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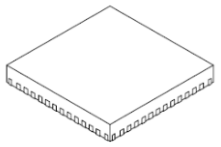
TOSHIBA BiCD Integrated Circuit Silicon Monolithic

TB67S109AFTG, TB67S109AFNG

CLOCK-in controlled Bipolar Stepping Motor Driver

The TB67S109A is a two-phase bipolar stepping motor driver using a PWM chopper. The clock in decoder is built in. Fabricated with the BiCD process, rating is 50 V/4.0 A .

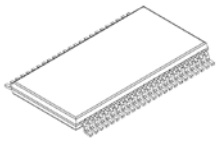
FTG



P-WQFN48-0707-0.50-003

Weight 0.10g (typ.)

FNG



HTSSOP48-P-300-0.50

Weight 0.21g (typ.)

Features

・BiCD process integrated monolithic IC.
・Capable of controlling 1 bipolar stepping motor.
・PWM controlled constant-current drive.
・Allows full, half, quarter, 1/8, 1/16, 1/32 step operation.
・Low on-resistance (High + Low side=0.49Ω(typ.)) MOSFET output stage.
・High efficiency motor current control mechanism (Advanced Dynamic Mixed Decay)
・High voltage and current (For specification, please refer to absolute maximum ratings and operation ranges)
・Error detection (TSD/ISD) signal output function
・Built-in error detection circuits (Thermal shutdown (TSD)、over-current shutdown (ISD), and power-on reset (POR))
・Built-in VCC regulator for internal circuit use.
・Chopping frequency of a motor can be customized by external resistance and capacitor.
・Multi package lineup
　　TB67S109AFTG: P-WQFN48-0707-0.50-003
　　TB67S109AFNG: HTSSOP48-P-300-0.50

Note) Please be careful about thermal conditions during use.

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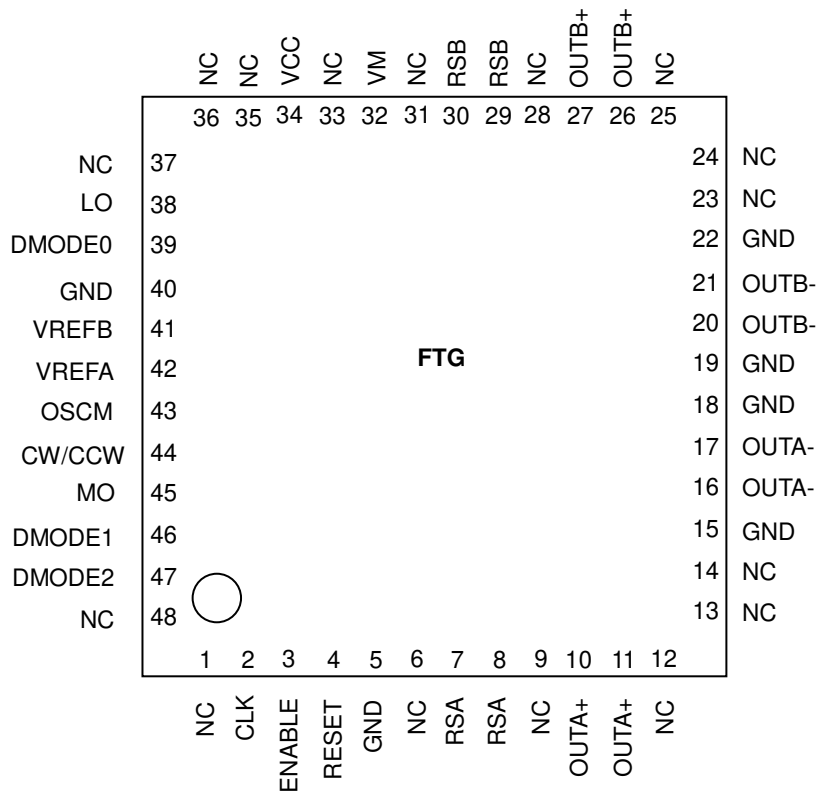
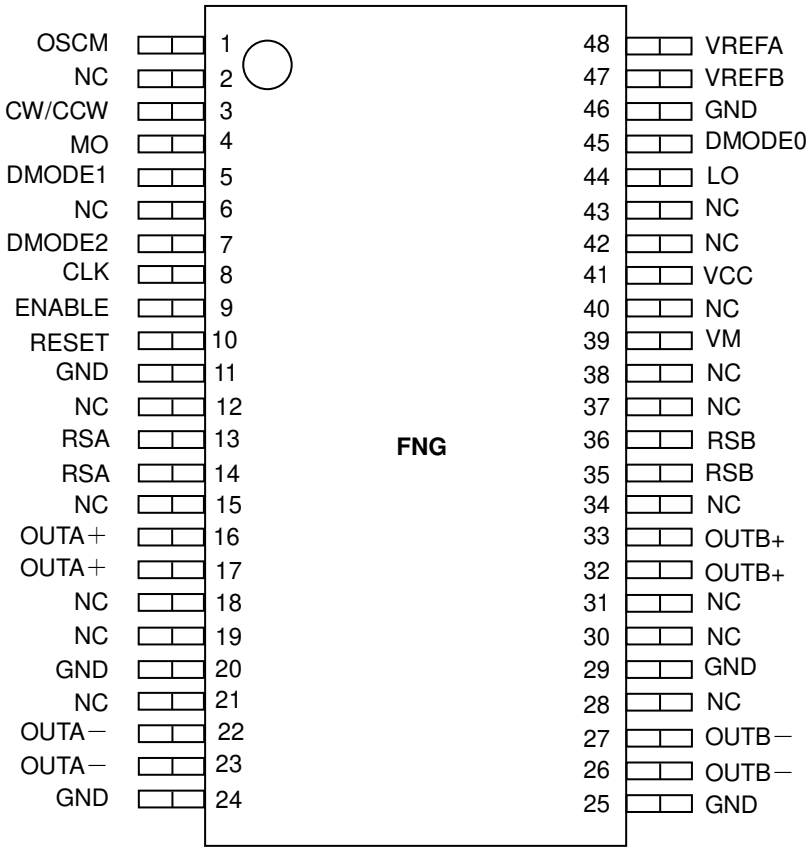
Pin assignment (TB67S109A)

(Top View)



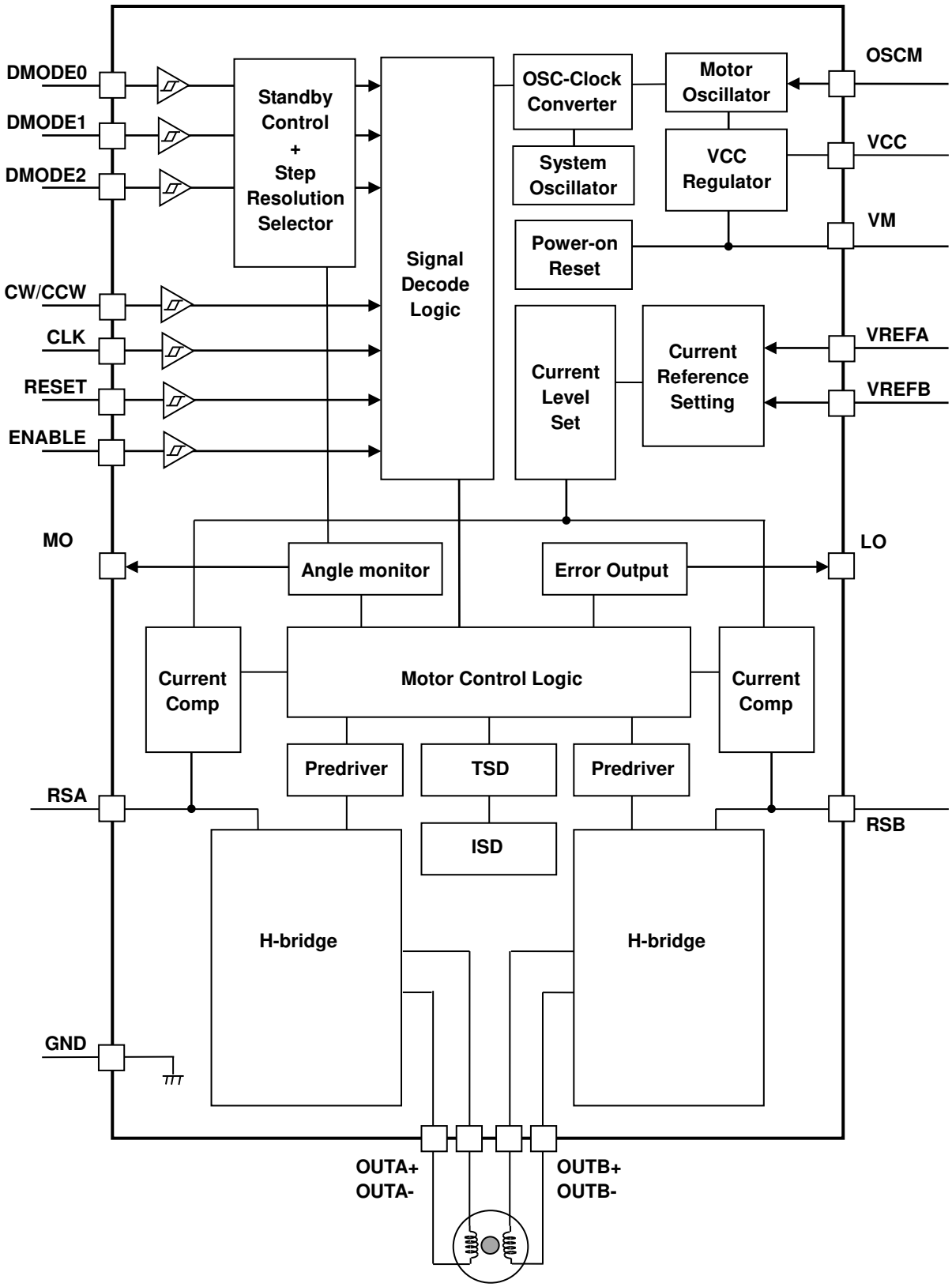
Please mount the four corner pins of the QFN package and the exposed pad to the GND area of the PCB.

(Top View)



Please mount the exposed pad of the HTSSOP package to the GND area of the PCB.

TB67S109A Block diagram



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

Application Notes

All the grounding wires of the TB67S109A must 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, VDD(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, RS, OUT, 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.

Pin explanations

TB67S109AFTG (QFN48)

Pin No.1 – 28

Pin No.	Pin Name	Function
1	NC	Non-connection pin
2	CLK	CLK signal input pin
3	ENABLE	Ach/Bch output stage ON/OFF control pin
4	RESET	Electric angle reset pin
5	GND	Ground pin
6	NC	Non-connection pin
7	RSA (*)	Motor Ach current sense pin
8	RSA (*)	Motor Ach current sense pin
9	NC	Non-connection pin
10	OUTA+ (*)	Motor Ach (+) output pin
11	OUTA+ (*)	Motor Ach (+) output pin
12	NC	Non-connection pin
13	NC	Non-connection pin
14	NC	Non-connection pin
15	GND	Ground pin
16	OUTA- (*)	Motor Ach (-) output pin
17	OUTA- (*)	Motor Ach (-) output pin
18	GND	Ground pin
19	GND	Ground pin
20	OUTB- (*)	Motor Bch (-) output pin
21	OUTB- (*)	Motor Bch (-) output pin
22	GND	Ground pin
23	NC	Non-connection pin
24	NC	Non-connection pin
25	NC	Non-connection pin
26	OUTB+ (*)	Motor Bch (+) output pin
27	OUTB+ (*)	Motor Bch (+) output pin
28	NC	Non-connection pin

Pin No.29 – 48

Pin No.	Pin Name	Function
29	RSB (*)	Motor Bch current sense pin
30	RSB (*)	Motor Bch current sense pin
31	NC	Non-connection pin
32	VM	Motor power supply pin
33	NC	Non-connection pin
34	VCC	Internal VCC regulator monitor pin
35	NC	Non-connection pin
36	NC	Non-connection pin
37	NC	Non-connection pin
38	LO	Error detect signal output pin
39	DMODE0	Step resolution set pin no.0
40	GND	Ground pin
41	VREFB	Motor Bch output set pin
42	VREFA	Motor Ach output set pin
43	OSCM	Oscillating circuit frequency for chopping set pin
44	CW/CCW	Motor rotation direction set pin
45	MO	Electric angle monitor pin
46	DMODE1	Step resolution set pin no.1
47	DMODE2	Step resolution set pin no.2
48	NC	Non-connection pin

・Please do not run patterns under NC pins.

* : Please connect the pins with the same pin name, while using the TB67S109A.

Pin explanations

TB67S109AFNG (HTSSOP48)

Pin No.1 – 28

Pin No.	Pin Name	Function
1	OSCM	Oscillating circuit frequency for chopping set pin
2	NC	Non-connection pin
3	CW/CCW	Motor rotation direction set pin
4	MO	Electric angle monitor pin
5	DMODE1	Step resolution set pin no.1
6	NC	Non-connection pin
7	DMODE2	Step resolution set pin no.2
8	CLK	CLK signal input pin
9	ENABLE	Ach/Bch output stage ON/OFF control pin
10	RESET	Electric angle reset pin
11	GND	Ground pin
12	NC	Non-connection pin
13	RSA (*)	Motor Ach current sense pin
14	RSA (*)	Motor Ach current sense pin
15	NC	Non-connection pin
16	OUTA+ (*)	Motor Ach (+) output pin
17	OUTA+ (*)	Motor Ach (+) output pin
18	NC	Non-connection pin
19	NC	Non-connection pin
20	GND	Ground pin
21	NC	Non-connection pin
22	OUTA- (*)	Motor Ach (-) output pin
23	OUTA- (*)	Motor Ach (-) output pin
24	GND	Ground pin
25	GND	Ground pin
26	OUTB- (*)	Motor Bch (-) output pin
27	OUTB- (*)	Motor Bch (-) output pin
28	NC	Non-connection pin

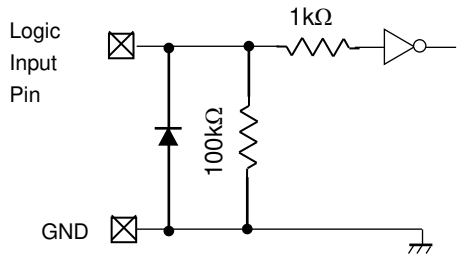
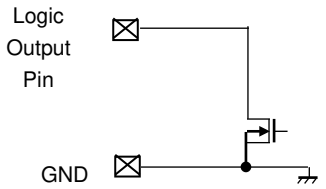
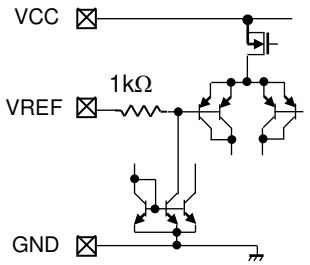
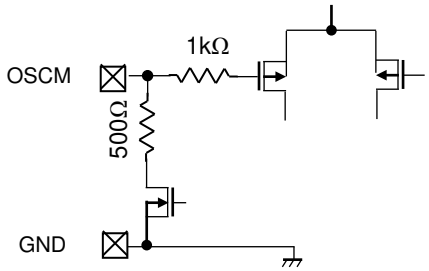
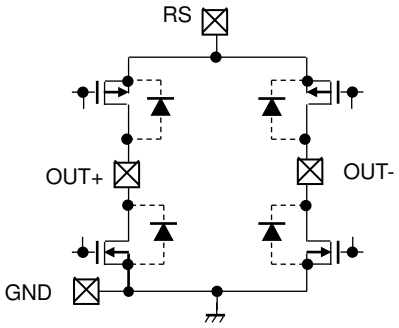
Pin No.29 – 48

Pin No.	Pin Name	Function
29	GND	Ground pin
30	NC	Non-connection pin
31	NC	Non-connection pin
32	OUTB+ (*)	Motor Bch (+) output pin
33	OUTB+ (*)	Motor Bch (+) output pin
34	NC	Non-connection pin
35	RSB (*)	Motor Bch current sense pin
36	RSB (*)	Motor Bch current sense pin
37	NC	Non-connection pin
38	NC	Non-connection pin
39	VM	Motor power supply pin
40	NC	Non-connection pin
41	VCC	Internal VCC regulator monitor pin
42	NC	Non-connection pin
43	NC	Non-connection pin
44	LO	Error detect signal output pin
45	DMODE0	Step resolution set pin no.0
46	GND	Ground pin
47	VREFB	Motor Bch output set pin
48	VREFA	Motor Ach output set pin

・Please do not run patterns under NC pins.

* : Please connect the pins with the same pin name, while using the TB67S109A.

INPUT/OUTPUT equivalent circuit (TB67S109A)

Pin name	IN/OUT signal	Equivalent circuit
DMODE0 DMODE1 DMODE2 CLK ENABLE RESET CW/CCW	Digital Input (VIH/VIL) VIH: 2.0V(min) to 5.5V(max) VIL : 0V(min) to 0.8V(max)	
LO MO	Digital Output (VOH/VOL) (Pullup resistance :10k to 100kΩ)	
VCC VREFA VREFB	VCC voltage range 4.75V(min) to 5.0V(typ.) to 5.25V(max) VREF voltage range 0V to 3.6V	
OSCM	OSCM frequency setting range 0.64MHz(min) to 1.12MHz(typ.) to 2.4MHz(max)	
OUT A+ OUT A- OUT B+ OUT B- RSA RSB	VM power supply voltage range 10V(min) to 47V(max) OUTPUT pin voltage 10V(min) to 47V(max)	

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

Function explanation (Stepping motor)

CLK Function

Each up-edge of the CLK signal will shift the motor's electrical angle per step.

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

ENABLE function

The ENABLE pin controls the ON and OFF of the corresponding output stage. This pin serves to select if the motor is stopped in OFF mode (High impedance) or activated. Please set the ENABLE pin to 'L' during VM power-on and power-off sequence.

ENABLE Input	Function
H	Output stage='ON' (Normal operation mode)
L	Output stage='OFF (High impedance mode)

CW/CCW function and the output pin function (Output logic at the time of a charge start)

The CW/CCW pin controls the rotation direction of the motor. When set to 'Clockwise', the current of OUTA is output first, with a phase difference of 90°. When set to 'Counter clockwise", the current of OUTB is output first with a phase difference of 90°.

CW/CCW Input	OUT (+)	OUT (-)
H : Clockwise operation(CW)	H	L
L : Counter clockwise operation(CCW)	L	H

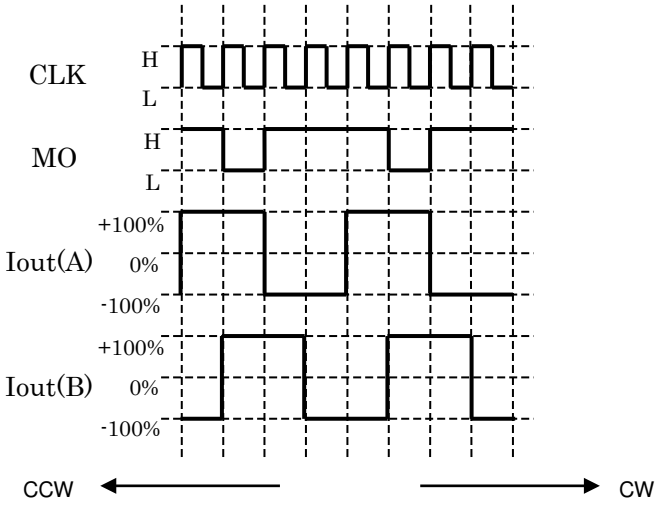
Step resolution select function

DMODE0	DMODE1	DMODE2	Function
L	L	L	Standby mode (the OSCM is disabled and the output stage is set to 'OFF' status)
L	L	H	Full step resolution
L	H	L	Half step resolution(Type A)
L	H	H	Quarter step resolution
H	L	L	Half step resolution(Type B)
H	L	H	1/8 step resolution
H	H	L	1/16 step resolution
H	H	H	1/32 step resolution

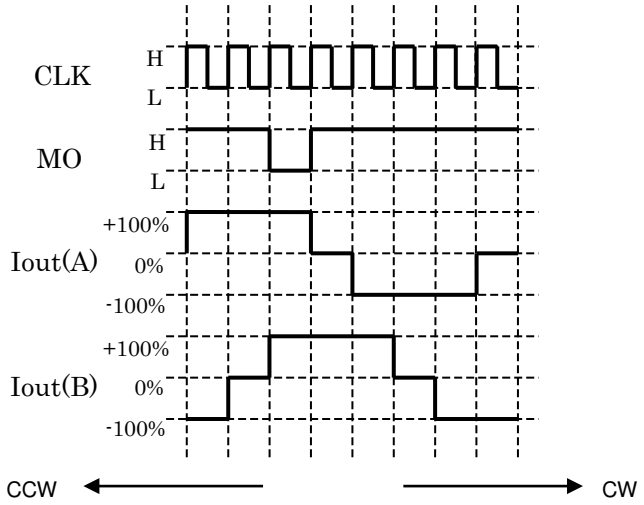
When switching the DMODE0,1,2; setting the RESET signal to Low (will set the electrical angle to the initial status), is recommended.

Step resolution setting and initial angle

[Full step resolution]

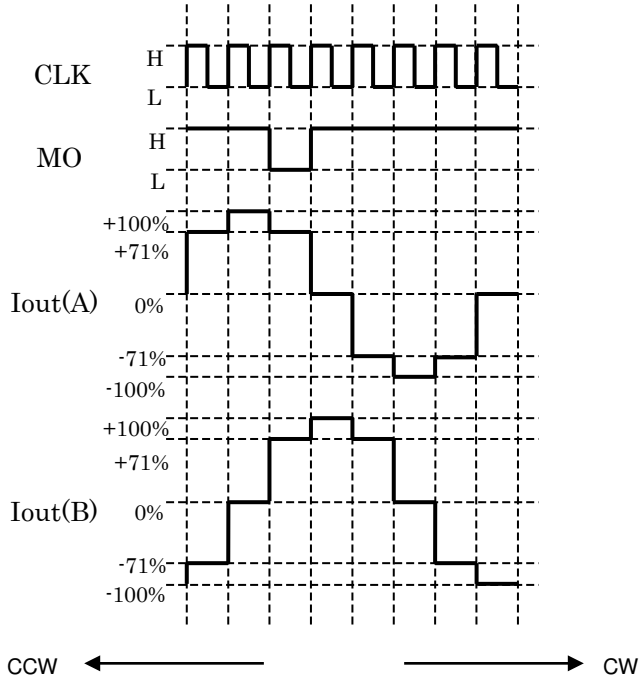


[Half step resolution (Type A)]

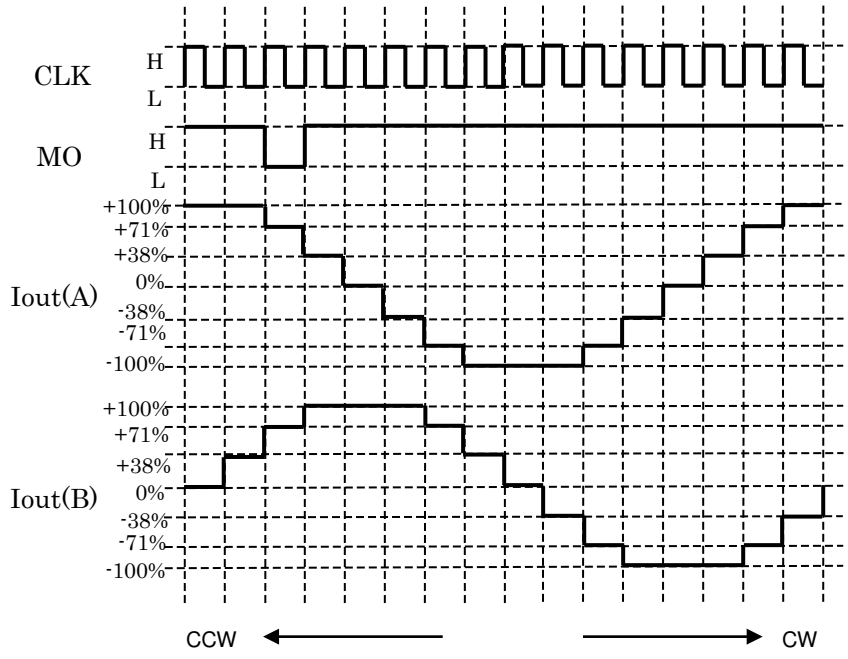


MO output shown in the timing chart is when the MO pin is pulled up.
Timing charts may be simplified for explanatory purpose.

[Half step resolution (Type B)]

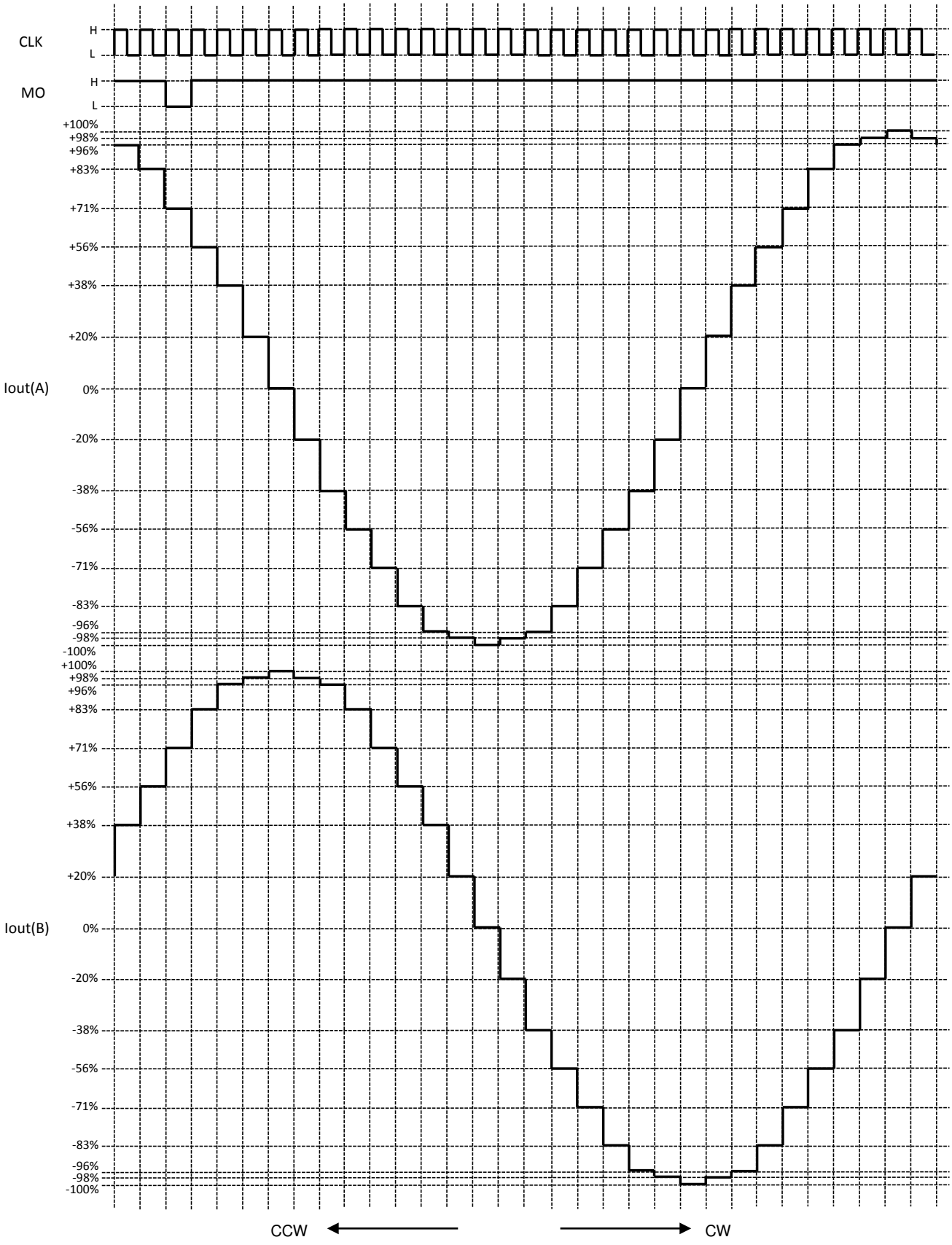


[Quarter step resolution]



MO output shown in the timing chart is when the MO pin is pulled up.
Timing charts may be simplified for explanatory purpose.

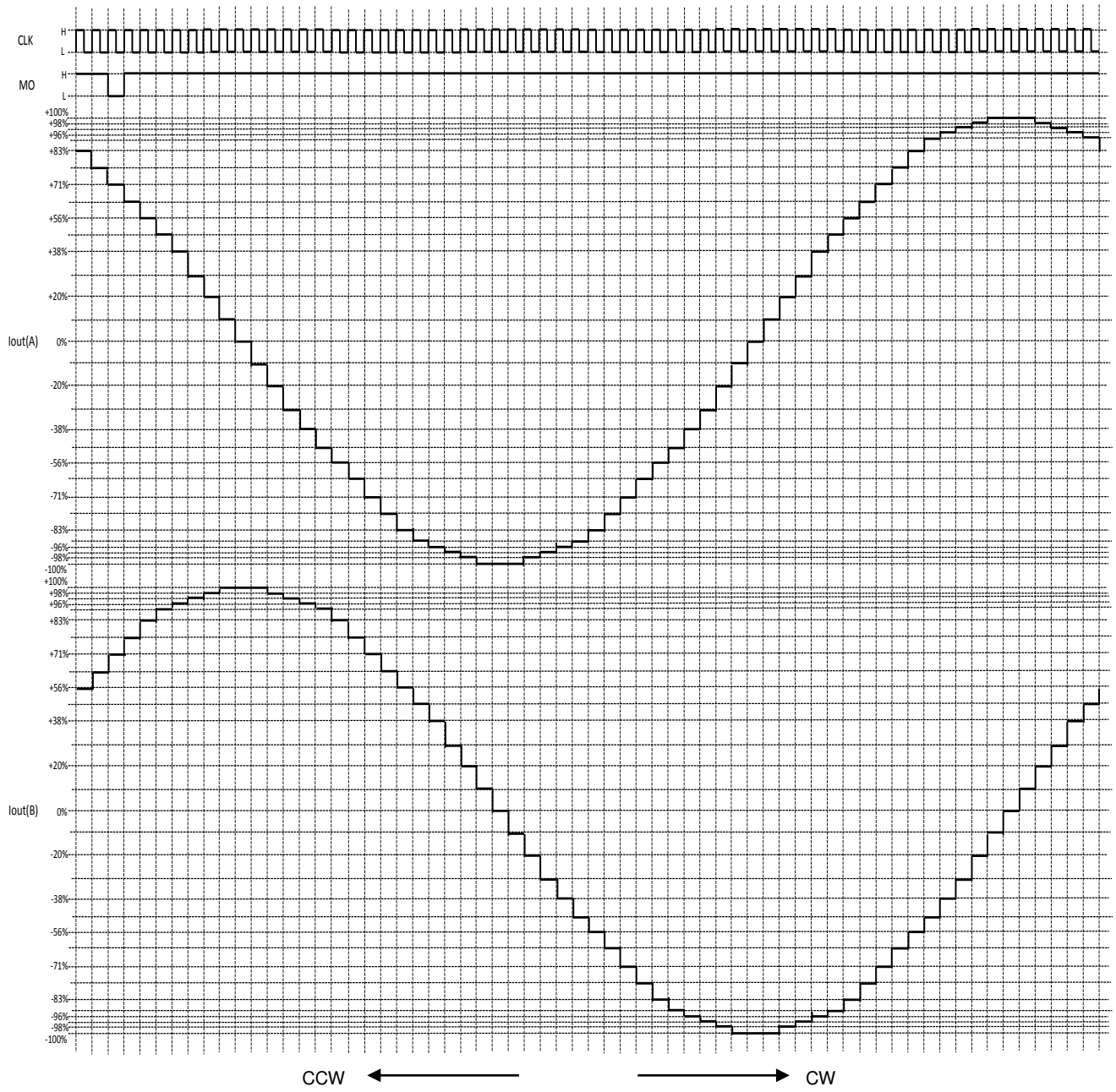
[1/8 step resolution]



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

Timing charts may be simplified for explanatory purpose.

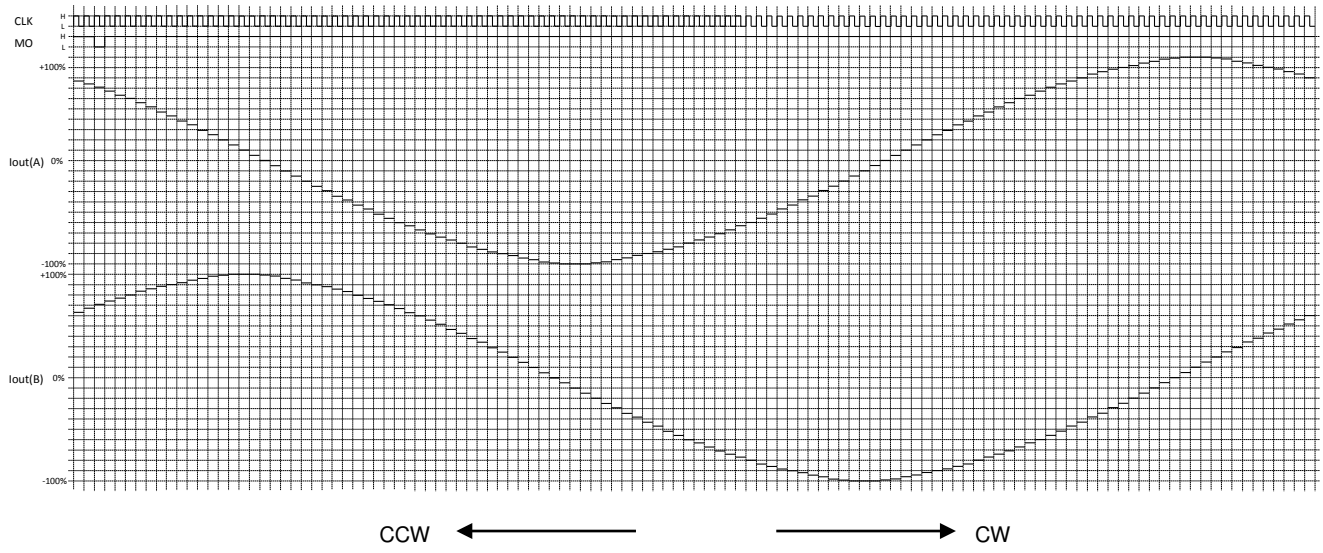
[1/16 step resolution]



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

Timing charts may be simplified for explanatory purpose.

[1/32 step resolution]



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

Timing charts may be simplified for explanatory purpose.

Step setting and current percentage

Current [%]	Full	Half (A)	Half (B)	Quarter	1/8	1/16	1/32
100%	○	○	○	○	○	○	○
99%						○	○
98%					○	○	○
97%						○	○
96%					○	○	○
94%							○
92%							○
90%						○	○
88%							○
86%							○
83%					○	○	○
80%							○
77%						○	○
74%							○
71%			○	○	○	○	○
67%							○
63%						○	○
60%							○
56%					○	○	○
52%							○
47%						○	○
43%							○
38%				○	○	○	○
34%							○
29%						○	○
25%							○
20%					○	○	○
15%							○
10%						○	○
5%							○
0%		○	○	○	○	○	○

RESET function

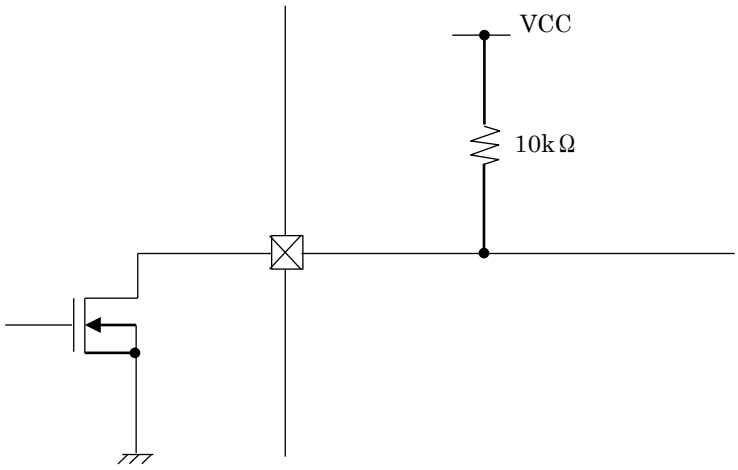
RESET Input	Function
H	Sets the electrical angle to the initial condition.
L	Normal operation mode

The current for each channel (while RESET is applied) is shown in the table below. MO will show 'L' at this time.

Step resolution setting	Ach current setting	Bch current setting	Default electrical angle
Full step	100%	100%	45°
Half step (Type A)	100%	100%	45°
Half step (Type B)	71%	71%	45°
Quarter step	71%	71%	45°
1/8 step	71%	71%	45°
1/16 step	71%	71%	45°
1/32 step	71%	71%	45°

LO(Error detect signal) output function

When Thermal shutdown(TSD) or Over-current shutdown(ISD) is applied, the LO voltage will be switched to Low(GND) level.

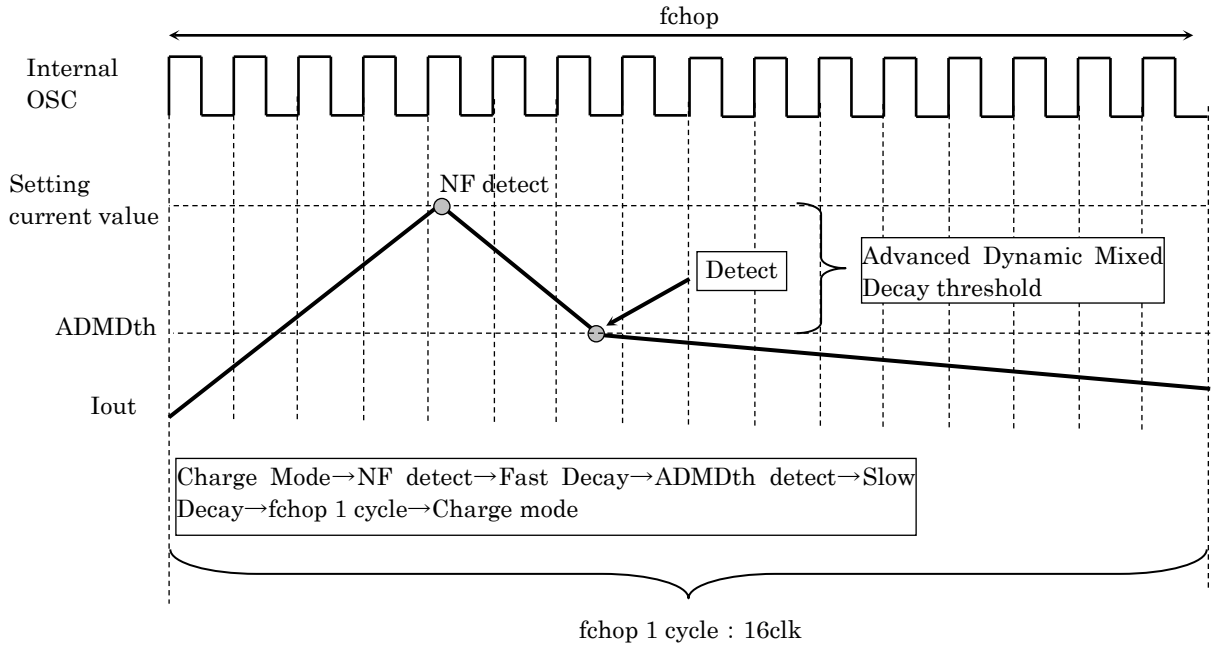


The LO is an open-drain output pin. LO pin needs to be pulled up to 3.3V/5.0V level for proper function. During regular operation, the LO pin level will stay High(VCC level). When error detection (TSD, ISD) is applied, the LO pin will show Low (GND) level.

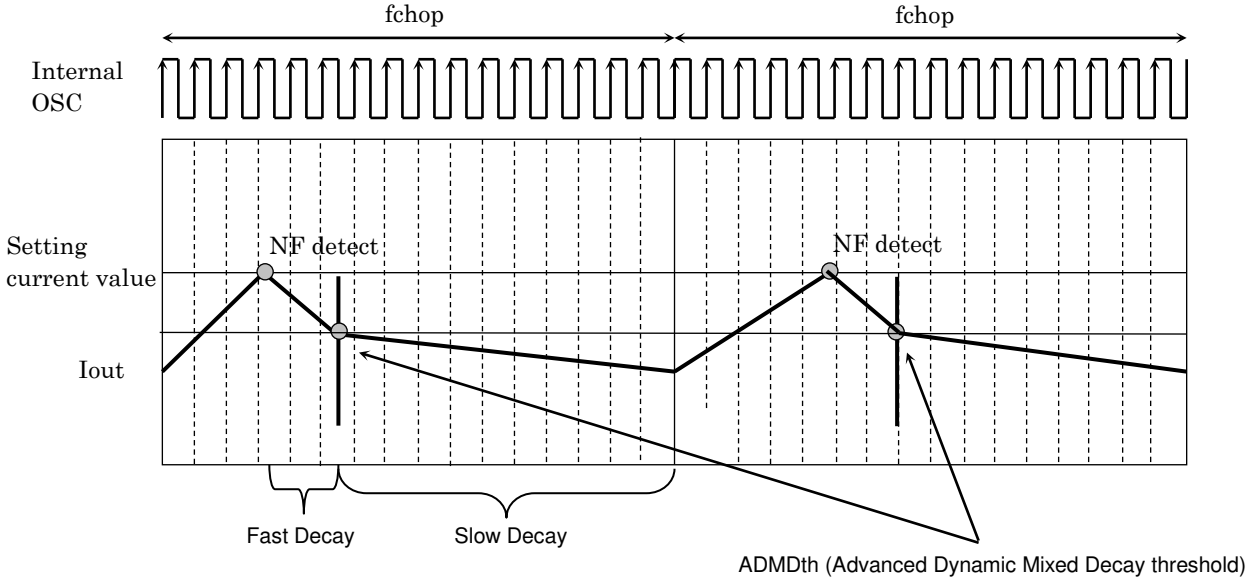
Decay function

ADMD(Advanced Dynamic Mixed Decay) constant current control

The Advanced Dynamic Mixed Decay threshold, which determines the current ripple level during current feedback control, is a unique value.



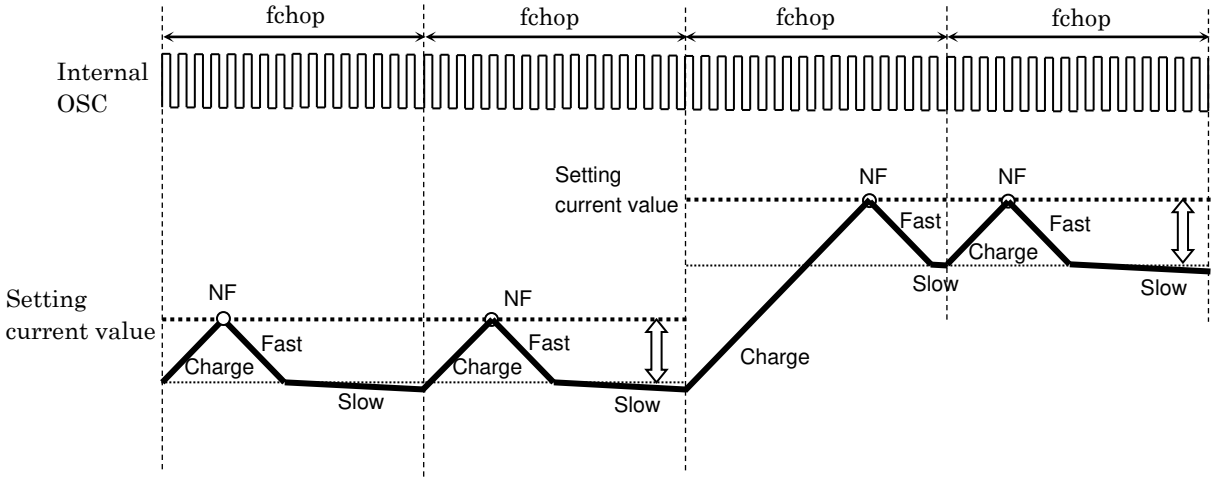
Auto Decay Mode current waveform



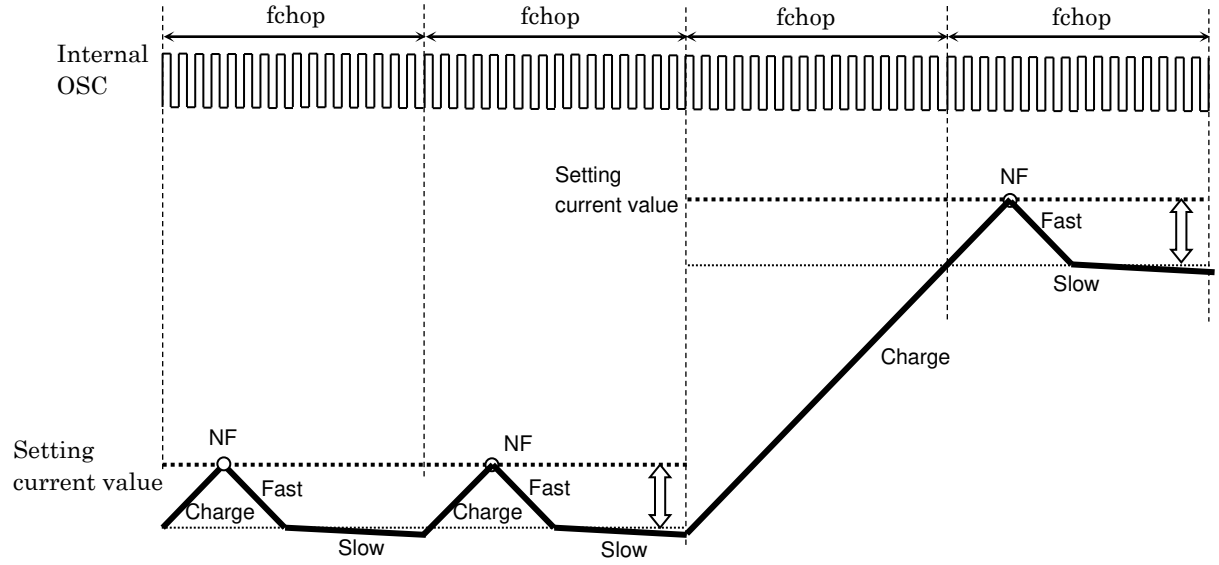
Timing charts may be simplified for explanatory purpose.

ADMD current waveform

・When the next current step is higher :

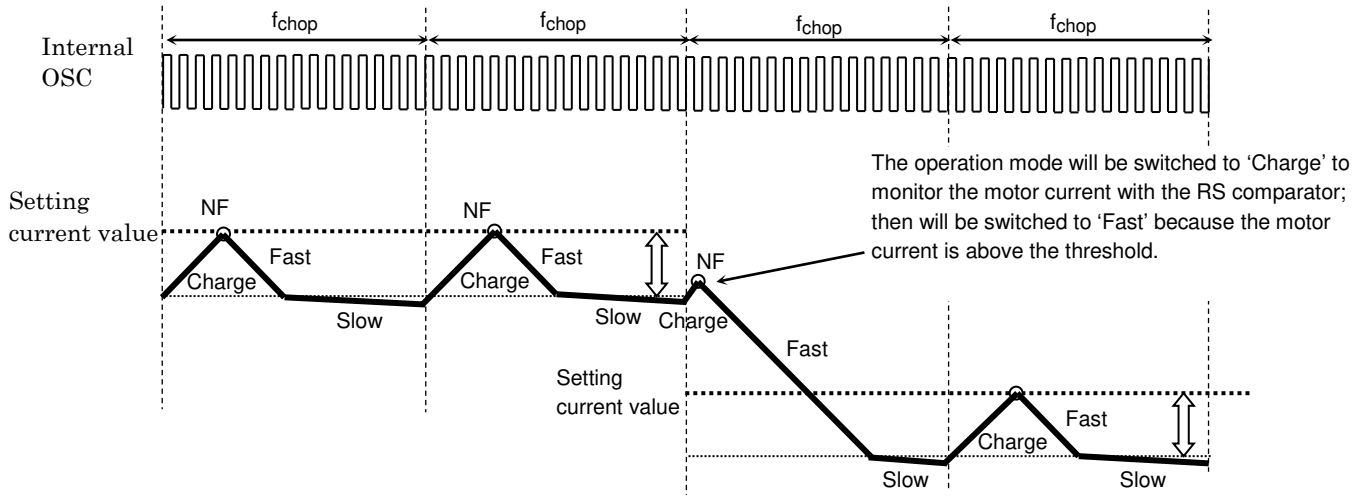


・When Charge period is more than 1 fchop cycle :

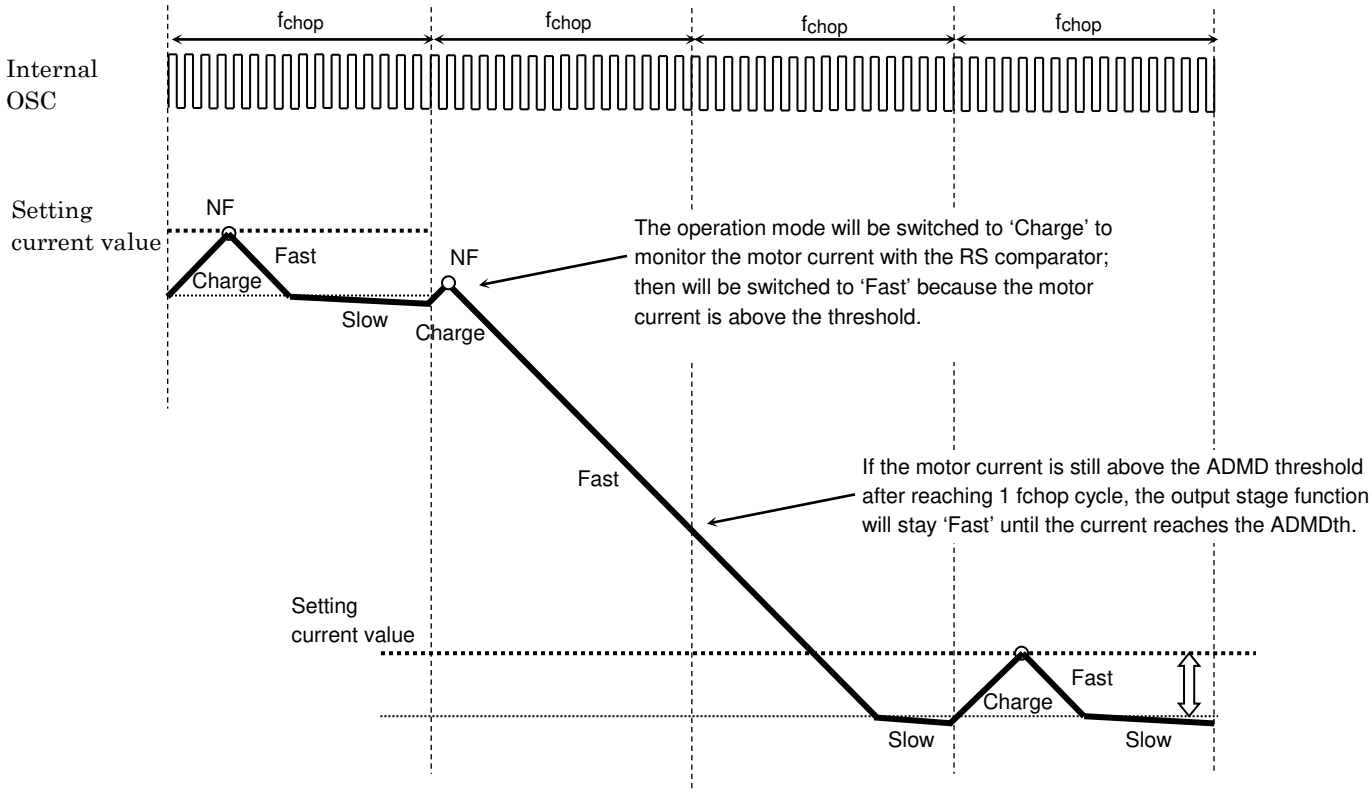


When the Charge period is longer than fchop cycle, the Charge period will be extended until the motor current reaches the NF threshold. Once the current reaches the next current step, then the sequence will go on to decay mode.

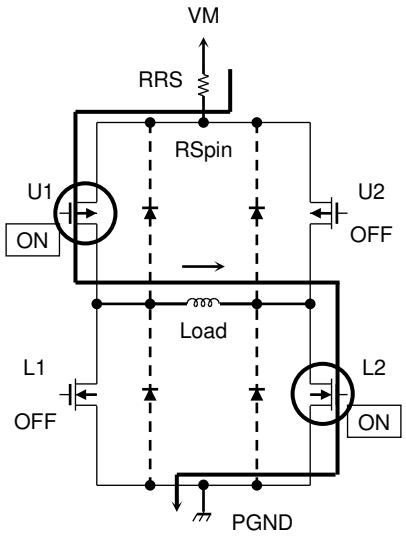
・When the next current step is lower :



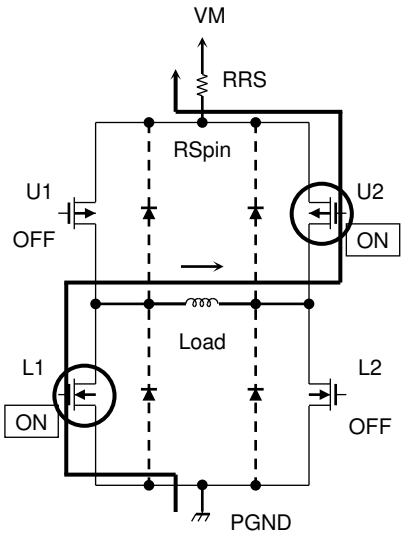
・When the Fast continues past 1 fchop cycle (the motor current not reaching the ADMD threshold during 1 fchop cycle)



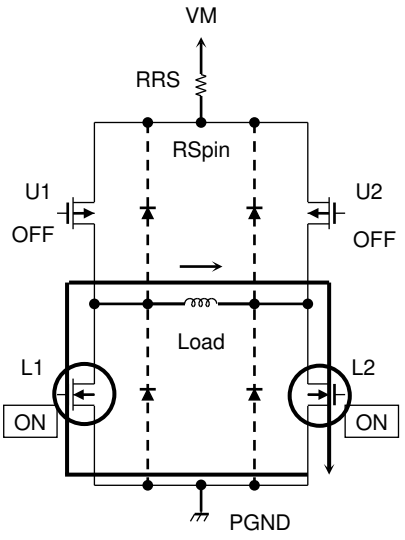
Output transistor function mode



Charge mode
A current flows into the motor coil.



Fast mode
The energy of the motor coil
is fed back to the power



Slow mode
A current circulates around the
motor coil and this device.

Output transistor function

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

Calculation of the Predefined Output Current

For PWM constant-current control, this IC uses a clock generated by the OSCM oscillator.
The peak output current (Setting current value) can be set via the current-sensing resistor (RS) and the reference voltage (Vref), as follows:

$$Iout(max) = Vref(gain) \times \frac{Vref(V)}{R_{RS}(\Omega)}$$

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

For example : In the case of a 100% setup
when Vref = 3.0 V, Torque=100%,RS=0.51Ω, the motor constant current (Setting current value) will be calculated as:

I_{out} = 3.0V / 5.0 / 0.51Ω= 1.18 A

Calculation of the OSCM oscillation frequency (chopper reference frequency)

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

fOSCM=1/[0.56x{Cx(R1+500)}]
……C,R1: External components for OSCM (C=270pF , R1=5.1kΩ => About fOSCM= 1.12MHz(Typ.))

fchop = fOSCM / 16
……fOSCM=1.12MHz => fchop =About 70kHz

If chopping frequency is raised, Rippl of current will become small and wave-like reproducibility will improve. However, the gate loss inside IC goes up and generation of heat becomes large.

By lowering chopping frequency, reduction in generation of heat is expectable. However, Rippl of current may become large. It is a standard about about 70 kHz. 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 supply		VM	50	V	-
Motor output voltage		Vout	50	V	-
Motor output current		Iout	4.0	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	-
MO output voltage		VMO	6.0	V	-
LO output voltage		VLO	6.0	V	-
MO Inflow current		IMO	30	mA	-
LO Inflow current		ILO	30	mA	-
Power dissipation	WQFN48	PD	1.3	W	(Note 2)
	HTSSOP48	PD	1.3	W	(Note 2)
Operating temperature		TOPR	-20 to 85	°C	-
Storage temperature		TSTR	-55 to 150	°C	-
Junction temperature		Tj(max)	150	°C	-

Note 1: Usually, the maximum current value at the time should use 70% or less of the absolute maximum ratings for a standard on thermal rating. The maximum output current may be further limited in view of thermal considerations, depending on ambient temperature and board conditions.

Note 2: Device alone (Ta =25°C)

Ta: Ambient temperature
Topr: Ambient temperature while the IC is active
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.

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 TB67S109AFTG 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 (Ta=-20 to 85°C)

Characteristics	Symbol	Min	Typ.	Max	Unit	Remarks
Motor power supply	VM	10	24	47	V	-
Motor output current	Iout	-	1.5	3.0	A	(Note 1)
Logic input voltage	VIN(H)	2.0	-	5.5	V	Logic input High Level
	VIN(L)	0	-	0.8	V	Logic input Low Level
MO output pin voltage	VMO	-	3.3	5.0	V	-
LO output pin voltage	VLO	-	3.3	5.0	V	-
Clock input frequency	fCLK	-	-	100	kHz	-
Chopper frequency	fchop(range)	40	70	150	kHz	-
Vref input voltage	Vref	GND	2.0	3.6	V	-

Note 1: 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).

Electrical Specifications 1 (Ta = 25°C, 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)=3.3V	-	33	-	μA
	LOW	IIN(L)	VIN(L)=0V	-	-	1	μA
MO output pin voltage	LOW	VOL(MO)	IOL=24mA output=Low	-	0.2	0.5	V
LO output pin voltage	LOW	VOL(LO)	IOL=24mA output=Low	-	0.2	0.5	V
Power consumption		IM1	Output pins=open Standby mode	-	2	3.5	mA
		IM2	Output pins=open Standby release ENABLE=Low	-	3.5	5.5	mA
		IM3	Output pins=open Full step resolution	-	5.5	7	mA
Output leakage current	High-side	IOH	VRS=VM=50V,Vout=0V	-	-	1	μA
	Low-side	IOL	VRS=VM=Vout=50V	1	-	-	μA
Motor current channel differential		ΔIout1	Current differential between Ch	-5	0	5	%
Motor current setting accuracy		ΔIout2	Iout=1.5A	-5	0	5	%
RS pin current		IRS	VRS=VM=24V	0	-	10	μA
Motor output ON-resistance (High-side+Low-side)		Ron(H+L)	Tj=25°C, Forward direction (High-side+Low-side)	—	0.49	0.6	Ω

Note: VIN (H) is defined as the VIN voltage that causes the outputs (OUTA,OUTB) to change when a pin under test is gradually raised from 0 V. V IN (L) is defined as the V IN voltage that causes the outputs (OUTA, OUTB) to change when the pin is then gradually lowered. The difference between V IN (H) and V IN (L) is defined as the V IN (HYS).

Note: When the logic signal is applied to the device whilst the VM power supply is not asserted; the device is designed not to function, but for safe usage, please apply the logic signal after the VM power supply is asserted and the VM voltage reaches the proper operating range.

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

Characteristics	Symbol	Test condition	Min	Typ.	Max	Unit
Vref input current	Iref	Vref=2.0V	-	0	1	μA
VCC voltage	VCC	ICC=5.0mA	4.75	5.0	5.25	V
VCC current	ICC	VCC=5.0V	-	2.5	5	mA
Vref gain rate	Vref(gain)	Vref=2.0V	1/5.2	1/5.0	1/4.8	—
Thermal shutdown(TSD) threshold (Note1)	T_jTSD	—	145	160	175	°C
VM recovery voltage	VMR	—	7.0	8.0	9.0	V
Over-current detection (ISD) threshold (Note2)	ISD	—	4.1	4.9	5.7	A

Note1: About TSD

When the junction temperature of the device reached 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 DMODE pins to standby mode. The TSD circuit is a backup function to detect a thermal error, therefore is not recommended to be used aggressively.

Note2: About ISD

When the output current reaches the threshold, the ISD circuit is triggered; the internal reset circuit then turns off the output transistors. 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 DMODE pins. 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. It must be fully verified that there is no risk that the TB62214AFG/AFTG 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.