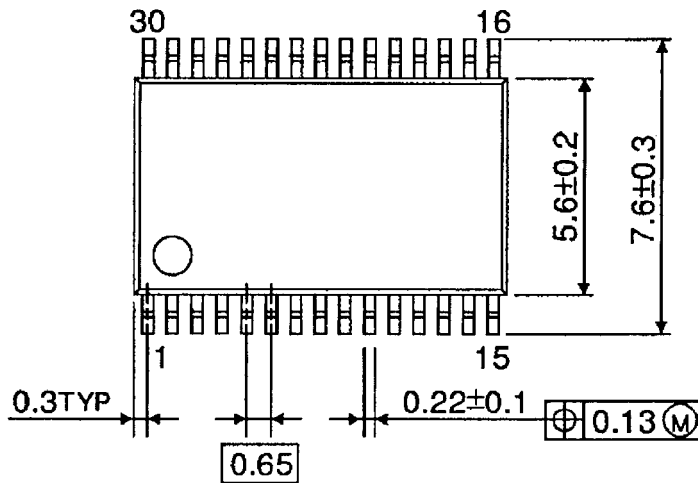
Note 2: Connect GND to signal ground on the application circuit.

Note 3: Utmost care is required in the design of the output, V<sub>CC</sub>, and GND lines since the IC may shatter or explode due to short-circuits between outputs, short to V<sub>CC</sub> or short to ground. The IC may also shatter or explode when it is installed in a wrong orientation.

**Package Dimensions**

SSOP30-P-300-0.65

Unit : mm



Weight: 0.17 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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### 5. Test Circuits

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

## 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] Use an appropriate power supply fuse to ensure that a large current does not continuously flow in case of over current and/or IC failure. The IC will fully break down when used under conditions that exceed its absolute maximum ratings, when the wiring is routed improperly or when an abnormal pulse noise occurs from the wiring or load, causing a large current to continuously flow and the breakdown can lead smoke or ignition. To minimize the effects of the flow of a large current in case of breakdown, appropriate settings, such as fuse capacity, fusing time and insertion circuit location, are required.
- [3] If your design includes an inductive load such as a motor coil, incorporate a protection circuit into the design to prevent device malfunction or breakdown caused by the current resulting from the inrush current at power ON or the negative current resulting from the back electromotive force at power OFF. IC breakdown may cause injury, smoke or ignition.  
Use a stable power supply with ICs with built-in protection functions. If the power supply is unstable, the protection function may not operate, causing IC breakdown. IC breakdown may cause injury, smoke or ignition.
- [4] 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****(1) Over current Protection Circuit**

Over current protection circuits (referred to as current limiter circuits) do not necessarily protect ICs under all circumstances. If the over current protection circuits operate against the over current, clear the over current status immediately.

Depending on the method of use and usage conditions, such as exceeding absolute maximum ratings can cause the over current protection circuit to not operate properly or IC breakdown before operation. In addition, depending on the method of use and usage conditions, if over current continues to flow for a long time after operation, the IC may generate heat resulting in breakdown.

**(2) 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 consideration the effect of IC heat radiation with peripheral components.

**(3) Back-EMF**

When a motor rotates in the reverse direction, stops or slows down abruptly, a current flow back to the motor's power supply due to the effect of back-EMF. If the current sink capability of the power supply is small, the device's motor power supply and output pins might be exposed to conditions beyond absolute maximum ratings. To avoid this problem, take the effect of back-EMF into consideration in system design.

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