

TOSHIBA BiCD Integrated Circuit Silicon Monolithic

## TB67S511FTAG

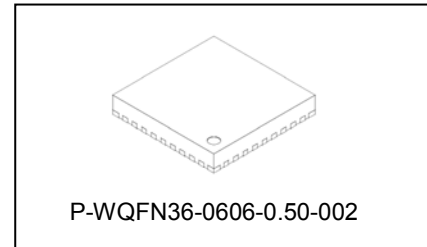
### Phase-in controlled Bipolar Stepping Motor Driver

The TB67S511FTAG is a two-phase bipolar stepping motor driver using a PWM chopper. An interface is phase-in control.

Fabricated with the BiCD process, rating is 40 V/2.0 A.

#### Features

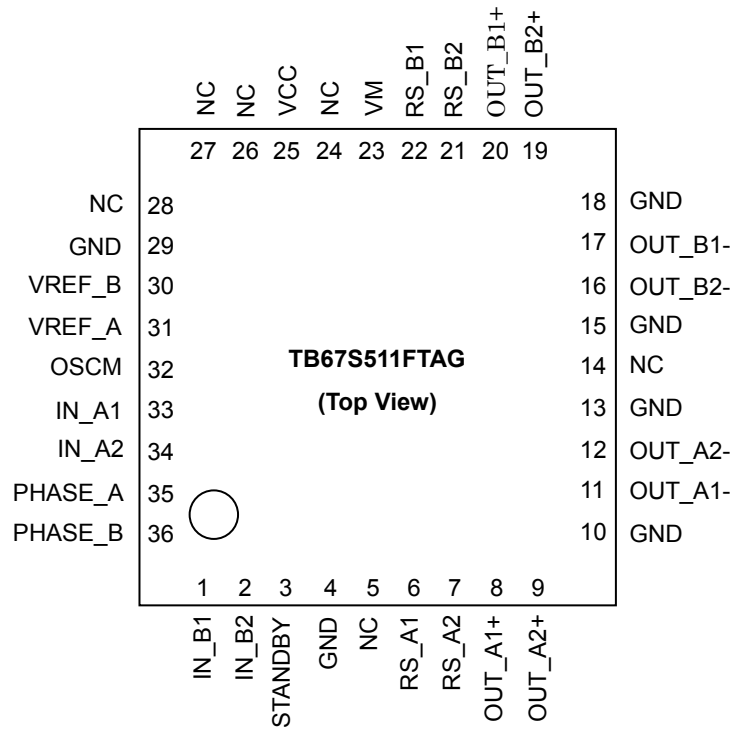
- Monolithic IC integrated by BiCD process
- Capable of controlling bipolar stepping motor by single IC
- PWM controlled constant-current drive
- Supporting full, half, and quarter step resolutions
- Built-in output MOSFET with low ON resistance (Upper + Lower side = 0.8  $\Omega$  (typ.))
- High voltage and current drive (For specifications, please refer to the absolute maximum ratings and the operation ranges)
- Built-in output functions of error detection (TSD and ISD) flags
- Built-in error detection circuits (Thermal shutdown (TSD), over-current detection circuit (ISD), and power-on reset (POR))
- Built-in VCC regulator for internal circuit drive
- Chopping frequency of a motor can be customized by external components
- Package: P-WQFN36-0606-0.50-002



Weight: 0.10 g (typ.)

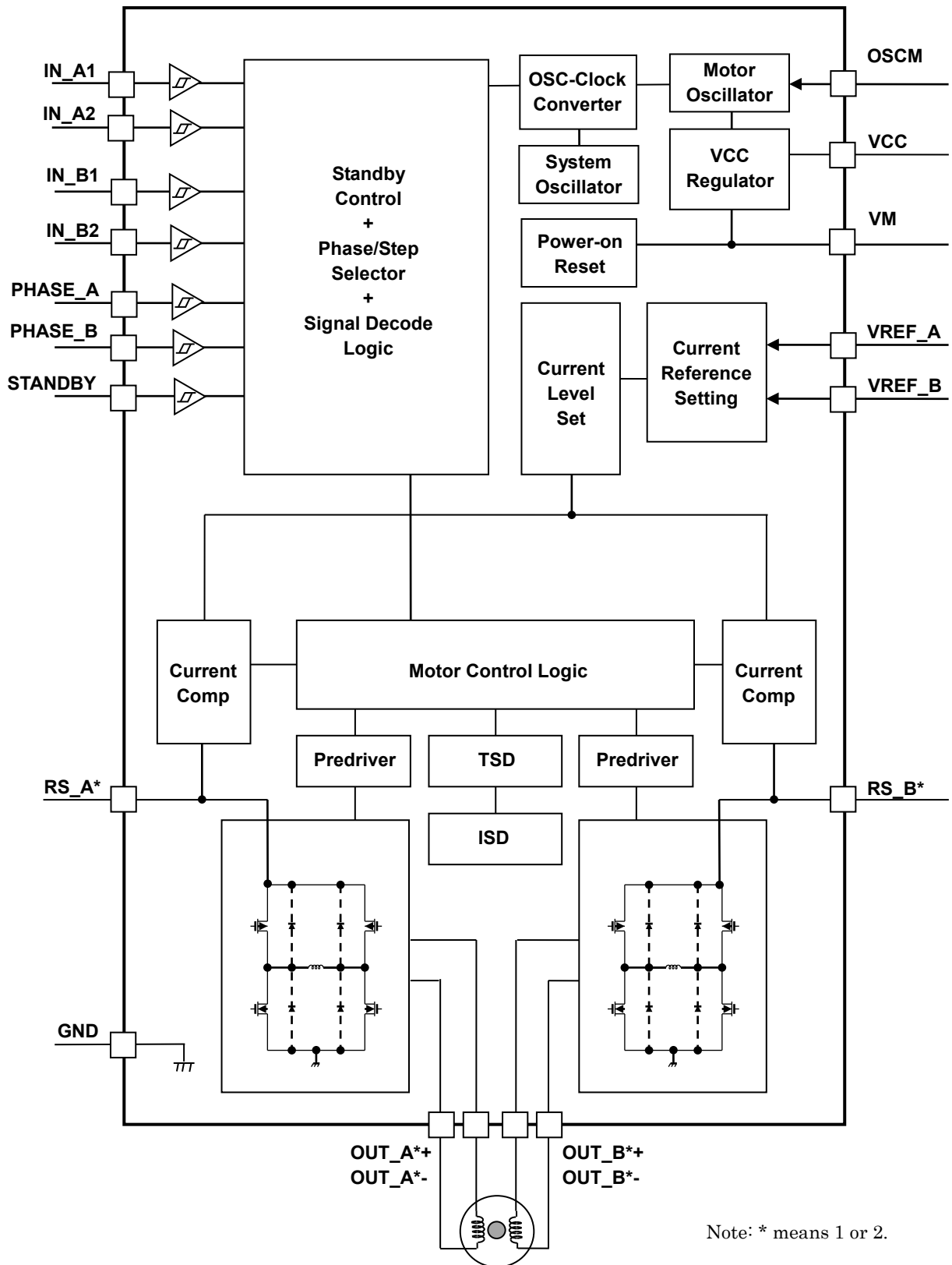
Note: Please be careful about thermal conditions during use.

**Pin assignment**



\*: Please mount the four-corner pins of the QFN package and the exposed pad to the GND area of the PCB.

Block diagram



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

**Note:**

All the grounding wires of the TB67S511FTAG should run on the solder mask on the PCB and be externally terminated at only one point. Also, a grounding method should be considered for efficient heat dissipation.

Utmost care is necessary in the design of the output, VM, and GND lines since the IC may be destroyed by short-circuiting between outputs, or by short-circuiting to the power supply or ground. Especially, if power supply pins (VM, RS, OUT, and GND), through which a particularly large current may run, are wired incorrectly, an operation error may occur or the device may be destroyed.

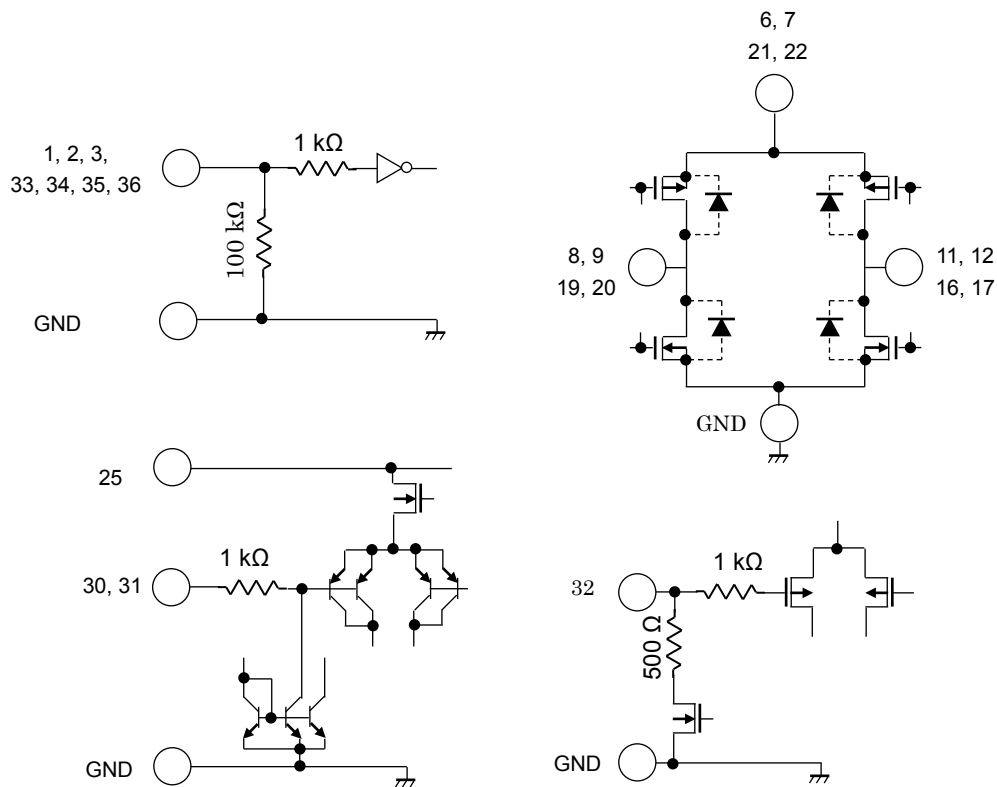
Also, if logic input pins are wired incorrectly, an operation error may occur or the device may be destroyed. In this case, the IC may be destroyed because over rating current flows. Pay enough attention in designing patterns and mounting the IC.

## Pin descriptions

Pin No.	Pin Name	Function
1	IN_B1	Bch step resolution control 1
2	IN_B2	Bch step resolution control 2
3	STANDBY	Standby mode set pin
4	GND	Ground pin
5	NC	Non-connection pin
6	RS_A1	Sense resistor connection pin for setting current of Ach output
7	RS_A2	Sense resistor connection pin for setting current of Ach output
8	OUT_A1+	Motor Ach (+) output pin
9	OUT_A2+	Motor Ach (+) output pin
10	GND	Power ground pin of Ach
11	OUT_A1-	Motor Ach (-) output pin
12	OUT_A2-	Motor Ach (-) output pin
13	GND	Power ground pin of Ach
14	NC	Non-connection pin
15	GND	Power ground pin of Bch
16	OUT_B2-	Motor Bch (-) output pin
17	OUT_B1-	Motor Bch (-) output pin
18	GND	Power ground pin of Bch
19	OUT_B2+	Motor Bch (+) output pin
20	OUT_B1+	Motor Bch (+) output pin
21	RS_B2	Sense resistor connection pin for setting current of Bch output
22	RS_B1	Sense resistor connection pin for setting current of Bch output
23	VM	VM power supply pin
24	NC	Non-connection pin
25	VCC	Internal VCC regulator monitor pin
26	NC	Non-connection pin
27	NC	Non-connection pin
28	NC	Non-connection pin
29	GND	Ground pin
30	VREF_B	Motor Bch current threshold set pin
31	VREF_A	Motor Ach current threshold set pin
32	OSCM	Internal oscillator frequency set pin for chopping
33	IN_A1	Ach step resolution control 1
34	IN_A2	Ach step resolution control 2
35	PHASE_A	Signal input pin of PWM current direction for Ach
36	PHASE_B	Signal input pin of PWM current direction for Bch

\*: Please keep NC pins open.

## Equivalent circuit



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

Pin No	Pin name
1	IN_B1
2	IN_B2
3	STANDBY
6, 7	RS_A*
8, 9	OUT_A*+
11, 12	OUT_A*-
16, 17	OUT_B*-
19, 20	OUT_B*+
21, 22	RS_B*
23	VM
25	VCC
30	VREF_B
31	VREF_A
32	OSCM
33	IN_A1
34	IN_A2
35	PHASE_A
36	PHASE_B

Note: \* means 1 or 2.

## Function description (Stepping motor modes)

Motor output current (I<sub>out</sub>): The flow from OUT+ to OUT- is defined as the plus current. The flow from OUT- to OUT+ is defined as the minus current.

### <Full step resolution>

A ch				B ch			
Input			Output	Input			Output
PHASE_A	IN_A1	IN_A2	I <sub>out</sub> (A)	PHASE_B	IN_B1	IN_B2	I <sub>out</sub> (B)
H	H	H	+100 %	H	H	H	+100 %
L	H	H	-100 %	H	H	H	+100 %
L	H	H	-100 %	L	H	H	-100 %
H	H	H	+100 %	L	H	H	-100 %

Please set IN\_A1, IN\_A2, IN\_B1, and IN\_B2 low in supplying a power.

### <Half step resolution>

A ch				B ch			
Input			Output	Input			Output
PHASE_A	IN_A1	IN_A2	I <sub>out</sub> (A)	PHASE_B	IN_B1	IN_B2	I <sub>out</sub> (B)
H	H	H	+100 %	H	H	H	+100 %
X	L	L	0 %	H	H	H	+100 %
L	H	H	-100 %	H	H	H	+100 %
L	H	H	-100 %	X	L	L	0 %
L	H	H	-100 %	L	H	H	-100 %
X	L	L	0 %	L	H	H	-100 %
H	H	H	+100 %	L	H	H	-100 %
H	H	H	+100 %	X	L	L	0 %

X: Don't care

## <Quarter step resolution>

A ch				B ch			
Input			Output	Input			Output
PHASE_A	IN_A1	IN_A2	Iout (A)	PHASE_B	IN_B1	IN_B2	Iout (B)
H	H	L	+71 %	H	H	L	+71 %
H	L	H	+38 %	H	H	H	+100 %
X	L	L	0 %	H	H	H	+100 %
L	L	H	-38 %	H	H	H	+100 %
L	H	L	-71 %	H	H	L	+71 %
L	H	H	-100 %	H	L	H	+38 %
L	H	H	-100 %	X	L	L	0 %
L	H	H	-100 %	L	L	H	-38 %
L	H	L	-71 %	L	H	L	-71 %
L	L	H	-38 %	L	H	H	-100 %
X	L	L	0 %	L	H	H	-100 %
H	L	H	+38 %	L	H	H	-100 %
H	H	L	+71 %	L	H	L	-71 %
H	H	H	+100 %	L	L	H	-38 %
H	H	H	+100 %	X	L	L	0 %
H	H	H	+100 %	H	L	H	+38 %

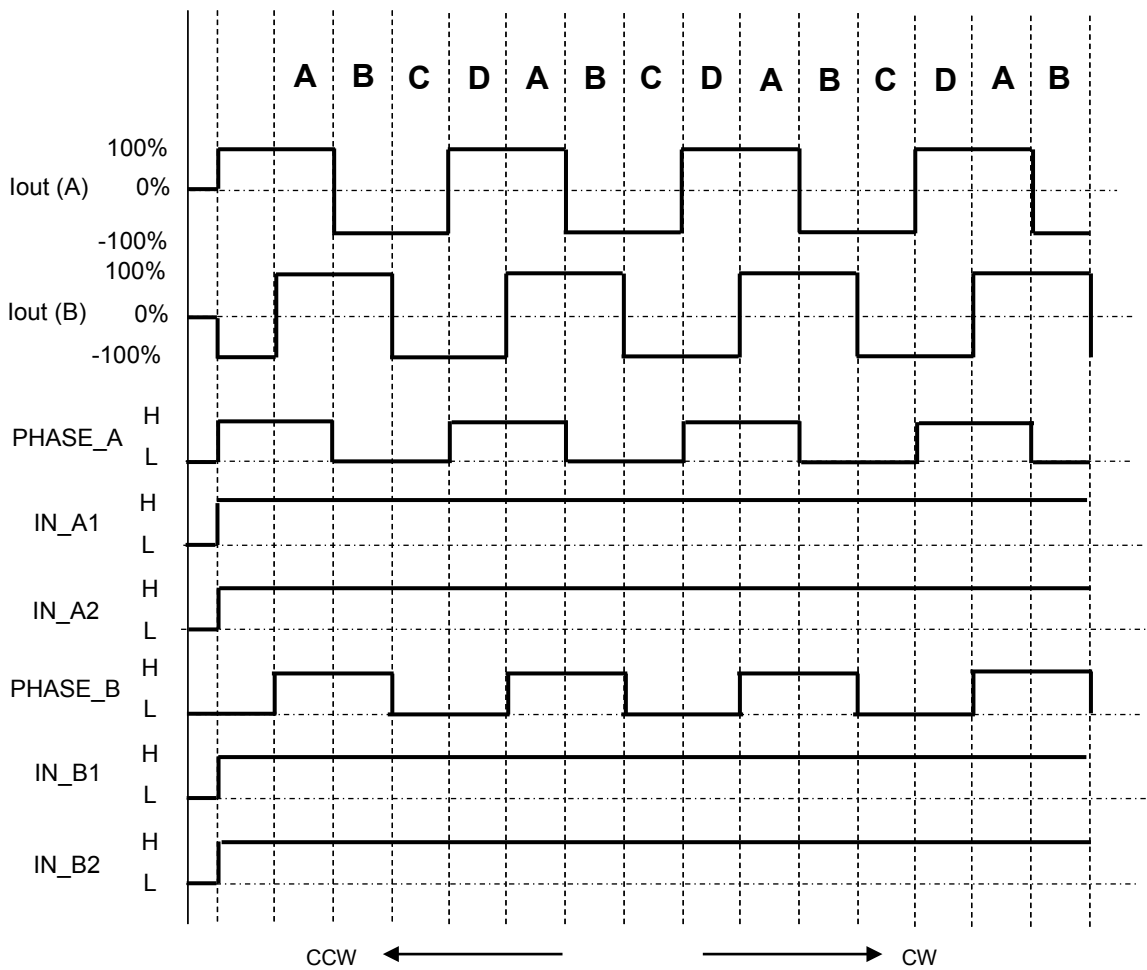
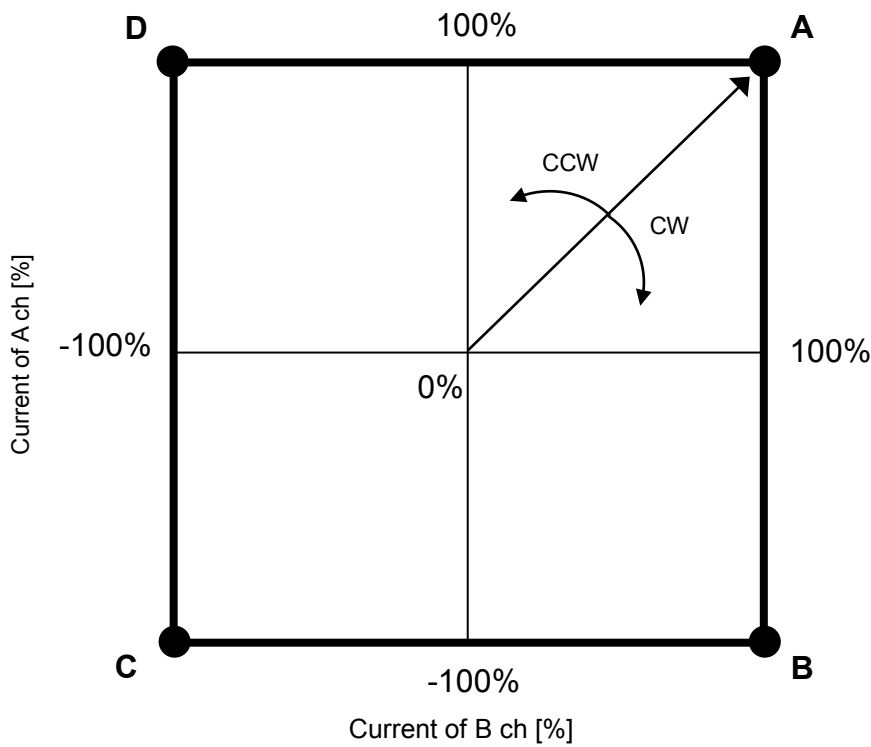
X: Don't care

## Others

Pin Name	H	L	Notes
IN_A1, IN_A2 IN_B1, IN_B2	The current value of each ch is set up with 2 inputs and 4 values.		Please refer to the above-mentioned current value setting table.
PHASE_A PHASE_B	OUT+: H OUT-: L	OUT+: L OUT-: H	When PHASE is set high, the charge current flows from OUT+ to OUT-.
STANDBY	Standby release	Standby mode	When STANDBY is set low, operations of an internal oscillating circuit and a motor output block stop. (The motor cannot drive.)

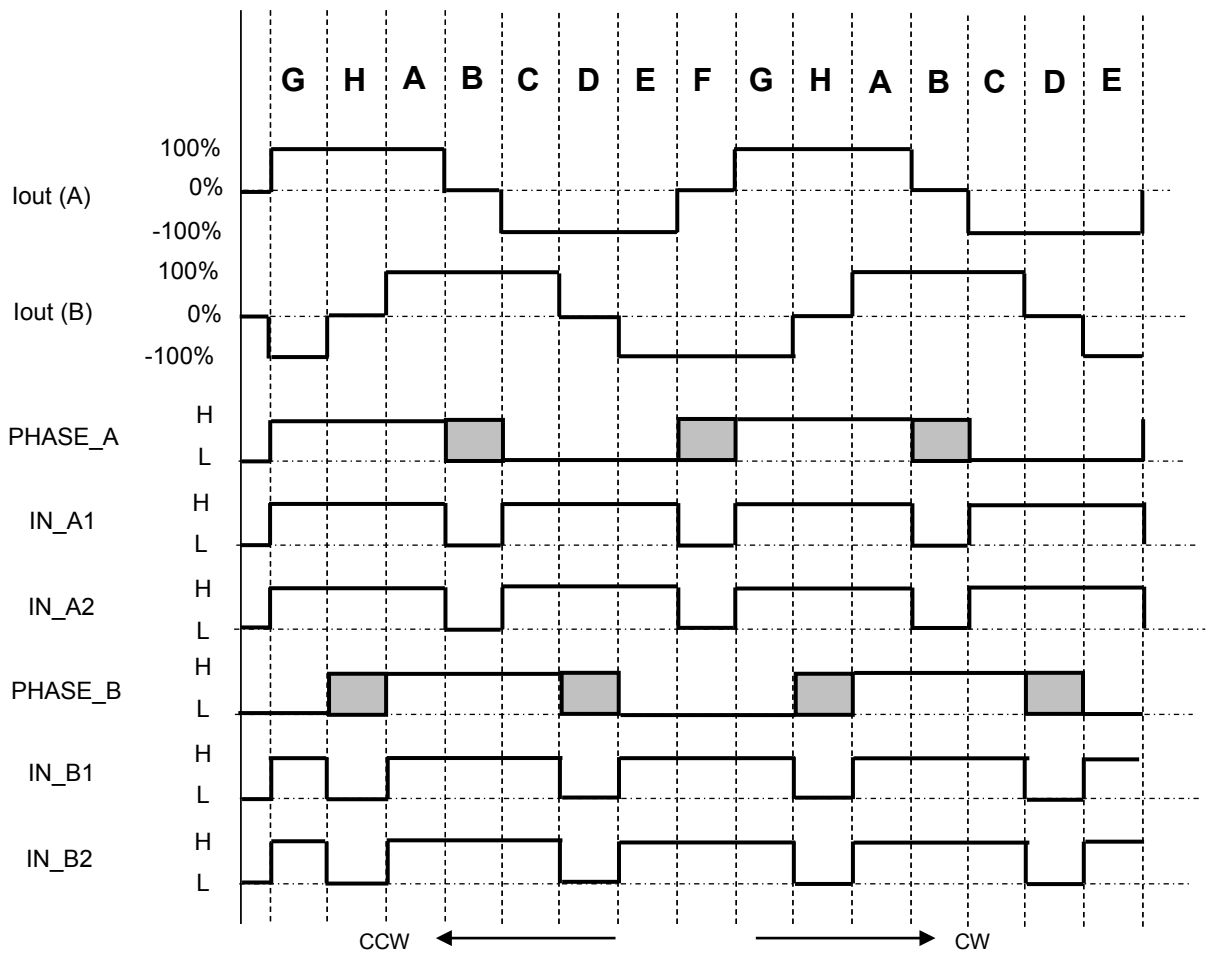
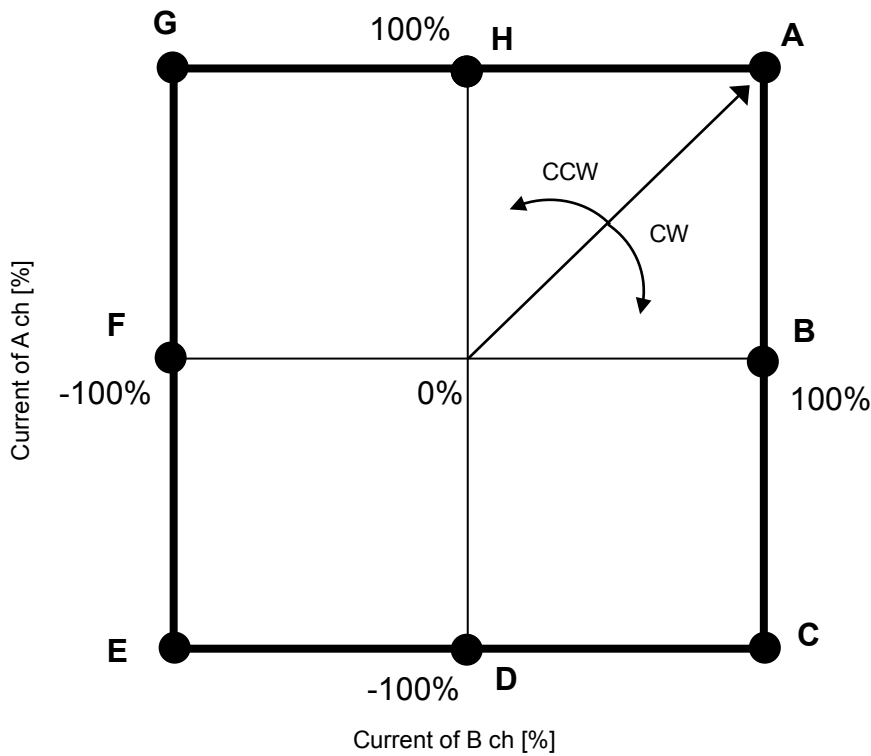


**Current vector (Full step resolution)**



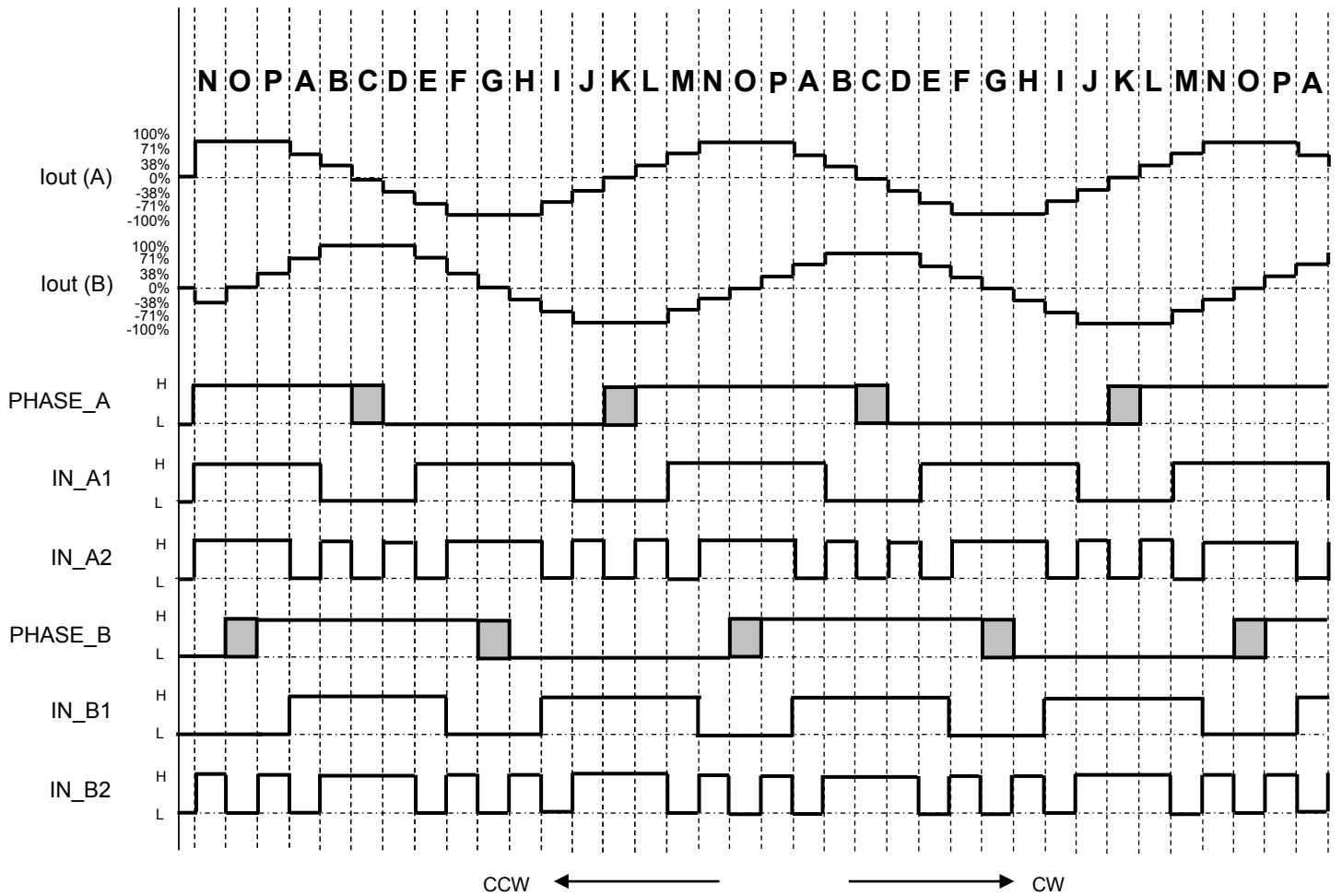
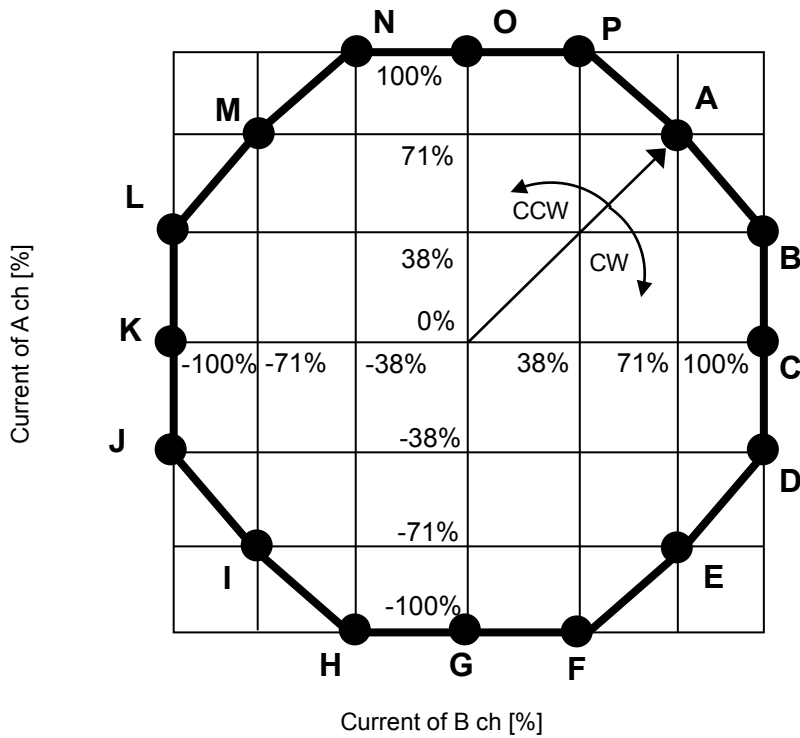
Timing charts may be simplified for explanatory purpose.  
 Please set IN\_A1, IN\_A2, IN\_B1, and IN\_B2 low in supplying a power.

**Current vector (Half step resolution)**



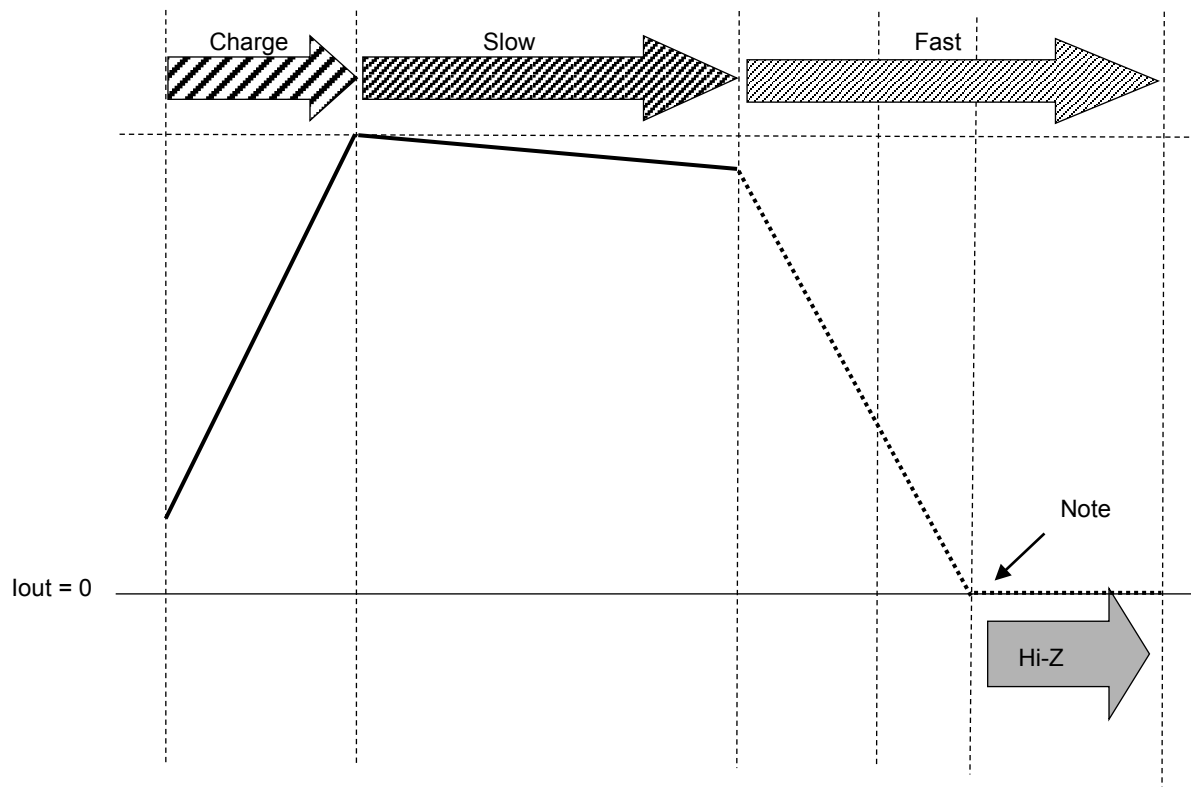
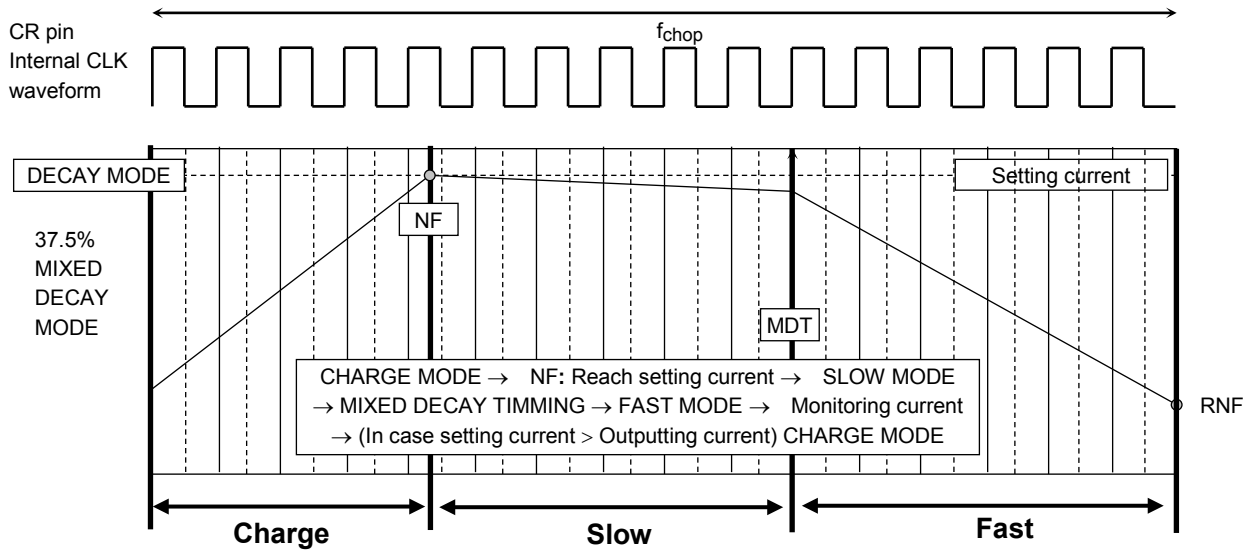
Timing charts may be simplified for explanatory purpose.  
 Please set IN\_A1, IN\_A2, IN\_B1, and IN\_B2 low in supplying a power.

**Current vector (Quarter step resolution)**



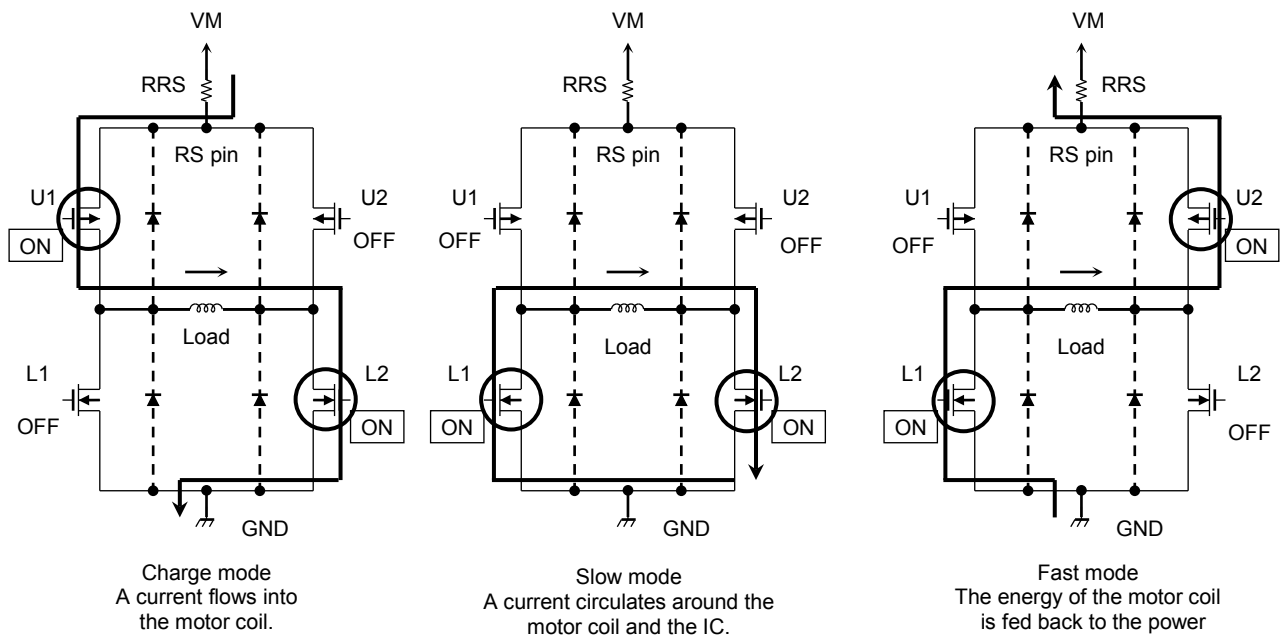
Timing charts may be simplified for explanatory purpose.  
Please set IN\_A1, IN\_A2, IN\_B1, and IN\_B2 low in supplying a power.

## Mixed Decay Mode /Detecting zero point



Note: When the motor current reaches zero level ( $I_{out} = 0 A$ ), the output becomes “Hi-Z” state.

**Output transistor function mode**



**Output transistor function**

MODE	U1	U2	L1	L2
CHARGE	ON	OFF	OFF	ON
SLOW	OFF	OFF	ON	ON
FAST	OFF	ON	ON	OFF

Note: In case of the current direction shown in the above figures.  
If the current flows in the opposite direction, refer to the following table.

MODE	U1	U2	L1	L2
CHARGE	OFF	ON	ON	OFF
SLOW	OFF	OFF	ON	ON
FAST	ON	OFF	OFF	ON

This IC controls the constant motor current by 3 modes listed above.  
The equivalent circuit diagrams may be simplified or some parts of them may be omitted for explanatory purposes.

**Calculation of setting current**

This IC drives a motor by controlling the PWM constant current with the base of the OSCM oscillating frequency. The peak output current (Setting current) can be determined by the current-sensing resistor (RS) and the reference voltage (Vref) as follows;

$$I_{out} (max) = V_{ref} (gain) \times \frac{V_{ref} (V)}{R_{RS} (\Omega)}$$

Vref (gain): Vref decay rate = 1/ 5.0 (typ.)

Example: In the case of a 100% setup,

When Vref = 3.0 V, Torque = 100%, and RS = 0.51 Ω, the constant output current (peak current) of the motor is calculated as follows;

$$I_{out} = 3.0 V / 5.0 / 0.51 \Omega = 1.18 A$$

**Calculation of the OSCM oscillation frequency (chopper reference frequency)**

An approximation of the OSCM oscillation frequency (fOSCM) and chopping frequency (fchop) can be calculated by the following formula.

$$f_{OSCM} = 1 / [0.56 \times \{C_x (R1+500)\}]$$

\*C and R1: External constant number for OSCM (When C = 270 pF and R1 = 3.6 kΩ, fOSCM = 1.6 MHz (typ.))

$$f_{chop} = f_{OSCM} / 16$$

\*When fOSCM = 1.6 MHz, fchop is approximately 100 kHz.

If chopping frequency is raised, the ripple of the current decreases and the waveform reproducibility is improved. However, the gate loss inside IC becomes large and the heat generation increases.

By lowering chopping frequency, reduction of heat generation is expectable. However, the ripple of the current may increase. Generally, a frequency of about 70 kHz is set as a reference value. A setup in the range of 50 to 100 kHz is recommended.

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

Characteristics	Symbol	Rating	Unit	Remarks
Motor power voltage	VM	40	V	—
Motor output voltage	Vout	40	V	—
Motor output current	Iout	2.0	A	(Note 1)
Internal logic power supply	VCC	6.0	V	When externally applied.
Logic input voltage	VIN(H)	6.0	V	—
	VIN(L)	-0.4	V	—
Vref reference voltage	Vref	5.0	V	—
Power dissipation	PD	1.3	W	(Note 2)
Operating temperature	Topr	-20 to 85	°C	—
Storage temperature	Tstg	-55 to 150	°C	—
Junction temperature	Tj(max)	150	°C	—

Note 1: The maximum current value in the normal operation should be set 70% or less of the absolute maximum ratings after thermal calculation. The maximum output current may be further limited in view of thermal considerations, depending on the ambient temperature and the board conditions.

Note 2: Device alone (Ta = 25°C)

When Ta exceeds 25°C, please correct the values by derating (10.4 mW/°C).

Ta: Ambient temperature

Topr: Ambient temperature while the IC is active

Tj: Junction temperature while the IC is active. The maximum junction temperature is limited by the thermal shutdown (TSD) circuitry. It is recommended to keep the maximum current below a certain level so that the maximum junction temperature (Tj (max)) will not exceed 120°C.

### Caution) Absolute maximum ratings

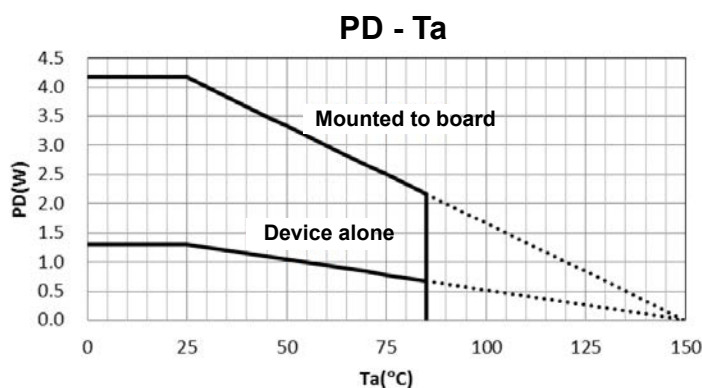
The absolute maximum ratings of a semiconductor device are a set of ratings that must not be exceeded, even for a moment. Do not exceed any of these ratings.

Exceeding the rating (s) may cause device breakdown, damage or deterioration, and may result in injury by explosion or combustion.

The value of even one parameter of the absolute maximum ratings should not be exceeded under any circumstances. The TB67S511FTAG does not have overvoltage detection circuit. Therefore, the device is damaged if a voltage exceeding its rated maximum is applied.

All voltage ratings, including supply voltages, must always be followed. The other notes and considerations described later should also be referred to.

### PD-Ta graph (Device alone / Mounted to board) (For reference only)



Board conditions  
 4-layer glass epoxy board  
 Cu thickness: 1 layer and 4 layers: 55 μm, 2 layers and 3 layers: 35 μm  
 Board size: 100 mm × 110 mm × 1.6 mm

## Operation Ranges (Ta = -20 to 85°C)

Characteristics	Symbol	Min	Typ.	Max	Unit	Remarks
Motor power supply	VM	10	24	35	V	—
Motor output current	Iout	—	—	2.0	A	(Note)
Logic input voltage	VIN(H)	2.0	—	5.5	V	Logic input High Level
	VIN(L)	0	—	0.8	V	Logic input Low Level
Phase input frequency	fPHASE	—	—	400	kHz	—
Chopping frequency	fchop(range)	40	70	150	kHz	—
Vref input voltage	Vref	0.5	2.0	3.6	V	—

Note: Maximum current for actual usage may be limited by the operating circumstances such as operating conditions (exciting mode, operating time, and so on), ambient temperature, and heat conditions (board condition and so on). Please confirm the maximum usage current by thermal calculation under the usage circumstances.

## Electrical characteristics 1 (Ta = 25°C and VM = 24 V, unless specified otherwise)

Characteristics		Symbol	Test condition	Min	Typ.	Max	Unit
Logic input voltage	HIGH	VIN(H)	Logic input (Note)	2.0	—	5.5	V
	LOW	VIN(L)	Logic input (Note)	0	—	0.8	V
Logic input hysteresis voltage		VIN(HYS)	Logic input (Note)	100	—	300	mV
Logic input current	HIGH	IIN(H)	VIN(H) = 3.3 V	—	33	—	μA
	LOW	IIN(L)	VIN(L) = 0 V	—	—	1	μA
Power consumption		IM1	Output pins = open STANDBY = L	—	2.5	3.5	mA
		IM2	Output pins = open STANDBY = H	—	4.0	5.5	mA
		IM3	Output pins = open (Full step resolution)	—	5	7	mA
Output leakage current	Upper	IOH	VRS = VM = 40 V, Vout = 0 V	—	—	1	μA
	Lower	IOL	VRS = VM = Vout = 40 V	1	—	—	μA
Motor current channel differential		ΔIout1	Current differential between Ch Iout = 1.0 A	-5	0	5	%
Motor current setting accuracy		ΔIout2	Iout = 1.0 A	-5	0	5	%
RS pin current		IRS	VRS = VM = 24 V	0	—	27	μA
Motor output ON-resistance between drain and source (Upper-side + Lower-side)		Ron(H+L)	Tj = 25°C, Forward direction (Upper-side + Lower-side) Design value	—	0.8	0.88	Ω

Note: VIN(H) is defined as the VIN voltage that makes the outputs (OUT\_A and OUT\_B) change when the test pin voltage is gradually raised from 0 V. VIN(L) is defined as the VIN voltage that makes the outputs (OUT\_A and OUT\_B) change when the test pin voltage is gradually lowered from 5 V. The difference between VIN(H) and VIN(L) is defined as the VIN (HYS).

Note: When the logic signal is input to the device while the VM is not supplied, the device is designed not to generate EMF and the leakage current. However, for safe usage, please control the logic signal to prevent motor operation by VM resupply.



**Electrical characteristics 2 (Ta =25°C and VM = 24 V, unless specified otherwise)**

Characteristics	Symbol	Test condition	Min	Typ.	Max	Unit
Vref input current	Iref	VREF = 2.0 V	—	0	1	μA
VCC voltage	VCC	ICC = 5.0 mA	4.75	5.0	5.25	V
VCC current	ICC	VCC = 5.0 V	—	2.5	5	mA
Vref gain rate	Vref(gain)	VREF = 2.0 V	1/5.2	1/5.0	1/4.8	—
Thermal shutdown (TSD) threshold (Note1)	TjTSD	—	145	160	175	°C
VM recovery voltage	VMR	—	7.0	8.0	9.0	V
Over current detection (ISD) threshold (Note2)	ISD	Design value	2.5	3.2	4.0	A

**Note 1: Thermal shutdown circuit (TSD)**

When the junction temperature of the device reaches the TSD threshold, the TSD circuit is triggered; the internal reset circuit then turns off the output transistors. Noise rejection blanking time is built-in to avoid misdetection. Once the TSD circuit is triggered, the device will be set to standby mode, and can be cleared by reasserting the VM power source, or setting the STANDBY pin to standby mode. The TSD circuit is a backup function to detect a thermal error, therefore is not recommended to be used aggressively.

**Note 2: Over current detection (ISD)**

When the output current reaches the threshold, the ISD circuit is triggered; the internal reset circuit then turns off the output transistors. Noise rejection blanking time is built-in to avoid misdetection occurred by switching. Once the ISD circuit is triggered, the device keeps the output off until power-on reset (POR), is reasserted or the device is set to standby mode by STANDBY pin. For fail-safe, please insert a fuse to avoid secondary trouble.

**Back-EMF**

While a motor is rotating, there is a timing at which power is fed back to the power supply. At that timing, the motor current recirculates back to the power supply due to the effect of the motor back-EMF.

If the power supply does not have enough sink capability, the power supply and output pins of the device might rise above the rated voltages. The magnitude of the motor back-EMF varies with usage conditions and motor characteristics.

**Cautions on Overcurrent detection (ISD) and Thermal shutdown (TSD)**

The ISD and TSD circuits are only intended to provide temporary protection against irregular conditions such as an output short-circuits; they do not necessarily guarantee the complete IC safety.

If the device is used beyond the specified operating ranges, these circuits may not operate properly: then the device may be damaged due to an output short-circuit.

The ISD circuit is only intended to provide a temporary protection against an output short-circuit. If such a condition persists for a long time, the device may be damaged due to overstress. Overcurrent conditions must be removed immediately by external hardware.

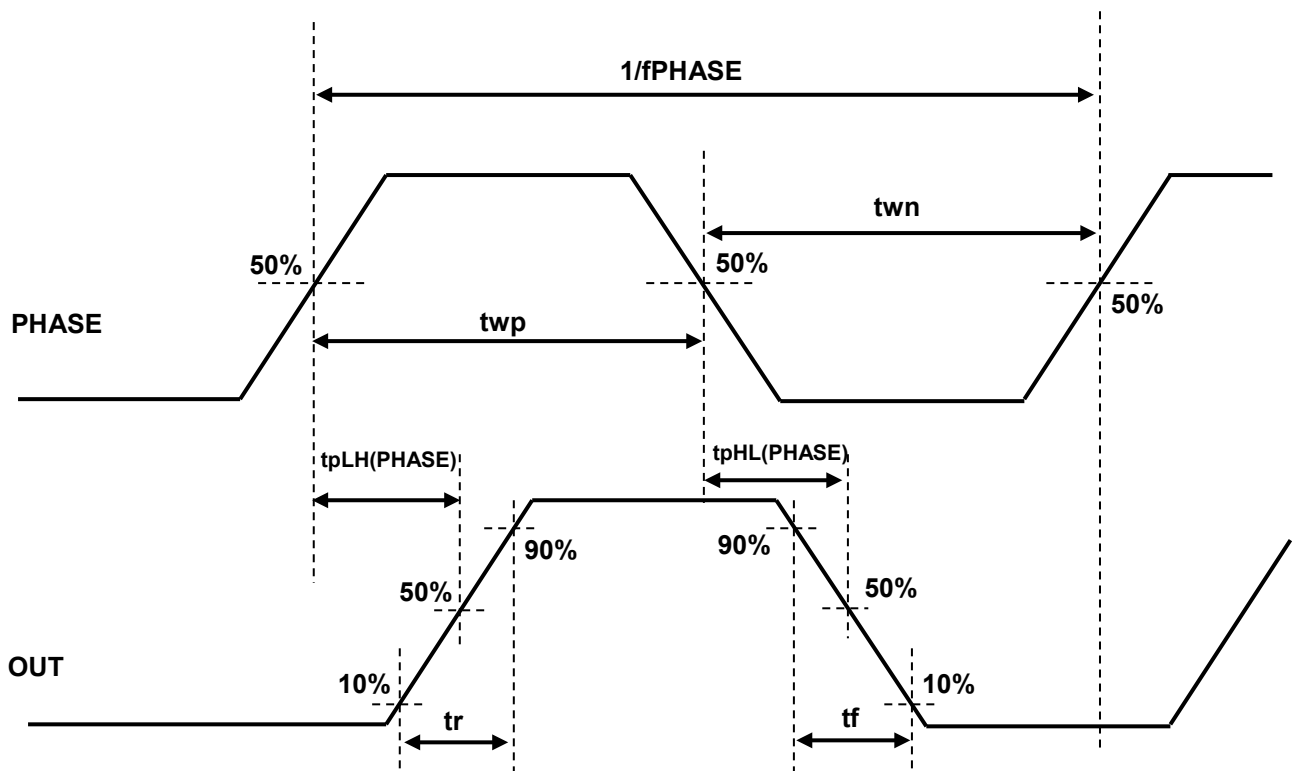
**IC Mounting**

Do not insert devices incorrectly or in the wrong orientation. Otherwise, it may cause breakdown, damage and/or deterioration of the device.

## AC electrical characteristics (Ta = 25°C, VM = 24 V, and 6.8 mH/5.7 Ω)

Characteristics	Symbol	Test condition	Min	Typ.	Max	Unit
Minimum PHASE pulse width	tPHASE(min)	—	100	—	—	ns
	twp	—	50	—	—	
	twm	—	50	—	—	
Output transistor switching characteristics	tr	—	150	200	250	ns
	tf	—	100	150	200	
	tpLH(PHASE)	Between PHASE and OUT	250	750	1200	
	tpHL(PHASE)	Between PHASE and OUT	250	750	1200	
Blanking time for noise reduction	AtBLK	VM = 24 V, IOOUT = 1.5 A Analog tblank	450	700	950	ns
OSCM oscillation frequency	fOSCM	Cosc = 270 pF, Rosc = 3.6 kΩ	1200	1600	2000	kHz
Chopping frequency	fchop	Output: Active (IOOUT = 1.5 A), fOSCM = 1600 kHz	—	100	—	kHz

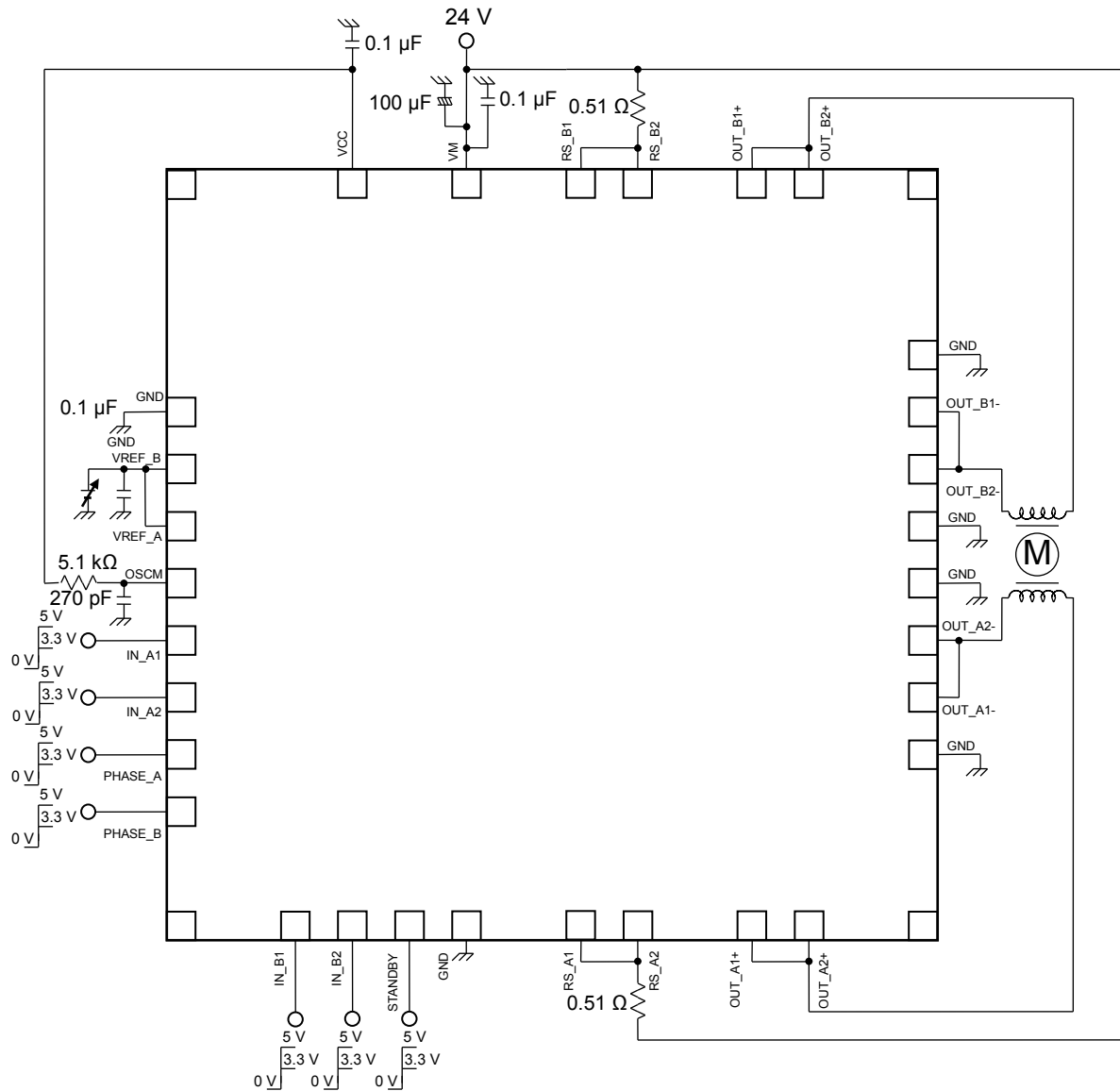
### AC characteristics timing chart



Timing charts may be simplified for explanatory purpose.

**Application circuit example (TB67S511FTAG) (in case chopping frequency = 70 kHz)**

The values in the following figure are recommended values.



Note: The addition of a bypass capacitor is recommended if necessary. The GND wiring should be connected to one point as much as possible.

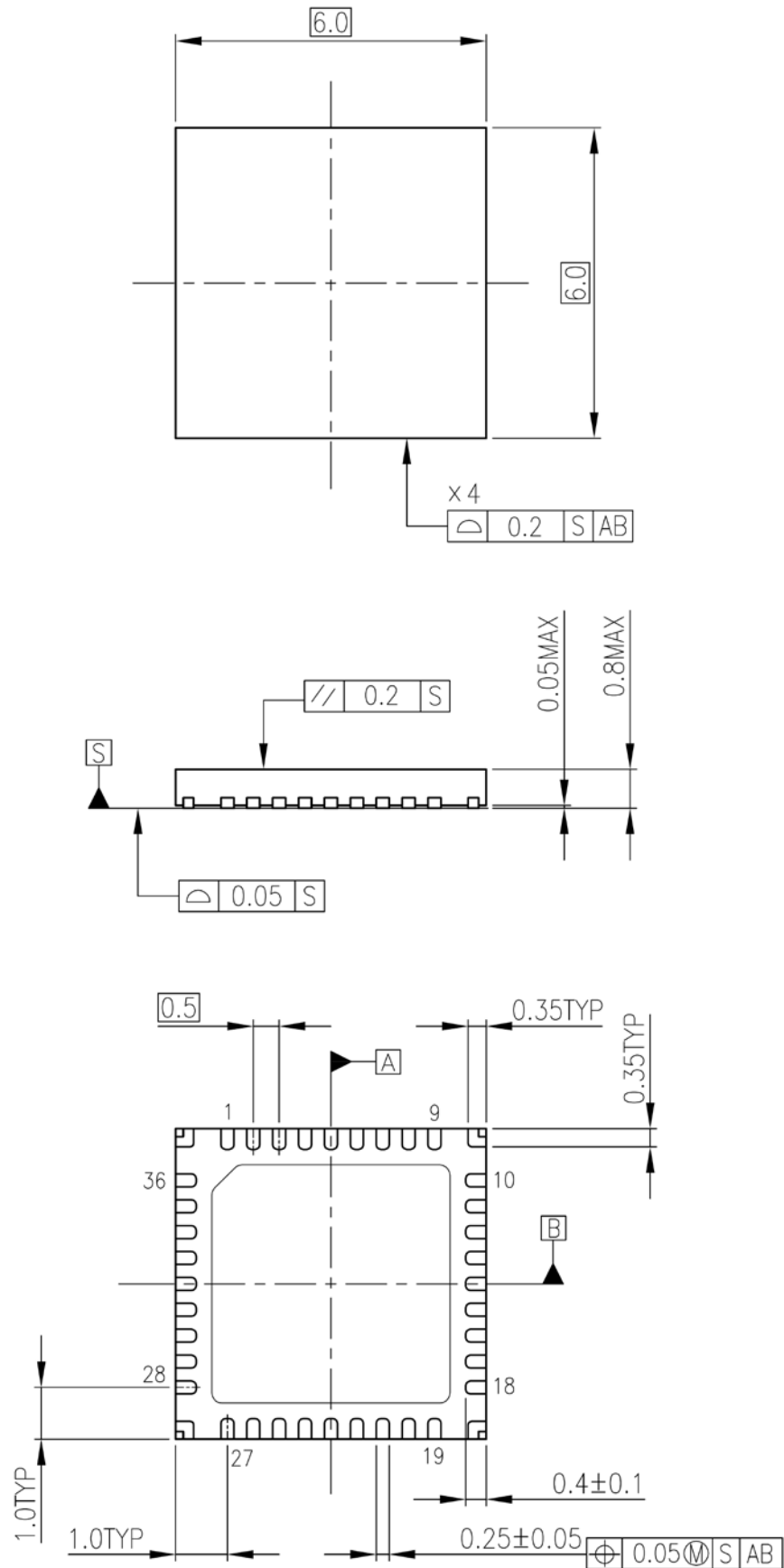
The application circuit shown above is provided for reference purposes only. Thorough evaluation is required, especially at the mass production design stage.

Toshiba does not grant any license to any industrial property rights by providing these examples of application circuits.

Package dimensions

P-WQFN36-0606-0.50-002

unit: mm



Weight: 0.10 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.

Toshiba does not grant any license to any industrial property rights by providing these examples of application circuits.

### 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 device breakdown, damage or deterioration, and may result in injury by explosion or combustion.
- (2) Do not insert devices in the wrong orientation or incorrectly. Make sure that the positive and negative terminals of power supplies are connected properly.  
Otherwise, the current or power consumption may exceed the absolute maximum rating, and exceeding the rating(s) may cause device breakdown, damage or deterioration, and may result in injury by explosion or combustion.  
In addition, do not use any device inserted in the wrong orientation or incorrectly to which current is applied even just once.
- (3) Use an appropriate power supply fuse to ensure that a large current does not continuously flow in the case of overcurrent 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 to smoke or ignition. To minimize the effects of the flow of a large current in the case of breakdown, appropriate settings, such as fuse capacity, fusing time and insertion circuit location, are required.
- (4) 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.
- (5) Carefully select external components (such as inputs and negative feedback capacitors) and load components (such as speakers), for example, power amp and regulator.  
If there is a large amount of leakage current such as from input or negative feedback capacitor, the IC output DC voltage will increase. If this output voltage is connected to a speaker with low input withstand voltage, overcurrent or IC failure may cause smoke or ignition. (The overcurrent may cause smoke or ignition from the IC itself.) In particular, please pay attention when using a Bridge Tied Load (BTL) connection-type IC that inputs output DC voltage to a speaker directly.

## **Points to remember on handling of ICs**

### **Overcurrent detection Circuit**

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

Depending on the method of use and usage conditions, exceeding absolute maximum ratings may cause the overcurrent detection circuit to operate improperly or IC breakdown may occur before operation. In addition, depending on the method of use and usage conditions, if overcurrent continues to flow for a long time after operation, the IC may generate heat resulting in breakdown.

### **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, exceeding absolute maximum ratings may cause the thermal shutdown circuit to operate improperly or IC breakdown to occur before operation.

### **Heat Radiation Design**

When using an IC with large current flow such as power amp, regulator or driver, design the device so that heat is appropriately radiated, in order not to exceed the specified junction temperature (T<sub>J</sub>) at any time or under any 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, when designing the device, take into consideration the effect of IC heat radiation with peripheral components.

### **Back-EMF**

When a motor rotates in the reverse direction, stops or slows abruptly, current flows back to the motor's power supply owing 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 the absolute maximum ratings. To avoid this problem, take the effect of back-EMF into consideration in system design.

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