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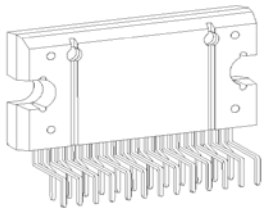
TOSHIBA BiCD Integrated Circuit Silicon Monolithic

TB6600HG

PWM Chopper-Type bipolar
Stepping Motor Driver IC

The TB6600HG is a PWM chopper-type single-chip bipolar sinusoidal micro-step stepping motor driver.
Forward and reverse rotation control is available with 2-phase, 1-2-phase, W1-2-phase, 2W1-2-phase, and 4W1-2-phase excitation modes.
2-phase bipolar-type stepping motor can be driven by only clock signal with low vibration and high efficiency.

TB6600HG



HZIP25-P-1.00F

Weight:
HZIP25-P-1.00F: 7.7g (typ.)

Features

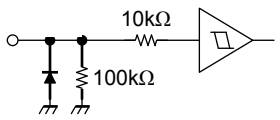
- Single-chip bipolar sinusoidal micro-step stepping motor driver
- Ron (upper + lower) = 0.4 Ω (typ.)
- Forward and reverse rotation control available
- Selectable phase drive (1/1, 1/2, 1/4, 1/8, and 1/16 step)
- Output withstand voltage: Vcc = 50 V
- Output current: I_{OUT} = 5.0 A (absolute maximum ratings, peak)
  I_{OUT} = 4.5 A (operating range, maximal value)
- Packages: HZIP25-P-1.00F
- Built-in input pull-down resistance: 100 kΩ (typ.), (only TQ terminal: 70 k Ω (typ.))
- Output monitor pins (ALERT): Maximum of I_{ALERT} = 1 mA
- Output monitor pins (MO): Maximum of I_{MO} = 1 mA
- Equipped with reset and enable pins
- Stand by function
- Single power supply
- Built-in thermal shutdown (TSD) circuit
- Built-in under voltage lock out (UVLO) circuit
- Built-in over-current detection (ISD) circuit

Pin Functions

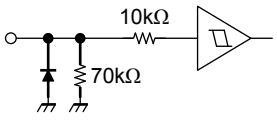
Pin No.	I/O	Symbol	Functional Description	Remark
1	Output	ALERT	TSD / ISD monitor pin	Pull-up by external resistance
2	—	SGND	Signal ground	
3	Input	TQ	Torque (output current) setting input pin	
4	Input	Latch/Auto	Select a return type for TSD.	L: Latch, H: Automatic return
5	Input	Vref	Voltage input for 100% current level	
6	Input	Vcc	Power supply	
7	Input	M1	Excitation mode setting input pin	
8	Input	M2	Excitation mode setting input pin	
9	Input	M3	Excitation mode setting input pin	
10	Output	OUT2B	B channel output 2	
11	—	N_{FB}	B channel output current detection pin	
12	Output	OUT1B	B channel output 1	
13	—	PGNDB	Power ground	
14	Output	OUT2A	A channel output 2	
15	—	N_{FA}	A channel output current detection pin	
16	Output	OUT1A	A channel output 1	
17	—	PGNDA	Power ground	
18	Input	ENABLE	Enable signal input pin	H: Enable, L: All outputs off
19	Input	RESET	Reset signal input pin	L: Initial mode
20	Input	Vcc	Power supply	
21	Input	CLK	CLK pulse input pin	
22	Input	CW/CCW	Forward/reverse control pin	L: CW, H:CCW
23	—	OSC	Resistor connection pin for internal oscillation setting	
24	Output	Vreg	Control side connection pin for power capacitor	Connecting capacitor to SGND
25	Output	MO	Electrical angle monitor pin	Pull-up by external resistance

<Terminal circuits>

Input pins
(M1, M2, M3,CLK, CW/CCW,
ENABLE, RESET, Latch/Auto)

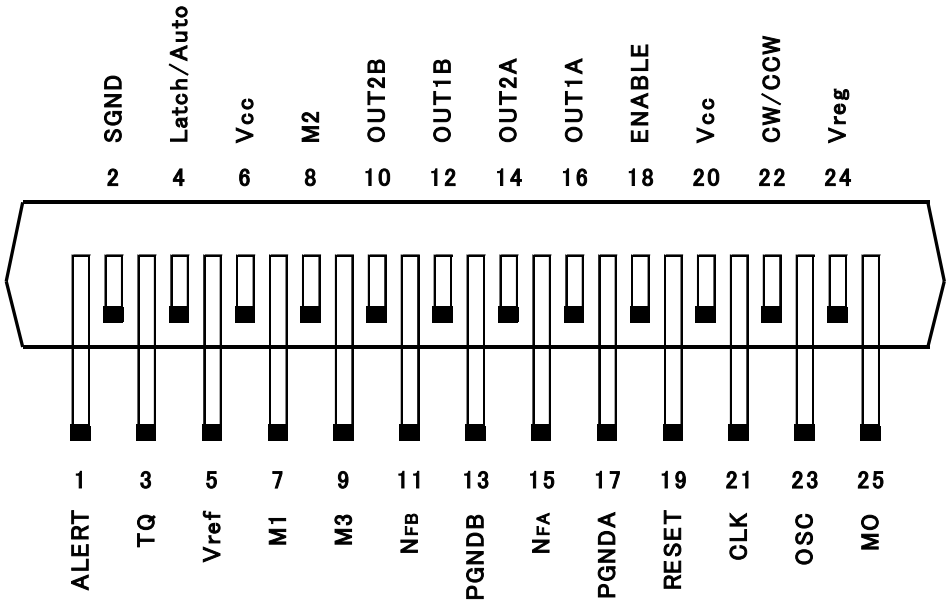


Input pins
(TQ)

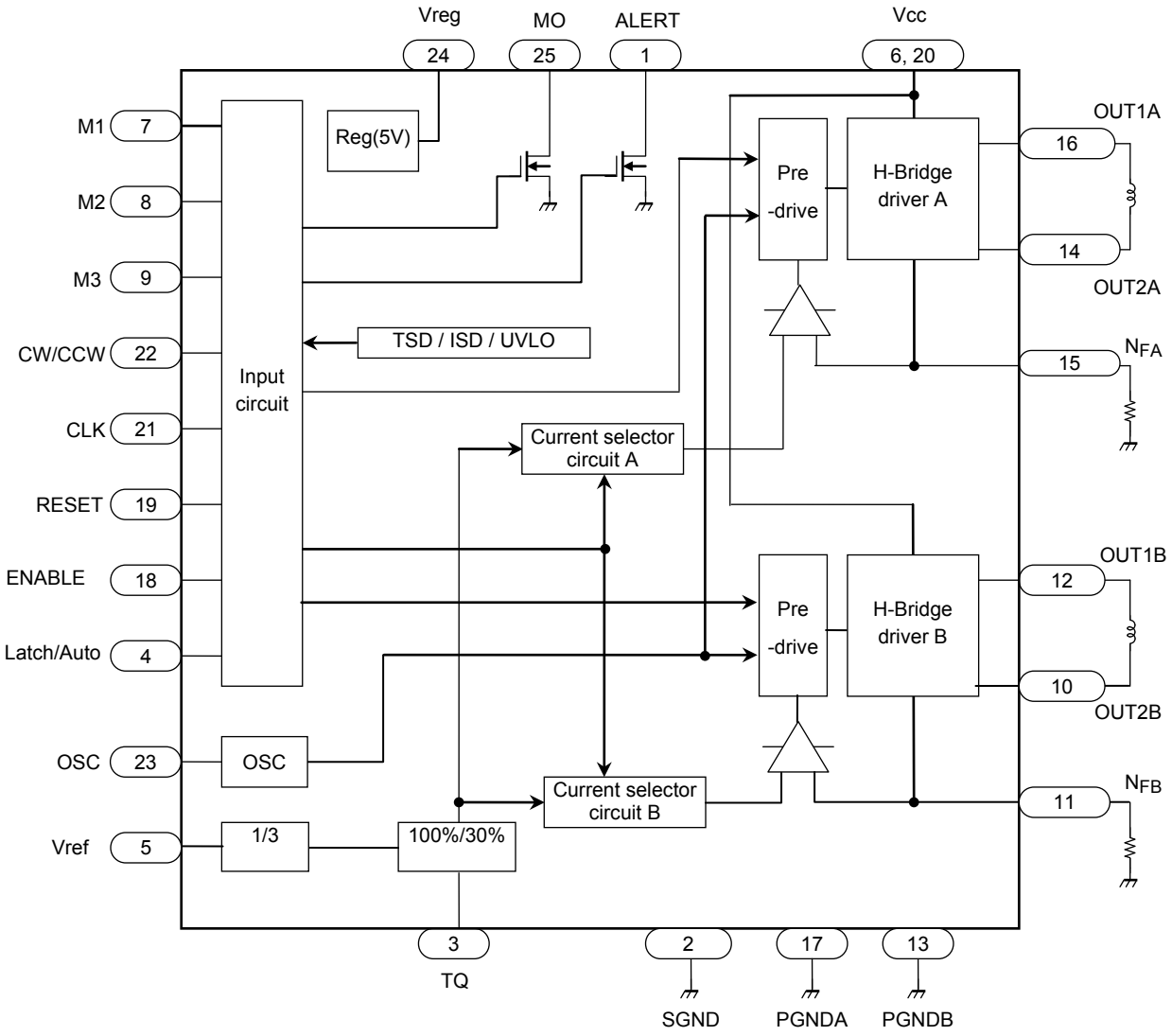


Pin Assignment

(Top View)



Block Diagram



Setting of Vref

Input TQ	Voltage ratio
L	30%
H	100%

Description of Functions

1. Excitation Settings

The excitation mode can be selected from the following eight modes using the M1, M2 and M3 inputs. New excitation mode starts from the initial mode when M1, M2, or M3 inputs are shifted during motor operation. In this case, output current waveform may not continue.

Input			Mode (Excitation)
M1	M2	M3	
L	L	L	Standby mode (Operation of the internal circuit is almost turned off.)
L	L	H	1/1 (2-phase excitation, full-step)
L	H	L	1/2A type (1-2 phase excitation A type) (0%, 71%, 100%)
L	H	H	1/2B type (1-2 phase excitation B type) (0%, 100%)
H	L	L	1/4 (W1-2 phase excitation)
H	L	H	1/8 (2W1-2 phase excitation)
H	H	L	1/16 (4W1-2 phase excitation)
H	H	H	Standby mode (Operation of the internal circuit is almost turned off.)

Note: To change the exciting mode by changing M1, M2, and M3, make sure not to set M1 = M2 = M3 = L or M1 = M2 = M3 = H.

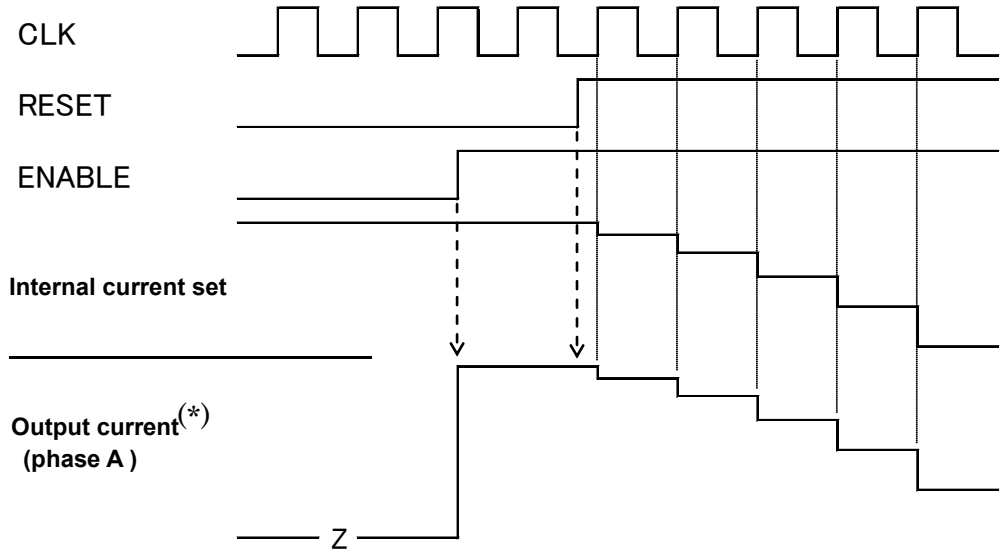
Standby mode

The operation mode moves to the standby mode under the condition M1 = M2 = M3 = L or M1 = M2 = M3 = H.
The power consumption is minimized by turning off all the operations except protecting operation.
In standby mode, output terminal MO is HZ.
Standby mode is released by changing the state of M1=M2=M3=L and M1=M2=M3=H to other state.
Input signal is not accepted for about 200 μs after releasing the standby mode.

2. Function

(1)To turn on the output, configure the ENABLE pin high. To turn off the output, configure the ENABLE pin low.
(2) The output changes to the Initial mode shown in the table below when the ENABLE signal goes High level and the RESET signal goes Low level. (In this mode, the status of the CLK and CW/CCW pins are irrelevant.)
(3) As shown in the below figure of Example 1, when the ENABLE signal goes Low level, it sets an OFF on the output. In this mode, the output changes to the initial mode when the RESET signal goes Low level. Under this condition, the initial mode is output by setting the ENABLE signal High level. And the motor operates from the initial mode by setting the RESET signal High level.

(Example 1)



(*: Output current starts rising at the timing of PWM frequency just after ENABLE pin outputs high.)

Input				Output mode
CLK	CW/CCW	RESET	ENABLE	
↑	L	H	H	CW
↑	H	H	H	CCW
X	X	L	H	Initial mode
X	X	X	L	Z

Command of the standby has a higher priority than ENABLE. Standby mode can be turned on and off regardless of the state of ENABLE.
X: Don't Care

3. Initial Mode

When RESET is used, the phase currents are as follows.

Excitation Mode	Phase A Current	Phase B Current
1/1 (2-phase excitation, full-step)	100%	-100%
1/2A type (1-2 phase excitation A type) (0%, 71%, 100%)	100%	0%
1/2B type (1-2 phase excitation B type) (0%, 100%)	100%	0%
1/4 (W1-2 phase excitation)	100%	0%
1/8 (2W1-2 phase excitation)	100%	0%
1/16 (4W1-2 phase excitation)	100%	0%

current direction is defined as follows.
OUT1A → OUT2A: Forward direction
OUT1B → OUT2B: Forward direction

4. 100% current settings (Current value)

100% current value is determined by Vref inputted from external part and the external resistance for detecting output current. Vref is doubled 1/3 inside IC.

$$Io\ (100\%) = (1/3 \times Vref) \div R_{NF}$$

The average current is lower than the calculated value because this IC has the method of peak current detection.

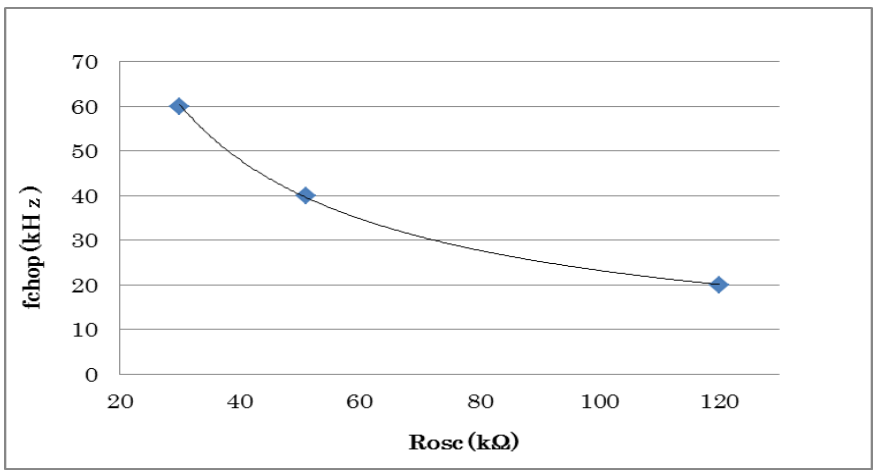
Pleas use the IC under the conditions as follows;

$0.11\Omega \leq R_{NF} \leq 0.5\Omega$, $0.3V \leq Vref \leq 1.95V$

5. OSC

Triangle wave is generated internally by CR oscillation by connecting external resistor to OSC terminal. Rosc should be from 30kΩ to 120kΩ. The relation of Rosc and fchop is shown in below table and figure. The values of fchop of the below table are design guarantee values. They are not tested for pre-shipment.

Rosc(kΩ)	fchop(kHz)		
	Min	Typ.	Max
30	-	60	-
51	-	40	-
120	-	20	-



6. Decay Mode

It takes approximately five OSCM cycles for charging-discharging a current in PWM mode. The 40% fast decay mode is created by inducing decay during the last two cycles in Fast Decay mode.
The ratio 40% of the fast decay mode is always fixed.
The relation between the master clock frequency (fMCLK), the OSCM frequency (fOSCM) and the PWM frequency (fchop) is shown as follows:

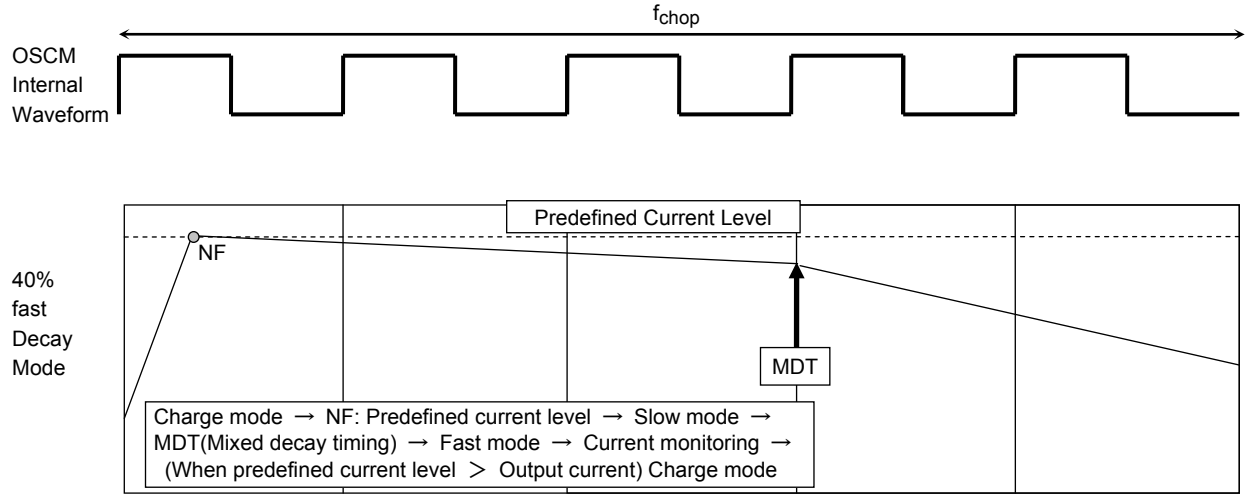
fOSCM = 1/20 ×fMCLK
fchop = 1/100 ×fMCLK

When Rosc=51kΩ, the master clock=4MHz, OSCM=200kHz, the frequency of PWM(fchop)=40kHz.

6-1. Current Waveform and Mixed Decay Mode settings

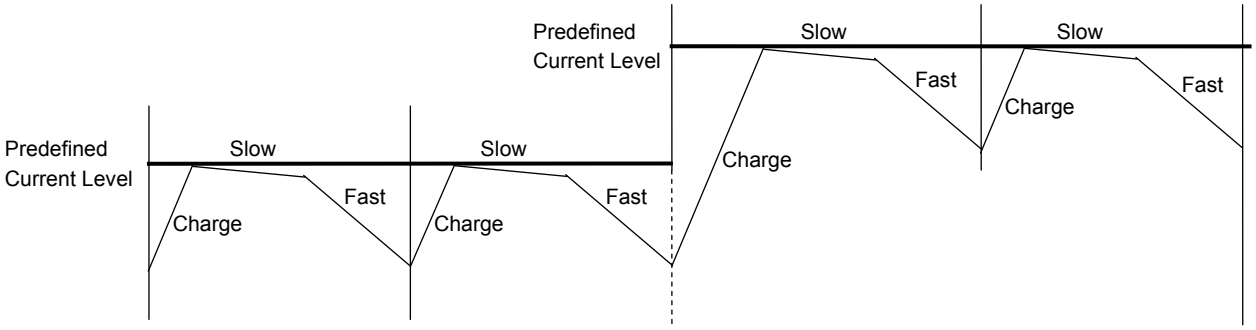
The period of PWM operation is equal to five periods of OSCM.
The ratio 40% of the fast decay mode is always fixed.
The "NF" refers to the point at which the output current reaches its predefined current level.

MDT means the point of MDT (MIXED DECAY TIMMING) in the below diagram.

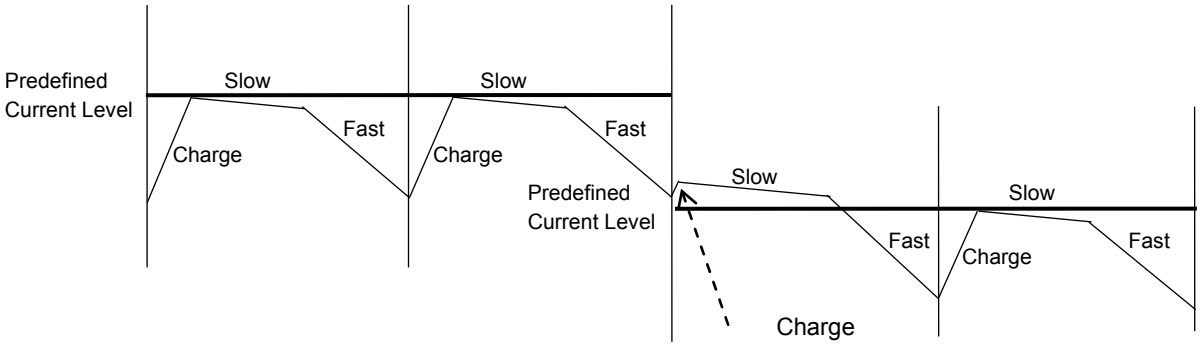


6-2. Effect of Decay Mode

- Increasing the current (sine wave)

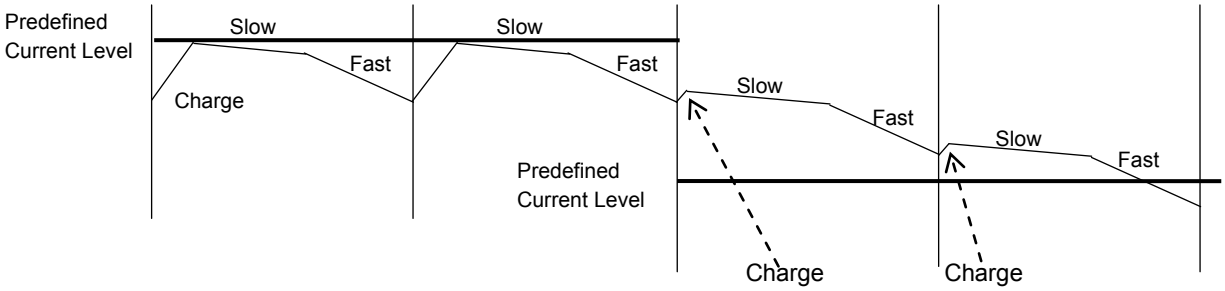


- Decreasing the current (In case the current is decreased to the predefined value in a short time because it decays quickly.)



Even if the output current rises above the predefined current at the RNF point, the current control mode is briefly switched to Charge mode for current sensing.

- Decreasing the current (In case it takes a long time to decrease the current to the predefined value because the current decays slowly.)

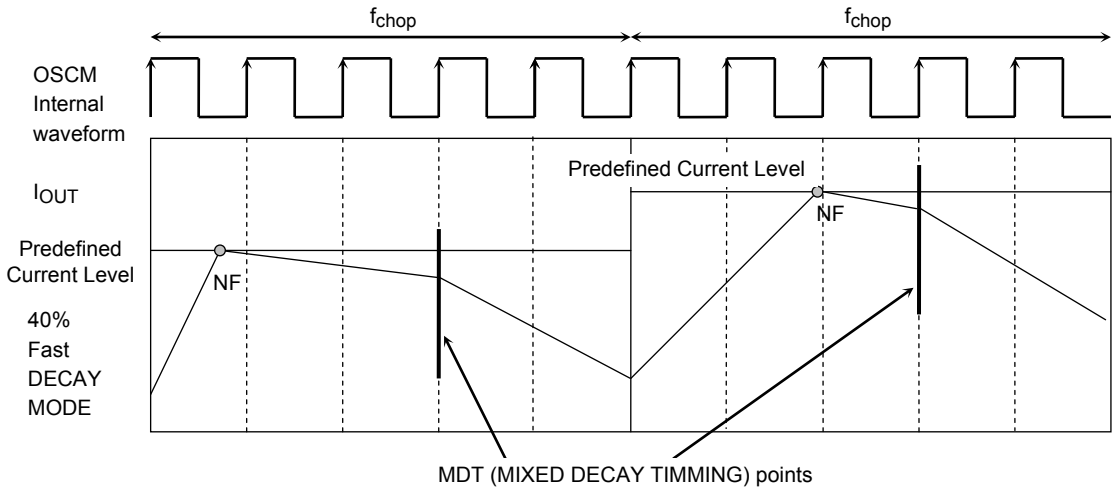


Even if the output current rises above the predefined current at the RNF point, the current control mode is briefly switched to Charge mode for current sensing.

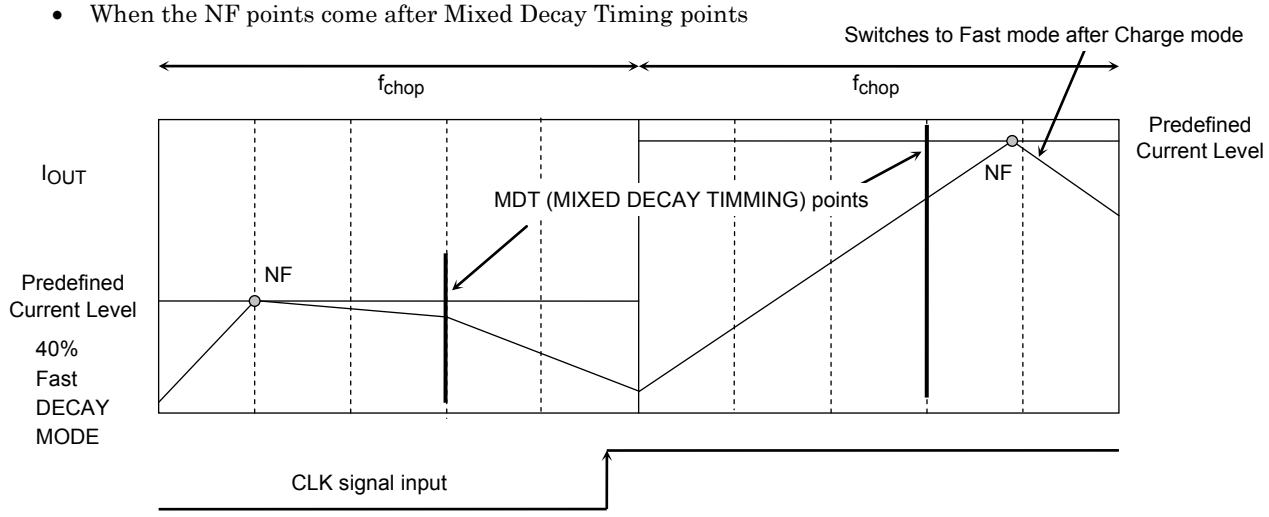
During Mixed Decay and Fast Decay modes, if the predefined current level is less than the output current at the RNF (current monitoring point), the Charge mode in the next chopping cycle will disappear (though the current control mode is briefly switched to Charge mode in actual operations for current sensing) and the current is controlled in Slow and Fast Decay modes (mode switching from Slow Decay mode to Fast Decay mode at the MDT point).

Note: The above figures are rough illustration of the output current. In actual current waveforms, transient response curves can be observed.

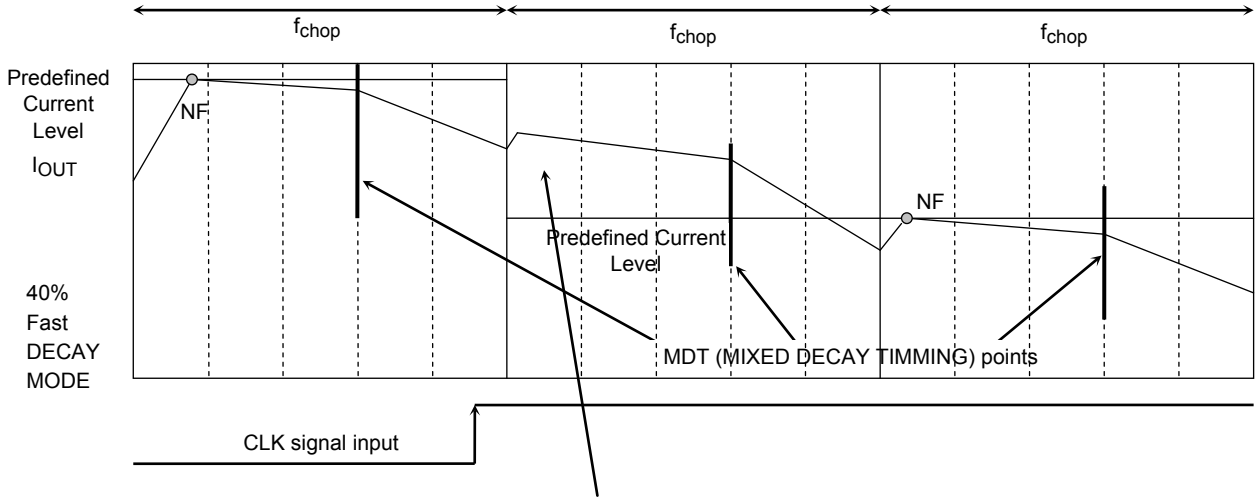
6-3. Current Waveforms in Mixed Decay Mode



- When the NF points come after Mixed Decay Timing points

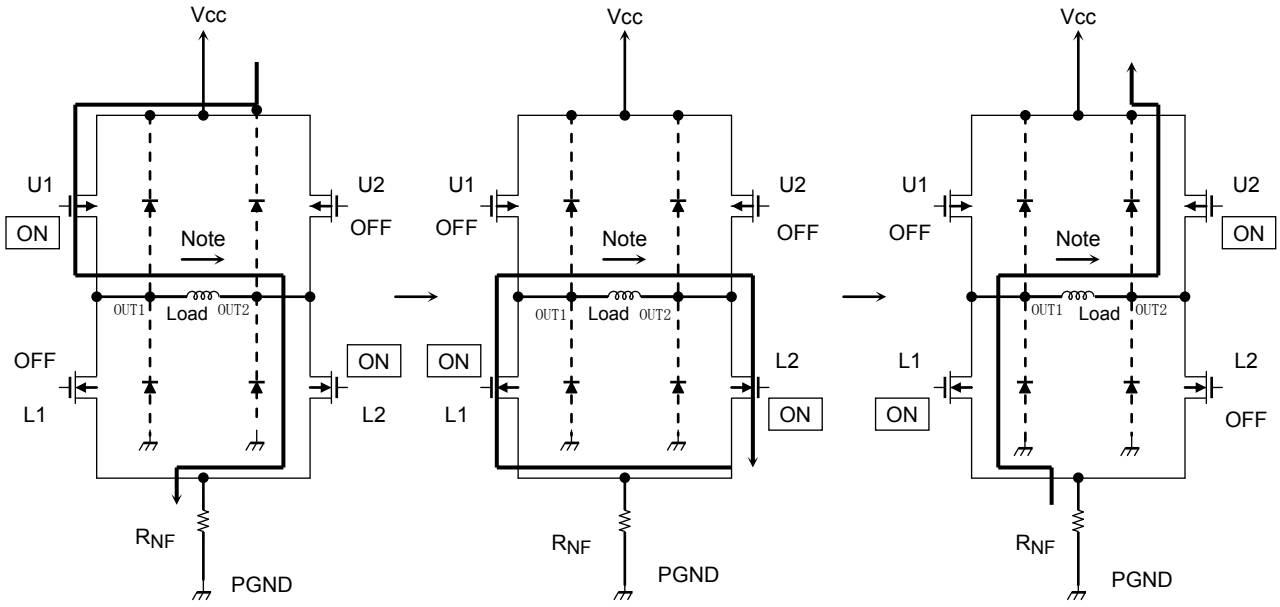


- When the output current value > predefined current level in Mixed Decay mode



Even if the output current rises above the predefined current at the RNF point, the current control mode is briefly switched to Charge mode for current sensing.

Output Stage Transistor Operation Mode



Charge Mode Slow Mode Fast Mode

Output Stage Transistor Operation Functions

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

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

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

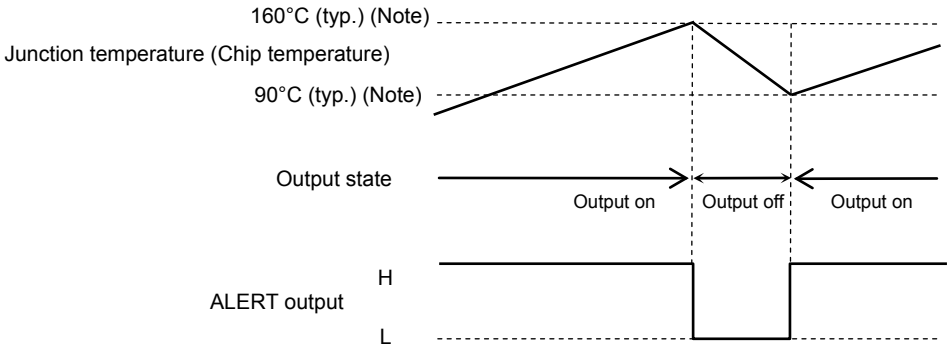
Upon transitions of above-mentioned functions, a dead time of about 300 ns (Design guarantee value) is inserted respectively.

Thermal Shut-Down circuit (TSD)

(1) Automatic return

TSD = 160°C (typ.) (Note)

TSDhys = 70°C (typ.) (Note)



Automatic return has a temperature hysteresis shown in the above figure.

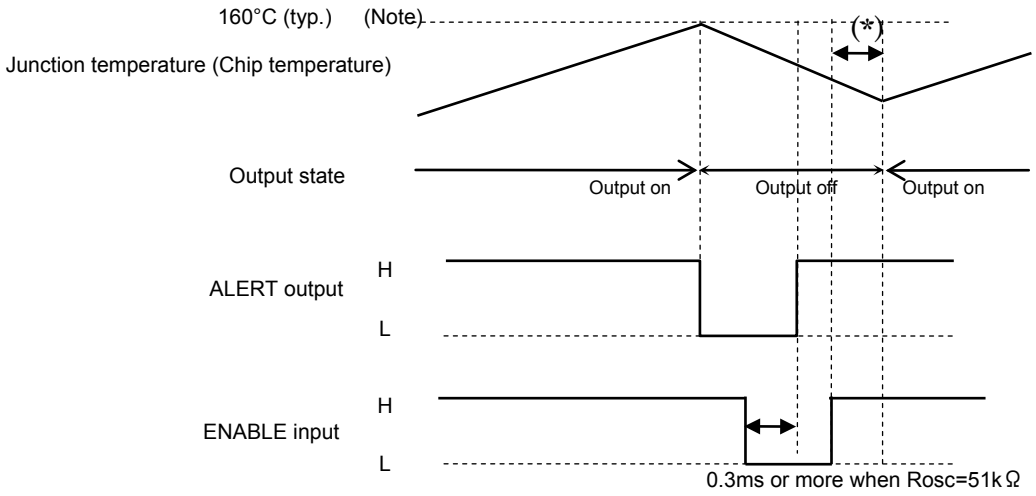
In case of automatic return, the return timing is adjusted at charge start of fchop after the temperature falls to the return temperature (90°C (typ.) in the above figure).

The return period after the temperature falls corresponds to one cycle to two cycles of fchop.

(2) Latch type

TSD = 160°C (typ.) (Note)

(*)Output current starts rising at the timing of PWM frequency just after ENABLE pin outputs high.



The operation returns by programming the ENABLE as H → L → H shown in above figure or turning on power supply and turning on UVLO function. In this time, term of L level of ENABLE should be 0.3ms or more.

To recover the operation, the junction temperature (the chip temperature) should be 90°C or less when ENABLE input is switched from L to H level. Otherwise, the operation does not recover.

Note: Pre-shipment testing is not performed.

・State of internal IC when TSD circuit operates.

The states of the internal IC and outputs, while the shutdown circuit is operating, correspond to the state when ENABLE is L.

The state after automatic return corresponds to the state when ENABLE is H. Please configure the Reset L to rotate the motor from the initial state.

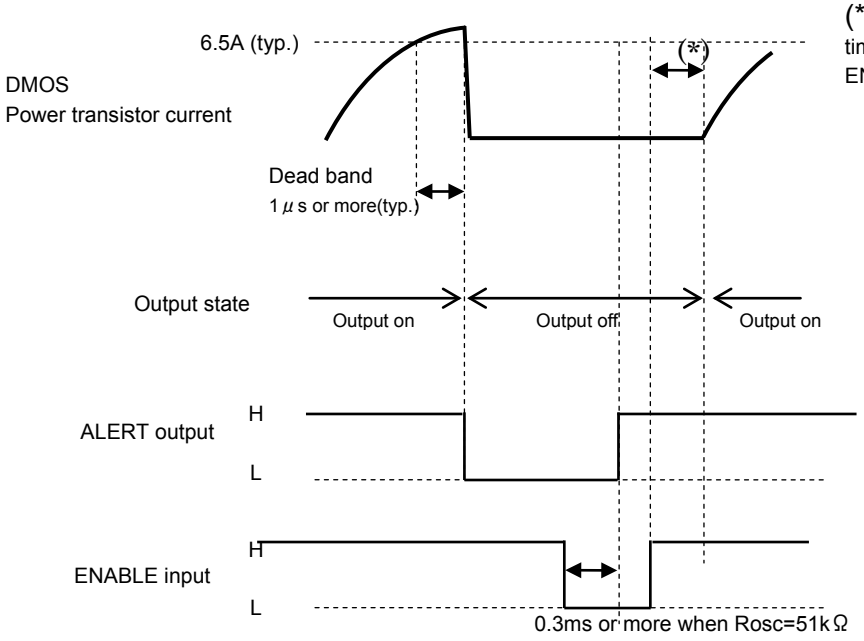
Latch/Auto is an input pin for determining the return method of TSD.
If Latch/Auto pin outputs low, TSD function returns by either of turning on power supply again or programming the ENABLE as H → L → H.
If Latch/Auto pin outputs high, it returns automatically.
In standby mode, TSD function returns automatically regardless of the state of the Latch/Auto pin.
When power supply voltage Vcc is less than 8V, TSD function cannot operate regardless of the state of the Latch/Auto pin.

ISD (Over current detection)

Current that flows through output power MOSFETs are monitored individually. If over-current is detected in at least one of the eight output power MOSFETs, all output power MOSFETs are turned off then this status is kept until ENABLE signal is input. In this time, term of L level of ENABLE should be 0.3ms or more.

Masking term of 1μs or more (typ. when Rosc=51kΩ) (Note) should be provided in order to protect detection error by noise. ISD does not work during the masking term.

Over current detection value ISD=6.5 A (Note)



(*)Output current starts rising at the timing of PWM frequency just after ENABLE pin outputs high.

The operation returns by programming the ENABLE as H → L → H shown in above figure or turning on power supply and turning on UVLO function.

Note: Pre-shipment testing is not performed.

・State of internal IC when ISD circuit operates.

The states of the internal IC and outputs, while the over current detection circuit is operating, correspond to the state when ENABLE is L.

The state after automatic return corresponds to the state when ENABLE is H. Please configure the Reset L to rotate the motor from the initial state.

Return method of ISD

ISD function returns by either of turning on power supply again or programming the ENABLE as H → L → H regardless of the state of the Latch/Auto pin.

In standby mode, ISD function cannot operate.

When power supply voltage Vcc is less than 8V, ISD function cannot operate.

Under Voltage Lock Out (UVLO) circuit

Outputs are shutoff by operating at 5.5 V (Typ.) of Vcc or less.

It has a hysteresis of 0.5 V (Typ.) and returns to output when Vcc reaches 6.0 V (Typ.). The following values are design guarantee values.

・State of internal IC when UVLO circuit operates.

The states of the internal IC and outputs correspond to the state in the ENABLE mode and the initial mode at the same time.

After a return, it can start from the initial mode.

When Vcc falls to around 5.5 V and UVLO operates, output turns off.

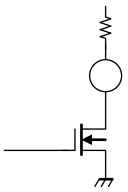
It recovers automatically from the initial mode when both Vcc rise to around 6.0 V or more. The following values are design guarantee values.

ALERT output

ALERT terminal outputs low in detecting either TSD or ISD.

ALERT terminal is connected to power supply externally via pull-up resistance.
V_{ALERT} = 0.5 V (max) at 1 mA

TSD	ISD	ALERT
Under TSD detection	Under ISD detection	Low
Normal	Under ISD detection	
Under TSD detection	Normal	
Normal	Normal	Z

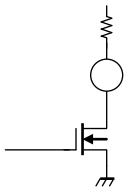


Applied voltage to pull-up resistance is up to 5.5 V. And conducted current is up to 1 mA.
It is recommended to gain 5 V by connecting the external pull-up resistance to Vreg pin.

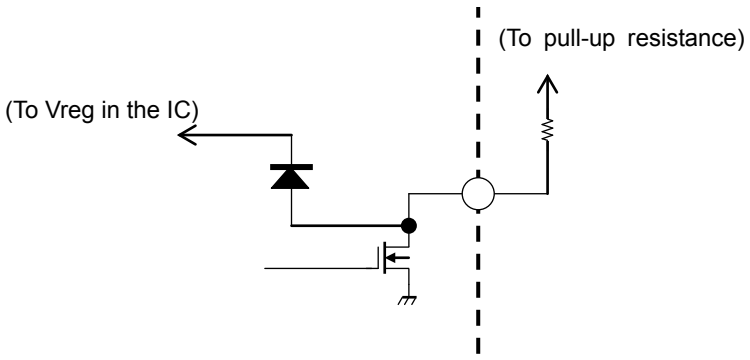
MO output

MO turns on at the predetermined state and output low.
MO terminal is connected to power supply externally via pull-up resistance.
V_{MO} = 0.5 V (max) at 1 mA

State	MO
Initial	Low
Not initial	Z



Applied voltage to pull-up resistance is up to 5.5 V. And conducted current is up to 1 mA.
It is recommended to gain 5 V by connecting the external pull-up resistance to Vreg pin.

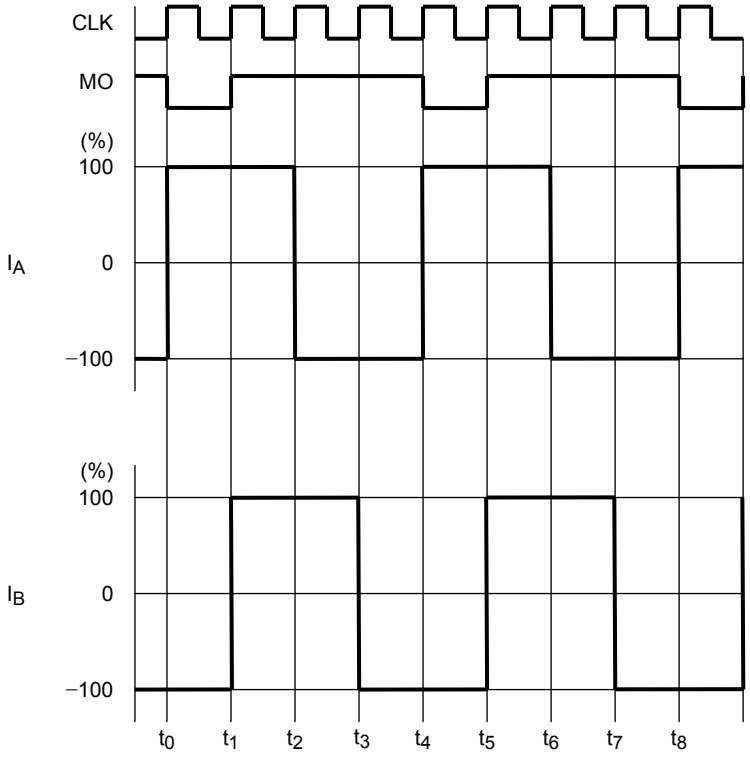


Voltage pull-up of MO and ALERT pins

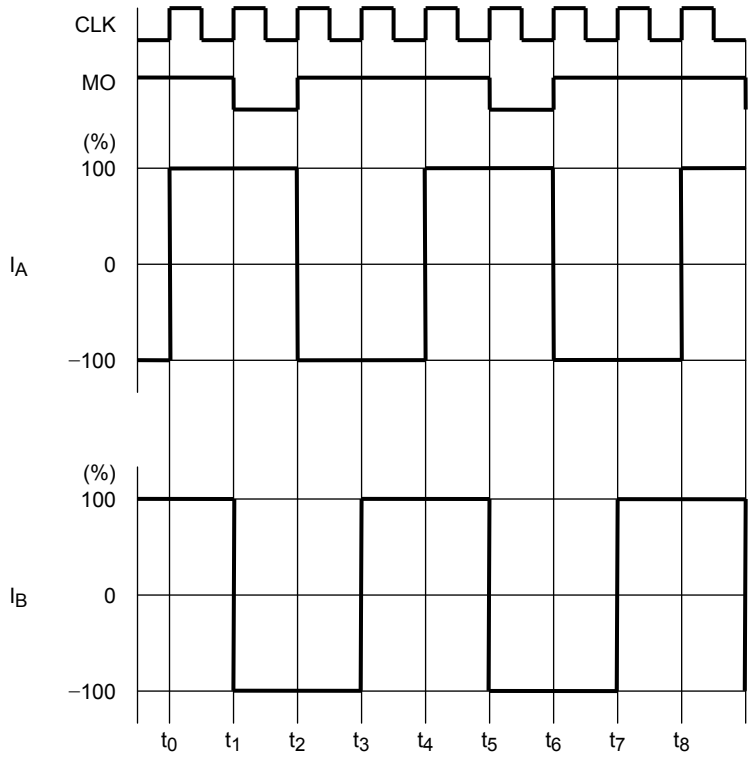
・It is recommended to pull-up voltage to Vreg pin.
・In case of pull-up to except 5 V (for instance, 3.3 V etc.), it is recommended to use other power supply (ex. 3.3 V) while Vcc output between the operation range. When Vcc decreases lower than the operation range and Vreg decreases from 5 V to 0 V under the condition that other power supply is used to pull-up voltage, the current continues to conduct from other power supply to the IC inside through the diode shown in the figure. Though this phenomenon does not cause destruction and malfunction of the IC, please consider the set design not to continue such a state for a long time.
・As for the pull-up resistance for MO and ALERT pins, please select large resistance enough for the conducting current so as not to exceed the standard value of 1 mA.
Please use the resistance of 30 kΩ or more in case of applying 5 V, and 20 kΩ or more in case of applying 3.3 V.

Sequence and current level in each excitation mode

1/1-step Excitation Mode (M1: L, M2: L, M3: H, CW Mode)

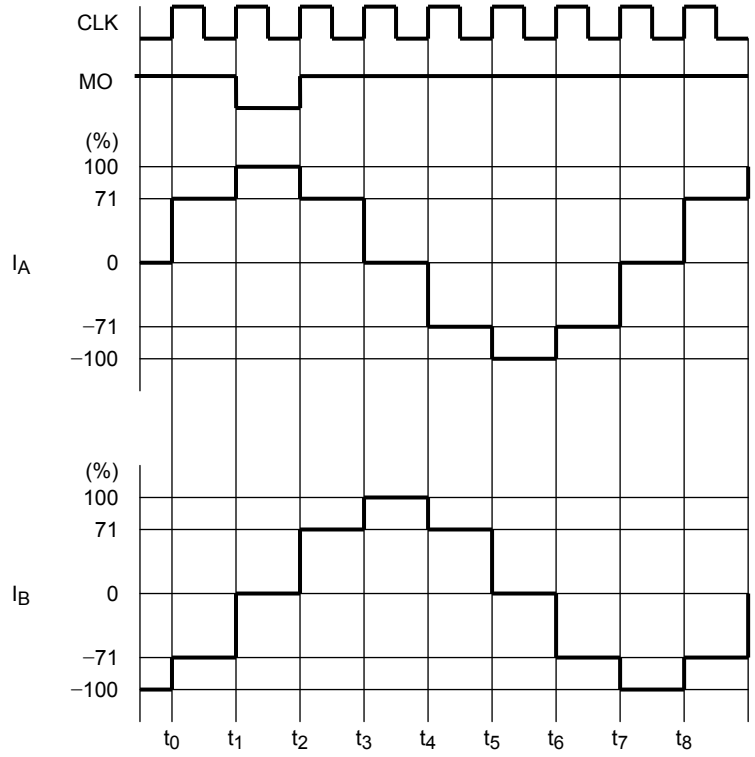


1/1-step Excitation Mode (M1: L, M2: L, M3: H, CCW Mode)

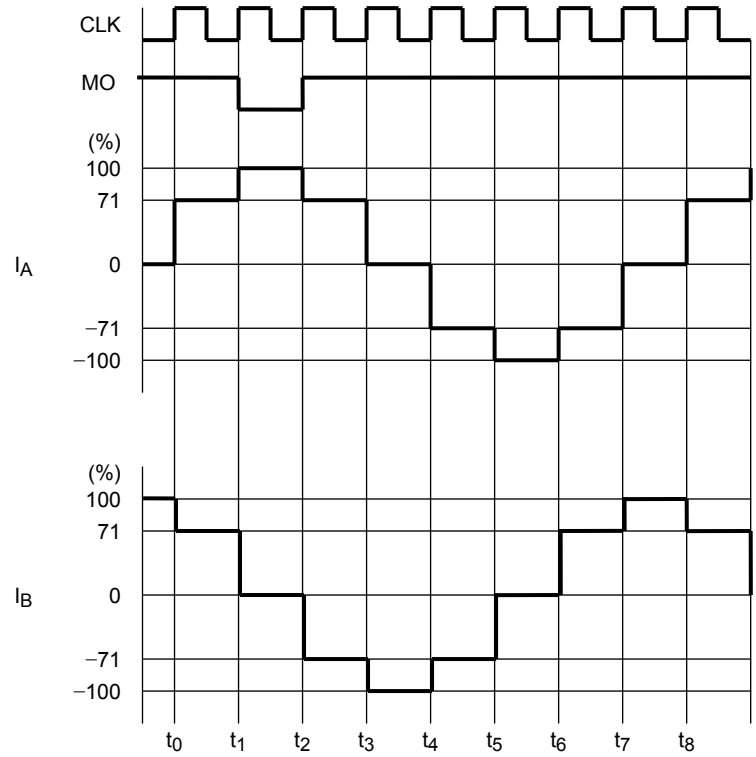


It operates from the initial state after the excitation mode is switched.

1/2-step Excitation Mode (A type) (M1: L, M2: H, M3: L, CW Mode)

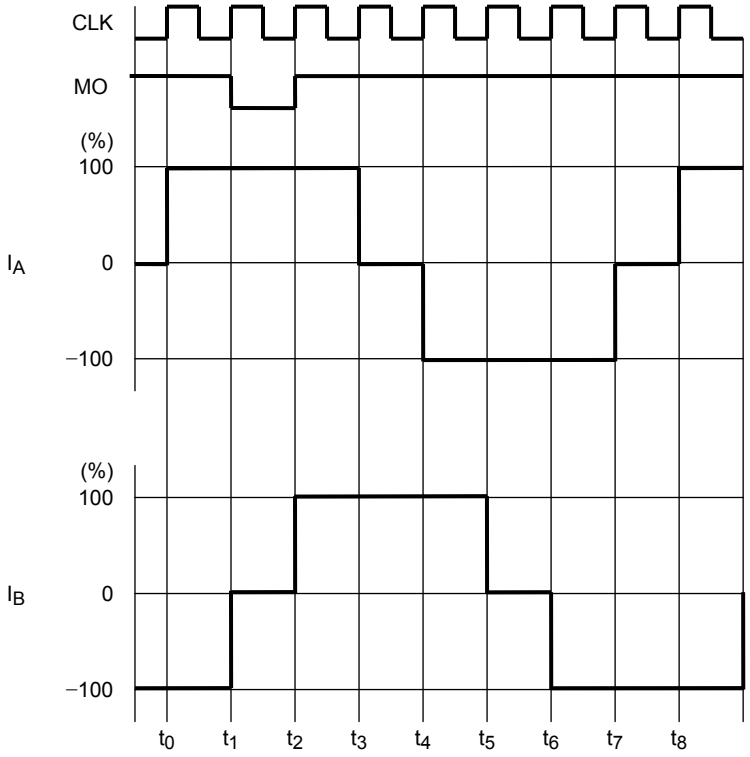


1/2-step Excitation Mode (A type) (M1: L, M2: H, M3: L, CCW Mode)

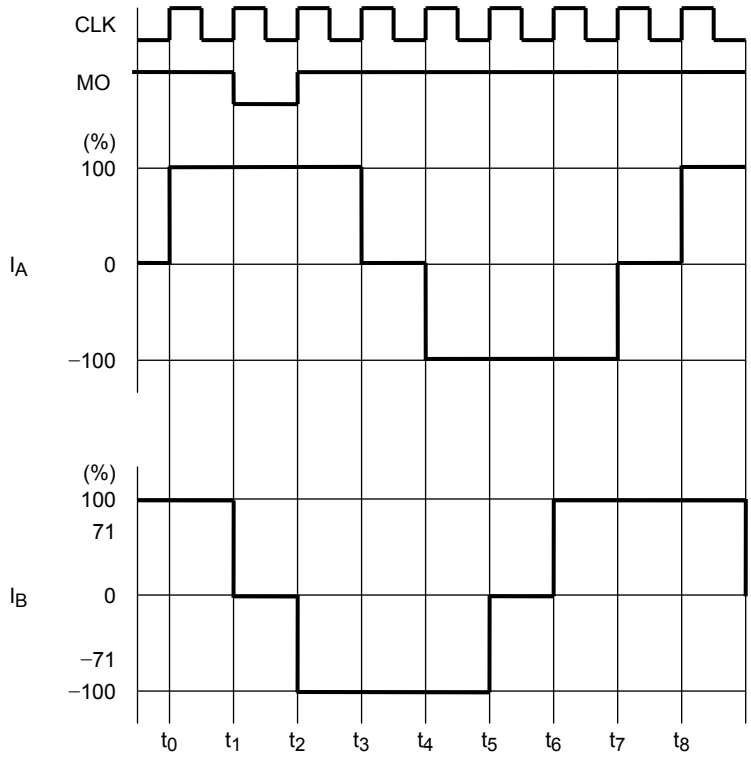


It operates from the initial state after the excitation mode is switched.

1/2-step Excitation Mode (B type) (M1: L, M2: H, M3: H, CW Mode)

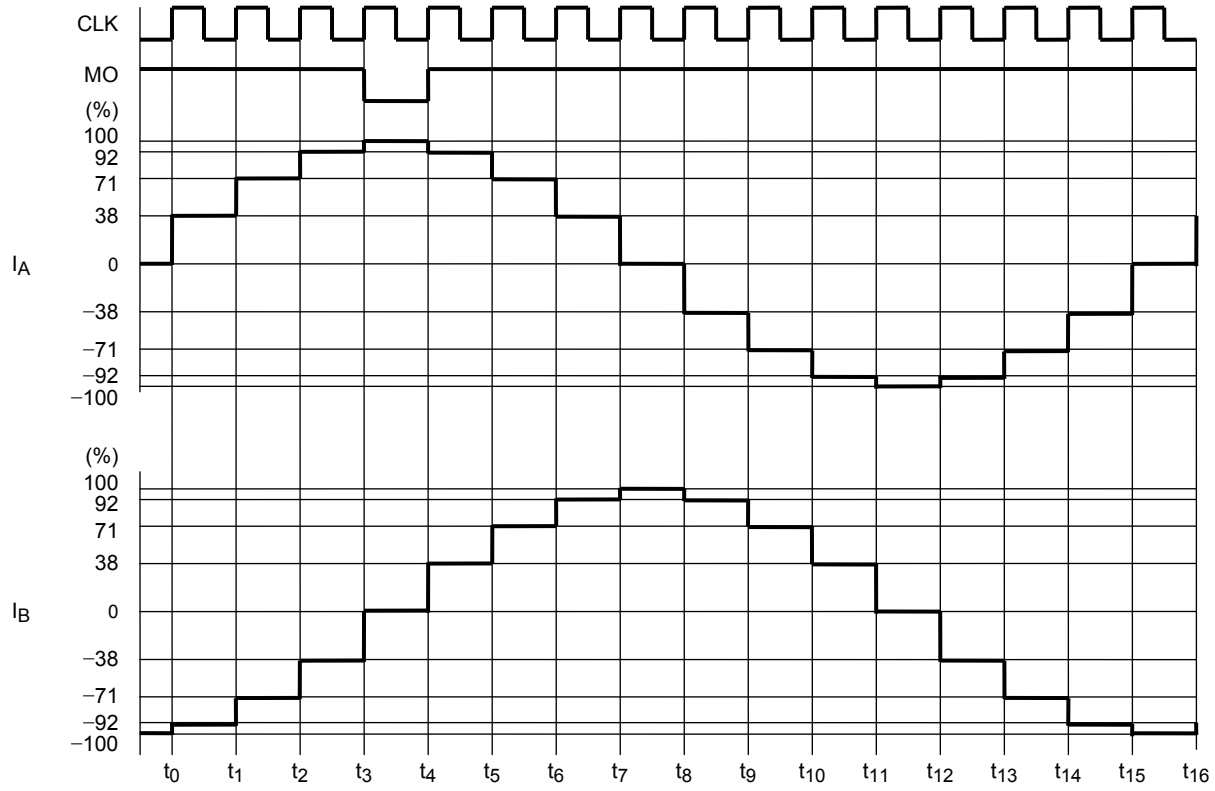


1/2-step Excitation Mode (B type) (M1: L, M2: H, M3: H, CCW Mode)

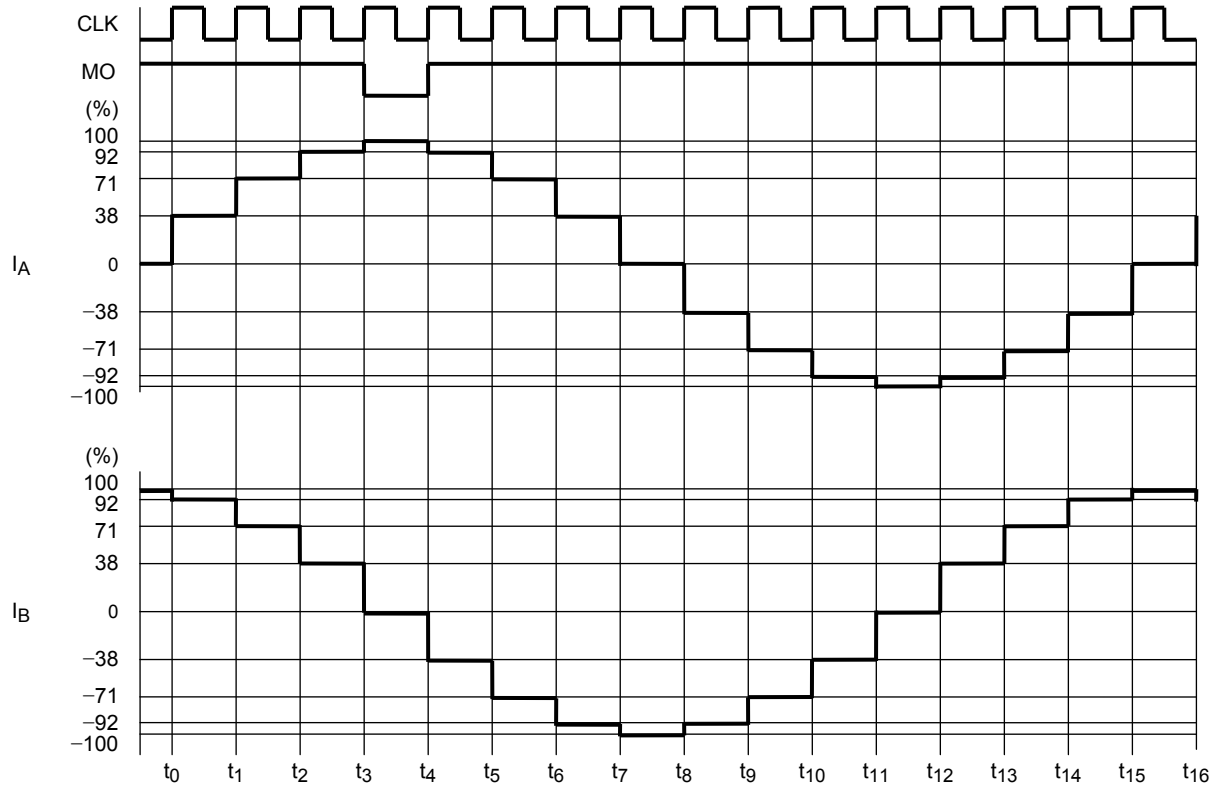


It operates from the initial state after the excitation mode is switched.

1/4-step Excitation Mode (M1: H, M2: L, M3: L, CW Mode)

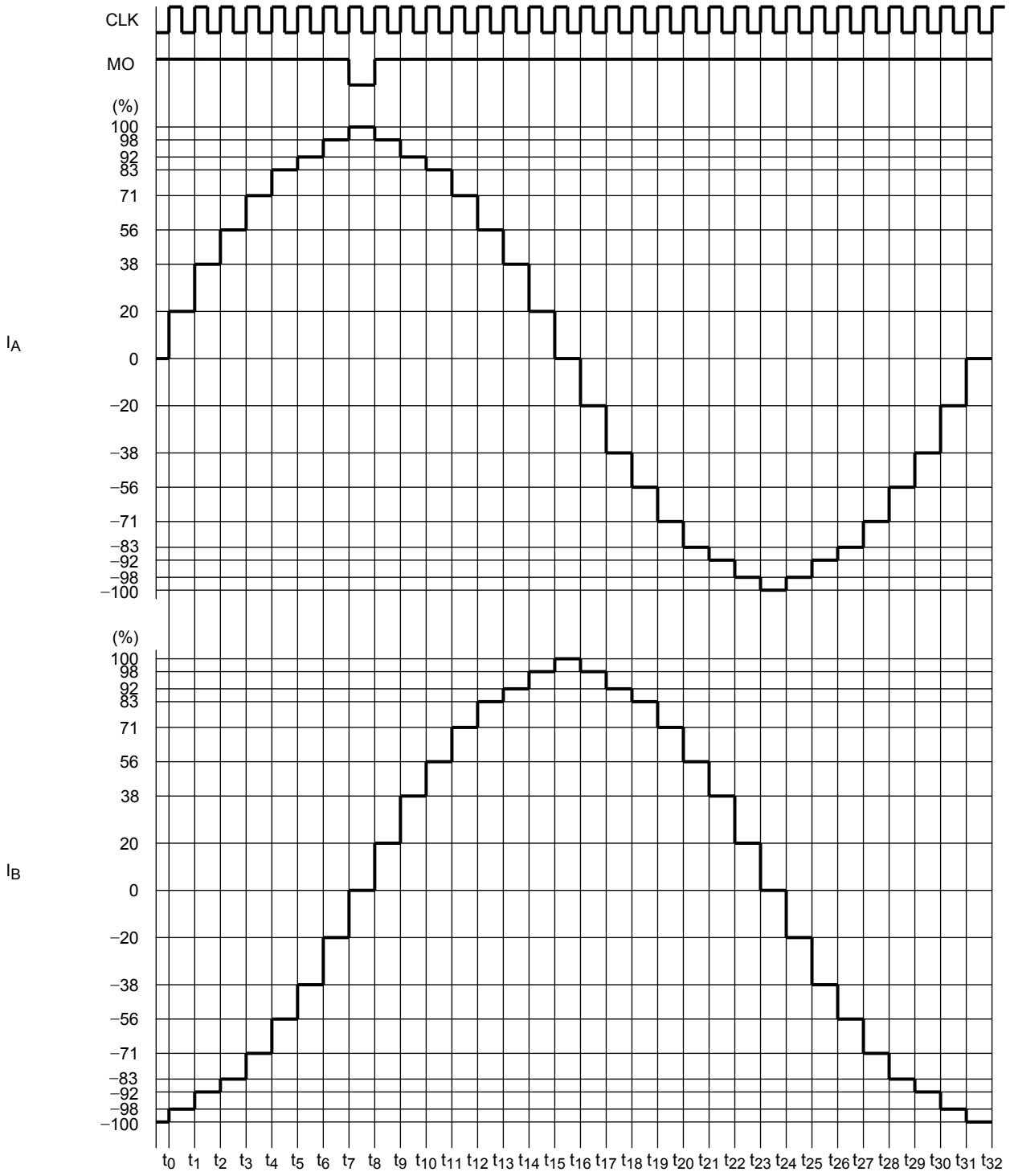


1/4-step Excitation Mode (M1: H, M2: L, M3: L, CCW Mode)



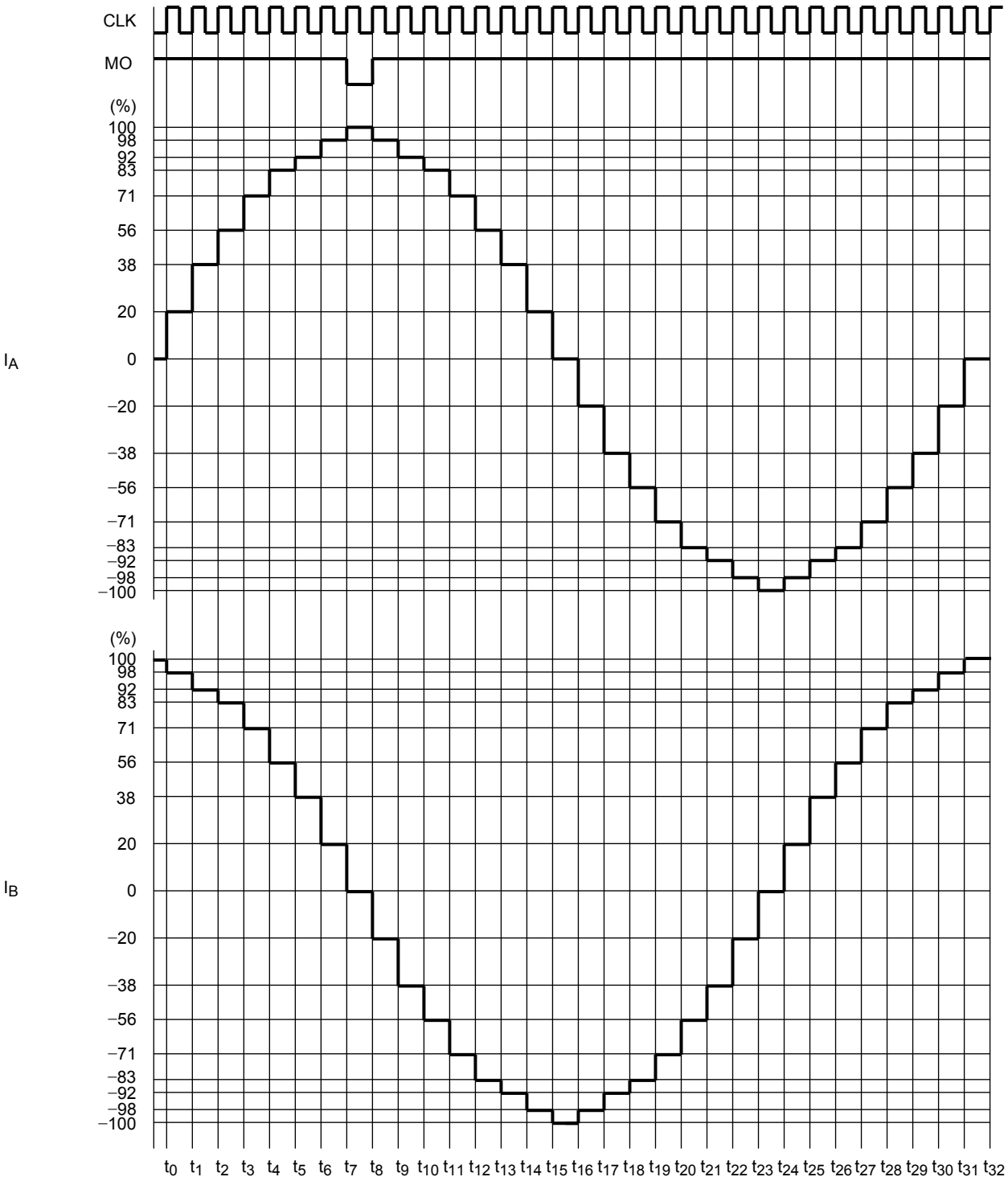
It operates from the initial state after the excitation mode is switched.

1/8-Step Excitation Mode (M1: H, M2: L, M3: H, CW Mode)



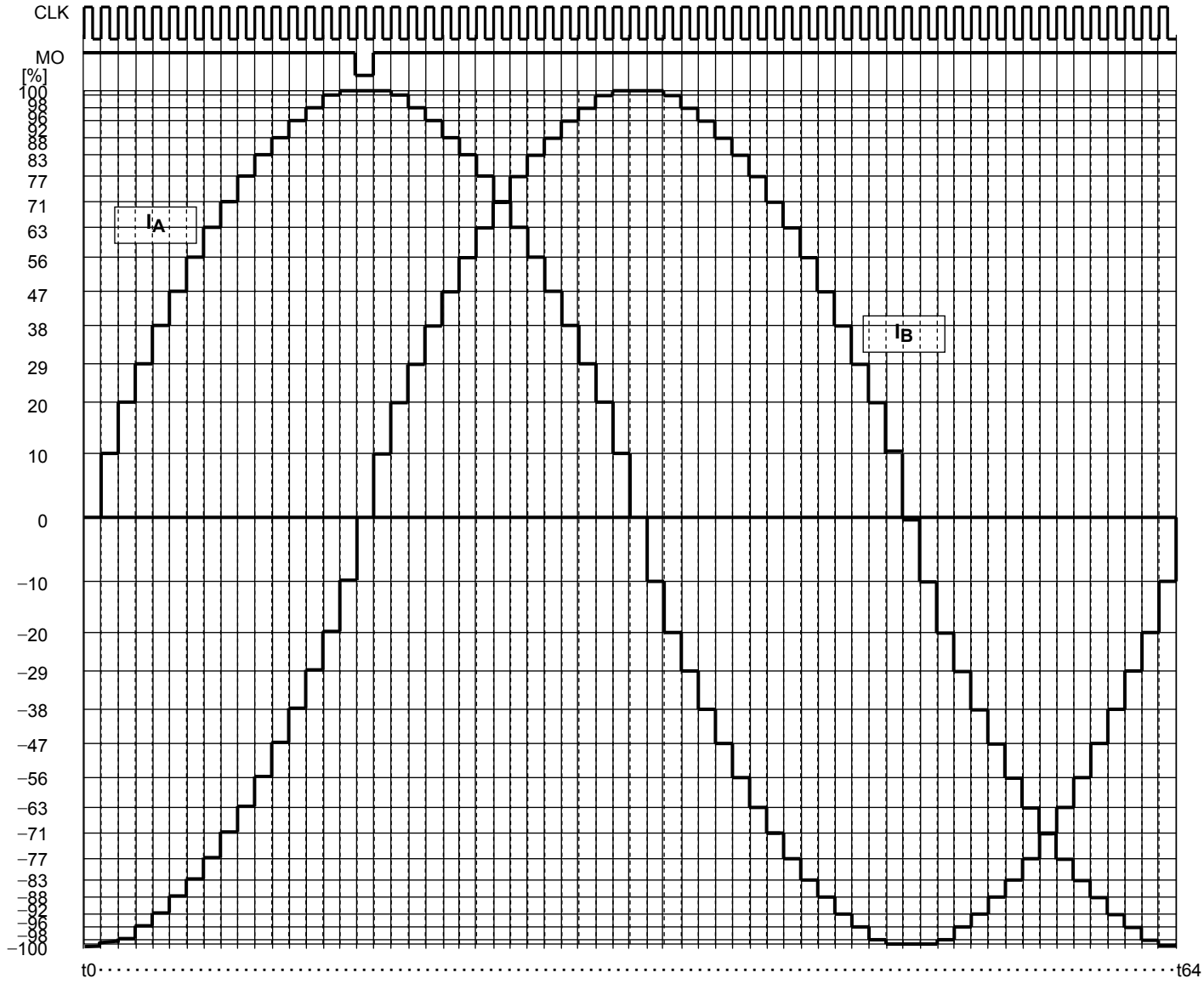
It operates from the initial state after the excitation mode is switched.

1/8-Step Excitation Mode (M1: H, M2: L, M3: H, CCW Mode)



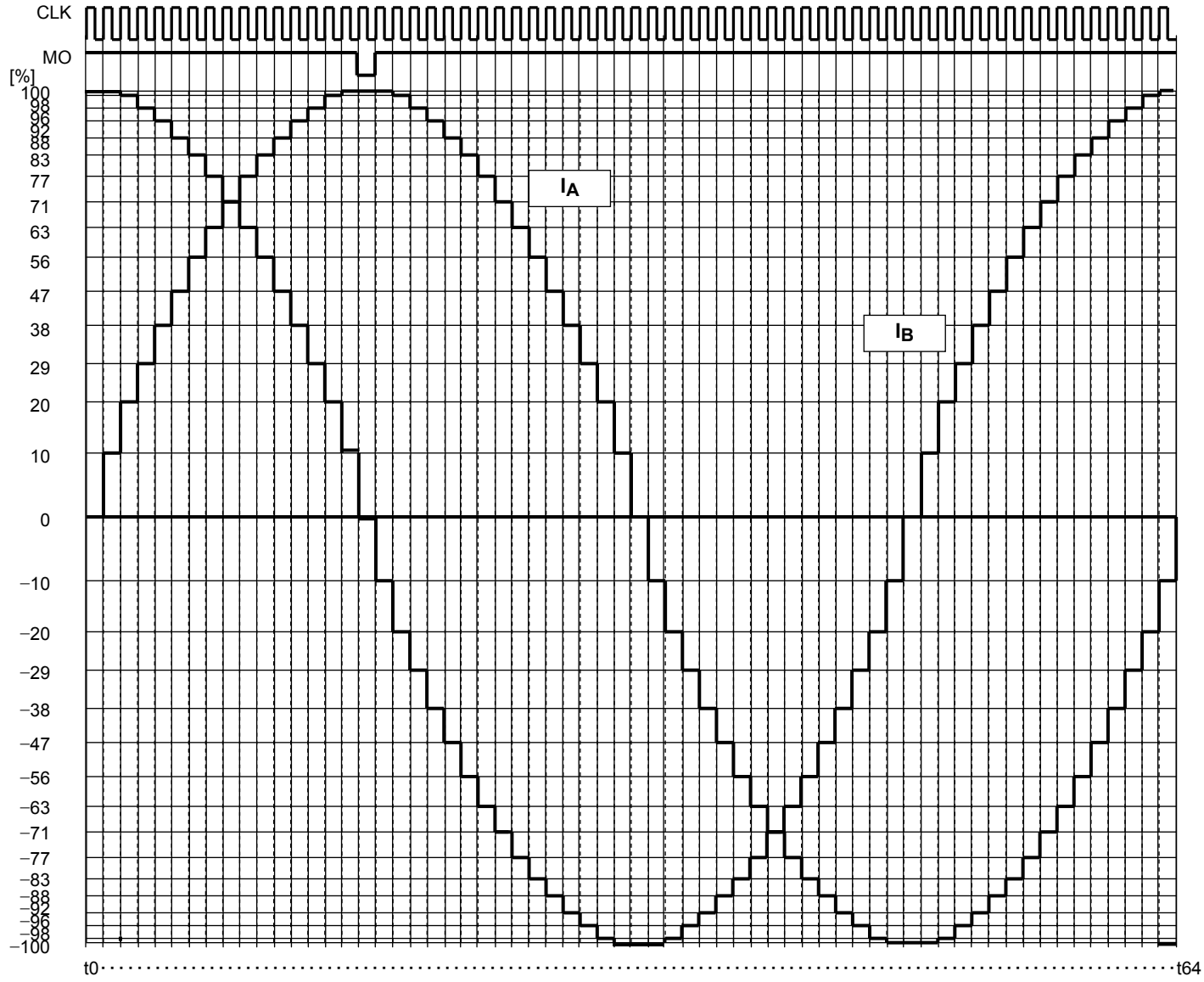
It operates from the initial state after the excitation mode is switched.

1/16-step Excitation Mode (M1: H, M2: H, M3: L, CW Mode)



It operates from the initial state after the excitation mode is switched.

1/16-step Excitation Mode (M1: H, M2: H, M3: L, CCW Mode)



It operates from the initial state after the excitation mode is switched.

Current level

2-phase, 1-2-phase, W1-2-phase, 2W1-2-phase, 4W1-2-phase excitation (unit: %)

Current level (1/16, 1/8, 1/4, 1/2, 1/1)

1/16, 1/8, 1/4, 1/2, 1/1	Min.	Typ.	Max.	Unit
θ16	---	100.0	---	%
θ15	95.5	99.5	100.0	
θ14	94.1	98.1	100.0	
θ13	91.7	95.7	99.7	
θ12	88.4	92.4	96.4	
θ11	84.2	88.2	92.2	
θ10	79.1	83.1	87.1	
θ9	73.3	77.3	81.3	
θ8	66.7	70.7	74.7	
θ7	59.4	63.4	67.4	
θ6	51.6	55.6	59.6	
θ5	43.1	47.1	51.1	
θ4	34.3	38.3	42.3	
θ3	25.0	29.0	33.0	
θ2	15.5	19.5	23.5	
θ1	5.8	9.8	13.8	
θ0	---	0.0	---	