

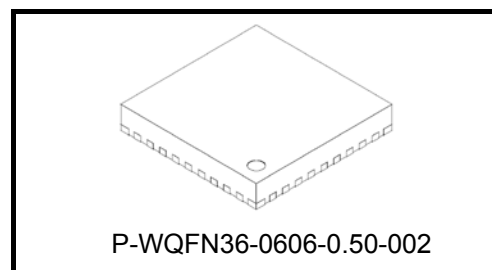
TB67S522FTAG

PWM method CLK-IN bipolar stepping motor driver

The TB67S522FTAG is a PWM chopper type two-phase bipolar stepping motor driver.

By applying the BiCD process, the TB67S522FTAG is rated at 40 V/2.8 A .

The internal voltage regulator allows control of the motor with a single VM power supply.



Weght: 0.14 g (typ.)

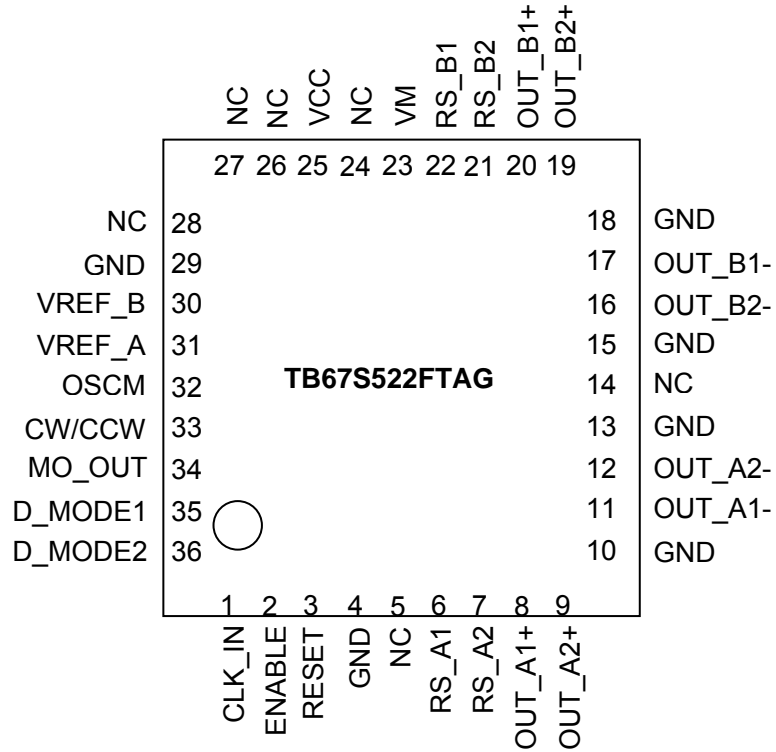
Features

- Bipolar stepping motor driver
- PWM constant current drive
- Operational in full, half, and quarter step resolutions
- Low on-resistance of output stage transistor by using BiCD process
- High withstand voltage and large current (For details, refer to absolute maximum ratings and operating ranges.)
- Built-in thermal shutdown circuit (TSD), over-current detection circuit (ISD), and POR for VM power supply
- Built-in VCC regulator allows the TB67S522FTAG to function with only VM power supply.
- Able to customize PWM signal frequency by external resistance/capacitor.
- Package: P-WQFN36-0606-0.50-002

Note: Please be careful about thermal conditions during use.

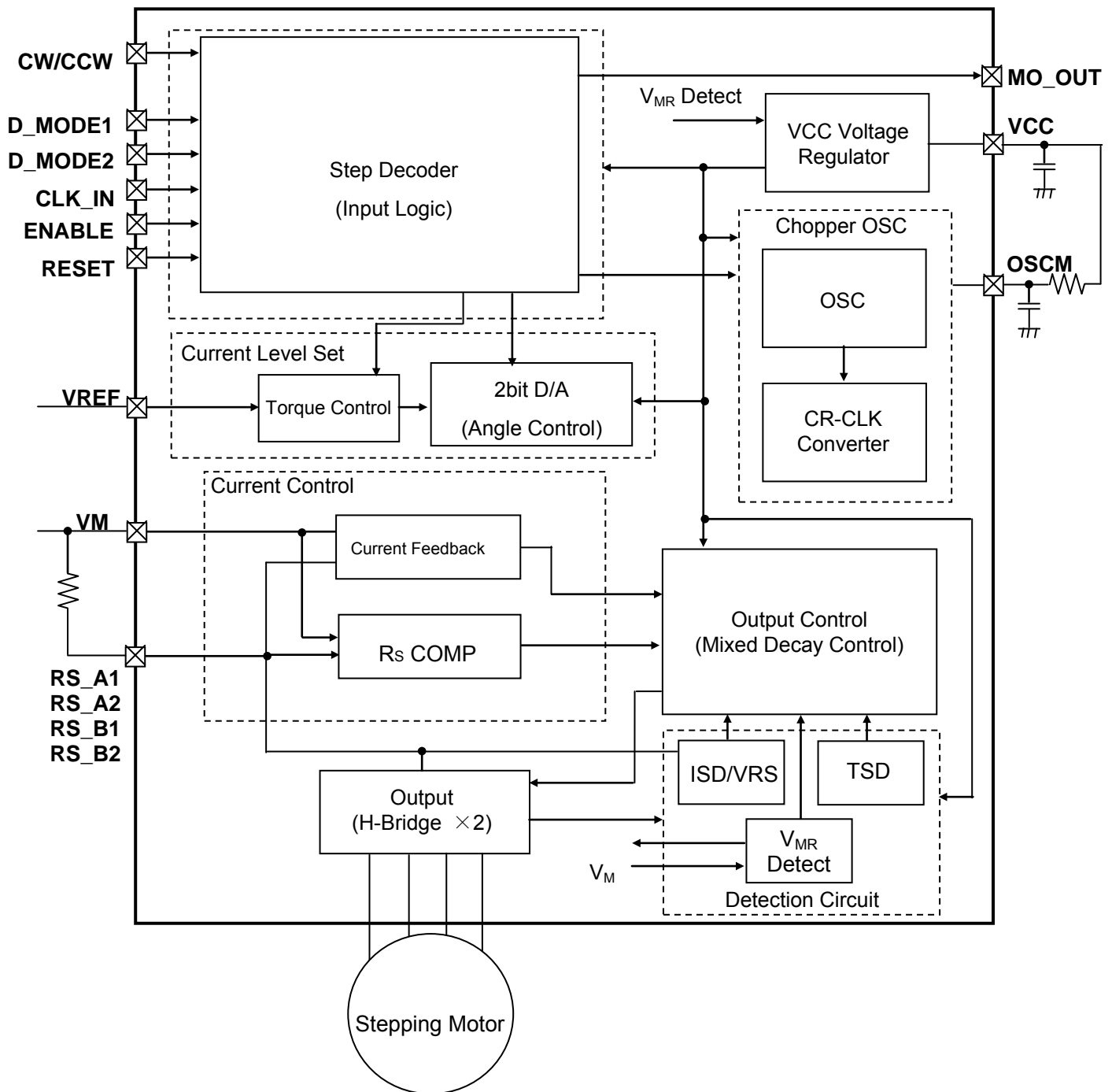
Pin Assignment

(Top View)



*: Please mount the four corner pads of the 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 TB67S522FTAG 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. Careful attention should be paid to the layout of the output, V_M and GND traces, to avoid short circuits across output pins or to the power supply or ground. If such a short circuit occurs, the device may be permanently damaged. Also, the utmost care should be taken for pattern designing and implementation of the device since it has power supply pins (V_M , RS_A1, RS_A2, RS_B1, RS_B2, OUT_A1+, OUT_A2+, OUT_A1-, OUT_A2-, OUT_B1+, OUT_B2+, OUT_B1-, OUT_B2-, and GND) through which a particularly large current may run. If these pins are wired incorrectly, an operation error may occur or the device may be destroyed. The logic input pins must also be wired correctly. Otherwise, the device may be damaged owing to a current running through the IC that is larger than the specified current. Careful attention should be paid to design patterns and mountings.

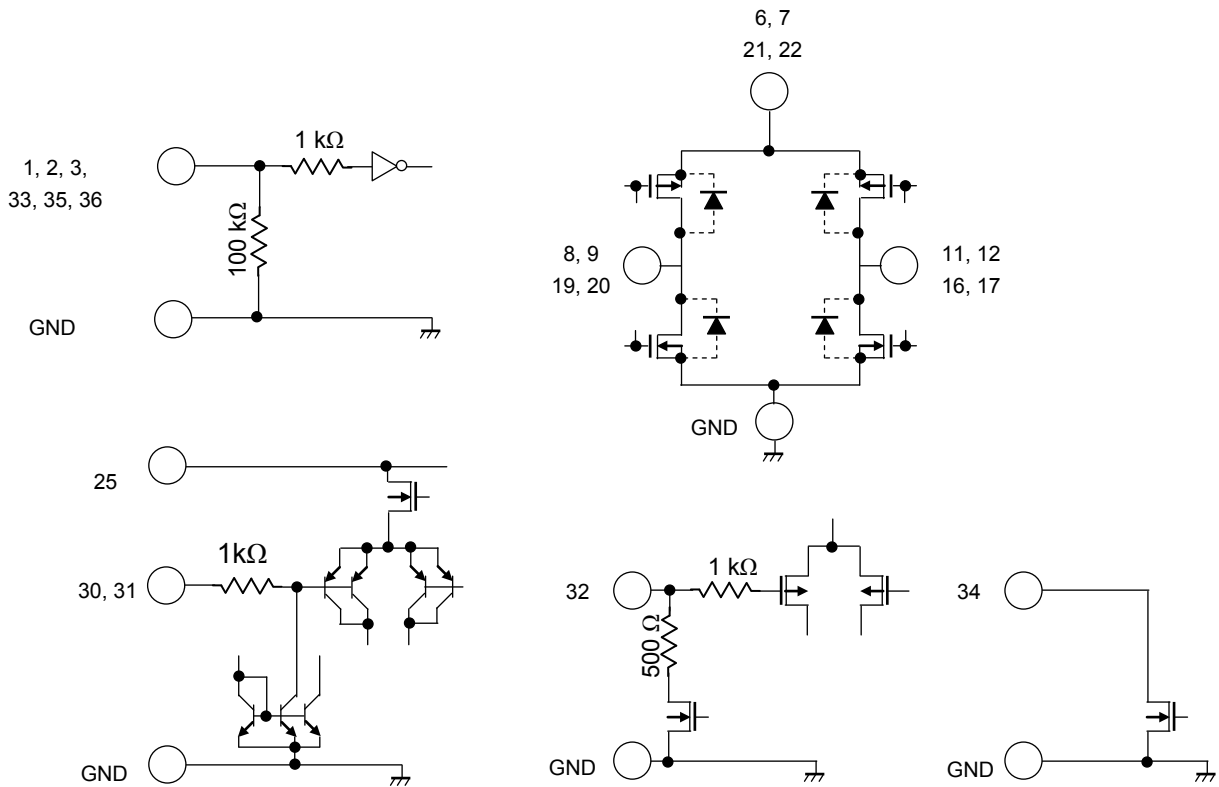
Pin Function Description

Pin number	Pin name	Function
1	CLK_IN	Clock signal input pin for determining the number of motor rotations The electrical angle progresses at rising.
2	ENABLE	Output enable pin of A ch and B ch
3	RESET	Electrical angle reset pin
4	GND	GND
5	NC	Non-connection
6	RS_A1 (Note)	Sense resistance connection pin for setting current value of A ch output
7	RS_A2 (Note)	Sense resistance connection pin for setting current value of A ch output
8	OUT_A1+ (Note)	A ch (+) output
9	OUT_A2+ (Note)	A ch (+) output
10	GND	GND
11	OUT_A1- (Note)	A ch (-) output
12	OUT_A2- (Note)	A ch (-) output
13	GND	GND
14	NC	Non-connection
15	GND	GND
16	OUT_B2- (Note)	B ch (-) output
17	OUT_B1- (Note)	B ch (-) output
18	GND	GND
19	OUT_B2+ (Note)	B ch (+) output
20	OUT_B1+ (Note)	B ch (+) output
21	RS_B2 (Note)	Sense resistance connection pin for setting current value of B ch output
22	RS_B1 (Note)	Sense resistance connection pin for setting current value of B ch output
23	VM	Monitor pin of motor power supply
24	NC	No connection
25	VCC	Monitor pin for internal generated VCC regulator
26	NC	Non-connection
27	NC	Non-connection
28	NC	Non-connection
29	GND	GND
30	VREF_B	Bias pin for current value setting for B ch output
31	VREF_A	Bias pin for current value setting for A ch output
32	OSCM	Oscillation circuit frequency setting pin for chopping
33	CW/CCW	Clockwise / counter clockwise of motor operation
34	MO_OUT	Monitor pin of electrical angle
35	D_MODE1	Step resolution setting pin 1
36	D_MODE2	Step resolution setting pin 2

The NC pin should be used open.

Note: Connect the same function pins (numbered 1, 2) indicated as (Note) after the pin name at near their respective pins.

Input/Output 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	CLK_IN
2	ENABLE
3	RESET
6,7	RS_A1, RS_A2
8,9	OUT_A1+, OUT_A2+
11,12	OUT_A1-, OUT_A2-
16,17	OUT_B2-, OUT_B1-
19,20	OUT_B2+, OUT_B1+
21,22	RS_B2, RS_B1
23	VM
25	VCC
30	VREF_B
31	VREF_A
32	OSCM
33	CW/CCW
34	MO_OUT
35	D_MODE1
36	D_MODE2

1. CLK Function

Each up-edge of the CLK signal shifts the motor's electrical angle per step. The signal is reflected at up-edge.

CLK Input	Function
Up-edge	Shifts the electrical angle per step.
Down-edge	State of the electrical angle does not change.

2. ENABLE Function

The ENABLE pin specifies ON and OFF of the current in the case of driving a stepping motor. This pin should be fixed to "L" during VM power-on and power off sequence.

ENABLE input	Function
H	Output transistor operation ON (Normal operation)
L	Output transistor operation OFF (High impedance)

3. CW/CCW Function

The CW/CCW pin controls the rotation direction of the stepping motor.

CW/CCW input	Input function
H	Clockwise (CW)
L	Counter clockwise (CCW)

4. Step Resolution Select Function

D_MODE1	D_MODE2	Function
L	L	STANDBY MODE The OSCM is disabled, the output stage is set to 'OFF' state, full step resolution, torque 100%
L	H	Full step resolution
H	L	Half step resolution
H	H	Quarter step resolution

When switching the D_MODE1,2; setting the RESET signal to Low (sets the electrical angle to the initial state), is recommended.

5. RESET Function

RESET input	Input function
H	Electrical angle RESET
L	Normal operation

In the case of RESET input, the current for each channel is as follows.
MO_OUT pin shows Low in this case.

Step resolution	Current of A ch	Current of B ch	Electrical angle
Full step	100 %	100 %	45°
Half step	100 %	100 %	45°
Quarter step	71 %	71 %	45°

Absolute Maximum Ratings (Ta = 25°C)

Characteristic	Symbol	Rating	Unit	Remark
Motor power supply	V _M	40	V	—
Motor output voltage	V _{OUT}	40	V	—
Motor output current	I _{OUT}	2.8	A/ch	(Note1)
Internal logic power supply	V _{CC}	6.0	V	When externally applied
Logic input pin voltage	V _{IN}	6.0	V	—
MO output pin voltage	V _{MO}	6.0	V	—
MO output pin inflow current	I _{MO}	30.0	mA	—
Power dissipation	P _D	1.3	W	(Note2)
Operating temperature	T _{opr}	-20 to 85	°C	—
Storage temperature	T _{stg}	-55 to 150	°C	—
Junction temperature	T _j (max)	150	°C	—

Note1: Maximum current value at normal operation should be used about 2 A per phase after thermal calculation. The maximum output current may be further limited in view of thermal considerations, depending on ambient temperature and board conditions.

Note2: When Ta exceeds 25°C for device alone measurement, please correct the P_D values by de-rating at 10.4 mW/°C.

Ta : Ambient temperature of the IC

Topr : Ambient temperature while the IC is activate

Tj : Junction temperature while the IC is active. Tj(max) is limited by the thermal shutdown (TSD) circuitry.

It is advisable to keep the maximum current below a certain level so that the maximum junction temperature, Tj (max), will not exceed 120°C.

Absolute maximum ratings

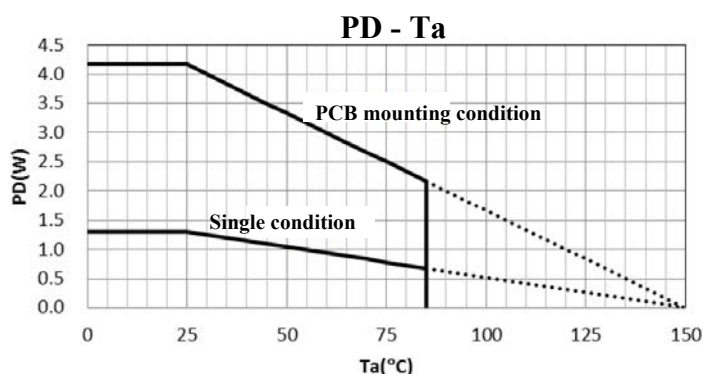
The absolute maximum ratings of a semiconductor device are a set of ratings that must not be exceeded, even for a moment. Do not exceed any of these ratings.

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 TB67S522FTAG 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.

■ (Reference) Relation between power dissipation (single, PCB mounted) and ambient temperature



Board condition
 4 layers board for glass epoxy exclusive use
 Cu thickness: 1st layer and 4th layer 55μm, 2nd layer and 3rd layer 35μm
 Board size: 100mm × 110mm × 1.6mm

Operating Ranges (Ta = 0 to 85°C)

Characteristic	Symbol	Min	Typ.	Max	Unit	Remark
Motor power supply voltage	V _M	10.0	24.0	35.0	V	—
Motor output current	I _{OUT}	—	1.5	2.5	A	Per 1 channel (Note1)
Logic input voltage	V _{IN} (H)	2.0	—	5.5	V	Logic High level
	V _{IN} (L)	-0.4	—	1.0	V	Logic Low level
MO output pin voltage	V _{MO}	—	3.3	5.5	V	Voltage of pull-up destination
Clock input frequency	f _{CLK}	—	—	100	kHz	—
Chopping frequency	f _{chop}	40	100	150	kHz	—
V _{ref} reference voltage	V _{ref}	GND	—	3.6	V	—
Sense resistance connection pin voltage	V _{RS}	0.0	±1.0	±1.5	V	Reference value: VM pin (Note2)

Note1: The actual maximum current may be limited by the operating environment (operating conditions such as excitation mode or operating duration, or by the surrounding temperature or board heat dissipation).

Confirm a realistic maximum current by calculating the heat generated under the operating environment.

Note2: The maximum V_{RS} voltage should not exceed the maximum rated voltage.

Electric Characteristic 1

(Unless otherwise specified, Ta = 25°C, V_M = 24 V)

Characteristic		Symbol	Test circuit	Test condition	Min	Typ.	Max	Unit
Logic input pin Input voltage	HIGH	V _{IN} (H)	DC	Logic input pin (Note)	2	3.3	5.5	V
	LOW	V _{IN} (L)	DC	Logic input pin (Note)	0	—	0.8	V
Input hysteresis		V _{IN} (HYS)	DC	Logic input pin (Note)	100	200	300	mV
Logic input pin Input current	HIGH	I _{IN} (H)	DC	Test logic input pin: 5 V	35	50	75	μA
	LOW	I _I (L)	DC	Test logic input pin: 5 V	—	—	1	μA
MO pin output voltage	HIGH	V _{OH} (MO)	DC	IOH=-24 mA Output: High	2.4	—	—	V
	LOW	V _{OL} (MO)	DC	IOL=24 mA Output: Low	—	—	0.5	V
Current consumption		I _{M1}	DC	Output: OPEN, in STANDBY mode	—	2	3	mA
		I _{M2}	DC	Output: OPEN, ENABLE=L	—	3.5	5	mA
		I _{M3}	DC	Output: OPEN (full step resolution)	—	5	7	mA
Motor output leak current	HIGH	I _{OH}	DC	V _{RS} =V _M =40 V, V _{OUT} =0 V	—	—	1	μA
	LOW	I _{OL}	DC	V _{RS} =V _M =V _{OUT} =40 V	1	—	—	μA
Differential between output current channels		ΔI _{OUT1}	DC	I _{OUT} =2 A	-5	0	5	%
Output current setting differential		ΔI _{OUT2}	DC	I _{OUT} =2 A	-5	0	5	%
R _S pin current		I _{RS}	DC	V _{RS} =V _M =24 V	0	—	27	μA
Output transistor drain-source ON-resistance (H-side + L-side)		R _{ON(D-S)}	DC	I _{OUT} =2.0 A, T _J =25°C (Design value)	—	0.53	0.64	Ω

Note: V_{IN} (H) is defined as the V_{IN} voltage that causes the outputs to change when a pin under test is gradually raised from 0V. V_{IN} (L) is defined as the V_{IN} voltage that causes the outputs to change when the pin is then gradually lowered.

The difference between V_{IN} (H) and V_{IN} (L) is defined as V_{IN} (HYS).

Electric Characteristic 2

(Unless otherwise specified, $T_a = 25^\circ\text{C}$, $V_M = 24\text{ V}$)

Characteristic	Symbol	Test circuit	Test condition	Min	Typ.	Max	Unit
V_{ref} input current	I_{ref}	DC	$V_{\text{ref}}=3.0\text{ V}$	—	0	1	μA
V_{ref} decay ratio	V_{ref} (gain)	DC	$V_{\text{ref}}=2.0\text{ V}$	1/4.8	1/5.0	1/5.2	—
TSD temperature (Note1)	T_{jTSD}	DC	—	140	150	170	$^\circ\text{C}$
V_M return voltage	V_{MR}	DC	—	7.0	8.0	9.0	V
ISD operation current (Note2)	ISD	DC	(Design value)	3.0	4.0	5.0	A
Power supply voltage for internal circuit operation (Note3) (Note4)	V_{cc}	DC	$I_{\text{cc}}=5.0\text{ mA}$	4.75	5.00	5.25	V

Note1: Thermal shut down (TSD) circuit

When the IC junction temperature reaches the specified value and become overheated under irregular conditions causing the TSD circuit to be activated, the internal halt circuit is activated shutting down all the outputs to off.

When the temperature is set between 140°C (min) to 170°C (max), the TSD circuit operates (design target value). When the TSD circuit is operating, it can be returned by re-starting the V_M power supply or setting $D_MODE_1/2$ to L/L (the STANDBY mode). The TSD function aims at detecting abnormal heating of ICs. Please avoid positively using the TSD function.

Note2: Over-current detection (ISD) circuit

When the current exceeding the specified value flows to the output under irregular conditions, the internal halt circuit is activated switching all the outputs to off. The blanking time of four cycles of CR cycle is set to avoid the incorrect operation by switching. It can be returned by re-starting the V_M power supply or setting $D_MODE1/2$ to L/L (the STANDBY mode). The IC is in the STANDBY mode when ISD function is operating.

Note3: When the power supply voltage (V_{CC}) for internal circuit operation is divided with external resistance and used as V_{ref} input voltage, the accuracy of the output setting value becomes $\pm 8\%$, together with the accuracy of V_{cc} output and V_{ref} decay ratio.

Note4: Even if the logic input signal is input in the state that the VM voltage is not supplied, although the circuit is designed so that electromotive force and leakage current by the signal input do not occur, please control the logic input signal so that the motor does not operate before re-supplying VM voltage.

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 is fed back to the power supply owing 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. It must be fully verified that there is no risk that the TB67S522FTAG or other components will be damaged or fail owing to the motor back-EMF.

Cautions on over-current shutdown (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 circuit; they do not necessarily guarantee 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 owing to an output short circuit.
- The ISD circuit is only intended to provide temporary protection against an output short circuit. If such a condition persists for a long time, the device may be damaged owing to overstress. Overcurrent conditions must be removed immediately by external hardware.

IC Mounting

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

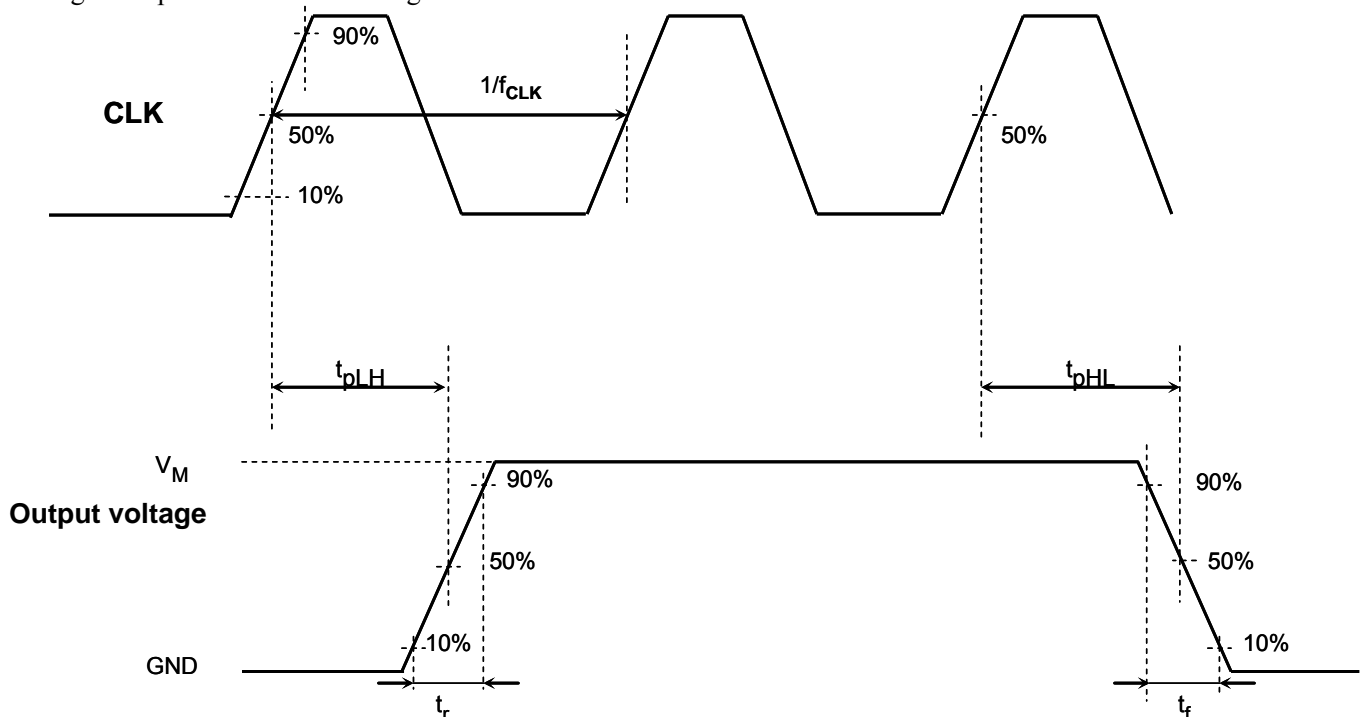
AC Electric Characteristic

($T_a = 25^\circ\text{C}$, $V_M = 24\text{ V}$, $6.8\text{ mH}/5.7\Omega$)

Characteristic	Symbol	Test circuit	Test condition	Min	Typ.	Max	Unit
CLK (clock) input frequency	f_{CLK}	AC	$f_{\text{OSC}}=1600\text{ kHz}$	—	—	100	kHz
Internal filter of CLK input minimum High width	$T_{\text{CLK (H)}}$	AC	The CLK (H) minimum pulse width	300	—	—	ns
Internal filter of CLK input minimum Low width	$T_{\text{CLK (L)}}$	AC	The CLK (L) minimum pulse width	250	—	—	ns
Switching characteristic of output transistor	t_r	AC	—	100	150	200	ns
	t_f	AC	—	100	150	200	ns
	$t_{\text{pLH (CLK)}}$	AC	Between CLK and output voltage	—	1000	—	ns
	$t_{\text{pHL (CLK)}}$	AC	Between CLK and output voltage	—	1500	—	ns
Noise rejection blanking time	t_{BLANK}	AC	$I_{\text{OUT}}=1.0\text{ A}$	200	300	500	ns
OSCM oscillation frequency	f_{OSC}	AC	$C_{\text{OSC}}=270\text{pF}$, $R_{\text{OSC}}=3.6\text{k}\Omega$	1200	1600	2000	kHz
Chopping frequency range	$f_{\text{Chop (range)}}$	AC	$V_M=24\text{ V}$, Output ACTIVE ($I_{\text{OUT}}=1.0\text{ A}$)	30	100	150	kHz
Chopping setting frequency	f_{Chop}	AC	Output ACTIVE ($I_{\text{OUT}}=1.0\text{ A}$), $\text{CR}=1600\text{ kHz}$	—	100	—	kHz
Over current detection blanking time (Note)	$t_{\text{ISD (Mask)}}$	AC	After exceeding a threshold when the outputs are short-circuited to the power supply and GND	—	4	—	Osc-CLK
Operation time of over current detection (Note)	t_{ISD}	AC		—	—	8	

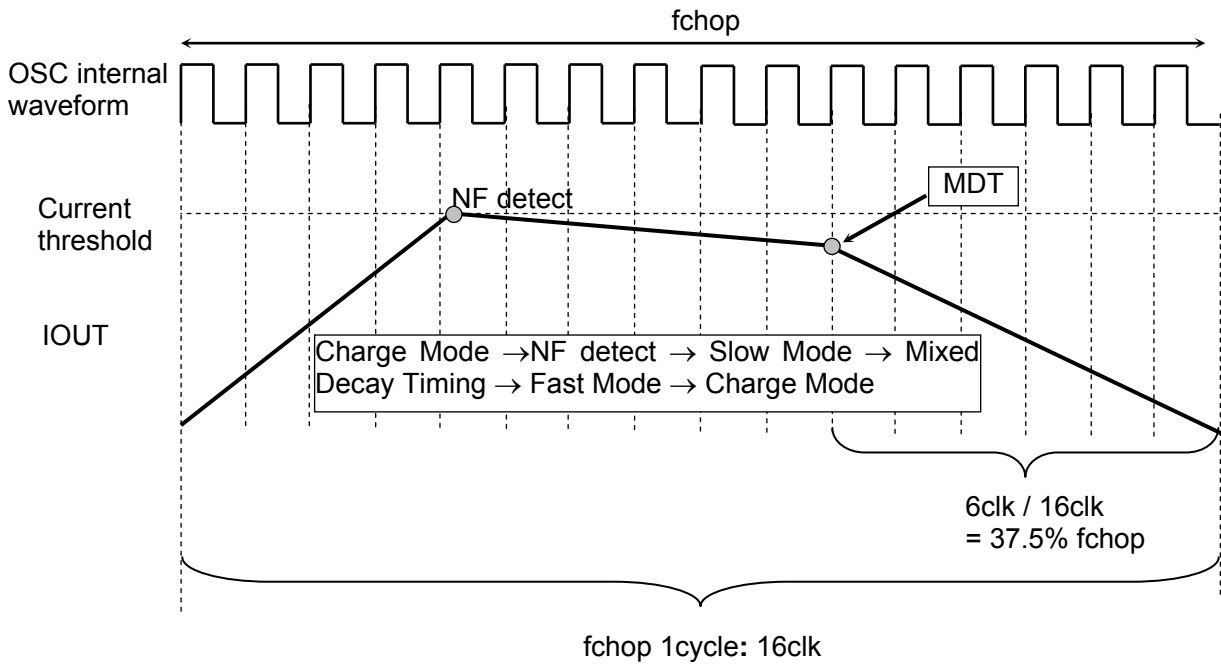
Note: Count using number of clocks of OSCM clock after exceeding ISD threshold when the outputs are short-circuited to the power supply and GND.

Timing of output transistor switching characteristic

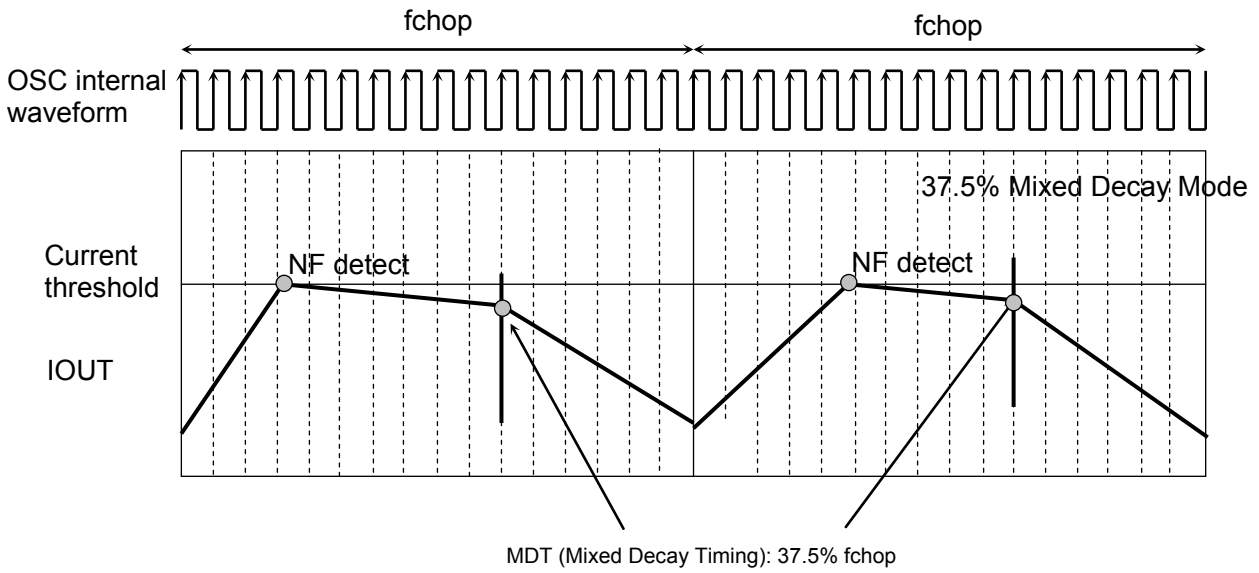


Timing charts may be simplified for explanatory purposes.

Mixed Decay Mode



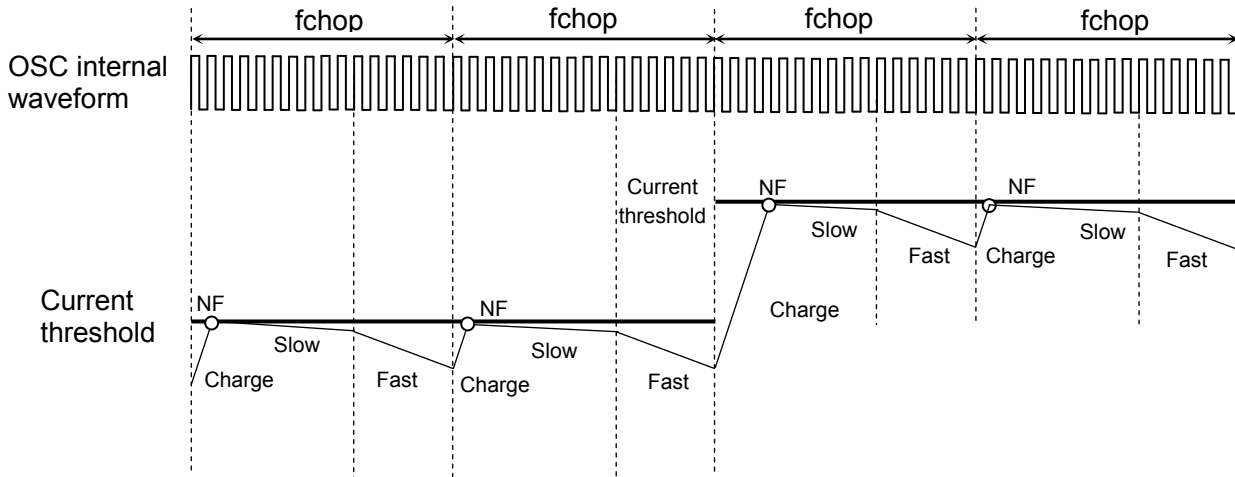
Mixed Decay Mode Sequence Waveform



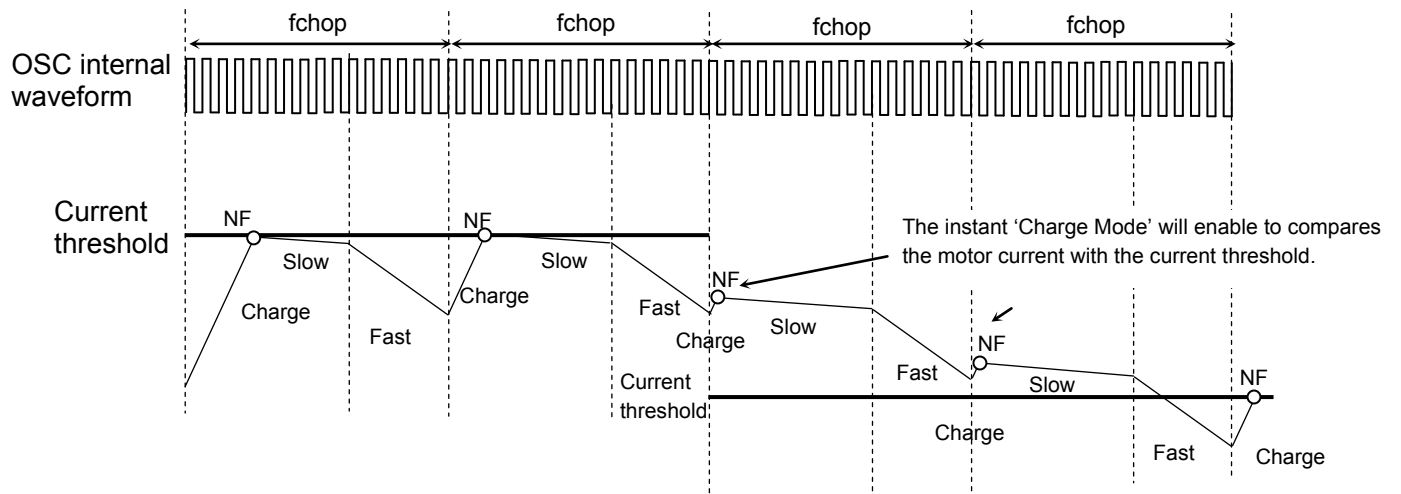
Timing charts may be simplified for explanatory purposes.

Mixed (Slow + Fast) Decay Mode Current Waveform

- When the next step's current threshold is more than that of the previous step

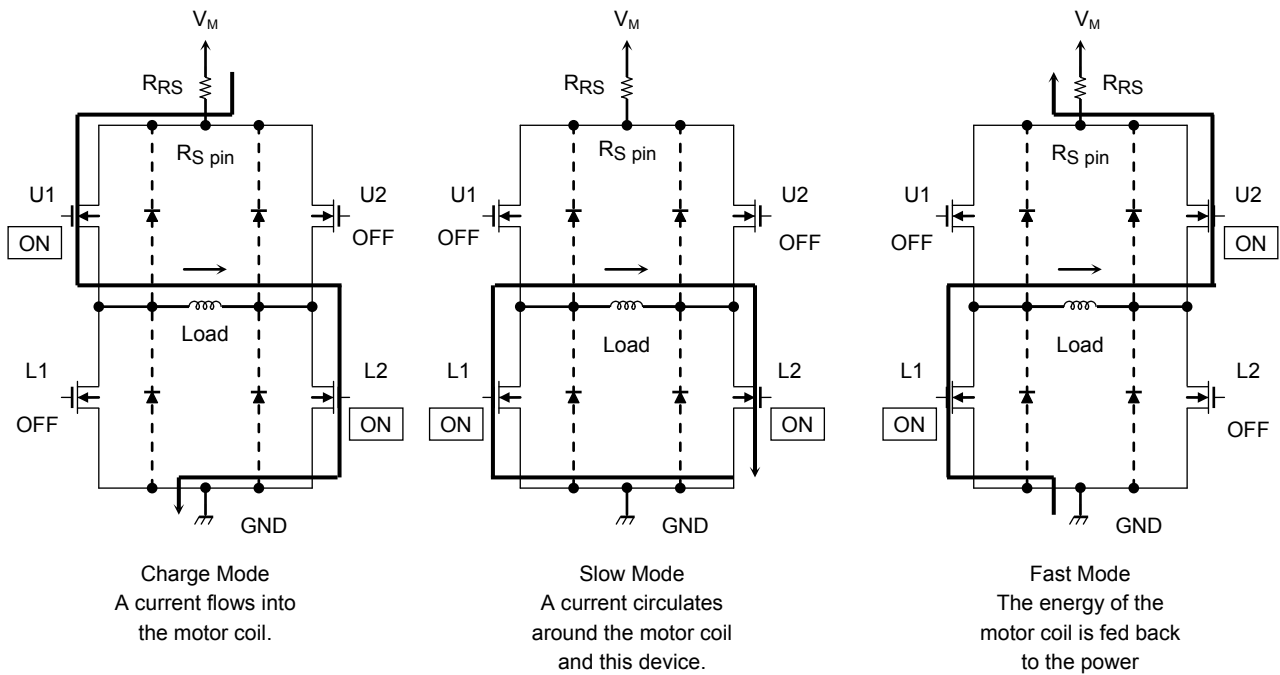


- When the next step's current threshold is less than that of the previous step



Timing charts may be simplified for explanatory purposes.

Output Transistor Operation Mode



Output Transistor Operating Function

Mode	U1	L1	U2	L2
Charge	ON	OFF	OFF	ON
Slow	OFF	ON	OFF	ON
Fast	OFF	ON	ON	OFF

Note: This table shows an example of when the current flows as indicated by the arrows in the figures shown above. If the current flows in the opposite direction, refer to the following table.

Mode	U1	L1	U2	L2
Charge	OFF	ON	ON	OFF
Slow	OFF	ON	OFF	ON
Fast	ON	OFF	OFF	ON

Calculation of the Setting Current

This IC drives a motor by controlling the PWM constant current base of the OSCM oscillating frequency.

The peak output current can be set via the current-sensing resistor (RS) and the reference voltage (V_{ref}), as follows:

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

V_{ref} (gain) : V_{ref} decay ratio is 1 / 5.0 (typ.)

Example : In case of 100 % setting,

When V_{ref} = 3.0 V, Torque = 100%, RS = 0.51 Ω,

constant current output value of the motor (Peak current) is calculated as follows;

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

Calculation of OSCM oscillation frequency (chopping reference frequency)

An approximation of the OSCM oscillation frequency (f_{OSCM}) and chopper frequency (f_{chop}) can be calculated by the following formulas.

$$f_{OSCM} = 1 / [0.56 \times \{C \times (R1 + 500)\}] \quad C, R1: \text{External constants for OSCM (C=270 pF, R1=3.6 k}\Omega\text{)}$$

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

If the chopping frequency is raised, the reappearance of a waveform is higher since the ripple of the current decreases. However the gate loss in the IC is raised and the heat generation becomes large.

It is expected that the heat generation is reduced by being lowered the chopping frequency, but the current pulsating flow may be increased. Generally it is recommended that the reference frequency is set as 70 kHz, the range from 50 kHz to 100 kHz.

IC Power Consumption

Power of the IC is consumed by the transistor of the output block and that of the logic block mainly.

1. Power consumed of power transistor (calculated as Ron H-side + L-side = 0.6Ω)

The power of output blocks is consumed by the transistor placed at H-side and L-side of H-bridge.

The power of a transistor of one H bridge can be shown in the following formula.

$$P (out) = I_{out} (A) \times V_{DS} (V) = I_{out} (A)^2 \times R_{on} (\Omega) \dots\dots\dots (1)$$

In the case of full step resolution, when the output current waveform becomes completely square waveform, the average power consumption can be calculated as follows.

In the case of Ron = 0.6Ω, Iout (peak: Max) = 1.0 A, VM = 24 V,

$$P (out) = 2 (Tr) \times 1.0 (A)^2 \times 0.6(\Omega) \dots\dots\dots (2)$$
$$= 1.2(W)$$

2. Power consumption of logic and IM domain

Power consumptions of logic and IM systems are calculated by separating the states (operating and stopping).

I (IM3) = 5 mA (typ.) : Opearting /axis

I (IM2) = 3.5 mA (typ.) : Stopping/axis

I (IM1) = 2 mA (typ.) : Standby/axis

Output block are connected to VM (24V). (Output block: Current consumed by the circuit connected to VM + Current consumed by switching output steps)

Power consumption is calculated as follows;

$$P (IM3) = 24 (V) \times 0.005 (A) \dots\dots\dots (3)$$
$$= 0.12 (W)$$

3. Power consumption

Total power consumption P is calculated from the values of formula (2) and (3).

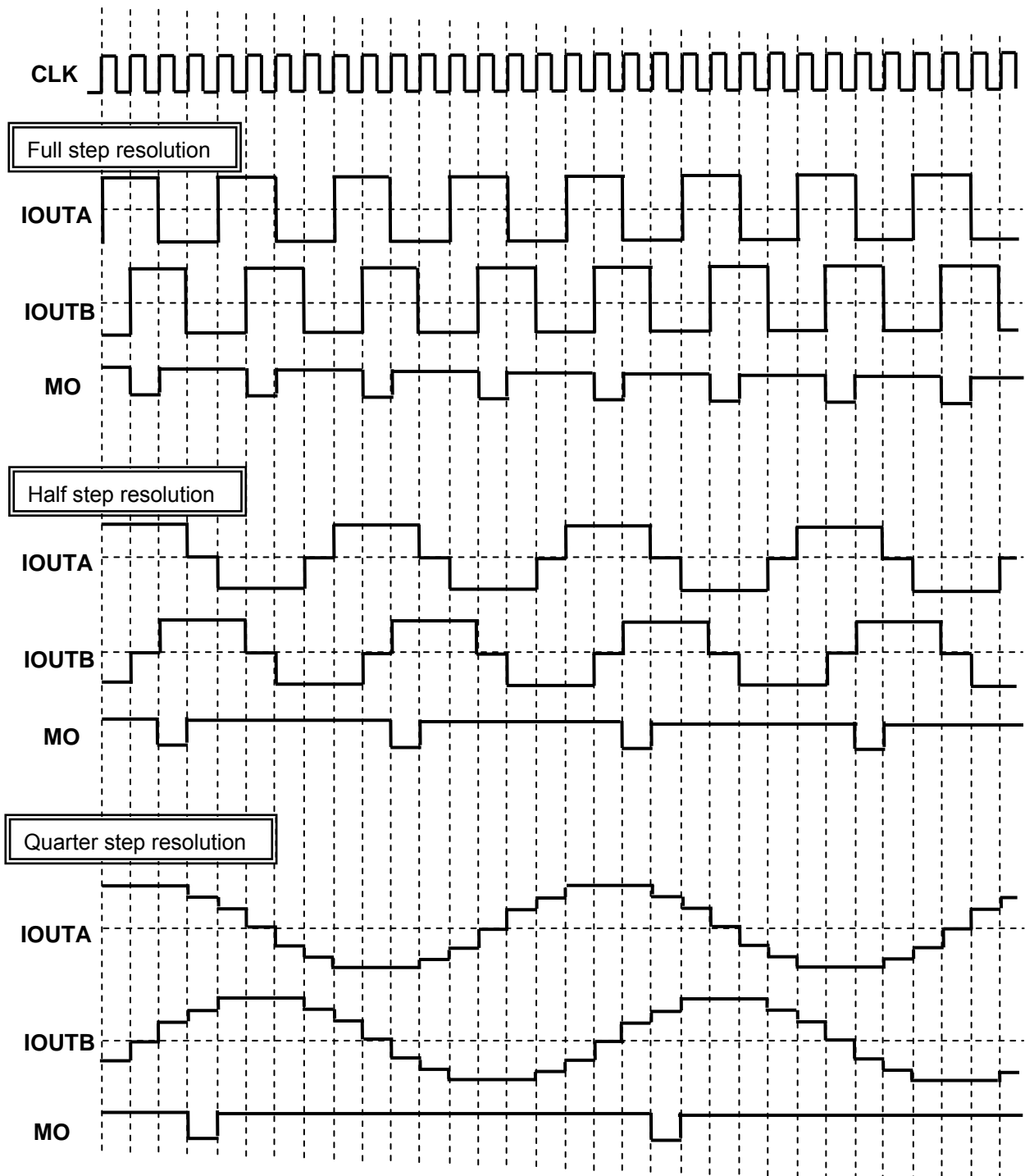
$$P = P (out) + P (IM3) = 1.32(W)$$

Moreover the power consumption of one axis in STANDBY is as follows.

$$P (in STANDBY) = 24 (V) \times 0.002 (A) = 0.048 (W)$$

For the heat design of the board, evaluate enough, and configure the appropriate margin.

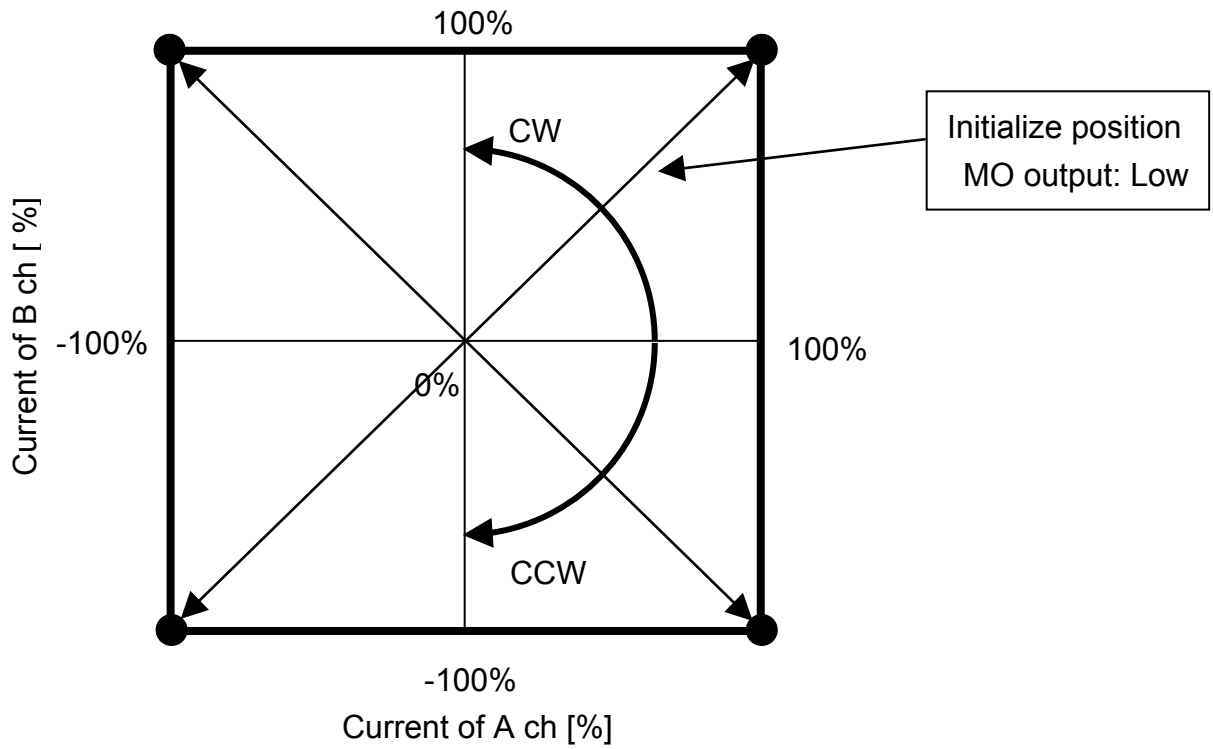
Sequence According to Drive Mode



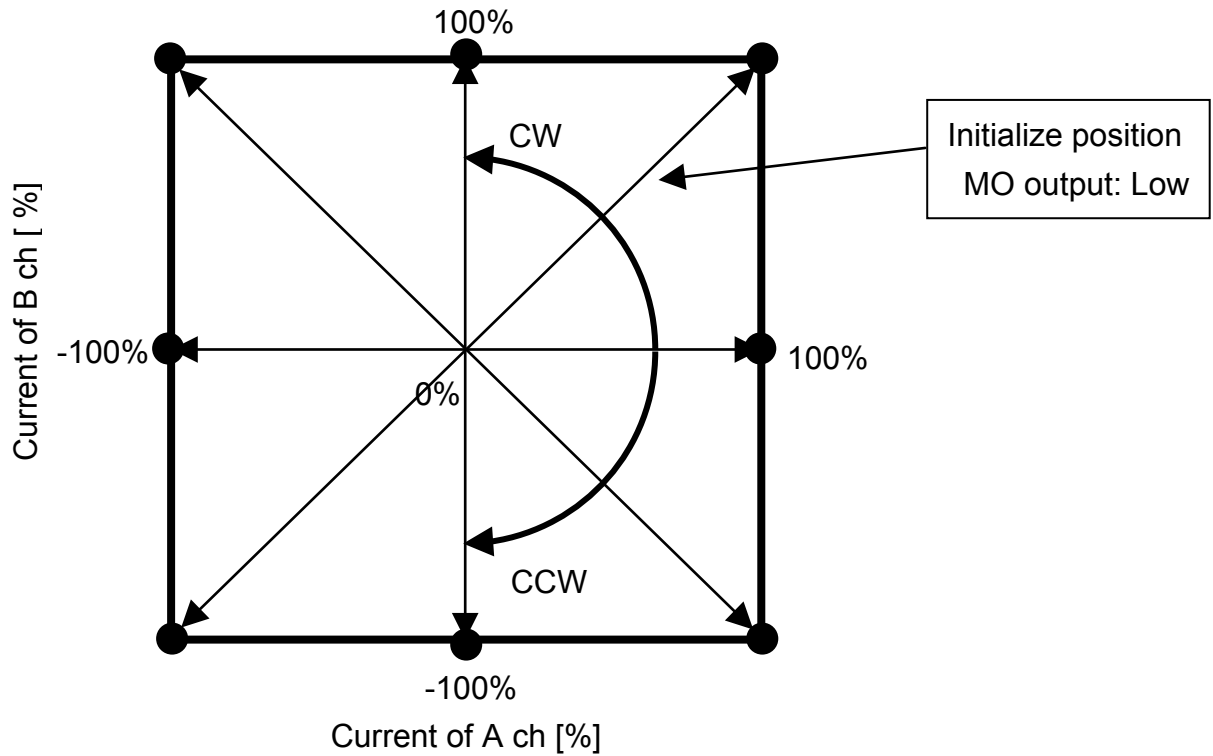
The MO output shown in the timing chart is when the MO pin is pulled-up.

Electrical Angle and Initialize Position of Step Resolution Mode

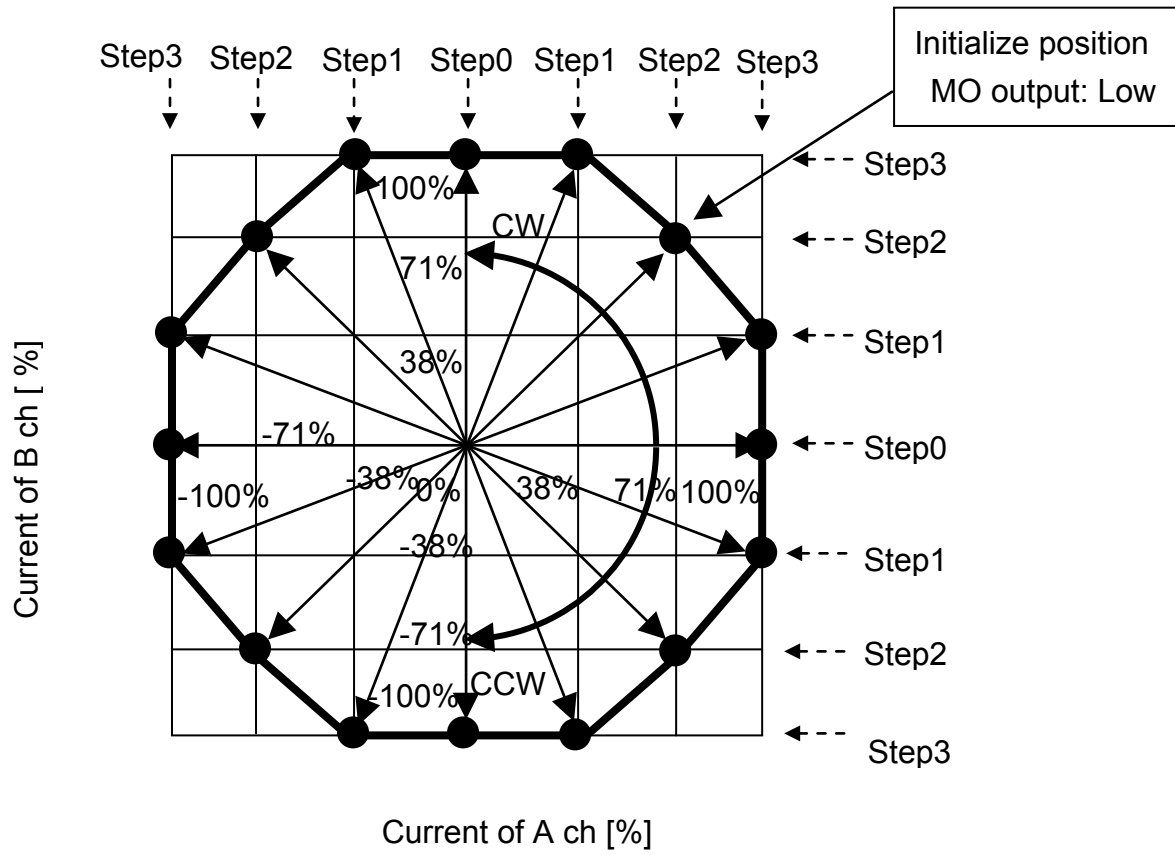
- Full step resolution mode



- Half step resolution mode

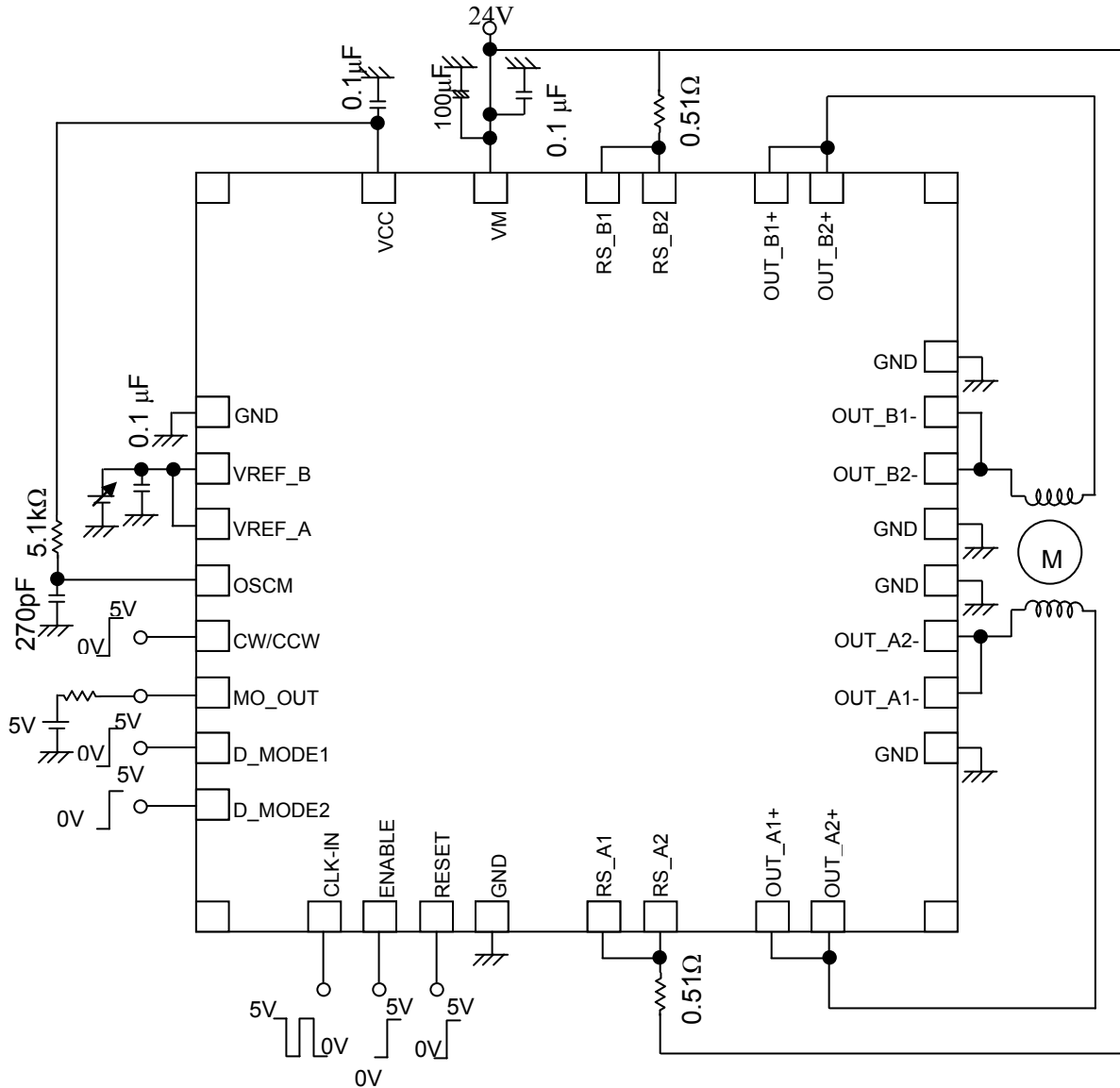


- Quarter step resolution mode



Example of Application Circuit (Chopping Frequency: 70 kHz)

The values shown in the following figure are recommended values. For input conditions, see the Operating Ranges.



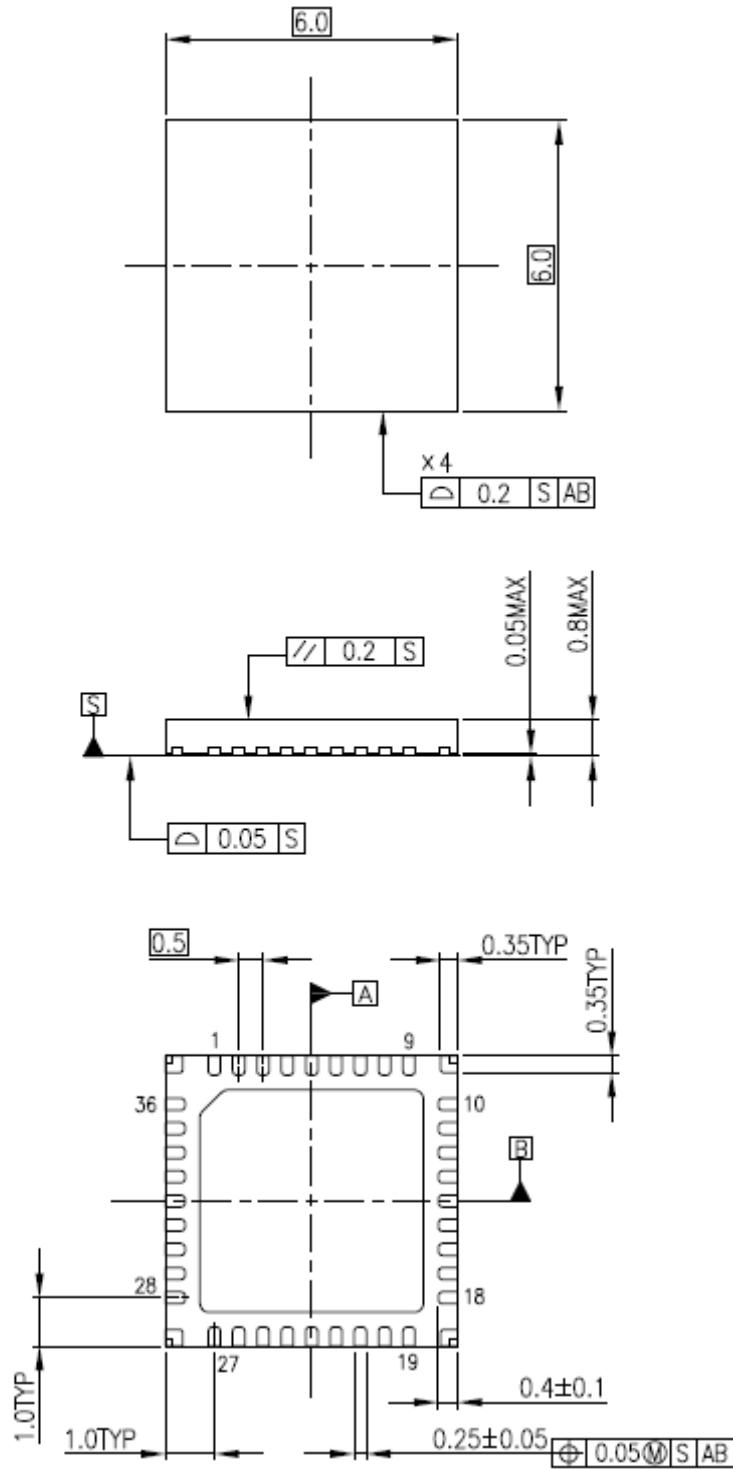
Note: It is recommended that a bypass capacitor is added if necessary.

The example of an applied circuit is for reference, and enough evaluation should be done before the mass-production design. Moreover, it is not the one to permit the use of the industrial property.

Package Dimensions

P-WQFN36-0606-0.50-002

Unit:mm



Weight: 0.14 g (typ.)

Note 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) Timing Charts

Timing charts may be simplified for explanatory purposes..

(3) 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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(4) 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) 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.
- (3) 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 Fast-blow 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 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, over-current or IC failure can cause smoke or ignition. (The over-current can 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

- (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 (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.
- (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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