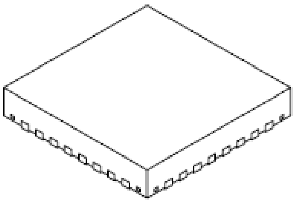
TOSHIBA Bi-CMOS Integrated Circuit Silicon Monolithic

TB67B054FTG

Sine-wave PWM Drive
Three-phase Full Wave Brushless Motor Controller

The TB67B054FTG is developed for three-phase brushless DC motors of motor fans.



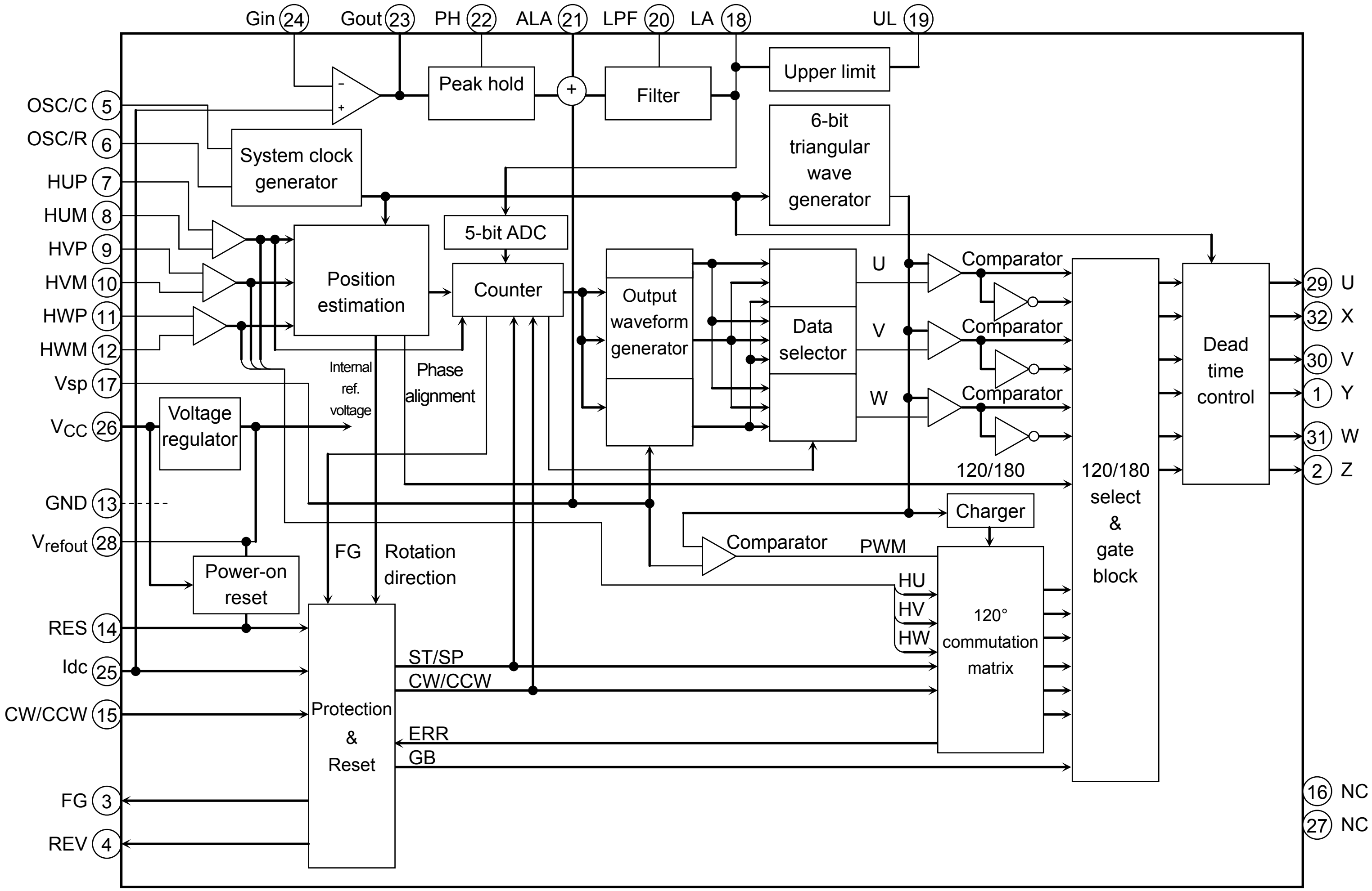
P-VQFN32-0505-0.50-005

Weight: 0.07 g (typ.)

Features

- Sine-wave PWM control
- Triangular-wave generator (carrier frequency = f_{osc}/252 Hz)
- Lead angle control (0° to 58° in 32 separate steps)
  External setting or automatic internal control
- Current-limiting input pin
- Internal voltage regulator circuit (V_{refout} = 5 V (typ.), 30 mA (max))
- Operating supply voltage range: V_{CC} = 6 V to 16.5 V

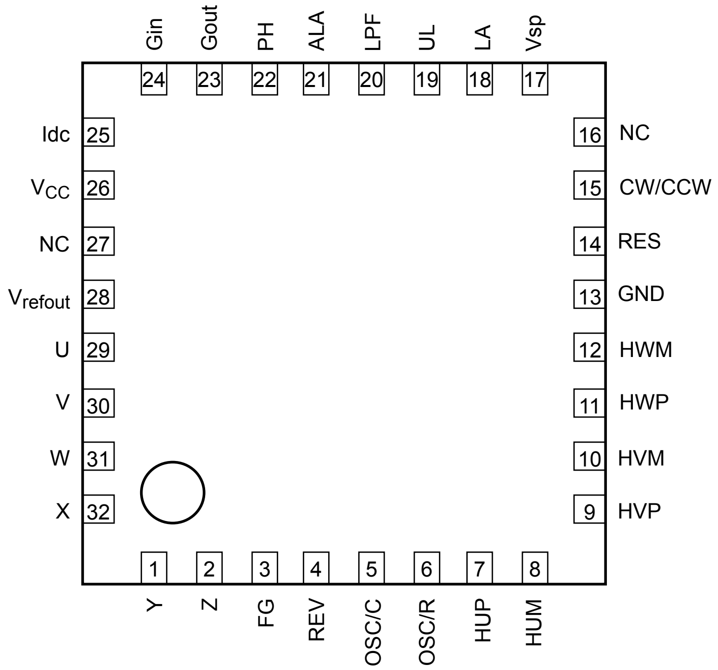
Block diagram



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

Pin assignment

<Top View>

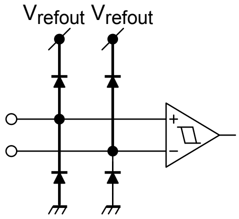
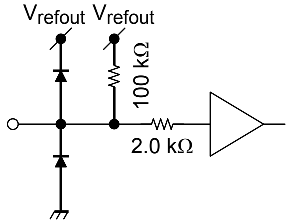
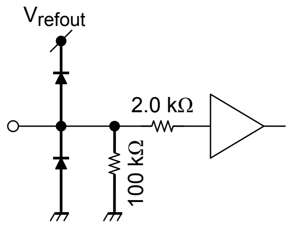
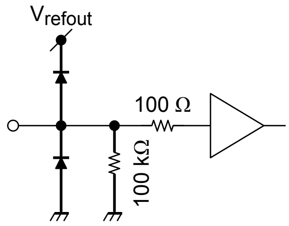
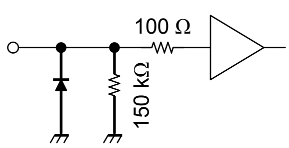


Pin description

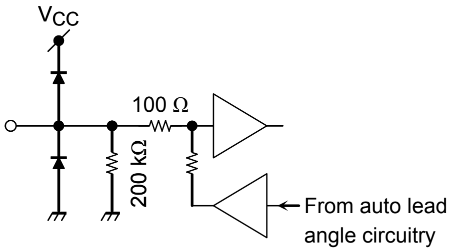
Pin No.	Symbol	Function	Description
5	OSC/C	Oscillator capacitor	CR oscillation
6	OSC/R	Oscillator resistor	
7	HUP	Hall signal input, U	Gate block protection is activated when hall signals of U, V, and W phases are all “H” or “L”. These inputs have internal digital filters (≈ 500 ns)
8	HUM		
9	HVP	Hall signal input, V	
10	HVM		
11	HWP	Hall signal input, W	
12	HWM		
13	GND	Ground	—
14	RES	Reset input	L: Motor operates, H: Motor stops (commutation output signals are forced low.) Built in pulldown resistor
15	CW/CCW	Clockwise/counterclockwise rotation	L: Clockwise rotation, H: Counterclockwise rotation Built-in pullup resistor
16	NC	NC pin	No connection
17	V_{sp}	Voltage command input	Built-in pulldown resistor
18	LA	Lead angle control input	LA input allows the lead angle to be adjusted between 0° and 58° in 32 separate steps.
19	UL	Upper limit for LA	UL input determines the upper limit for the lead angle (UL = 0 V to 5.0 V).
20	LPF	RC low-pass filter capacitor	A capacitor for the RC low-pass filter is connected to this pin. (Built-in a 100 kΩ resistor)
21	ALA	Auto lead angle mode select input	Built-in pulldown resistor L or open: Feeds back Idc and Vsp to generate the modulated waves per electrical angle of 60°. H: Feeds back Idc to generate the modulated waves per electrical angle of 360°.
22	PH	Peak hold	A peak-hold capacitor and a discharge resistor are connected to this pin.
23	Gout	Gain setting	The Gin and Gout pins are used to amplify the Idc level so that the lead angle will be optimal.
24	Gin		
25	Idc	Current limit control input	The DC-link current is applied to the Idc input. The reference voltage is 0.5 V. The Idc input has an internal RC filter (with a time constant of 1 μs) and a digital filter (with a time constant of 1 μs).
26	V_{CC}	Power supply	V_{CC} = 6 V to 16.5 V
27	NC	NC pin	Non connection
28	V_{refout}	Reference voltage output	5 V (typ.), 30 mA (max) A capacitor for oscillation prevention is connected to the V_{refout} output.
29	U	Commutation signal output U, (U high-side)	High-active
30	V	Commutation signal output V, (V high-side)	
31	W	Commutation signal output W, (W high-side)	
32	X	Commutation signal output X, (U low-side)	
1	Y	Commutation signal output Y, (V low-side)	
2	Z	Commutation signal output Z, (W low-side)	
3	FG	FG signal output	The FG output gives two pulses per electrical revolution.
4	REV	Reverse rotation detection signal	The REV output is used to detect an occurrence of reverse rotation.

Input/output equivalent circuits

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

Pin	Symbol	Input/output signal	Internal circuit
Hall signal input, U Hall signal input, V Hall signal input, W	HUP HUM HVP HVM HWP HWM	Analog Hysteresis: ± 7.5 mV (typ.)	
Clockwise/counterclockwise rotation L: forward (CW) H: reverse (CCW)	CW/CCW	Digital L: 0.8 V (max) H: V_{refout} − 1 V (min)	
Reset input L: Motor operation H: Motor stop (Reset)	RES	Digital L: 0.8 V (max) H: V_{refout} − 1 V (min)	
Auto lead angle mode select L or open: Idc and Vsp / 60° H: Idc / 360°	ALA	Digital L: 0.8 V (max) H: V_{refout} − 1 V (min)	
Voltage command signal 1.0 V < Vsp ≤ 2.1 V Refresh operation (The X, Y and Z pins have a conduction duty cycle of 8 %.)	V_{sp}	Analog Vsp voltage range: 0 V to 10 V When 5.7 V ≤ Vsp ≤ 7.3 V, the PWM duty cycle is fixed at 92% (typ.). When 8.2 V ≤ Vsp ≤ 10 V, the TB67B054FTG is put in test mode.	

<table>
<tr><th>Pin</th><th>Symbol</th><th>Input/output signal</th><th>Internal circuit</th></tr>
<tr>
<td>Lead angle control input

0 V: 0°
5 V: 58°
(5-bit ADC)</td>
<td>LA</td>
<td>To fix the lead angle externally, UL and V_{refout} should be connected together. The lead angle is linearly determined according to the voltage applied to the LA input.
LA voltage range: 0 to 5.0 V (V_{refout})
If LA > V_{refout}, the commutation occurs with the maximum lead angle of 58°.
When configured for auto lead angle control, the LA input should be left open. At this time, the LA input can be used to check the lead angle in real time.</td>
<td>
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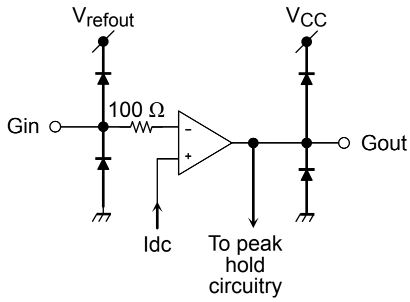
</tr>
<tr>
<td>Gain setting
(Lead angle control circuitry)</td>
<td>Gin
Gout</td>
<td>Non-inverting amplifier
25 dB max
Gout: Output voltage
L: GND
H: V_{CC} – 1.7 V</td>
<td>
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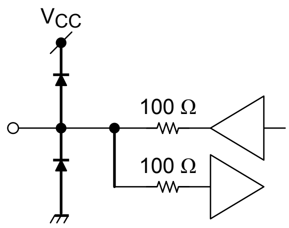
<tr>
<td>Peak hold
(Lead angle control circuitry)</td>
<td>PH</td>
<td>A peak-hold capacitor and a discharge resistor are connected to the PH pin.
Recommended R/C values: 100 kΩ/0.1 μF</td>
<td>
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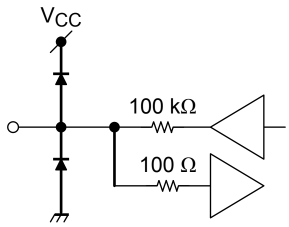
</tr>
<tr>
<td>Low-pass filter
(Lead angle control circuitry)</td>
<td>LPF</td>
<td>A capacitor for the RC low-pass filter is connected to this pin.
Built-in a 100 kΩ (typ.) resistor
Recommended C value: 0.1 μF</td>
<td>
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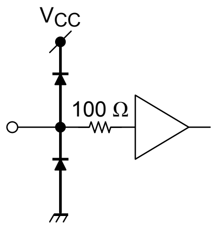
<tr>
<td>Upper limit for LA</td>
<td>UL</td>
<td>If the voltage applied to the LA input exceeds the upper limit set by this input, it is clipped to limit the lead angle.
UL = 0 to 5.0 V</td>
<td>
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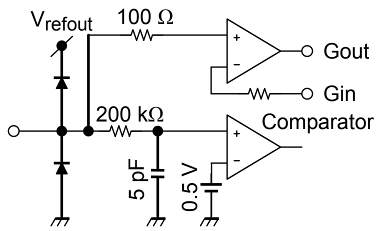
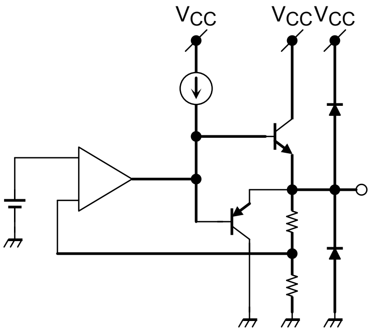
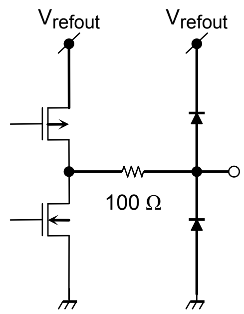
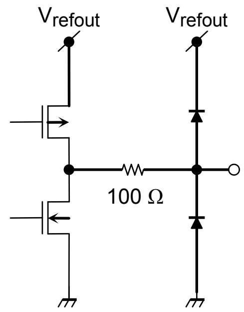
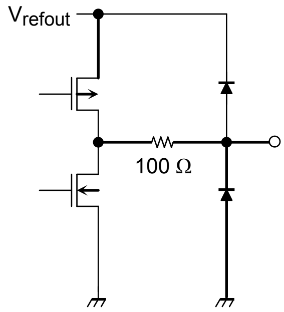
Pin	Symbol	Input/output signal	Internal circuit
Current limit control input	Idc	Analog filter time constant: 1 μs (typ.) Digital filter time constant: 1 μs (typ.) Gate block protection is activated when the Idc voltage exceeds 0.5 V. (It is disabled after every carrier cycle.) If Idc is left unconnected, all the commutation outputs are disabled.	
Reference voltage output	V_{refout}	5 ± 0.5 V (30 mA max)	
Reverse rotation detection signal	REV	Digital Push-pull output (±1 mA max)	
FG signal output	FG	Digital Push-pull output (±1 mA max) The FG output gives two pulses per electrical revolution.	
Commutation signal output, U Commutation signal output, V Commutation signal output, W Commutation signal output, X Commutation signal output, Y Commutation signal output, Z	U V W X Y Z	Digital Push-pull outputs (±2 mA max) L: 0.78 V (max) H: V_{refout} – 0.78 V (min)	

Absolute maximum ratings (Ta = 25°C)

Characteristics	Symbol	Rating	Unit
Supply voltage	V_{CC}	18	V
Input voltage	$V_{IN\ (1)}$	−0.3 to V_{CC} (Note 1)	V
	$V_{IN\ (2)}$	−0.3 to V_{refout} + 0.3 (Note 2)	
Commutation output current	I_{OUT}	2	mA
V_{refout} output current	I_{refout}	30 (Note 3)	mA
Power dissipation	P_D	4.1 (Note 4)	W
Operating temperature	T_{opr}	−30 to 115 (Note 5)	°C

Note: 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 absolute maximum ratings. Exceeding the absolute maximum rating (s) may cause the device breakdown, damage or deterioration, and may result injury by explosion or combustion. Please use the IC within the specified operating ranges.

Note 1: V_{IN} (1) pin: Vsp, LA, and UL

Note 2: V_{IN} (2) pins: HUP, HVP, HWP, HUM, HVM, HWM CW/CCW, RES, Idc, ALA, and Gin

Note 3: Since the V_{refout} pin delivers a maximum output current of 30 mA, care should be exercised to the output impedance.

Note 4: When mounted on a board (4 layers, FR4, 76.2 mm×114.3 mm×1.6 mm), Rth (j-a) = 29.9°C/W

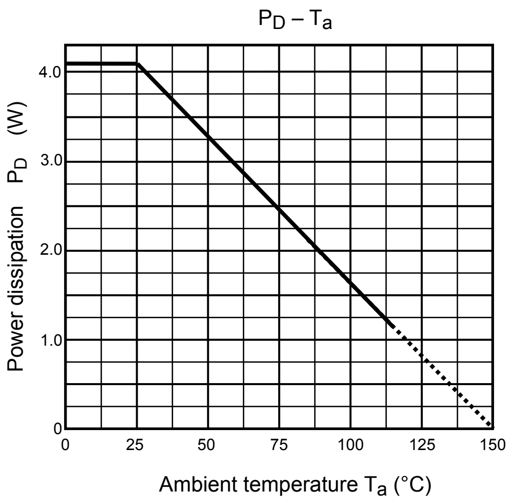
Note 5: The operating temperature range is determined by the 'P_D − Ta characteristics'.

Operating ranges (Ta = 25°C)

Characteristics	Symbol	Min	Typ.	Max	Unit
Supply voltage	V_{CC}	6	15	16.5	V
Oscillation frequency	f_{osc}	3	4.5	6	MHz

Power dissipation (for reference only)

When mounted on a board (4 layers, FR4, 76.2 mm × 114.3 mm × 1.6 mm), Rth (j-a) = 29.9°C/W



Electrical characteristics (Ta = 25°C, V_{CC} = 15 V)

Characteristics		Symbol		Test Condition		Min	Typ.	Max	Unit
Supply current		I_{CC}		V_{refout} = OPEN		—	5	8	mA
Input current		$I_{IN\ (1)\text{-}1}$		V_{IN} = 5 V LA		—	25	50	μA
		$I_{IN\ (1)\text{-}2}$		V_{IN} = 5 V V_{sp}		—	35	70	
		$I_{IN\ (2)\text{-}1}$		V_{IN} = 5 V ALA, RES		—	50	100	
		$I_{IN\ (2)\text{-}2}$		V_{IN} = 0 V CW/CCW		−100	−50	—	
Input voltage		V_{IN}	H	CW/CCW, RES, ALA		V_{refout} −1	—	V_{refout}	V
			L			—	—	0.8	
		V_{sp}	T	Forced 120° commutation, conduction duty cycle = 92% −3.8 μs (typ.)		8.2	—	10	
			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 sensor inputs	Input sensitivity	V_S		Differential inputs		100	—	—	mVpp
	Common-mode input voltage	V_W		—		1.5	—	3.5	V
	Input hysteresis	$V_{H\ (1)}$			(Note)	±5.5	±7.5	±9.5	mV
Input delay time		T_{DT}		Hall inputs	(f_{osc} = 4.5 MHz)	—	1.0	—	μs
		T_{DC}		Idc	(f_{osc} = 4.5 MHz)	—	2.5	—	
Output voltage		$V_{OUT\ (H)\text{-}1}$		I_{OUT} = 2 mA	U, V, W, X, Y, Z	V_{refout} − 0.78	V_{refout} − 0.3	—	V
		$V_{OUT\ (L)\text{-}1}$		I_{OUT} = −2 mA	U, V, W, X, Y, Z	—	0.3	0.78	
		$V_{REV\ (H)}$		I_{OUT} = 1 mA	REV	V_{refout} − 1.0	V_{refout} − 0.2	—	
		$V_{REV\ (L)}$		I_{OUT} = −1 mA	REV	—	0.2	1.0	
		$V_{FG\ (H)}$		I_{OUT} = 1 mA	FG	V_{refout} − 1.0	V_{refout} − 0.2	—	
		$V_{FG\ (L)}$		I_{OUT} = −1 mA	FG	—	0.2	1.0	
		V_{refout}		I_{OUT} = 30 mA	V_{refout}	4.5	5.0	5.5	
Output leakage current		$I_{L\ (H)}$		V_{OUT} = 0 V	U, V, W, X, Y, Z	—	0	10	μA
		$I_{L\ (L)}$		V_{OUT} = V_{refout}	U, V, W, X, Y, Z	—	0	10	
Dead time (cross conduction protection)		T_{OFF}		(f_{osc} = 4.5 MHz), I_{OUT} = ± 2 mA		1.7	2.0	2.3	μs
Current sensing		V_{DC}		Idc		0.46	0.5	0.54	V
LA gain setting amp		AMP_{OUT}		Gin, Gout 100 kΩ/10 kΩ Idc = 0.2 V, I_{OUT} = 1 mA		2.0	2.2	2.4	V
		AMP_{OFS}		Gin, Gout 100 kΩ/10 kΩ, Idc = 0.2 V		—	5	—	mV
LA limit setting error		ΔU		UL = 2.0 V		−20	—	20	mV
LA peak hold output voltage		PHOUT		Gin, Gout 100 kΩ/10 kΩ Idc = 0.2 V, I_{OUT} = 5 mA		2.0	2.2	2.4	V
Lead angle correction		$T_{LA\ (0)}$		LA = 0 V or Open, Hall inputs = 100 Hz		—	0	—	°
		$T_{LA\ (2.5)}$		LA = 2.5 V, Hall inputs = 100 Hz		26	30	33	
		$T_{LA\ (5)}$		LA = 5 V, Hall inputs = 100 Hz		52	57	60	
V_{CC} monitor		V_{CC} (H)		Output turn-on threshold		4.2	4.5	4.8	V
		V_{CC} (L)		Output turn-off threshold		3.7	4.0	4.3	
		V_H		Input hysteresis width		—	0.5	—	

Characteristics	Symbol	Test Condition	Min	Typ.	Max	Unit
PWM oscillation frequency (carrier frequency)	F_C (20)	OSC/C = 330 pF, OSC/R = 9.1 kΩ	18	20	22	kHz
	F_C (18)	OSC/C = 330 pF, OSC/R = 10 kΩ	16.2	18	19.8	
Maximum conduction duty cycle	T_{ON} (max)	OSC/C = 330 pF, OSC/R = 10 kΩ Vsp = 5.7 V	89	92	95	%

Note: No shipping inspection.

Functional description

1. Basic operation

During startup, the motor is driven by square-wave commutation signals that are generated according to the hall signals. When the hall signals indicate a rotational speed (f) of 5.7 Hz or more, the TB67B054FTG estimates the rotor positions from the hall signals and modulate them. The TB67B054FTG then generates sine-wave by comparing the modulated signals against a triangular waveform.

0 (startup) $\le$ f < 5.7 Hz : Square-wave drive (120° commutation); $f = f_{osc} / (2^{12} \times 32 \times 6)$

5.7 Hz $\le$ f : Sine-wave PWM drive (180° commutation); f will be approximately 5.7 Hz when f_{osc} = 4.5 MHz

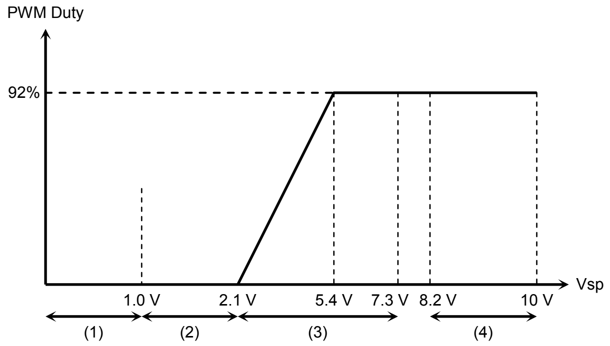
2. Voltage command (Vsp) signal and bootstrap voltage regulation

(1) When Vsp $\le$ 1.0 V :
The commutation signal outputs are disabled (i.e., gate protection is activated).

(2) When 1.0 V < Vsp $\le$ 2.1 V :
The low-side transistors are turned on at a regular (PWM carrier) frequency. (The conduction duty cycle is approx. 8 %.)

(3) When 2.1 V < Vsp $\le$ 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 %.)

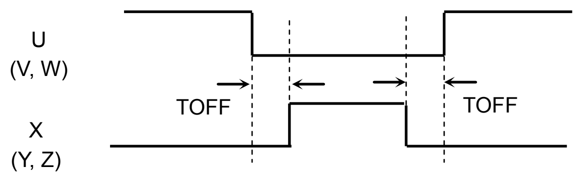
(4) When 8.2 V $\le$ Vsp $\le$ 10 V (test mode) :
The TB67B054FTG is forced into square-wave drive mode. The drive mode switches from sine-wave PWM to square-wave drive at a Vsp of 7.9 V (typ.). The conduction duty cycle during square-wave drive is calculated as PWM carrier period × 92% − 3.8 μs (typ.)



3. Dead time insertion (cross conduction protection)

To prevent a short-circuit between external low-side and high-side power devices 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.)

$T_{OFF} = 9/f_{osc}$
TOFF ≈ 2.0 μs when fosc = 4.5 MHz, where fosc is the reference clock frequency (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 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.)

5. PWM carrier frequency

The triangular waveform generator provides a carrier frequency of fosc/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 = fosc/252 (Hz), where fosc = reference clock (CR oscillator) frequency

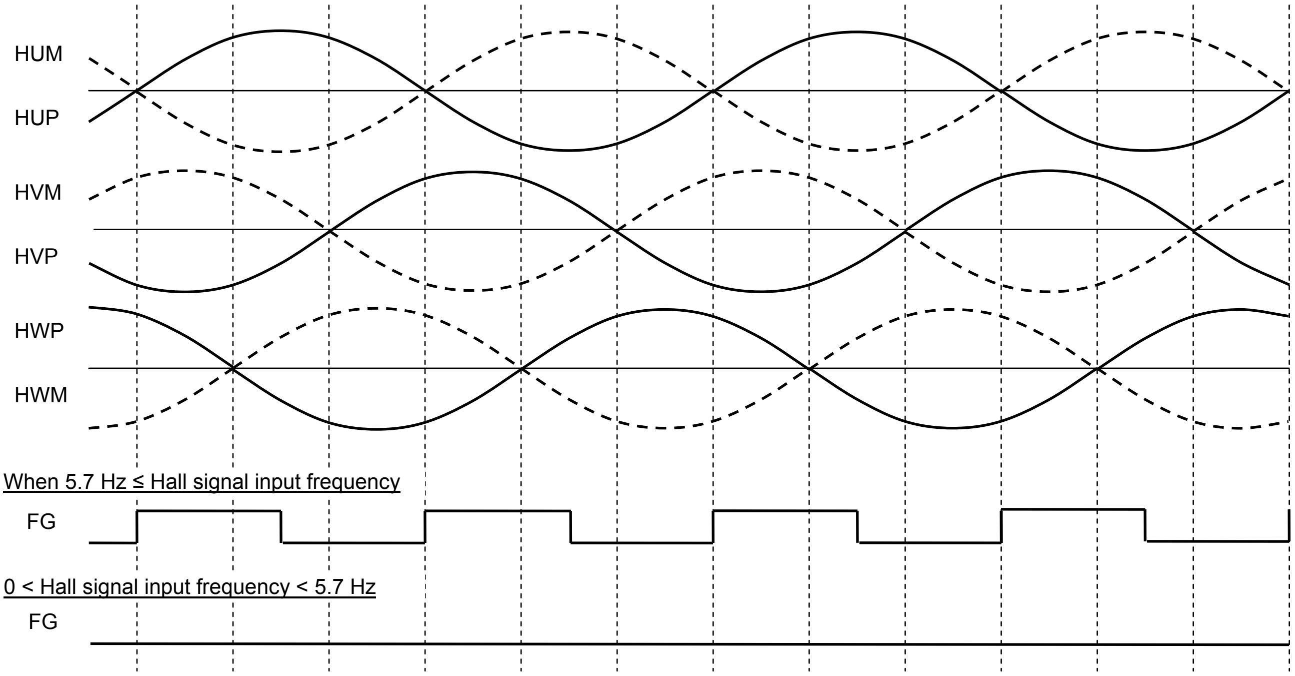
6. Reverse rotation signal

The rotational direction of the motor is detected every 360 electrical degrees.
When REV pin is L level, the operation moves to the 180° commutation mode (with Hall signal inputs ≥ 5.7 Hz)

CW/CCW pin	Actual motor rotation direction	REV pin
L (CW)	CW (forward)	L
	CCW (reverse)	H
H (CCW)	CW (forward)	H
	CCW (reverse)	L

7. Rotation frequency pulse output

Rotational pulses (2 pulses per electrical revolution) are outputted from FG pin.
When the frequency of the hall signal input is 5.7 Hz (when fosc is 4.5 MHz) or more, 2 pulses are outputted per one cycle of the hall signal. Moreover, when the frequency of the hall signal input is less than 5.7 Hz, L level is outputted.



8. Protection-related 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 L. Overcurrent protection is disabled after every carrier cycle.
Reference voltage = 0.5 V (typ.)

(2) Gate block protection (RES pin)
When the RES input is H, the commutation outputs are disabled. When the RES input is then set L or open, 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.

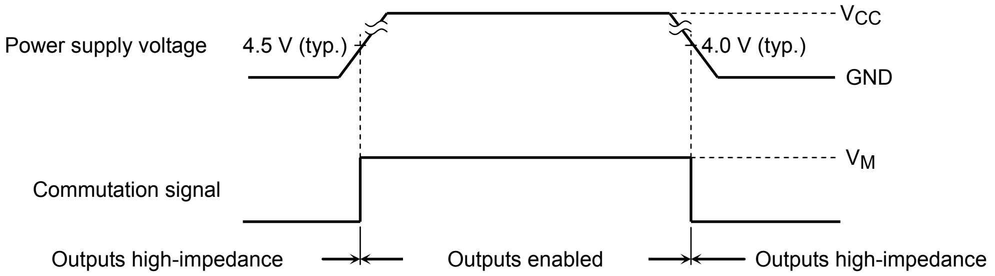
RES pin	Commutation output signals (U, V, W, X, Y, Z)
H	L
L or open	Motor can be driven

(When RES = H, charging of the bootstrap capacitor stops. Also when the operation re-enable, charging of the bootstrap capacitor stops.)

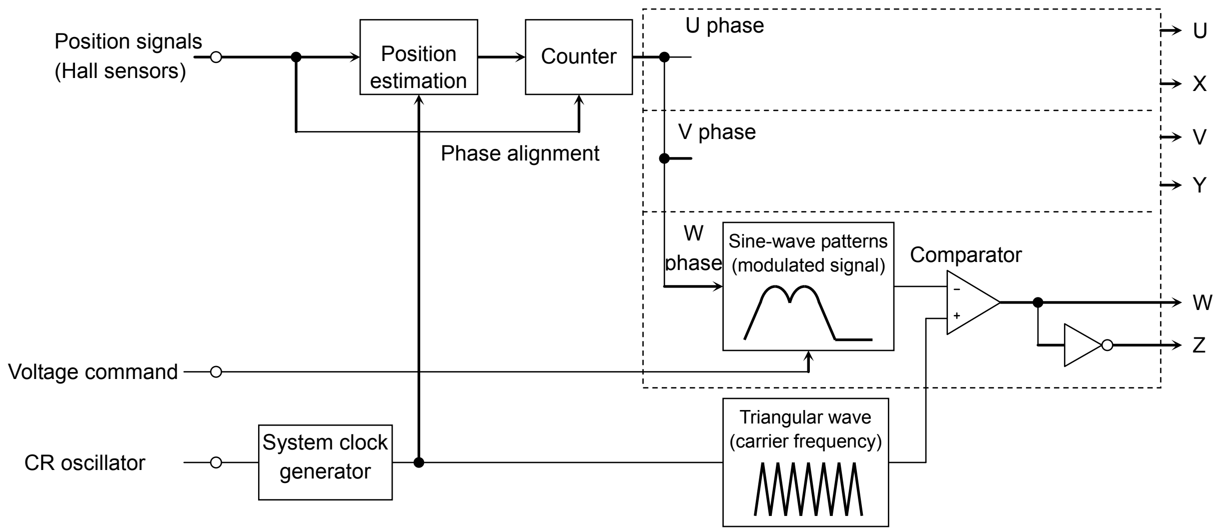
(3) Internal protection

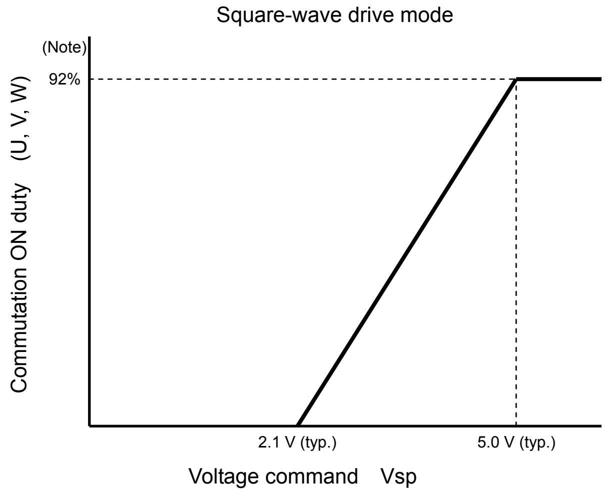
- Abnormal hall signal protection
When the hall signal inputs (UVW) are all H or all L, the commutation outputs are forced off (i.e., set L). When these inputs are then set to any other combination, the commutation outputs are re-enabled. (The all-H and all-L conditions are internal hall amplifier outputs.)

- Under voltage lockout (V_{CC} 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 devices from damage due to short-circuits.

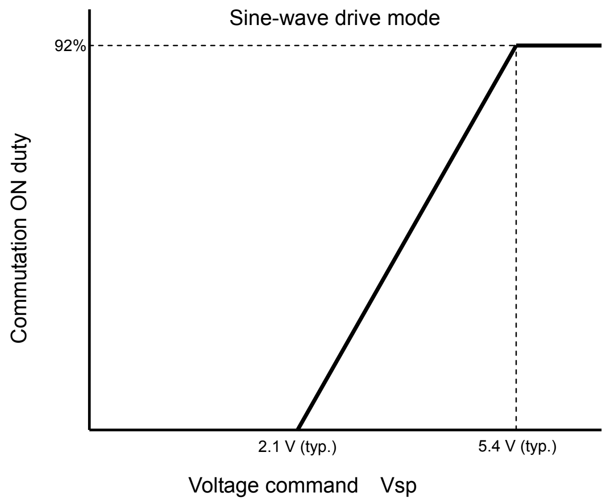


Operation flow





Note: The conduction time is reduced by the dead period. (carrier cycle×92% − Td×2)



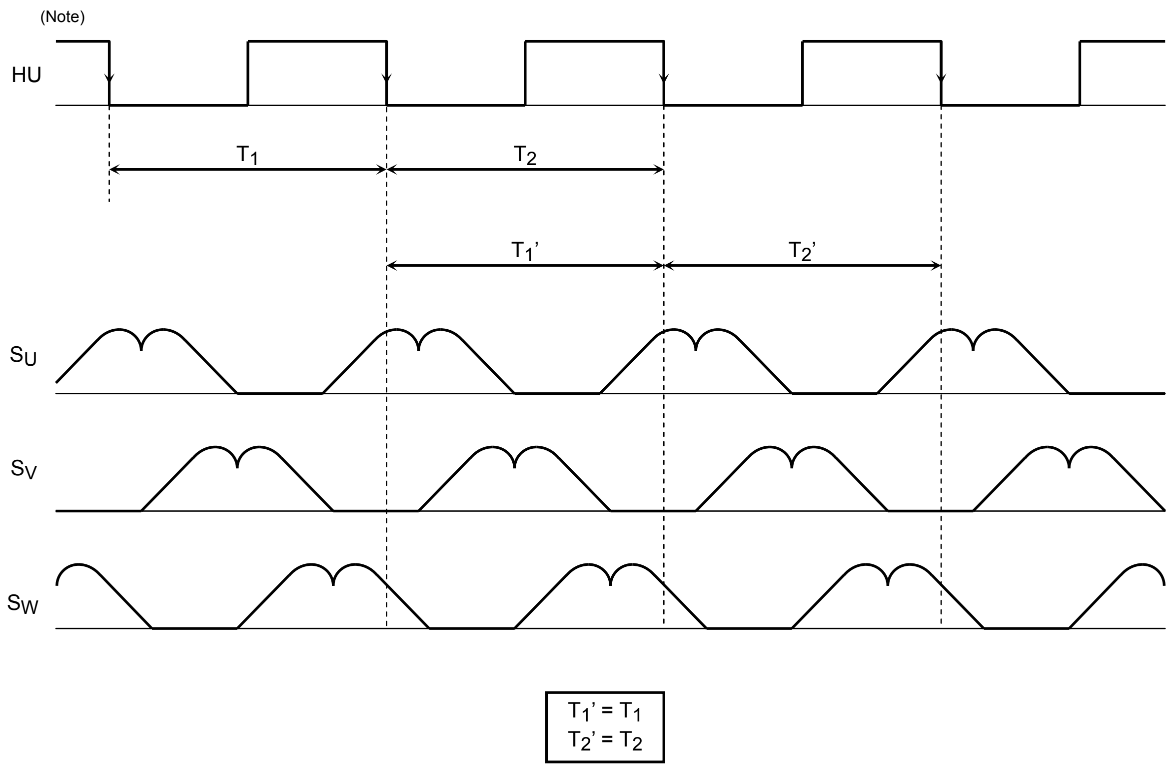
Timing of modulated signals

Reset timing for modulation can be selected by setting ALA pin.
Moreover, the auto lead angle mode can be also selected by ALA pin configuration.

ALA	Modulated signal generation	Auto lead angle mode
H	Modulated for each 360 electrical degrees	Feedback Idc
L	Modulated for each 60 electrical degrees	Feedback Idc and Vsp

Modulated when ALA= H

The hall signals from Hall sensors are modulated, and the modulated signals are then compared against a triangular waveform to generate a sinusoidal PWM waveform.
The counter measures the period from a given falling edge of the HU input to its next falling edge (360 electrical degrees). This period is then used as 360° phase data for the next modulation.
A total of 192 ticks comprise 360 electrical degrees; the length of a tick equals 1/192nds the time period of the immediately preceding 360° phase.



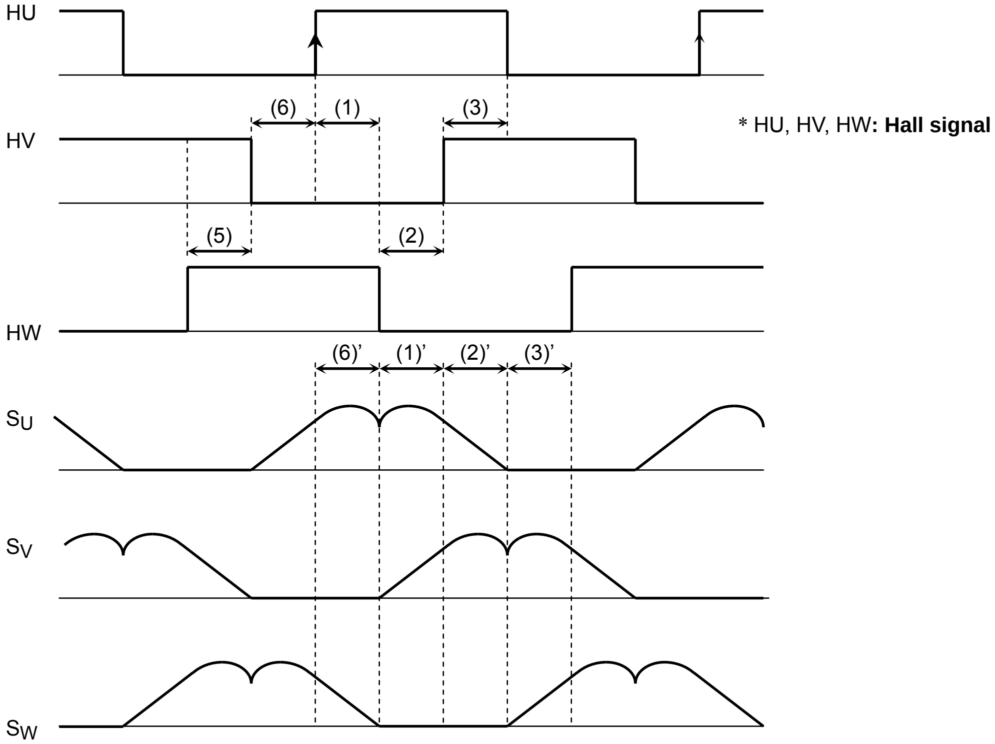
In the above diagram, the modulated waveforms have an interval (T1') that is equal to the interval between a falling edge of HU to its next falling edge (T1) of the previous cycle. If there is not an HU falling edge before T1' ends, T2' becomes equal to T1' until the next falling edge of HU.

Modulation is reset on each falling edge of HU, which occurs every 360 electrical degrees. While the motor is accelerating or decelerating, the modulated waveform becomes discontinuous upon each reset.

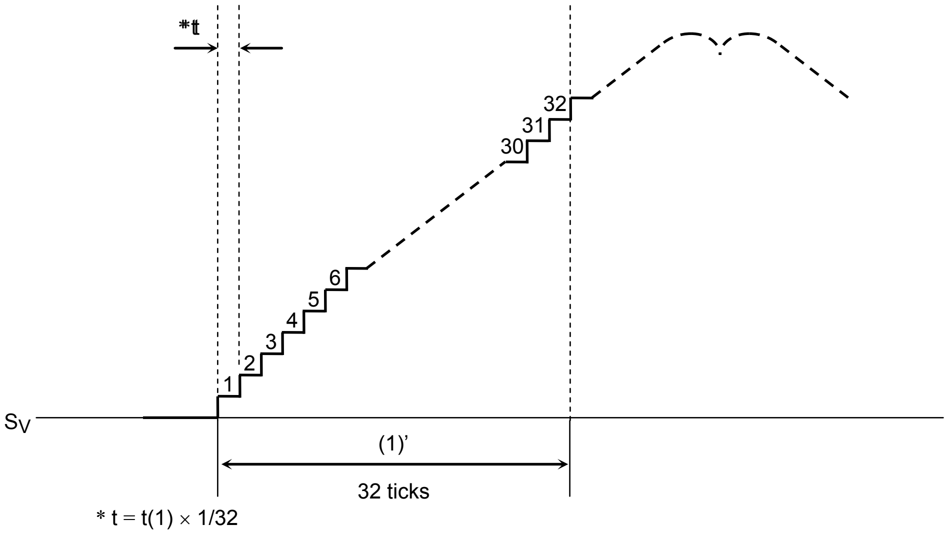
Note: In the above diagram, hall signals are shown as square waveforms for the sake of simplicity.

Modulated when ALA = L

The hall signals from Hall sensors are modulated, and the modulated signals are then compared against a triangular waveform to generate a sinusoidal PWM waveform.
The counter measures the period from a given rising edge (falling edge) of three Hall signals to its next falling edge (rising edge) where electrical angle is 60°. 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.



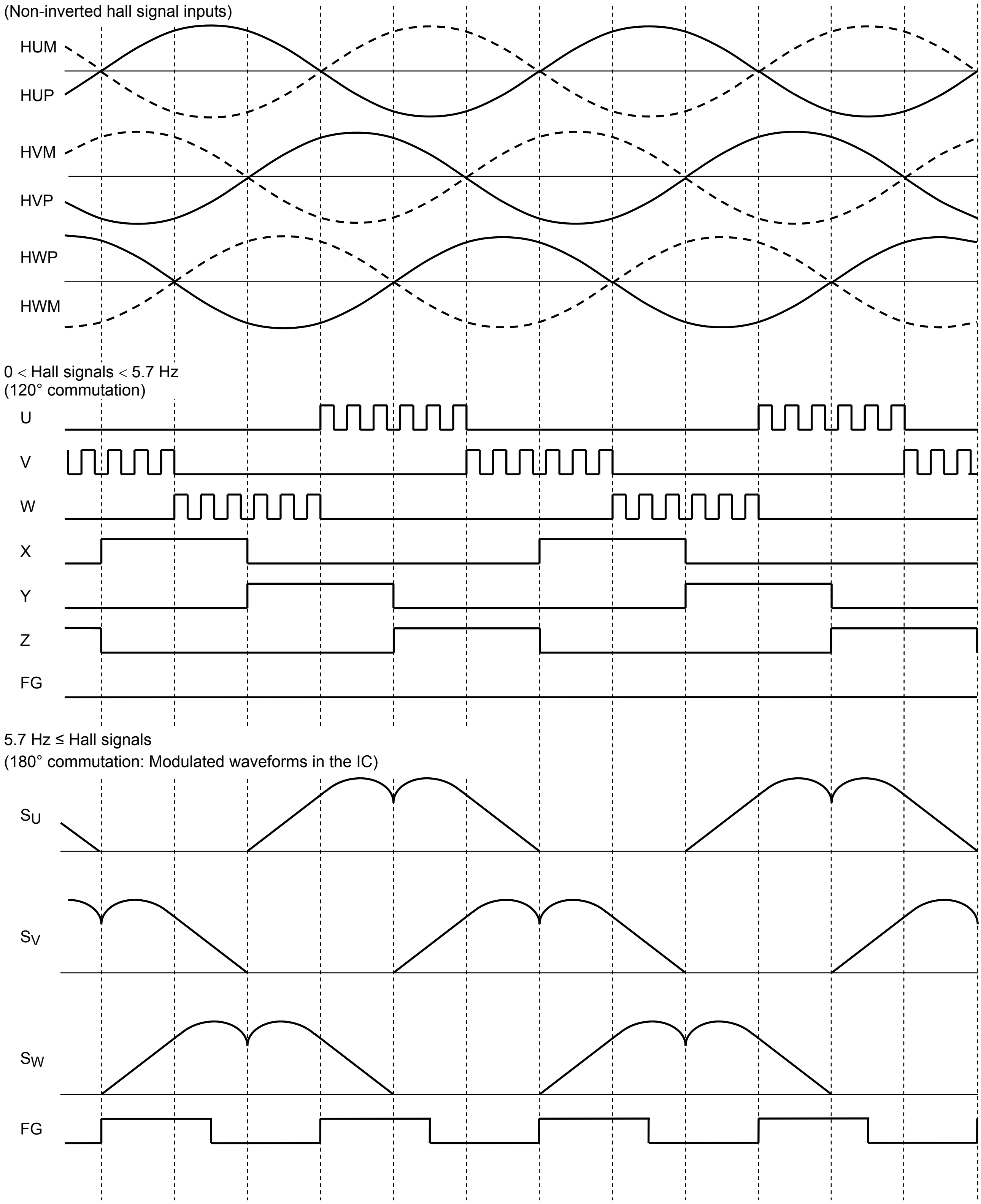
In the above diagram, the modulated waveforms have an interval (1)' that is equal to the interval between a rising edge of HU to a falling edge of HW (1) of the previous cycle. In the same way, the modulated waveforms have an interval (2)' that is equal to the interval between a falling edge of HW to a rising edge of HV (2) of the previous cycle. If there is not a next edge before 32 ticks end, next 32 ticks become equal to the next period until the next edge.



Phase matching between the hall signal and the modulated waveform is carried out for every zero cross of the hall signal.
Modulation is reset on each rising edge and falling edge of the hall signal, which occurs every 60 electrical degrees. While Hall signal is shifted or the motor is accelerating or decelerating, the modulated waveform becomes discontinuous upon each reset.

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

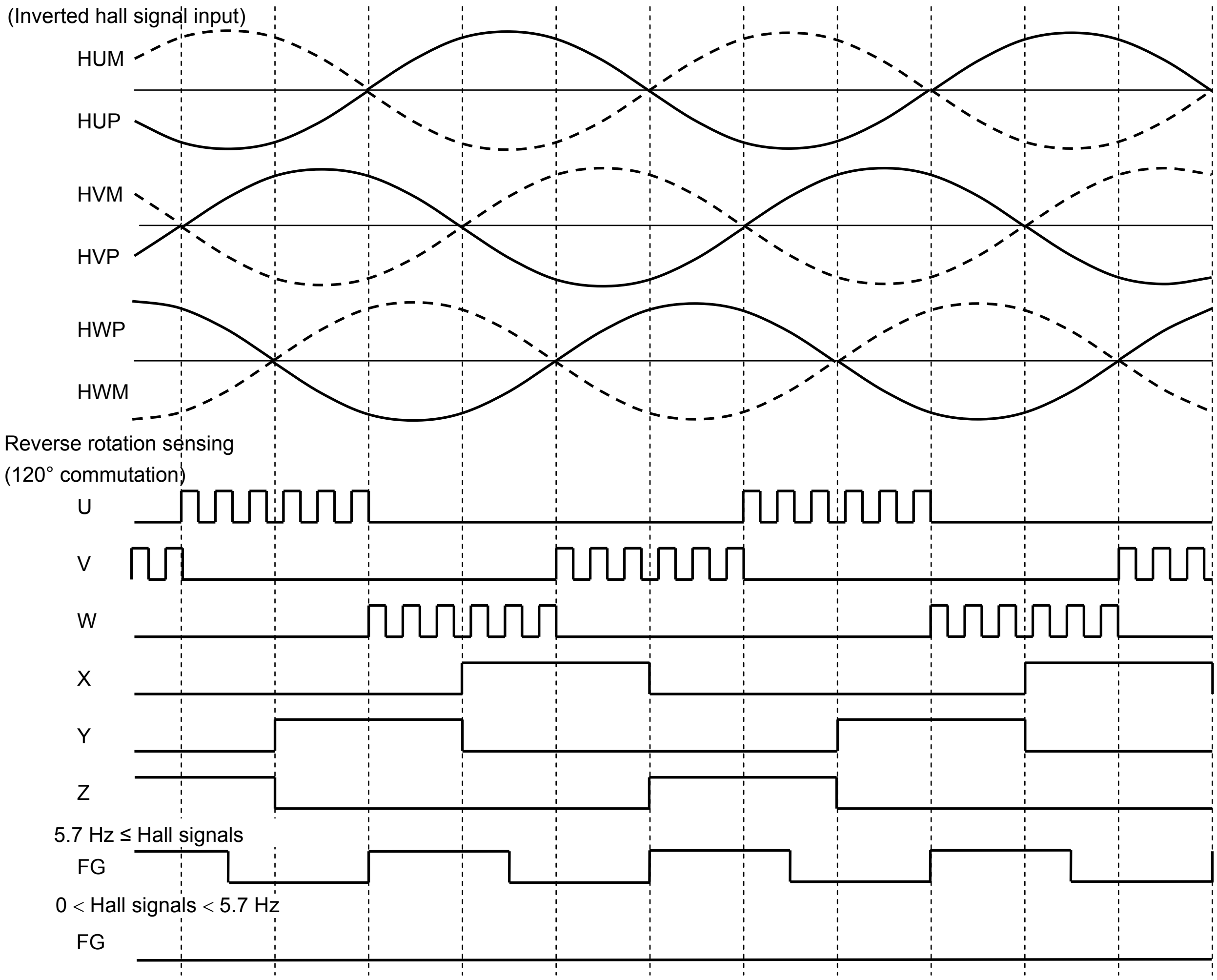
Forward rotation timing chart (CW/CCW = L, LA = GND)



*: When the Hall input frequency is 5.7 Hz or more (@ f_{osc} = 4.5 MHz), lead angle control is activated according the LA input.

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

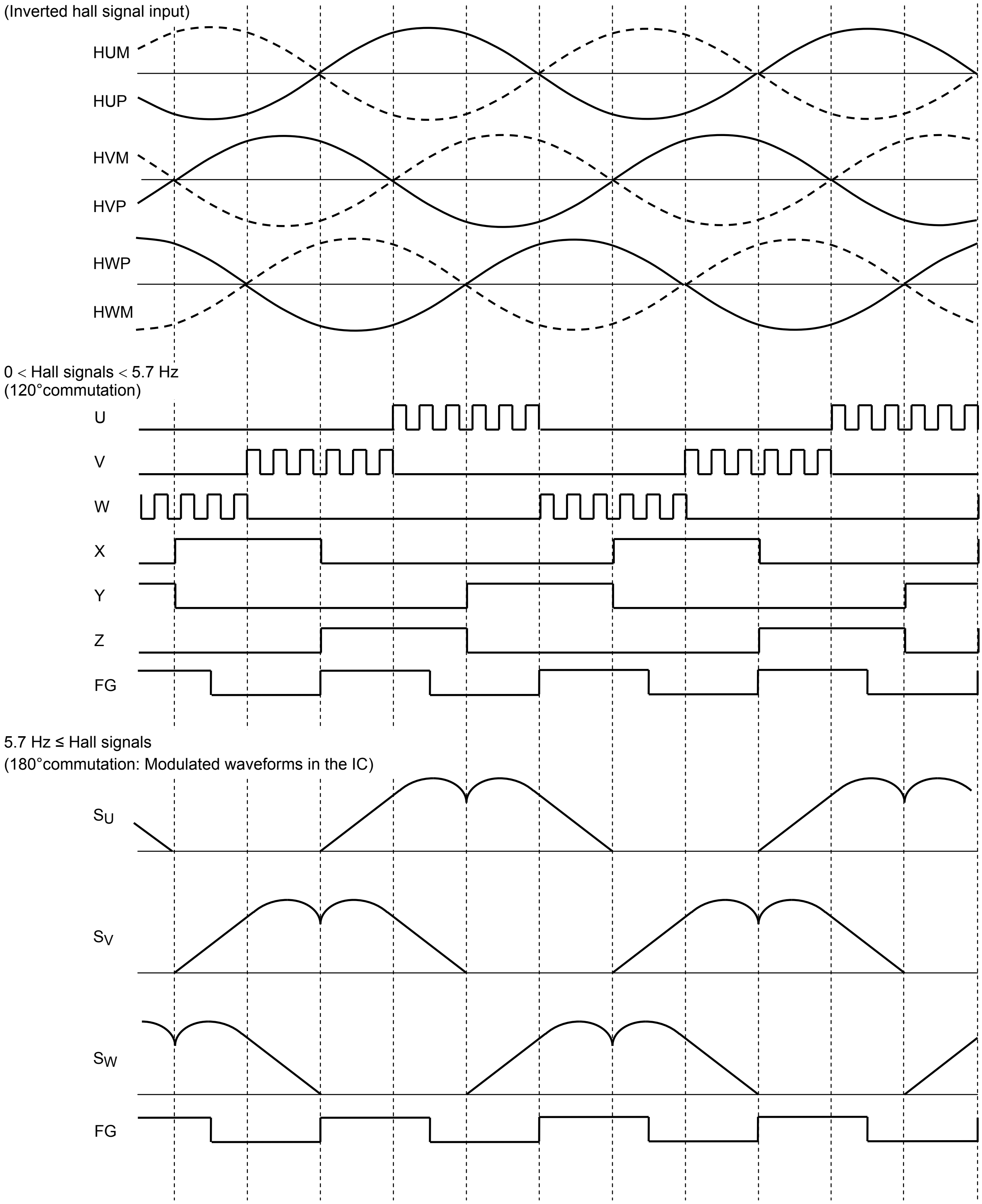
Forward rotation timing chart (CW/CCW = L, LA = GND)



*: When CW/CCW = L, inverted Hall signals put the TB67B054FTG 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.

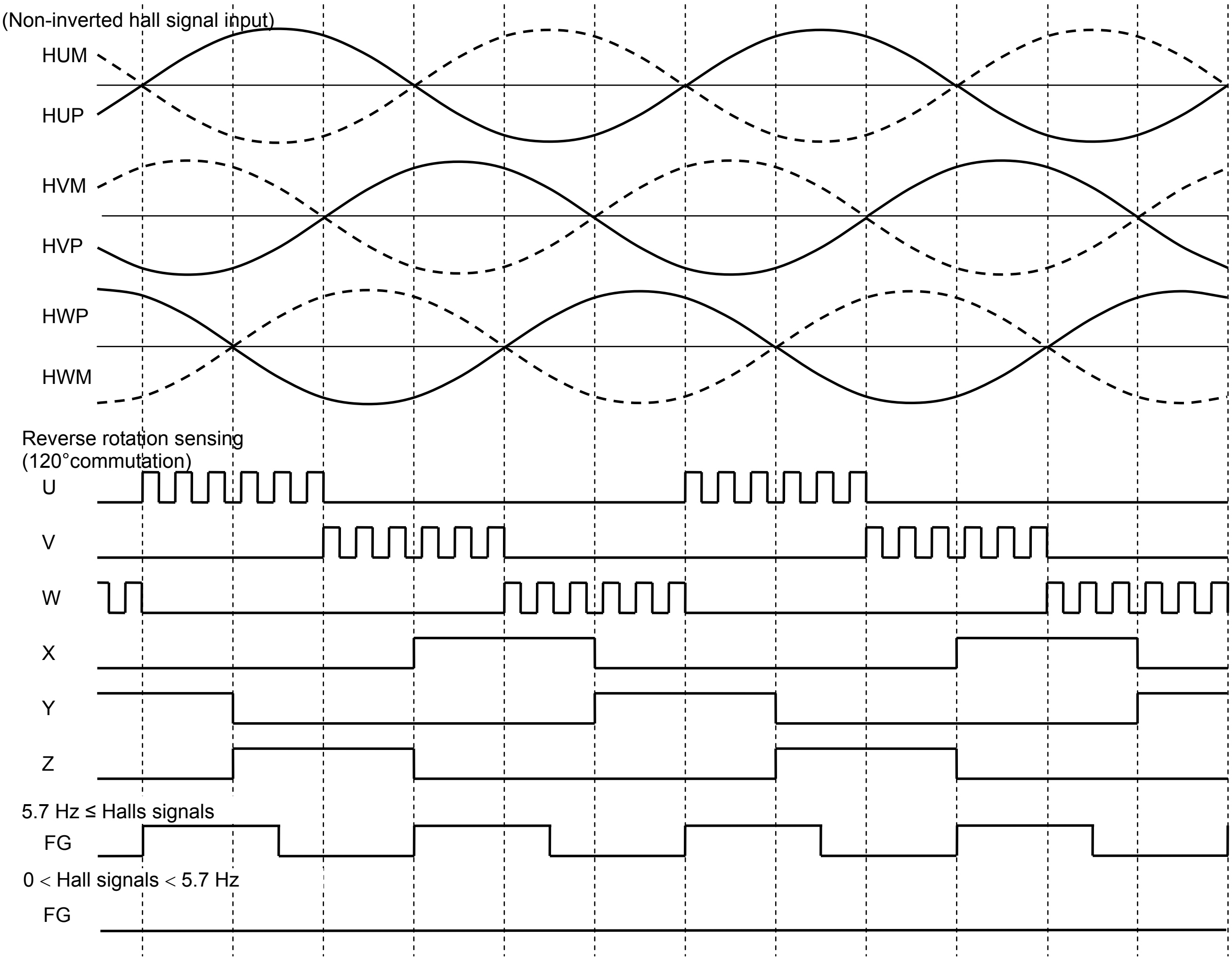
Reverse rotation timing chart (CW/CCW = H, LA = GND)



*: When the Hall input frequency is 5.7 Hz or more (@ fosc = 4.5 MHz), lead angle control is activated according the LA input.

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

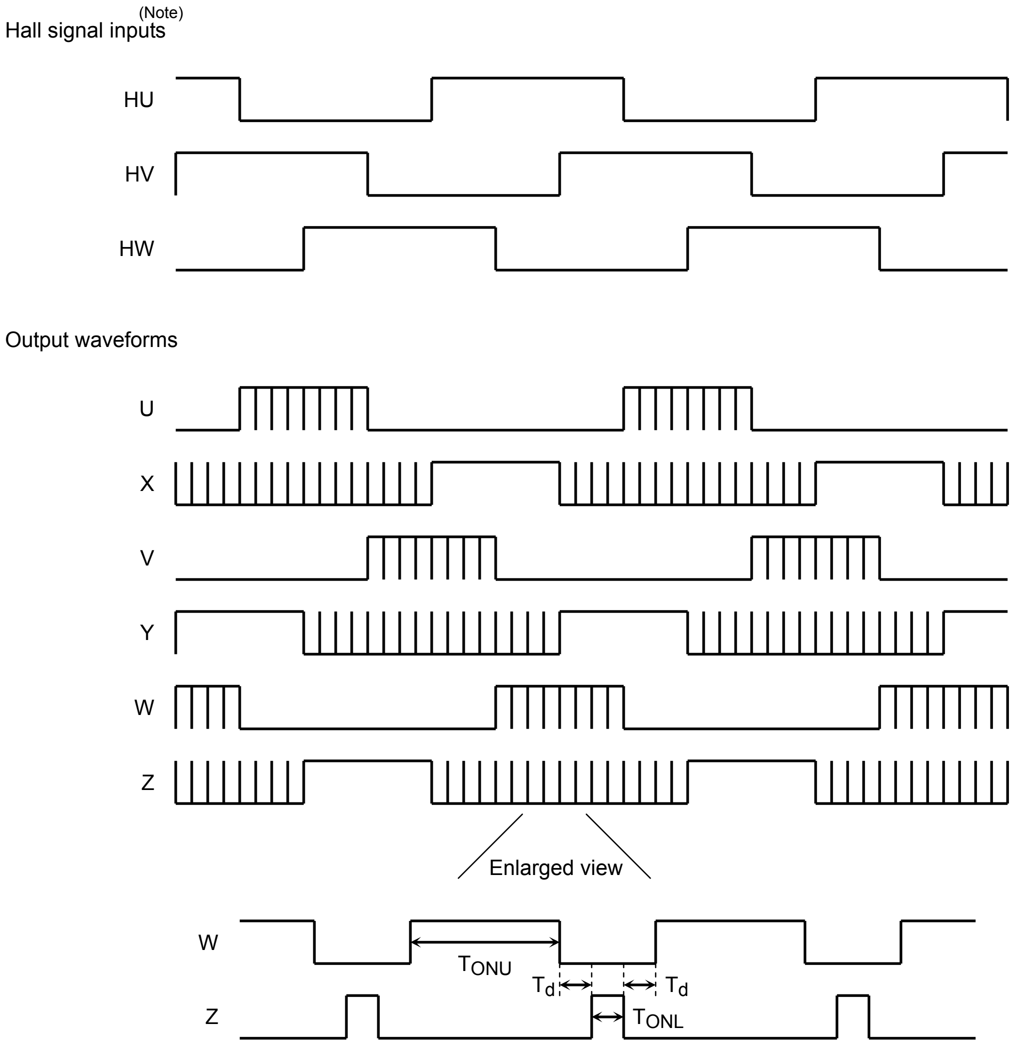
Reverse rotation timing chart (CW/CCW = H, LA = GND)



*: When CW/CCW = H, non-inverted Hall signals put the TB67B054FTG 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 = L)



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. (Td varies with the Vsp input.)

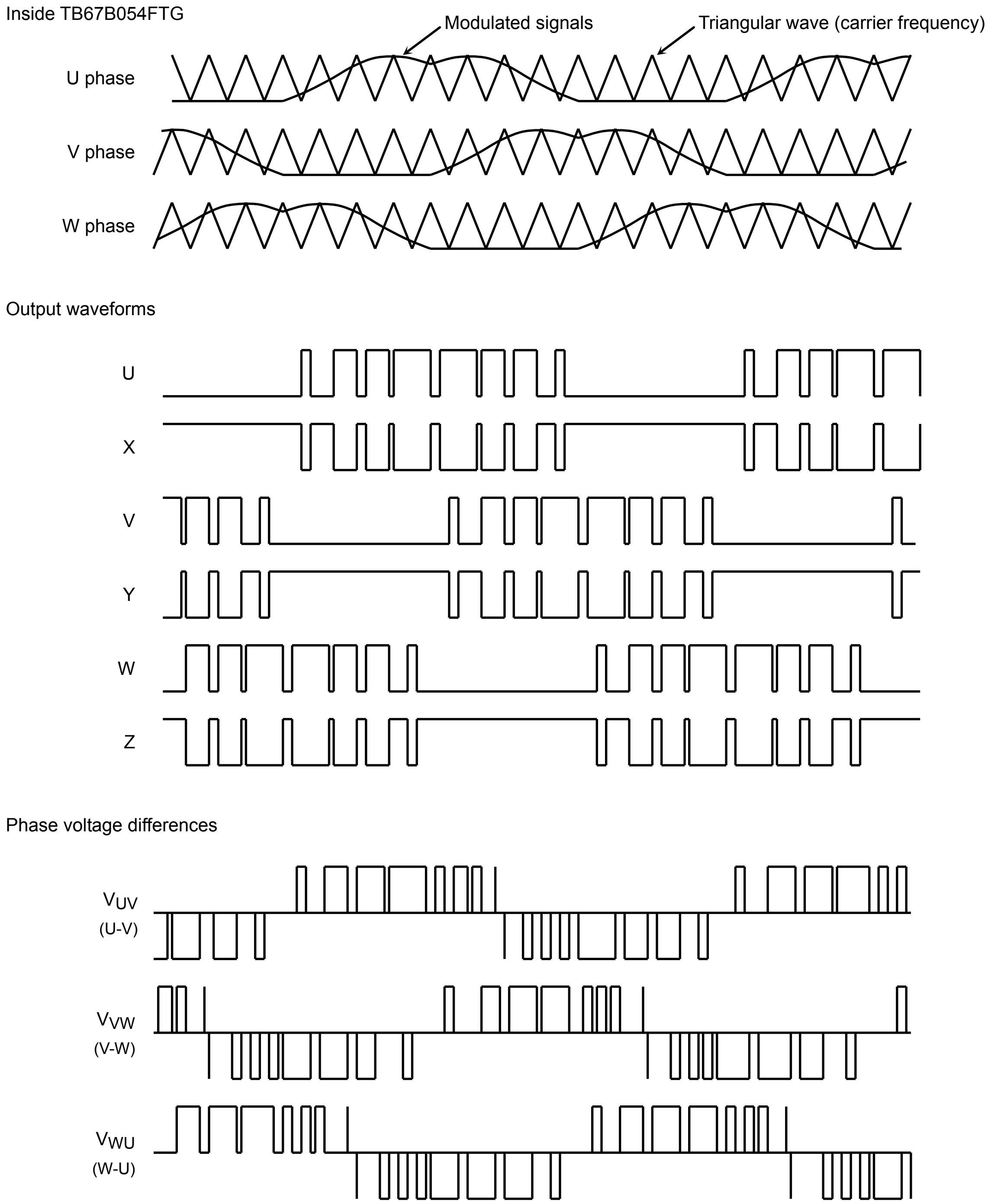
Carrier frequency = $f_{osc}/252$ (Hz) Dead time: $T_d = 9/f_{osc}$ (s) (Vsp ≥ 5.0 V)

T_{ONL} = carrier period × 8% (s) (constant regardless of the Vsp input)

In square-wave drive mode, the changing of the motor speed is enabled, depending on the Vsp voltage; the motor speed is determined by the duty cycle of T_{ONU}. (See the Square-wave drive mode diagram on page 14.)

Note: At startup, the motor is driven by a square wave when the Hall signal frequency is less than 5.7 Hz (@ fosc = 4.5 MHz) and when the motor is rotating in the direction reverse to the settings of the TB67B054FTG (REV = H).

Sine-wave drive waveform (CW/CCW = L)

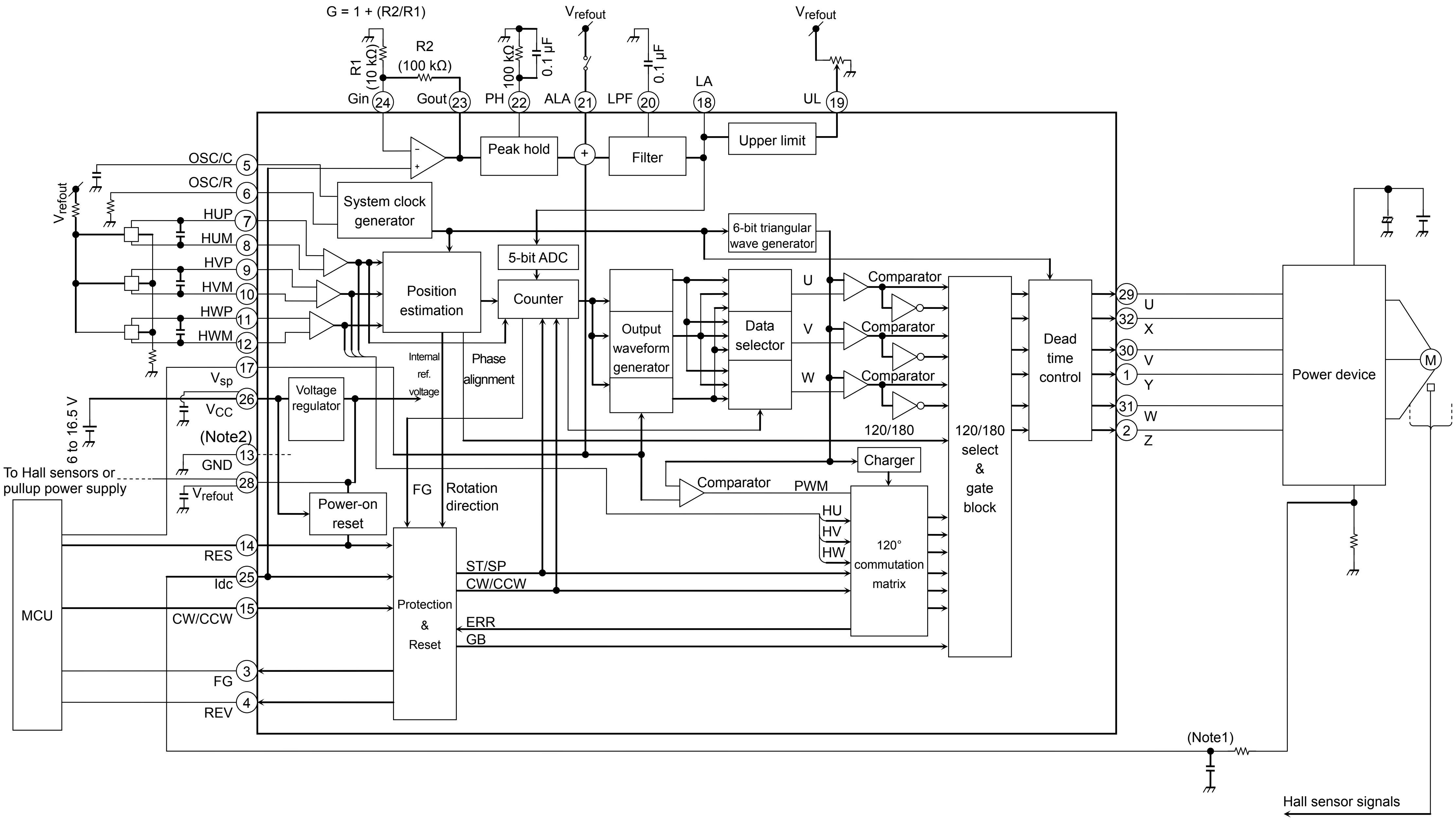


In sine-wave drive mode, the amplitude of the modulated signals varies with the Vsp voltage and the motor speed changes with the conduction duty cycle of the output waveforms. (See the Sine-wave drive mode diagram on page 14.)

Triangular wave frequency = carrier frequency = $f_{OSC}/252$ (Hz)

Note: At startup, the motor is driven by a sine wave when the Hall signal frequency is 5.7 Hz or more (@ fosc = 4.5 MHz) and when the motor is rotating in the same direction as settings of the TB67B054FTG (REV = L).

Application circuit example



Note1: Connect to ground as necessary to prevent IC malfunction due to noise.

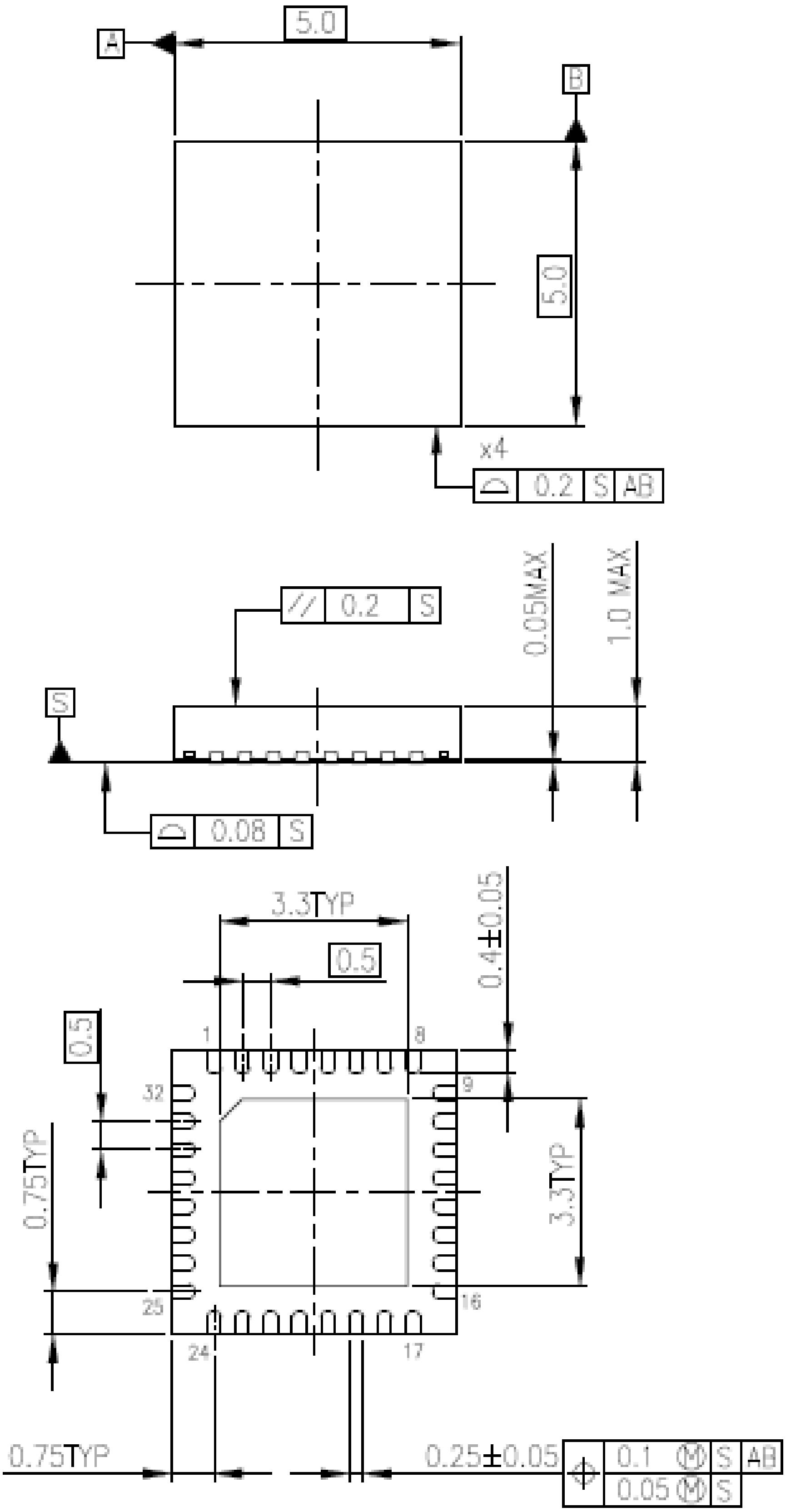
Note2: Connect GND to signal ground on the application circuit.

Note3: Utmost care is required in the design of the output, VCC, and GND lines since the IC may shatter or occur fire, or over voltage or over current may be applied to peripheral components due to short-circuits between outputs, short to VCC or short to ground.
The IC may also shatter or occur fire when it is installed in a wrong orientation.

Package dimensions

P-VQFN32-0505-0.50-005

Unit: mm



Weight: 0.07 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.
Providing these application circuit examples does not grant a license for industrial property rights.

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 (TJ) 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.

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

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