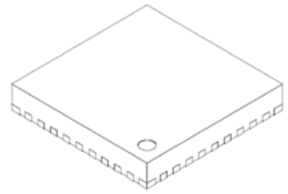
TOSHIBA BiCD Integrated Circuit Silicon Monolithic

TB67S508FTG

BiCD Constant-Current Two-Phase Bipolar Stepping Motor Driver IC

The TB67S508FTG is a two-phase bipolar stepping motor driver using a PWM chopper.
Fabricated with the BiCD process, the TB67S508FTG rating is 40 V/3.0 A.
Motor can be operated with single power supply (VM) by built-in regulator.



P-VQFN36-0505-0.50-002

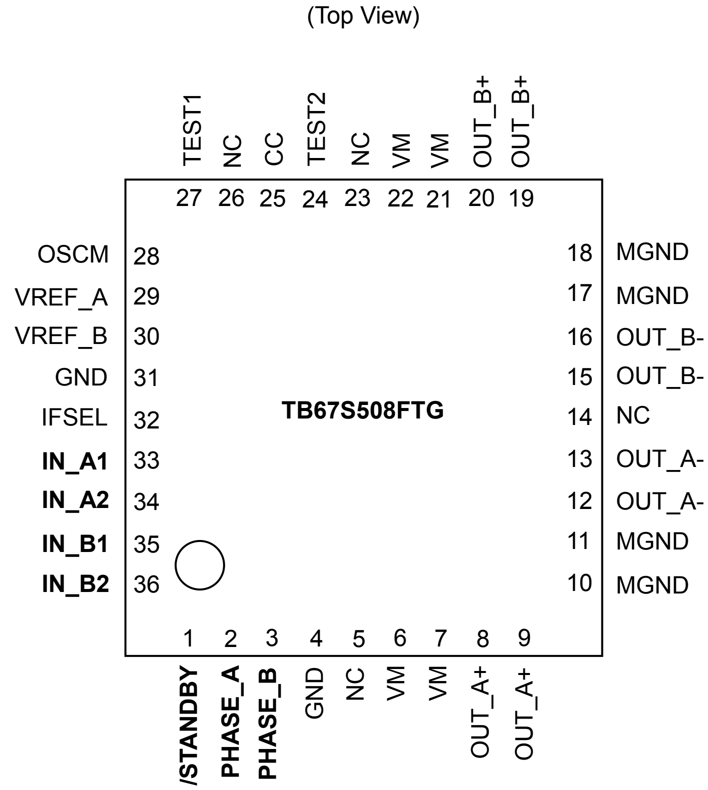
Weight: 0.06 g (Typ.)

Features

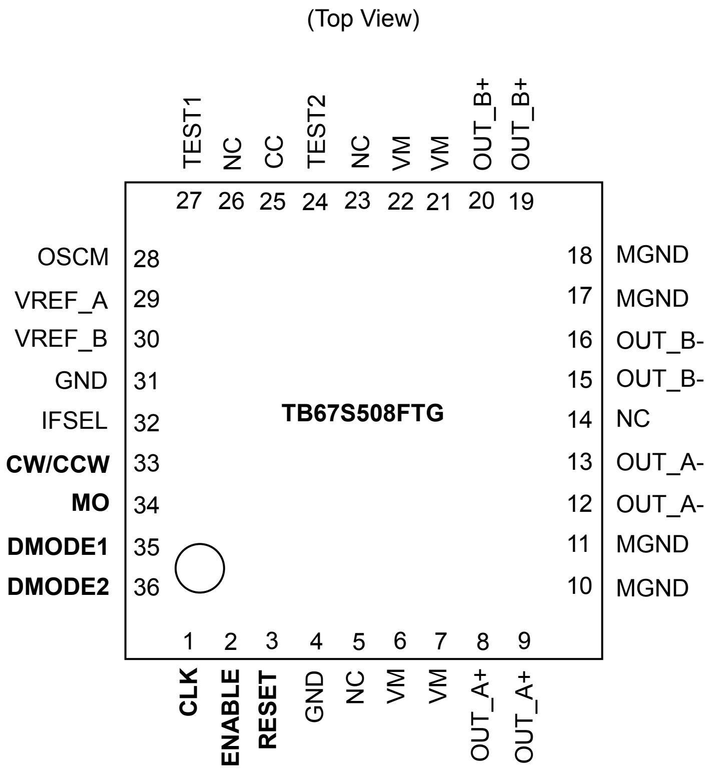
- BiCD process monolithic IC
- Capable of controlling bipolar stepping motor
- PWM controlled constant-current drive without resistance for motor current detection
- Built-in ACDS (Advanced Current Detect System) function enables a PWM constant current control without external current detection resistors.
- Built-in ADMD(Advanced Dynamic Mixed Decay) function enables a high efficiency PWM constant current control.
- I/F: Capable of switching between the phase input control and the clock input control
- Full-step/Half-step/Quarter-step resolutions
- BiCD: DMOSFET is adopted to output power transistor.
- High withstand voltage and large current: 40 V / 3.0 A (absolute maximum ratings)
- Built-in thermal shutdown detection (TSD), Over current detection (ISD), and Under voltage lockout detection(UVLO)
- Decreasing number of external components by reducing charge pump
- Package: P-VQFN36-0505-0.50-002

Pin Assignment

IFSEL=”H” (Phase input control)

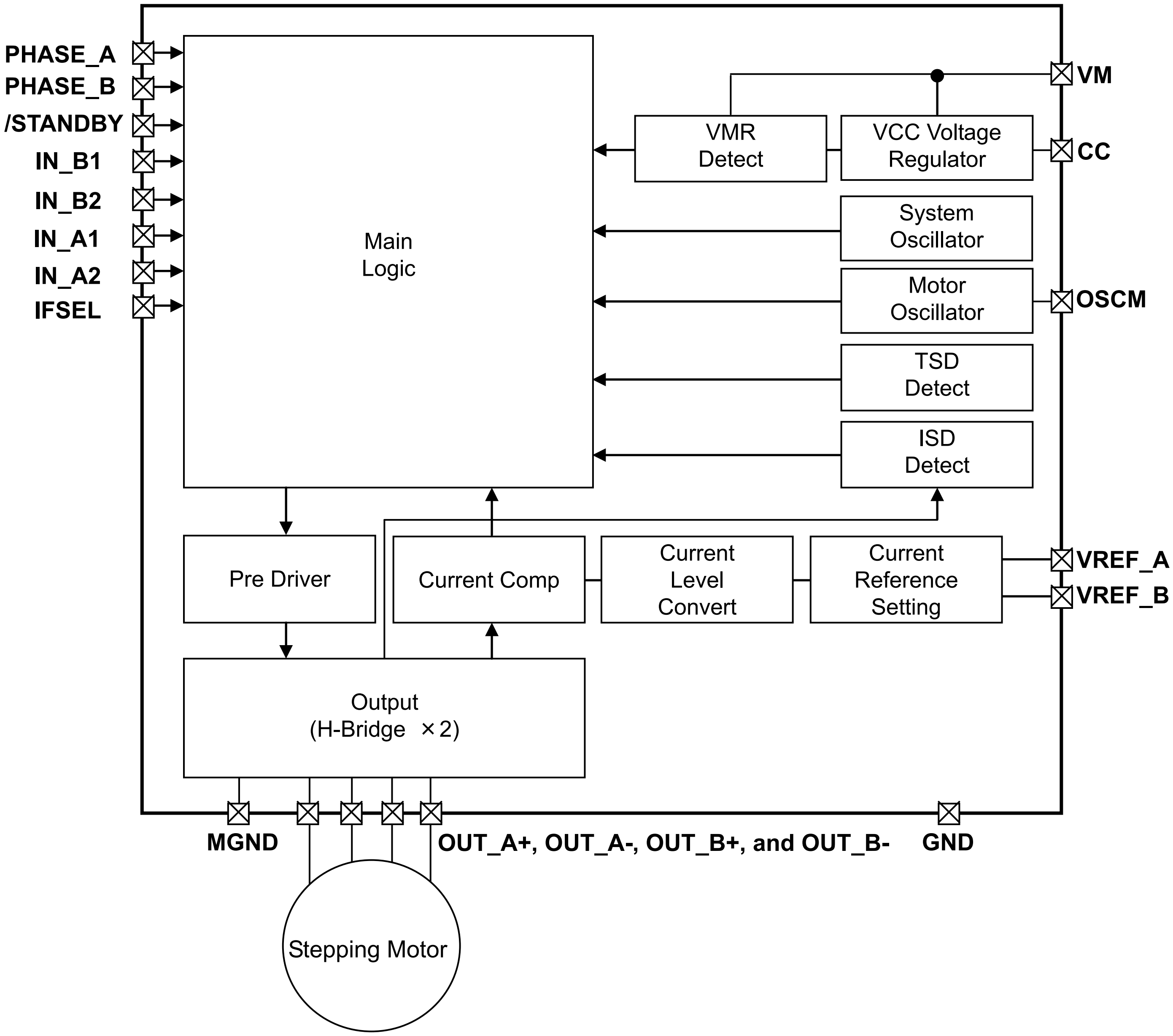


IFSEL=”L” (Clock input control)



Block Diagram

IFSEL="H" (Phase input control)



Functional blocks/circuits/constants in the block chart etc. may be omitted or simplified for explanatory purposes.

Note: All the grounding wires of the TB67S508FTG 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, VM 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 (VM, OUT_A+, OUT_A-, OUT_B+, OUT_B-, GND, and MGND) 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 Explanations

IFSEL="H" (Phase input control)

Pin No.	Pin Name	Function
1	/STANDBY	Standby signal input pin
2	PHASE_A	Control signal input pin for Ach motor output
3	PHASE_B	Control signal input pin for Bch motor output
4	GND	Ground pin
5	NC	Non-connection pin
6	VM	Motor power supply pin
7	VM	Motor power supply pin
8	OUT_A+	Motor Ach (+) output pin
9	OUT_A+	Motor Ach (+) output pin
10	MGND	Motor ground pin
11	MGND	Motor ground pin
12	OUT_A-	Motor Ach (-) output pin
13	OUT_A-	Motor Ach (-) output pin
14	NC	Non-connection pin
15	OUT_B-	Motor Bch (-) output pin
16	OUT_B-	Motor Bch (-) output pin
17	MGND	Motor ground pin
18	MGND	Motor ground pin
19	OUT_B+	Motor Bch (+) output pin
20	OUT_B+	Motor Bch (+) output pin
21	VM	Motor power supply pin
22	VM	Motor power supply pin
23	NC	Non-connection pin
24	TEST2	Toshiba test pin for shipment (please set open in using.)
25	CC	Monitor pin for internal regulator
26	NC	Non-connection pin
27	TEST1	Toshiba test pin for shipment (please set GND in using.)
28	OSCM	Frequency set pin for internal oscillation circuit
29	VREF_A	Current set pin for Ach motor output
30	VREF_B	Current set pin for Bch motor output
31	GND	Ground pin
32	IFSEL	I/F mode set pin
33	IN_A1	Control signal input pin for Ach motor output
34	IN_A2	Control signal input pin for Ach motor output
35	IN_B1	Control signal input pin for Bch motor output
36	IN_B2	Control signal input pin for Bch motor output

* NC: Please set open.
* Please connect the pins with the same pin name nearby.

IFSEL="L" (Clock input control)

Pin No.	Pin Name	Function
1	CLK	Clock signal input pin for electrical-angle step
2	ENABLE	Signal input pin for switching output (ON/OFF)
3	RESET	Signal input pin for initialization of electrical angle
4	GND	Ground pin
5	NC	Non-connection pin
6	VM	Motor power supply pin
7	VM	Motor power supply pin
8	OUT_A+	Motor Ach (+) output pin
9	OUT_A+	Motor Ach (+) output pin
10	MGND	Motor ground pin
11	MGND	Motor ground pin
12	OUT_A-	Motor Ach (-) output pin
13	OUT_A-	Motor Ach (-) output pin
14	NC	Non-connection pin
15	OUT_B-	Motor Bch (-) output pin
16	OUT_B-	Motor Bch (-) output pin
17	MGND	Motor ground pin
18	MGND	Motor ground pin
19	OUT_B+	Motor Bch (+) output pin
20	OUT_B+	Motor Bch (+) output pin
21	VM	Motor power supply pin
22	VM	Motor power supply pin
23	NC	Non-connection pin
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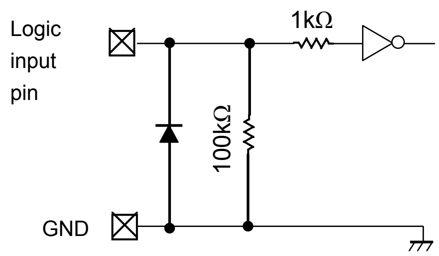
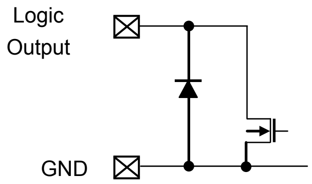
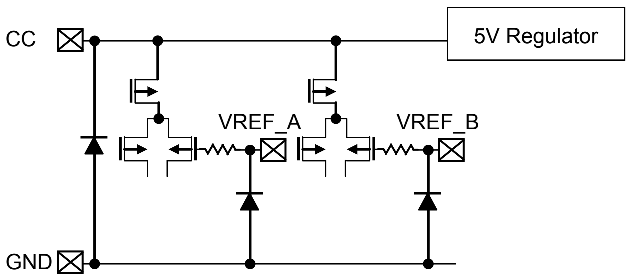
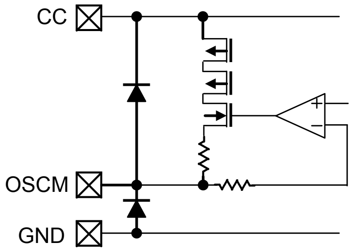
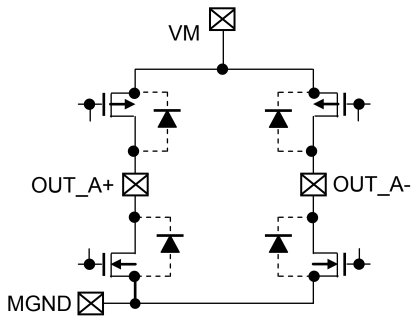
28	OSCM	Frequency set pin for internal oscillation circuit
29	VREF_A	Current set pin for Ach motor output
30	VREF_B	Current set pin for Bch motor output
31	GND	Ground pin
32	IFSEL	I/F mode set pin
33	CW/CCW	Signal input pin for rotation direction set
34	MO	Electrical angle monitor pin (Open-drain output)
35	DMODE1	Excitation mode set pin
36	DMODE2	Excitation mode set pin

* NC: Please set open.

* Please connect the pins with the same pin name nearby.

Input/Output Equivalent Circuit

Pin name	Equivalent circuit
/STANDBY (CLK) PHASE_A (ENABLE) PHASE_B (RESET) IN_A1 (CW/CCW) IN_A2 IN_B1 (DMODE1) IN_B2 (DMODE2) IFSEL	
MO	
CC VREF_A VREF_B	
OSCM	
VM OUT_A+ OUT_A- OUT_B+ OUT_B- MGND	 * OUT_B+, OUT_B-: Same

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

Operation Description

- **IFSEL="H" (Phase input control)**

Functions of IN_A1, IN_A2, IN_B1, IN_B2, PHASE_A, and PHASE_B

Input			Output		
PHASE_A PHASE_B	IN_A1 IN_B1	IN_A2 IN_B2	OUT_A+ OUT_B+	OUT_A- OUT_B-	IOUT
H	H	H	H	L	100%
	H	L	H	L	71%
	L	H	H	L	38%
	L	L	Output OFF	Output OFF	0%
L	H	H	L	H	-100%
	H	L	L	H	-71%
	L	H	L	H	-38%
	L	L	Output OFF	Output OFF	0%

Definition of current flowing direction at IOUT:
From OUT_A+ (OUT_B+) to OUT_A-(OUT_B-): Plus current
From OUT_A-(OUT_B-) to OUT_A+ (OUT_B+): Minus current

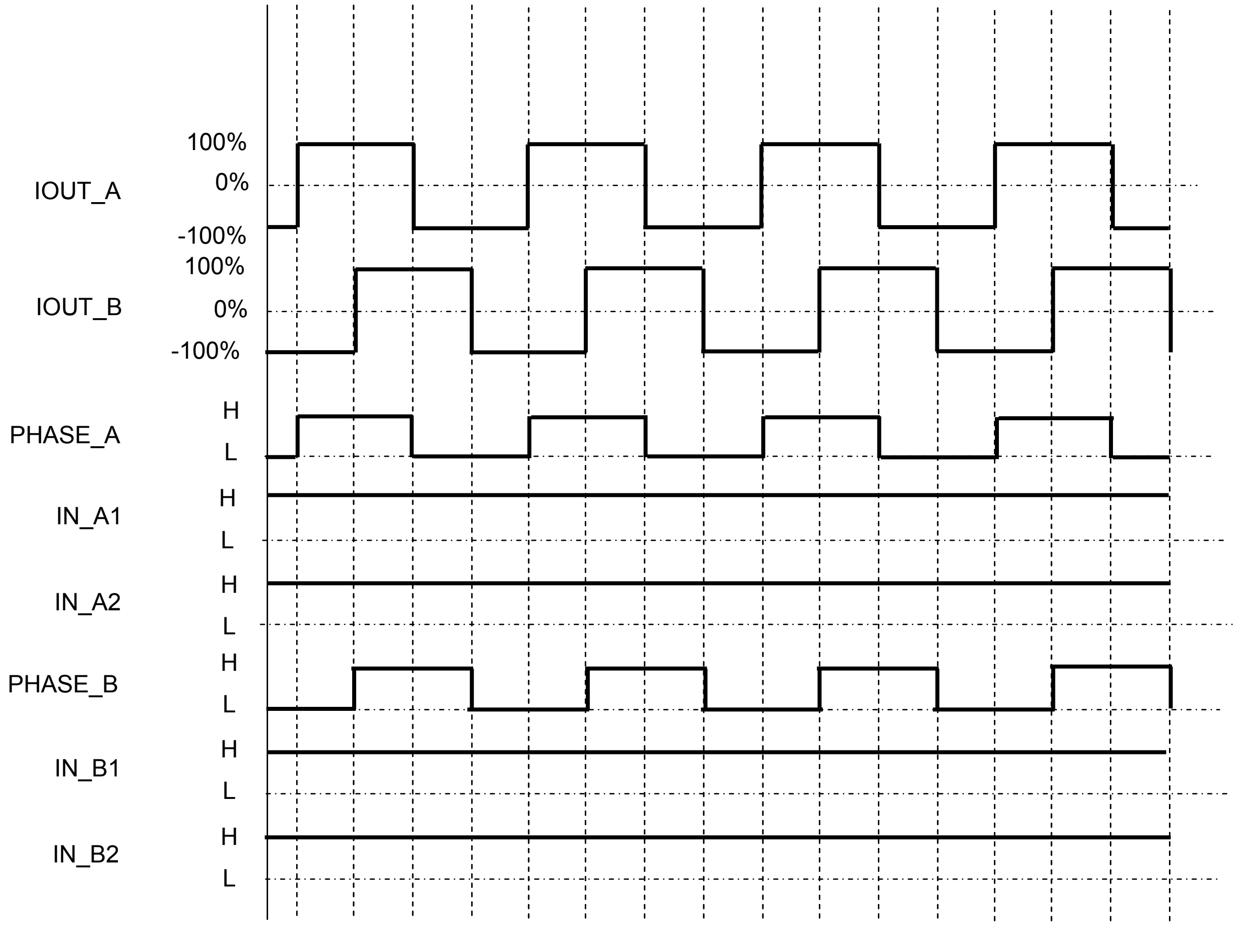
Function of /STANDBY

The operation can resume from the forced off mode, which is configured by the thermal shutdown detection (TSD) and the over current detection (ISD), by setting standby mode once and then setting the normal operation mode again.

Input	Output
/STANDBY	OUT_A+, OUT_B+, OUT_A-, OUT_B-
H	Normal operation mode
L	Standby mode (Internal oscillation circuit (OSCM) and MOSFET output: OFF)

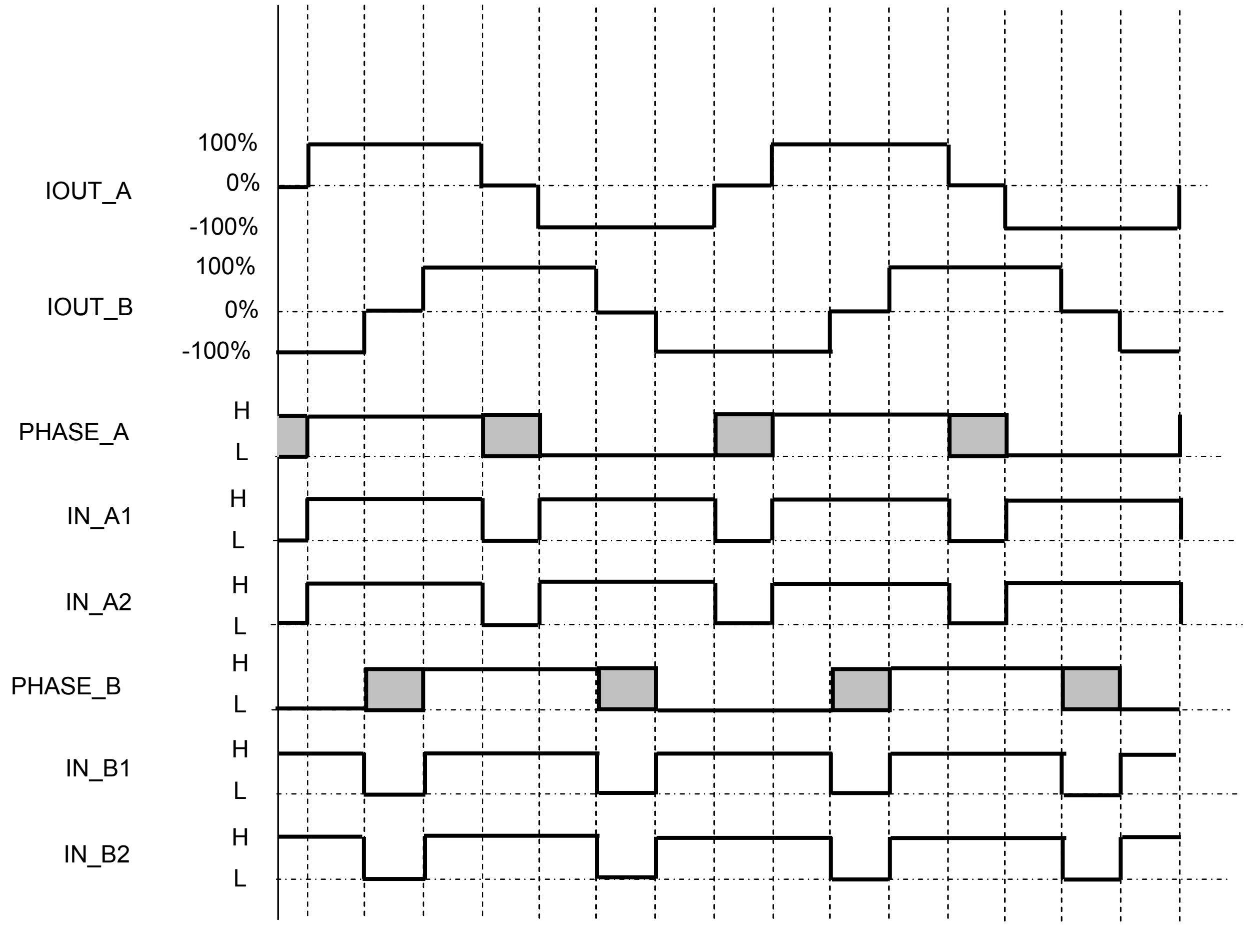
Sequence in each Drive Mode: IFSEL="H" (phase input control)

Full-step resolution



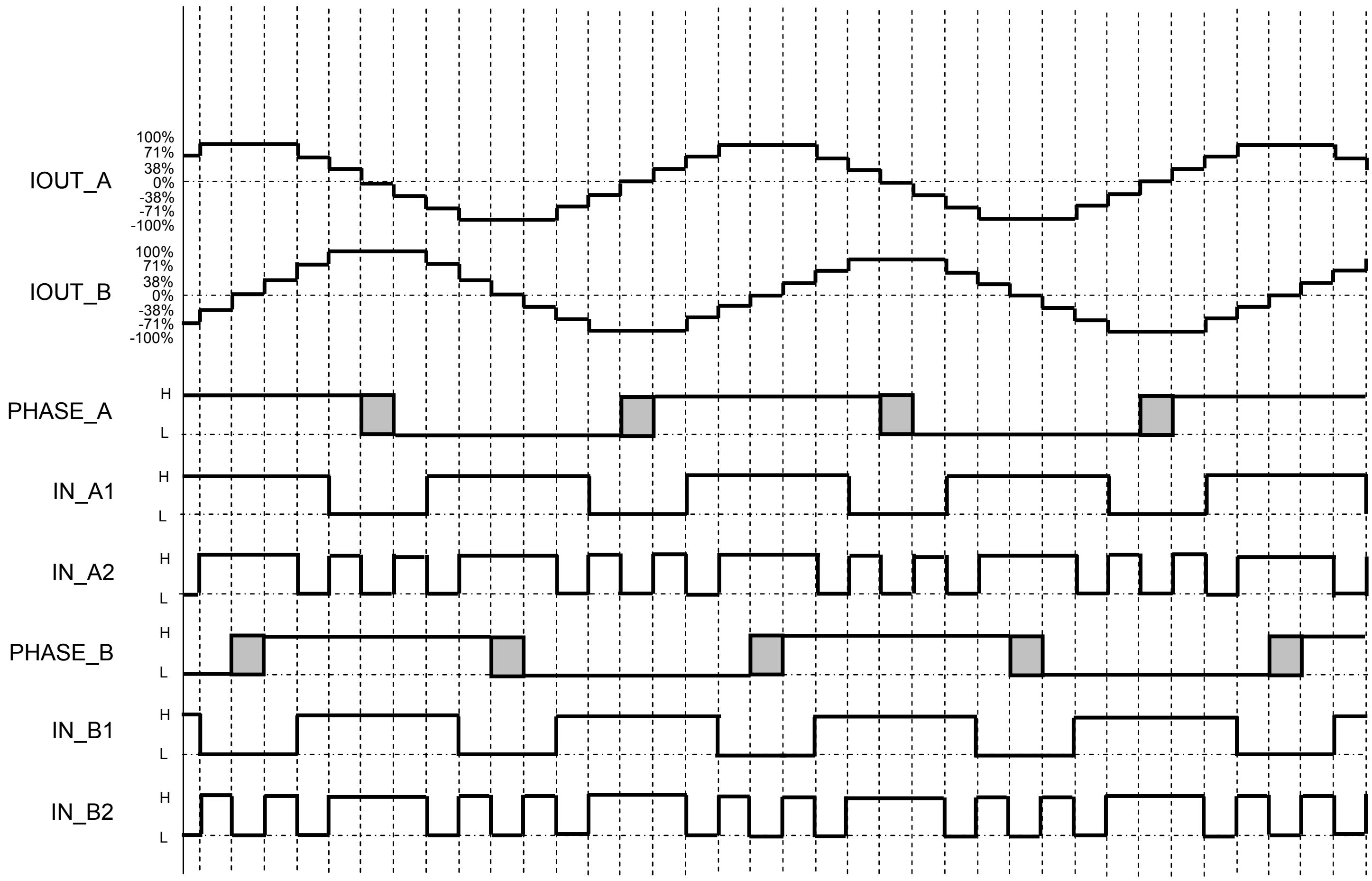
Timing charts may be simplified for explanatory purpose.

Half-step resolution



Timing charts may be simplified for explanatory purpose.

Quarter-step resolution



Timing charts may be simplified for explanatory purpose.

Operation Description

IFSEL=”L” (Clock input control)

CLK function

Each up-edge of the CLK signal shifts the motor’s electrical angle per step.

CLK	Function
↑	Shifts the electrical angle per step.
↓	- (State of the electrical angle does not change.)

ENABLE function

The ENABLE pin controls the ON and OFF of the corresponding output stage. Normal constant current control starts by turning on the motor operation. MOSFET is turned off and the output state becomes high impedance by turning off the motor operation.

ENABLE	Function
H	Output MOSFET: ON (Normal operation)
L	Output MOSFET: OFF (Operation OFF, High impedance)

CW/CCW function

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

CW/CCW	Function
H	Forward rotation (CW)
L	Reverse rotation (CCW)

Function of DMODE1 and DMODE2

The DMODE pins switch the step resolution. The operation moves to the standby mode by setting DMODE1 and DMODE2 pins ”L”. The operation can resume from the forced off mode, which is configured by the thermal shutdown detection (TSD) and the over current detection (ISD), by setting standby mode once and then setting the normal operation mode again.

DMODE1	DMODE2	Function
L	L	Standby mode (Internal oscillation circuit (OSCM) and output MOSFET: OFF)
L	H	Normal operation mode: Full-step resolution
H	L	Normal operation mode: Half-step resolution
H	H	Normal operation mode: Quarter-step resolution

Setting of DMODE1 and DMODE2 is recommended to change after configuring RESET ”L” in the initial state (MO = “L”).

RESET function

The RESET pin initializes the internal electrical angles.

RESET	Function
H	Set the electrical angle to the initial state
L	Normal operation mode

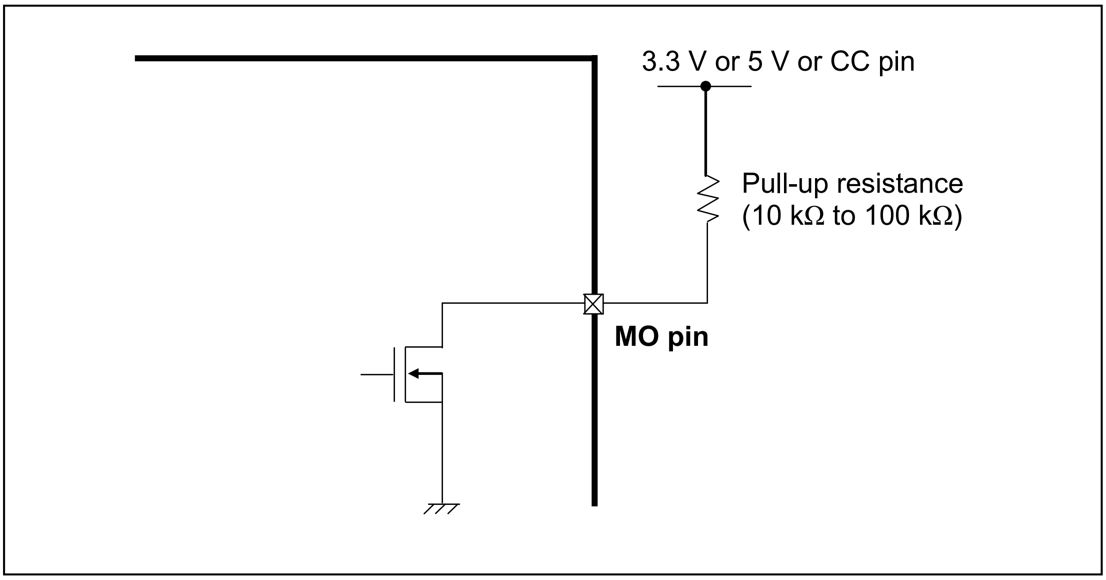
The current of each channel (while RESET is applied) is shown in the table below.

Step resolution setting	Ach current setting	Bch current setting	Default electrical angle
Full step	100%	100%	45°
Half step	100%	100%	45°
Quarter step	71%	71%	45°

MO function

The MO pin confirms the internal electrical angles.

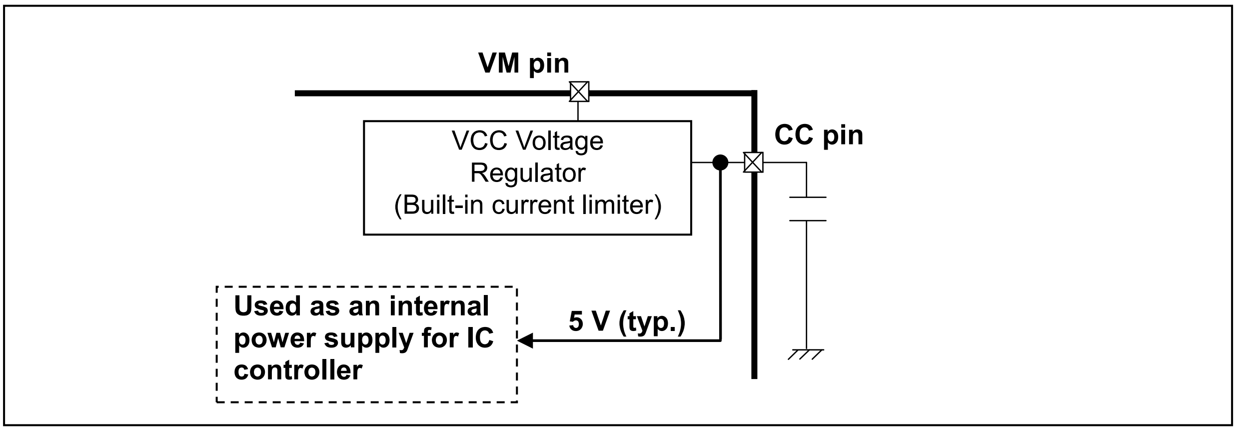
MO	Function
H (Pull-up)	Electrical angle: except initial value
L	Electrical angle: initial value



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

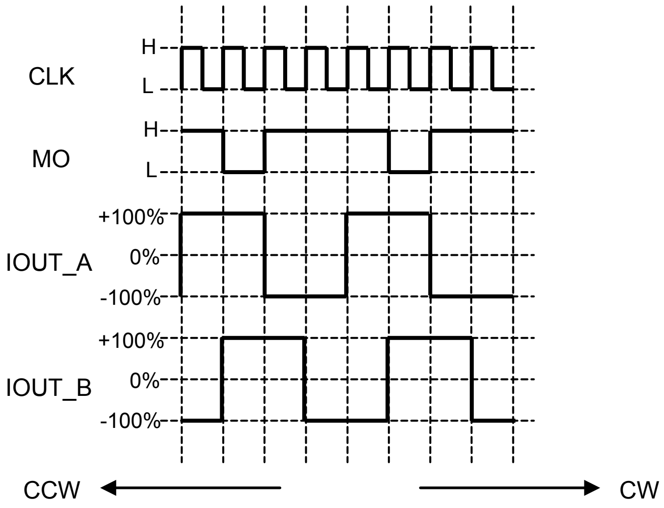
CC pin (Internal regulator monitor pin)

CC pin is a connect pin of the coupling capacitor for the internal regulator. Please connect the capacitor of 0.1μF or more as close to the CC pin as possible.
CC pin can be applied as a power supply for the connection, where the pull-up resistor of MO pin is connected. In case of applying CC pin as a 5 V-power supply, the usage current (external load current) is recommended to be 5.0 mA or less. And the current limiter is built in to limit the current when the motor drive output is short to the ground.



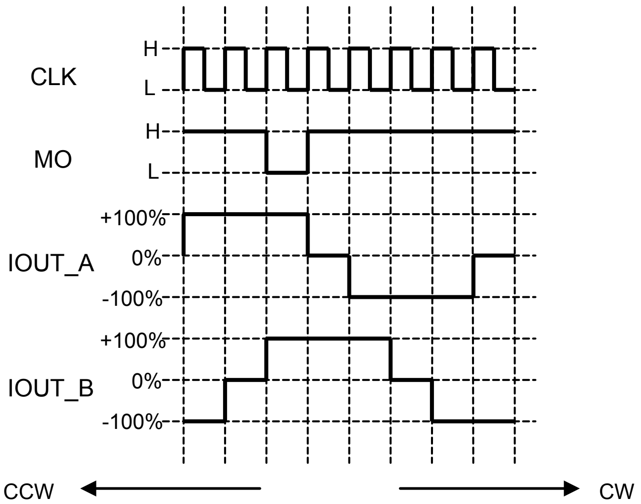
Sequence in each Drive Mode: IFSEL=”L” (Clock input control)

Full-step resolution



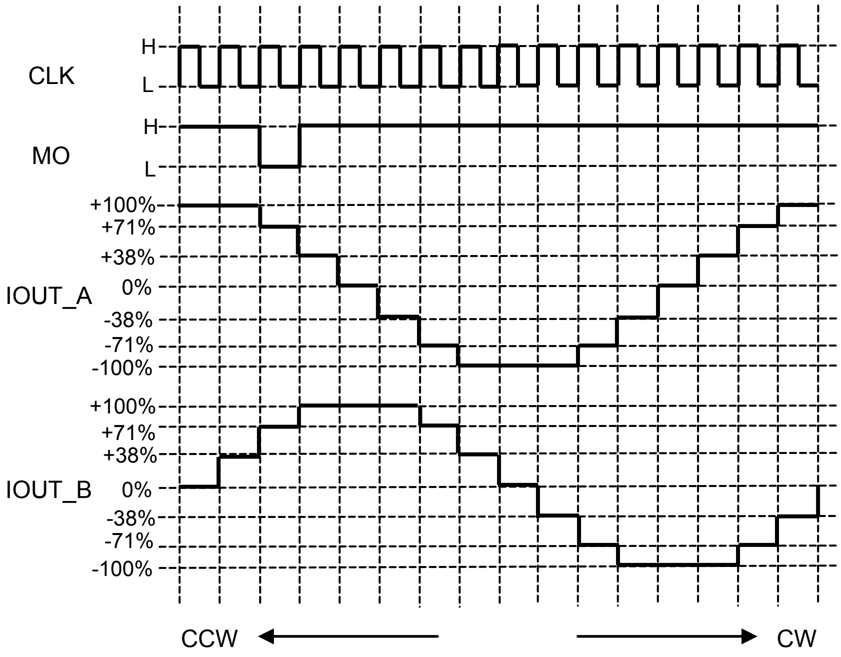
Waveform of MO output: State of pull-up.
Timing charts may be simplified for explanatory purpose.

Half-step resolution



Waveform of MO output: State of pull-up.
Timing charts may be simplified for explanatory purpose.

Quarter-step resolution



Waveform of MO output: State of pull-up.
Timing charts may be simplified for explanatory purpose.

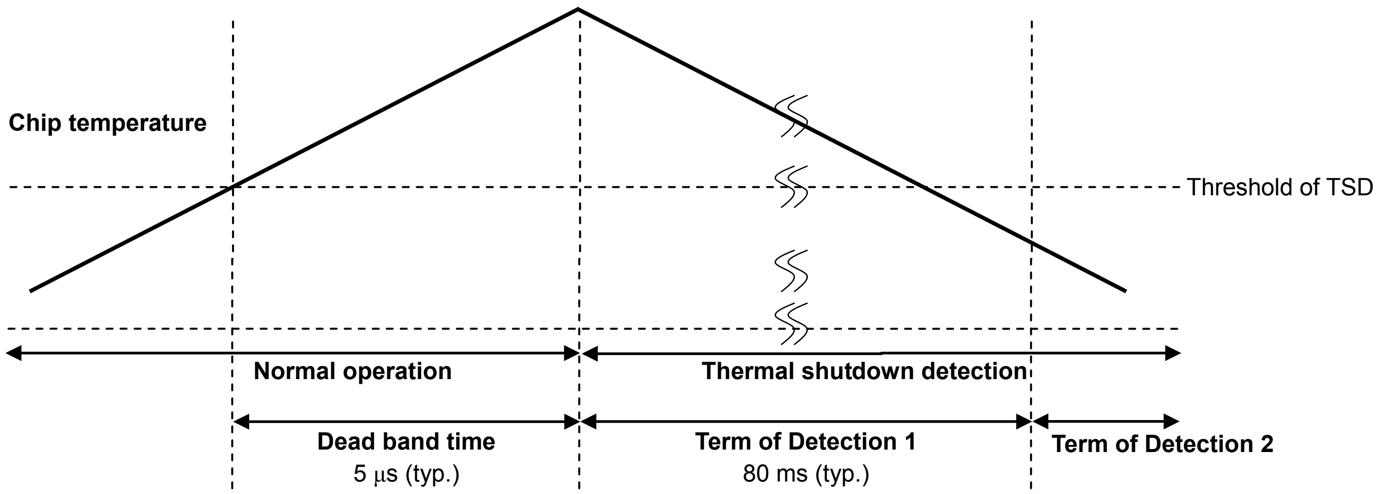
Detection Function

Built-in below detection functions.

Detection	Target	Detection level	Protection method	Resume method from detection state
Thermal shutdown (TSD)	Chip temperature	160°C(typ.) or more Dead band time of 5.0 μs (typ.)	All outputs are OFF forcedly 80 ms (typ.) after the abnormality is detected.	The function has a latch to maintain the operation state before detection. The operation resumes by below process. · Power supply is reapplied. or · Standby mode is set once and normal mode is set again.
Over current detection (ISD)	Output current	4.75 A(typ.) or more Dead band time of 1.25 μs (typ.)	All outputs are OFF forcedly 80 ms (typ.) after the abnormality is detected.	
Under voltage lockout (UVLO)	Voltage of VM	7.5 V(typ.) or less Dead band time of 1.41 μs (typ.)	All outputs are OFF forcedly. Internal circuits are reset.	VM is raised to 8.0 V (typ.) or more.
	Voltage of CC	4.0 V(typ.) or less Dead band time of 1.41 μs (typ.)		VM is raised to 4.2 V (typ.) or more.

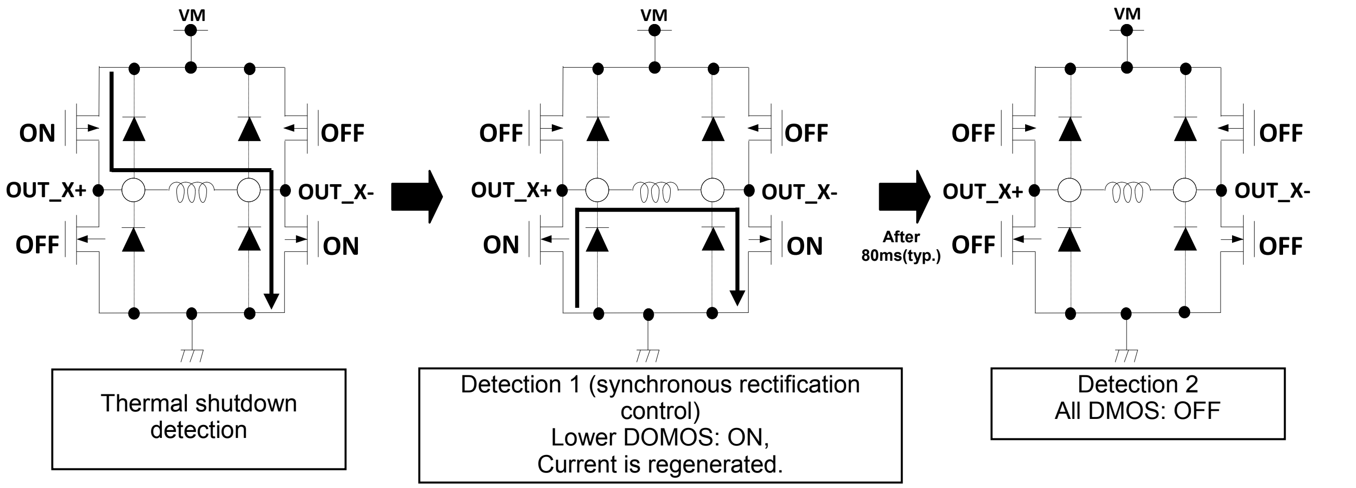
Thermal shutdown detection (Latch type: Operation state before detection is maintained.)

This function turns off the IC operation temporarily when the over heat of the device is detected. It has a dead band time to avoid error detection occurred by the external noise. All DMOS are turned off after the energy of the motor coil is discharged. Therefore, outputs are turned off after the current is regenerated by the synchronous rectification control. When over heat is detected, all channels are turned off.



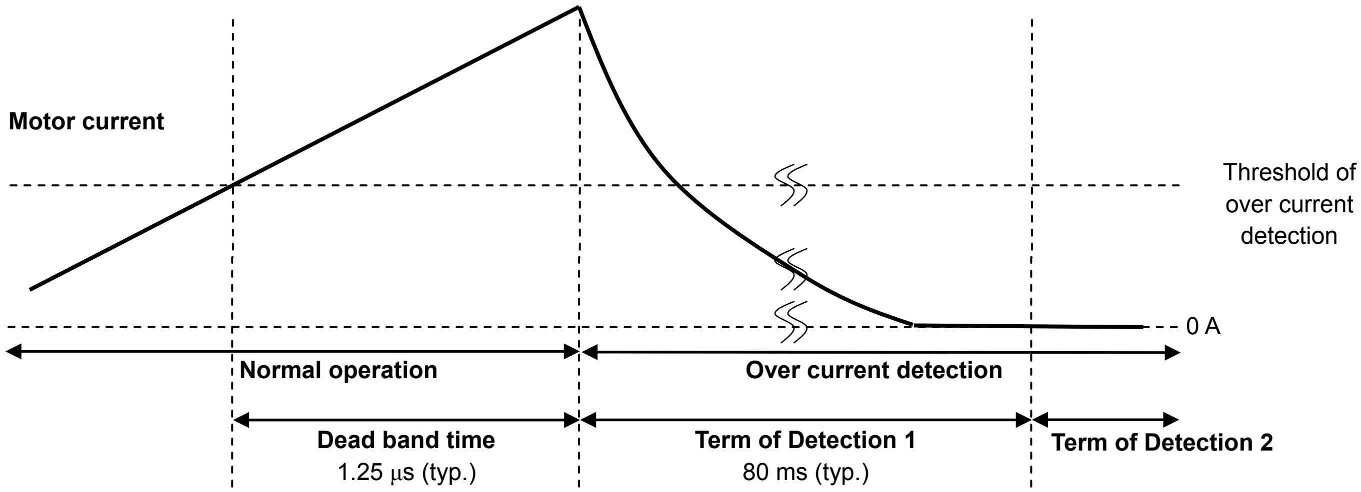
Timing charts may be simplified for explanatory purposes. The value in the timing chart is the reference value.

• When over heat is detected



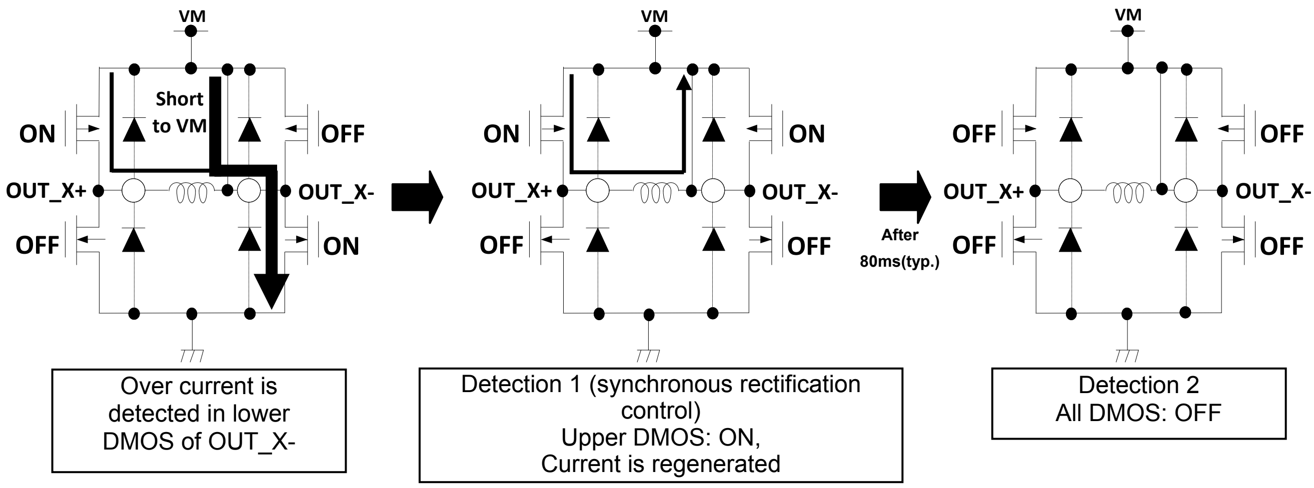
Over current detection (Latch type: Operation state before detection is maintained.)

This function turns off the IC operation temporarily when the short-circuiting between outputs and the short-circuiting to the power supply or ground occur. It has a dead band time to avoid error detection occurred by the spike current which generates in switching and the external noise. All DMOS are turned off after the energy of the motor coil is discharged. Therefore, outputs are turned off after the current is regenerated by the synchronous rectification control. When over current is detected, not only the corresponding channels but both channels are turned off.

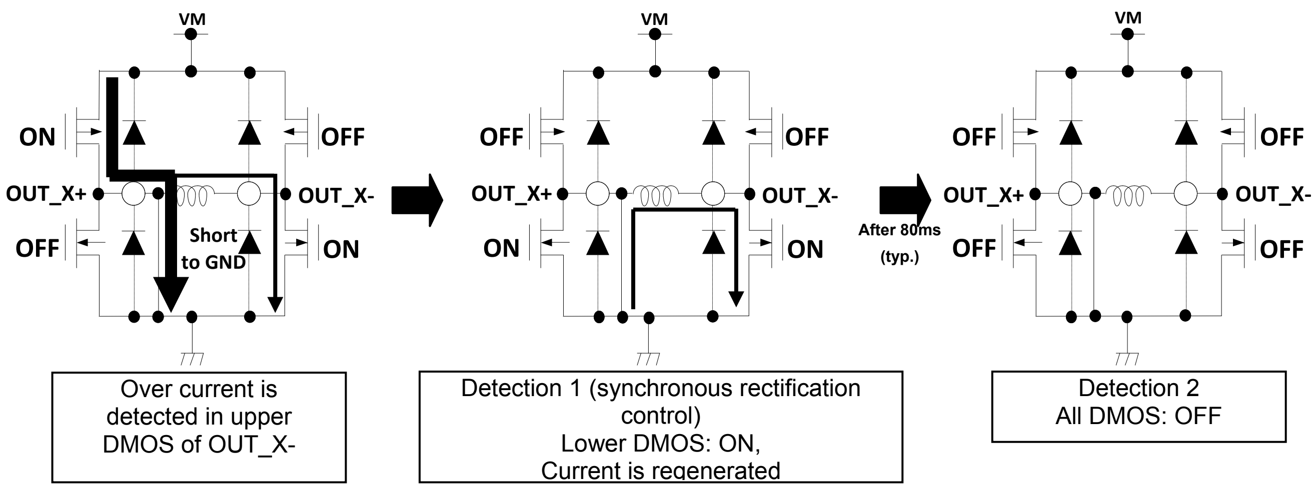


Timing charts may be simplified for explanatory purposes. The value in the timing chart is the reference value.

- When over current is detected in the lower DMOS of H-bridge by the short-circuiting to the power supply



- When over current is detected in the upper DMOS of H-bridge by the short-circuiting to the ground



Absolute Maximum Ratings (T_a = 25°C)

Characteristics	Symbol	Rating	Unit
Motor power supply	V_M	40	V
Motor output voltage	V_{OUT}	40	V
Motor output current (Note1)	I_{OUT}	3.0	A/phase
Monitor voltage for internal regulator	V_{CC}	6.0	V
Logic input voltage	V_{IN}	6.0	V
V_{ref} reference voltage	V_{ref}	6.0	V
Monitor voltage for electrical angle	V_{MO}	6.0	V
Power dissipation (Note2)	P_D	4.3	W
Operating temperature	T_{opr}	-20 to 85	°C
Storage temperature	T_{stg}	-55 to 150	°C
Junction temperature	$T_{j(MAX)}$	150	°C

Note1: The maximum current value in normal operation should be kept 2.8 A or less per phase after calculating heat generation. The maximum output current may be further limited in view of the thermal considerations, depending on the ambient temperature and board conditions.

Note2: Based on JEDEC standard 4-layer PCB (T_a = 25°C)
When T_a exceeds 25°C, derating with 34.4mW/°C is necessary.

T_a : Ambient temperature of the IC
T_{opr} : Ambient temperature while the IC is active.
T_j : Junction temperature while the IC is active. The maximum junction temperature is limited by the thermal shutdown circuit (TSD).

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 TB67S508FTG 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.

Operation Ranges (T_a = -20 to 85°C)

Characteristics	Symbol	Min	Typ.	Max	Unit	Remarks
Motor power supply (Note1)	V_M	10.0	24.0	35.0	V	—
Motor output current	I_{OUT}	—	—	2.8	A	Per phase (Note2)
Logic input voltage	$V_{IN(H)}$	2.0	—	5.5	V	Logic input High Level
	$V_{IN(L)}$	-0.5	—	0.8	V	Logic input Low Level
Chopping frequency	f_{CHOP}	40	70	150	kHz	—
PHASE frequency	f_{PHASE}	—	—	400	kHz	—
Clock frequency	f_{CLK}	—	—	100	kHz	—
V_{ref} reference voltage	V_{REF}	0	—	3.6	V	—

Note1: Slew rate in the range of 0 V to 10 V: 1 ms or more is recommended.

Note2: The actual maximum current may be limited by the operating environment (operating conditions such as exciting mode and operating time, or by the surrounding temperature or board heat dissipation). Determine a realistic maximum current by calculating the heat generated under the operating environment.

Electrical Characteristics 1 (T_a = 25°C, V_M = 24 V, unless specified otherwise)

Characteristics		Symbol	Test condition	Min	Typ.	Max	Unit
Logic input voltage	High	$V_{IN(H)}$	Logic input pin (Note)	2.0	—	5.5	V
	Low	$V_{IN(L)}$	Logic input pin (Note)	-0.5	—	0.8	V
Logic input hysteresis voltage		$V_{IN(HIS)}$	Logic input pin (Note)	100	200	300	mV
Logic input current	High	$I_{IN(H)}$	Logic input voltage: 5 V	35	50	75	μA
	Low	$I_{IN(L)}$	Logic input voltage: 0 V	—	—	1	μA
MO output pin voltage		$V_{OL(MO)}$	IOL=5 mA, Output: Low	—	0.2	0.5	V
Power consumption		I_{M1}	Output pin: Open, Standby mode	—	2	3	mA
		I_{M2}	Output pin: Open, Operating mode	—	4	6	mA
		I_{M3}	Output pin: Open (Full-step resolution) Chopping frequency: 40 kHz	—	7	9	mA
Output leakage current	High-side	I_{OH}	V_M = 40 V, V_{OUT} = 0 V	—	—	1	μA
	Low-side	I_{OL}	V_M = V_{OUT} = 40 V	1	—	—	μA
Motor current channel differential		ΔI_{OUT1}	Current differential between Ch I_{OUT} = 1.0 A	-5	0	5	%
Motor current setting accuracy		ΔI_{OUT2}	I_{OUT} = 1.0 A	-5	0	5	%
Motor output ON-resistance (High-side + Low-side)		$R_{ON(D-S)}$	T_j = 25°C I_{OUT} = 2.0 A	—	0.45	0.65	Ω

Note: V_{IN} (H) is defined as the V_{IN} voltage that changes the output voltage by being applied to the test pin and raising this voltage from 0V gradually. V_{IN} (L) is defined as the V_{IN} voltage that changes the output voltage by being applied to the test pin and lowering this voltage gradually. The difference between V_{IN} (H) and V_{IN} (L) is defined as V_{IN} (HYS).

Electrical Characteristics 2 (T_a =25°C, V_M = 24 V, unless specified otherwise)

Characteristics	Symbol	Test condition	Min	Typ.	Max	Unit
V_{ref} input current	I_{REF}	V_{ref} = 3.6 V	—	0	1	μA
V_{ref} decay ratio	$V_{REF(GAIN)}$	V_{ref} = 2.0 V	0.791	0.833	0.875	—
TSD threshold	T_{jTSD}	—	145	160	175	°C
VM power ON reset voltage	$V_{MPOR(H)}$	Release POR	7.5	8.0	8.5	V
	$V_{MPOR(L)}$	Detect POR	7.0	7.5	8.0	
Over-current detection threshold	I_{SD}	—	3.5	4.75	6.0	A
Power supply voltage for operating internal circuit	V_{CC}	I_{CC} = 5.0 mA (External load)	4.75	5.00	5.25	V

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. It must be fully verified that there is no risk that the TB67S508FTG or other components will be damaged or fail due to the motor back-EMF.

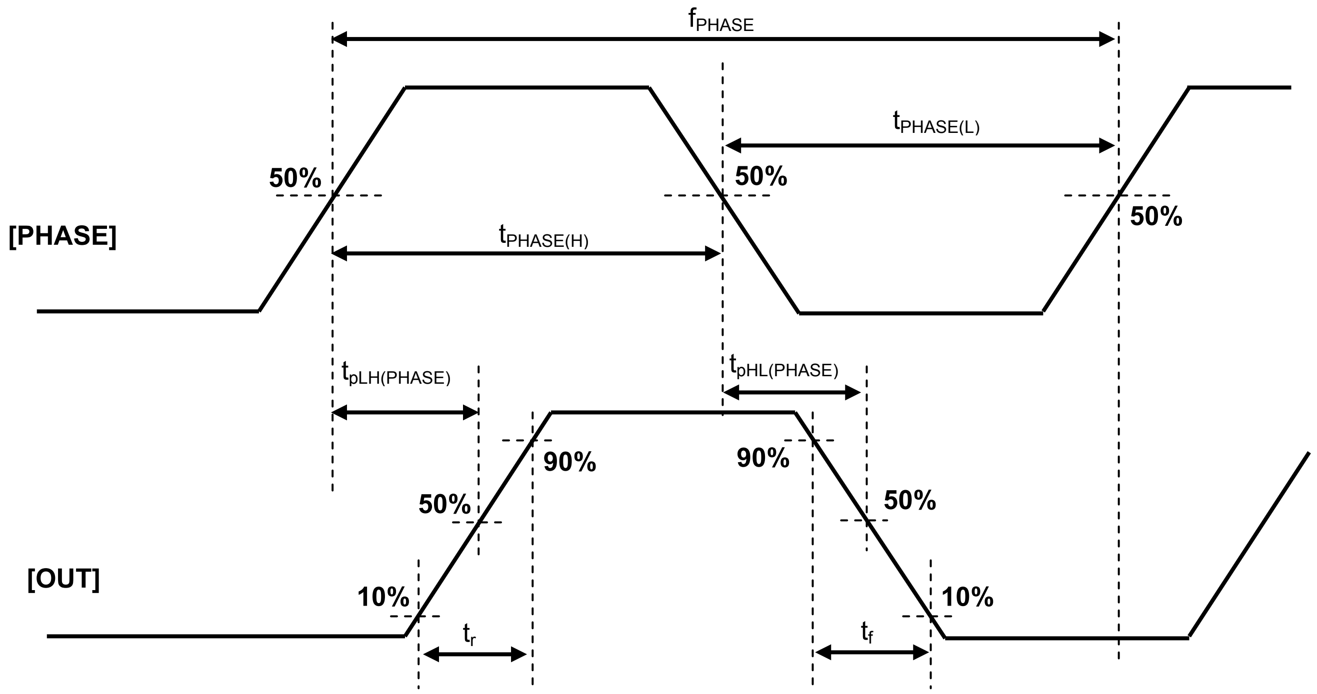
Cautions on Overcurrent Shutdown (ISD) and Thermal Shutdown (TSD)
The ISD and TSD circuits are only intended to provide temporary protection against irregular conditions such as an output short-circuit; they do not necessarily guarantee the complete IC safety.
If the device is used beyond the specified 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 (T_a = 25°C, V_M = 24V)

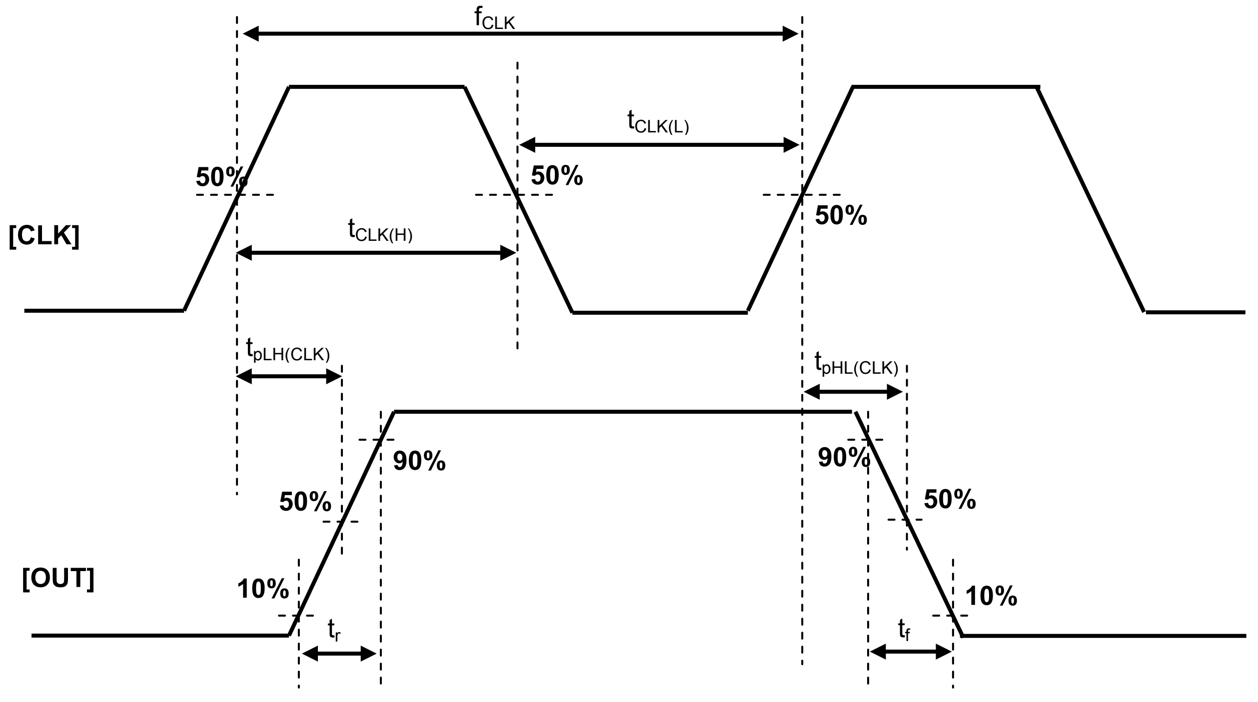
Characteristics	Symbol	Test condition	Min	Typ.	Max	Unit
Minimum phase pulse width	$t_{PHASE(H)}$	—	600	—	—	ns
	$t_{PHASE(L)}$	—	600	—	—	ns
Minimum clock pulse width	$t_{CLK(H)}$	—	300	—	—	ns
	$t_{CLK(L)}$	—	250	—	—	ns
Output transistor Switching characteristics	t_r	—	40	70	100	ns
	t_f	—	50	80	110	ns
	$t_{pLH(CLK)}$	—	—	400	—	ns
	$t_{pHL(CLK)}$	—	—	400	—	ns
	$t_{pLH(PHASE)}$	—	—	400	—	ns
	$t_{pHL(PHASE)}$	—	—	400	—	ns
Oscillator reference frequency	f_{OSCM1}	R_{OSC}=10 kΩ	860	1100	1340	kHz
	f_{OSCM2}	OSCM: Open or connecting to GND	866	1080	1293	
Chopping frequency	f_{CHOP}	f_{OSCM} = 1100 kHz	—	68.8	—	kHz

AC Electrical Characteristics Timing chart
IFSEL=”H” (Phase input control)



Timing charts may be simplified for explanatory purpose.

IFSEL=”L” (clock input control)

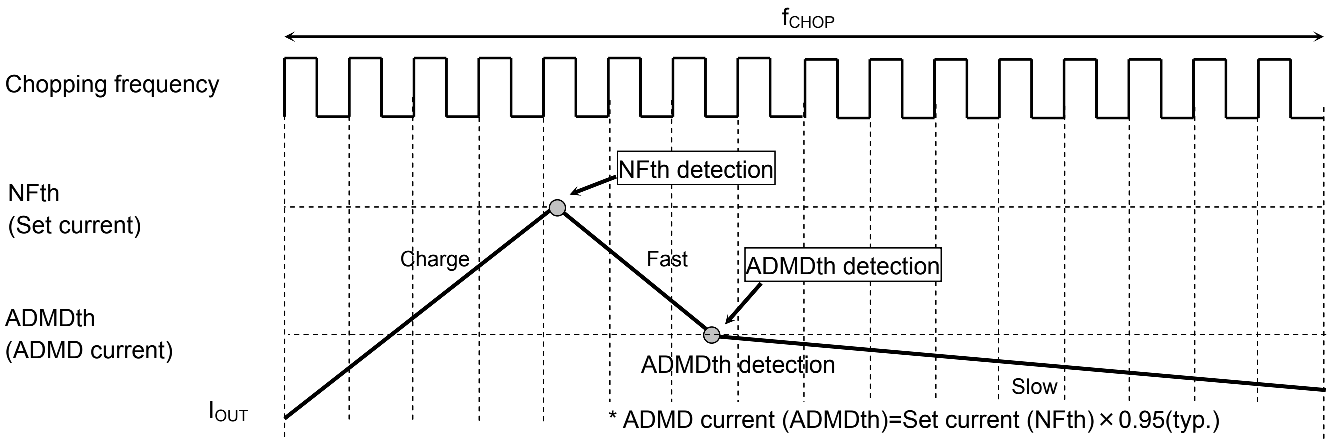


Timing charts may be simplified for explanatory purpose.

Constant PWM Control

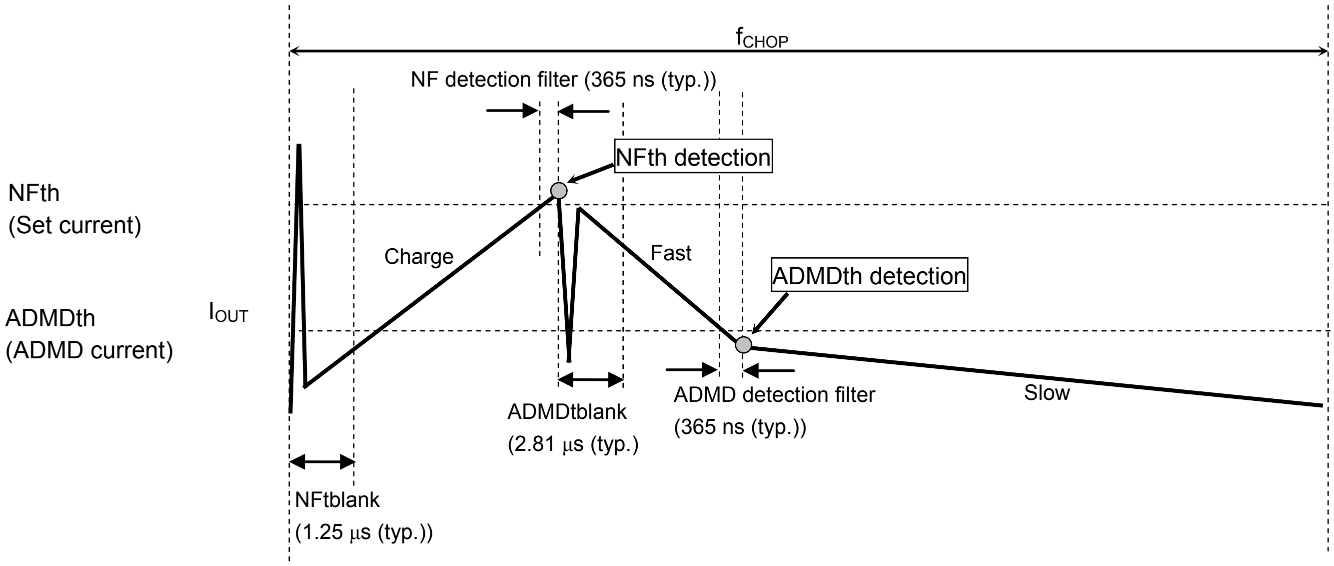
ADMD (Advanced Dynamic Mixed Decay) Control

ADMD control adjusts the regeneration amount of the power supply by monitoring the charge current, which flows from the power supply to the motor, and the regeneration current, which flows from the motor to the power supply. Then, the motor is controlled efficiently.
Sequence of ADMD control is shown in the below timing chart.
Sequence: Charge mode → NF detection → Fast mode → ADMDth detection → Slow mode → f_{CHOP}1 cycle → Charge mode



Timing charts may be simplified for explanatory purposes. The value in the timing chart is the reference value.

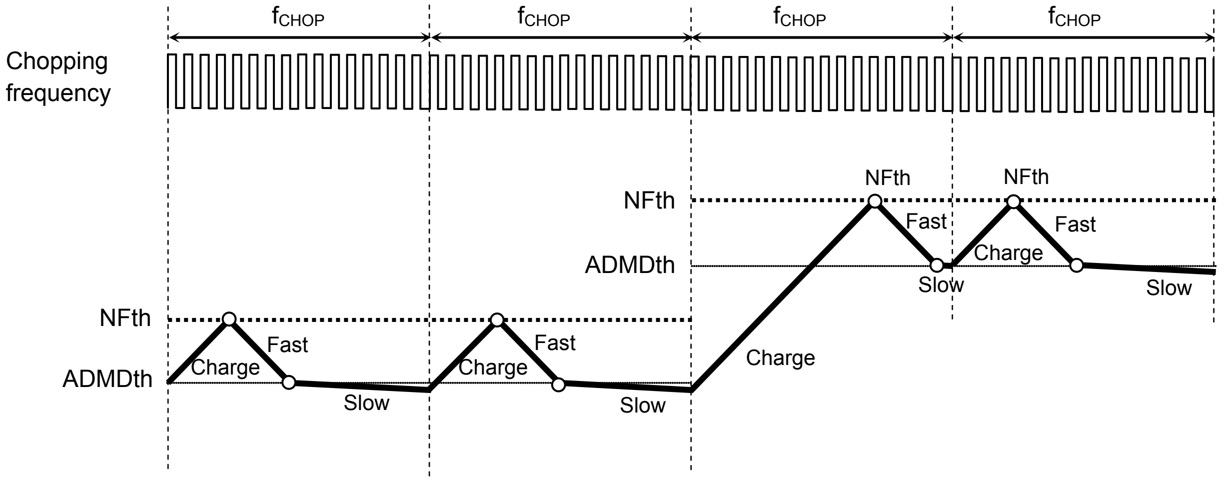
Each filter is attached in order to avoid current-detection error caused by the external noise, etc. (Shown in below figure.)
L value of the motor to be used is small, and when the current value reaches ADMDth (ADMD current value) within the ADMDtblank period, it changes to Slow operation after progress during the ADMDtblank. In this case, the ADMD current value (ADMDth) becomes smaller than ''setting current value (NFth) x 0.95 (typ.)''.



Timing charts may be simplified for explanatory purposes. The value in the timing chart is the reference value.

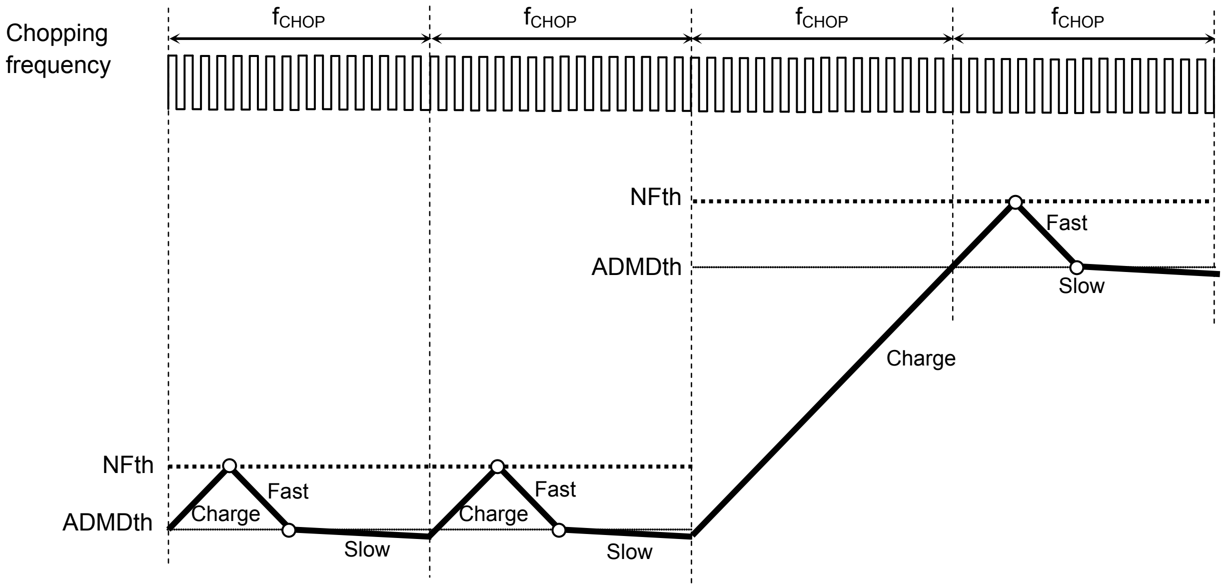
ADMD Current Waveform

· When the next current step (NFth) is higher:



Timing charts may be simplified for explanatory purposes.

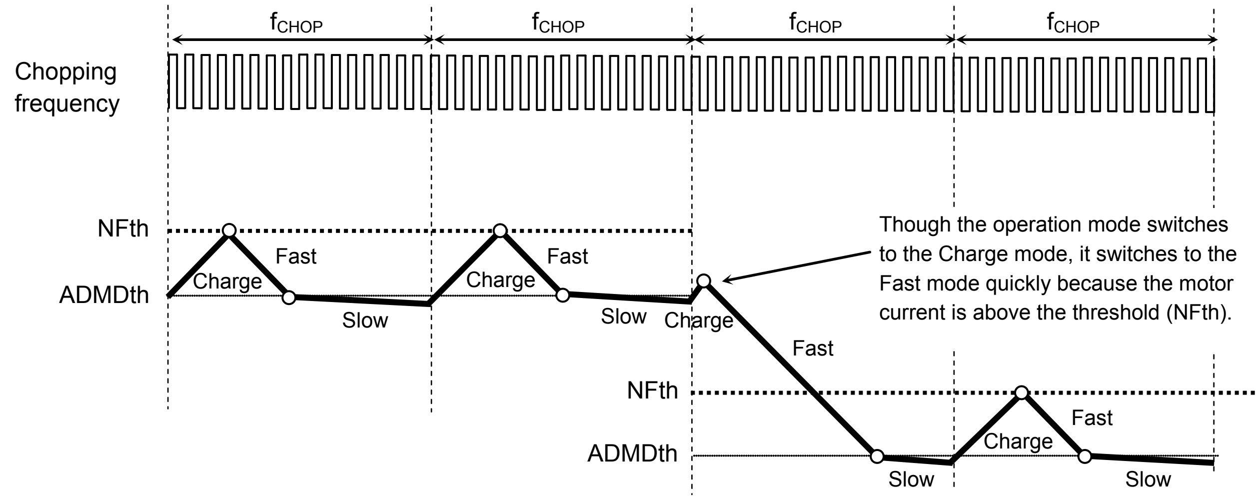
· When Charge term ≥ 1 fchop cycle:



Timing charts may be simplified for explanatory purposes.

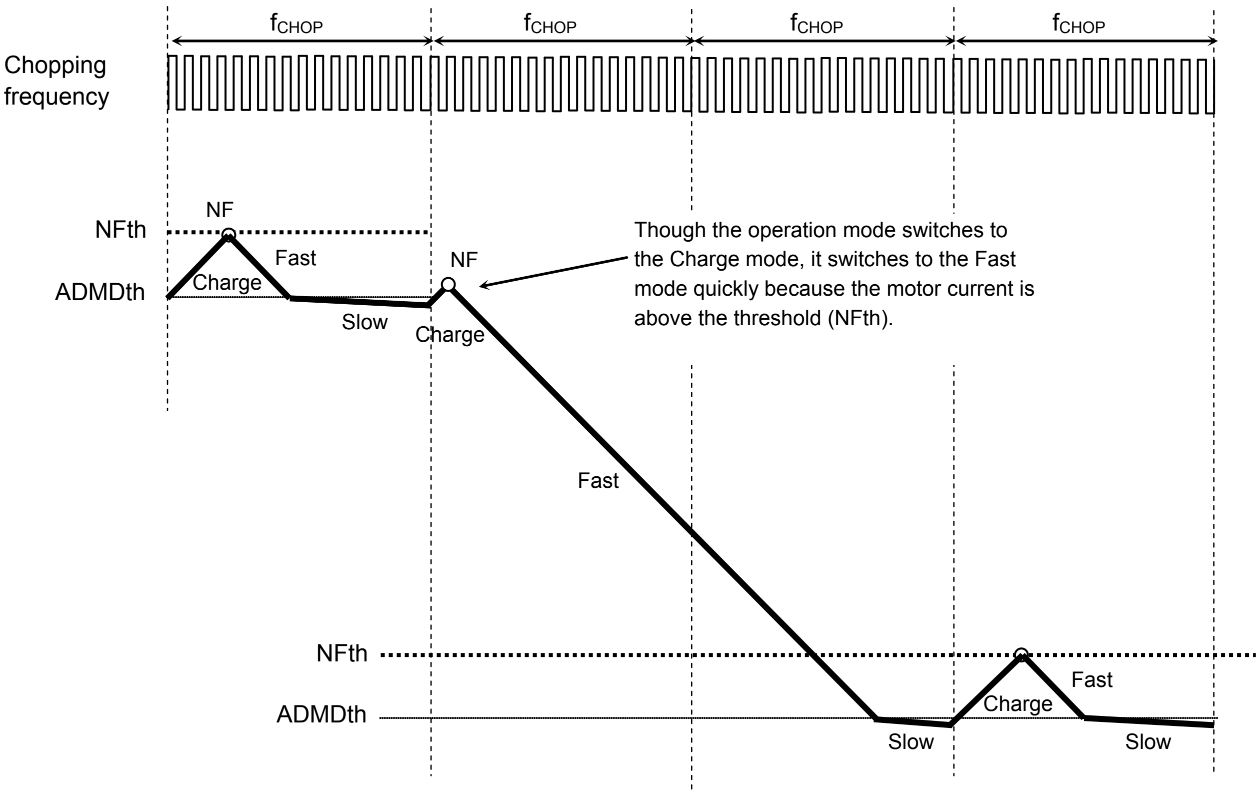
When the motor current value does not reach the threshold (NFth) during 1 cycle of the chopping frequency (f_{CHOP}), the Charge mode continues in the next chopping cycle (f_{CHOP}). The operation mode moves to the Fast mode after the motor current value reaches the threshold (NFth).

· **When the next current step (NFth) is lower:**



Timing charts may be simplified for explanatory purposes.

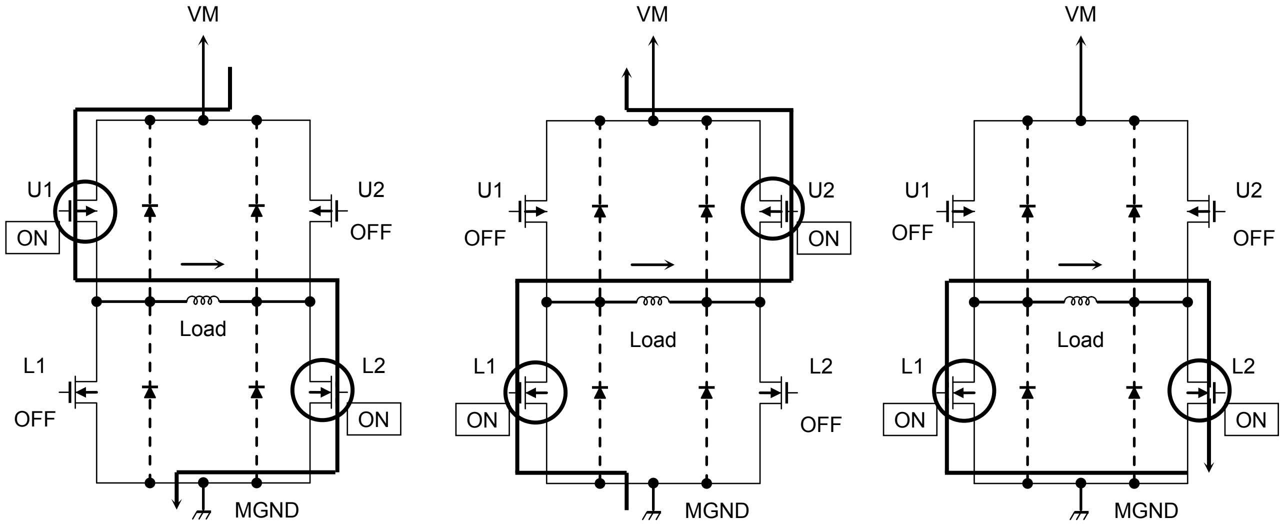
· **When the Fast mode continues for the term that exceeds 1 fchop cycle (the motor current does not reach the ADMD threshold during 1 fchop cycle)**



Timing charts may be simplified for explanatory purposes.

When the motor current value does not reach the threshold (ADMDth) during 1 cycle of the chopping frequency (f_{CHOP}), the Fast mode continues in the next chopping cycle (f_{CHOP}). The operation mode moves to the Slow mode after the motor current value reaches the threshold (ADMDth).

Output Transistor Function Mode (Advanced Dynamic Mixed Decay)



Charge mode
: Current flows into the coil.

Fast mode
: Energy of the coil returns to the power supply.

Slow mode
: Current flows between the coil and the IC.

* When output switches, cross-conduction protection time is provided in the IC to avoid penetrating current.

Output transistor function

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

Note: This table shows an example of when the current flows as indicated by the arrows 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
FAST	ON	OFF	OFF	ON
SLOW	OFF	OFF	ON	ON

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

Setting Current Value (I_{OUT})

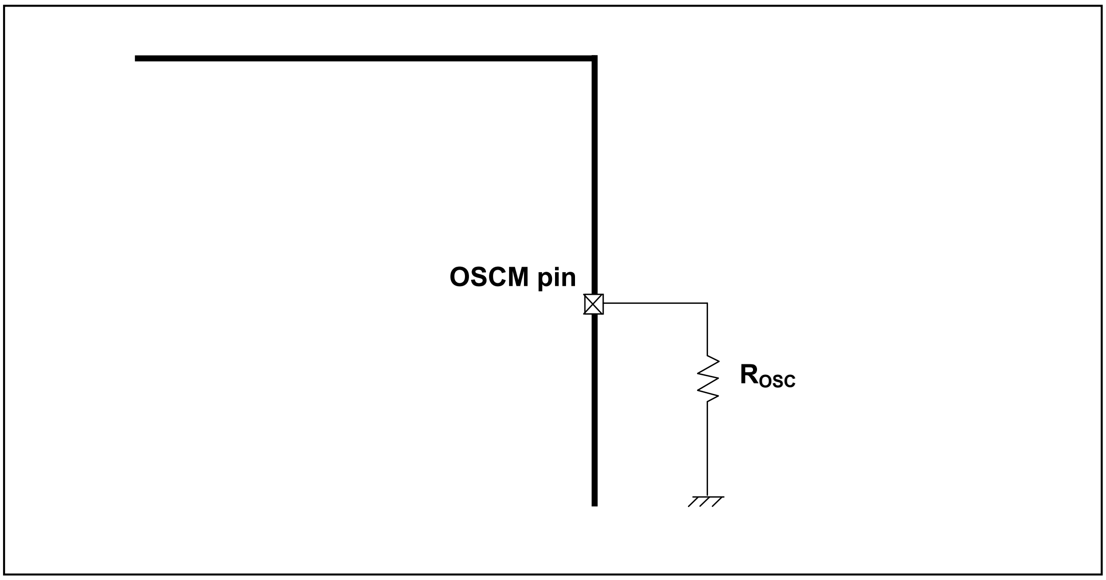
The setting current value in the PWM constant-current control mode is determined by the reference voltage (V_{REF}) as follows;

The current value to be set can be calculated by the following formula.

$I_{OUT} = V_{REF} \times 0.833$
Ex.) When V_{REF} = 2.0 V, I_{OUT} = 1.67 A

Chopping Frequency (f_{CHOP})

Chopping frequency of the constant current control can be configured by the resistor (**R_{OSC}**) connected to OSCM pin. The IC can operate by the fixed chopping frequency without attaching the external part to OSCM pin.



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

Chopping frequency (f_{CHOP}) is calculated from below formula.
Generally, a standard frequency is approximately 70 kHz. A setup in the range of 40 to 100 kHz is recommended.

$f_{CHOP} = f_{OSCM} / 16$
$f_{OSCM} = 1 / (90.9 \times 10^{-12} \times R_{OSC})$
Ex.): When R_{OSC}=10 kΩ, f_{OSCM}=1.1 MHz (typ.), f_{CHOP}=68.8 kHz (typ.)

Under the condition that OSCM pin is open or connected to the GND, the IC operates by the frequency generated automatically (f_{OSCM2}=1.080 MHz (typ.), f_{CHOP}=67.5 kHz (typ.)).

Power consumption of the IC

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

1. Power consumption of the power transistor

Power of the output block is consumed by the upper and lower MOSFET of the H-Bridge.

Power consumption of the upper or lower transistor of the H-Bridge is calculated from below formula.

P (out) = Iout (A) × VDS (V) = Iout $(A)^2$ × Ron (Ω)..........(1)

When the current waveform of the motor output corresponds to the ideal square waveform in the full-step resolution, average power of output block can be provided as follows

When Ron = 0.45 Ω, Iout (peak: Max) = 1.0 A, and VM = 24 V,
P (out) = 2 (Tr) × 1.0 $(A)^2$ × 0.45(Ω)..........(2)
= 0.9(W)

2. Power consumption of logic and IM systems

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

I (IM3) = 7 mA (typ.) : Operating/axis
I (IM2) = 4 mA (typ.) : Stopping/axis
I (IM1) = 2 mA (typ.) : Standby/axis

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

Power consumption is calculated as follows;

P (IM3) = 24 (V) × 0.007 (A) ....(3)
= 0.17 (W)

3. Power consumption

Total power consumption P (total) is calculated from the results of ‘1’ and ’2’ above.

P = P (out) + P (IM3) = 1.07(W)

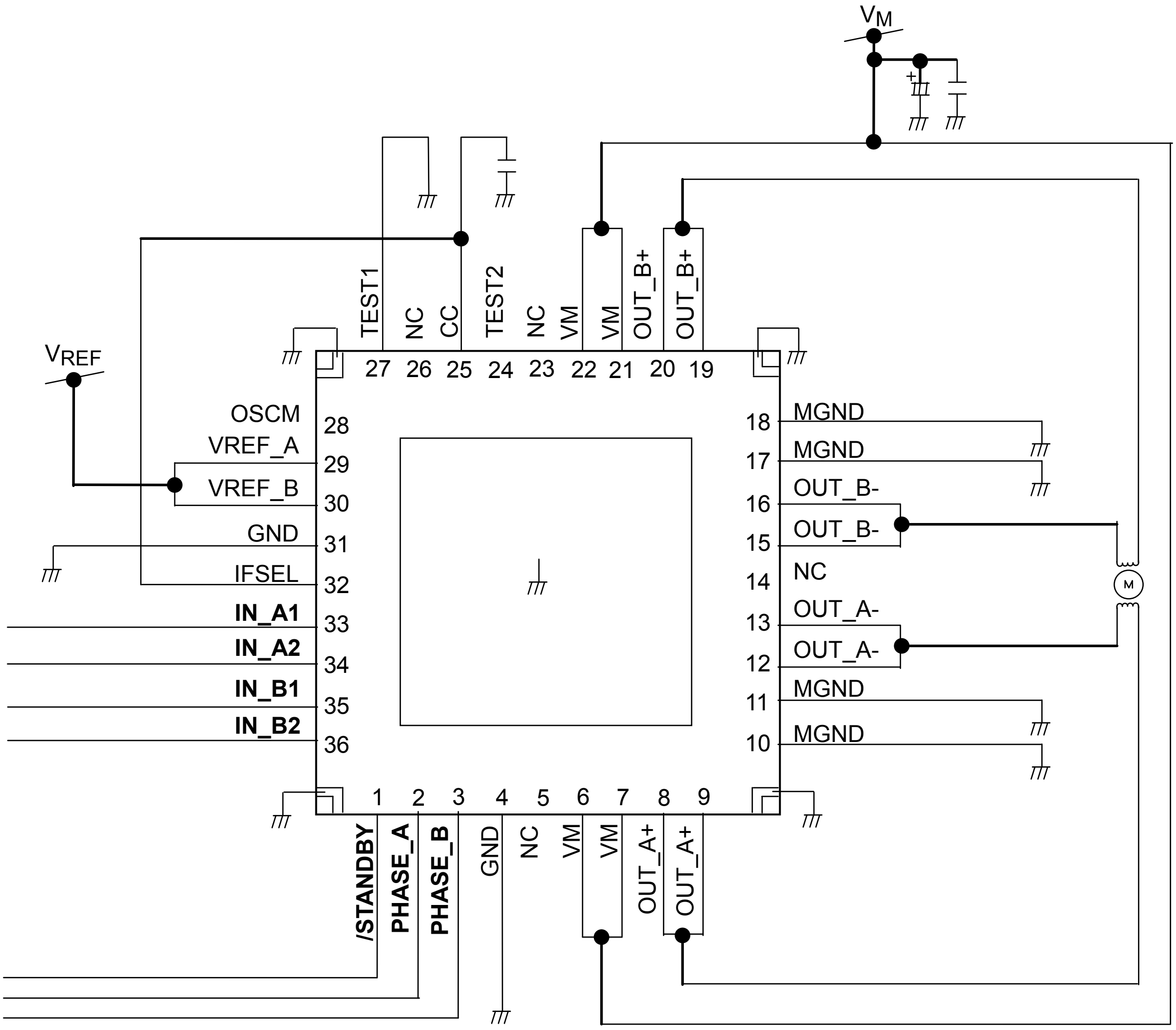
Power consumption of 1 axle in standby mode is as follows;

P (Standby mode) = 24 (V) × 0.002 (A) = 0.048 (W)

About the heat design of the board etc., please evaluate it by the actual board enough, and configure the appropriate margin.

Example of application circuit

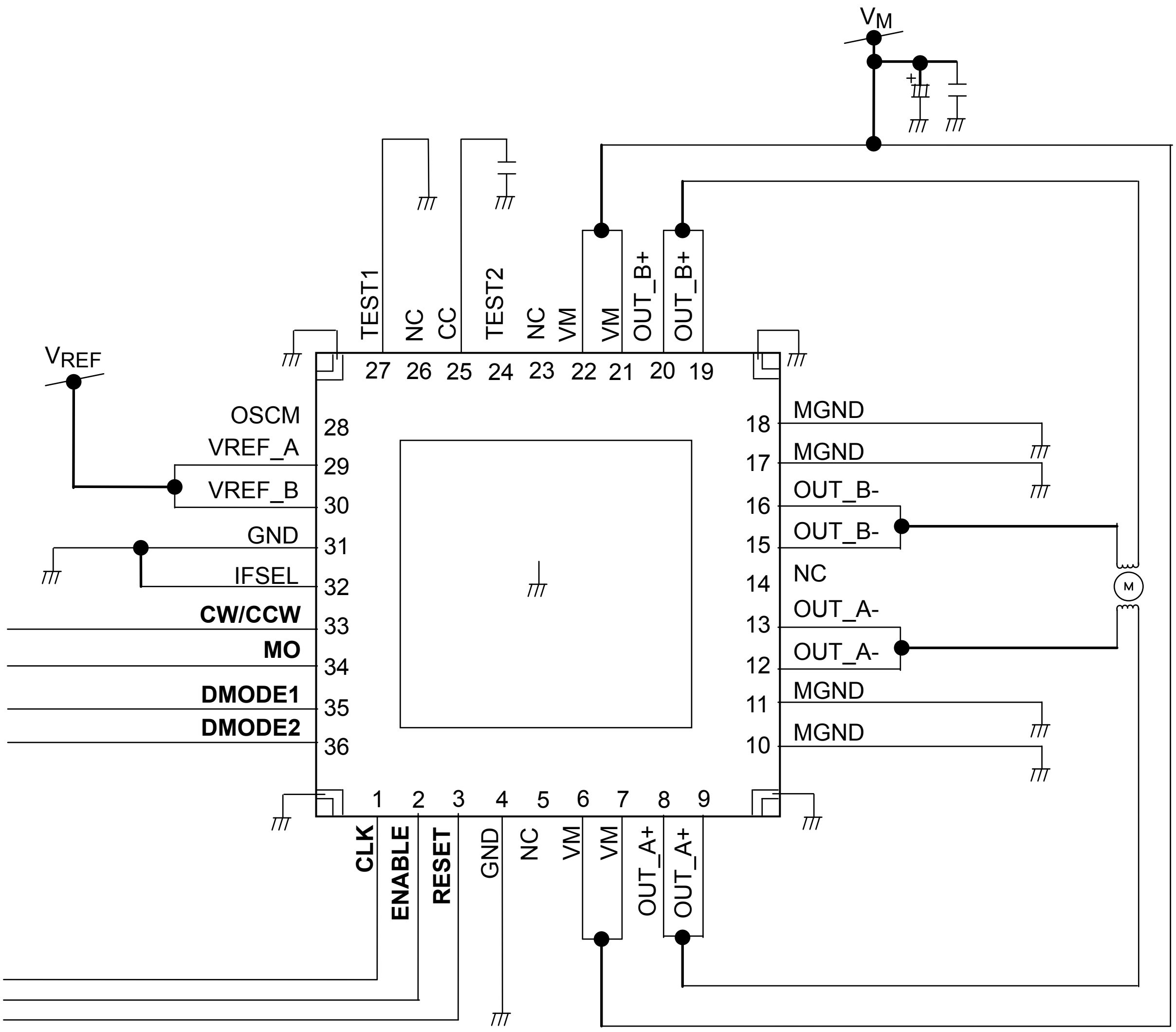
Phase input control mode



Heat dissipation PAD (4 corners and the center part) on the back of the package is recommended to connect to the GND of the board for improved heat dissipation.

The example of application circuit may be simplified or some parts of them may be omitted for explanatory purposes.

Clock input control mode



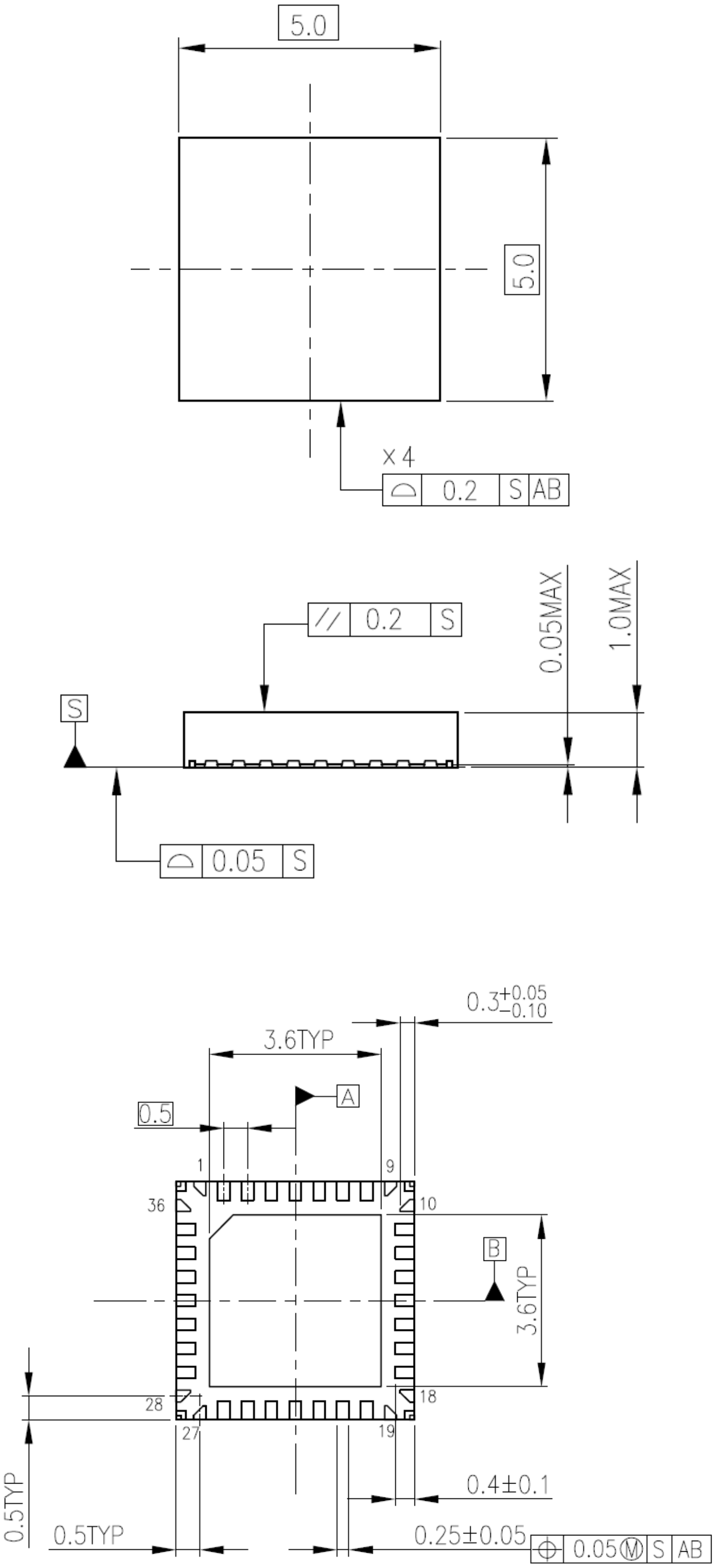
Heat dissipation PAD (4 corners and the center part) on the back of the package is recommended to connect to the GND of the board for improved heat dissipation.

The example of application circuit may be simplified or some parts of them may be omitted for explanatory purposes.

Package Dimensions

P-VQFN36-0505-0.50-002

Unit: mm



Weight: 0.06 g (typ.)

Notes on Contents

Block Diagrams

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

Timing Charts

Timing charts may be simplified for explanatory purposes.

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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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 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 condenser, 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 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 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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