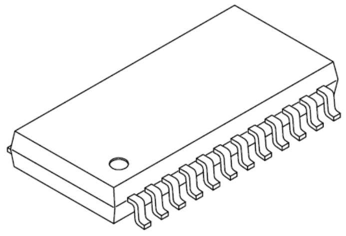
TOSHIBA Bi-CMOS Integrated Circuit Silicon Monolithic

TB6586BFG

Three-Phase Full-Wave Brushless Motor Controller

The TB6586BFG 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.)

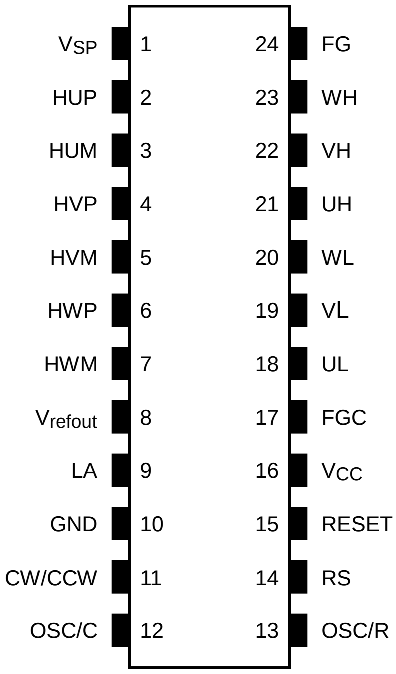
Features

- Designed for low-speed motor operation:
  Minimum ON duty = 0.6 μs (typ.)
- 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
- Pulses-per-revolution output:
  FGC = High: 1 pulse/electrical angle: 360°
  FGC = Low: 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 bits)
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	FGC	FG pulse count select (High = 1 ppr; Low or open = 3 ppr)
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	Pulses-per-revolution output

Pin Layout


VSP
HUP
HUM
HVP
HVM
HWP
HWM
Vrefout
LA
GND
CW/CCW
OSC/C
1
2
3
4
5
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8
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12
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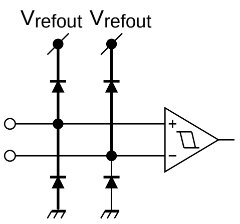
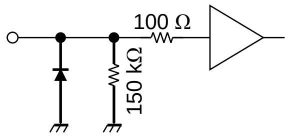
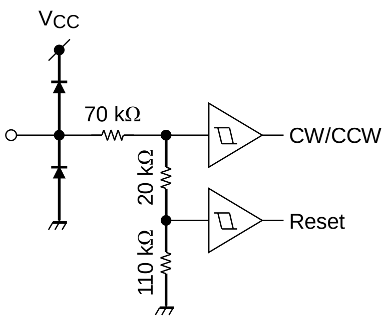
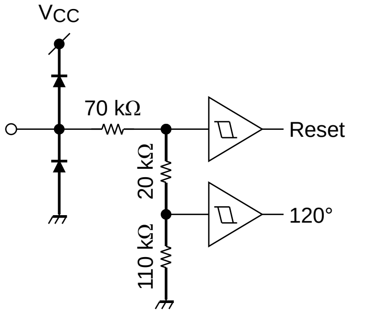
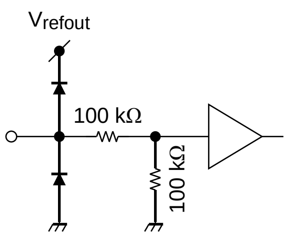
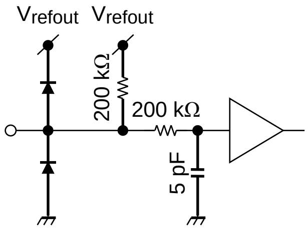
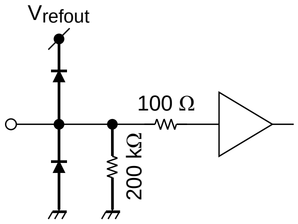
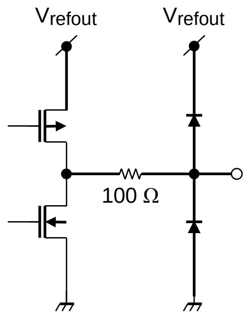
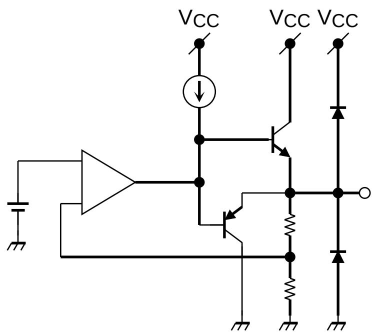
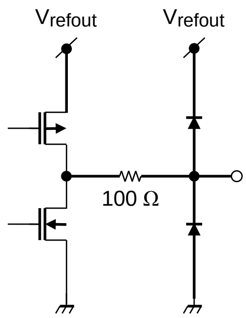
23
22
21
20
19
18
17
16
15
14
13
FG
WH
VH
UH
WL
VL
UL
FGC
VCC
RESET
RS
OSC/R

Input/Output Equivalent Circuits

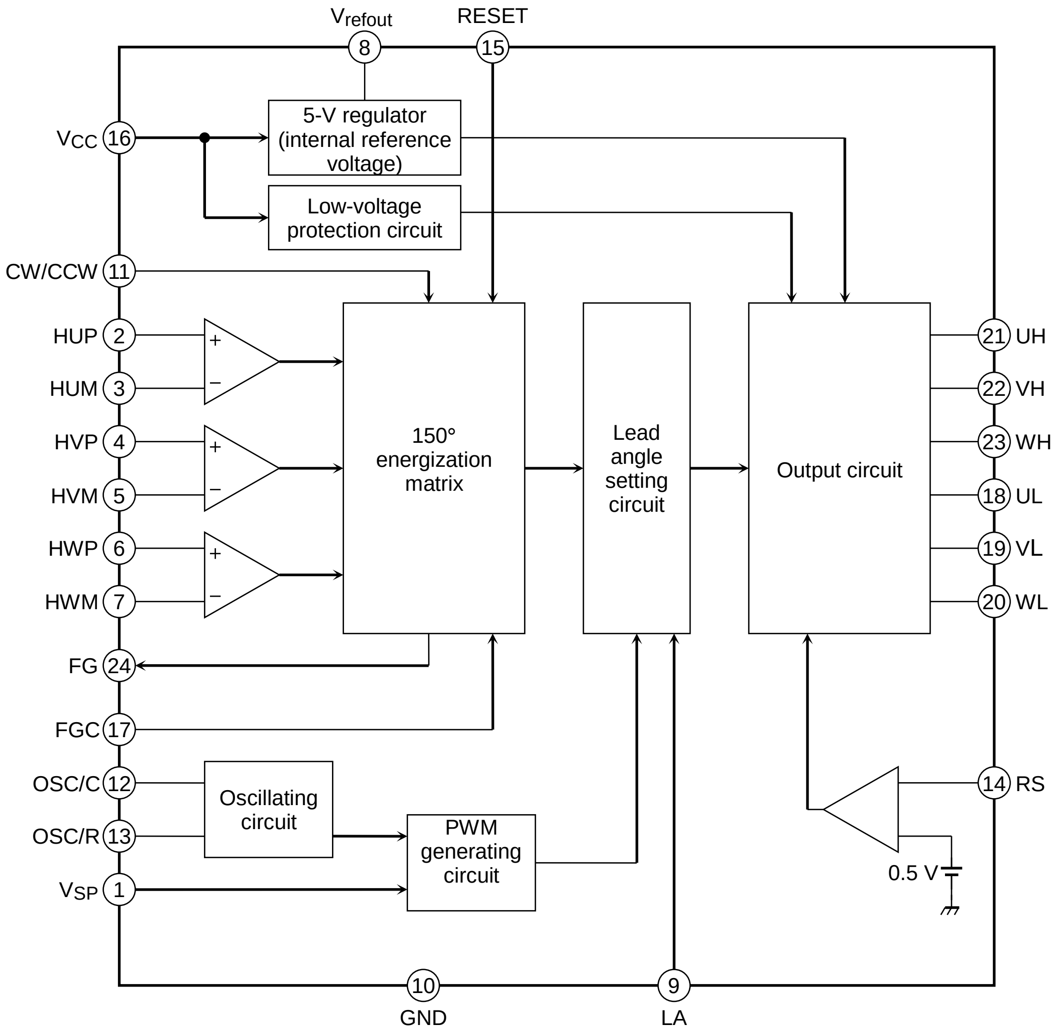
The equivalent circuit diagrams may be simplified or some parts of them may be omitted for explanatory purposes.

Pin Description	Symbol	Input/Output Signal	Input/Output Internal Circuit
Positional signal input pin	HUP HUM HVP HVM HWP HWM	Analog/Digital Hysteresis ± 7.5 mV (typ.) Digital filter: 1.6 μs (typ.)	
Speed control signal input pin	V_{SP}	Analog Input range 0 to 7 V	
Rotation direction signal input pin L: Forward (CW) H: Reverse (CCW)	CW/CCW	Digital L: 0.8 V (max) H: V_{refout} − 1 V (min) Test input If CW/CCW = 6.35 V (typ.) or higher, the system resets Hysteresis 150 mV (typ.)	
Reset input L: 150° energization H: Reset	RESET	Digital L: 0.8 V (max) H: V_{refout} − 1 V (min) If RESET = 6.35 V (typ.) or higher, then 120° energization drive is selected. Hysteresis 150 mV (typ.) During a reset: Output OFF (all phases Low). The internal counter continues to operate.	
Lead angle setting signal input	LA	Analog Input range 0 to 5.0 V (V_{refout}) Electrical angle 0° to 28° can be divided into 16 by 4-bit data. Lead angle 0° : LA = 0 V (GND) Lead angle 28°: LA = 5 V (V_{refout})	

Pin Description	Symbol	Input/Output Signal	Input/Output Internal Circuit
Overcurrent protection signal input	RS	Analog Analog filter 0.5 μs (typ.) If RS > 0.5 V (typ.), UL, VL and WL pin goes low (released at carrier cycle)	
FG pulse count select	FGC	Digital L: 0.8 V (max) H: Vrefout − 1 V (min) Low or Open: Three pulses/electrical angle: 360° High: One pulse/electrical angle: 360°	
Pulses-per-revolution output	FG	Digital Push-pull output (± 2 mA (max))	
Reference voltage signal output pin	Vrefout	5.0 ± 0.5 V (35 mA) 5.0 ± 0.3 V (15 mA)	
Energization signal output	UH UL VH VL WH WL	Push-pull output (± 2 mA (max))	

Block Diagram

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



Absolute Maximum Ratings (Ta = 25°C)

Characteristics	Symbol	Rating	Unit
Supply voltage	V_{CC}	18	V
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)	
Energization output current	I_{OUT}	2	mA
Power dissipation	P_D	0.8 (Note 4)	W
		1.0 (Note 5)	
Operating temperature	T_{opr}	−30 to 85	°C
Storage temperature	T_{stg}	−55 to 150	

Note 1: CW/CCW, RESET

Note 2: V_{SP}

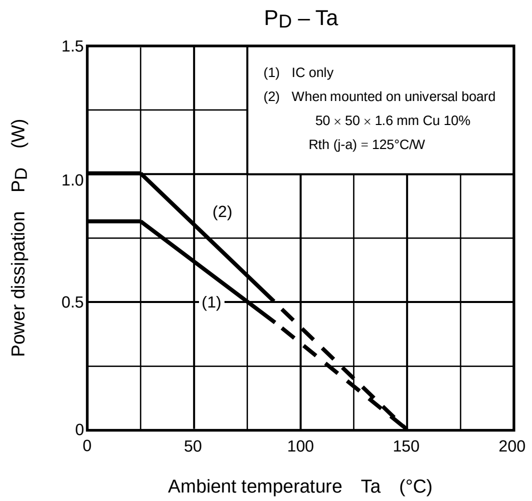
Note 3: LA, FGC

Note 4: Without a heatsink

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

Operating Ranges (Ta = 25°C)

Characteristics	Symbol	Min	Typ.	Max	Unit
Supply voltage	V_{CC}	6.5	15	16.5	V
Oscillation frequency	F_{osc}	2	5	8	MHz



Electrical Characteristics (unless otherwise specified Ta = 25°C, V_{CC} = 15 V)

Characteristics	Symbol	Test Condition	Min	Typ.	Max	Unit
Supply current	I_{CC}	V_{refout} = OPEN, OSC/C = 390 pF, OSC/R = 9.1 kΩ	2.0	5.5	10	mA
Input current	$I_{IN\ (LA)}$	V_{IN} = 5 V LA	—	25	50	μA
Input current	$I_{IN\ (SP)}$	V_{IN} = 5 V V_{SP}	—	35	70	μA
Input current	$I_{IN\ (RESET)}$	V_{IN} = 5 V RESET	—	25	50	μA
Input current	$I_{IN\ (CW)}$	V_{IN} = 5 V CW/CCW	—	25	50	μA
Input current	$I_{IN\ (FGC)}$	V_{IN} = 5 V FGC	—	25	50	μA
Input current	$I_{IN\ (RS)}$	V_{IN} = 0 V RS	—	−25	−50	μA
Input voltage	$V_{IN(CW/CCW)}$ RST	System reset	6.0	6.35	7.1	V
Input voltage	$V_{IN(CW/CCW)}$ High	CCW (Reverse)	V_{refout} − 1	—	V_{refout}	V
Input voltage	$V_{IN(CW/CCW)}$ Low	CW (Forward)	0	—	0.8	V
Input voltage	$V_{IN(RESET)}$ RST	120° energization	6.0	6.35	7.1	V
Input voltage	$V_{IN(RESET)}$ High	Output off reset	2.2	—	V_{refout}	V
Input voltage	$V_{IN(RESET)}$ Low	150° energization	0	—	0.8	V
Input voltage	V_{SP} H	PWM ON duty 95%	5.1	5.4	5.7	V
Input voltage	V_{SP} M	Refresh → Start motor operation.	1.8	2.1	2.4	V
Input voltage	V_{SP} L	Energization OFF → Refresh	0.7	1.0	1.3	V
Hall element input: Input sensitivity	V_S	Differential input	40	—	—	mVpp
Hall element input: Common mode	V_W		1.5	—	3.5	V
Hall element input: Input hysteresis	$V_{H\ (1)}$	(Note)	±4.5	±7.5	±10.5	mV
Input hysteresis voltage	$V_{H\ (2)}$	RESET, CW/CCW (Note)	—	0.15	—	V
Input delay	T_{RS}	RS → Output Off. RS input: 0 V/ 2 V	—	1.2	—	μs
Output voltage	V_{OUT-H}	I_{OUT} = 2 mA	V_{refout} − 0.8	V_{refout} − 0.3	—	V
Output voltage	V_{OUT-L}	I_{OUT} = 2 mA	—	0.3	0.8	V
Output voltage	$V_{FG\ (H)}$	I_{OUT} = 2 mA FG	4	—	—	V
Output voltage	$V_{FG\ (L)}$	I_{OUT} = 2 mA FG	—	—	1.0	V
Output voltage	$V_{refout1}$	I_{OUT} = 15 mA V_{refout}	4.7	5.0	5.3	V
Output voltage	$V_{refout2}$	I_{OUT} = 35 mA V_{refout}	4.5	5.0	5.3	V
Output leakage current	$I_{L\ (H)}$	V_{OUT} = 0 V	—	0	1	μA
Output leakage current	$I_{L\ (L)}$	V_{OUT} = 5 V	—	0	1	μA
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	—	°
Lead angle correction	$T_{LA\ (2.5)}$	LA = 2.5 V, Hall IN = 100 Hz	—	17	—	°
Lead angle correction	$T_{LA\ (5)}$	LA = 5 V, Hall IN = 100 Hz	—	28	—	°
V_{CC} monitor	V_{CC} (H)	Output start operation point	5.7	6.0	6.3	V
V_{CC} monitor	V_{CC} (L)	No output operation point	4.7	5.0	5.3	V
V_{CC} monitor	$V_{H\ (4)}$	Input hysteresis width (Note)	—	1.0	—	V
PWM oscillator frequency (carrier frequency)	$F_{C\ (20)}$	OSC/C = 390 pF, OSC/R = 9.1 kΩ	18	20	22	kHz
PWM oscillator frequency (carrier frequency)	$F_{C\ (18)}$	OSC/C = 390 pF, OSC/R = 10 kΩ	16.2	18	19.8	kHz
Output duty	T_{on} (max)	OSC/C = 390 pF, OSC/R = 9.1 kΩ	92	95	98	%
Output duty	T_{on} (min)	OSC/C = 390 pF, OSC/R = 9.1 kΩ (Note)	—	0.6	—	μs

Note: Not tested in production

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 $\quad$ fs = $f_{osc}/(120 \times 2^5 \times 2^8)$

5 Hz or higher: 120° energization or 150° energization * $\quad$ 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°.

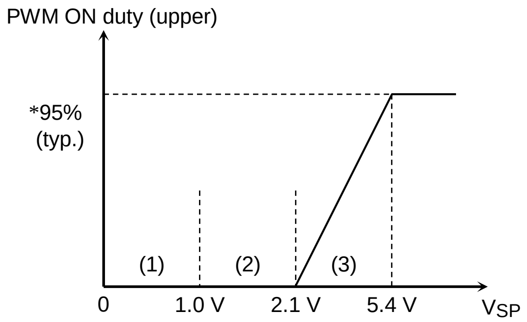
2. VSP Voltage Command Signal Function

(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 the lower transistor on for a fixed time with 1.0 V < VSP ≤ 2.1 V.

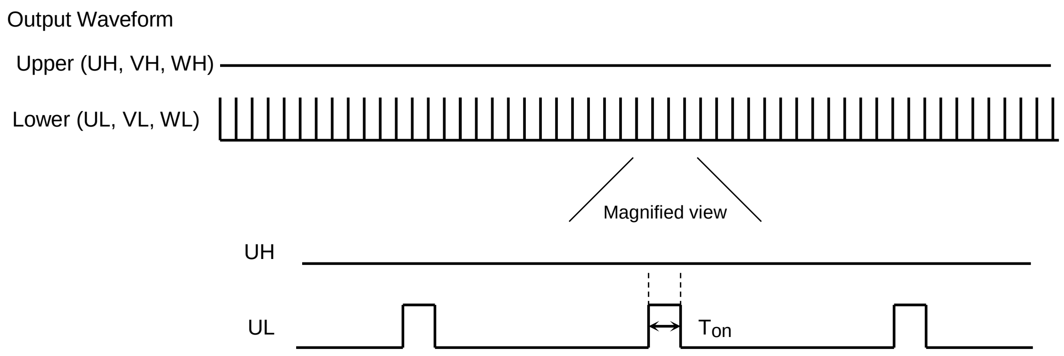


*: The maximum ON duty is Ton = 95% (typ.) when VSP = 5.4 V (typ.).
Example: If fosc = 5 MHz, then ON time = 48 μs (typ.) (fc = 19.8 kHz)
If fosc = 4 MHz, then ON time = 60 μs (typ.) (fc = 15.9 kHz)

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.

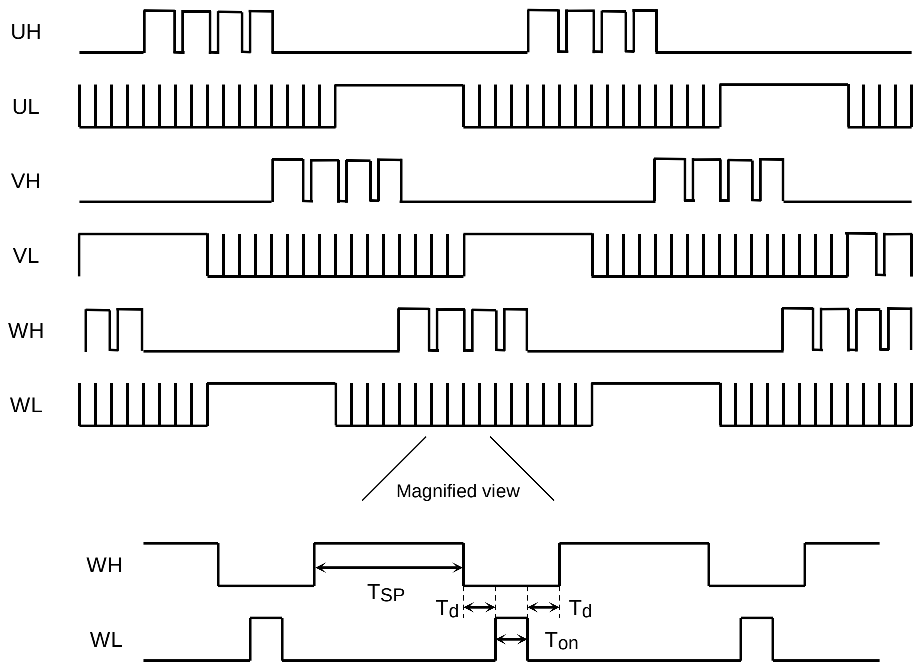
(1) If the VSP input voltage is 1.0 V < VSP ≤ 2.1 V, the ON signal based on the carrier cycle is output to the lower phase (UL, VL, WL) and the OFF signal (Low) is output to the upper phase (UH, VH, WH).



Ton = 18/fosc
Example: fosc = 5 MHz Ton = 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, and 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

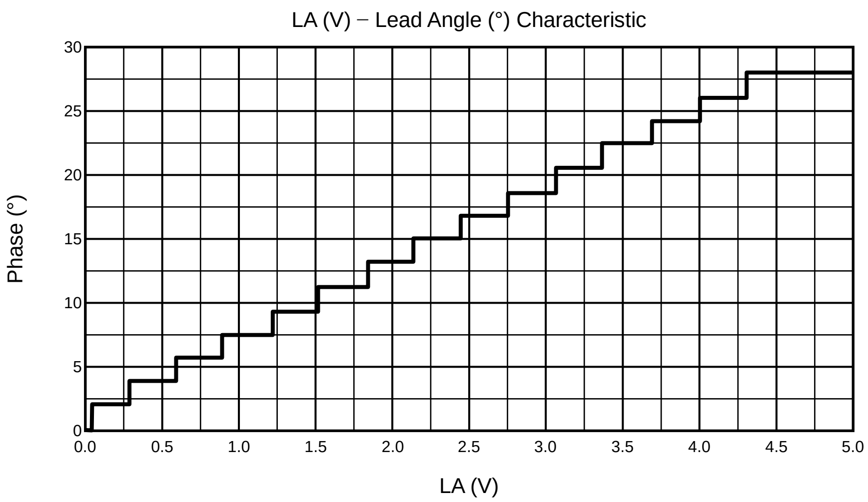
The lead angle can be corrected in the turn-on signal range from 0 to 28° in relation to the induced voltage.
Analog input from the LA pin (0 V to 4.3 V divided by 16):

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



5. Setting the Carrier Frequency

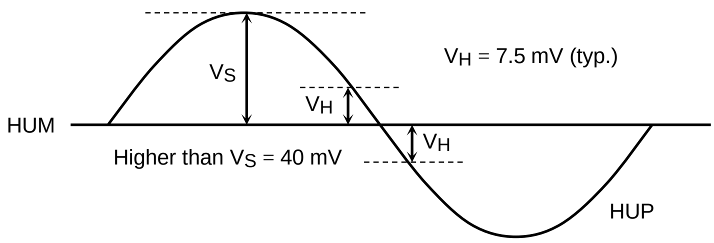
This function involves setting the triangular wave frequency (carrier frequency) necessary for generating PWM signals.

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

Example: If f_{osc} = 5 MHz, then fc = 19.8 kHz
If f_{osc} = 4 MHz, then fc = 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.).

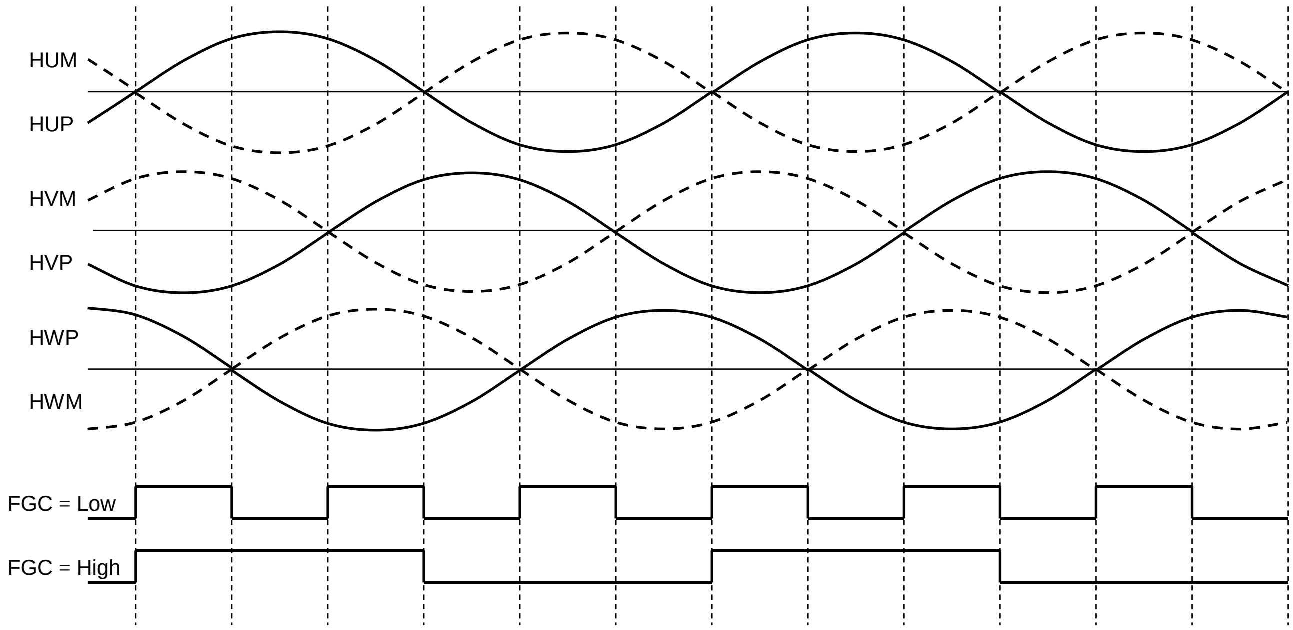


7. Pulses-Per Revolution Output

The number of pulses to be generated from the FG output is selectable from one or three pulses per electrical degree via the FGC input. When one pulse per electrical degree is selected, pulses are generated from the U-phase Hall signal. When three pulses per electrical degree is selected, pulses are generated by combining the rising edges of the U-, V- and W-phase Hall signals.

FGC	FG
High	One pulse/electrical angle
Low or open	Three pulses/electrical angle

FG Signal Timing Chart

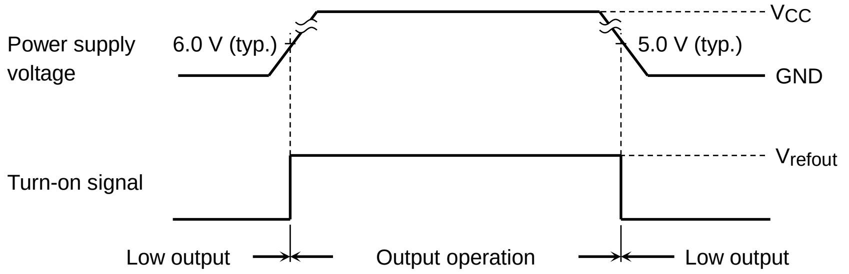


8. Protecting Input Pin

(1) Overcurrent protection (RS Pin)
If the current converted a voltage into exceeds the internal reference voltage (0.5 V (typ.)), each output (UH, VH, WH) on the high side becomes a low and each output (UL, VL, WL) on the low side outputs a drive signal in accordance with the signal from the hall elements as shown on the timing chart.
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.



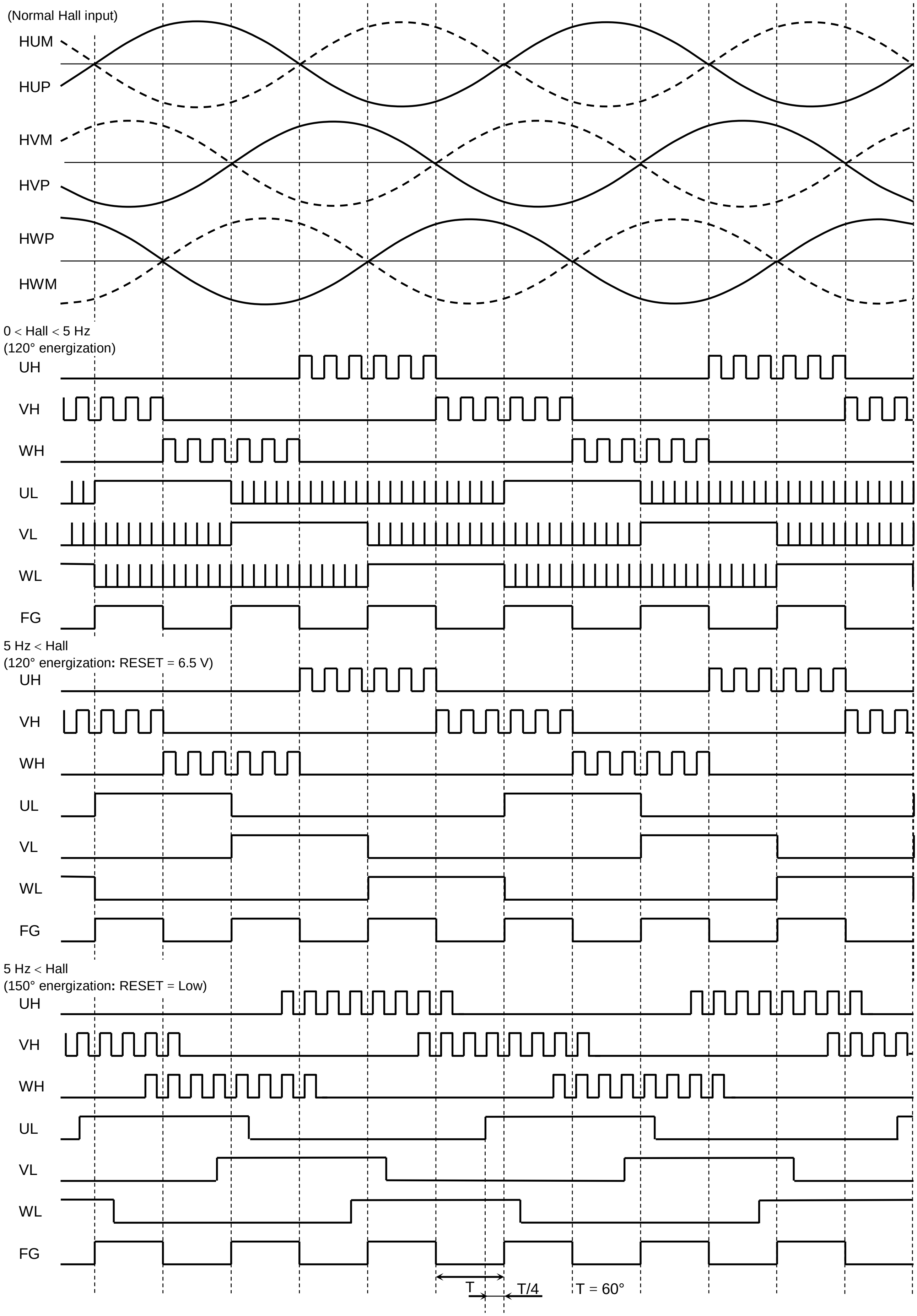
(4) Output pulse width restriction
To prevent damage to the output driver (externally attached), the drive output signals (UH, VH, WH, UL, VL, WL) are restricted from being output at a pulse width of 0.4 μs or less.

(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.)). Then, normal drive will 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. The FG signal is not output during a system reset.

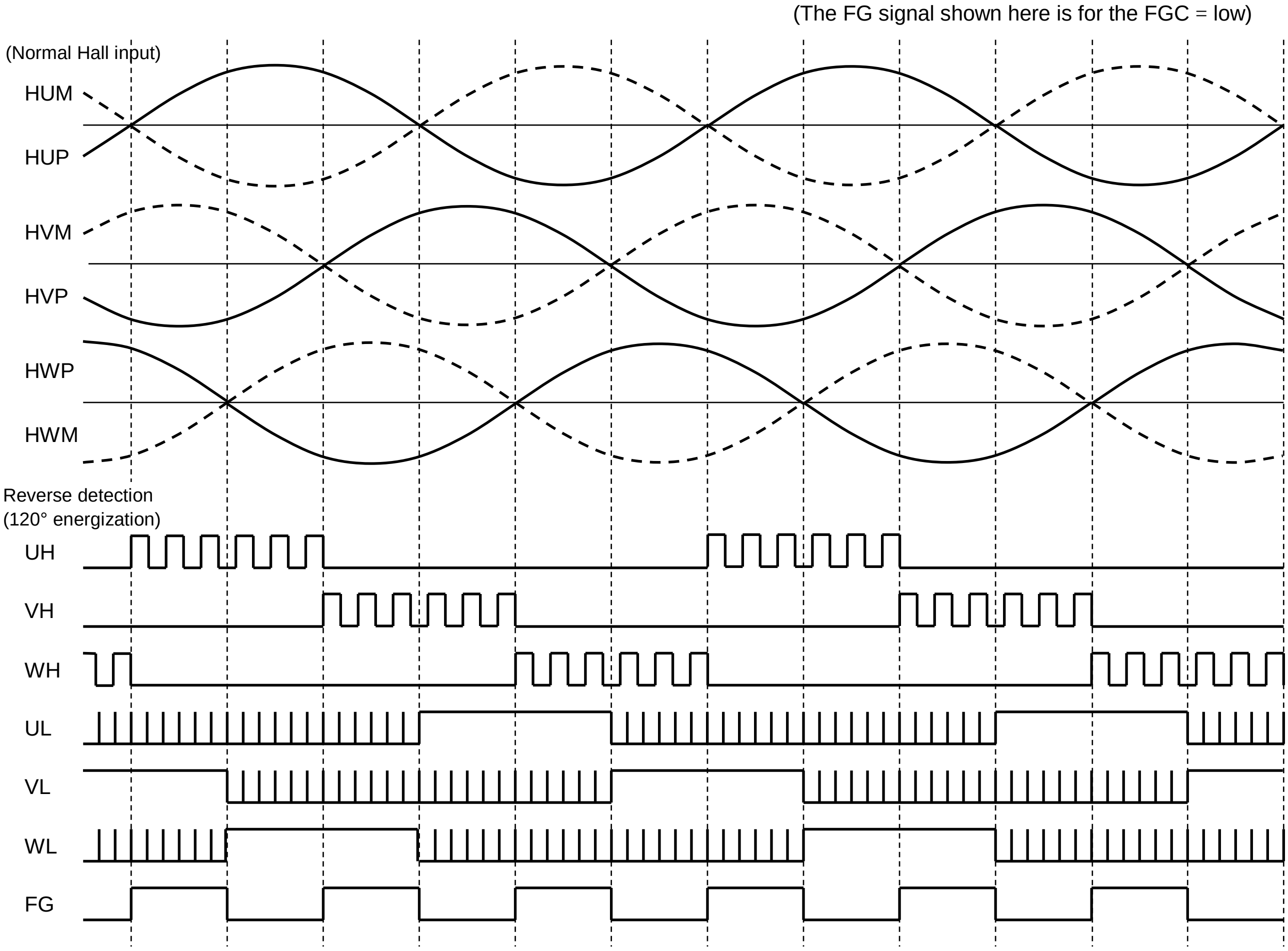
Timing Chart (CW/CCW = Low, LA = GND)

(The FG signal shown here is for the FGC = low)



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

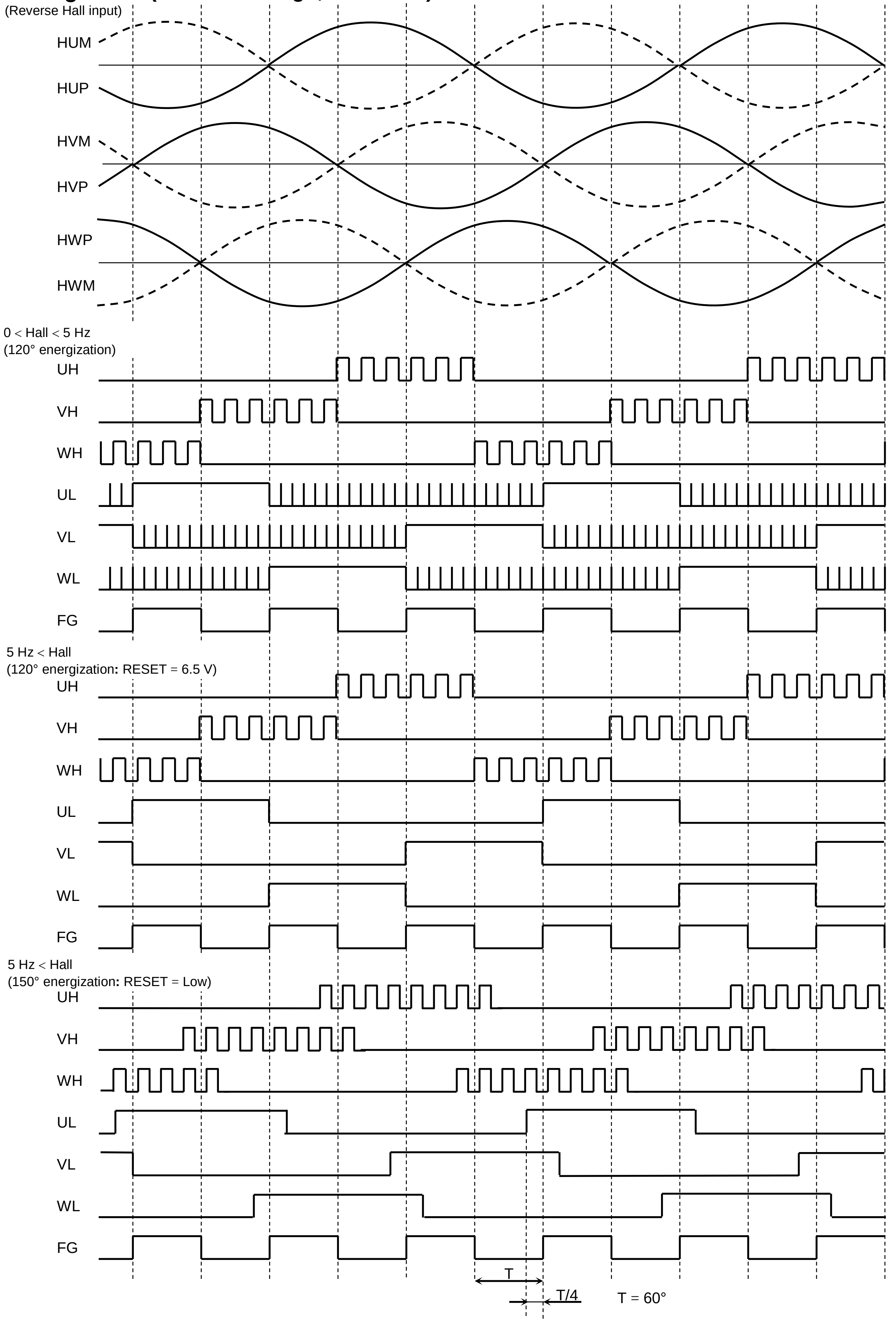
Timing Chart (CW/CCW = High, LA = GND)



*: 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)

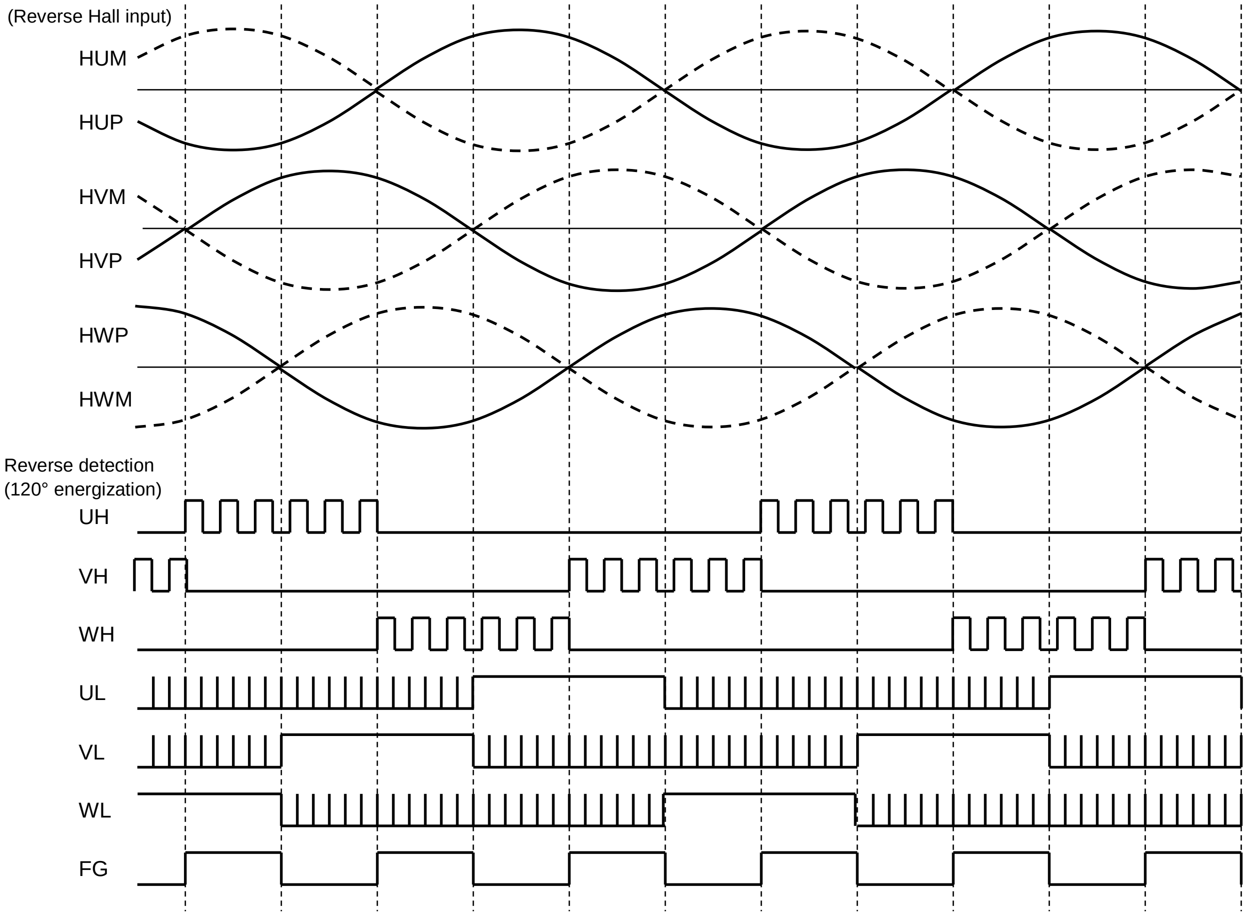
(The FG signal shown here is for the FGC = low.)



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

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

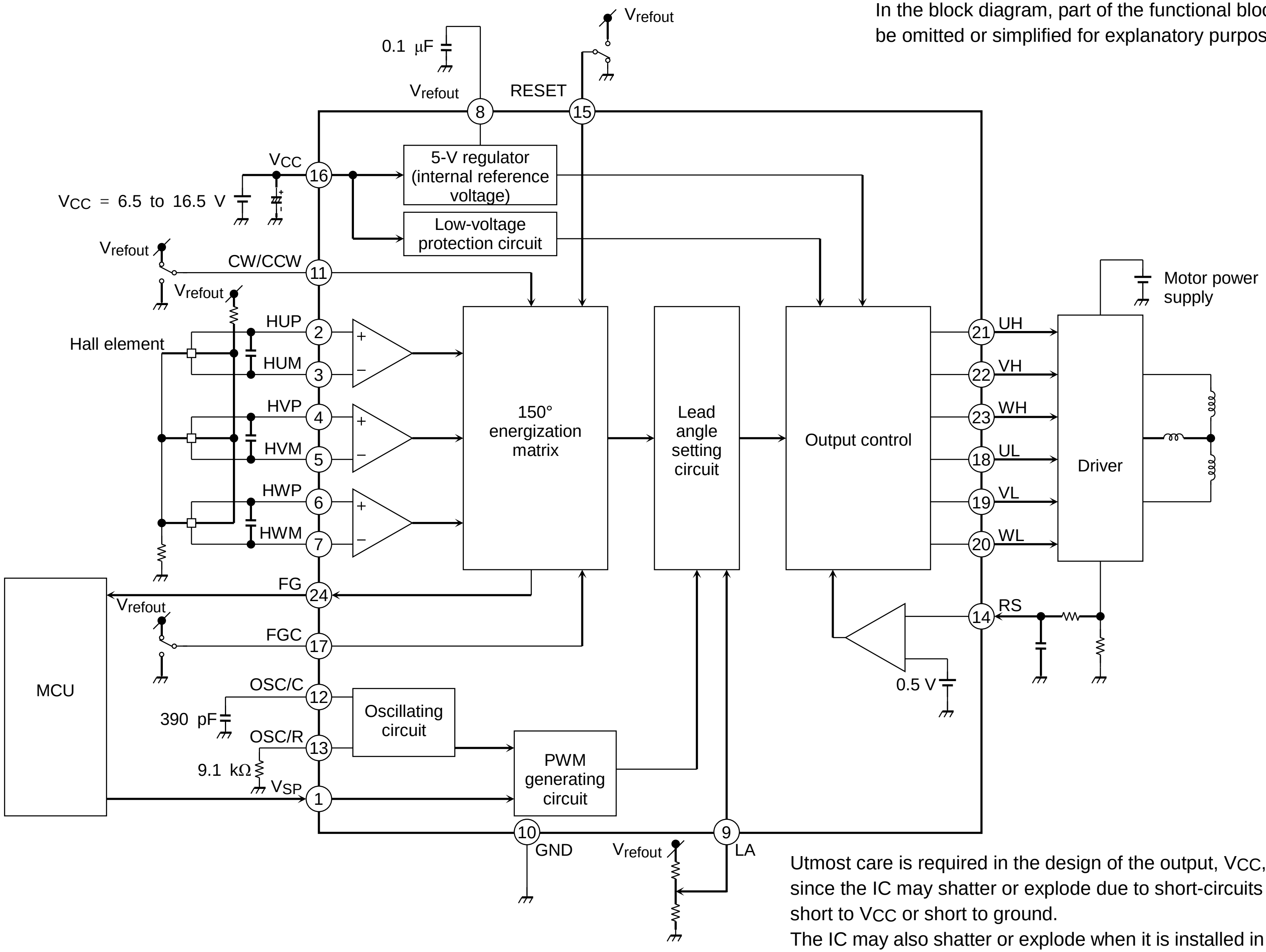
(The FG signal shown here is for the FGC = low.)



*: 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)

Application Circuit Example

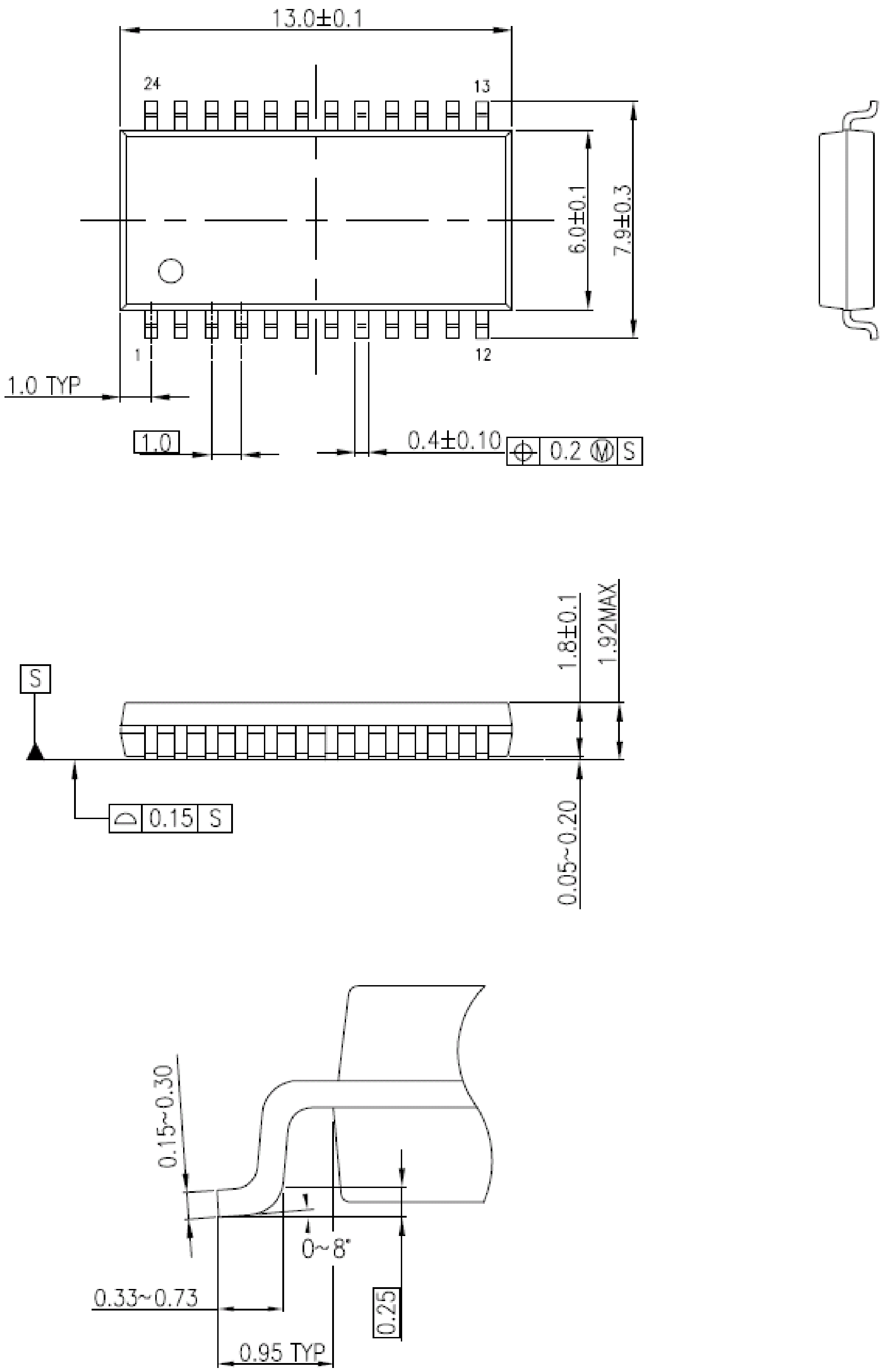
In the block diagram, part of the functional blocks or constants may be omitted or simplified for explanatory purposes.



Utmost care is required in the design of the output, VCC, and GND lines since the IC may shatter or explode due to short-circuits between outputs, short to VCC or short to ground.
The IC may also shatter or explode when it is installed in a wrong orientation.

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.
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) Thermal Shutdown Circuit

Thermal shutdown circuits do not necessarily protect ICs under all circumstances. If the thermal shutdown circuits operate against the over temperature, clear the heat generation status immediately. Depending on the method of use and usage conditions, such as exceeding absolute maximum ratings can cause the thermal shutdown circuit to not operate properly or IC breakdown before operation.

(3) 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.

(4) 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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