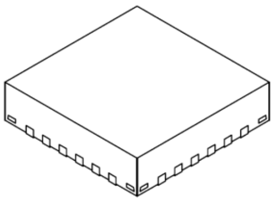
Toshiba BiCD Process Integrated Crcuit Silicon Monolithic

TB67S549FTG

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

The TB67S549FTG is a PWM chopper type 2-phase bipolar stepping motor drive. Owing to the BiCD process, the output withstand voltage of 40 V and a maximum output current of 1.5 A are realized. The motor can be driven by a single VM power supply with a built-in regulator for the device operation.



P-VQFN24-0404-0.50-004
Weight:0.0417g (typ.)

Features

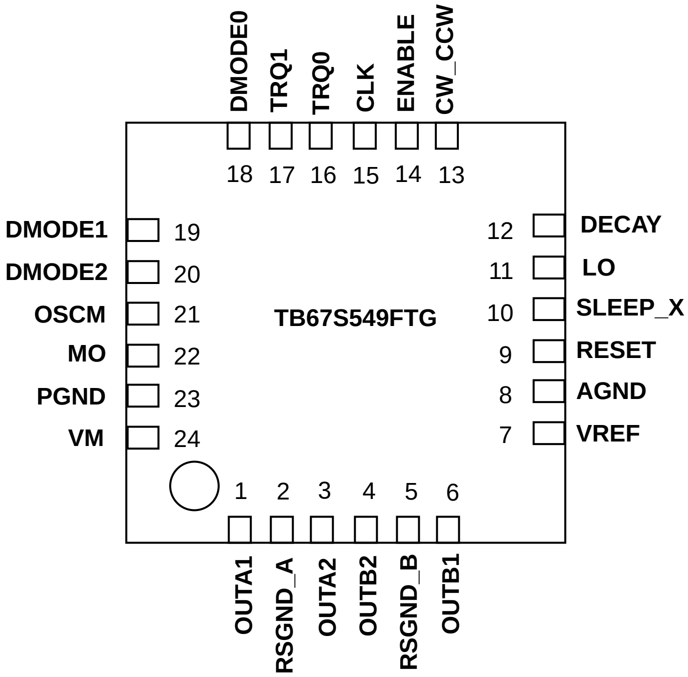
- Monolithic device using BiCD process
- Device for driving a bipolar stepping motor
- A PWM constant current drive is realized without external current detection resistors owing to the built-in function of Advanced Current Detect System (ACDS).
- A high efficiency PWM constant-current drive is realized owing to the built-in function of Advanced Dynamic Mixed Decay (ADMD).
- Clock input control
- Full, Half, Quarter, 1/8, 1/16, and 1/32 step resolutions are available.
- BiCD process : DMOSFETs are integrated for output power transistors
- High withstand voltage and high output current: 40 V / 1.5 A (absolute maximum rating)
- Over-temperature detection (TSD), over-current detection (ISD), and low supply voltage detection (UVLO) are built-in.
- Reduced external components for charge pump
- Package: QFN24 (4mm × 4mm)

Start of commercial production
2022-07

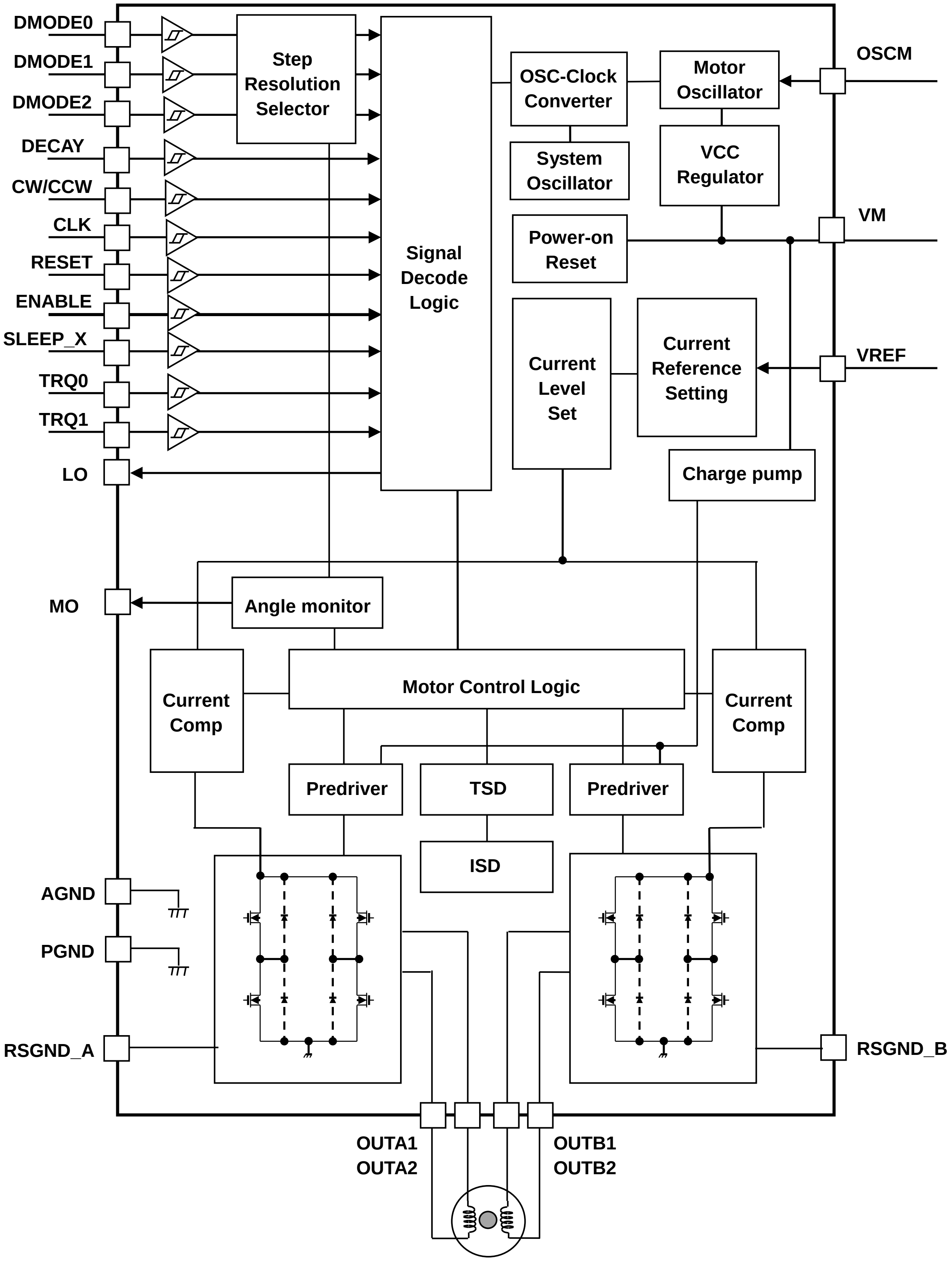
Pin Assignment

TB67S549FTG

(Top View)



Block Diagram



Functional blocks/circuits/constants in the block diagram have been partially omitted or simplified to explain their functions.

Note: For the layout design of this device, the ground wiring should be a solid connection, and the part taken out from the board should be grounded at a single point, and heat dissipation should be also considered.

The output line, VM line, and GND line should be designed carefully because the device may be destroyed in the event of a short circuit between outputs or in the event of power or ground fault.

When the power supply related pins (VM, OUTA1, OUTA2, OUTB1, OUTB2, AGND, PGND, RSGND_A, RSGND_B), through which particularly a large current is flown, are not wired correctly, problems may occur, including destruction.

In addition when the logic input pins are not wired correctly, incorrect operation may occur and the device may be destroyed. In this case, the device may be destroyed due to a higher current than the specified value, or etc..

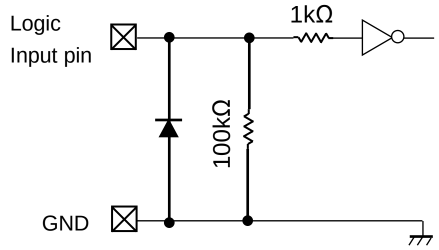
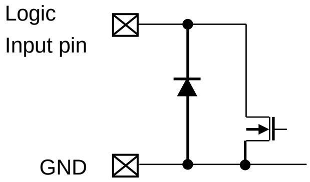
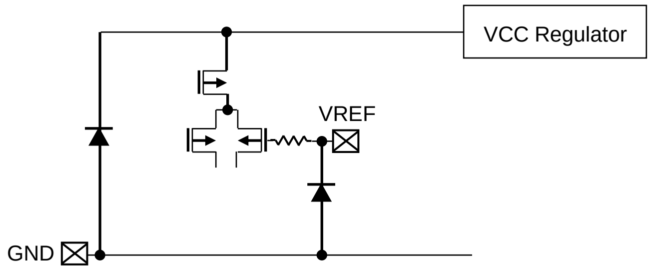
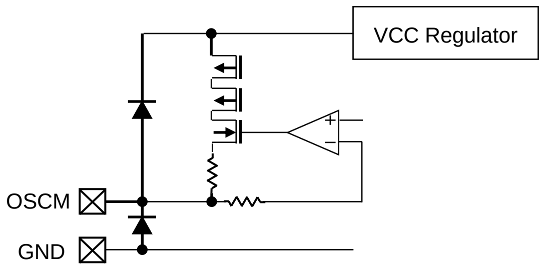
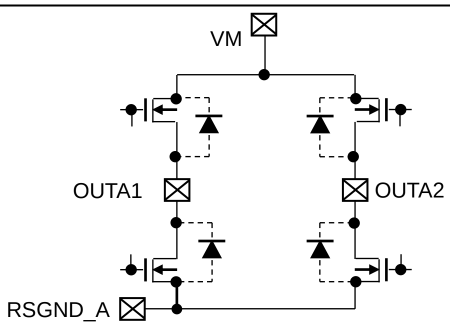
Please be careful when designing the pattern and mounting the device.

Pin Function Description

TB67S549FTG

Pin number	Pin name	Function
1	OUTA1	Motor A channel output pin
2	RSGND_A	Motor A channel ground pin
3	OUTA2	Motor A channel output pin
4	OUTB2	Motor B channel output pin
5	RSGND_B	Motor B channel ground pin
6	OUTB1	Motor B channel output pin
7	VREF	Reference power supply pin for setting current value of A channel output and B channel output
8	AGND	Ground pin
9	RESET	RESET signal input pin. The electric angle is initialized.
10	SLEEP_X	SLEEP signal input pin
11	LO	Reset signal output pin when a failure is detected
12	DECAY	Switching pin for constant current chopping control
13	CW_CCW	Switching pin for rotation direction
14	ENABLE	ENABLE signal input pin for controlling output ON/OFF of A channel and channel B.
15	CLK	Clock signal input pin. Electric angle advances at the rising edge.
16	TRQ0	Torque switching pin
17	TRQ1	Torque switching pin
18	DMODE0	Setting pin for excitation mode
19	DMODE1	Setting pin for excitation mode
20	DMODE2	Setting pin for excitation mode
21	OSCM	Connection pin for the OSCM setting resistor
22	MO	Electric angle monitor pin
23	PGND	Ground pin for motor output
24	VM	VM voltage input pin

Input and Output Equivalent Circuit

Pin name	Equivalent circuit
CLK ENABLE RESET CW/CCW DMODE0 DMODE1 DMODE2 TRQ0 TRQ1 SLEEP_X DECAY	
MO LO	
VREF	
OSCM	
VM OUTA1 OUTA2 OUTB1 OUTB2 RSGND_A RSGND_B	 * Same as OUTB1 and OUTB2

Equivalent circuits have been partially omitted or simplified to explain their circuit.

Operation Description: TB67S549FTG

SLEEP_X Function

By setting the sleep mode once and then setting the normal operation mode again, the operation can be resumed from the forced OFF state due to the operation of the over-temperature detection (TSD) or the over-current detection circuit (ISD).

The power saving mode is entered after 100µsec. by setting SLEEP_X=Low. The normal operation is resumed within 10ms (max.) after inputting SLEEP_X=High.

SLEEP_X	Function
L	Power saving mode (Charge pump stopped, and VCC Reg. stopped.)
H	Normal operation

CLK Function

The electric angle is advanced by one for each CLK. The signal is captured on the Up edge.

CLK	Function
↑	Transition to next step on the up edge
↓	(The previous state is held.)

ENABLE Function

ON and OFF of stepping motor drive are switched. The normal constant current control is started by turning the motor drive ON, while by setting the motor drive OFF the outputs are turned high impedance because the MOSFETs are set to OFF.

ENABLE	Function
H	State of output MOSFETs: ON (normal operation)
L	State of output MOSFETs: OFF (operation stopped, high impedance)

CW/CCW Function

The directions of the stepping motor rotation are switched.

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

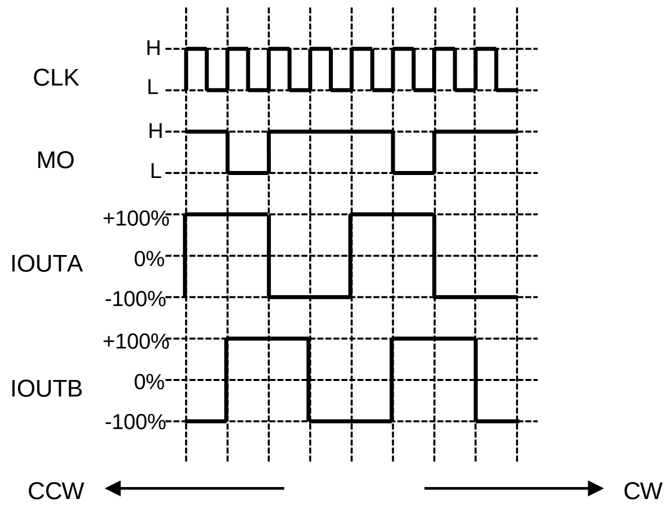
DMODE0, DMODE1, DMODE2 Function

Step resolutions are switched.

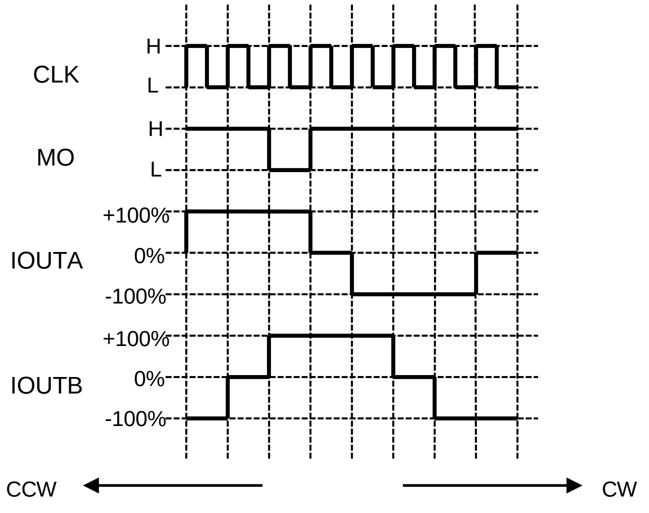
DMODE0	DMODE1	DMODE2	Function
L	L	L	setting of Full step resolution
L	L	H	setting of Half step resolution (a)
L	H	L	setting of Half step resolution (b)
L	H	H	setting of Quarter step resolution
H	L	L	setting of 1/8 step resolution
H	L	H	setting of 1/16 step resolution
H	H	L	setting of 1/32 step resolution
H	H	H	setting of 1/32 step resolution

Each sequence by step resolution in clock input control mode

[Setting of Full step resolution]



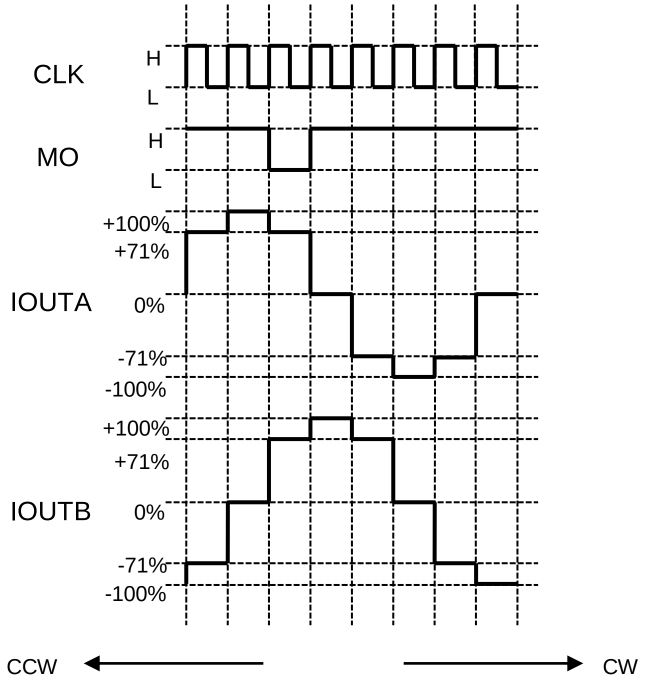
[Setting of Half step resolution (a)]



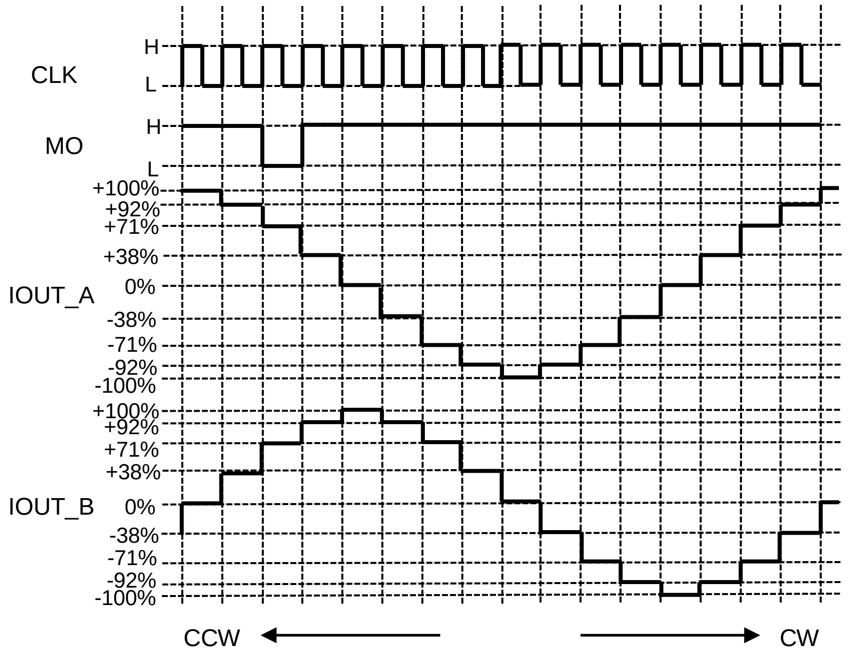
MO is a waveform of the pin output in pull-up state.

The timing chart has been simplified to explain the function and operation.

[Setting of Half step resolution (b)]



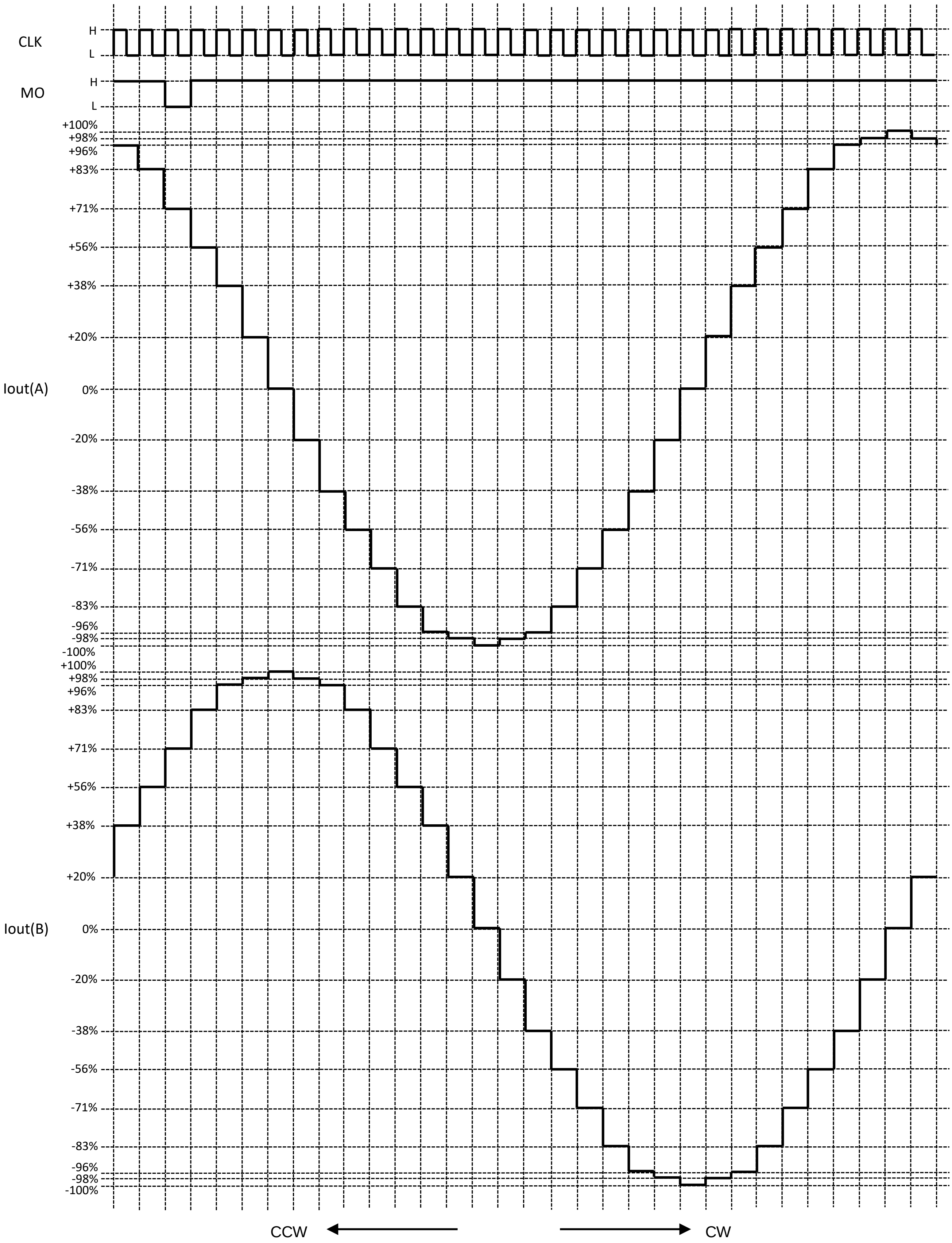
[Setting of Quarter step resolution]



MO is a waveform of the pin output in pull-up state.

The timing chart has been simplified to explain the function and operation.

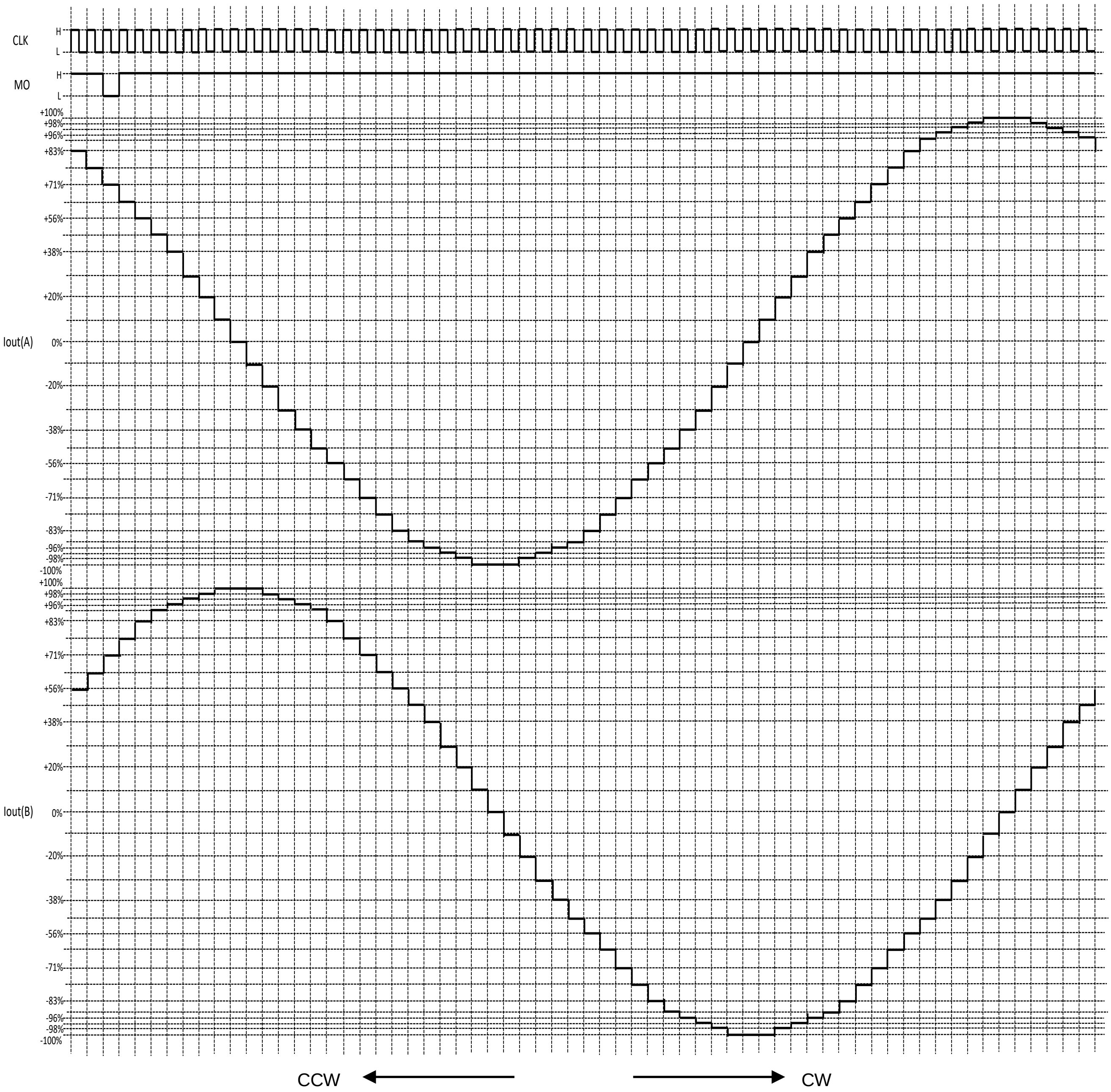
[Setting of 1/8 step resolution]



MO is a waveform of the pin output in pull-up state.

The timing chart has been simplified to explain the function and operation.

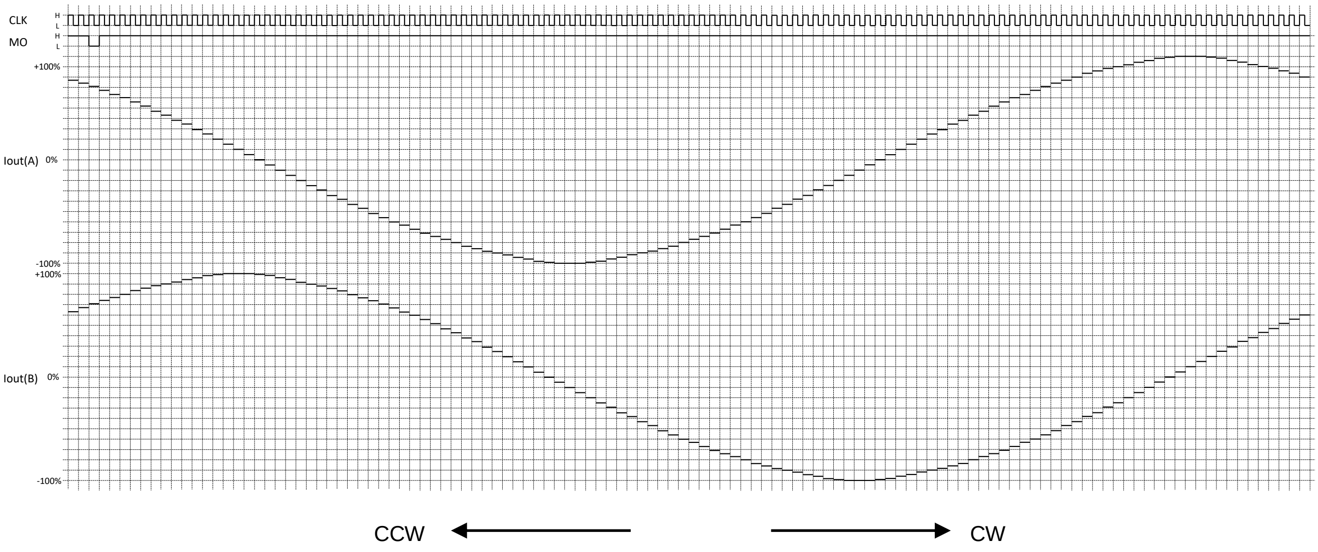
[Setting of 1/16 step resolution]



MO is a waveform of the pin output in pull-up state.

The timing chart has been simplified to explain the function and operation.

[Setting of 1/32 step resolution]



MO is a waveform of the pin output in pull-up state.

The timing chart has been simplified to explain the function and operation.

Step resolution and set current value

Regarding the set current value of each step resolution, refer to the table below. The table shows the case of CW_CCW=High setting.

STEP	1/32		1/16		1/8		1/4		1/2(b)		1/2(a)		Full	
—	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)
θ0	100	0	100	0	100	0	100	0	100	0	100	0		
θ1	100	5												
θ2	100	10	100	10										
θ3	99	15												
θ4	98	20	98	20	98	20								
θ5	97	24												
θ6	96	29	96	29										
θ7	94	34												
θ8	92	38	92	38	92	38	92	38						
θ9	90	43												
θ10	88	47	88	47										
θ11	86	51												
θ12	83	56	83	56	83	56								
θ13	80	60												
θ14	77	63	77	63										
θ15	74	67												
θ16	71	71	71	71	71	71	71	71	71	71	100	100	100	100
θ17	67	74												
θ18	63	77	63	77										
θ19	60	80												
θ20	56	83	56	83	56	83								
θ21	51	86												
θ22	47	88	47	88										
θ23	43	90												
θ24	38	92	38	92	38	92	38	92						
θ25	34	94												
θ26	29	96	29	96										
θ27	24	97												
θ28	20	98	20	98	20	98								
θ29	15	99												
θ30	10	100	10	100										
θ31	5	100												
θ32	0	100	0	100	0	100	0	100	0	100	0	100		
θ33	-5	100												
θ34	-10	100	-10	100										
θ35	-15	99												
θ36	-20	98	-20	98	-20	98								
θ37	-24	97												
θ38	-29	96	-29	96										
θ39	-34	94												
θ40	-38	92	-38	92	-38	92	-38	92						
θ41	-43	90												
θ42	-47	88	-47	88										
θ43	-51	86												

STEP	1/32		1/16		1/8		1/4		1/2(b)		1/2(a)		Full	
—	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)
θ44	-56	83	-56	83	-56	83								
θ45	-60	80												
θ46	-63	77	-63	77										
θ47	-67	74												
θ48	-71	71	-71	71	-71	71	-71	71	-71	71	-100	100	-100	100
θ49	-74	67												
θ50	-77	63	-77	63										
θ51	-80	60												
θ52	-83	56	-83	56	-83	56								
θ53	-86	51												
θ54	-88	47	-88	47										
θ55	-90	43												
θ56	-92	38	-92	38	-92	38	-92	38						
θ57	-94	34												
θ58	-96	29	-96	29										
θ59	-97	24												
θ60	-98	20	-98	20	-98	20								
θ61	-99	15												
θ62	-100	10	-100	10										
θ63	-100	5												
θ64	-100	0	-100	0	-100	0	-100	0	-100	0	-100	0		
θ65	-100	-5												
θ66	-100	-10	-100	-10										
θ67	-99	-15												
θ68	-98	-20	-98	-20	-98	-20								
θ69	-97	-24												
θ70	-96	-29	-96	-29										
θ71	-94	-34												
θ72	-92	-38	-92	-38	-92	-38	-92	-38						
θ73	-90	-43												
θ74	-88	-47	-88	-47										
θ75	-86	-51												
θ76	-83	-56	-83	-56	-83	-56								
θ77	-80	-60												
θ78	-77	-63	-77	-63										
θ79	-74	-67												
θ80	-71	-71	-71	-71	-71	-71	-71	-71	-71	-71	-100	-100	-100	-100
θ81	-67	-74												
θ82	-63	-77	-63	-77										
θ83	-60	-80												
θ84	-56	-83	-56	-83	-56	-83								
θ85	-51	-86												
θ86	-47	-88	-47	-88										
θ87	-43	-90												
θ88	-38	-92	-38	-92	-38	-92	-38	-92						
θ89	-34	-94												
θ90	-29	-96	-29	-96										
θ91	-24	-97												

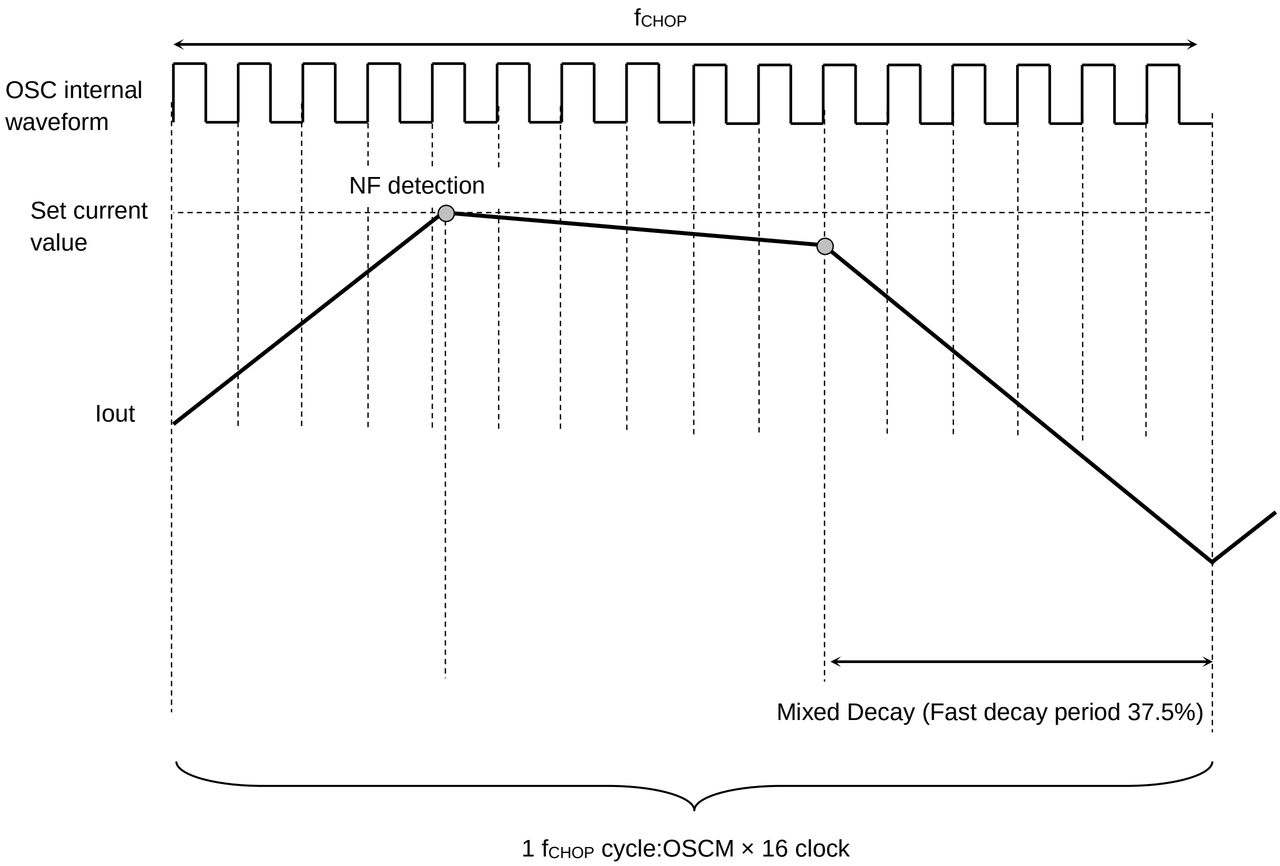
STEP	1/32		1/16		1/8		1/4		1/2(b)		1/2(a)		Full	
—	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)
θ92	-20	-98	-20	-98	-20	-98								
θ93	-15	-99												
θ94	-10	-100	-10	-100										
θ95	-5	-100												
θ96	0	-100	0	-100	0	-100	0	-100	0	-100	0	-100		
θ97	5	-100												
θ98	10	-100	10	-100										
θ99	15	-99												
θ100	20	-98	20	-98	20	-98								
θ101	24	-97												
θ102	29	-96	29	-96										
θ103	34	-94												
θ104	38	-92	38	-92	38	-92	38	-92						
θ105	43	-90												
θ106	47	-88	47	-88										
θ107	51	-86												
θ108	56	-83	56	-83	56	-83								
θ109	60	-80												
θ110	63	-77	63	-77										
θ111	67	-74												
θ112	71	-71	71	-71	71	-71	71	-71	71	-71	100	-100	100	-100
θ113	74	-67												
θ114	77	-63	77	-63										
θ115	80	-60												
θ116	83	-56	83	-56	83	-56								
θ117	86	-51												
θ118	88	-47	88	-47										
θ119	90	-43												
θ120	92	-38	92	-38	92	-38	92	-38						
θ121	94	-34												
θ122	96	-29	96	-29										
θ123	97	-24												
θ124	98	-20	98	-20	98	-20								
θ125	99	-15												
θ126	100	-10	100	-10										
θ127	100	-5												
θ128	100	0	100	0	100	0	100	0	100	0	100	0		

Selectable Mixed Decay Function

The Selectable Mixed Decay is a function that the amount of current recirculation during the current recirculation (Decay) period can be adjusted by the DECAY pin.

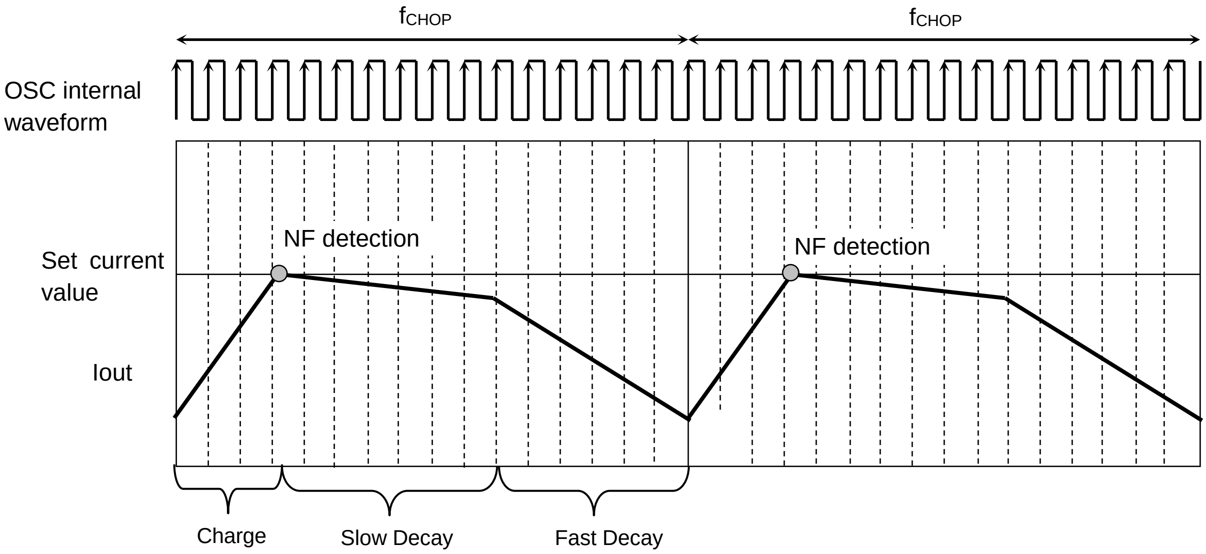
The control of Mixed Decay itself is realized by switching among three controls: Charge, Slow, and Fast. The constant current control can be selected from two settings by the DECAY pin. When this setting is switched during the constant current operation, the new setting is applied from the next chopping cycle.

DECAY pin	Function
L	Mixed Decay
H	ADMD



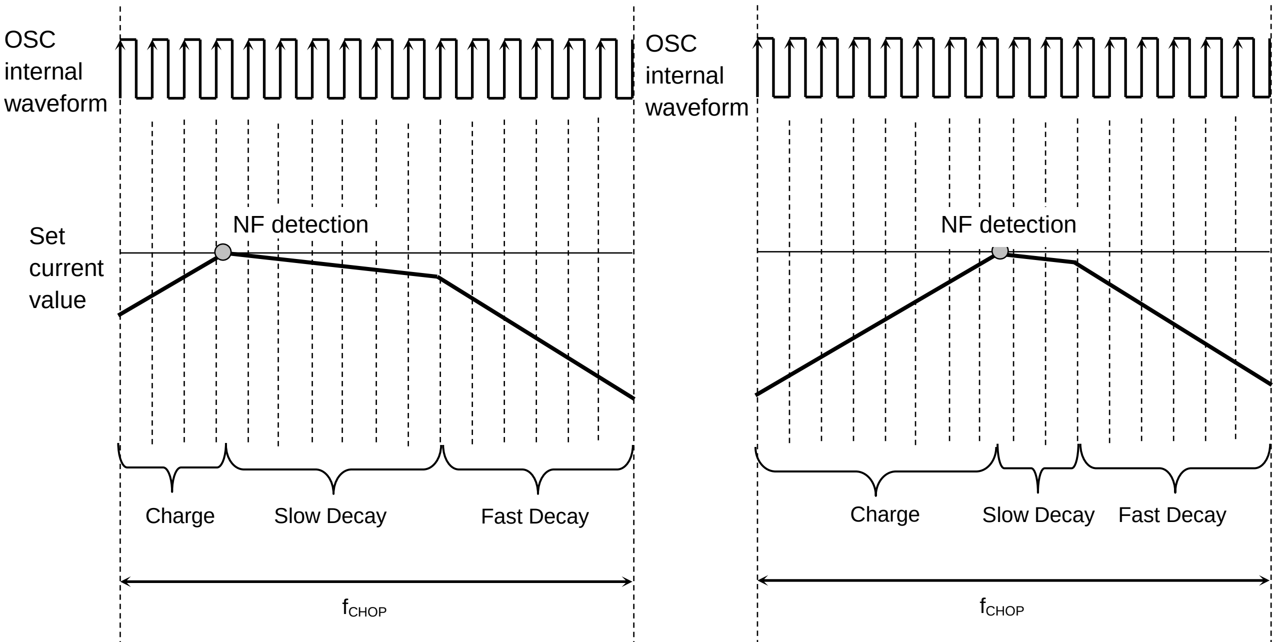
Note: The timing chart has been simplified to explain functions and operations.

Mixed Decay Waveform (Current Waveform)



Note: The timing chart has been simplified to explain functions and operations.

Each period of the constant current PWM operation



When the NF detection is performed at the early timing of the f_{CHOP} cycle, the period of Slow Decay is longer.

When the NF detection is performed at the early timing of the f_{CHOP} cycle, the period of Slow Decay is longer.

The Charge period (the time required for the current flowing in the motor to reach the set current value) varies depending on drive conditions.

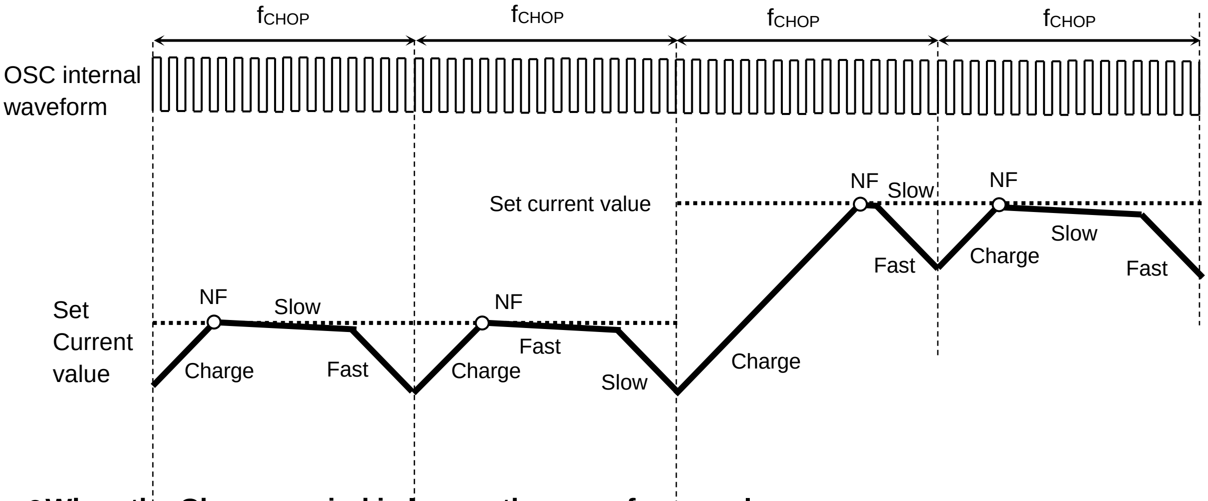
The timing of NF detection (the motor current reaches the set current value) during the mixed decay chopping cycle (f_{CHOP}) varies from time to time. As shown in the example above, when the NF detected is performed at a relatively early timing of the f_{CHOP} cycle, the period of Slow Decay is longer, and when it is performed later of the f_{CHOP} cycle, the period of Slow Decay is shorter.

Note: Basically, f_{CHOP} period - (Charge + Fast decay period) = Slow decay period. (Fast decay period is fixed at 37.5% (OSCM: 6 clocks)).

Note: The timing chart has been simplified to explain functions and operations.

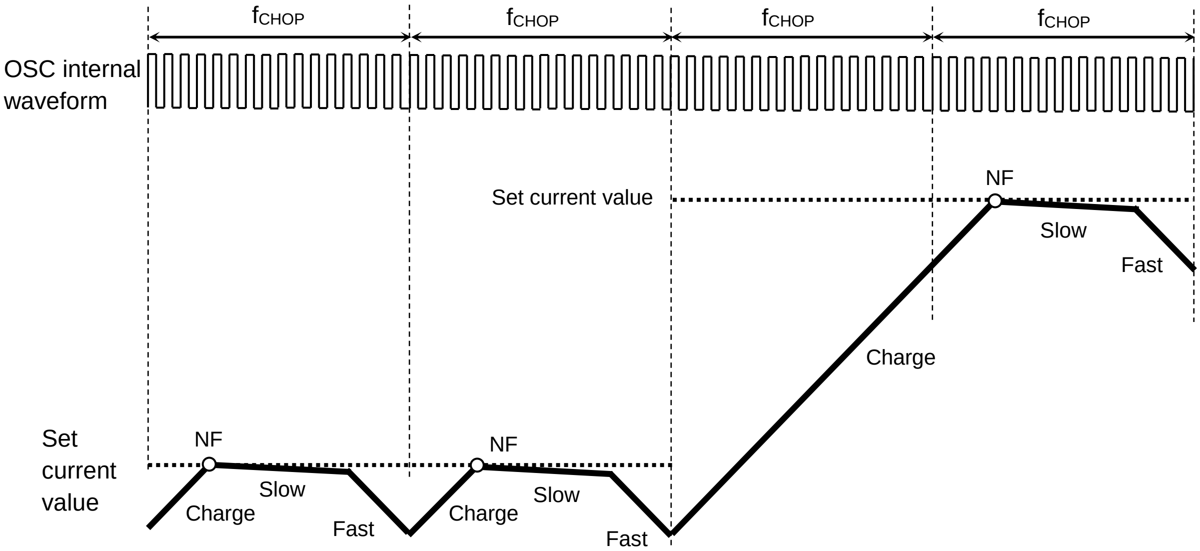
Mixed Decay Current Waveform

●When the set current value is in the increasing direction

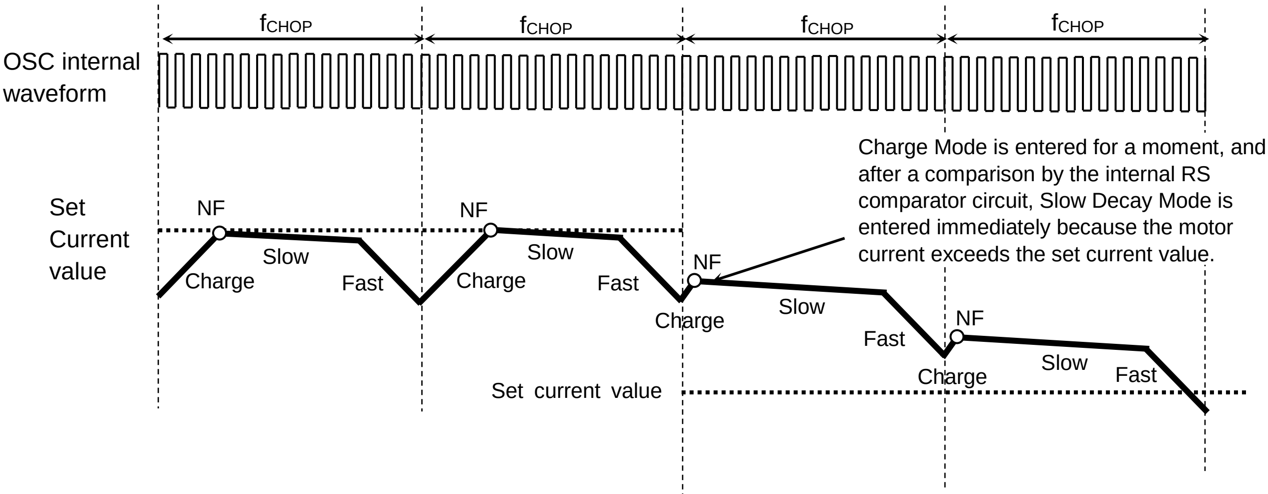


●When the Charge period is longer than one f_{CHOP} cycle

When the period until the motor current reaches the next set value (Charge period) exceeds one cycle of the set chopping cycle (f_{CHOP}), such as when the set current values (steps) are switched, Charge continues for the next f_{CHOP} cycle, and the control mode is shifted to Mixed Decay control after reaching NF.



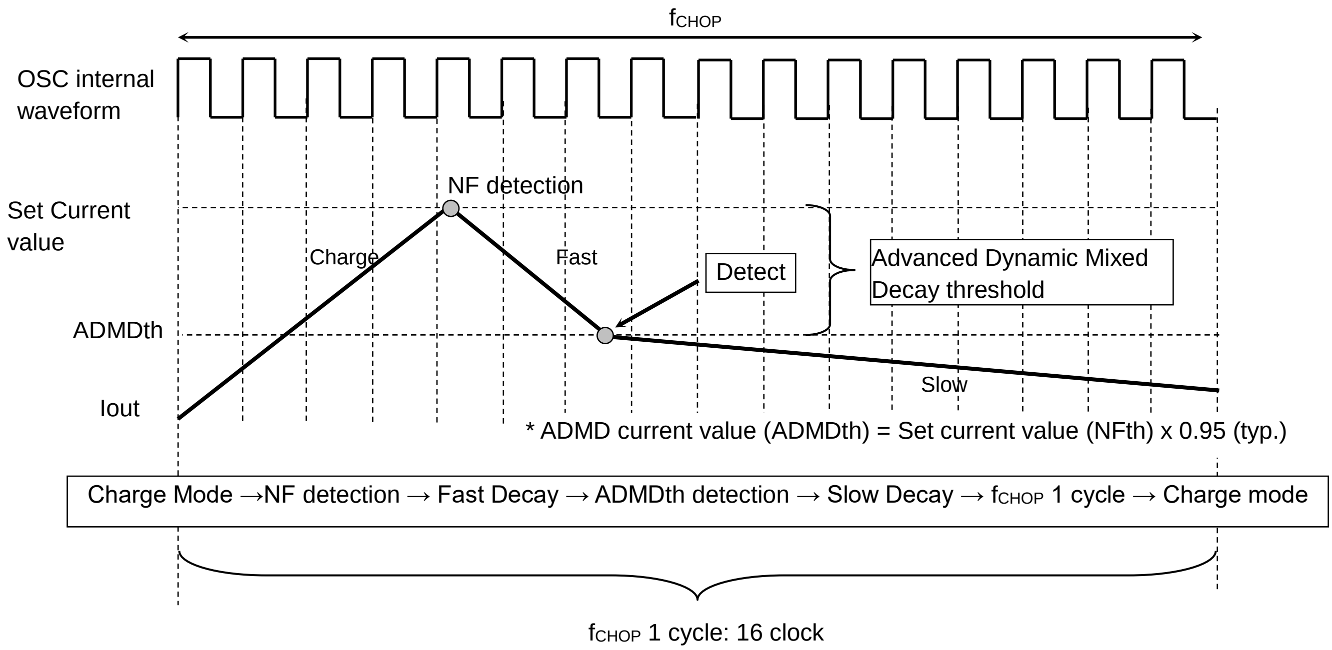
●When the set current value is in the decreasing direction



The timing chart has been simplified to explain functions and operations.

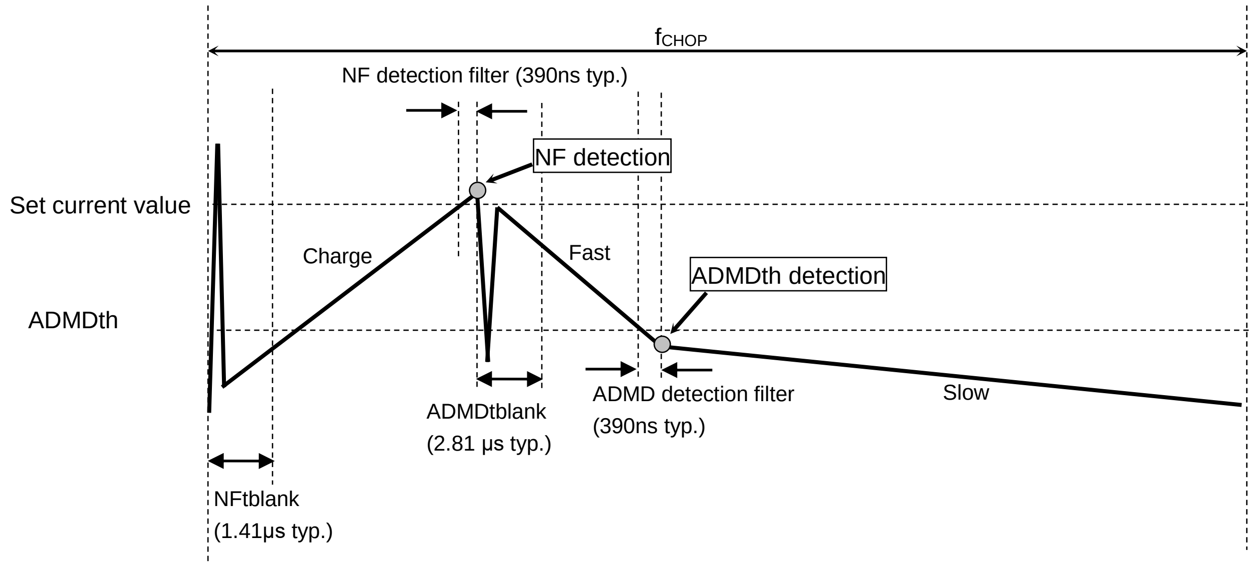
ADMD (Advanced Dynamic Mixed Decay) Constant Current Control

In ADMD both the current flowing from the power supply to the motor and the current re-circulated from the motor to the power supply are monitored to perform constant current PWM control. The basic sequence of ADMD is shown below.



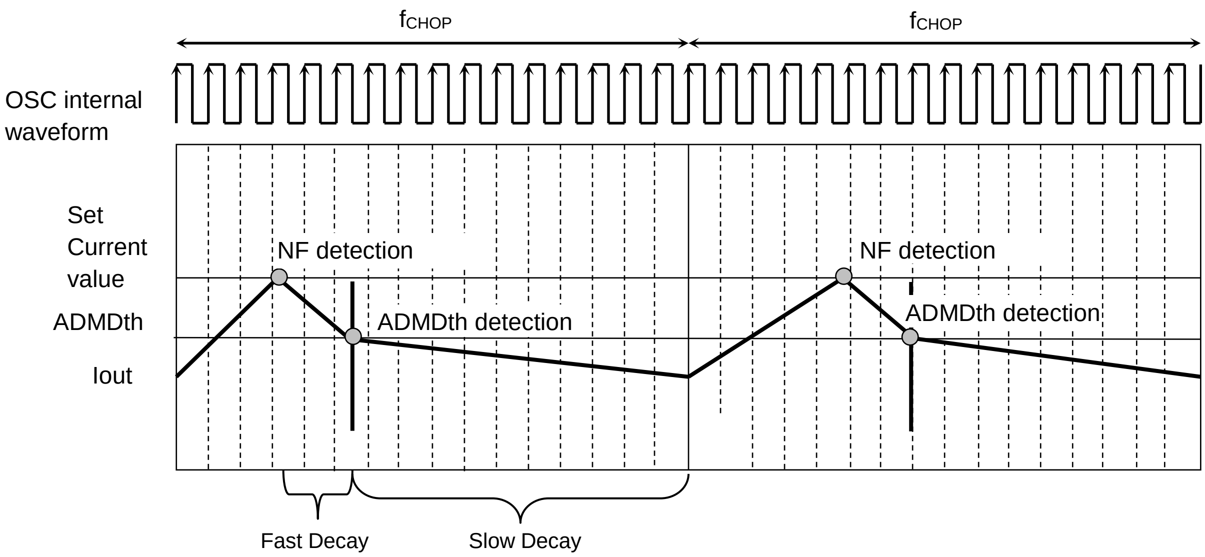
Note: The timing chart has been simplified to explain functions and operations.
The values in the timing chart are for reference only.

Each filter is provided as shown in the figure below to avoid current mis-detection caused by external jumping noise, etc.. When the L value of the motor in use is small and the current value reaches ADMDth (ADMD current value) within the ADMDtblank period, the mode is switched to Slow operation after the ADMDtblank period. In this case, the ADMD current value (ADMDth) is smaller than the set current value (NFth) x 0.95 (typ.).



Note: The timing chart has been simplified to explain functions and operations.
The values in the timing chart are for reference only.

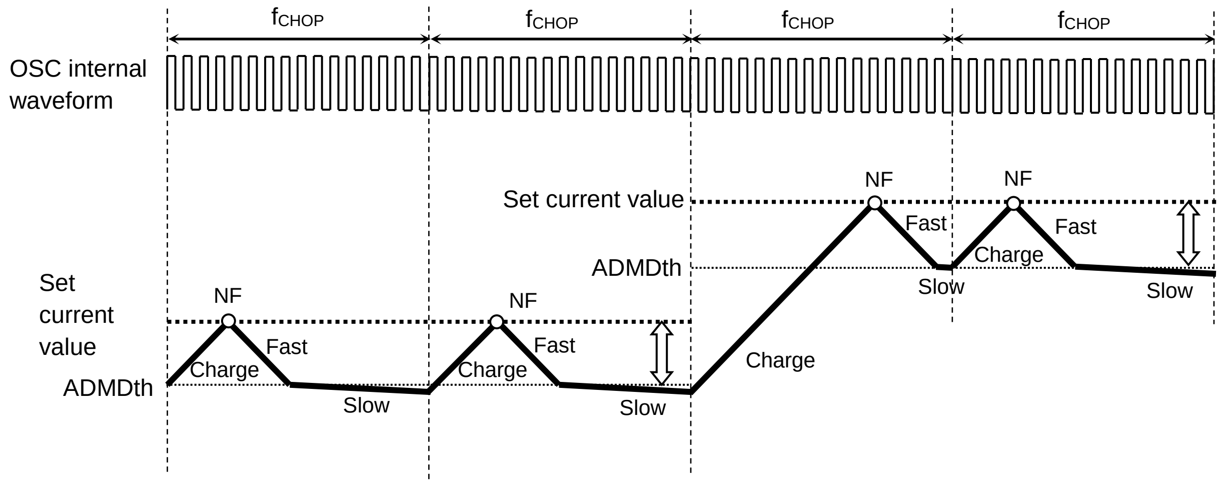
Auto Decay Mode Waveform



Note: The timing chart has been simplified to explain functions and operations.

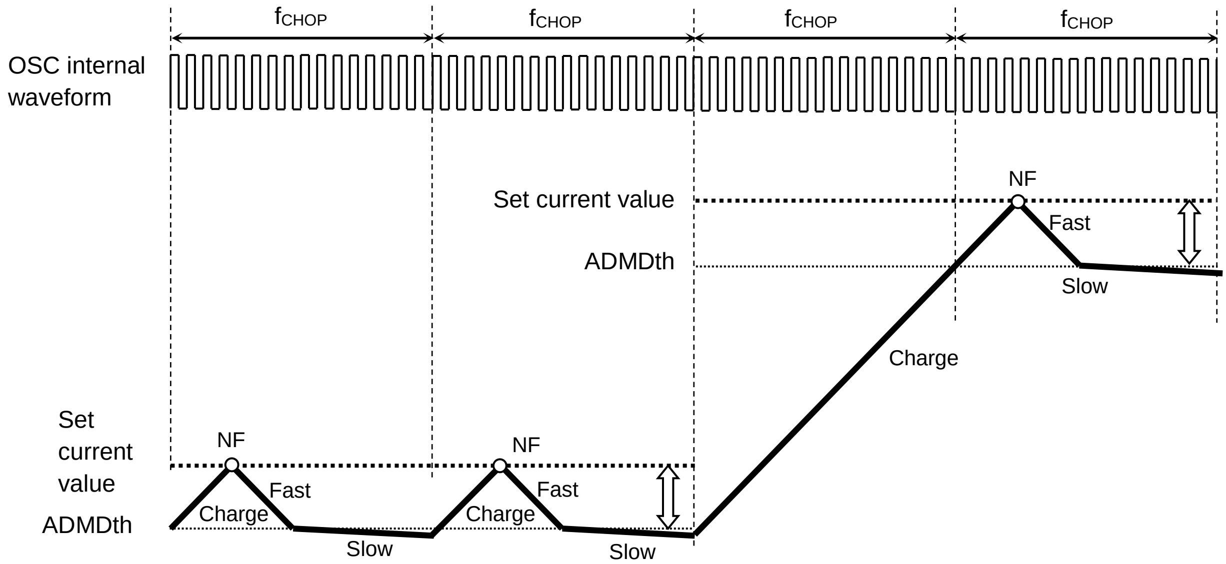
Auto Decay Mode Waveform

●When the set current value is in the increasing direction



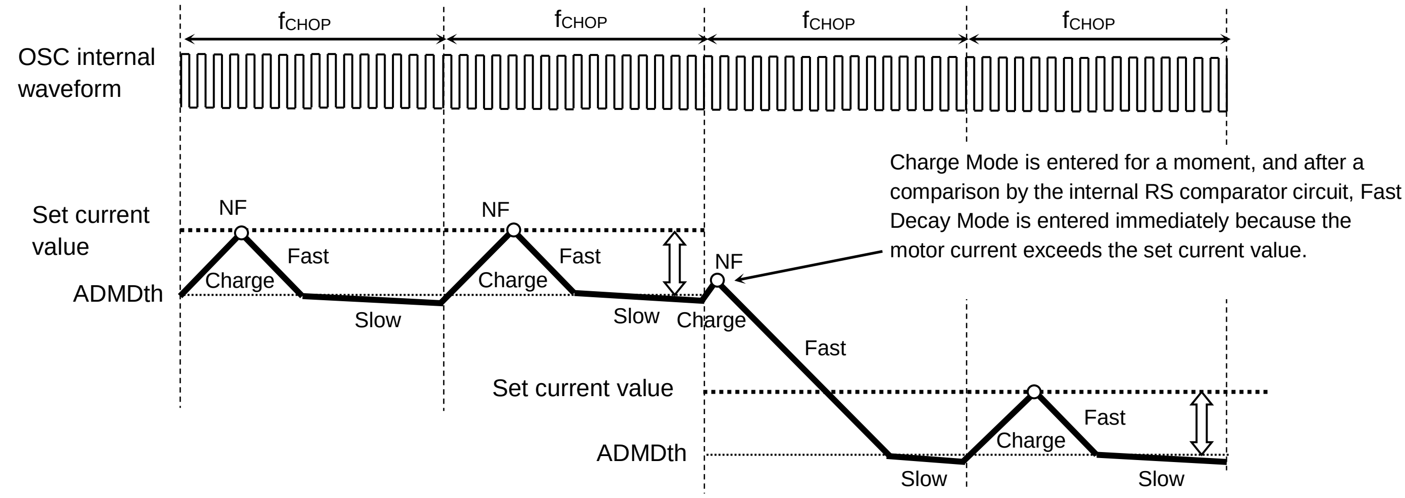
●When the Charge period is longer than one f_{CHOP} cycle

When the period until the motor current reaches the next set value (Charge period) exceeds one cycle of the set chopping cycle (f_{CHOP}), such as when the set current value (step) is switched, Charge continues for the next f_{CHOP} cycle, and the control mode is shifted to Mixed Decay control after reaching NF.

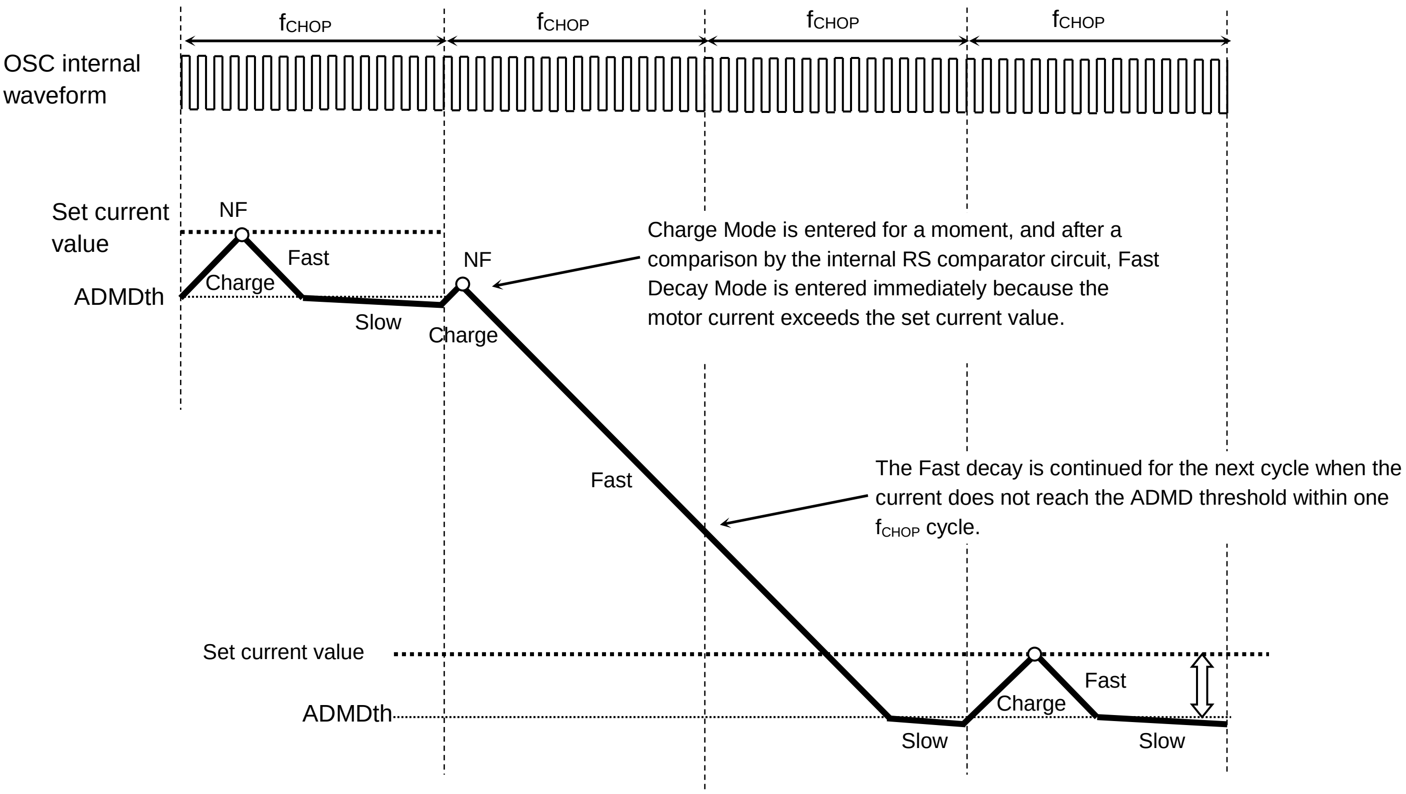


Note: The timing chart has been simplified to explain functions and operations.

●**When the set current value is in the decreasing direction**



●**When the Fast period is longer than one f_{CHOP} cycle**
(The output current does not reach the ADMD threshold within one f_{CHOP} cycle.)



Note: The timing chart has been simplified to explain functions and operations.

RESET Function

The internal electric angle can be initialized.

RESET	Function
H	Initialization of Electric angle
L	Normal operation

The current in each channel when RESET is turned on is designed as follows.

Step resolution	A channel current	B channel current	Initial electric angle
Full step resolution	100%	100%	45°
Half step resolution (a)	100%	100%	45°
Half step resolution (b)	71%	71%	45°
Quarter step resolution	71%	71%	45°
1/8 step resolution	71%	71%	45°
1/16 step resolution	71%	71%	45°
1/32 step resolution	71%	71%	45°

Torque Function

The torque of motor is set.

TRQ1 pin input	TRQ0 pin input	Function
L	L	Torque setting: 100%.
L	H	Torque setting: 75%.
H	L	Torque setting: 50%.
H	H	Torque setting: 25%.

MO Function

Internal electrical angle can be checked by connecting the output of the MO pin to 3.3 V or 5 V power supply through a pull-up resistor in the range of 10 k to 100 kΩ.

MO	Function
H (pill-up)	Electric angle is other than the initial value
L	Electric angle is the initial value

LO (Error Detection Flag Output) Function

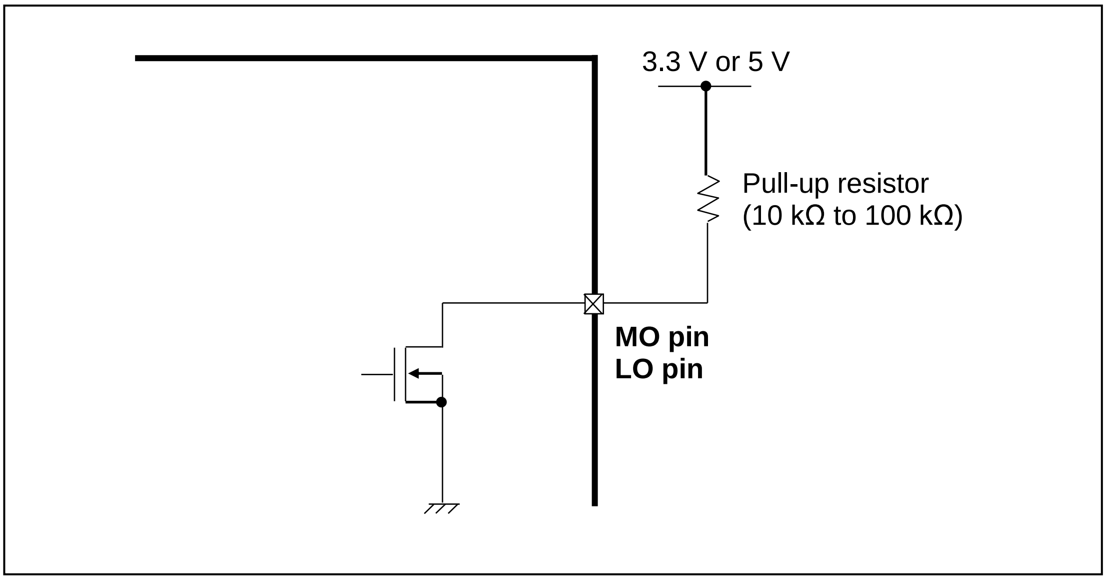
The LO is a function to output an external signal when the error detection function is activated.

In use of this function, the output of the LO pin should be connected to 3.3 V or 5 V power supply through a pull-up resistor in the range of 10 k to 100 kΩ due to an open drain internal structure of this pin.

In normal operation, the LO pin level is Hi-Z (the internal MOSFET is OFF). When the error detection function (over-temperature detection (TSD) or over-current detection (ISD)) is activated, the LO pin level is turned Low (internal MOSFET is ON).

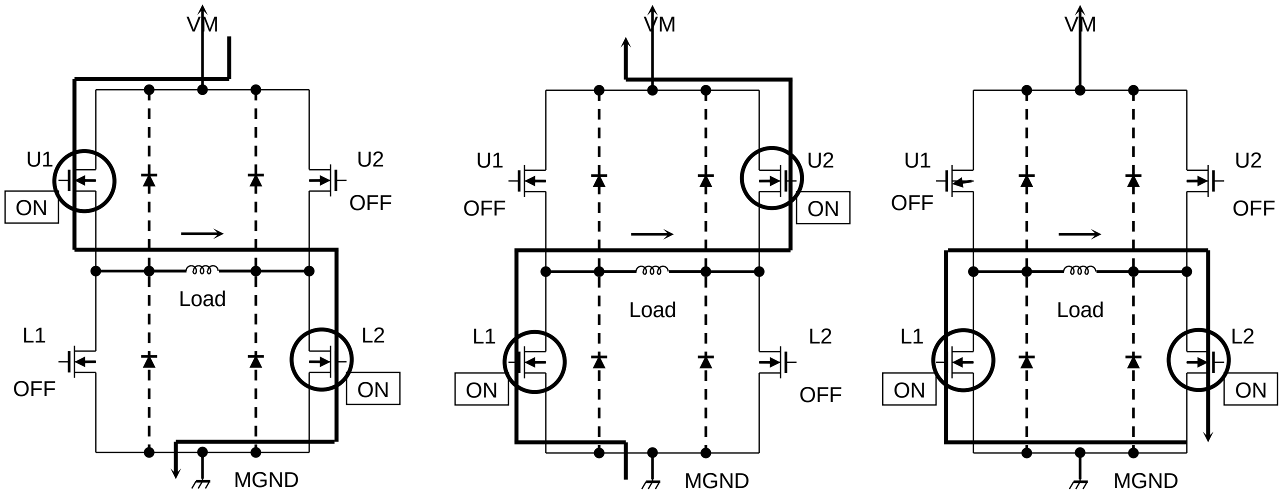
When the error detection is canceled by re-turning the VM power supply on or by the sleep mode, the LO pin is returned to the "normal state (normal operation)" again. When the LO function is not used, leave this pin open.

LO pin output	Function
H (pull-up)	Normal state (normal operation)
L	Over-temperature detection (TSD) Over-current detection (ISD)



Equivalent circuits have been partially omitted or simplified to explain the circuit.

Action of output transistors in each mode (Advanced Dynamic Mixed Decay)



Charge mode
Current is fed into the coil.

Fast mode
Energy of the coil is returned to the power supply.

Slow mode
Current is flown between the coil and the device.

*A shoot through-current prevention period (dead time) is provided inside the device to prevent shoot through-current when switching outputs.

Action of output transistors in each mode

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

Note: The above table shows the case where the current flows in the direction of the arrow in the above figure as an example. In the opposite direction, the table below shows the case.

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

In this device the three modes shown in the above figure are automatically switched to perform constant current control.
Equivalent circuits have been partially omitted or simplified to explain the circuit.

Set current value (I_{OUT})

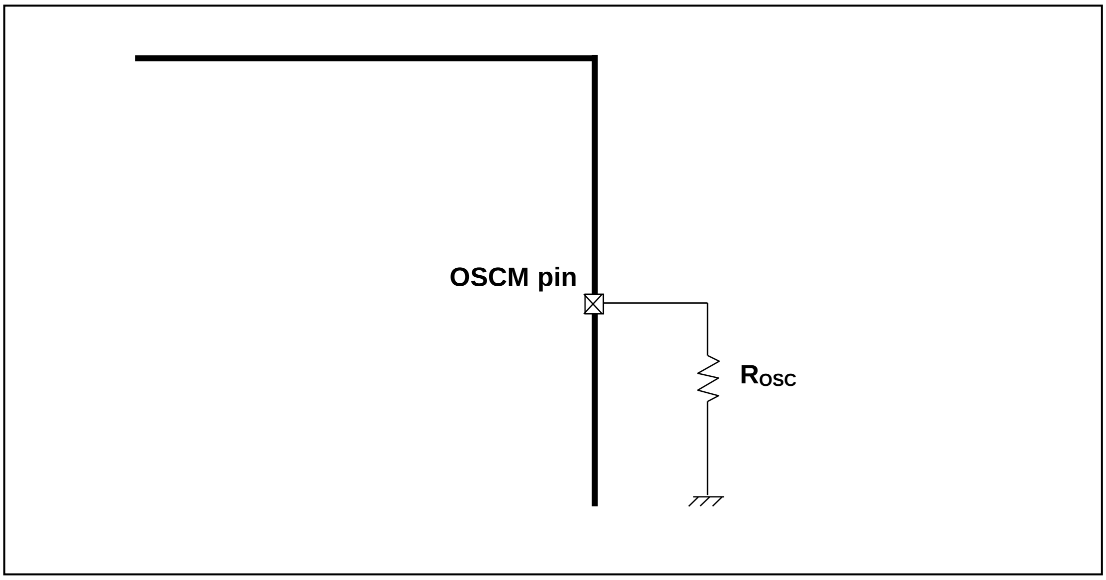
The set current value for constant current PWM control can be determined by setting the reference voltage (V_{REF}).

The set current value (I_{OUT}) can be calculated by the following formula.

$I_{OUT} = V_{REF} \times 0.556$
Example: When V_{REF} = 2.0 V, I_{OUT} = 1.11 A

Chopping frequency (f_{CHOP})

The chopping frequency of the constant current control (of the motor current) can be set by the resistor ROSC connected to the OSCM pin. And the device can be used with a fixed value chopping frequency without connecting any external components to the OSCM pin. And use of a fixed chopping frequency with no external components to the OSCM pin is also available.



Equivalent circuits have been partially omitted or simplified to explain the circuit.

The chopping frequency (f_{CHOP}) can be calculated using the following formula.
In general, it is recommended that the frequency is set in the range of 40 kHz to 100 kHz, with a frequency of approximately 70 kHz as a center value.

$f_{CHOP} = f_{OSCM} / 16$
$f_{OSCM} = 1/(\alpha \times R_{OSC} + \beta)$ [MHz] $*\alpha = 1.7 \times 10^{-5}$, $\beta = 0.0285$
Example: When R_{OSC} = 47 kΩ, f_{OSCM} = 1.2 MHz (typ.), f_{CHOP} = 75 kHz (typ.)

When the OSCM pin is left open or shorted the ground, this device is operated at the frequency that f_{OSCM2} = 914 kHz (typ.) and f_{CHOP} = 57.1kHz (typ.) those are automatically generated inside the device.

Power consumption of the device

The power consumed in the device is roughly divided into two parts : the power consumed by the transistors in the output block and the power consumed by the logic block.

1. Power consumption of the power transistor block

The power in the output section is consumed by the high-side MOSFETs and the low-side MOSFETs of the H-bridge.

The power consumption in the MOSFET section of one H-bridge (one axis) can be calculated by the following formula.

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

The average power dissipation of the output block when the output current waveform is a perfect square in the full step excitation is calculated as follows.

When Ron = 0.8Ω, Iout (peak: Max.) = 0.7A, and VM = 24 V,

P (out) = 2 (Tr) × $0.7(A)^2$ ×1.5(Ω)...(2)

= 1.47(W)

2. Power consumption of logic block and IM system

The power consumptions of the logic block and IM system are calculated separately for operating and stand-by conditions.

I (IM3) =5.4mA (typ.) : in operation / axis
I (IM2) =4.8mA (typ.) : in non-operation / axis
I (IM1) =0.03μA (typ.) : stand-by / axis

The output system is connected to VM (24V). (Output system : the combined currents which is consumed by the circuit connected to VM and consumed by switching the output stage.)

Power consumption can be estimated as follows

P (IM3) = 24 (V) × 0.0054(A) ....(3)
=0.13(W)

3. Total power consumption

From the results of 1 and 2, the overall power consumption P is calculated as follows.

P = P (out) + P (IM3) = 1.6 (W)

In addition, the power consumption for one axis during stand-by mode is as follows.

P (stand-by) = 24 (V) ×0.03(μA) = 0.72(μW)

For thermal design of the board, etc., please design with a margin after thorough mounted evaluation.

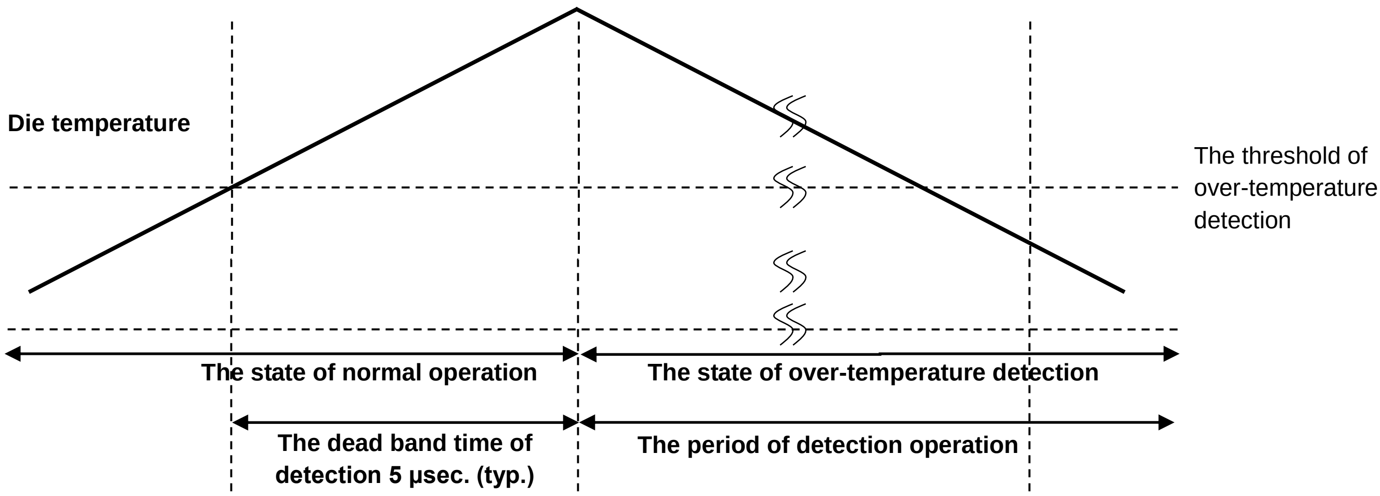
Detection Functions

The following detection functions are built-in.

Detection Function	Detection point	Detection level	Operation at detection	Method of recovery from detection state
Over-temperature detection (TSD)	Die temperature	160°C (typ.) or higher 5.0 μs (typ.) of dead band time provided	The all outputs forced OFF.	These functions are a latch type that maintains the operation at the time of detection. The operation is resumed by one of the following processes. ･To turn on power supply again. ･To set the SLEEP mode once and then set the normal operation mode again.
Over-current detection (ISD)	Output current	3 A (typ.) or more 1.25 μsec. (typ.) of dead band time provided	The all outputs forced OFF.	
Under-voltage lockout (UVLO)	VM pin voltage	4.0V (typ.) or less 1.41 μs (typ.)of dead band time provided	The all outputs forced OFF. Internal circuits are reset.	VM voltage is raised to 4.2V (typ.) or higher.

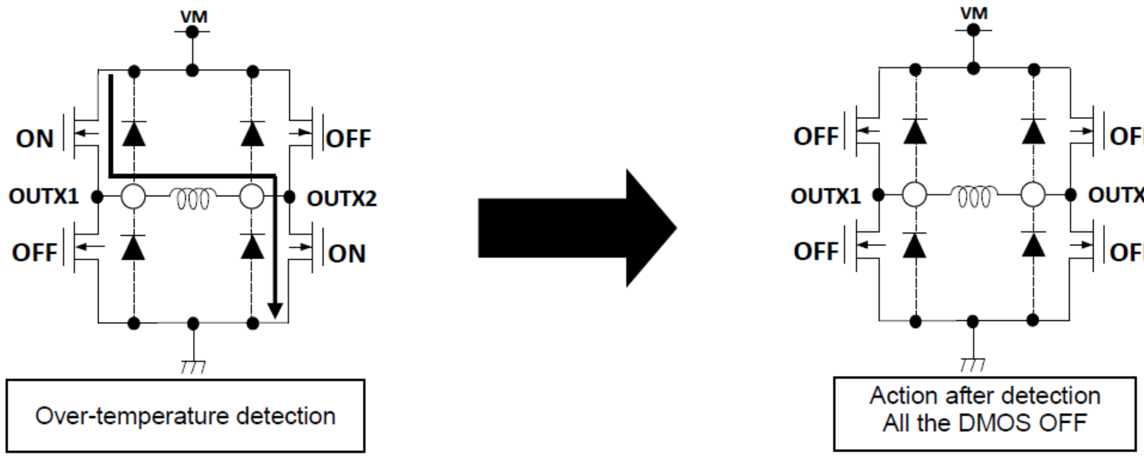
Over-temperature detection (This function is a latch type that maintains operation at the time of detection.)

Over-temperature detection is a function to force the device operation temporarily stop when an abnormal over-heating of the device is detected. A dead band time is provided for the over-temperature detection to prevent false detection caused by external noise. When an over-heating is detected, all the channels are turned off.



The timing chart has been simplified to explain functions and operations. The values in the timing chart are for reference only.

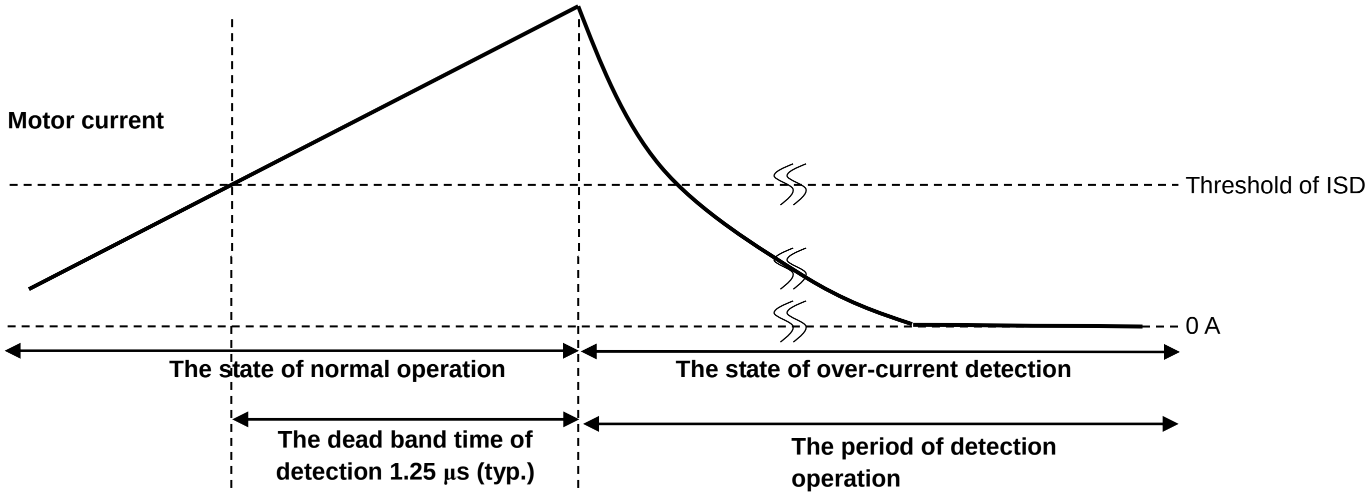
● V



※X=A or B

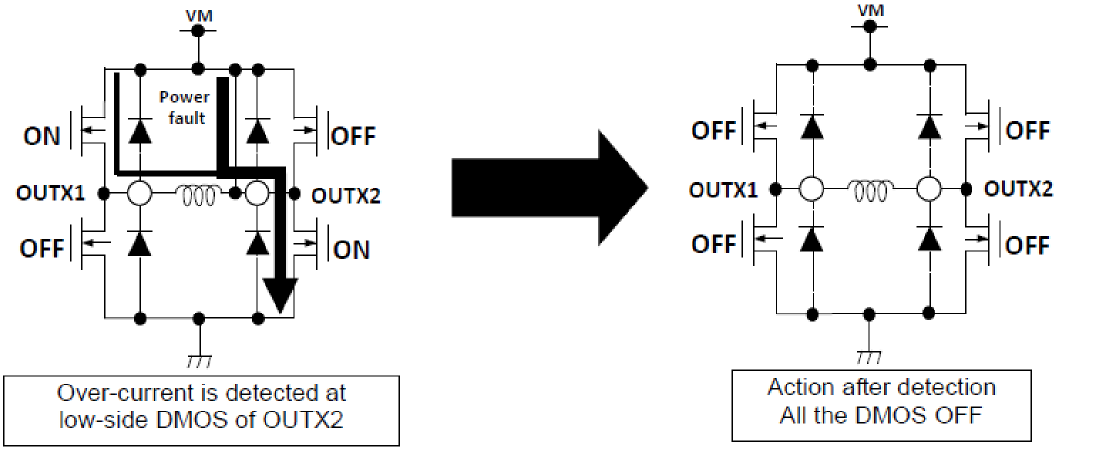
Over-current detection (This function is a latch type that maintains operation at the time of detection.)

Over-current detection is a function to force the device operation temporarily stop in the event of failure conditions such as a short-circuit between motor outputs or a power/ground fault. For over-current detection, a dead band time is provided to prevent false detection caused by spike current during switching or noise jumped in. When an over-current is detected, not only the corresponding channels but also all the channels are turned off.

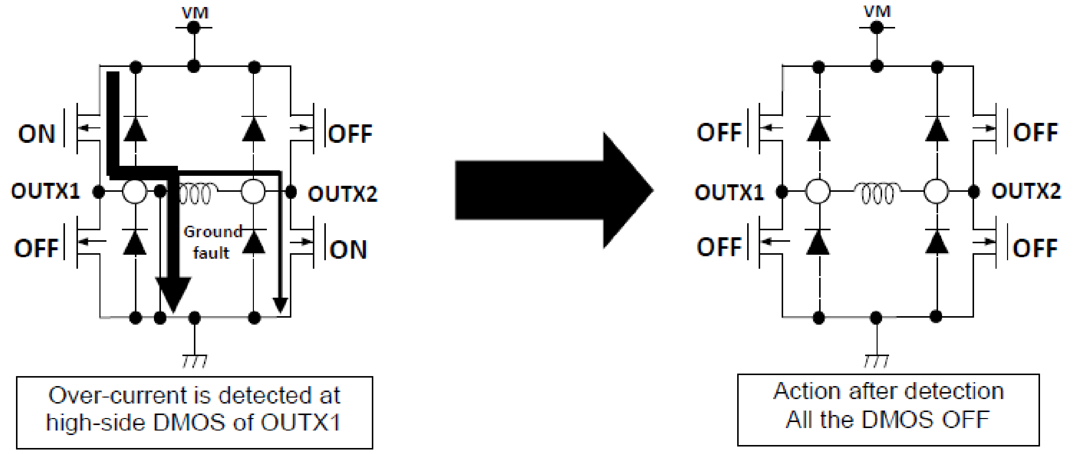


The timing chart has been simplified to explain functions and operations. The values in the timing chart are for reference only.

● When an over-current is detected in the low-side DMOS of the H-bridge caused by a power fault of the output pins.



●When an over-current is detected in the high-side DMOS of the H-bridge caused by a ground fault of the output pins.



※X=A or B

Absolute Maximum Ratings (Ta = 25°C)

Characteristics	Symbol	Rating	Unit
Motor power supply	V_M	35	V
Motor output voltage	V_{OUT}	40	V
Moto output current (Note1)	I_{OUT}	1.5	A
Voltage for internal regulator	V_{CC}	6.0	V
Logic input pin voltage	V_{IN}	6.0	V
V_{ref} reference voltage	V_{ref}	6.0	V
MO and LO pins voltage	V_{MO}	6.0	V
Poe dissipation (Note2)	P_D	0.374	W
Operating temperature	T_{opr}	-40 to 85	°C
Storage temperature	T_{stg}	-55 to 150	°C
Junction temperature	$T_{j(MAX)}$	150	°C

Note 1: The maximum current value under normal conditions should be 1.2 A or less per phase after thermal calculation. This current may be more limited than normal conditions of the heat generation depending on the ambient temperature and board conditions.

Note 2 : IC standalone (Ta = 25°C)
When Ta exceeds 25°C (Ta = 25°C), a derating with 2.992 mW/°C is required.

T_a : Ambient temperature of the device
T_{opr} : The ambient temperature of the device in operation
T_j : Die temperature of the device in operation. the maximum value of Tj is limited by the temperature of TSD (thermal shutdown circuit).

It is recommended that the maximum value of Tj be designed considering the maximum current used, which should be approximately 120°C.

Absolute Maximum Ratings

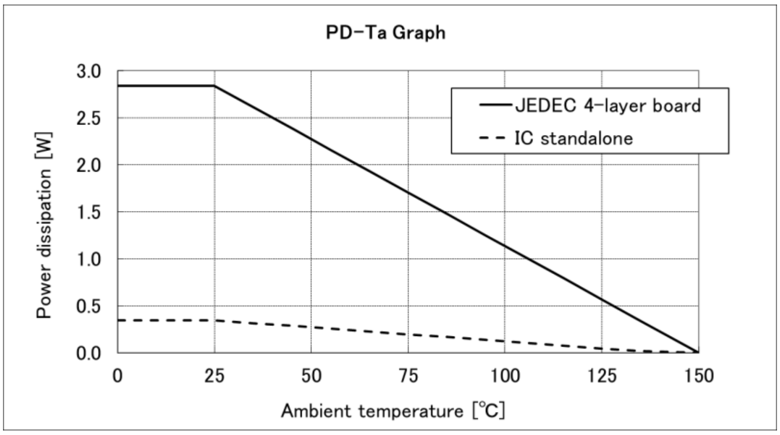
Absolute maximum ratings are the specifications that must not be exceeded even momentarily.

Exceeding the absolute maximum ratings may cause destruction, degradation, or damage to the device, may also cause destruction, damage, or deterioration of other than this device. Design in a manner that none of the parameter exceeds the absolute maximum ratings under any operating conditions.

In addition, as no over-voltage detection circuit is integrated in the TB67S549FTG, the device is destroyed when an excessive voltage above the specified is applied. Therefore, please be sure to use this device within each specified voltage range, including the supply voltage.

Please also refer to the precautions section on the following page for more information on this precaution.

･PD-Ta graph (reference)



Operating Ranges (Ta = -20 to 85°C)

Characteristics	Symbol	Min.	Typ.	Max.	Unit	Remarks
Motor power supply (Note1)	V_M	4.5	24.0	33	V	-
Motor output current	I_{OUT}	-	-	1.2	A	Per channel (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	-
Clock frequency	f_{CLK}	-	-	250	kHz	-
V_{ref} reference voltage	V_{REF}	0	-	3.6	V	-

Note1: For a slew rate of 0 V to 10 V when the power is turned on, use it under the condition of 1 ms or more.
If you use it under different conditions, please evaluate it thoroughly for your product alone or for the entire system, and decide whether or not it is applicable at your own risk.

Note 2: The actual maximum current may be limited by the operating environment (the operating conditions such as excitation mode and operating time, and the heat generating conditions such as ambient temperature conditions and board conditions). Please confirm the maximum current value that can actually be used after a thermal calculation under the operating environment.

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

Characteristics		Symbol	Test condition	Min.	Typ.	Max.	Unit
Logic input pin 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
Input hysteresis		$V_{IN(HYS)}$	Logic input pin (Note)	-	150	-	mV
Logic input pin input current	High	$I_{IN(H)}$	Test logic pin: 5 V	35	50	75	µA
	Low	$I_{IN(L)}$	Test logic pin: 0 V	-	-	1	µA
LO and MO pins output voltage		$V_{OL(MO)}$	IOL=5 mA, Output: Low	-	0.2	0.5	V
Power consumption		I_{M1}	Output: Open, Sleep mode	-	0.03	1	µA
		I_{M2}	Output: Open SLEEP=H, ENABLE=L	-	4.8	5.5	mA
		I_{M3}	Output: Open (Full step resolution) SLEEP=H, ENABLE=H Chopping frequency: 40 kHz	-	5.4	7	mA
Motor output leakage current	上側	I_{OH}	V_M = 35V, V_{OUT} = 0 V	-	-	1	µA
	下側	I_{OL}	V_M = V_{OUT} = 35 V	1	-	-	µA
Output current differential between channels		ΔI_{OUT1}	Output current differential between channels I_{OUT} = 1.0 A	-5	0	5	%
Output set current accuracy		ΔI_{OUT2}	I_{OUT} = 1.0 A	-5	0	5	%
Output transistor between drain and source On resistance (upper + lower)		$R_{ON(D-S)}$	T_j = 25°C I_{OUT} = 2.0 A	-	1.2	1.5	Ω

Note: The V_{IN} voltage applied to the measurement pin is increased from 0 V, and the V_{IN} voltage where the motor output pin voltage changes is defined as $V_{IN(H)}$. And this V_{IN} voltage is lowered, and the V_{IN} voltage where the motor output pin voltage changes is defined as $V_{IN(L)}$.
Furthermore, the difference between $V_{IN(H)}$ and $V_{IN(L)}$ is defined as $V_{IN(HYS)}$.

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

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	0.528	0.556	0.584	-
TSD threshold	T_{jTSD}	-	145	160	175	°C
VM power on reset voltage	V_{MPOR}	-	3.8	4.0	4.2	V
VM power on reset hysteresis	$V_{MPOR(HYS)}$	-	-	200	-	mV
Over-current detection threshold	I_{SD}	-	2.1	3.0	3.6	A

Regarding Back EMF

Power re-circulation timing occurs while a motor is rotating, at which point the motor current is re-circulated to the power supply due to the back EMF of the motor.

In case of insufficient sink capability of the power supply, the power supply pins and the outputs pin of the device may be raised above the rated value.

Since the back EMF of the motor varies depending on the conditions of application and the characteristics of motor, please confirm thoroughly that there is no destruction or no operational problems of the device, and no malfunction or no destruction of peripheral circuits, etc. caused by the back EMF.

Over-current Detection and Over-temperature Detection

・These detection functions are intended to temporarily avoid abnormal conditions such as output short-circuits, and are not intended to guarantee that the device is not destroyed.

・Those detection function do not work outside the guaranteed operating range, and the device may destroyed when the outputs are short-circuited.

・The over-current detection function is intended to detect a temporary short-circuit. When a short-circuit is continued for a long period of time, the device is over-stressed and may be destroyed. The system should be configured to release the over-current state immediately.

Mounting of the device

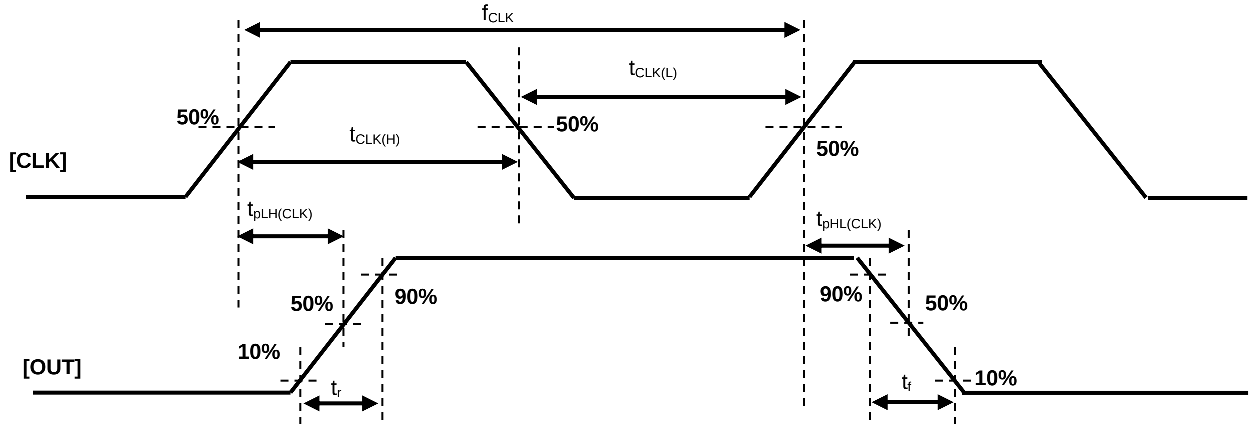
Do not mount the device incorrectly, including rotated mounting, as this may result in destruction, damage, or deterioration of the device or the peripheral circuits.

AC electrical characteristics (T_a = 25°C, V_M = 24V)

Characteristics	Symbol	Test condition	Min.	Typ.	Max.	Unit
Minimum clock pulse width	$t_{CLK(H)}$	-	600	-	-	ns
	$t_{CLK(L)}$	-	600	-	-	ns
Minimum pulse width 1 of logic input signal	$t_{RS(H)}$	RESET、SLEEP_X、DECAY	1.5	-	-	μs
	$t_{RS(L)}$	RESET、SLEEP_X、DECAY	1.5	-	-	μs
Minimum pulse width 2 of logic input signal	$t_{DTE(H)}$	TRQ0/1、ENABLE	600	-	-	ns
	$t_{DTE(L)}$	TRQ0/1、ENABLE	600	-	-	ns
Set-up time	$t_{SU(STEP)}$	CW_CCW、DMODE0/1/2	600	-	-	ns
Hold time	$t_{H(STEP)}$	CW_CCW、DMODE0/1/2	600	-	-	ns
Output transistor switching characteristics	t_r	-	40	70	100	ns
	t_f	-	50	80	110	ns
	$t_{pLH(CLK)}$	-	-	1000	-	ns
	$t_{pHL(CLK)}$	-	-	1000	-	ns
OSCM oscillation frequency	f_{OSCM1}	R_{OSC}=47 kΩ	1020	1200	1380	kHz
	f_{OSCM2}	OSCM pin: Open or connecting to ground	777	914	1051	kHz
Chppling frequency	f_{CHOP}	f_{OSCM} = 1200 kHz	-	75	-	kHz

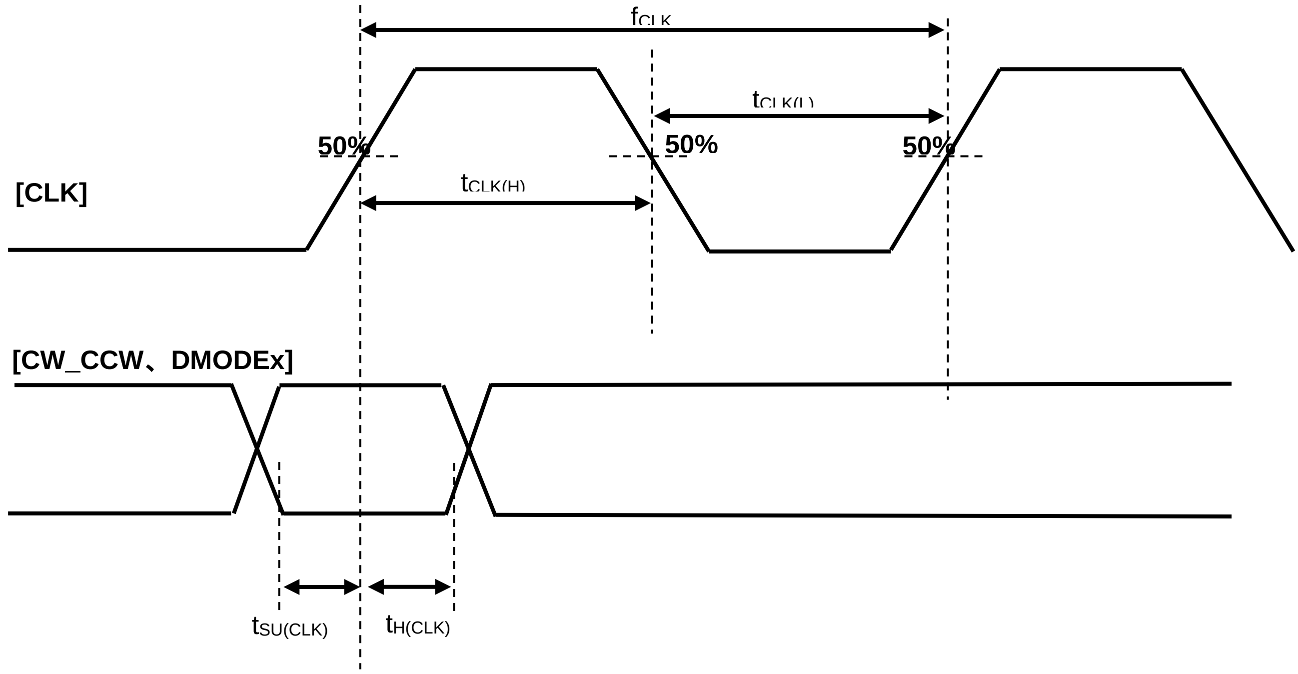
AC Electrical Characteristics Timing Chart

TB67S549FTG (Relationship between CLK and output)



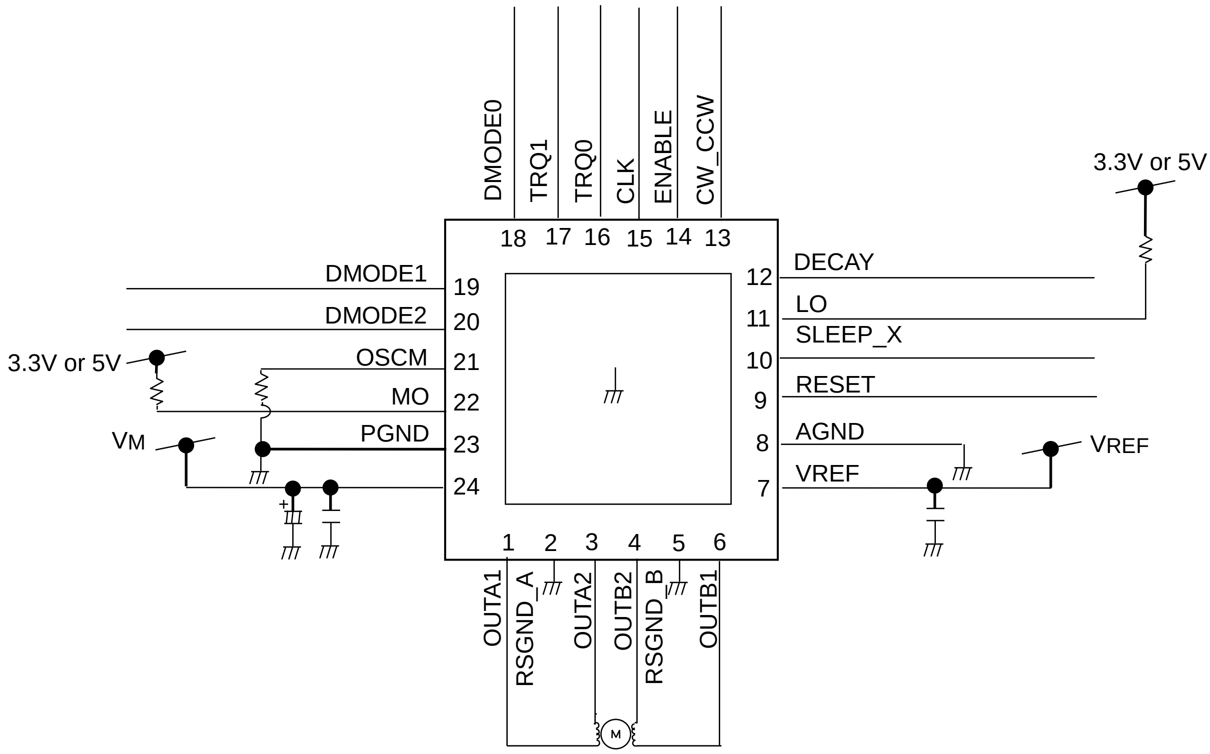
Timing charts are simplified to explain functions and operations.

TB67S549FTG (Relationship between CLK and other control signals)



Timing charts are simplified to explain functions and operations.

Application Circuit Example



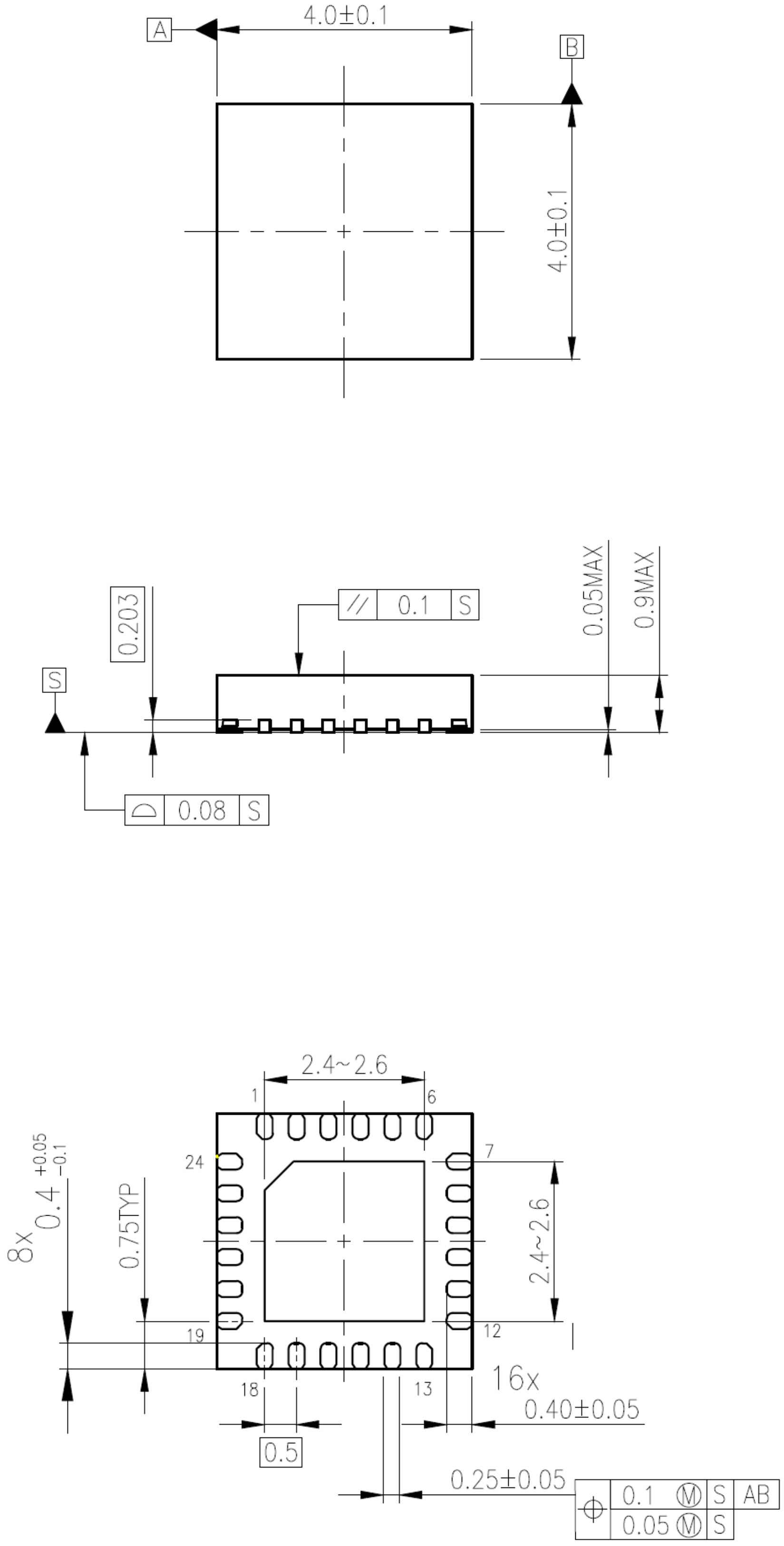
Heat dissipation PAD (the center part) on the back of the package is recommended to connect to the ground of the board for improved heat dissipation.

The application circuit example has been partially omitted or simplified to explain the circuit.

Package Dimensions

P-VQFN24-0404-0.50-004

Unit: mm



Weight: 0.0417 g (typ.)

Note 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 Circuit Example

The application circuits shown in this document are provided for reference purposes only. Thorough evaluation is required, especially at the mass production design stage.
Providing these application circuit examples does not grant a license for industrial property rights.

IC Usage Considerations

Notes on handling of ICs

(1) The absolute maximum ratings of a semiconductor device are a set of ratings that must not be exceeded, even for a moment. Do not exceed any of these ratings.
Exceeding the rating(s) may cause the device breakdown, damage or deterioration, and may result injury by explosion or combustion.

(2) 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, 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

Over-current detection circuit

Over-current detection 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.

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.

Heat radiation design

In using an IC with large current flow such as power amp, regulator or driver, please design the device so that heat is appropriately radiated, not to exceed the specified junction temperature (Tj) at any time and condition. These ICs generate heat even during normal use. An inadequate IC heat radiation design can lead to decrease in IC life, deterioration of IC characteristics or IC breakdown. In addition, please design the device taking into considerate the effect of IC heat radiation with peripheral components.

Back-EMF

When a motor reverses the rotation 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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