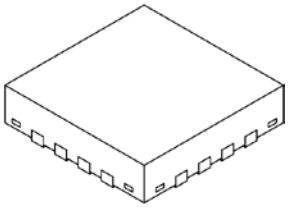
TOSHIBA CD process Integrated Circuit Silicon Monolithic

TC78H670FTG

Clock-in and Serial controlled Bipolar Stepping Motor Driver

1. Outline

The TC78H670FTG is a two-phase bipolar stepping motor driver using a PWM chopper which incorporate DMOS with low on-resistance in output transistors. The clock-in decoder is built in.



P-VQFN16-0303-0.50-001

Weight: 22.9 mg (typ.)

2. Features

- Built-in Dual H Bridges, Capable of controlling 1 bipolar stepping motor
- PWM controlled constant-current drive
- Power supply operating voltage: 2.5 V to 16.0 V
- Output current ratings: 2.0 A (max)
- Low on-resistance (High + Low side = 0.48 Ω (typ.)) MOSFET output stage
- Allows full, half, quarter, 1/8, 1/16, 1/32, 1/64, 1/128 step operation
- Built-in Sense resistor less current control architecture (Advanced Current Detection System)
- Multi error detect functions (Thermal shutdown (TSD), Over current (ISD), motor load open (OPD) and Under voltage lockout(UVLO))
- Error detection (TSD/ISD/OPD) flag output function
- Built-in VCC regulator for internal circuit
- Chopping frequency of a motor can be adjusted by external resistor
- Small QFN package with thermal pad (16pin)

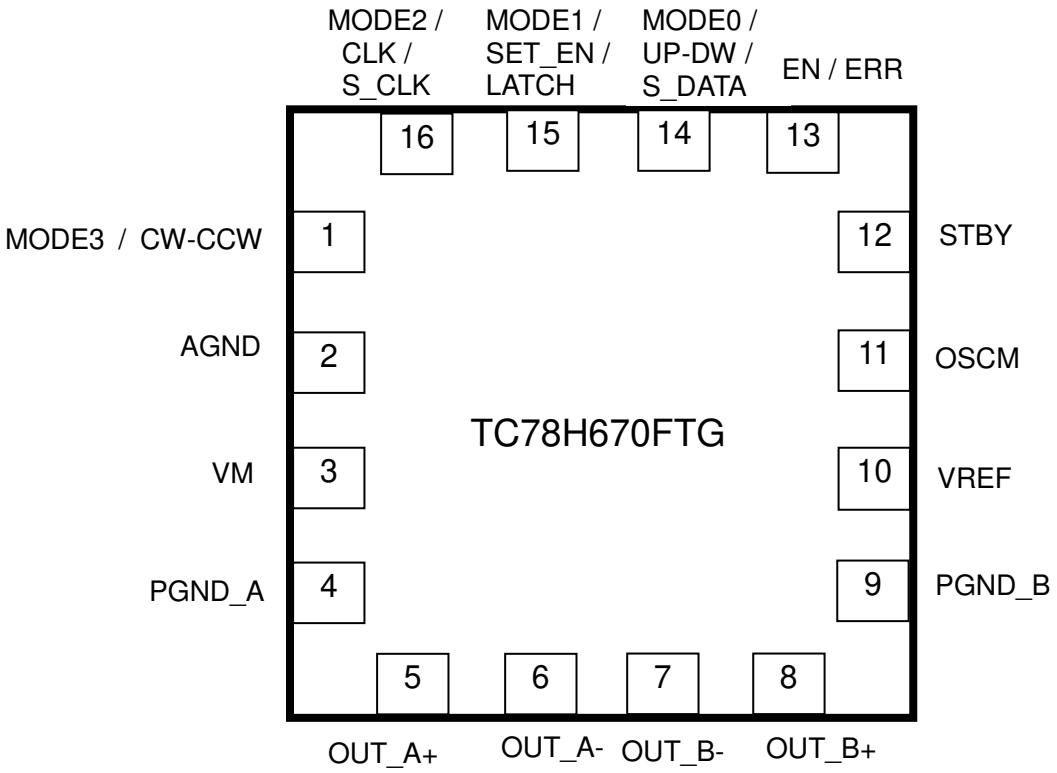
Note: Please be careful about thermal conditions during using.

Note: It is possible to detect OPD only when Serial mode is selected.

Start of commercial production
2020-01

3. Pin Assignment

(Top View)

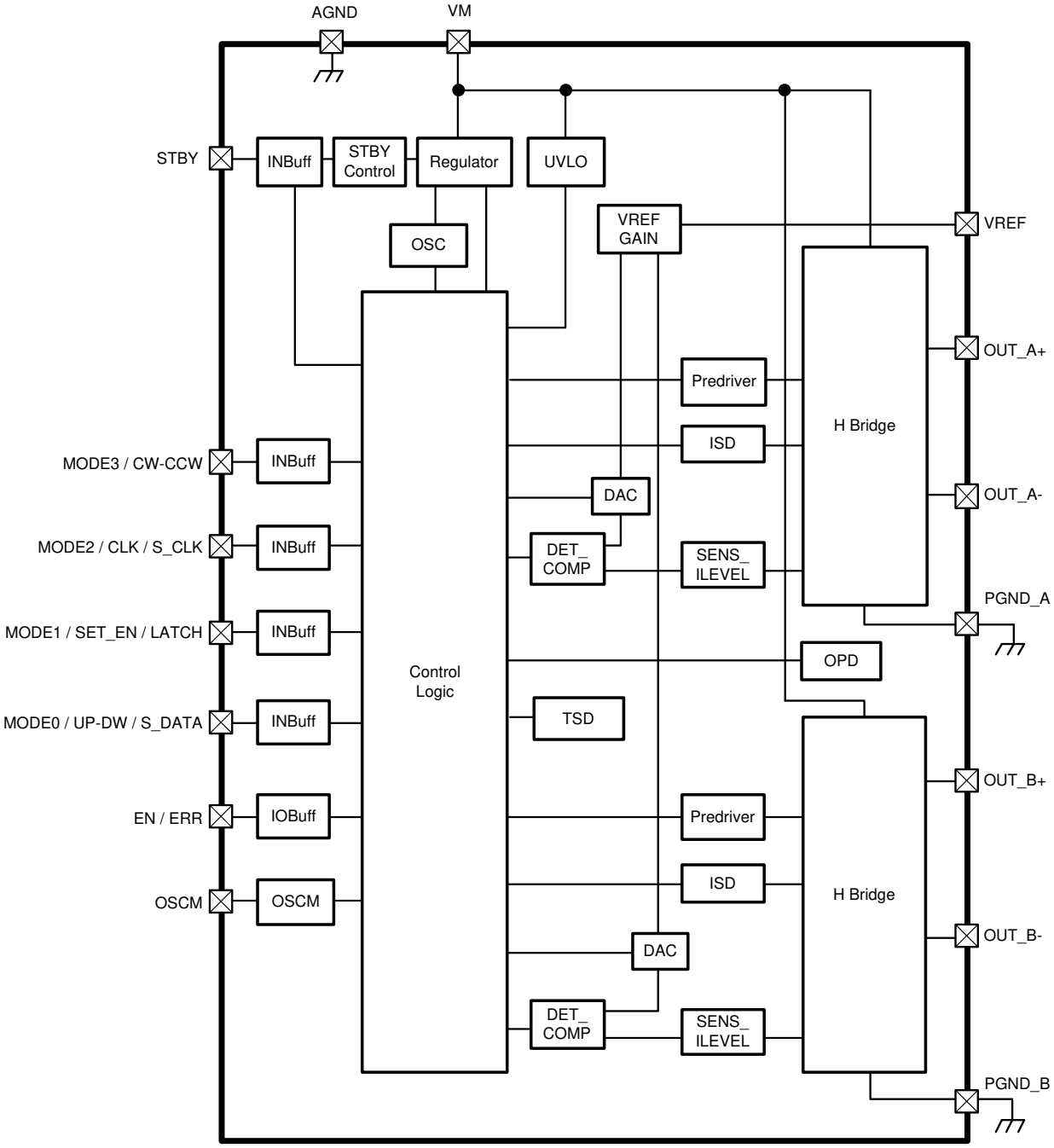


Note: Please solder the corner pads and the rear thermal pad of the QFN package, to the GND pattern of the PCB.

4. Pin Description

Pin No.	STBY = Low	STBY = High		Pin description
		CLK-IN mode	Serial mode	
1	MODE3	CW-CCW	—	MODE3: Step mode select pin CW-CCW: Current direction setup pin
2	AGND	←	←	GND pin
3	VM	←	←	Motor power supply input pin
4	PGND_A	←	←	Ach Power GND pin
5	OUT_A+	←	←	A channel motor output(+) pin
6	OUT_A-	←	←	A channel motor output(-) pin
7	OUT_B-	←	←	B channel motor output(-) pin
8	OUT_B+	←	←	B channel motor output(+) pin
9	PGND_B	←	←	Bch Power GND pin
10	VREF	←	←	Current threshold reference pin
11	OSCM	←	←	Internal oscillator frequency setting pin
12	STBY	←	←	Standby pin
13	EN/ERR	←	←	Enable(Motor output ON/OFF) pin / Error detection flag output pin
14	MODE0	UP-DW	S_DATA	MODE0: Step mode select pin UP-DW: Step mode setting pin S_DATA: Serial data input pin
15	MODE1	SET_EN	LATCH	MODE1: Step mode select pin SET_EN: Step mode setting enable pin LATCH: Latch enable pin
16	MODE2	CLK	S_CLK	MODE2: Step mode select pin CLK: Step Clock input pin S_CLK: Serial clock input pin

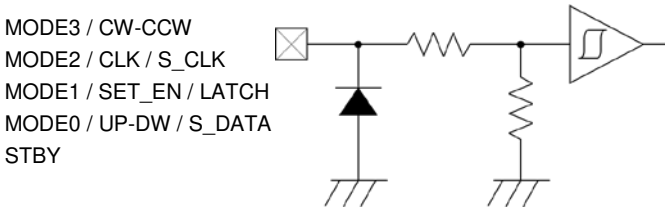
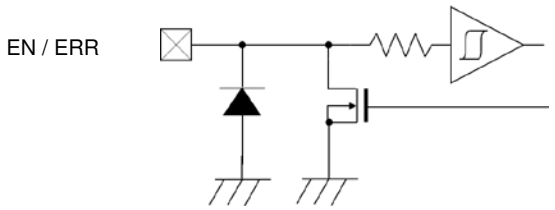
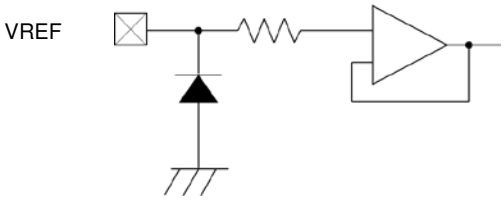
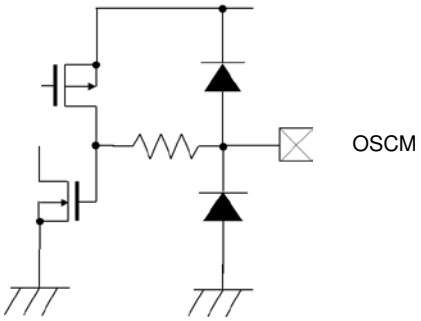
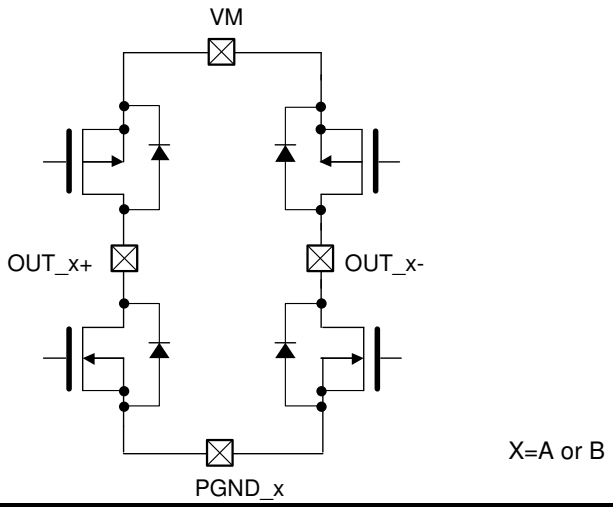
5. Block Diagram



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

Note: All the grounding wires should be solid patterns 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, AGND, PGND_x, OUT_x+ and OUT_x- (x = A or B)) 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 mounting.

6. Input / Output Equivalent Circuit

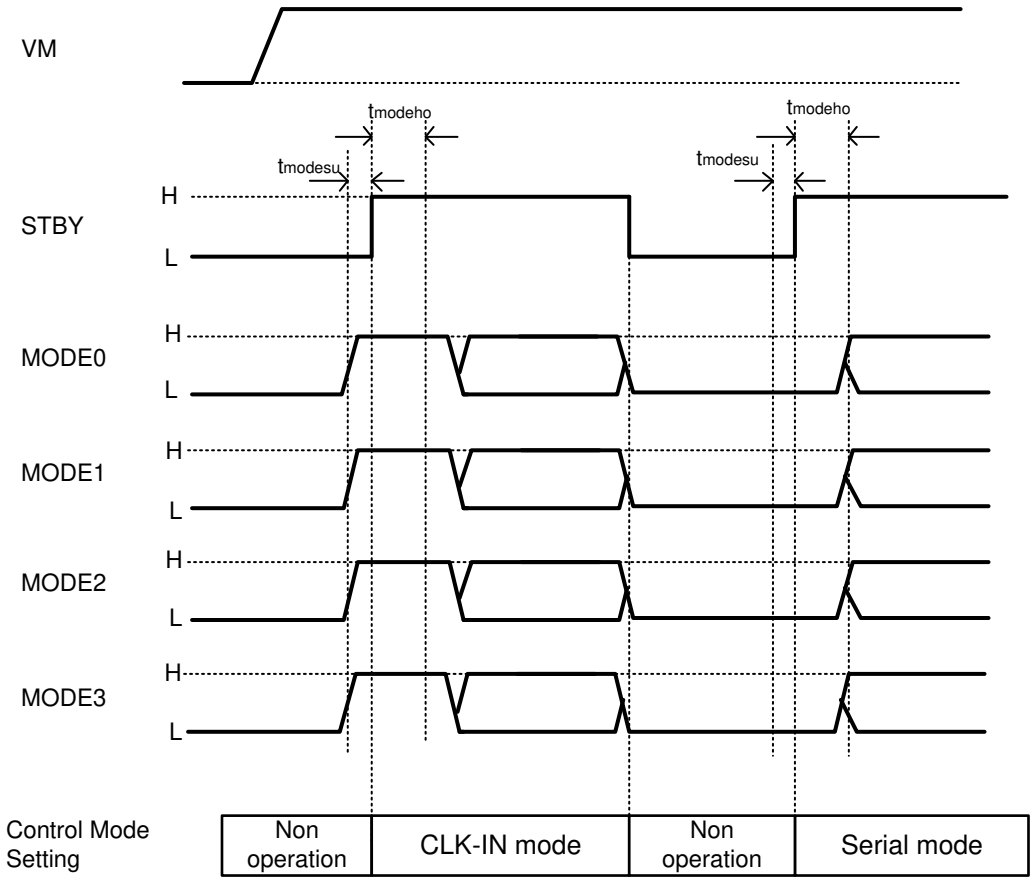
Pin name	Equivalent circuit
MODE3 / CW-CCW MODE2 / CLK / S_CLK MODE1 / SET_EN / LATCH MODE0 / UP-DW / S_DATA STBY	
EN / ERR	
VREF	
OSCM	
OUT_A+ OUT_A- OUT_B+ OUT_B- PGND_A PGND_B	

Note: The equivalent circuit diagrams may be simplified for explanatory purposes.

7. Control Mode Select Function

The MODE0-3 pins set Serial mode or CLK-IN mode.
The control mode is set up by the input state of the MODE0-3 pins after releasing standby mode.

MODE3 pin input	MODE2 pin input	MODE1 pin input	MODE0 pin input	Function
L	L	L	L	Serial mode
Other than the above				CLK-IN mode



Characteristics	Symbol	Test condition	Min	Typ.	Max	Unit
Mode setting Setup time	t_{modesu}	To STBY edge	1	—	—	μs
Mode setting Data hold time	t_{modeho}	From STBY edge	100	—	—	μs

8. Functional Description 1 (for CLK-IN mode)

8.1. CLK Function

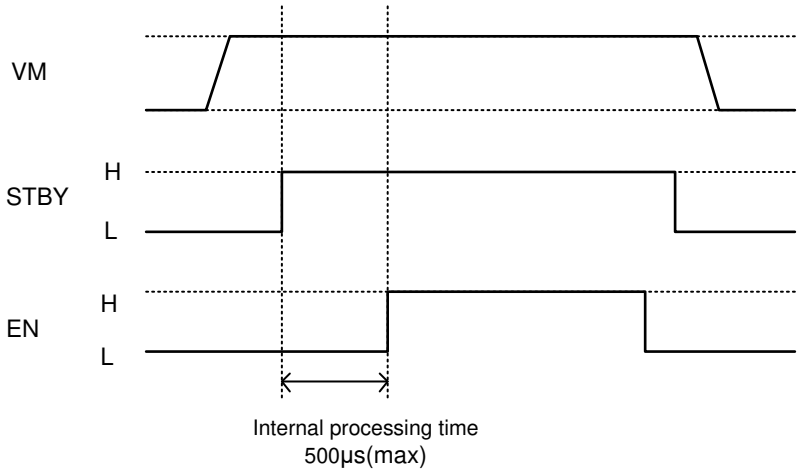
Each up-edge of the CLK signal will shift the motor's electrical angle per step.

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

8.2. ENABLE Function

The EN pin controls the ON and OFF of the stepping motor outputs. Motor operation starts and stops by setting H and L to the EN pin.
(When the EN pin is set to L (OFF), all of the MOSFETs turn off and become high impedance (hereafter, Hi-Z).)
Setting the EN pin to L, and avoiding the motor to operate during VM power-on and power-off (i.e., outside of the operating voltage range) is recommended. Then, switch the EN pin to H after the VM reaches the target voltage and becomes stable.
The EN pin should input High level through a resistor.

EN pin input	Function
L	OFF (Hi-Z)
H	ON (Normal operation mode)



8.3. CW-CCW Function

CW-CCW pin controls the rotation direction of the motor.

CW-CCW pin input	Function
L	Counter clockwise operation (CCW)
H	Clockwise operation (CW)

8.4. Step Resolution Select Function

Step resolution is set up. TC78H670FTG has the two modes, Variable Mode and Fixed Mode. These modes are set up by the input state of MODE0-3 pins after releasing standby mode.

Variable Mode: Variable mode can be started with Full step resolution and changed step resolution during motor operating
Fixed Mode: Fixed mode can be started with the mode user selected and continued it during motor operating

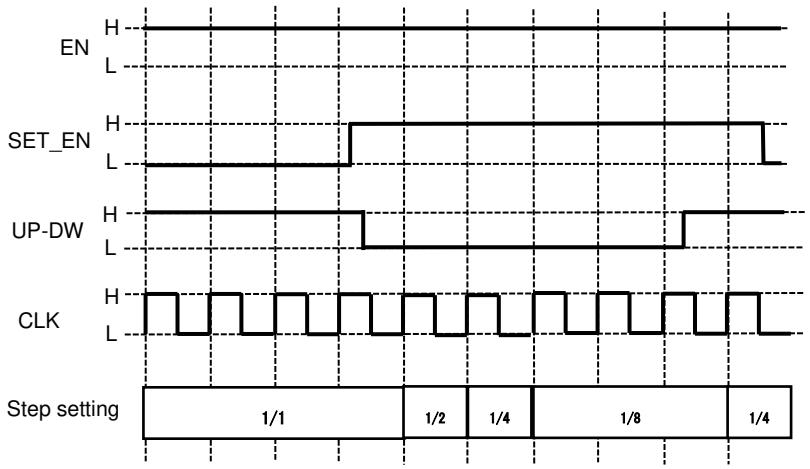
MODE3 pin input	MODE2 pin input	MODE1 pin input	MODE0 pin input	Mode	Function
L	L	L	H	Variable Mode	Full step resolution <-> 1/2 step resolution (2-phase excitation) (1-2-phase excitation)
L	L	H	L		Full step resolution <-> 1/4 step resolution (2-phase excitation) (W1-2-phase excitation)
L	L	H	H		Full step resolution <-> 1/8 step resolution (2-phase excitation) (2W1-2-phase excitation)
L	H	L	L		Full step resolution <-> 1/16 step resolution (2-phase excitation) (4W1-2-phase excitation)
L	H	L	H		Full step resolution <-> 1/32 step resolution (2-phase excitation) (8W1-2-phase excitation)
L	H	H	L		Full step resolution <-> 1/64 step resolution (2-phase excitation) (16W1-2-phase excitation)
L	H	H	H		Full step resolution <-> 1/128 step resolution (2-phase excitation) (32W1-2-phase excitation)
H	L	L	L	Fixed Mode	Full step resolution (2-phase excitation)
H	L	L	H		1/2 step resolution (1-2-phase excitation)
H	L	H	L		1/4 step resolution (W1-2-phase excitation)
H	L	H	H		1/8 step resolution (2W1-2-phase excitation)
H	H	L	L		1/16 step resolution (4W1-2-phase excitation)
H	H	L	H		1/32 step resolution (8W1-2-phase excitation)
H	H	H	L		1/64 step resolution (16W1-2-phase excitation)
H	H	H	H		1/128 step resolution (32W1-2-phase excitation)

When Step mode is changed during operating, Step resolution can be set by SET_EN pin and UP-DW pin.
Step mode is changed synchronously with Step Clock.

SET_EN pin input	Function
L	Setting step mode is invalid
H	Setting step mode is available

UP-DW pin input	Function
L	Change step mode to high resolution
H	Change step mode to Low resolution

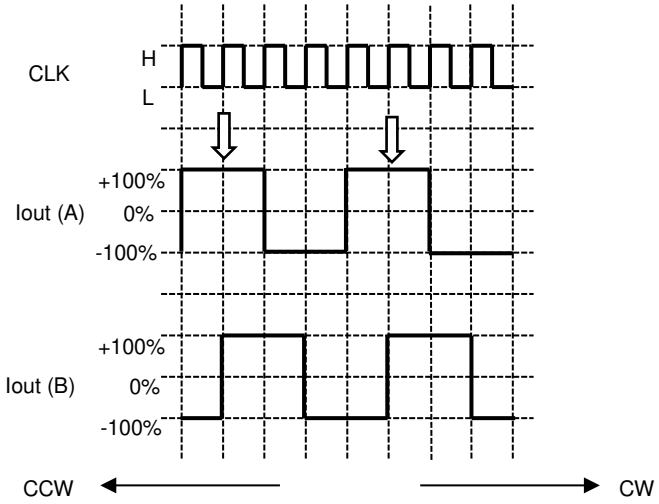
[Example: Full Step <-> 1/8 Step]



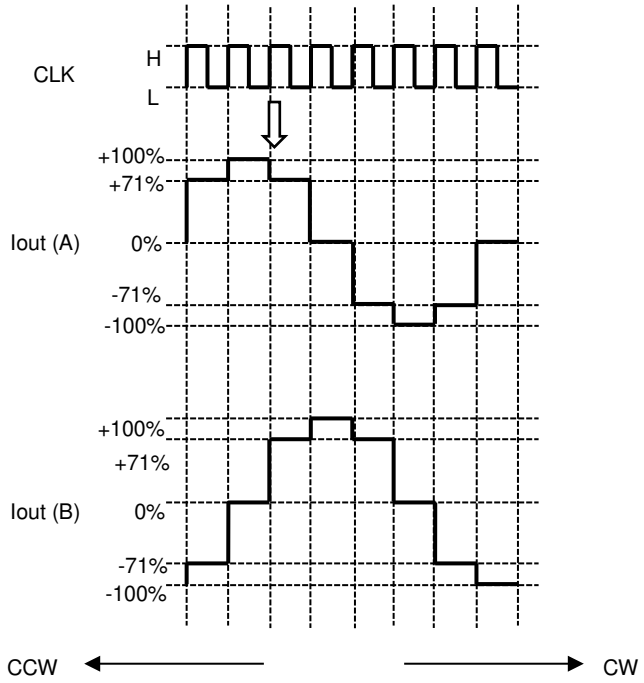
8.5. Timing Chart of Step Resolution Setting and Initial Angle

The arrow in the below figures indicates the timing of initial angle.

[Full step resolution]

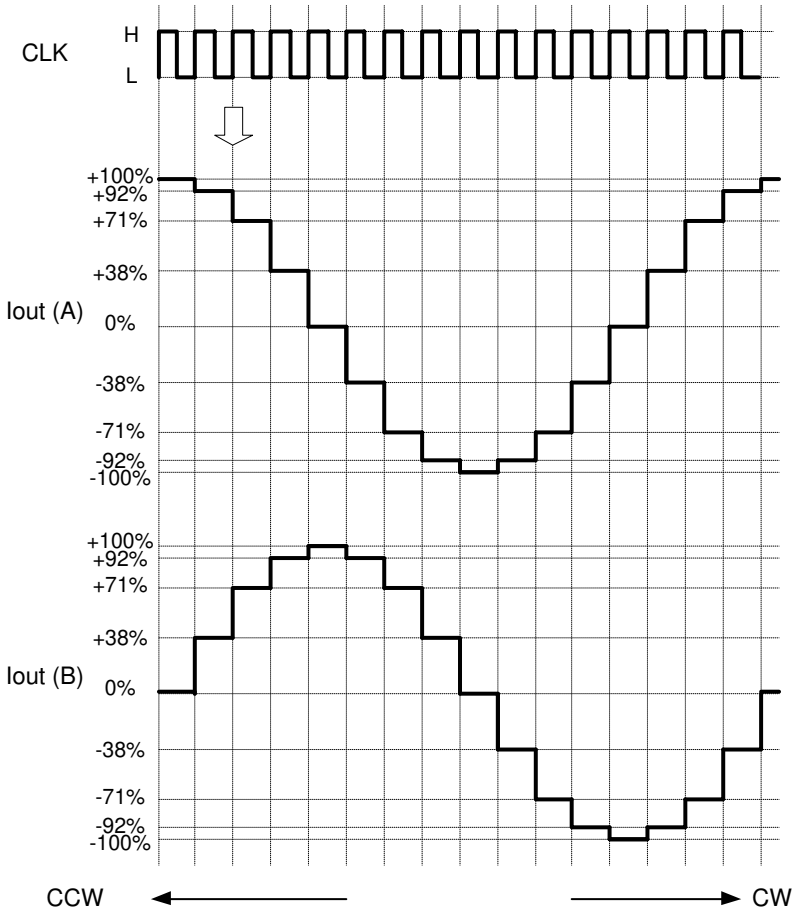


[1/2 step resolution]



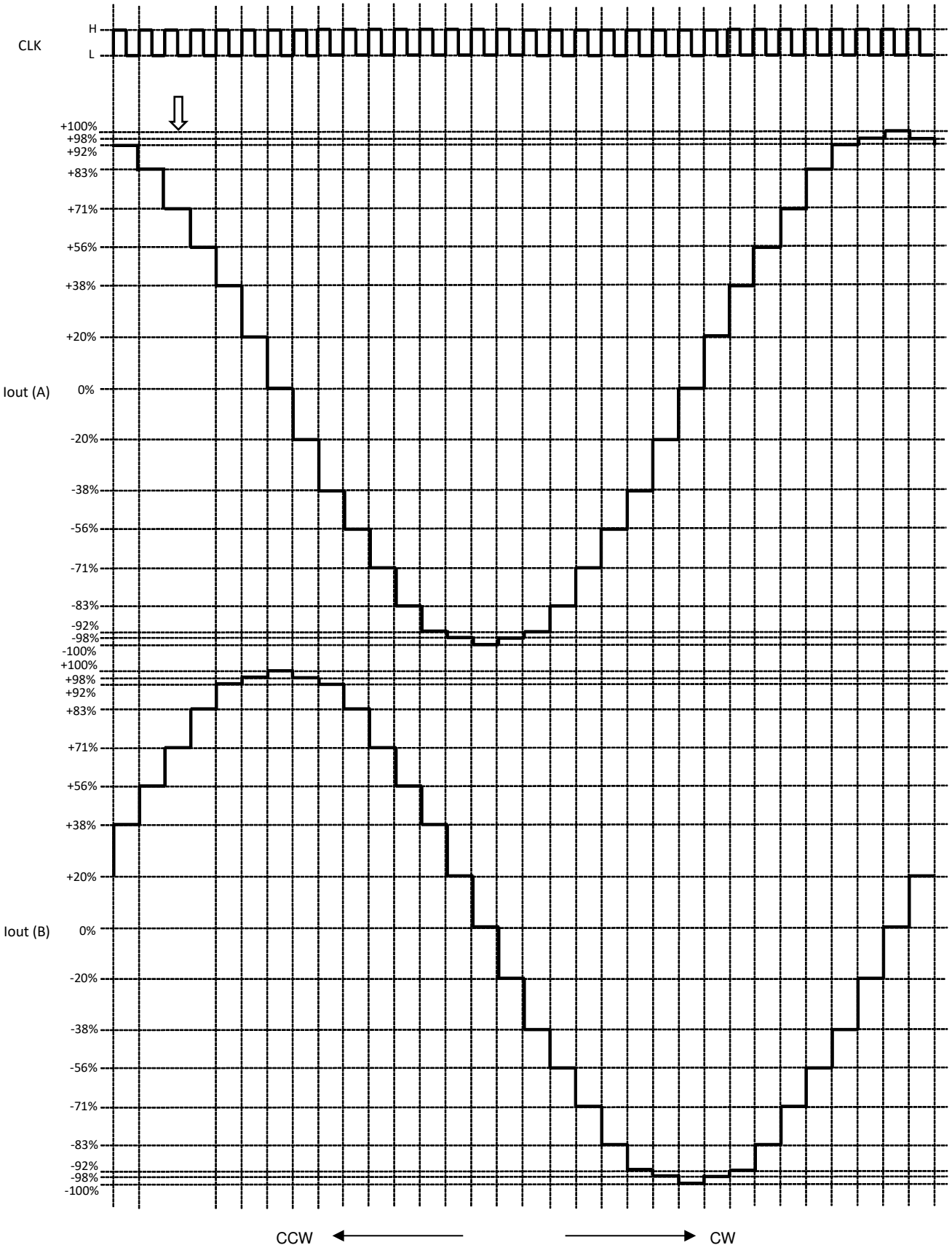
Note: Timing charts may be simplified for explanatory purpose.

[1/4 step resolution]



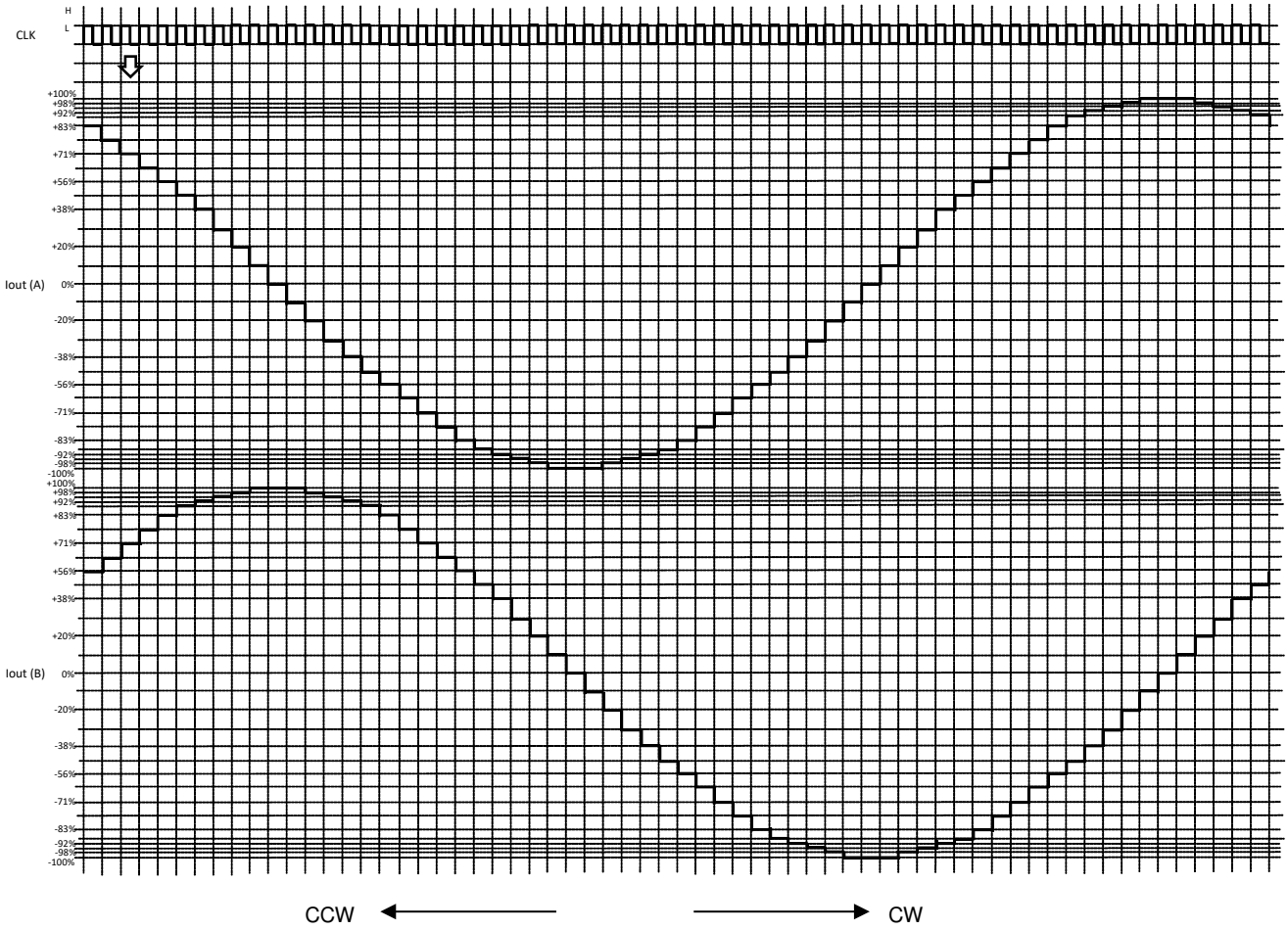
Note: Timing charts may be simplified for explanatory purpose.

[1/8 step resolution]



Note: Timing charts may be simplified for explanatory purpose.

[1/16 step resolution]



Note: Timing charts may be simplified for explanatory purpose.

8.6. Step Setting and Current Percentage

Current (%)	1/1	1/2	1/4	1/8	1/16	1/32	1/64	1/128
100%	○	○	○	○	○	○	○	○
99%					○	○	○	○
98%				○	○	○	○	○
97%					○	○	○	○
96%				○	○	○	○	○
95%							○	○
94%						○	○	○
93%							○	○
92%						○	○	○
91%							○	○
90%					○	○	○	○
89%							○	○
88%						○	○	○
87%							○	○
86%						○	○	○
85%								○
84%							○	○
83%				○	○	○	○	○
82%							○	○
81%								○
80%						○	○	○
79%							○	○
78%								○
77%					○	○	○	○
76%							○	○
75%								○
74%						○	○	○
73%								○
72%							○	○
71%		○	○	○	○	○	○	○
70%								○
69%							○	○
68%								○
67%						○	○	○
66%								○
65%							○	○
64%								○
63%					○	○	○	○
62%							○	○
61%								○
60%						○	○	○
59%								○
58%							○	○
57%								○
56%				○	○	○	○	○
55%								○
53%							○	○
52%								○

Current (%)	1/1	1/2	1/4	1/8	1/16	1/32	1/64	1/128
51%						○	○	○
50%								○
49%							○	○
48%								○
47%					○	○	○	○
46%								○
45%							○	○
44%								○
43%						○	○	○
42%								○
41%							○	○
39%								○
38%			○	○	○	○	○	○
37%								○
36%							○	○
35%								○
34%						○	○	○
33%								○
31%							○	○
30%								○
29%					○	○	○	○
28%								○
27%							○	○
25%						○		○
24%							○	○
23%								○
22%							○	○
21%								○
20%				○	○	○	○	○
18%								○
17%							○	○
16%								○
15%						○	○	○
13%								○
12%							○	○
11%								○
10%					○	○	○	○
9%								○
7%							○	○
6%								○
5%						○	○	○
4%								○
2%							○	○
1%								○
0%		○	○	○	○	○	○	○

8.7. Step Resolution and Set Current

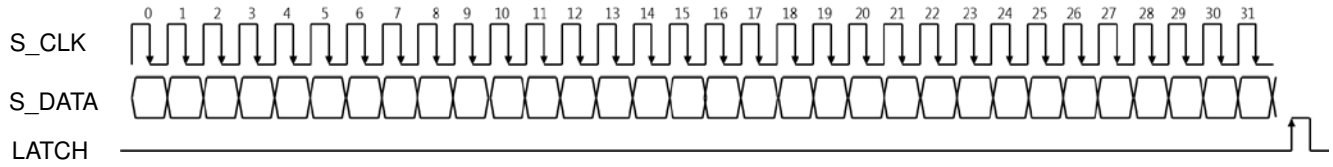
STEP	1/128		1/64		1/32		1/16		1/8		1/4		1/2		Full	
—	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)
θ0	100	0	100	0	100	0	100	0	100	0	100	0	100	0		
θ1	100	1														
θ2	100	2	100	2												
θ3	100	4														
θ4	100	5	100	5	100	5										
θ5	100	6														
θ6	100	7	100	7												
θ7	100	9														
θ8	100	10	100	10	100	10	100	10								
θ9	99	11														
θ10	99	12	99	12												
θ11	99	13														
θ12	99	15	99	15	99	15										
θ13	99	16														
θ14	99	17	99	17												
θ15	98	18														
θ16	98	20	98	20	98	20	98	20	98	20						
θ17	98	21														
θ18	98	22	98	22												
θ19	97	23														
θ20	97	24	97	24	97	24										
θ21	97	25														
θ22	96	27	96	27												
θ23	96	28														
θ24	96	29	96	29	96	29	96	29								
θ25	95	30														
θ26	95	31	95	31												
θ27	95	33														
θ28	94	34	94	34	94	34										
θ29	94	35														
θ30	93	36	93	36												
θ31	93	37														
θ32	92	38	92	38	92	38	92	38	92	38	92	38				
θ33	92	39														
θ34	91	41	91	41												
θ35	91	42														
θ36	90	43	90	43	90	43										
θ37	90	44														
θ38	89	45	89	45												
θ39	89	46														
θ40	88	47	88	47	88	47	88	47								
θ41	88	48														

STEP	1/128		1/64		1/32		1/16		1/8		1/4		1/2		Full	
—	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)
042	87	49	87	49												
043	86	50														
044	86	51	86	51	86	51										
045	85	52														
046	84	53	84	53												
047	84	55														
048	83	56	83	56	83	56	83	56	83	56						
049	82	57														
050	82	58	82	58												
051	81	59														
052	80	60	80	60	80	60										
053	80	61														
054	79	62	79	62												
055	78	62														
056	77	63	77	63	77	63	77	63								
057	77	64														
058	76	65	76	65												
059	75	66														
060	74	67	74	67	74	67										
061	73	68														
062	72	69	72	69												
063	72	70														
064	71	71	71	71	71	71	71	71	71	71	71	71	71	71	100	100
065	70	72														
066	69	72	69	72												
067	68	73														
068	67	74	67	74	67	74										
069	66	75														
070	65	76	65	76												
071	64	77														
072	63	77	63	77	63	77	63	77								
073	62	78														
074	62	79	62	79												
075	61	80														
076	60	80	60	80	60	80										
077	59	81														
078	58	82	58	82												
079	57	82														
080	56	83	56	83	56	83	56	83	56	83						
081	55	84														
082	53	84	53	84												
083	52	85														
084	51	86	51	86	51	86										
085	50	86														

STEP	1/128		1/64		1/32		1/16		1/8		1/4		1/2		Full	
—	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)	Ach (%)	Bch (%)
θ86	49	87	49	87												
θ87	48	88														
θ88	47	88	47	88	47	88	47	88								
θ89	46	89														
θ90	45	89	45	89												
θ91	44	90														
θ92	43	90	43	90	43	90										
θ93	42	91														
θ94	41	91	41	91												
θ95	39	92														
θ96	38	92	38	92	38	92	38	92	38	92	38	92				
θ97	37	93														
θ98	36	93	36	93												
θ99	35	94														
θ100	34	94	34	94	34	94										
θ101	33	95														
θ102	31	95	31	95												
θ103	30	95														
θ104	29	96	29	96	29	96	29	96								
θ105	28	96														
θ106	27	96	27	96												
θ107	25	97														
θ108	24	97	24	97	24	97										
θ109	23	97														
θ110	22	98	22	98												
θ111	21	98														
θ112	20	98	20	98	20	98	20	98	20	98						
θ113	18	98														
θ114	17	99	17	99												
θ115	16	99														
θ116	15	99	15	99	15	99										
θ117	13	99														
θ118	12	99	12	99												
θ119	11	99														
θ120	10	100	10	100	10	100	10	100								
θ121	9	100														
θ122	7	100	7	100												
θ123	6	100														
θ124	5	100	5	100	5	100										
θ125	4	100														
θ126	2	100	2	100												
θ127	1	100														
θ128	0	100	0	100	0	100	0	100	0	100	0	100	0	100		

9. Functional Description 2 (for Serial mode)

Under the serial mode, it performs setting and motor control in the following 32-bit format.
For the motor control, each current value is set in the serial setting, and the output is updated to the set current value at the timing of the LATCH signal.



D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15
MDT_A0	MDT_A1	PHA	CA0	CA1	CA2	CA3	CA4	CA5	CA6	CA7	CA8	CA9	—	—	—

D16	D17	D18	D19	D20	D21	D22	D23	D24	D25	D26	D27	D28	D29	D30	D31
MDT_B0	MDT_B1	PHB	CB0	CB1	CB2	CB3	CB4	CB5	CB6	CB7	CB8	CB9	TRQ0	TRQ1	OPD

Note: Every issuing a command, the current setting transfers by one step.

9.1. Register

The registers to use the serial control are shown below.

9.1.1. PHx (x = A or B)

The polality of the output current can be selected by PHx registers for each channel.

PHx	Function
L	Setting the direction of the output current to minus * Default
H	Setting the direction of the output current to plus

9.1.2. Cx0 to Cx9 (x = A or B)

The output of each channel's DAC for current limitation can be set by Cx0 to Cx9 registers.
The relation between Setting DAC and the output current (Iout) are shown below.

$$\text{Iout (Max)} = \text{Vref (V)} \times \frac{\text{Cx[9:0]}}{1023} \times \text{Setting torque by the torque function (\%)}$$

9.1.3. TRQ0 and TRQ1

The value of the motor torque can be set by TRQ0 and TRQ1 registers.

TRQ1	TORQ0	Function
L	L	Torque setting: 100% * Default
L	H	Torque setting: 75%
H	L	Torque setting: 50%
H	H	Torque setting: 25%

9.1.4. OPD

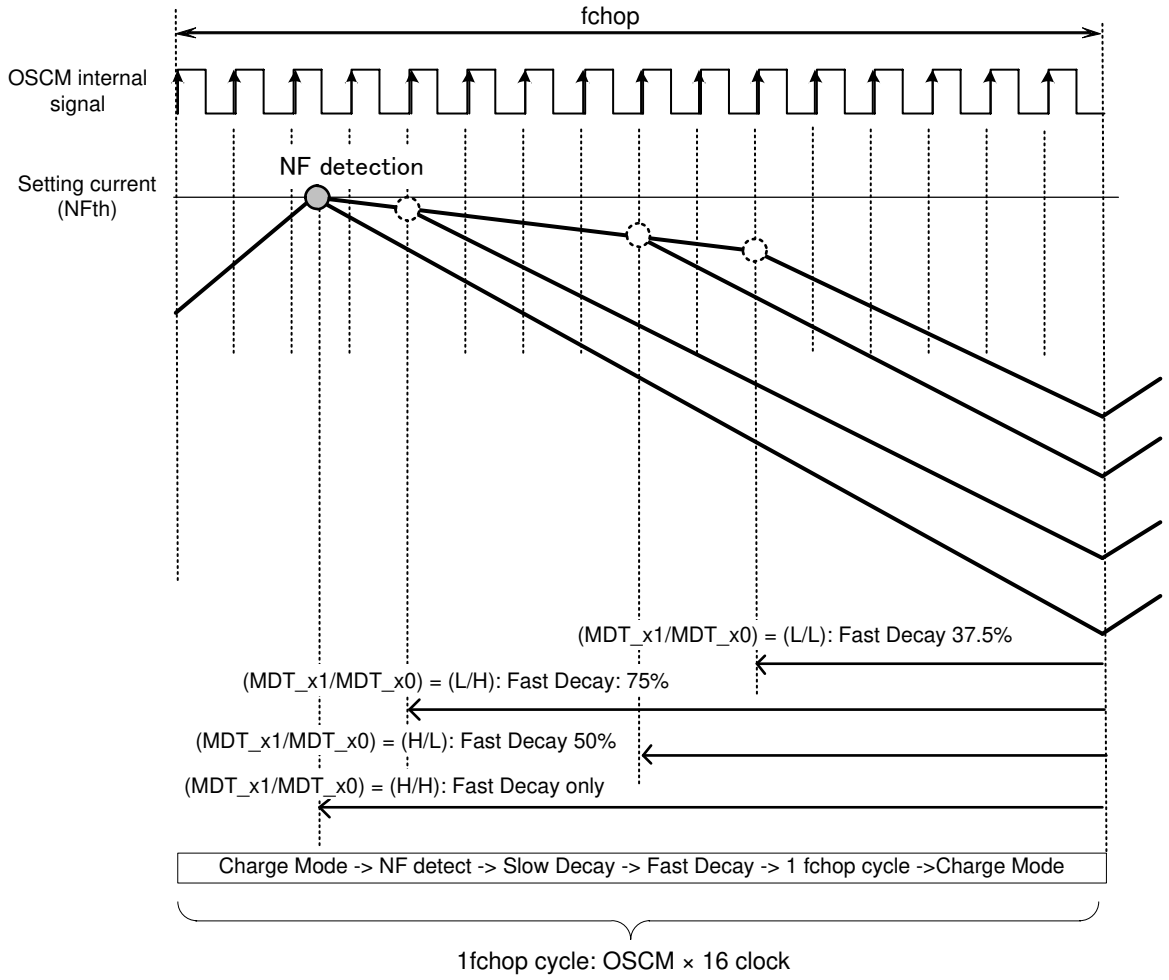
An ON/OFF of the open detection function of motor output pins can be switched by OPD register.

OPD	Function
L	Open detection OFF * Default
H	Open detection ON

9.1.5. Selectable Mixed Decay Function MDT_x0 and MDT_x1 (x = A or B)

The Selectable Mixed Decay can adjust the current regeneration amount during the period of current regeneration. Though the Mixed Decay is determined by controlling 2 different types of Decay (Fast Decay and Slow Decay), this function enables the user to select the ratio of the Mixed Decay using MDT_x0 and MDT_x1 register.

MDT_x1	MDT_x0	Function
L	L	Fast Decay: 37.5% (Fast Decay = OSCM × 6) * Default
L	H	Fast Decay: 75%
H	L	Fast Decay: 50%
H	H	Fast Decay only



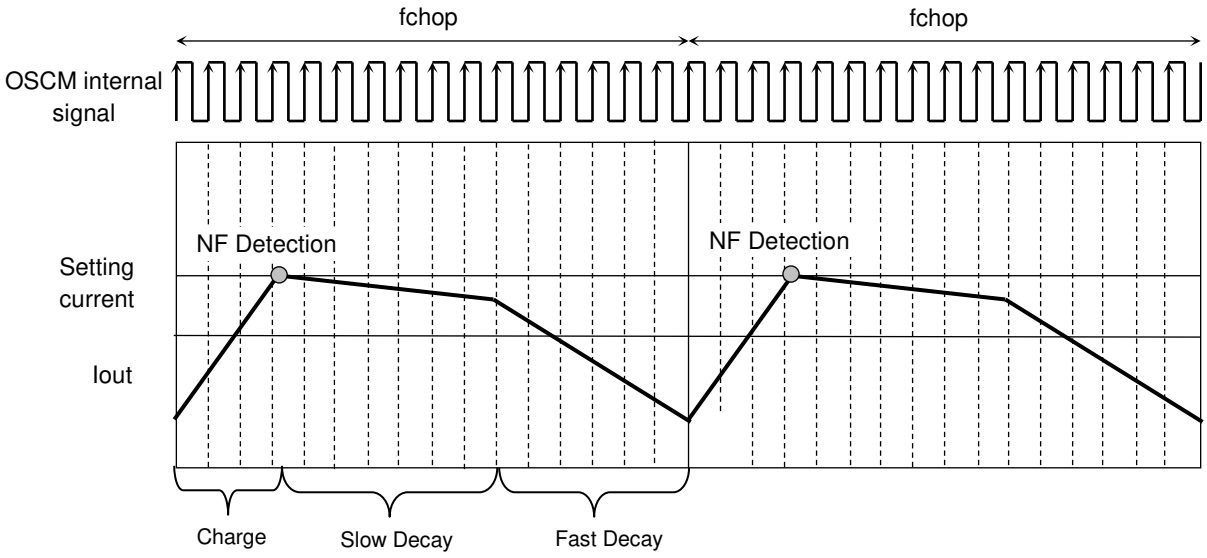
Note: x = A or B

Note: Decay control is controlled in order of Charge, Slow Decay and Fast Decay.

Note: The blanking time(AtBLK) is also set to prevent an incorrect operation in the NF detection (the motor current reaches the set current value (NFth))..

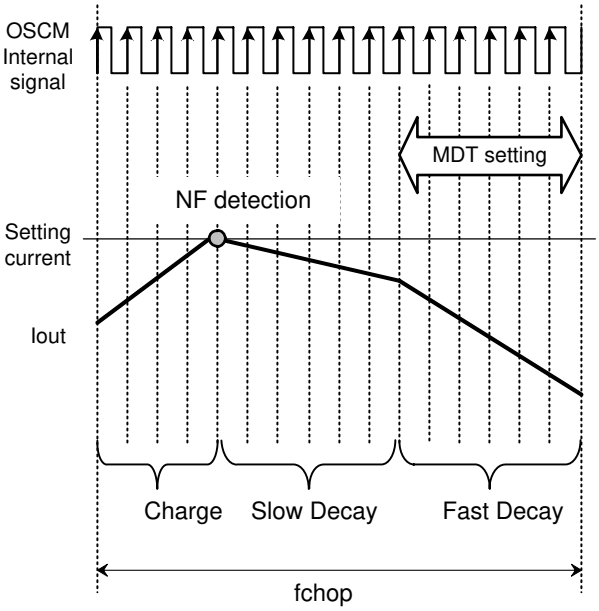
Note: Timing charts may be simplified for explanatory purpose.

9.1.5.1. Mixed Decay Waveform (Current Waveform) *Charge → Slow Decay → Fast Decay

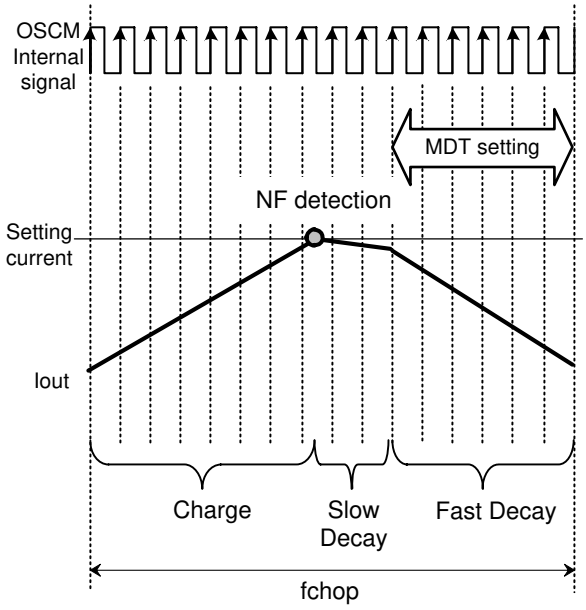


Note: Timing charts may be simplified for explanatory purpose.

9.1.5.2. Constant Current PWM Function and Timings *Charge → Slow Decay → Fast Decay



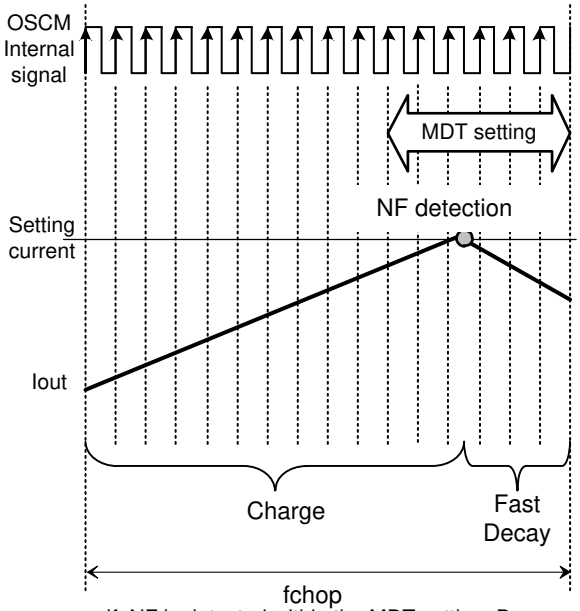
If the NF is detected during the early timing of the fchop cycle, the Slow Decay will be longer.



If the NF is detected during the late timing of the fchop cycle, the Slow Decay will be shorter.

The Charge period (the time until the motor current reaches the set current value) is determined by the operating status. Therefore the NF detection timing (the motor current reaches the set current value) with the chopping cycle (fchop) may change. If NF is detected in the early period of the fchop cycle, the Slow Decay will be longer. If NF is detected in the late period of the fchop cycle, the Slow Decay will be shorter, as shown above.

Note: The chopping cycle is determined as: fchop - (Charge + Fast Decay) = Slow Decay
(Fast Decay ratio can be changed by MDT_x0 and MDT_x1 (x = A or B) registers setting.)

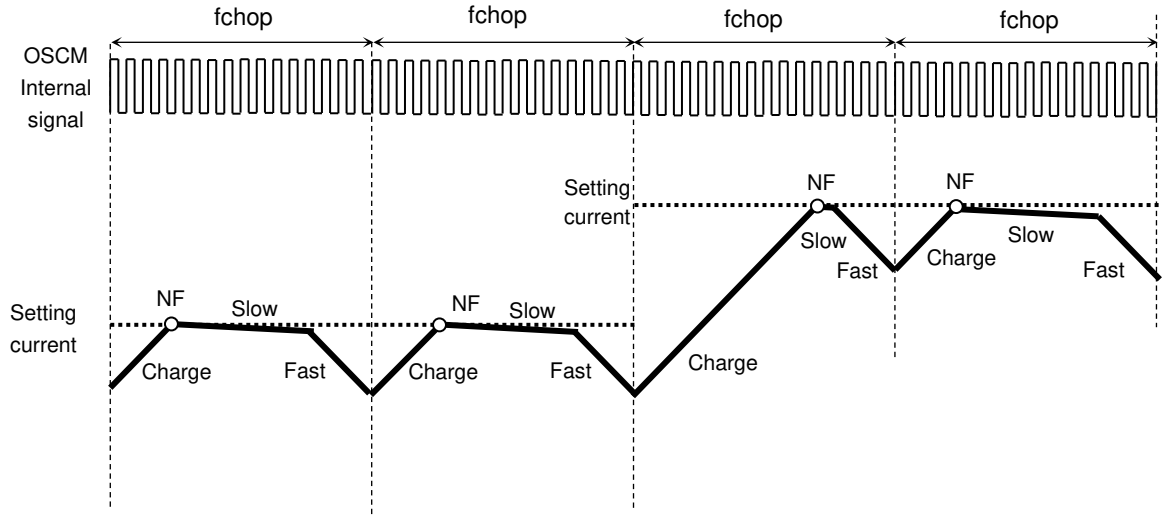


If NF is detected within the MDT setting, Decay sequence will only be Fast Decay.(Slow Decay does not appear.)

Note: Timing charts may be simplified for explanatory purpose.

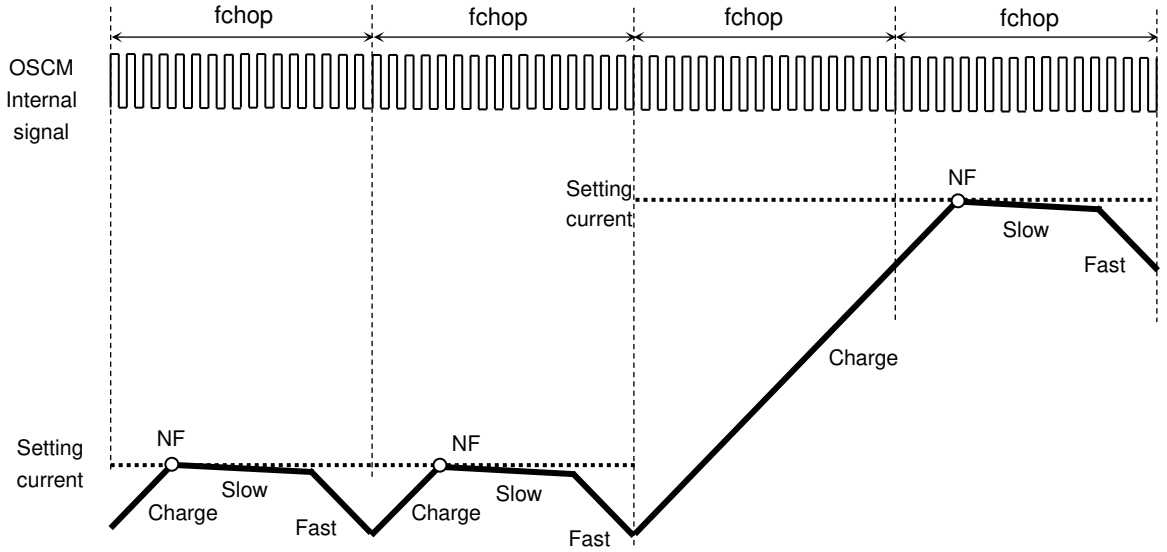
9.1.5.3. Mixed Decay current waveform *Charge → Slow Decay → Fast Decay

- **When the next current step is higher:**

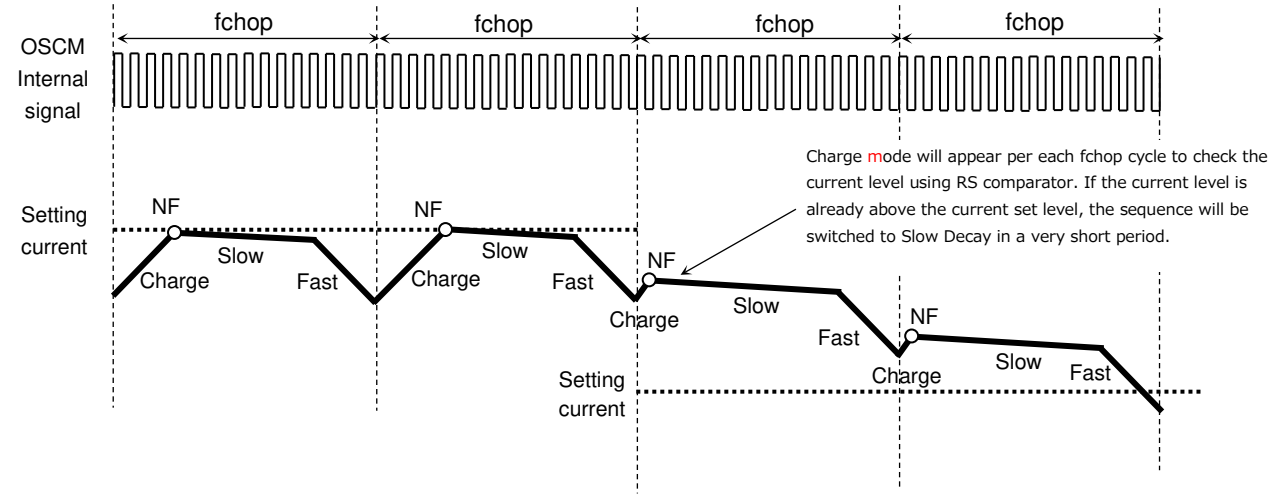


- **When Charge Period is More Than 1 fchop Cycle:**

When the Charge period is longer than fchop cycle, the Charge period extends until the motor current reaches the NF threshold. Once the current reaches the next current step, then the sequence goes on to Decay mode.



- **When the Next Current Step is lower:**



Note: Timing charts may be simplified for explanatory purpose.

9.2. Serial Setting Example when driving a motor

Serial setting example for motor operation is shown below.
The motor operates with full step resolution by transmitting from the 1st to 4th commands repeatedly.

1st Command

D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15
0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0

D16	D17	D18	D19	D20	D21	D22	D23	D24	D25	D26	D27	D28	D29	D30	D31
0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0

2nd Command

D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15
0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0

D16	D17	D18	D19	D20	D21	D22	D23	D24	D25	D26	D27	D28	D29	D30	D31
0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0

3rd Command

D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15
0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0

D16	D17	D18	D19	D20	D21	D22	D23	D24	D25	D26	D27	D28	D29	D30	D31
0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0

4th Command

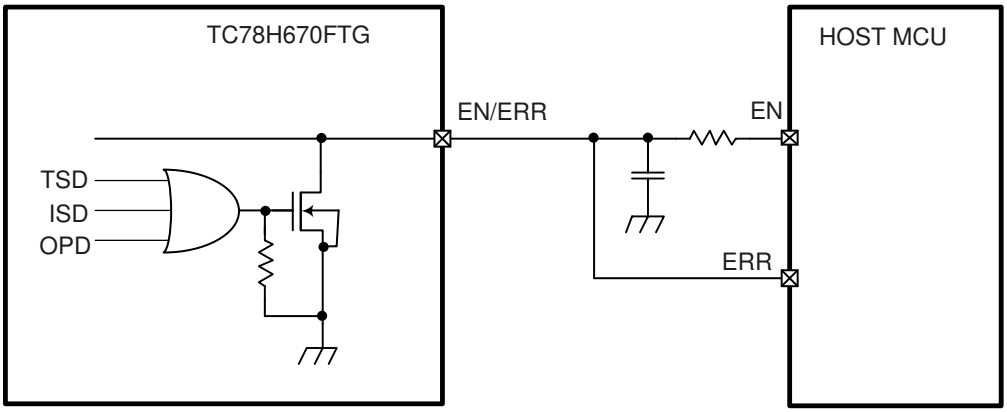
D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15
0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0

D16	D17	D18	D19	D20	D21	D22	D23	D24	D25	D26	D27	D28	D29	D30	D31
0	0	0	1	1	1	1	1	1	1	1	1	1	0	0	0

10. Common Function (CLK-IN Mode and Serial Mode)

10.1. Error Function (Error detect flag output)

When TC78H670FTG detects some errors, ERR pin outputs low level to peripheral block.
Since ERR pin and EN pin share the function, the below peripheral circuit between TC78H670FTG and HOST MCU should be inserted. EN pin should input High level through a resistor.
In normal status, since the internal MOSFET is OFF, the level of ERR pin is equal to the EN control voltage from outside. When the error function (Thermal shutdown (TSD), Over current (ISD), or motor load open (OPD)) occurs, ERR pin will become Low (the internal MOSFET is ON). When the error detection is released by reasserting the VM power supply or setting the device to STANDBY mode, ERR pins show “normal status”.



Note: This figure may be simplified for explanatory purpose.

Note: It is possible to detect OPD only when Serial mode is selected.

ERR pin output	Function
H (Pull-up)	Normal status (Normal operation)
L	Detect error status (ISD, TSD, OPD)

After detecting TSD detection: TC78H670FTG draws out currents of motor by Fast mode. If the output current is zero-detected or for 1ms at maximum, the output becomes Hi-Z.

After detecting ISD detection: In H Bridge high-side (Pch DMOS) detection, TC78H670FTG draws out currents of motor by Slow mode on low-side. The output after 80 ms (typ.) becomes Hi-Z. In H Bridge low-side (Nch DMOS) detection, it draws out by Slow mode on high-side.

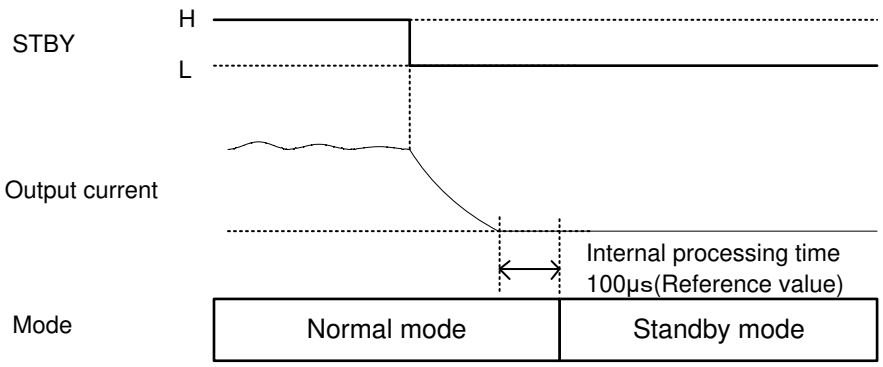
Note: Above times are reference values, and are not guaranteed.

10.2. STANDBY Function

It is possible to switch to Standby mode by STBY pin.

STBY pin input	Function	MEMO
L	Standby mode	Electrical angle: 45°
H	Normal operation	—

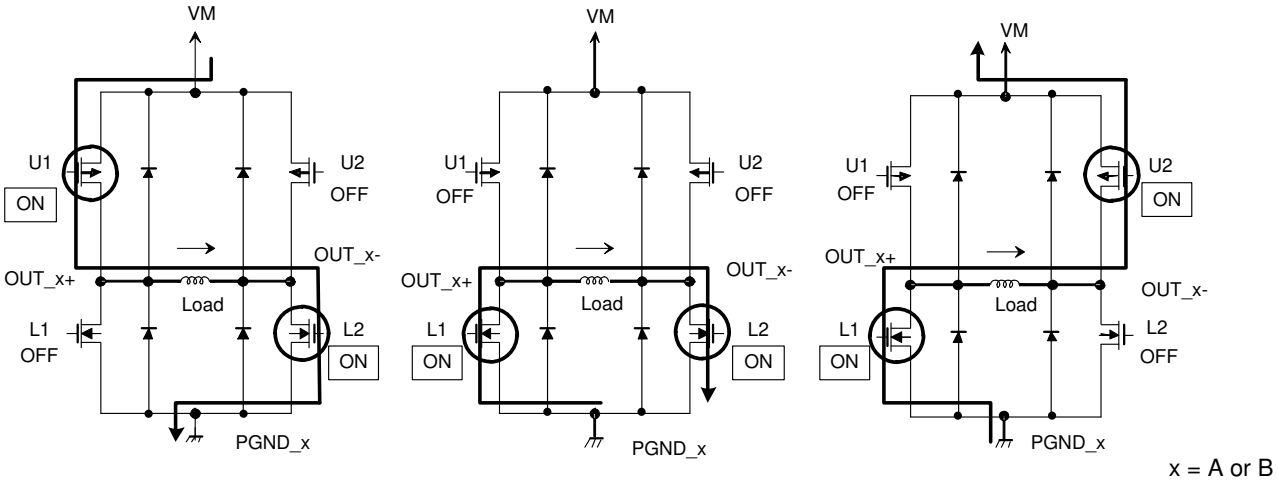
Note: When STBY pin is Low, TC78H670FTG stops supplying the power to logic circuit. Therefore, Logic circuit is reset and Electrical angle and Step mode are initialized.



If the output current is zero-detected, the operation mode enters into the standby mode after 100 μs. The mode enters into the standby mode forcedly after 1 ms(max) from STBY=L.

Note: Above times are reference values, and are not guaranteed.

11. Output Transistor Function Mode



x = A or B

Charge mode
A current flows into the motor coil.

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

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

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

11.1. 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 changing 3 modes listed above automatically

Note: To eliminate shoot-through current that flows from supply to ground due to the simultaneous conduction of high side and low side transistors in the bridge output, a dead time (100ns (Reference value)) is generated in this IC when transistors switch from on to off, or vice versa.

12. Calculation of the Predefined Output Current

The peak output current (Setting current value) can be set via the reference voltage (Vref), as follows:

$$Iout\ (Max) = 1.1 \times Vref\ (V)$$

13. OSCM Oscillation Frequency and Chopping Frequency

The OSCM oscillation frequency (fOSCM) and chopping frequency (fchop) can be adjusted by the external resistor (ROSC) connecting to OSCM pin.

ROSC[kΩ]	fOSCM [kHz](typ.)	fchop[kHz](typ.)
18	3290	206
22	2691	168
30	1982	124
39	1526	95
47	1266	79
56	1064	66
75	795	50
91	656	41

If chopping frequency is raised, ripple 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, ripple of current may become large.

It is a standard about 70 kHz. A setup in the range of 50 kHz to 100 kHz is recommended.

14. Absolute Maximum Ratings (Ta = 25°C)

Characteristics	Symbol	Rating	Unit	Remarks
Motor output voltage	Vout	20	V	Outputs are OFF
		18	V	Outputs are ON
Motor power supply (non-active)	VM	20	V	STBY pin = L
Motor power supply (active)		-0.4 to 18	V	STBY pin = H
Motor output current	Iout	2.0	A	(Note 1)
Logic input voltage	VIN(H)	6.0	V	—
	VIN(L)	-0.4	V	—
ERR output pin voltage	VLO	6.0	V	—
ERR output pin inflow current	ILO	6.0	mA	—
Power dissipation	P_D	1.79	W	(Note 2)
Operating temperature	Topr	-40 to 85	°C	—
Storage temperature	Tstg	-55 to 150	°C	—
Junction temperature	Tj(max)	150	°C	—

Note1: 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.

Note2: When mounted on the board (JEDEC 4 layers) (Ta =25°C)
When Ta exceeds 25°C, it is necessary to do the derating with 14.3 mW/°C.
Ta: Ambient temperature
Topr: Ambient temperature while the IC is active
Tj: Junction temperature while the IC is active.
The maximum junction temperature is limited by the thermal shutdown (TSD) circuitry. It is 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 TC78H670FTG 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.

15. Operating Range (Ta = -40 to 85°C)

Characteristics	Symbol	Min	Typ.	Max	Unit	Remarks
Motor power supply	VM	2.5	-	16.0	V	-
Motor output current	Iout	-	1.1	2.0	A	(Note 1)
ERR pin output voltage	VLO	-	-	5.5	V	-
Vref reference voltage	Vref	0	-	1.8	V	-

Note1: 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).

16. Electrical Specifications 1

(Ta = 25°C, VM = 2.5 to 16V unless otherwise specified)

Characteristics		Symbol	Test condition	Min	Typ.	Max	Unit
Logic input voltage	HIGH	VIN(H)	Logic input (Note1)	1.5	—	5.5	V
	LOW	VIN(L)	Logic input (Note1)	0	—	0.7	V
Logic input hysteresis voltage		VIN(HYS)	Logic input (Note1)	—	60	—	mV
Logic input current	HIGH	IIN(H)	VIN(H) = 3.3 V	—	33	45	μA
	LOW	IIN(L)	VIN(L) = 0 V	—	—	1	μA
ERR pin output voltage	LOW	VOL(LO)	IOL = 5 mA, output = L	—	—	0.5	V
Current consumption		IM1	Output pins = open Standby mode	—	—	0.1	μA
		IM2	Output pins = open EN pin = L in releasing Standby mode	—	2.8	3.5	mA
		IM3	Output pins = open Full step resolution fCLK=75 kHz	—	3.3	4.3	mA
Output leakage current	High-side	IOH	VM = 18 V, Vout = 0 V	—	—	1	μA
	Low-side	IOL	VM = Vout = 18 V	-1	—	—	μA
Motor current channel differential		ΔIout1	Current differential between Ch	-5	0	5	%
Motor current setting accuracy		ΔIout2	Iout = 1.1 A	-5	0	5	%
Motor output ON resistance (High side + Low side)		Ron(H+L)	Tj = 25°C, VM = 12 V, Iout = 1 A	—	0.48	0.6	Ω

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.

Note1: VIN(H) is defined as the VIN voltage that causes the outputs (OUT_A+ pin, OUT_A- pin, OUT_B+ pin, OUT_B- pin) to change when a pin under test is gradually raised from 0 V.VIN(L) is defined as the VIN voltage that causes the outputs (OUT_A+ pin, OUT_A- pin, OUT_B+ pin, OUT_B- pin) to change when the pin is then gradually lowered from 5V. The difference between VIN(H) and VIN(L) is defined as the VIN(HYS).

17. Electrical Specifications 2

(Ta = 25°C, VM = 2.5 to 16V unless otherwise specified)

Characteristics	Symbol	Test condition	Min	Typ.	Max	Unit
Vref input current	Iref	Vref = 1.8 V	—	0	1	μA
Thermal shutdown (TSD) threshold (Note1)	TjTSD	—	145	165	175	°C
UVLO release voltage (Note 2)	VUVLO	At rising VM	2.1	2.3	—	V
UVLO hysteresis voltage	Vhys_uvlo	—	—	200	—	mV
Over current detection (ISD) threshold (Note3)	ISD	VM = 12V	2.5	3.2	4.2	A

Note1: Thermal shutdown (TSD)

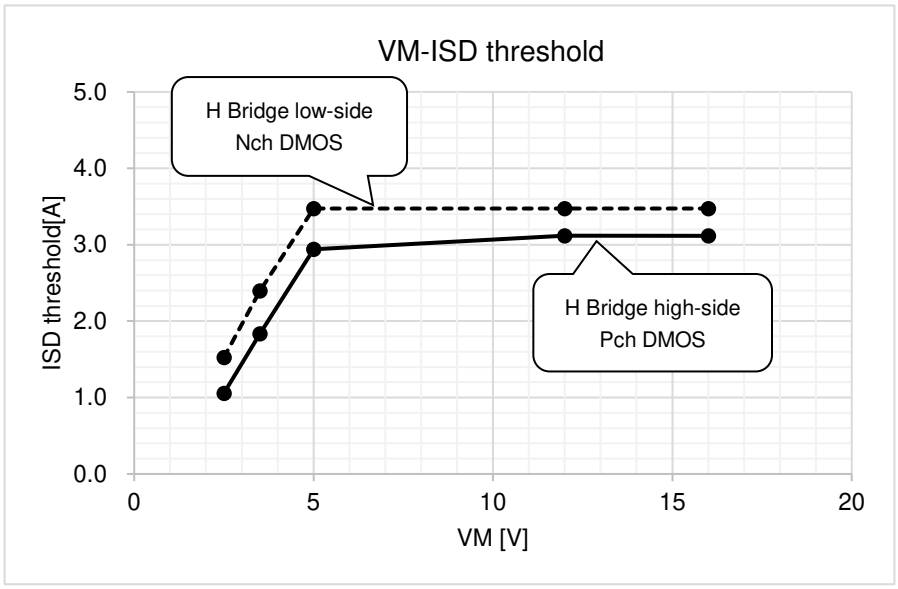
When the junction temperature of the device reaches the TSD threshold, the TSD circuit is triggered; the internal reset circuit then turns off the output transistors. Once the TSD circuit is triggered, the device will set output pin to Hi-Z, and can be cleared by reasserting the VM power source, or setting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

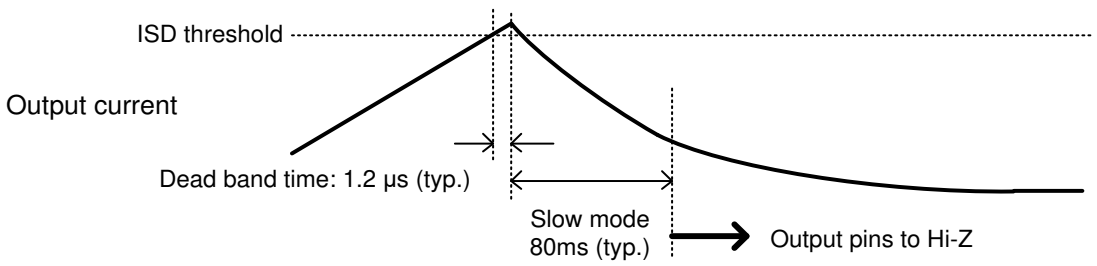
Note 2: Under voltage lockout (UVLO)

When the supply voltage to VM pin is 2.1 or less (typ.), the internal circuit is triggered; the internal reset circuit then turns off the output transistors. Once the UVLO is triggered, it can be cleared by reasserting the VM supply voltage to 2.3V or more (typ.)

Note3: Over current detection (ISD)

When the output current reaches the threshold, the ISD circuit is triggered; the internal reset circuit then turns off the output transistors. It has a dead band time of 1.2 μs (typ.) to avoid ISD false triggering by switching noise. Once the ISD circuit is triggered, the device will set output pins to Hi-Z, and can be cleared by reasserting the VM power source, or setting the STBY pin to standby mode.





Note: Above ISD operation threshold value and band times are reference values, and are not guaranteed.

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 TC78H670FTG 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

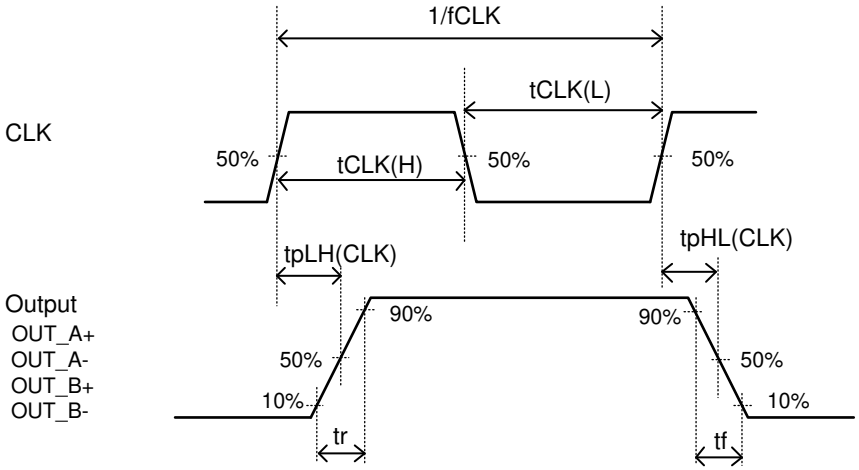
Do not insert devices incorrectly or in the wrong orientation. Otherwise, it may cause breakdown, damage and/or deterioration of the device.

18. AC Electrical Specification 1

(Ta = 25°C, VM =12V, 6.8 mH/5.7 Ω unless otherwise specified)

Characteristics	Symbol	Test condition	Min	Typ.	Max	Unit
CLK input frequency	fCLK	—	—	—	400	kHz
Inside filter of CLK input minimum High width	tCLK(H)	The CLK(H) minimum pulse width	500	—	—	ns
Inside filter of CLK input minimum Low width	tCLK(L)	The CLK(L) minimum pulse width	500	—	—	ns
Output transistor switching specific	tr	—	10	20	30	ns
	tf	—	10	20	30	ns
	tpLH(CLK)	—	—	840	—	ns
	tpHL(CLK)	—	—	900	—	ns
Analog noise blanking time	AtBLK	VM = 12 V	340	540	740	ns
Oscillator frequency accuracy	ΔfOSCM	ROSC = 47 kΩ VM = 2.5 V to 16 V	-15	—	+15	%
Oscillator reference frequency	fOSCM	ROSC = 47 kΩ	1076	1266	1456	kHz
Chopping frequency	fchop	Output: Active, fOSCM = 1266 kHz	—	79	—	kHz

AC Electrical Specification Timing chart

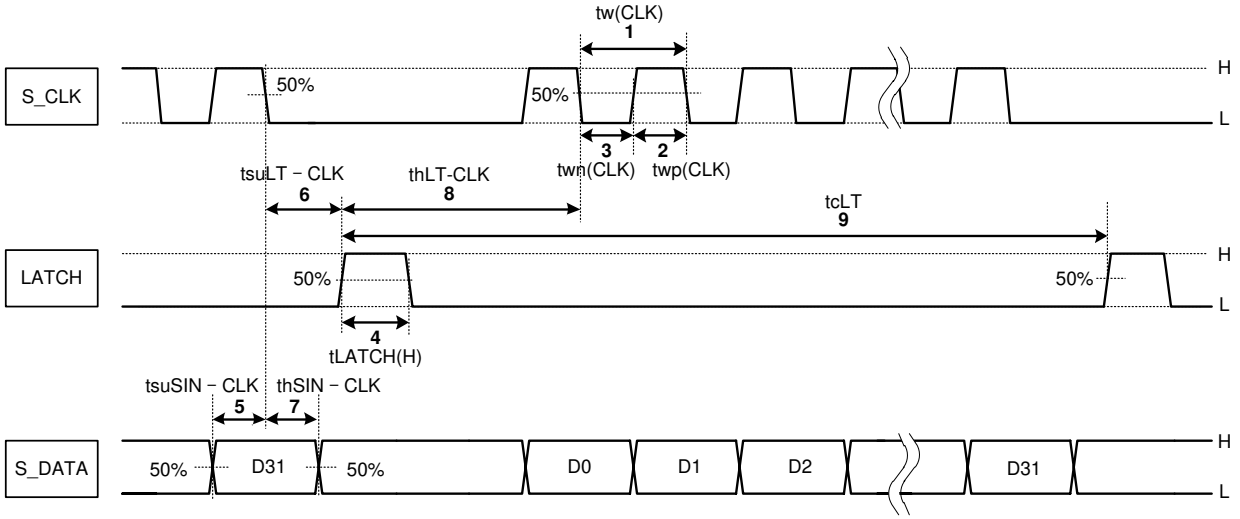


Note: Timing charts may be simplified for explanatory purpose.

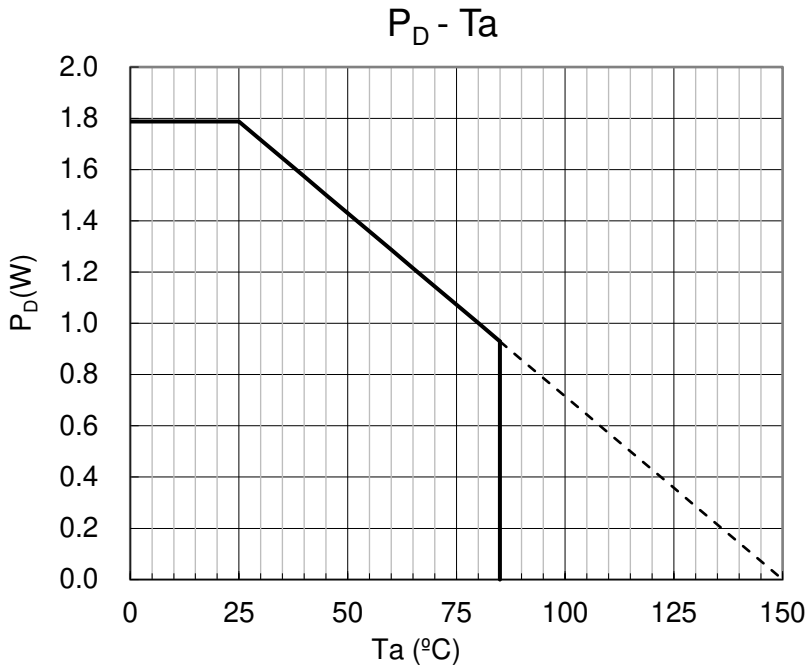
19. AC Electrical Specification 2

(Ta = 25°C, VM = 2.5 to 16V unless otherwise specified)

Characteristics	Symbol	Test condition	Min	Typ.	Max	Unit	No.in Timing Chart
Serial CLK frequency	fSCLK	VIN = 3.3 V	1.0	—	25	MHz	—
CLK cycle	tsCKW	VIH = 3.3 V, VIL = 0 V, tr = tf = 23 ns	46	—	—	ns	—
Minimum CLK pulse width	tw(CLK)	VIN = 3.3 V	40	—	—	ns	1
	twp(CLK)		20	—	—	ns	2
	twn(CLK)		20	—	—	ns	3
Minimum LATCH pulse width	tLATCH (H)	VIN = 3.3 V	20	—	—	ns	4
Data setup time	tsuSIN - CLK	VIN = 3.3 V	10	—	—	ns	5
	tsuLT - CLK		10	—	—	ns	6
Data hold time	thSIN - CLK	VIN = 3.3 V	10	—	—	ns	7
	thLT - CLK		40	—	—	ns	8
LATCH cycle	tcLT	VIN = 3.3 V	1.32	—	—	μs	9



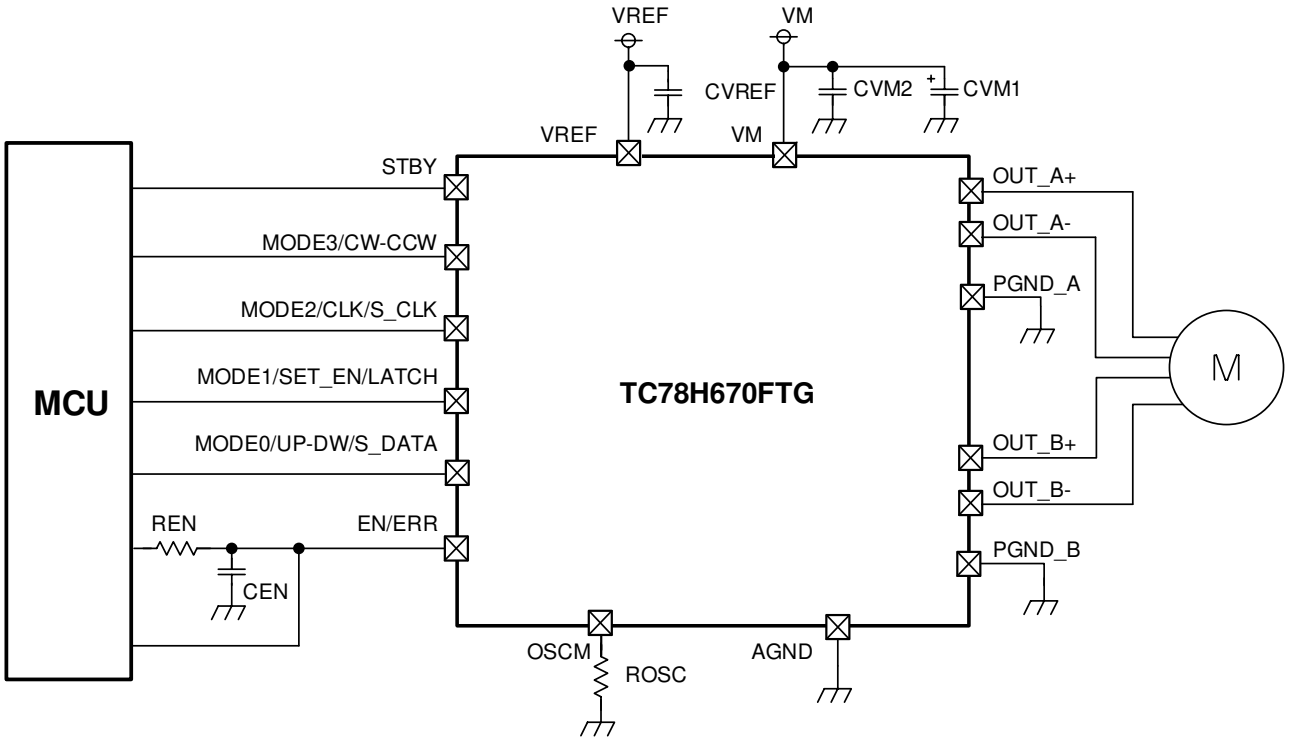
20. (Reference data) P_D-Ta Characteristics



When mounted on the board (JEDEC 4 layers)

Note: Characteristics shown above are reference values and not guaranteed.

21. Application Circuit Example



The application circuit shown in this document is provided for reference purposes only. The data for mass production are not guaranteed.

Component values (for reference only)

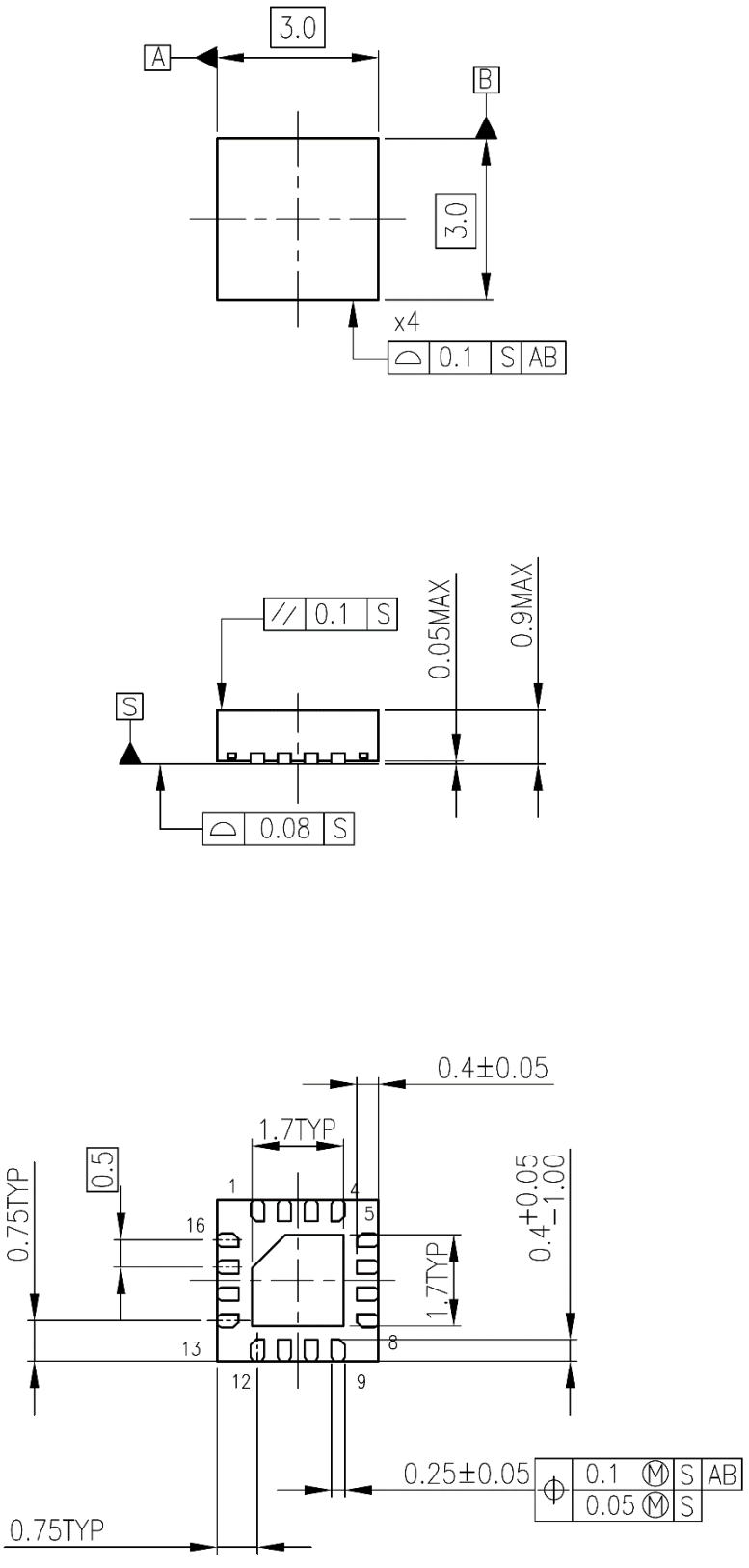
Part's symbol	Component	Value
CVM1	Electrolytic capacitor	47 μF
CVM2	Ceramic capacitor	0.1 μF
CVREF	Ceramic capacitor	0.1 μF
CEN	Ceramic capacitor	22 nF
ROSC	Resistor	47 kΩ
REN	Resistor	10 kΩ

Note: Componet values in above table are for reference only. Some components other than reference value can be adopted depending on the usage conditions.

22. Package Dimensions

P-VQFN16-0303-0.50-001

Unit: mm



Weight: 22.9 mg (typ.)

Notes on Contents

1. Block Diagrams

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

2. Equivalent Circuits

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

3. Timing Charts

Timing charts may be simplified for explanatory purposes.

4. Application Circuits

The application circuits shown in this document are provided for reference purposes only. Thorough evaluation is required, especially at the mass production design stage.
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) 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.

(3) 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.

(4) 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.

(5) Carefully select external components (such as inputs and negative feedback capacitors) and load components (such as speakers), for example, power amp and regulator. If there is a large amount of leakage current such as from input or negative feedback 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 may cause smoke or ignition. (The overcurrent may cause smoke or ignition from the IC itself.) In particular, please pay attention when using a Bridge Tied Load (BTL) connection-type IC that inputs output DC voltage to a speaker directly.

Points to remember on handling of ICs

(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 (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.

(4) 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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