TB6600FG

Usage considerations

Summary

The TB6600FG drives a two-phase bipolar stepping motor.
It drives at a constant current by PWM control. The TB6600FG can be used in applications that require full step, half-step, quarter-step, 1/8-step, and 1/16-step resolution. It is capable of forward and reverse driving of a two-phase bipolar stepping motor using only a clock signal.

Contents

1. Power supply

1.1. Operating Range of Power supply Voltage

Characteristic	Symbol	Operating Voltage Range	Absolute Maximum Rating	Unit
Power supply voltage	Vcc	8.0 to 42	50	V

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.
If a voltage outside the operating range as follows; 8.0 V ≤ Vcc ≤ 42 V is applied, the IC may not operate properly or the IC and peripheral parts may be permanently damaged. Ensure that the voltage range does not exceed the upper and lower limits of the specified range.

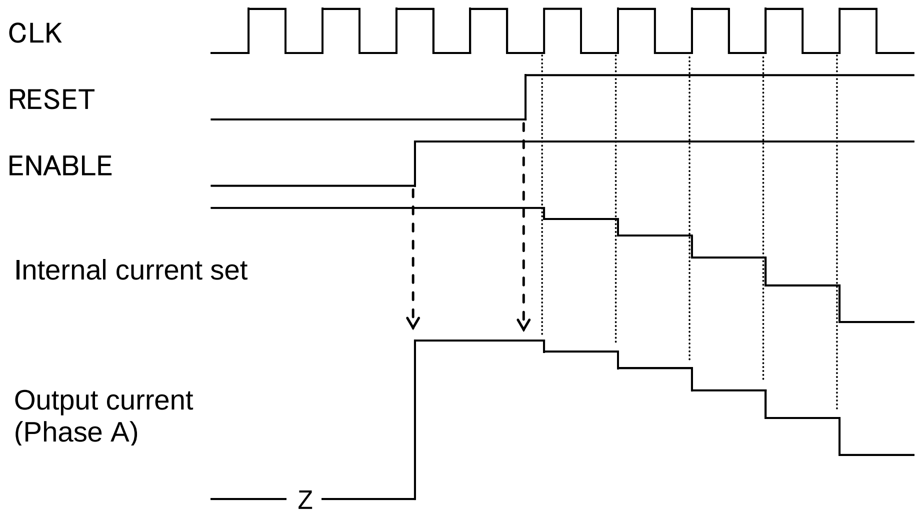
1.2. Power-on Sequence with Control Input Signals

In applying Vcc or shutdown, ENABLE should be Low.
See Example 1(ENABLE = High -> RESET = High) and Example 2(RESET = High -> ENABLE = High) as follows. In example 1, a motor can start driving from the initial mode.

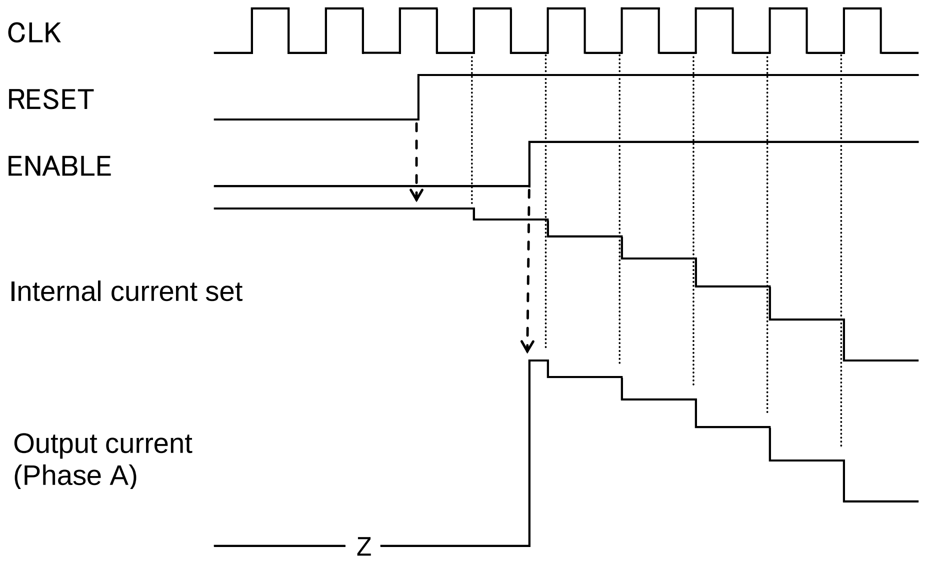
(1) CLK: Current step proceeds to the next mode with respect to every rising edge of CLK.
(2) ENABLE: It is in Hi-Z state in low level. It is output in high level.
RESET: It is in the initial mode (Phase A=100%) in low level.
- (I) ENABLE=Low and RESET=Low: Hi-Z. Internal current setting is in initial mode.
- (II) ENABLE=Low and RESET=High: Hi-Z. Internal current setting proceeds by internal counter.
- (III) ENABLE=High and RESET=Low: Output in the initial mode (Phase A=100%).
- (IV) ENABLE=High and RESET=High: Output at the value which is determined by the internal counter.

<**Recommended control input sequence**>

(Example 1)



(Example 2)



2. Output Current

The absolute maximum rating is 4.50 A per phase, and the upper limit of operating current is 4.0 A per phase. 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.
The average permissible current is restricted by total power dissipation. Please use the IC within the range of the power dissipation.

3. Output ON-Resistance

Output ON-resistances for H-bridge: 0.4 Ω typical and 0.6 Ω maximum (upper and lower sum) with a test condition of the Iout = 4.0 A

4. Output Residual Voltage

The residual voltages of the MO and ALERT output pins are up to 0.5 V each where Io = 1 mA.

5. Description of Functions

5.1. 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.

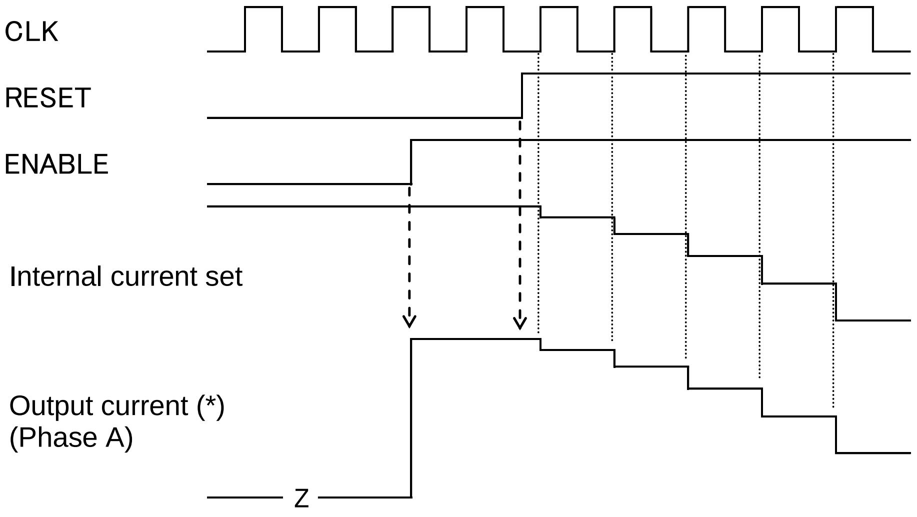
Standby mode

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 Hi-Z.
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.

5.2. 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	
↑	Low	High	High	CW
↑	High	High	High	CCW
X	X	Low	High	Initial mode
X	X	X	Low	Z

X: Don’t Care

Command of the standby has a higher priority than ENABLE. Standby mode can be turned on and off regardless of the state of ENABLE.

5.3. 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 to OUT2A: Forward direction
OUT1B to OUT2B: Forward direction

5.4. 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.

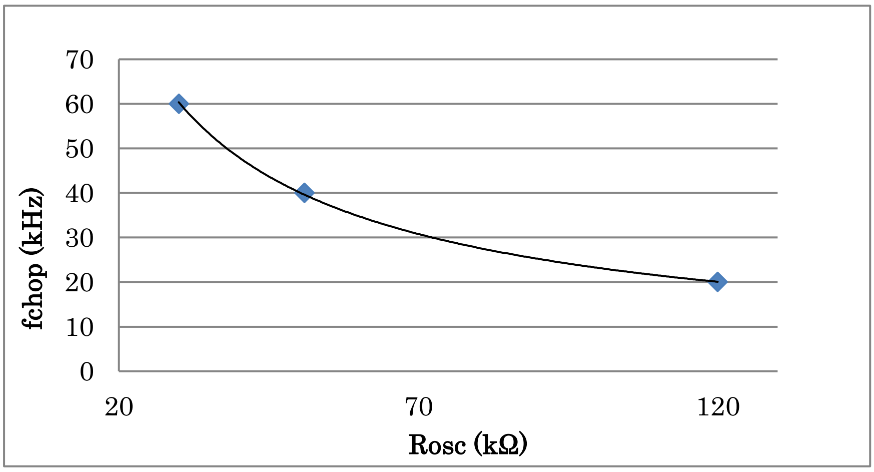
$$Io\ (100\%) = (1 / 3 \times Vref) / RNF$$

The average current is lower than the calculated value because this IC has the method of peak current detection.
Please use the IC under the conditions as follows;
$0.11\ \Omega \le RNF \le 0.5\ \Omega$, $0.3\ V \le Vref \le 1.95\ V$

5.5. OSC

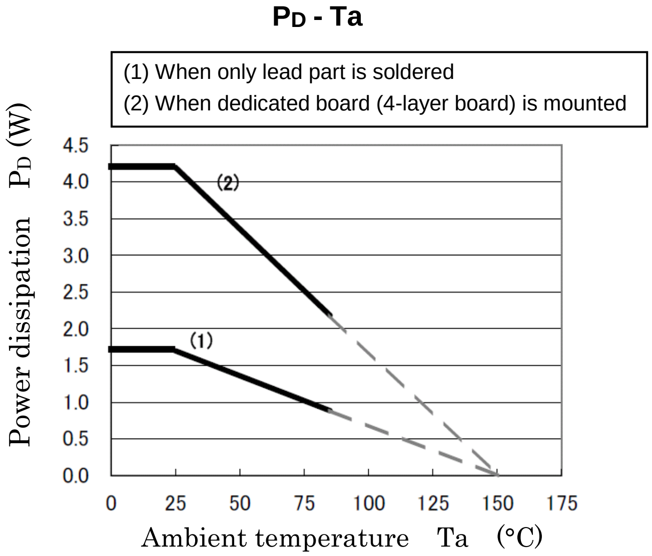
Triangle wave is generated internally by CR oscillation by connecting external resistor to OSC terminal.
Rosc should be from 30 kΩ to 120 kΩ. The relation of Rosc and fchop is shown in below table and figure. The values of fchop of the below table are design values. They are not tested for pre-shipment.

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



6. Power Dissipation

P_D-Ta curve of the TB6600FG in each mounted condition are shown below.



Power consumption in each excitation mode is calculated at a rough estimate as follows:

Full-step resolution

$P = Vcc \times Icc + (Ron\ (U + L) \times Io \times Io) \times 2$

Half-step resolution

$P = Vcc \times Icc + \{(Ron\ (U + L) \times Io \times 100\% \times Io \times 100\% \times (2 / 8))$
$+ (Ron\ (U + L) \times Io \times 71\% \times Io \times 71\% \times (4 / 8))$
$+ (Ron\ (U + L) \times Io \times 0\% \times Io \times 0\% \times (2 / 8))\} \times 2$

Quarter-step resolution

$P = Vcc \times Icc + \{(Ron\ (U + L) \times Io \times 100\% \times Io \times 100\% \times (2 / 16))$
$+ (Ron\ (U + L) \times Io \times 92\% \times Io \times 92\% \times (4 / 16)) + (Ron\ (U + L) \times Io \times 71\% \times Io \times 71\% \times (4 / 16))$
$+ (Ron\ (U + L) \times Io \times 38\% \times Io \times 38\% \times (4 / 16)) + (Ron\ (U + L) \times Io \times 0\% \times Io \times 0\% \times (2 / 16))\} \times 2$

1/8 step resolution

$P = Vcc \times Icc + \{(Ron\ (U + L) \times Io \times 100\% \times Io \times 100\% \times (2 / 32))$
$+ (Ron\ (U + L) \times Io \times 98\% \times Io \times 98\% \times (4 / 32)) + (Ron\ (U + L) \times Io \times 92\% \times Io \times 92\% \times (4 / 32))$
$+ (Ron\ (U + L) \times Io \times 83\% \times Io \times 83\% \times (4 / 32)) + (Ron\ (U + L) \times Io \times 71\% \times Io \times 71\% \times (4 / 32))$
$+ (Ron\ (U + L) \times Io \times 56\% \times Io \times 56\% \times (4 / 32)) + (Ron\ (U + L) \times Io \times 38\% \times Io \times 38\% \times (4 / 32))$
$+ (Ron\ (U + L) \times Io \times 20\% \times Io \times 20\% \times (4 / 32)) + (Ron\ (U + L) \times Io \times 0\% \times Io \times 0\% \times (2 / 32))\} \times 2$

1/16 step resolution

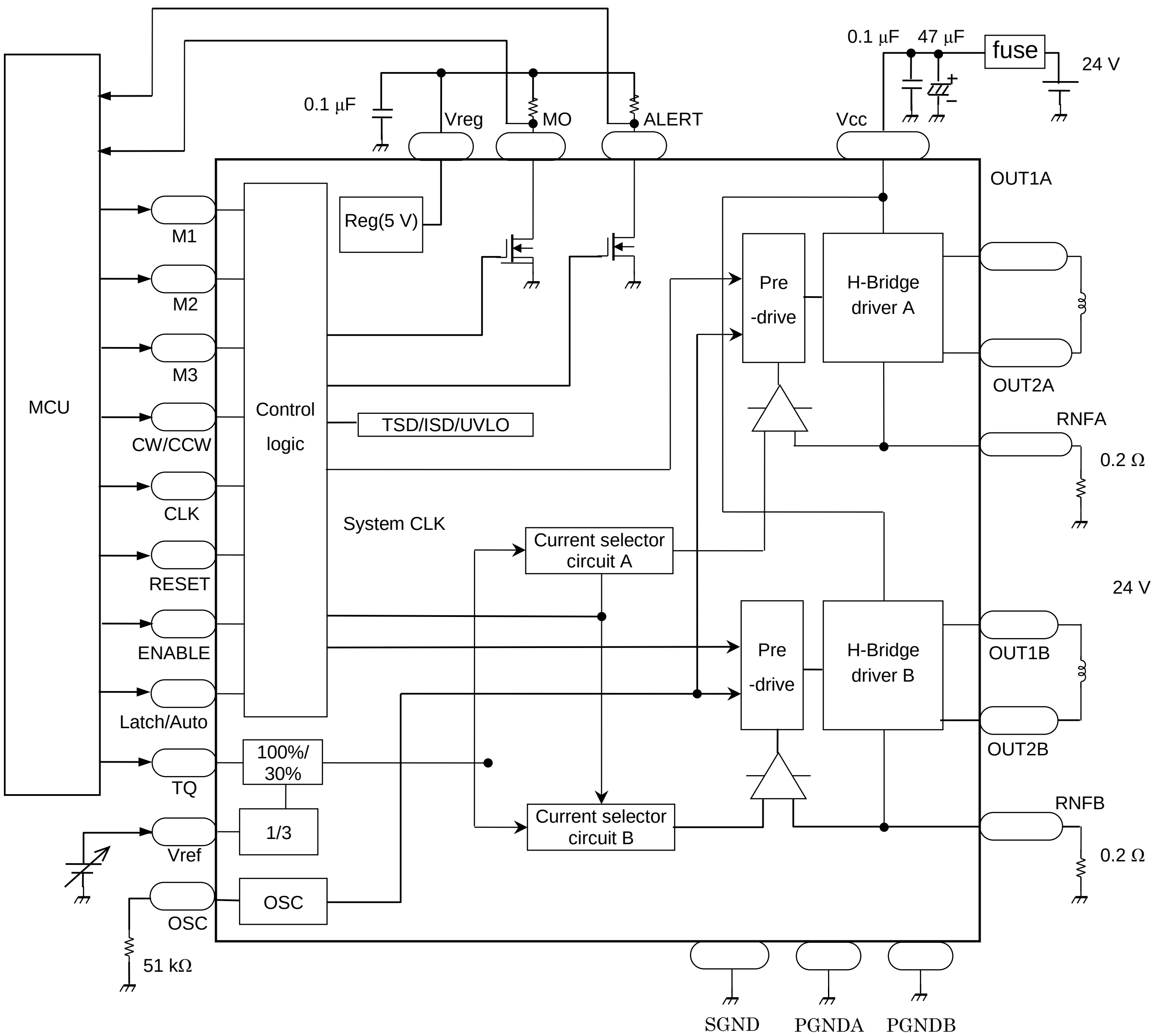
$P = Vcc \times Icc + \{(Ron\ (U + L) \times Io \times 100\% \times Io \times 100\% \times (6 / 64))$
$+ (Ron\ (U + L) \times Io \times 98\% \times Io \times 98\% \times (4 / 64))$
$+ (Ron\ (U + L) \times Io \times 96\% \times Io \times 96\% \times (4 / 64)) + (Ron\ (U + L) \times Io \times 92\% \times Io \times 92\% \times (4 / 64))$
$+ (Ron\ (U + L) \times Io \times 88\% \times Io \times 88\% \times (4 / 64)) + (Ron\ (U + L) \times Io \times 83\% \times Io \times 83\% \times (4 / 64))$
$+ (Ron\ (U + L) \times Io \times 77\% \times Io \times 77\% \times (4 / 64)) + (Ron\ (U + L) \times Io \times 71\% \times Io \times 71\% \times (4 / 64))$
$+ (Ron\ (U + L) \times Io \times 63\% \times Io \times 63\% \times (4 / 64)) + (Ron\ (U + L) \times Io \times 56\% \times Io \times 56\% \times (4 / 64))$
$+ (Ron\ (U + L) \times Io \times 47\% \times Io \times 47\% \times (4 / 64)) + (Ron\ (U + L) \times Io \times 38\% \times Io \times 38\% \times (4 / 64))$
$+ (Ron\ (U + L) \times Io \times 29\% \times Io \times 29\% \times (4 / 64)) + (Ron\ (U + L) \times Io \times 20\% \times Io \times 20\% \times (4 / 64))$
$+ (Ron\ (U + L) \times Io \times 10\% \times Io \times 10\% \times (4 / 64)) + (Ron\ (U + L) \times Io \times 10\% \times Io \times 10\% \times (2 / 64))\} \times 2$

(Notes)

Vcc = Power supply voltage
Icc = Supply current
Ron(U + L) = Output on-resistance (Upper + lower)
Io = Output current (Peak value of 100%)

Please confirm the operation in the actual operation conditions because thermal characteristics changes widely depending on the discharge characteristics of the board and the transient characteristics in the mounted state.
Heat loss can be promoted by taking the GND pattern of the print board widely. Usage of a heat sink is recommended to promote more heat loss.

7. Application Circuit Example



Note 1: Capacitors for the power supply lines should be connected as close to the IC as possible.
Note 2: Current detecting resistances (RNFA and RNFB) should be connected as close to the IC as possible.
Note 3: Pay attention for wire layout of PCB not to allow GND line to have large common impedance.
Note 4: External capacitor connecting to Vreg should be 0.1µF. Pay attention for the wire between this capacitor and Vreg terminal and the wire between this capacitor and SGND not to be influenced by noise.
Note 5: The IC may not operate normally when large common impedance is existed in GND line or the IC is easily influenced by noise. For example, if the IC operates continuously for a long time under the circumstance of large current and high voltage, the number of clock signals inputted to CLK terminal and that of steps of output current waveform may not proportional. And so, the IC may not operate normally. To avoid this malfunction, make sure to conduct Note.1 to Note.4 and evaluate the IC enough before using the IC.
Note6: Two Vcc terminals should be programmed the same voltage.
Note7: The power supply voltage of 42 V and the output current of 4.0 A are the maximum values of operating range. Please design the circuit with enough derating within this range by considering the power supply variation, the external resistance, and the electrical characteristics of the IC. In case of exceeding the power supply voltage of 42 V and the output current of 4.0 A, the IC will not operate normally.

7.1. Usage Considerations

- A large current might abruptly flow through the IC in case of a short-circuit across its outputs, a short-circuit to power supply or a short-circuit to ground, leading to a damage of the IC. Also, the IC or peripheral parts may be permanently damaged or emit smoke or fire resulting in injury especially if a power supply pin (Vcc) or an output pin (OUT1A, OUT2A, OUT1B and OUT2B) is short-circuited to adjacent or any other pins. These possibilities should be fully considered in the design of the output, Vcc, and ground lines.
- Wiring of the SGND, PGNDA and PGNDB Pins
- The SGND pin, PGNDA pin and PGNDB pin must be connected electrically outside the TB6600FG. Extreme care must be taken for wiring them since they may be exposed to the potential differences due to the short and thick wiring in the vicinity of the TB6600FG.
- An Appropriate Power Supply Fuse Must be Used
  Add the appropriate fuses to ensure that a large current does not continuously flow in case of over current and/or IC failure. A fuse should be connected to the power supply line. The rated absolute maximum current of the TB6600FG is 4.5A/phase. Considering those absolute maximum ratings, an appropriate fuse must be selected depending on operating conditions of a motor to be used. Toshiba recommends that a fast-blow fuse be used.
- Power Supply Procedure
  Follow the power supply procedure described in this document. Otherwise, excess current may be applied to the TB6600FG and peripheral devices, which fully damages them.
- 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.
- If a voltage outside the operating range specified on page 3 (8.0 V ≤ Vcc ≤ 42 V) is applied, the IC may not operate properly or the IC and peripheral parts may be permanently damaged. Ensure that the voltage range does not exceed the upper and lower limits of the specified range.

7.2. Capacitors for the Power Supply Lines

Capacitors for the power supply lines between Vcc and GND should be connected as close to the IC as possible.

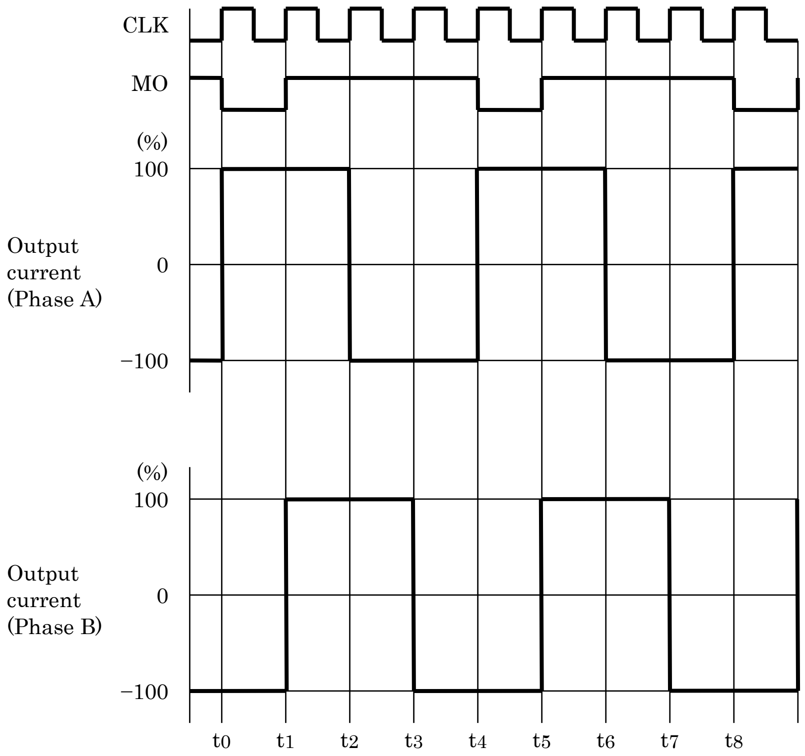
Recommended Value

Characteristic	Recommended Value	Remarks
Vcc - GND	10 μF to 100 μF	Electrolytic capacitor
	0.1 μF to 1 μF	Ceramic capacitor

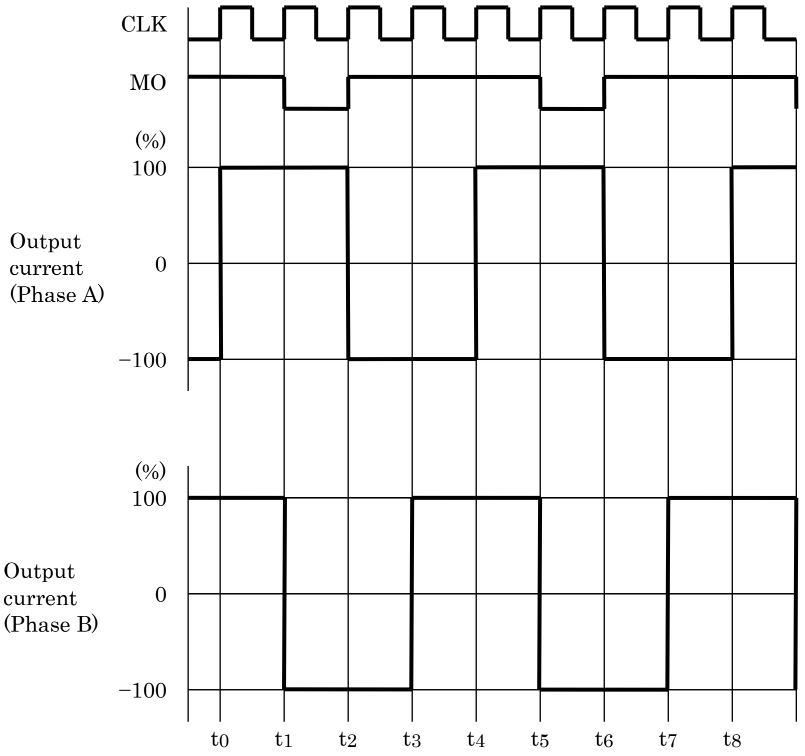
8. Excitation Mode Setting

The excitation mode can be selected from full-step, half-step, quarter-step, 1/8-step, and 1/16-step resolution using the M1, M2 and M3 inputs. It is capable of forward and reverse driving of a two-phase bipolar stepping motor with CW and CCW terminals using only a clock signal.

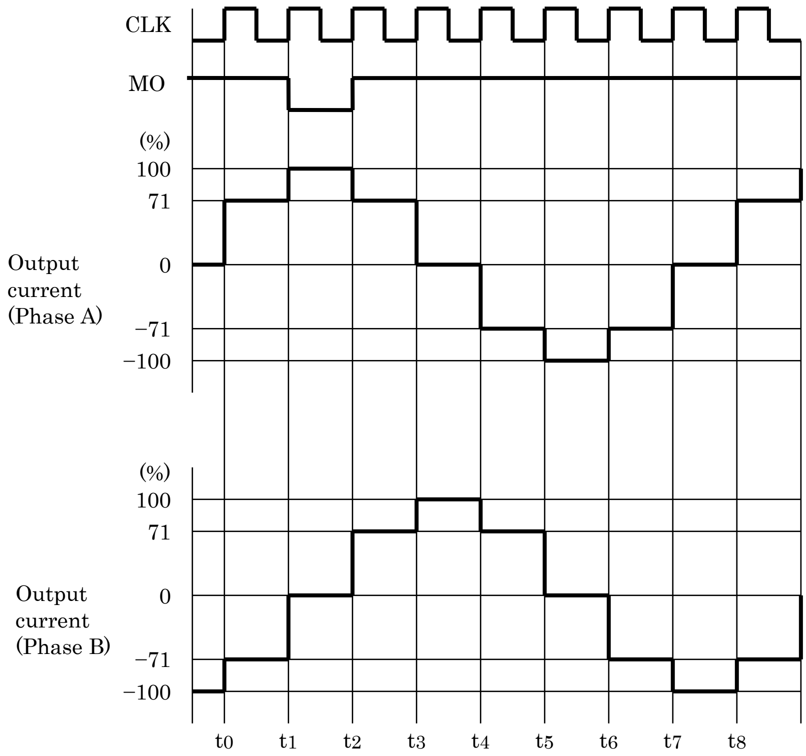
Full-step resolution (M1: L, M2: L, M3: H, CW Mode)



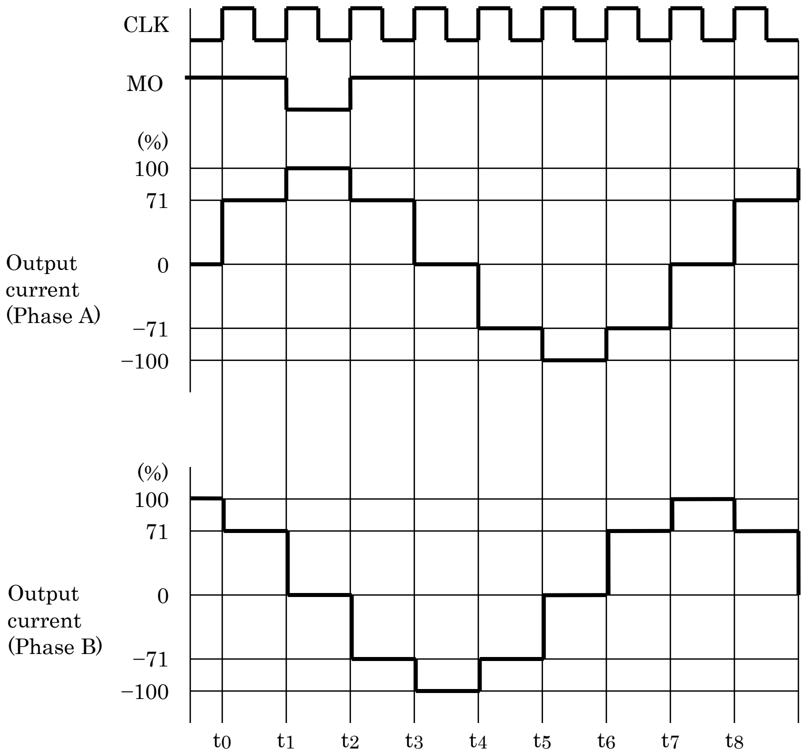
Full-step resolution (M1: L, M2: L, M3: H, CCW Mode)



Half-step resolution (A type) (M1: L, M2: H, M3: L, CW Mode)

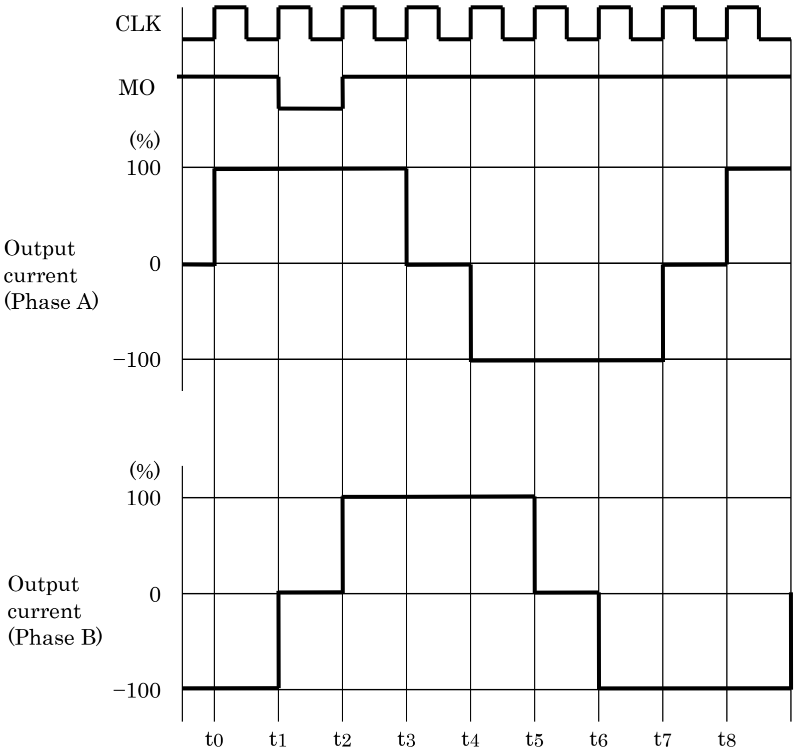


Half-step resolution (A type) (M1: L, M2: H, M3: L, CCW Mode)

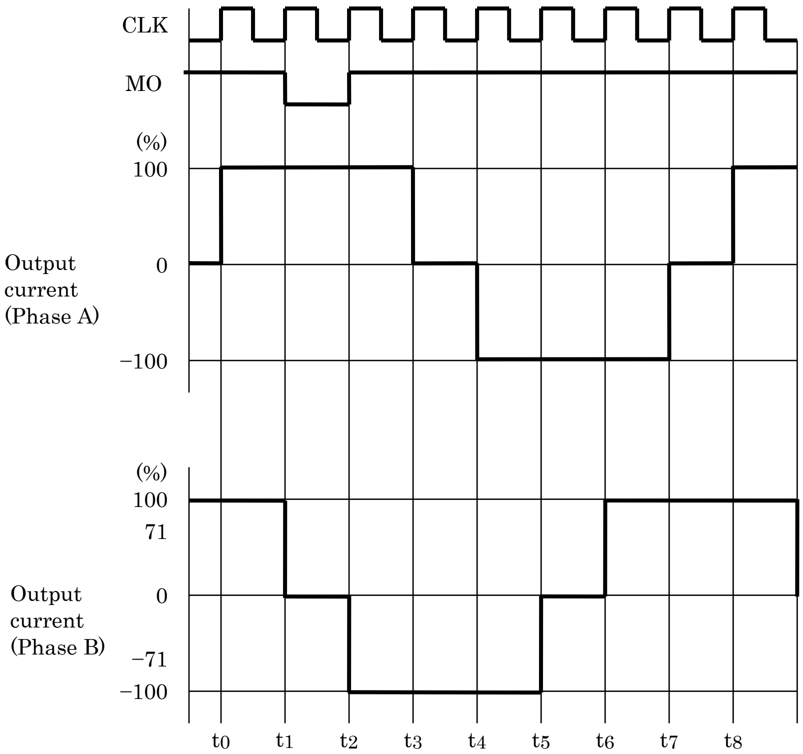


It operates from the initial state after the excitation mode is switched.

Half-step resolution (B type) (M1: L, M2: H, M3: H, CW Mode)

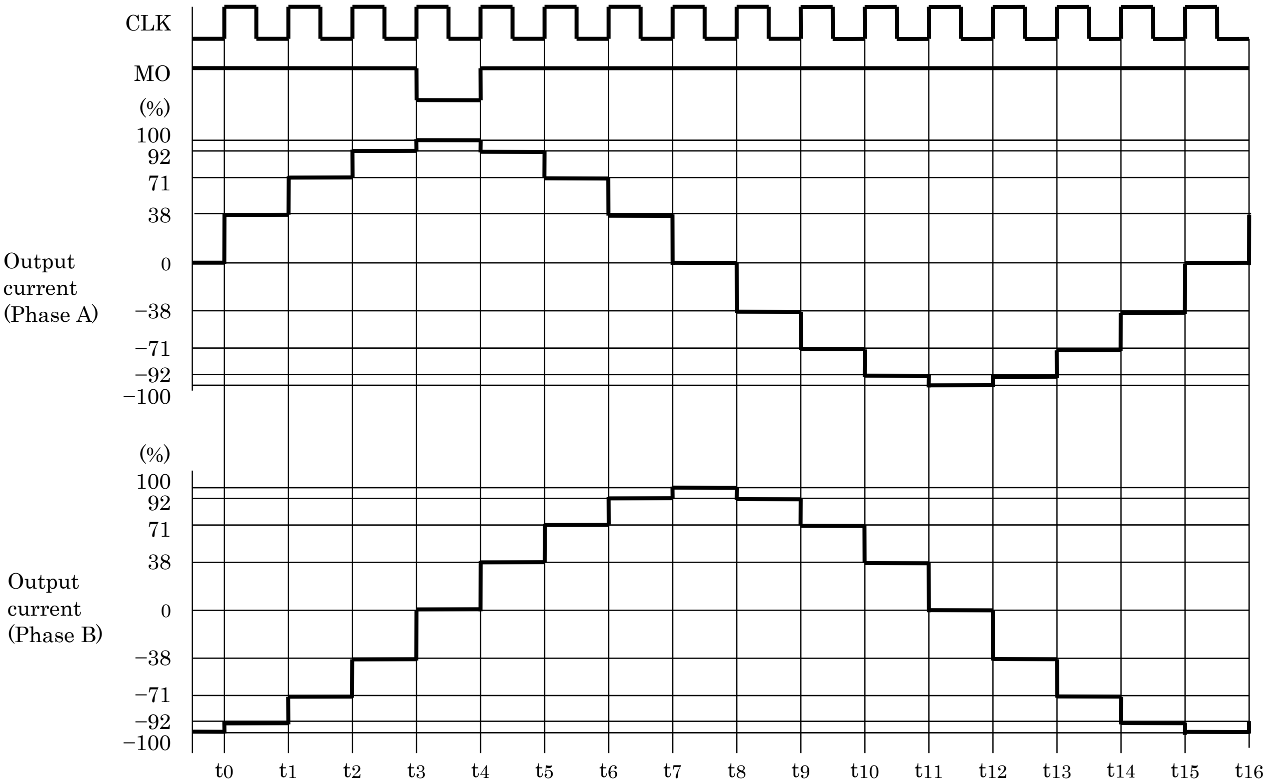


Half-step resolution (B type) (M1: L, M2: H, M3: H, CCW Mode)

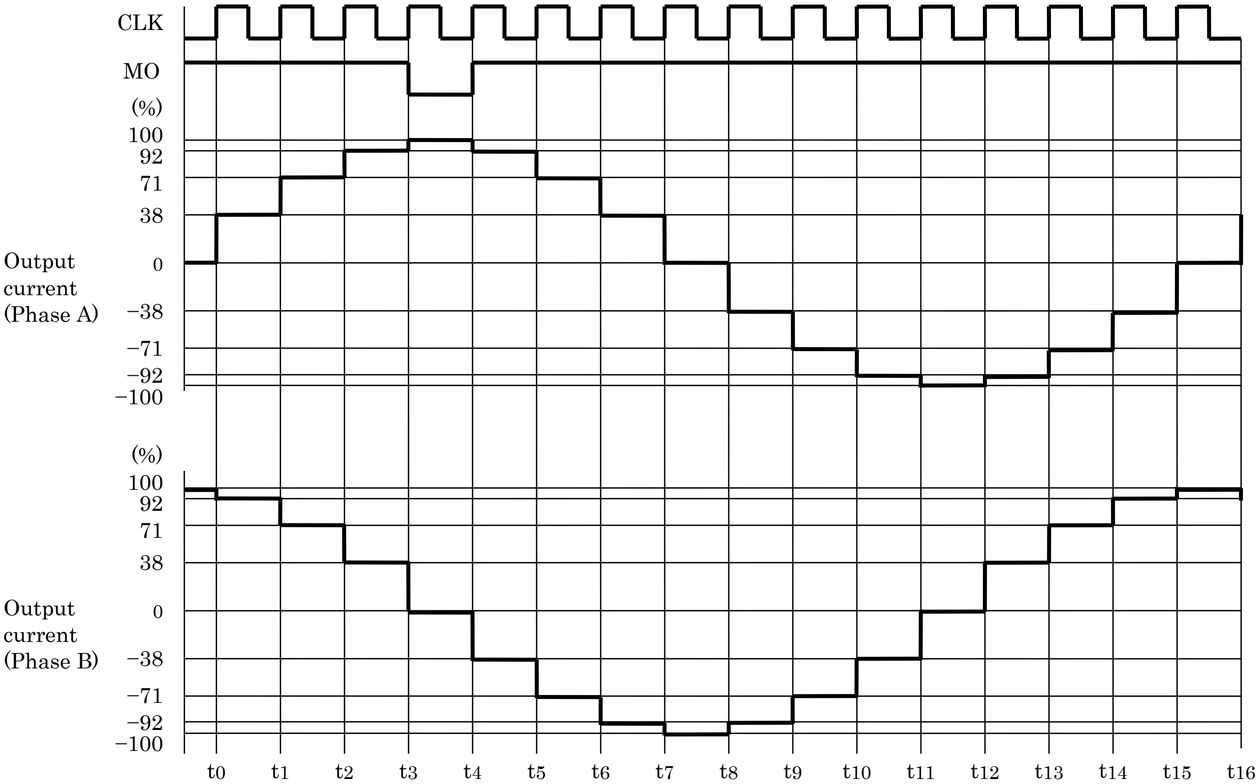


It operates from the initial state after the excitation mode is switched.

Quarter-step resolution (M1: H, M2: L, M3: L, CW Mode)

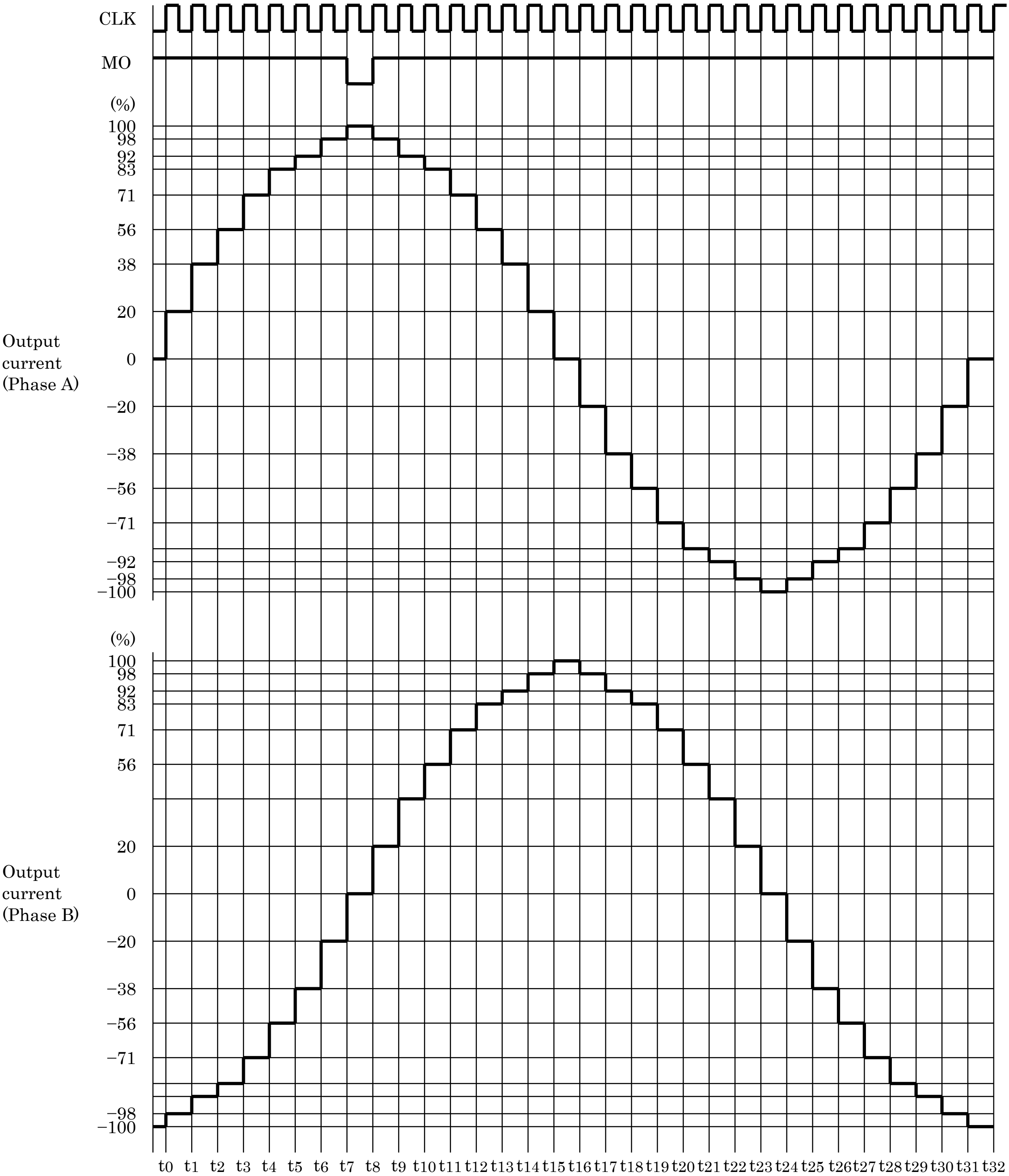


Quarter-step resolution (M1: H, M2: L, M3: L, CCW Mode)



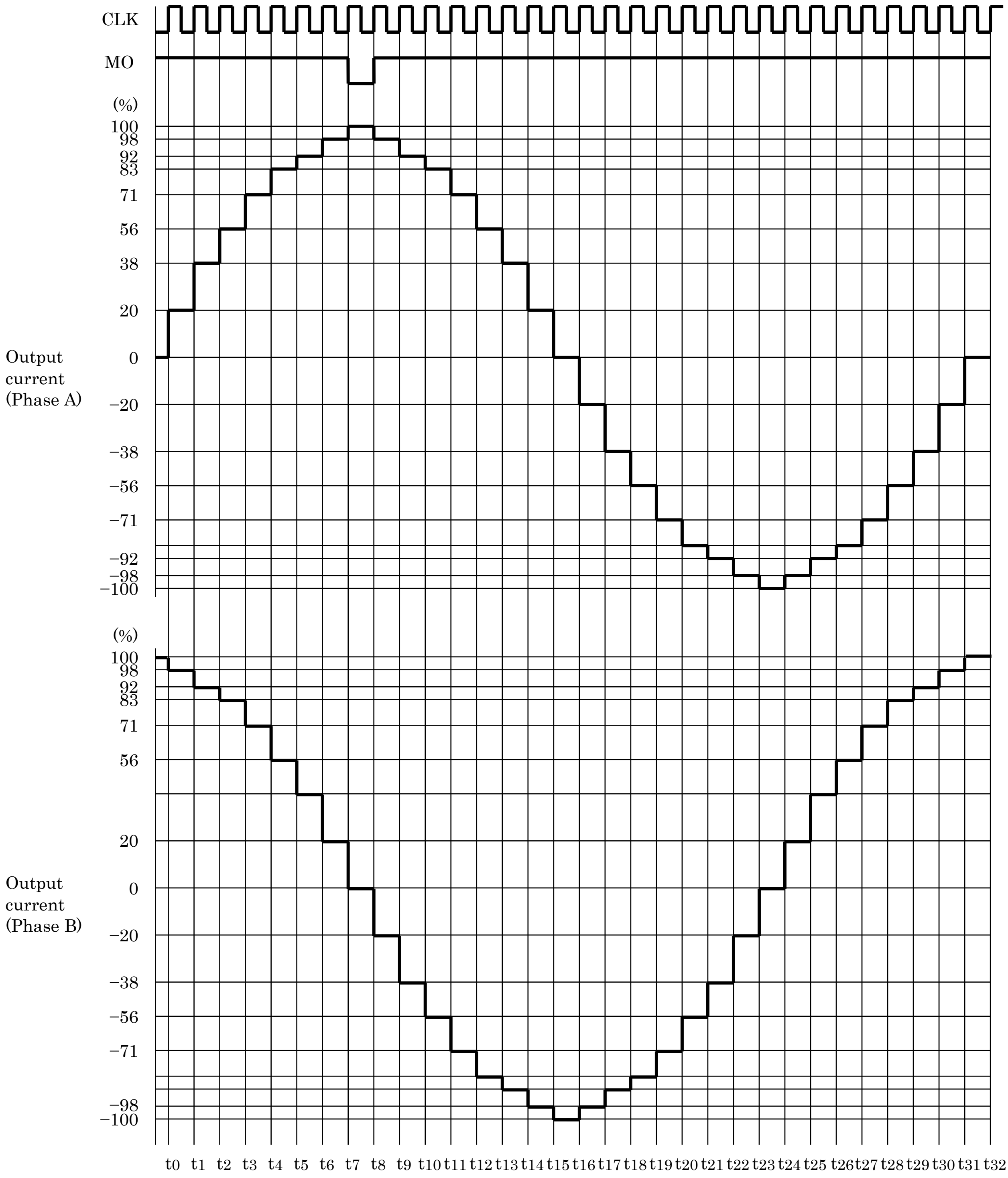
It operates from the initial state after the excitation mode is switched.

1/8-step resolution (M1: H, M2: L, M3: H, CW Mode)



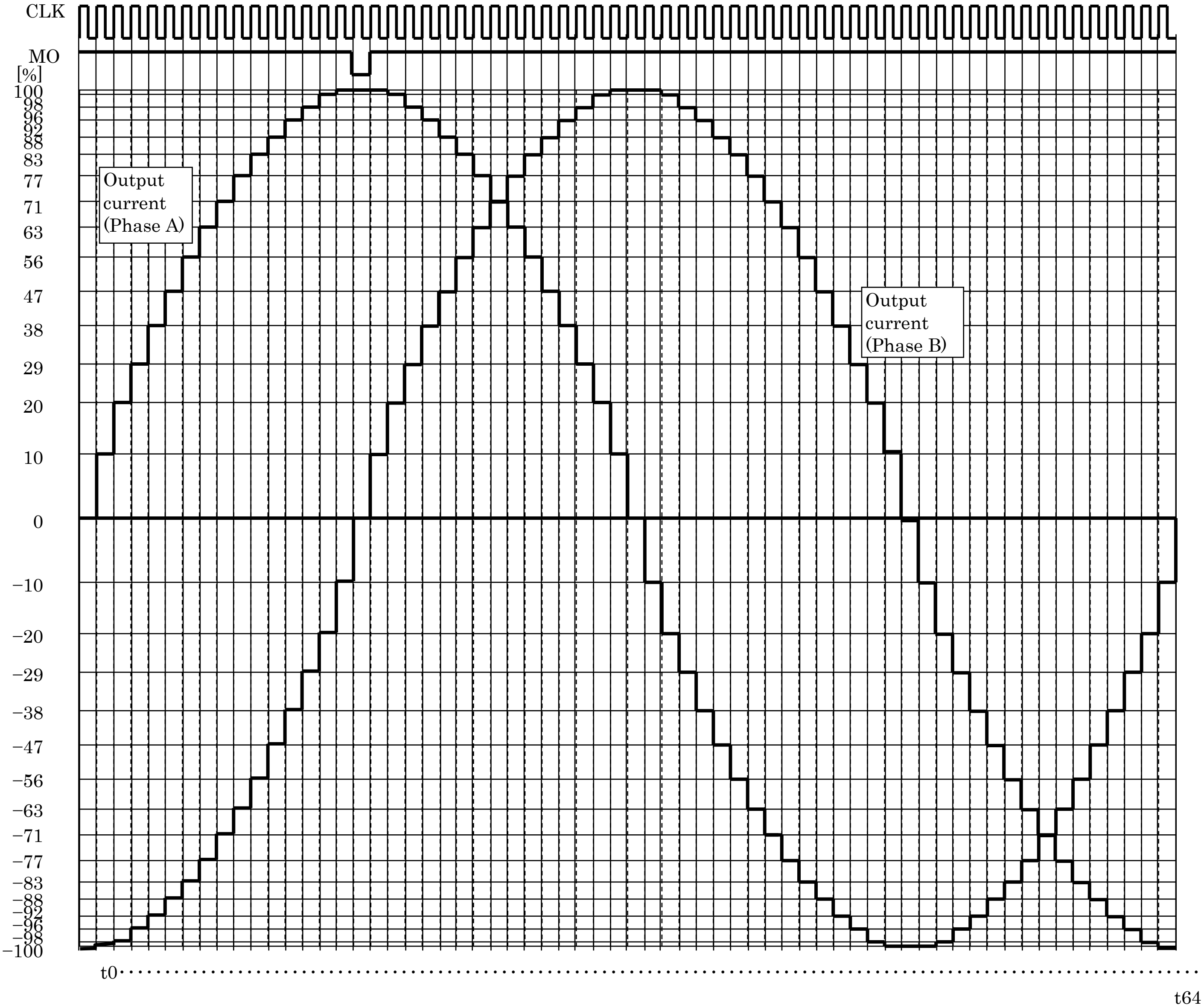
It operates from the initial state after the excitation mode is switched.

1/8-step resolution (M1: H, M2: L, M3: H, CCW Mode)



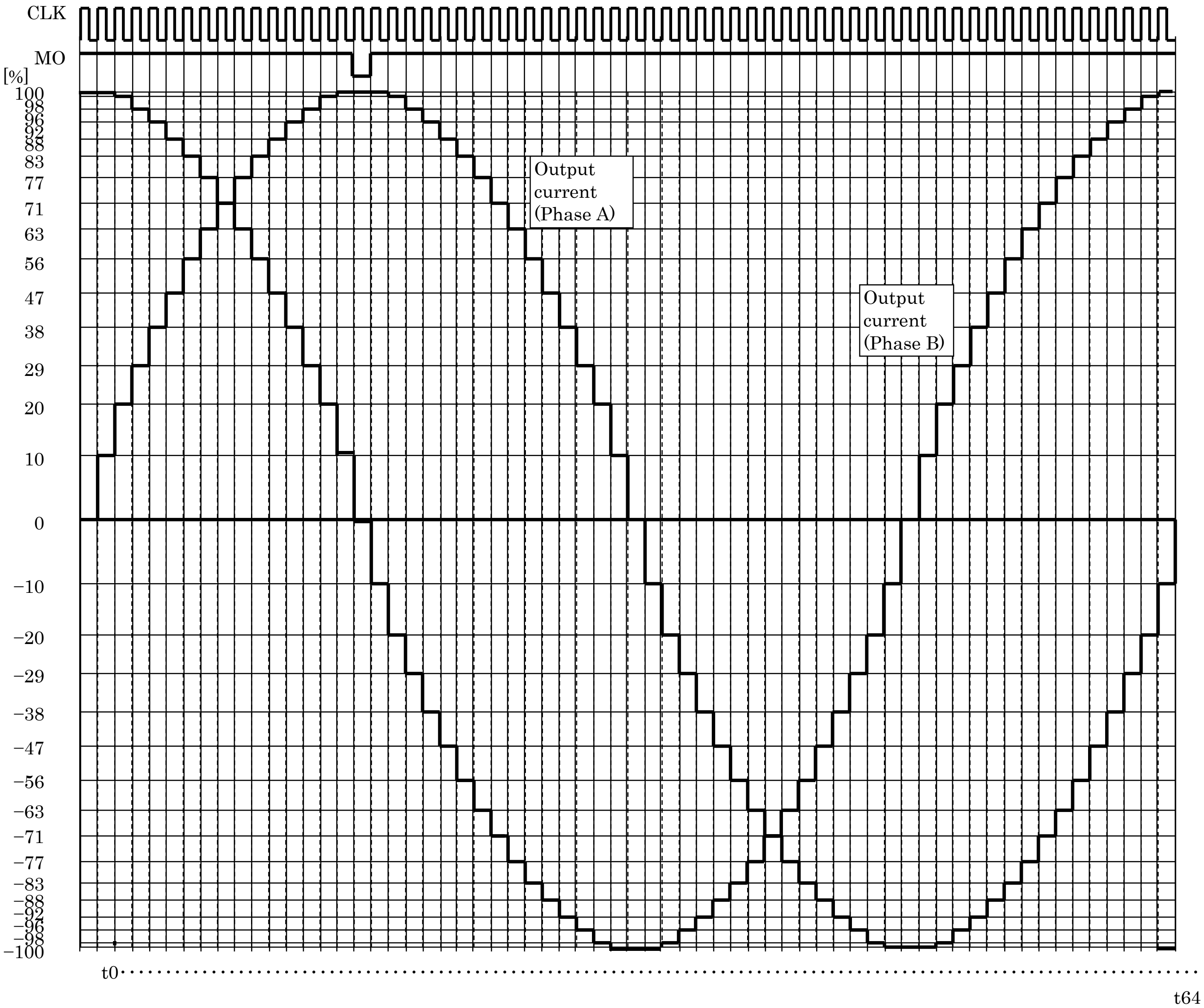
It operates from the initial state after the excitation mode is switched.

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



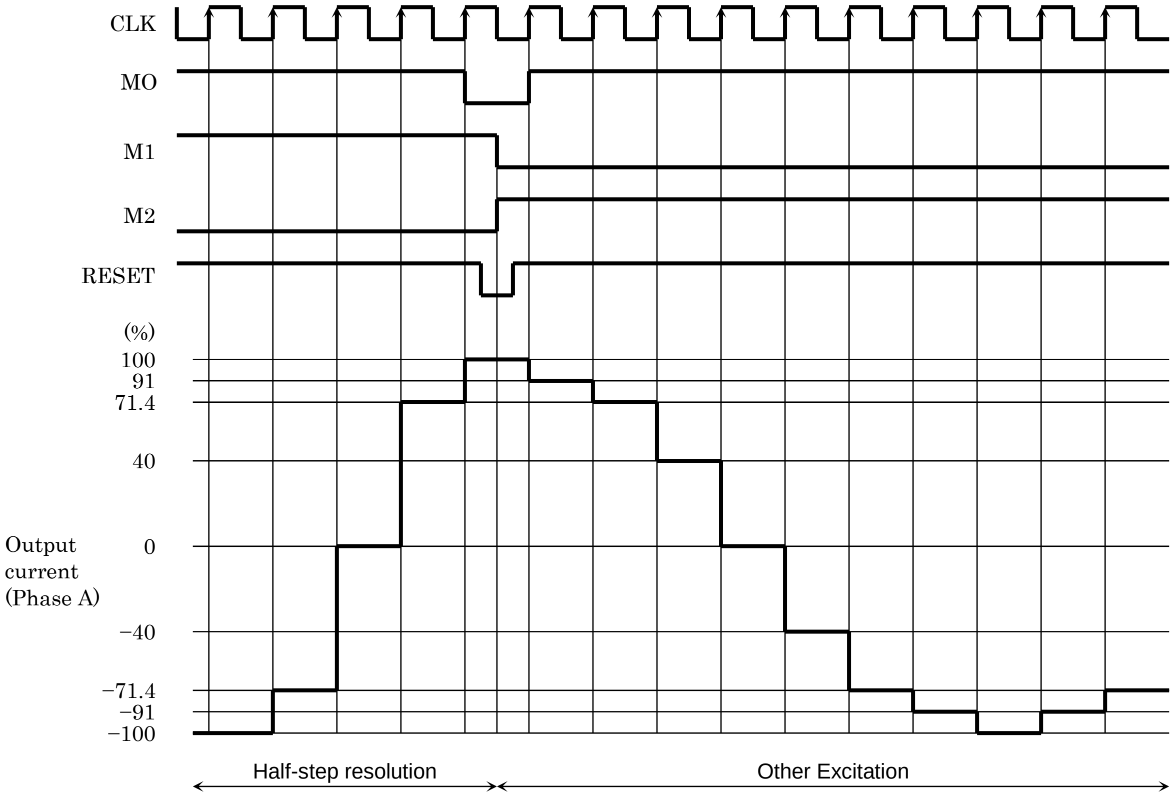
It operates from the initial state after the excitation mode is switched.

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



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

9. Input Signal Example (In Switching Excitation Mode)



It is recommended that the state of the M1, M2 and M3 pins be changed after setting the RESET signal Low during the Initial state (MO = Low). Even when the MO signal is Low, changing the M1, M2 and M3 signals without setting the RESET signal Low may cause a discontinuity in the current waveform.

10. Short-Circuit to GND and Short-Circuit Between Output Pins in the TB6600FG

"Short-circuit to Vcc" means that each OUT1A, OUT2A, OUTB1, and OUT2B is short-circuited to Vcc.
"Short-circuit to GND" means that each OUT1A, OUT2A, OUTB1, and OUT2B is short-circuited to GND (GND as defined here is SGND, PGNDA, and PGNDB).
"Short-circuit between output pins" means that OUT1A (or OUT1B) is short-circuited to OUT2A (or OUT2B).

We confirmed that the pin combination shown below may lead to smoke or burst as a result of our short-circuit test without fuse.
Depending on the specified voltage and current, the IC may be damaged by these short-circuits.
A large current might abruptly flow through the TB6600FG in case of a short-circuit between any pins that are listed below. If the large current persists, it may lead to a smoke emission.

(Short-circuit to GND)

(1)	OUT1A and GND	Possibility to burst, No smoking, firing
(2)	OUT1B and GND	Possibility to burst, No smoking, firing
(3)	OUT2B and GND	Possibility to burst, No smoking, firing

(Short-circuit between output pins)

(4)	OUT1A and OUT2A	Possibility to burst, smoke, No firing
(5)	OUT1B and OUT2B	Possibility to burst, No smoking, firing

Therefore, to avoid a continuous overcurrent due to the above-described short-circuit and allow the TB6600FG to be fail-safe, an appropriate fuse should be added at the right place, or overcurrent shutdown circuitry should be added to the power supply. The rated current of a fuse may vary depending on actual applications and its characteristics. Thus, an appropriate fuse must be selected experimentally.

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