TB6600HG

Usage considerations

Summary

The TB6600HG drives a two-phase bipolar stepping motor.
It drives at a constant current by PWM control. The TB6600HG 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) 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; $8.0 \le Vcc \le 42$ 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.

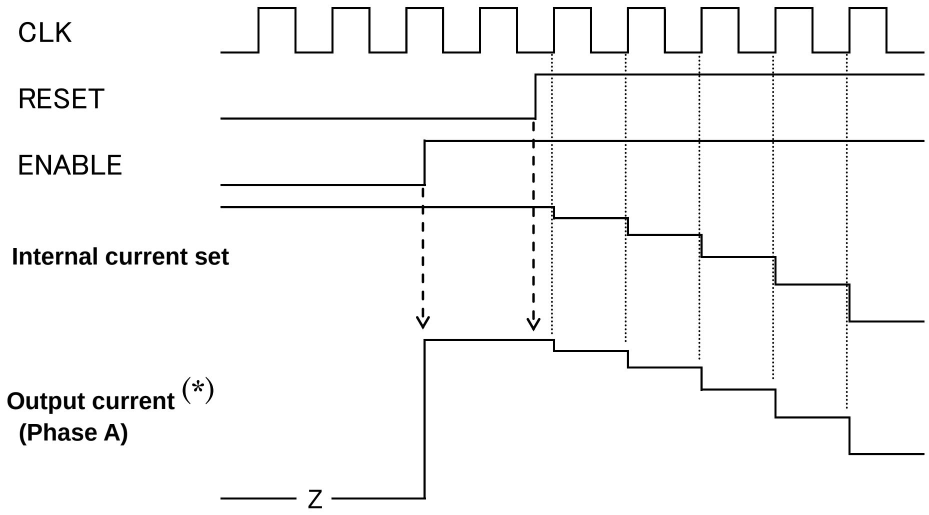
(2) Power-on Sequence with Control Input Signals

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.

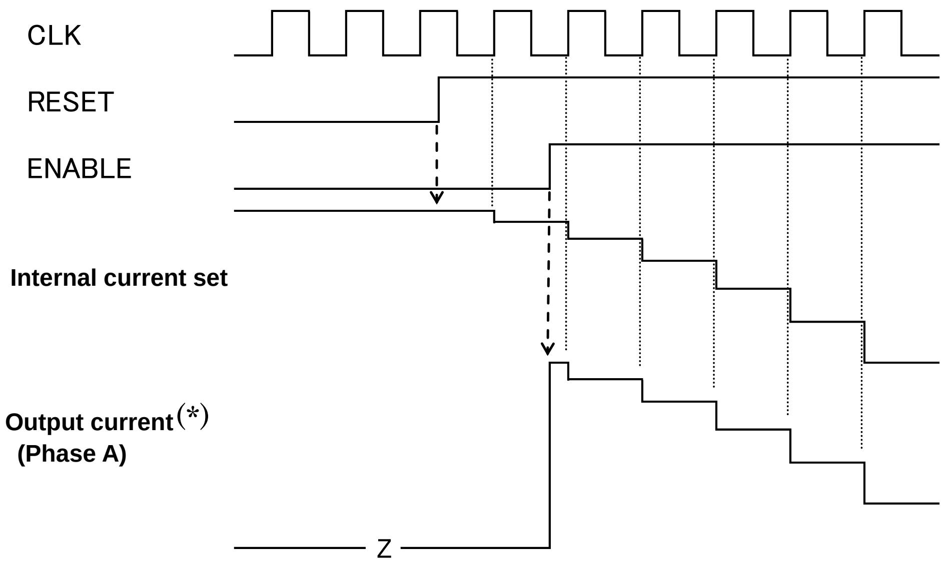
(1) CLK: Current step proceeds to the next mode with respect to every rising edge of CLK.
(2) ENABLE: It is in Hi-Z state in low level. It is output in high level.
RESET: It is in the initial mode (Phase A=100% and Phase B=0%) in low level.
(Ⅰ)ENABLE=Low and RESET=Low: Hi-Z. Internal current setting 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% and Phase B=0%).
(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 5.0 A per phase, and the upper limit of operating current is 4.5 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 I_{out} = 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

(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.

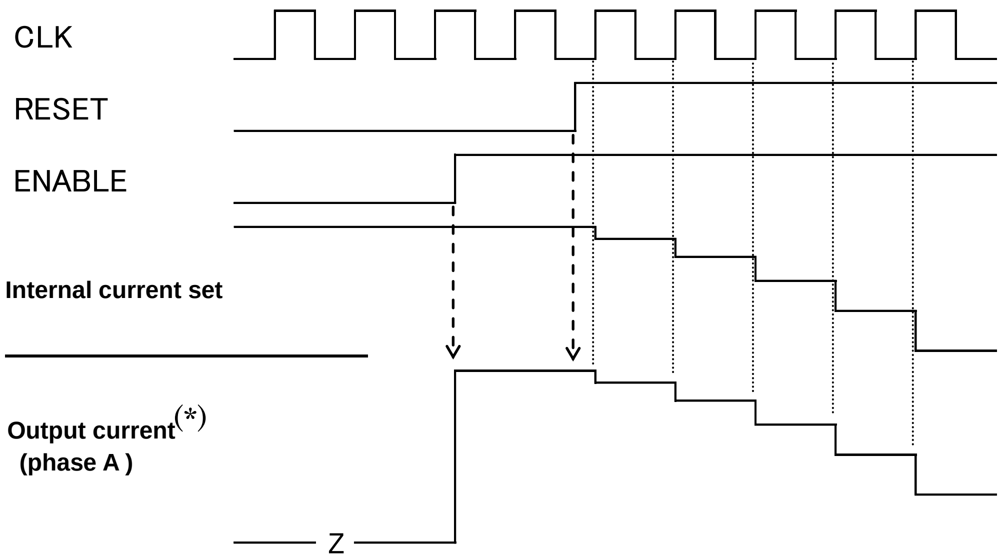
(2) Function

(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.

$$I_o\ (100\%) = (1/3 \times V_{ref}) \div R_{NF}$$

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;

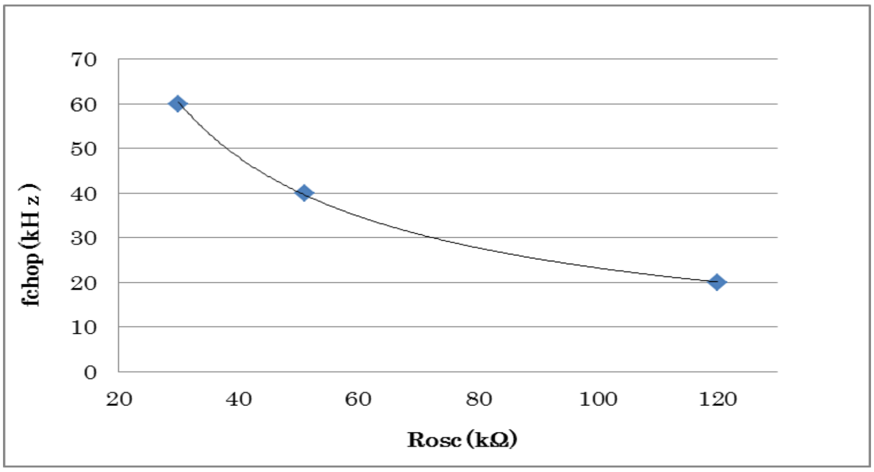
$0.11\Omega \leq R_{NF} \leq 0.5\Omega$, $0.3V \leq V_{ref} \leq 1.95V$

(5) OSC

Triangle wave is generated internally by CR oscillation by connecting external resistor to OSC terminal.

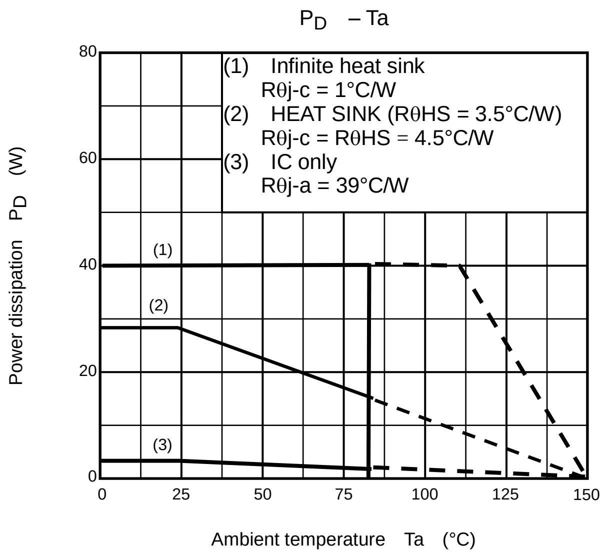
Rosc should be from 30kΩ to 120kΩ. The relation of Rosc and fchop is shown in below table and figure. The values of fchop of the below table are design guarantee values. They are not tested for pre-shipment.

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



6. Power Dissipation

P_D-Ta curve of the TB6600HG 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 × Icc + (Ron(U + L) × Io × Io) × 2

Half-step resolution

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

Quarter-step resolution

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

1/8-step resolution

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

1/16-step resolution

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

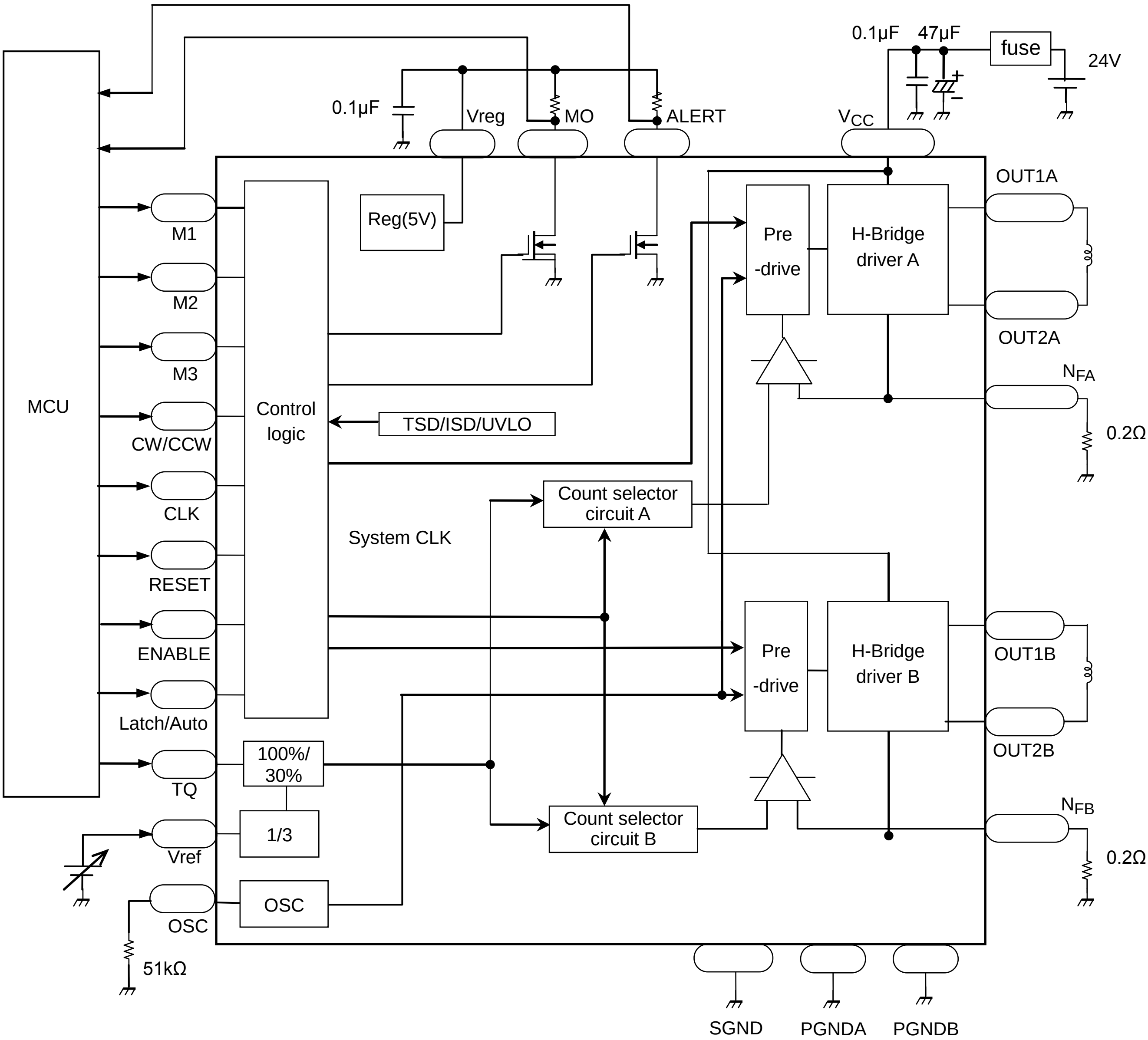
(Notes)

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 (R_{NFA} and R_{NFB}) 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 4.5 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 4.5 A, the IC will not operate normally.

(1) Usage Considerations

1) 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.
2) Wiring of the SGND, PGNDA and PGNDB Pins
The SGND (No.2) pin, PGNDA (No.17) pin and PGNDB (No.13) pin must be connected electrically outside the TB6600HG. 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 TB6600HG.
3) 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 TB6600HG is 5.0A/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.
4) Power Supply Procedure
Follow the power supply procedure described in this document. Otherwise, excess current may be applied to the TB6600HG and peripheral devices, which fully damages them.
5) Thermal Design
Care must be taken for the thermal design.
6) 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.
7) If a voltage outside the operating range specified on page 1 ($8.0 \le Vcc \le 42$) 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.

(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

(3) 100% current settings (Current value)

100% current value is determined by both Vref inputted from external part and the external resistances (RNFA and RNFB) for detecting output current. Vref is doubled 1/3 inside IC.

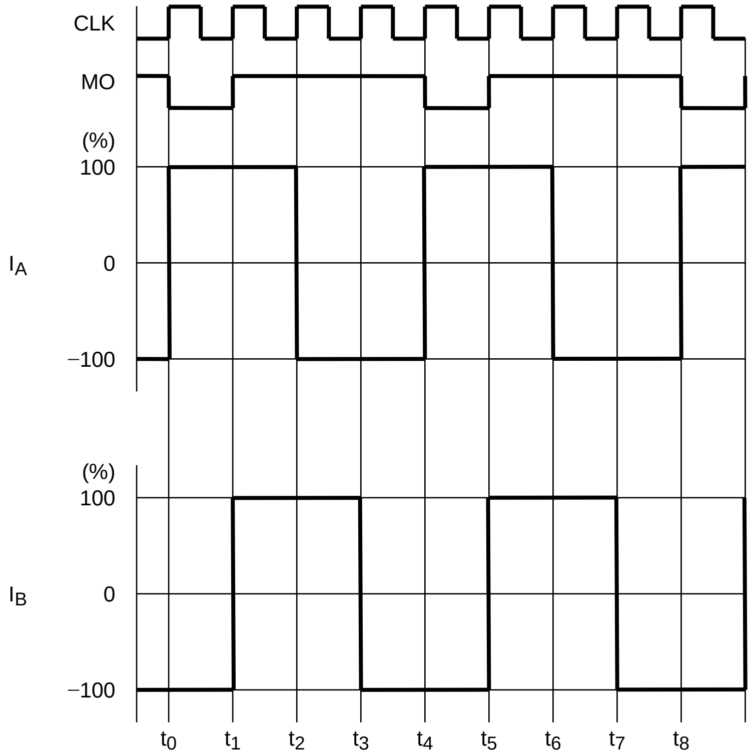
$$Io(100\%) = (1/3 \times Vref) \div R_{NF}$$

The average current is lower than the calculated value because this IC has the method of peak current detection.
RNF should be $0.11\Omega \le RNF \le 0.5\Omega$.
Vref should be $0.3V \le Vref \le 1.95V$.

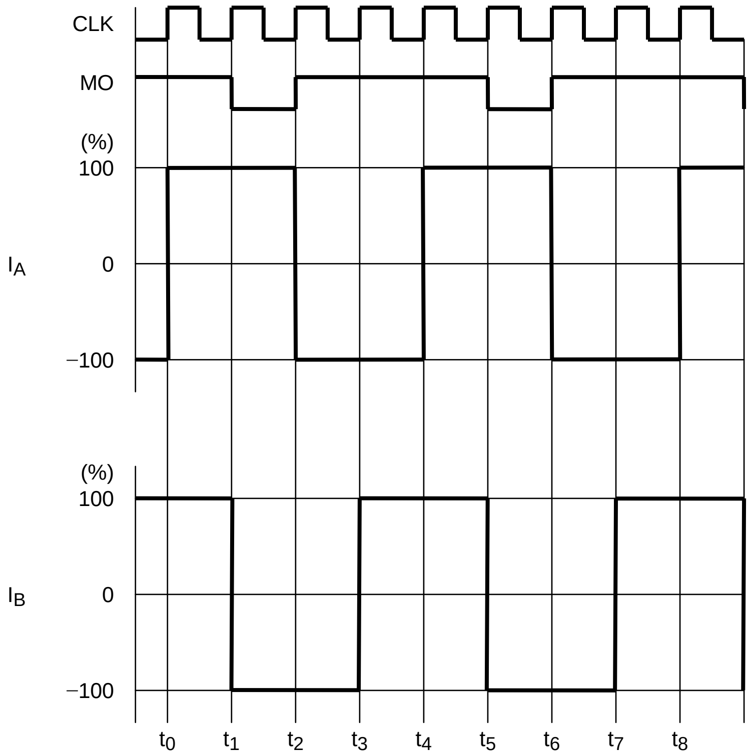
8. Excitation Mode Setting

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)

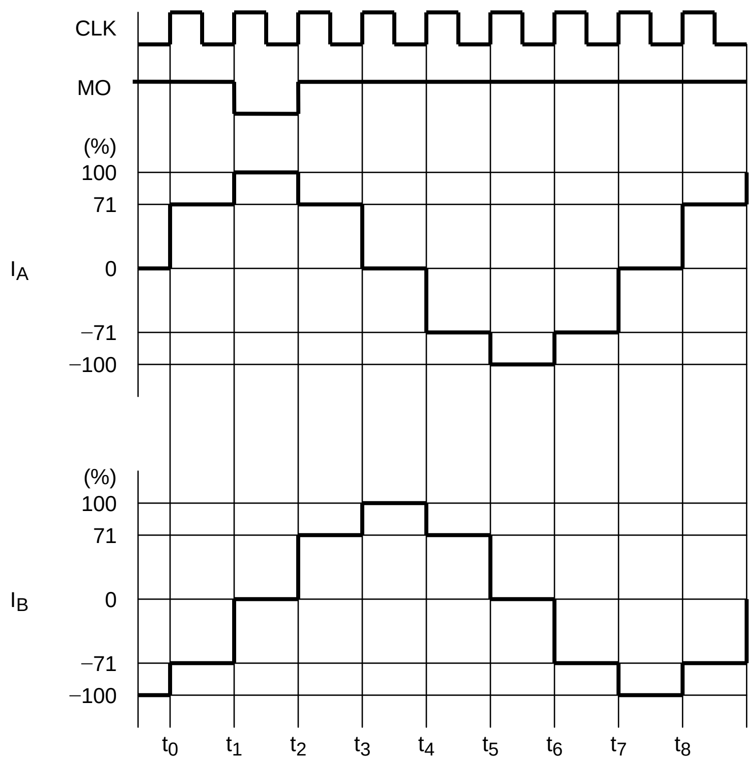


Full-step resolution (M1: L, M2: L, M3: H, CCW Mode)

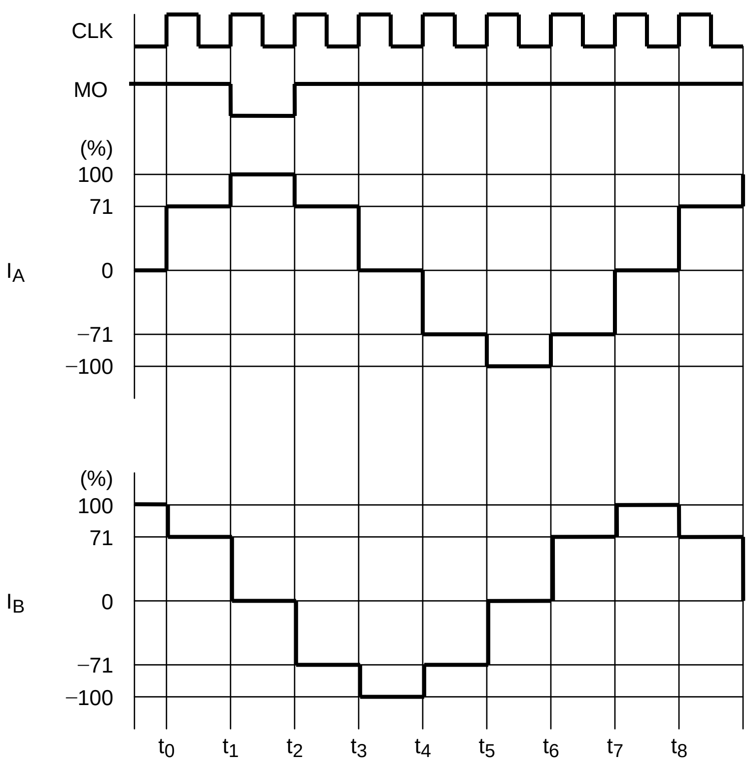


It operates from the initial state after the excitation mode is switched.

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

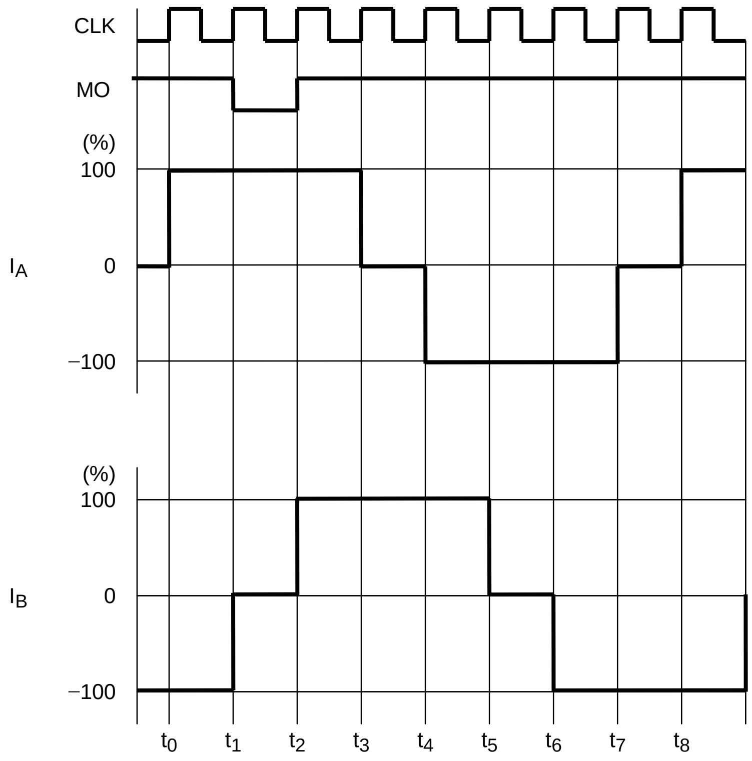


Half-step resolution (A type) (M1: L, M2: H, M3: L, CCW Mode)

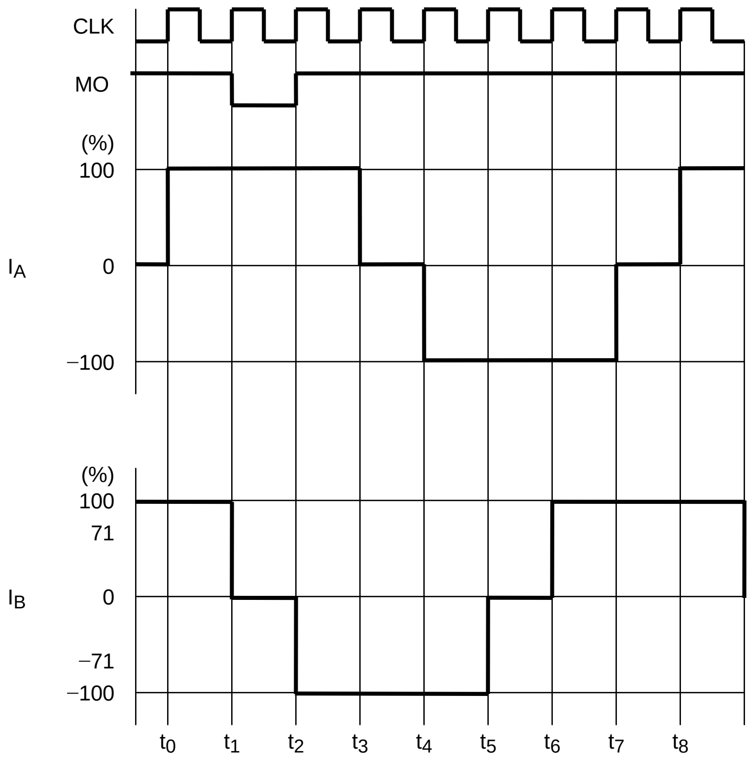


It operates from the initial state after the excitation mode is switched.

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

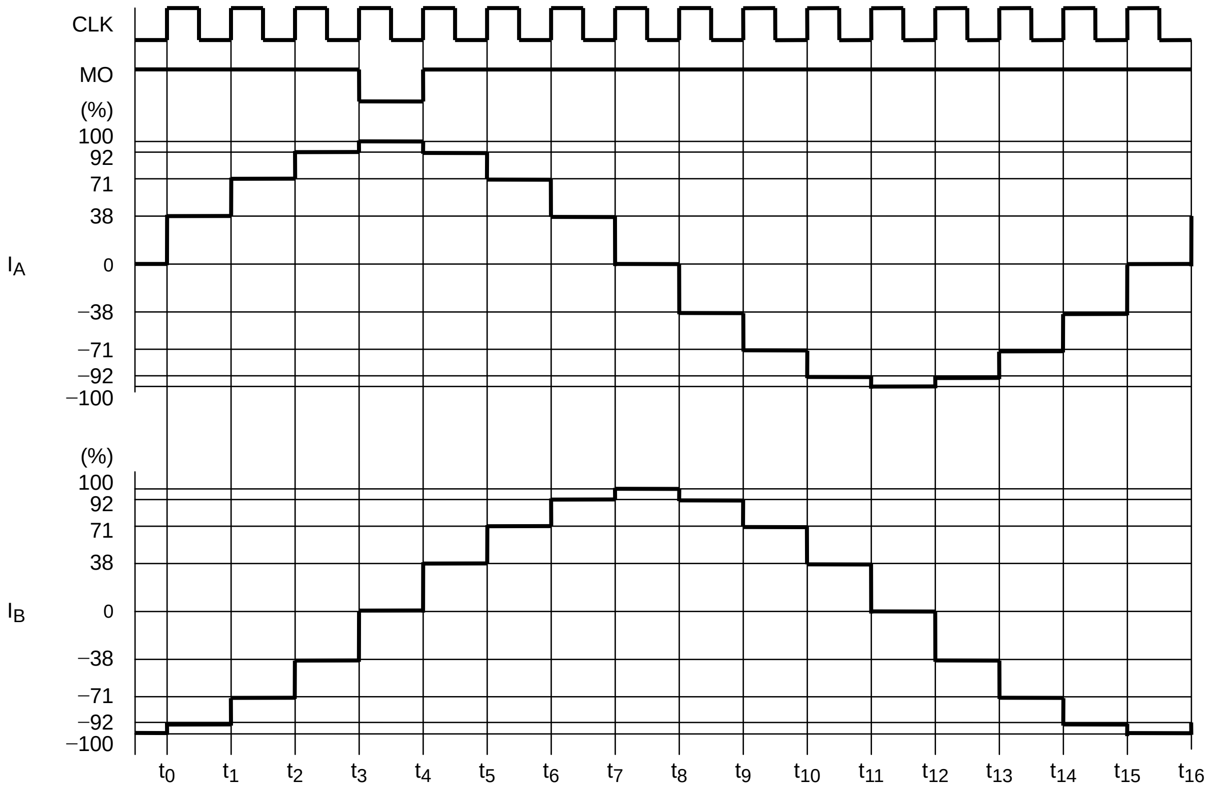


Half-step resolution (B type) (M1: L, M2: H, M3: H, CCW Mode)

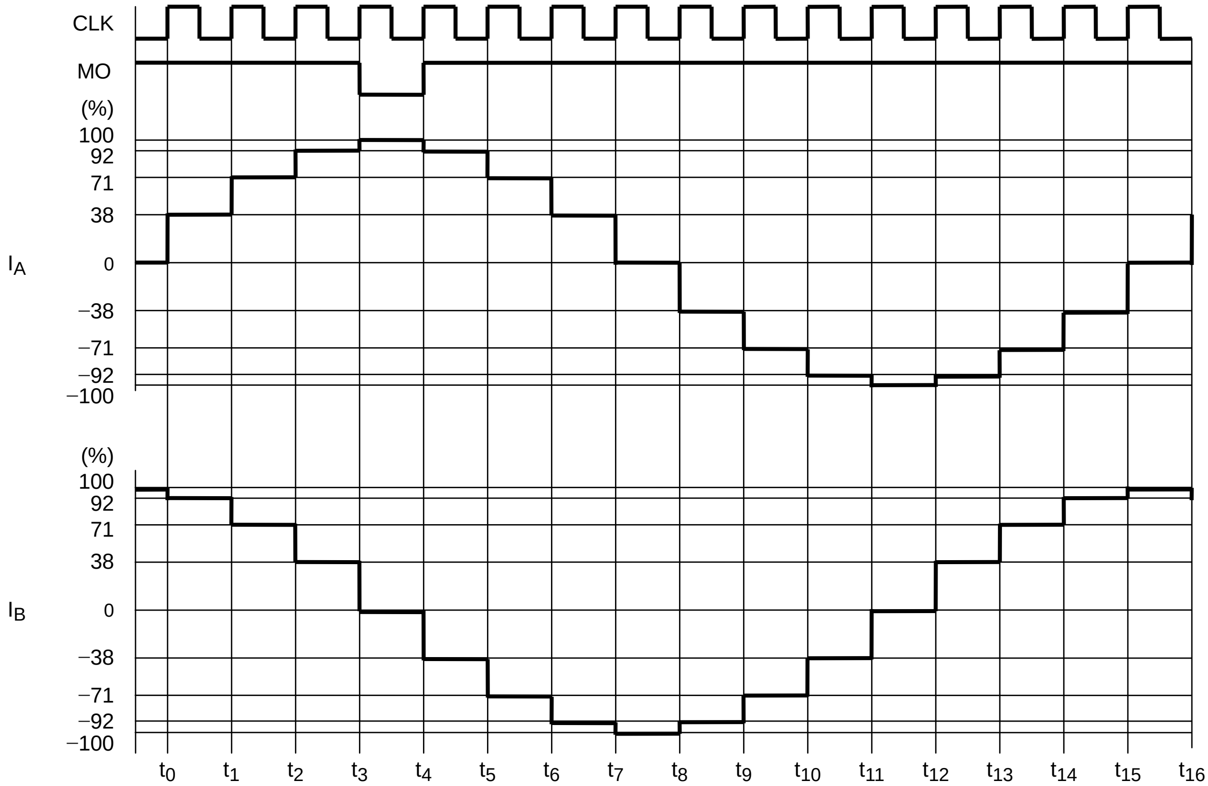


It operates from the initial state after the excitation mode is switched.

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

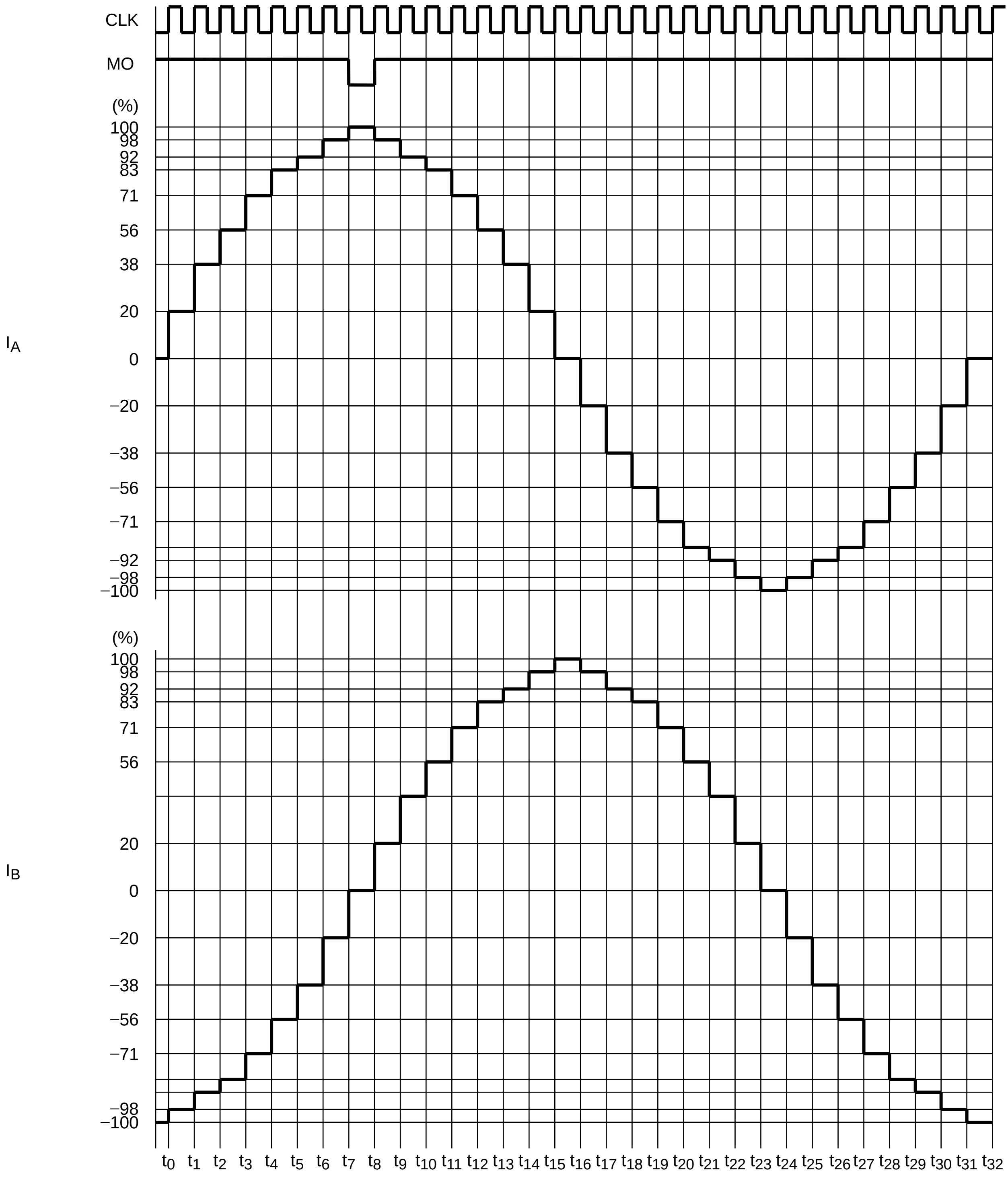


Quarter-step resolution (M1: H, M2: L, M3: L, CCW Mode)



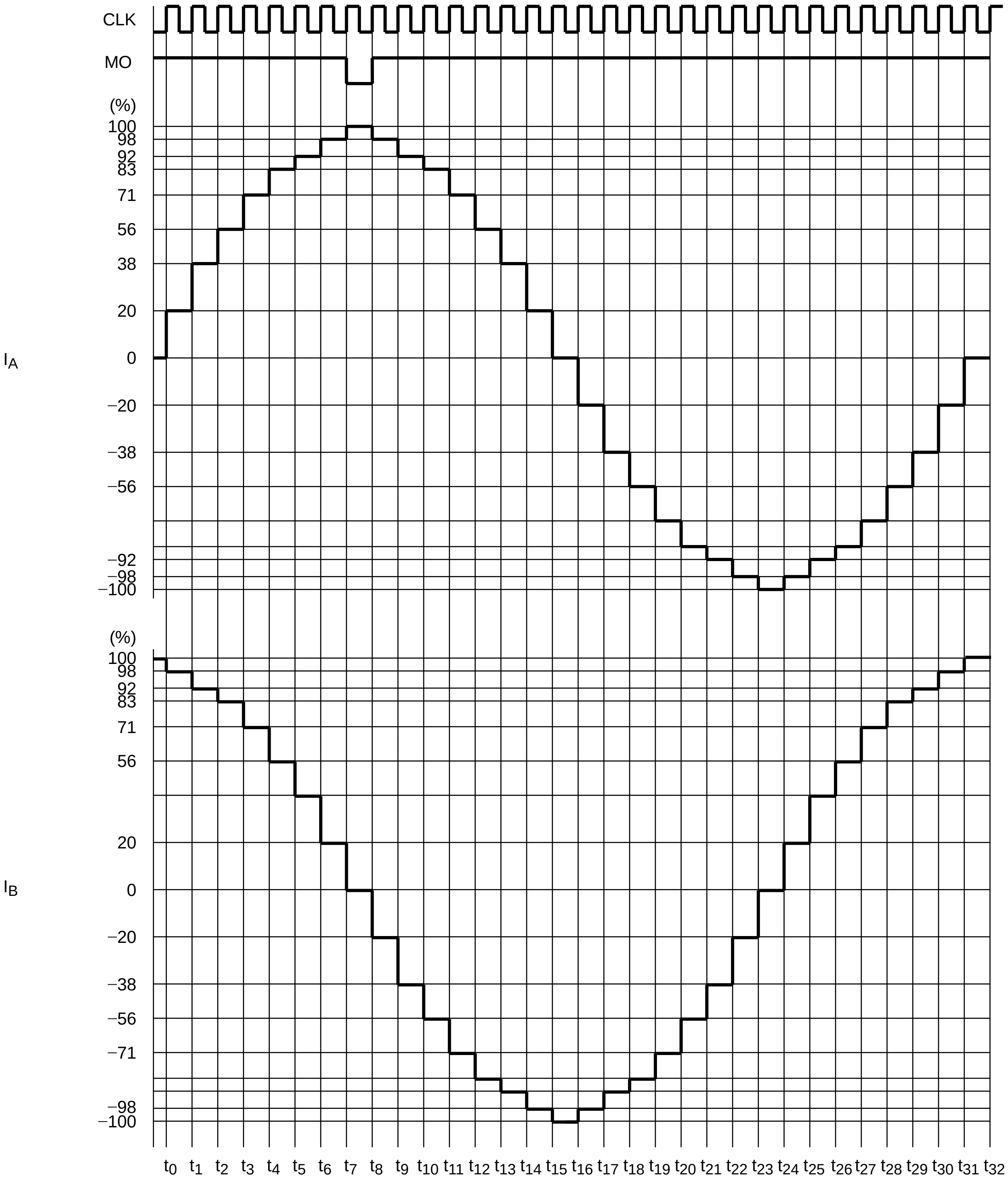
It operates from the initial state after the excitation mode is switched.

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



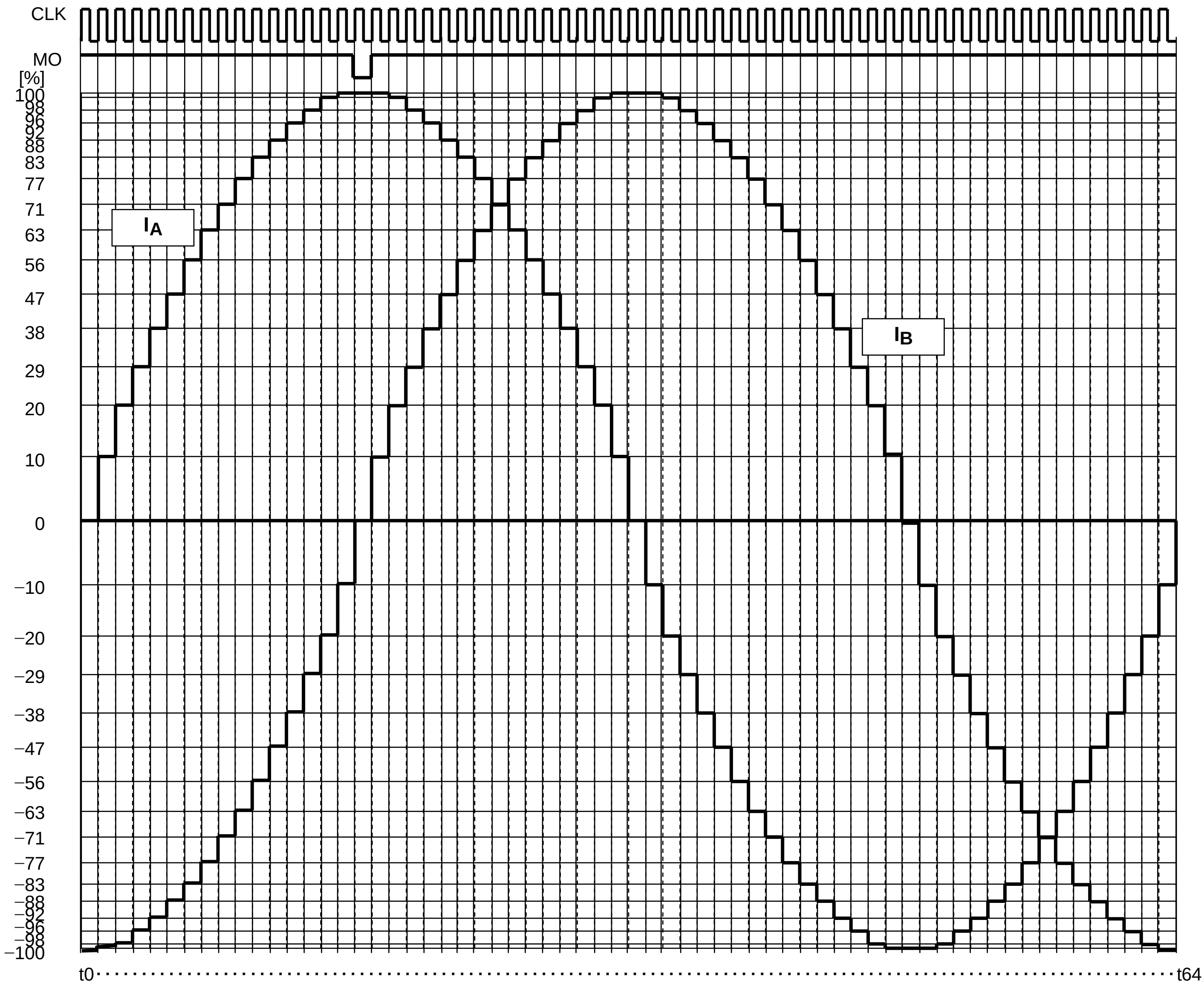
It operates from the initial state after the excitation mode is switched.

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



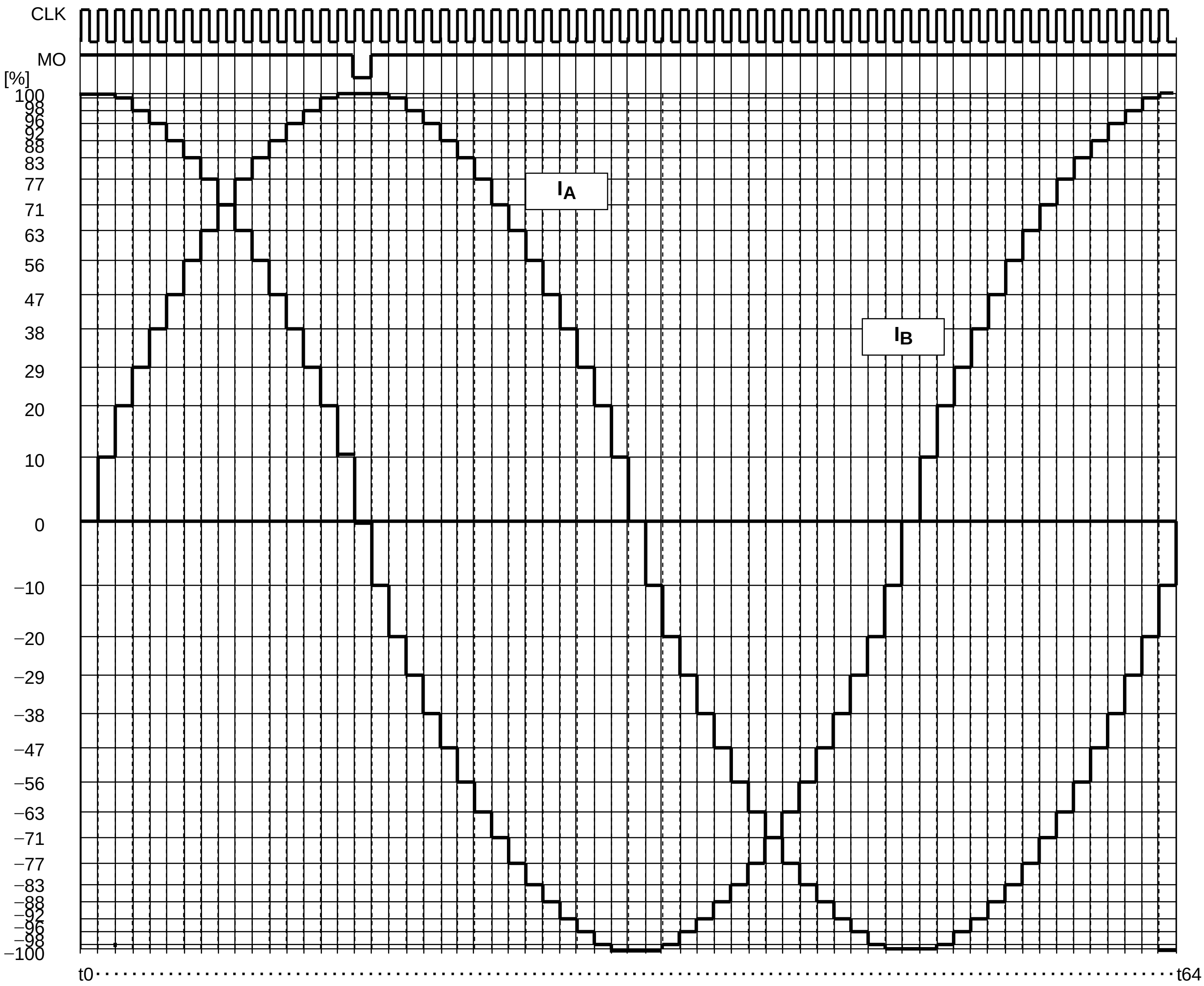
It operates from the initial state after the excitation mode is switched.

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



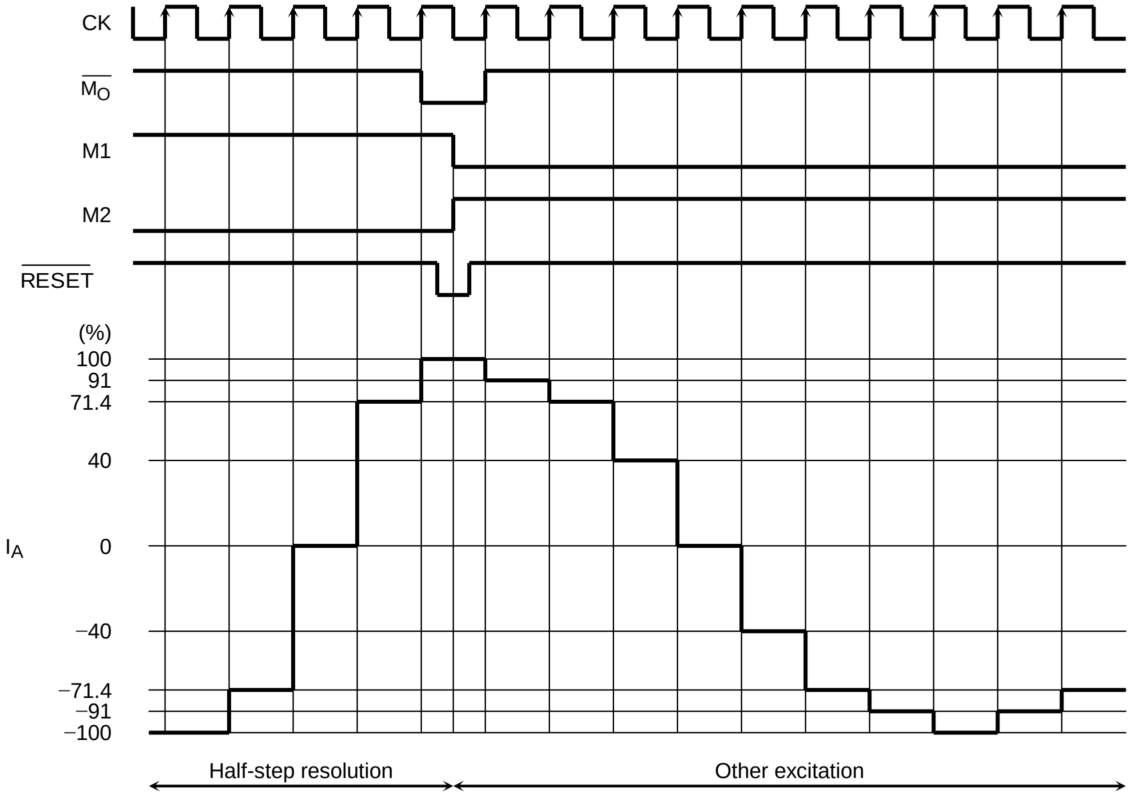
It operates from the initial state after the excitation mode is switched.

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 commutation mode)



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

10. Short-Circuits Between Adjacent Pins in the TB6600HG

In the TB6600HG, the term "adjacent pin" includes a pin diagonally closest to a given pin. For example, pin 3 has four adjacent pins: 1, 2, 4 and 5.

Depending on the specified voltage and current, a large current might abruptly flow through the TB6600HG in case of a short-circuit between any adjacent pins that are listed below. If the large current persists, it may lead to a smoke emission.

1) Pins 14 and 15
2) Pins 15 and 16

Therefore, to avoid a continuous overcurrent due to the above-described short-circuit and allow the TB6600HG 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.

We confirmed that some adjacent terminals may lead to smoke or burst as a result of our short-circuit test between adjacent terminals without fuse. These adjacent terminals are indicated by a table below.

Pin No., Pin symbol		ALERT 1	SGND 2	TQ 3	Latch/Auto 4	Vref 5	VCCB 6	M1 7	M2 8	M3 9	OUT2B 10	NFB 11	OUT1B 12	PGNDB 13	OUT2A 14	NFA 15	OUT1A 16	PGNDA 17	ENABLE 18	RESET 19	VCCA 20	CLK 21	CW/CCW 22	OSC 23	Vreg 24	MO 25
ALERT	1	\																								
SGND	2	O	\																							
TQ	3	O	O	\																						
Latch/Auto	4		O	O	\																					
Vref	5			O	O	\																				
VCCB	6				O	O	\																			
M1	7					O	O	\																		
M2	8						O	O	\																	
M3	9							O	O	\																
OUT2B	10								O	O	\															
NFB	11									O	O	\														
OUT1B	12										O	O	\													
PGNDB	13											O	O	\												
OUT2A	14												O	O	\											
NFA	15													O	Δ	\										
OUT1A	16														O	Δ	\									
PGNDA	17															O	O	\								
ENABLE	18																O	O	\							
RESET	19																	O	O	\						
VCCA	20																		O	O	\					
CLK	21																			O	O	\				
CW/CCW	22																				O	O	\			
OSC	23																					O	O	\		
Vreg	24																						O	O	\	
MO	25																							O	O	\

(Legend) O: No smoking, firing, burst.

Δ: Possibility to smoke or burst.

RESTRICTIONS ON PRODUCT USE

- Toshiba Corporation, and its subsidiaries and affiliates (collectively "TOSHIBA"), reserve the right to make changes to the information in this document, and related hardware, software and systems (collectively "Product") without notice.
- This document and any information herein may not be reproduced without prior written permission from TOSHIBA. Even with TOSHIBA's written permission, reproduction is permissible only if reproduction is without alteration/omission.
- Though TOSHIBA works continually to improve Product's quality and reliability, Product can malfunction or fail. Customers are responsible for complying with safety standards and for providing adequate designs and safeguards for their hardware, software and systems which minimize risk and avoid situations in which a malfunction or failure of Product could cause loss of human life, bodily injury or damage to property, including data loss or corruption. Before customers use the Product, create designs including the Product, or incorporate the Product into their own applications, customers must also refer to and comply with (a) the latest versions of all relevant TOSHIBA information, including without limitation, this document, the specifications, the data sheets and application notes for Product and the precautions and conditions set forth in the "TOSHIBA Semiconductor Reliability Handbook" and (b) the instructions for the application with which the Product will be used with or for. Customers are solely responsible for all aspects of their own product design or applications, including but not limited to (a) determining the appropriateness of the use of this Product in such design or applications; (b) evaluating and determining the applicability of any information contained in this document, or in charts, diagrams, programs, algorithms, sample application circuits, or any other referenced documents; and (c) validating all operating parameters for such designs and applications. **TOSHIBA ASSUMES NO LIABILITY FOR CUSTOMERS' PRODUCT DESIGN OR APPLICATIONS.**
- **PRODUCT IS NEITHER INTENDED NOR WARRANTED FOR USE IN EQUIPMENTS OR SYSTEMS THAT REQUIRE EXTRAORDINARILY HIGH LEVELS OF QUALITY AND/OR RELIABILITY, AND/OR A MALFUNCTION OR FAILURE OF WHICH MAY CAUSE LOSS OF HUMAN LIFE, BODILY INJURY, SERIOUS PROPERTY DAMAGE AND/OR SERIOUS PUBLIC IMPACT ("UNINTENDED USE").** Except for specific applications as expressly stated in this document, Unintended Use includes, without limitation, equipment used in nuclear facilities, equipment used in the aerospace industry, medical equipment, equipment used for automobiles, trains, ships and other transportation, traffic signaling equipment, equipment used to control combustions or explosions, safety devices, elevators and escalators, devices related to electric power, and equipment used in finance-related fields. **IF YOU USE PRODUCT FOR UNINTENDED USE, TOSHIBA ASSUMES NO LIABILITY FOR PRODUCT.** For details, please contact your TOSHIBA sales representative.
- Do not disassemble, analyze, reverse-engineer, alter, modify, translate or copy Product, whether in whole or in part.
- Product shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable laws or regulations.
- The information contained herein is presented only as guidance for Product use. No responsibility is assumed by TOSHIBA for any infringement of patents or any other intellectual property rights of third parties that may result from the use of Product. No license to any intellectual property right is granted by this document, whether express or implied, by estoppel or otherwise.
- **ABSENT A WRITTEN SIGNED AGREEMENT, EXCEPT AS PROVIDED IN THE RELEVANT TERMS AND CONDITIONS OF SALE FOR PRODUCT, AND TO THE MAXIMUM EXTENT ALLOWABLE BY LAW, TOSHIBA (1) ASSUMES NO LIABILITY WHATSOEVER, INCLUDING WITHOUT LIMITATION, INDIRECT, CONSEQUENTIAL, SPECIAL, OR INCIDENTAL DAMAGES OR LOSS, INCLUDING WITHOUT LIMITATION, LOSS OF PROFITS, LOSS OF OPPORTUNITIES, BUSINESS INTERRUPTION AND LOSS OF DATA, AND (2) DISCLAIMS ANY AND ALL EXPRESS OR IMPLIED WARRANTIES AND CONDITIONS RELATED TO SALE, USE OF PRODUCT, OR INFORMATION, INCLUDING WARRANTIES OR CONDITIONS OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, ACCURACY OF INFORMATION, OR NONINFRINGEMENT.**
- Do not use or otherwise make available Product or related software or technology for any military purposes, including without limitation, for the design, development, use, stockpiling or manufacturing of nuclear, chemical, or biological weapons or missile technology products (mass destruction weapons). Product and related software and technology may be controlled under the applicable export laws and regulations including, without limitation, the Japanese Foreign Exchange and Foreign Trade Law and the U.S. Export Administration Regulations. Export and re-export of Product or related software or technology are strictly prohibited except in compliance with all applicable export laws and regulations.
- Please contact your TOSHIBA sales representative for details as to environmental matters such as the RoHS compatibility of Product. Please use Product in compliance with all applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive. **TOSHIBA ASSUMES NO LIABILITY FOR DAMAGES OR LOSSES OCCURRING AS A RESULT OF NONCOMPLIANCE WITH APPLICABLE LAWS AND REGULATIONS.**