

# TB6600HG

## PWM Chopper-Type bipolar Stepping Motor Driver IC

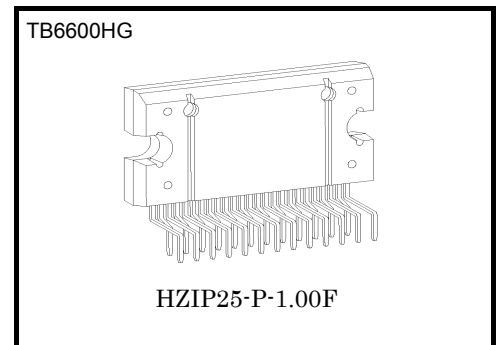
The TB6600HG is a PWM chopper-type single-chip bipolar sinusoidal micro-step stepping motor driver.

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.

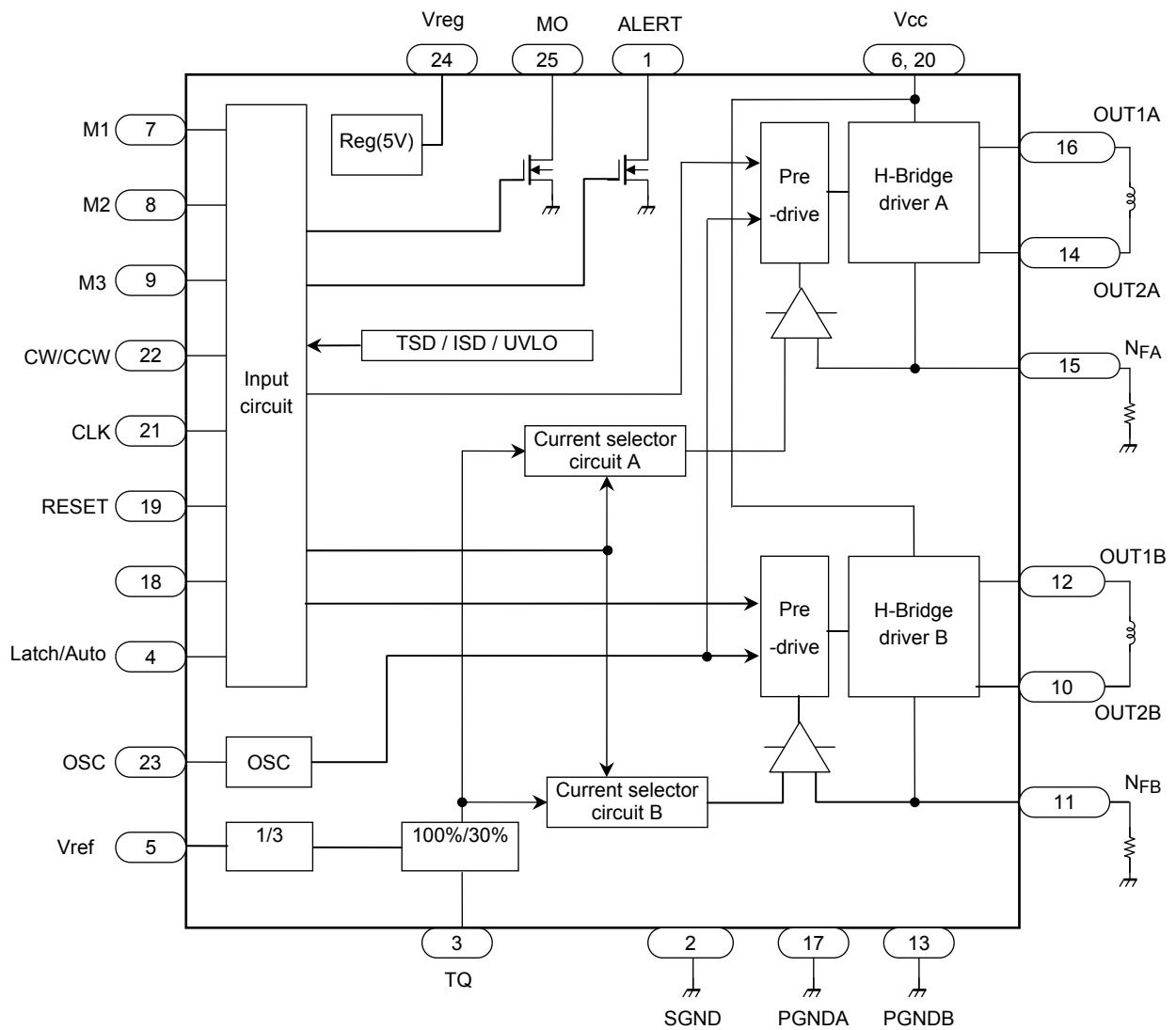
### Features

- Single-chip bipolar sinusoidal micro-step stepping motor driver
- $R_{on}$  (upper + lower) = 0.4  $\Omega$  (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:  $V_{CC} = 50$  V
- Output current:  $I_{OUT} = 5.0$  A (absolute maximum ratings, peak, within 100ms)  
 $I_{OUT} = 4.5$  A (operating range, maximal value)
- Packages: HZIP25-P-1.00F
- Built-in input pull-down resistance: 100 k $\Omega$  (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



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

## Block Diagram



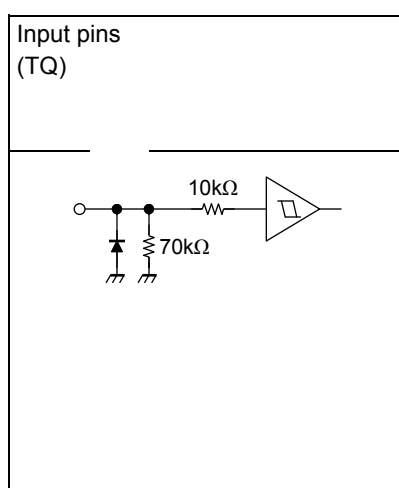
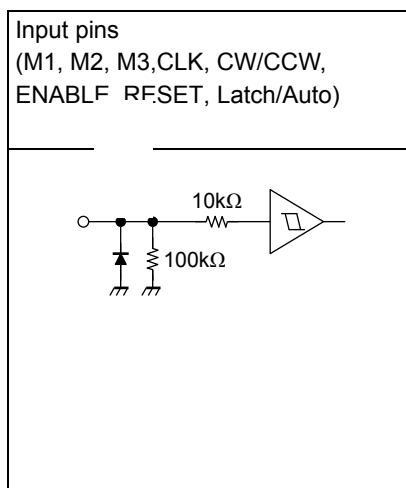
Setting of Vref

| Input | Voltage ratio |
|-------|---------------|
| TQ    |               |
| L     | 30%           |
| H     | 100%          |

## 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  | V <sub>CC</sub>  | 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 <sub>FB</sub>  | 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 <sub>FA</sub>  | 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  | V <sub>CC</sub>  | 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 | V <sub>reg</sub> | 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>



## Absolute Maximum Ratings (Ta = 25°C)

| Characteristic                 | Symbol                | Rating       | Unit |
|--------------------------------|-----------------------|--------------|------|
| Power supply voltage           | V <sub>CC</sub>       | 50           | V    |
| Output current (per one phase) | I <sub>O</sub> (PEAK) | 5.0 (Note 1) | A    |
| Drain current (ALERT, DOWN)    | I (ALERT)             | 1            | mA   |
|                                | I (MO)                |              |      |
| Input voltage                  | V <sub>IN</sub>       | 6            | V    |
| Power dissipation              | P <sub>D</sub>        | 3.2 (Note 2) | W    |
|                                |                       | 40 (Note 3)  |      |
| Operating temperature          | T <sub>opr</sub>      | -30 to 85    | °C   |
| Storage temperature            | T <sub>stg</sub>      | -55 to 150   | °C   |

Note 1: T = 100ms

Note 2: Ta = 25°C, No heat sink

Note 3: Ta = 25°C, with infinite heat sink.

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.

Please use the IC within the specified operating ranges.

## Operating Range (Ta = 25°C)

| Characteristic       | Symbol            | Test Condition           | Min | Typ. | Max  | Unit |
|----------------------|-------------------|--------------------------|-----|------|------|------|
| Power supply voltage | V <sub>CC</sub>   | —                        | 8.0 | —    | 42   | V    |
| Output current       | I <sub>OUT</sub>  | —                        | —   | —    | 4.5  | A    |
| Input voltage        | V <sub>IN</sub>   | —                        | 0   | —    | 5.5  | V    |
|                      | V <sub>ref</sub>  | —                        | 0.3 | —    | 1.95 | V    |
| Clock frequency      | f <sub>CLK</sub>  | —                        | —   | —    | 200  | kHz  |
| Chopping frequency   | f <sub>chop</sub> | R <sub>osc</sub> = 51 kΩ | —   | 40   | —    | kHz  |
| Chopping frequency   | f <sub>chop</sub> | See page 8.              | 20  | 40   | 60   | kHz  |

Note: V<sub>CCA</sub> and V<sub>CCB</sub> should be programmed the same voltage.

The maximum current of the operating range can not be necessarily conducted depending on various conditions because output current is limited by the power dissipation P<sub>d</sub>.

Make sure to avoid using the IC in the condition that would cause the temperature to exceed T<sub>j</sub> (avg.) = 107°C.

## Electrical Characteristics (Ta = 25°C, VCC = 24 V)

| Characteristic                          |                       | Symbol                                      | Test Condition  | Min  | Typ. | Max | Unit |
|---|-----------------------|---|---|------|------|-----|------|
| Input voltage                           | High                  | V <sub>IN (H)</sub>                         | M1, M2, M3, CW/CCW, CLK, RESET, ENABLE, Latch/Auto, TQ                            | 2.0  | —    | 5.5 | V    |
|   | Low                   | V <sub>IN (L)</sub>                         |   | -0.2 | —    | 0.8 |      |
| Input hysteresis voltage                |                       | V <sub>H</sub>                              |   |      | —    | 400 | —    |
| Input current                           | I <sub>IN (H)</sub>   | I <sub>IN (H)</sub>                         | M1, M2, M3, CW/CCW, CLK, RESET, ENABLE, Latch/Auto<br>V <sub>IN</sub> = 5.0 V     | —    | 55   | 80  | μA   |
|   |                       |   | TQ, V <sub>IN</sub> = 5.0 V   | —    | 70   | 105 |      |
|   | I <sub>IN (L)</sub>   | I <sub>IN (L)</sub>                         | V <sub>IN</sub> = 0 V   | —    | —    | 1   |      |
| VCC supply current                      | I <sub>CC1</sub>      | I <sub>CC1</sub>                            | Output open,<br>RESET: H, ENABLE: H,<br>M1:L, M2:L, M3:H (1/1-step mode)<br>CLK:L | —    | 3.1  | 7   | mA   |
|   | I <sub>CC2</sub>      | I <sub>CC2</sub>                            | Output open,<br>RESET: L, ENABLE: L<br>M1:L, M2:L, M3:H (1/1-step mode)<br>CLK:L  | —    | 3.1  | 7   |      |
|   | I <sub>CC3</sub>      | I <sub>CC3</sub>                            | Standby mode (M1:L, M2:L, M3:L)   | —    | 1.8  | 4   |      |
| Vref input circuit                      | Current limit voltage | V <sub>ref</sub>                            | V <sub>ref</sub> = 3.0 V(Note 1)  | 0.9  | 1.0  | 1.1 | V    |
|   | Input current         | I <sub>IN(ref)</sub>                        | V <sub>ref</sub> = 3.0 V(Note 1)  | —    | —    | 1   | μA   |
|   | Divider ratio         | V <sub>ref</sub> /V <sub>NF</sub>           | Maximum current: 100%   | —    | 3    | —   | —    |
| Minimum CLK pulse width                 | tw <sub>CLKH</sub>    | tw <sub>CLKH</sub>                          |   | 2.2  | —    | —   | μs   |
|   | tw <sub>CLKL</sub>    | tw <sub>CLKL</sub>                          |   |      |      |     |      |
| Output residual voltage                 | V <sub>OL MO</sub>    | V <sub>OL MO</sub><br>V <sub>OL ALERT</sub> | I <sub>OL</sub> = 1 mA  | —    | —    | 0.5 | V    |
|   | V <sub>OL ALERT</sub> |   |   |      |      |     |      |
| Internal constant voltage               | V <sub>reg</sub>      | V <sub>reg</sub>                            | External capacitor = 0.1 μF<br>(in standby mode)                                  | 4.5  | 5.0  | 5.5 | V    |
| TSD operation temperature (Note 2)      | TSD                   | TSD   | Design target value   | —    | 160  | —   | °C   |
| TSD hysteresis(Note 2)                  | TSDhys                | TSDhys                                      | Design target value   | —    | 40   | —   | °C   |
| Over current detection current (Note 2) | ISD                   | ISD   | All outputs, Design target value  | —    | 6.5  | —   | A    |
| Oscillation frequency                   | f <sub>OSC</sub>      | f <sub>OSC</sub>                            | External resistance R <sub>osc</sub> = 51 kΩ                                      | 2.8  | 4    | 5.2 | MHz  |

Note 1: Though V<sub>ref</sub> of the test condition for pre-shipment is 3.0V, make sure to configure V<sub>ref</sub> within the operating range which is written in page 4 in driving the motor.

Note 2: Pre-shipment testing is not performed.

## Electrical Characteristics (Ta = 25°C, VCC = 24 V)

| Characteristic                              |            | Symbol                                | Test Condition                      | Min | Typ. | Max | Unit |
|---|------------|---------------------------------------|-------------------------------------|-----|------|-----|------|
| Output ON resistor                          |            | R <sub>on U</sub> + R <sub>on L</sub> | I <sub>OUT</sub> = 4 A              | —   | 0.4  | 0.6 | Ω    |
| Output transistor switching characteristics |            | t <sub>r</sub>                        | V <sub>NF</sub> = 0 V, Output: Open | —   | 50   | —   | ns   |
|   |            | t <sub>f</sub>                        |                                     | —   | 500  | —   |      |
| Output leakage current                      | Upper side | I <sub>LH</sub>                       | V <sub>CC</sub> = 50 V              | —   | —    | 5   | μA   |
|   | Lower side | I <sub>LL</sub>                       |                                     | —   | —    | 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<br>(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)<br>( 0% - 71% - 100% )         |
| L     | H  | H  | 1/2B type (1-2 phase excitation B type)<br>( 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.

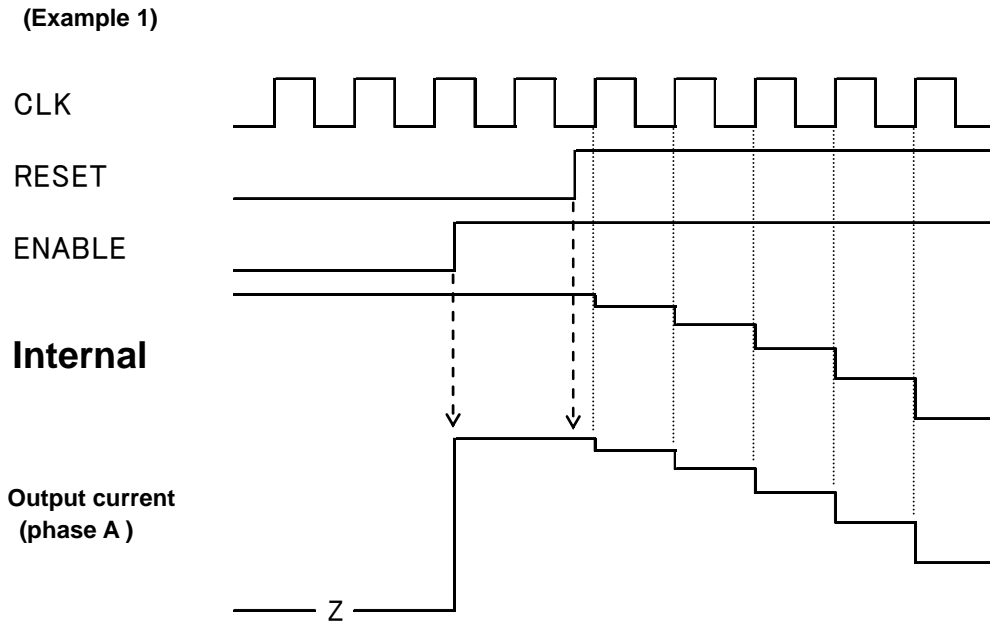
In standby mode, output terminal MO is HZ.

To release the standby mode, release the condition of M1 = M2 = M3 = L or M1 = M2 = M3 = H.

Input signal is not accepted for about 200 μs after releasing the standby mode.

**2. Function**

- (1) When the ENABLE signal goes Low level, it sets an OFF on the output.
- (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) 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.



| 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)<br>( 0% - 71% - 100% ) | 100%            | 0%              |
| 1/2B type (1-2 phase excitation B type)<br>( 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%              |

In this specification, 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.

Please use the IC under the conditions as follows:

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

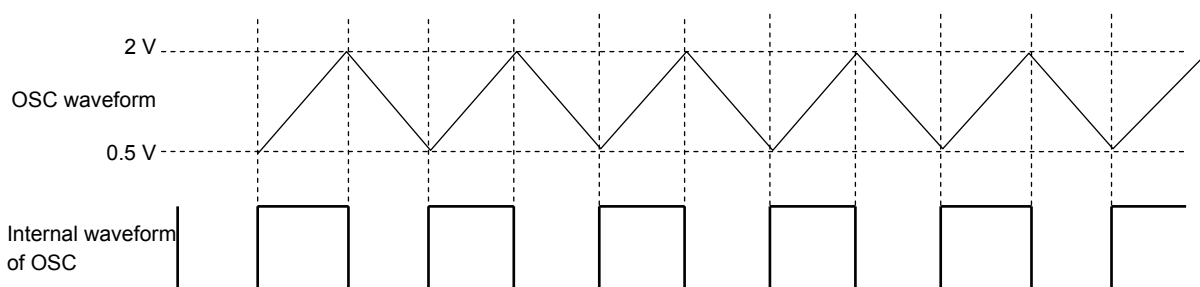
**5. OSC**

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. The values of fchop of the below table are design target values. They are not tested for pre-shipment.

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

**OSC waveform**





**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.

OSCM = 20 dividing frequency of the master clock (4 MHz, typ.).

**6-1. Current Waveform and Mixed Decay Mode settings**

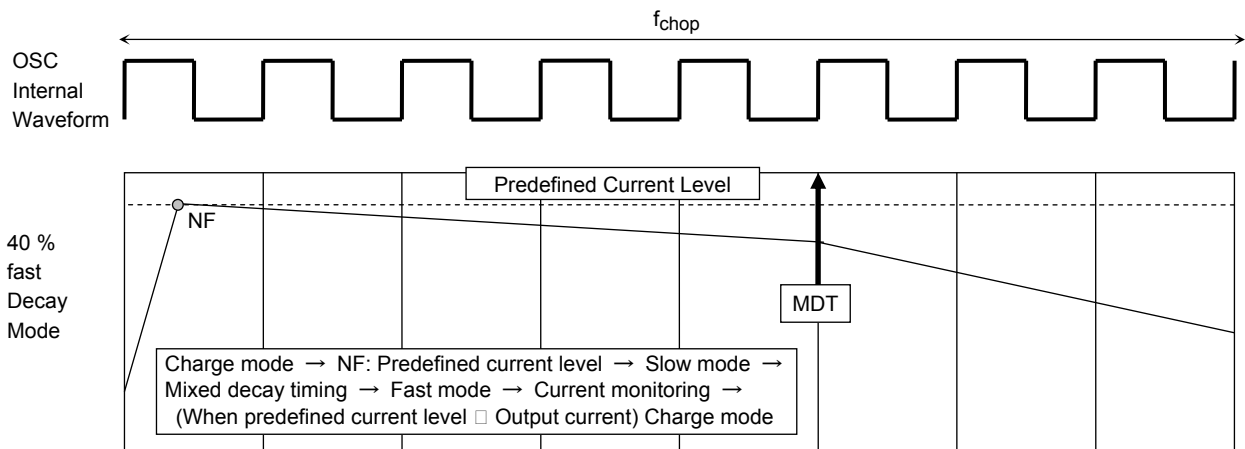
The period of PWM operation is equal to five periods of OSCM.

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.

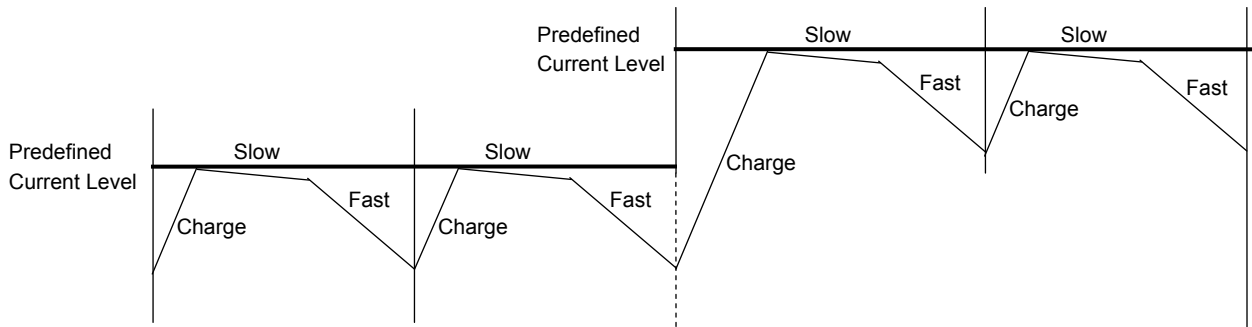
The smaller the MDT value, the smaller the current ripple amplitude. However, the current decay rate decreases.

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

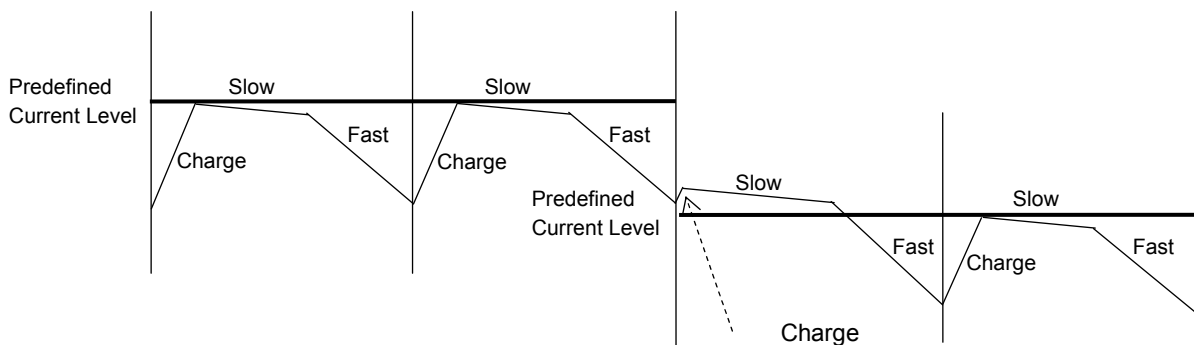


**6-2. Effect of Decay Mode**

- Increasing the current (sine wave)

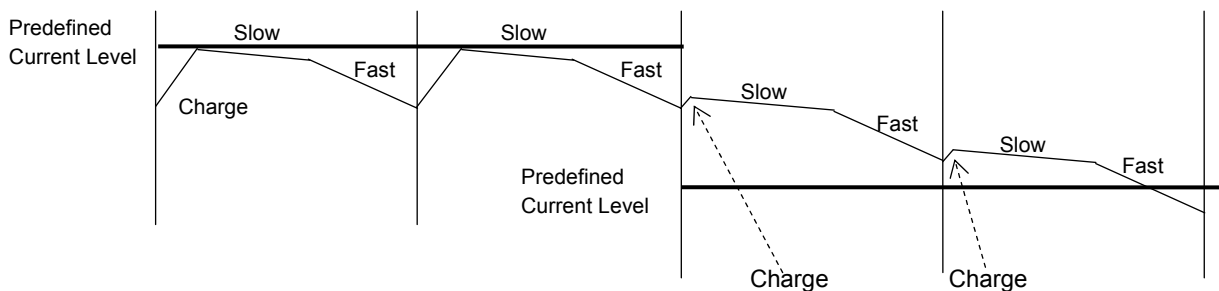


- Decreasing the current (In case the current is decreased to the predefined value in a short time because it decays quickly.)



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.)

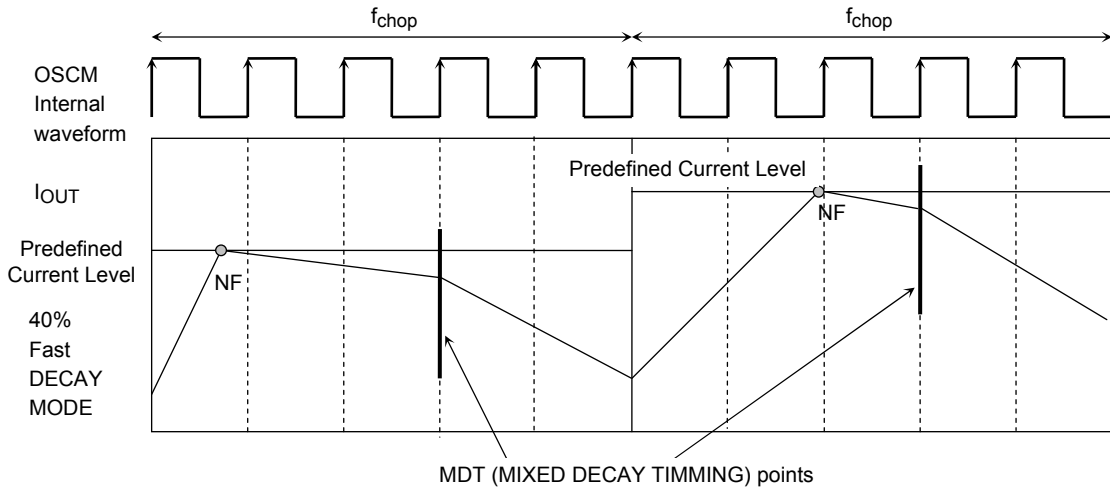


Even if the output current rises above the predefined current at the RNF point, the current control mode is briefly switched to Charge mode for current sensing.

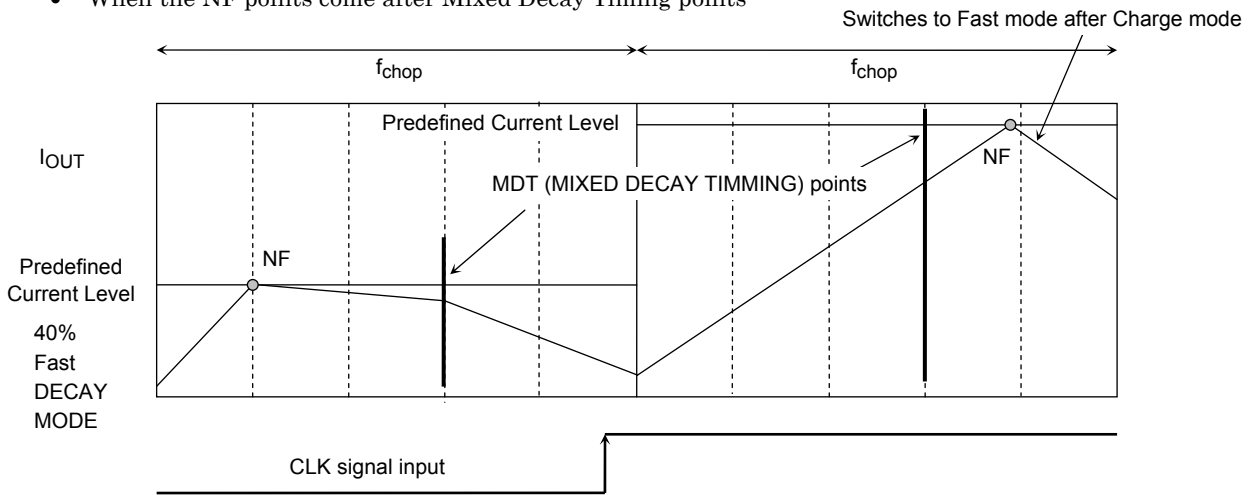
During Mixed Decay and Fast Decay modes, if the predefined current level is less than the output current at the RNF (current monitoring point), the Charge mode in the next chopping cycle will disappear (though the current control mode is briefly switched to Charge mode in actual operations for current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

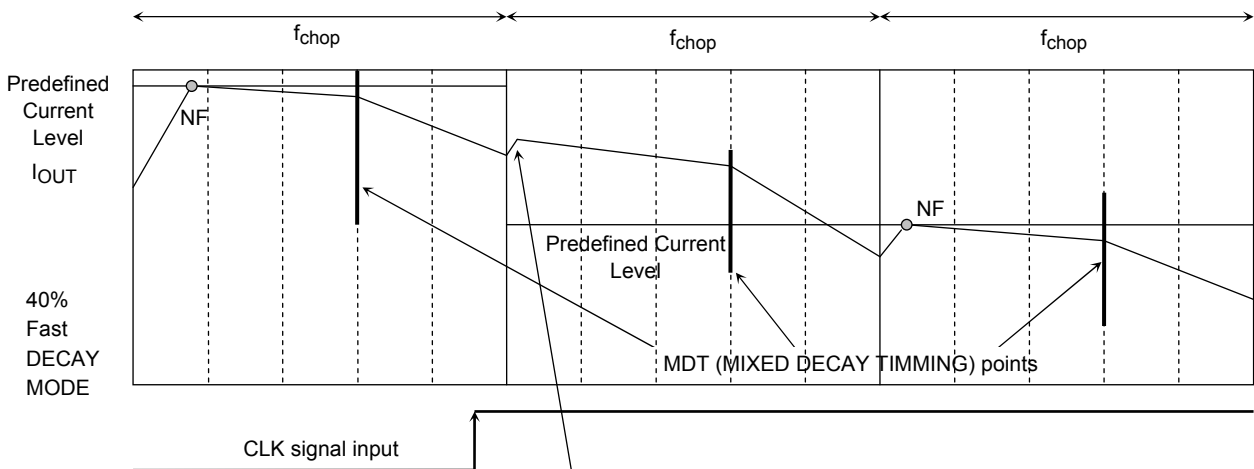
6-3. Current Waveforms in Mixed Decay Mode



- When the NF points come after Mixed Decay Timing points



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

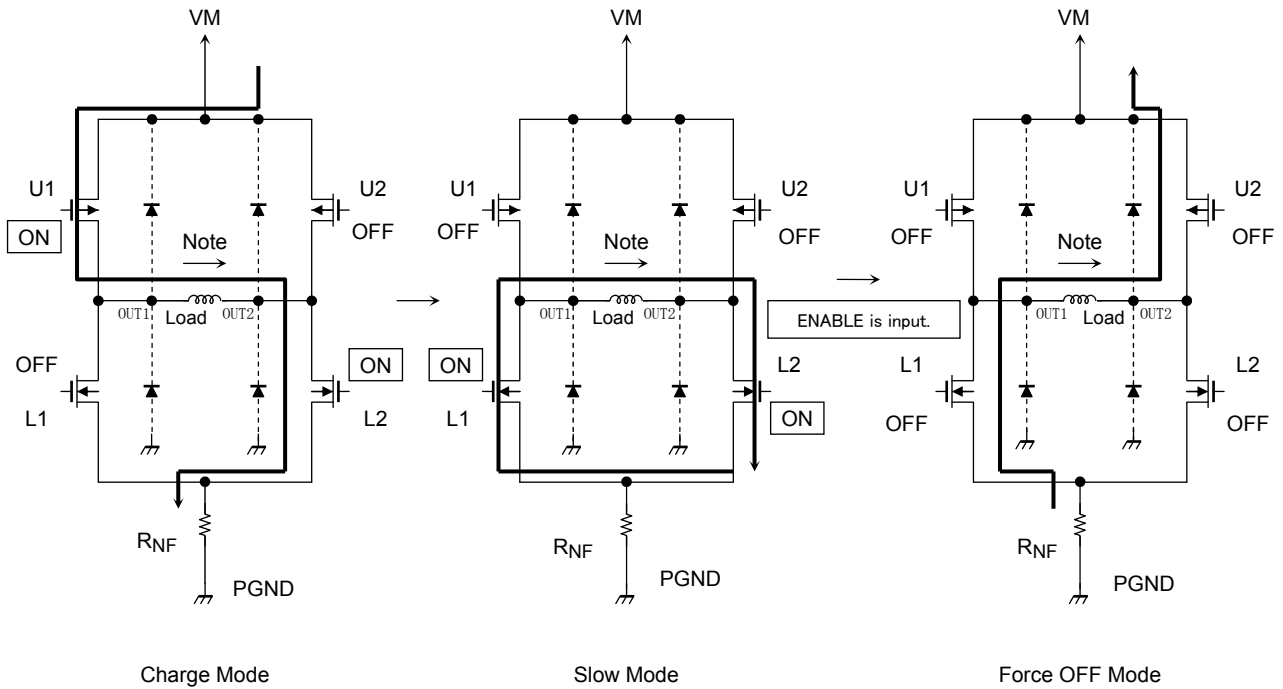


Even if the output current rises above the predefined current at the RNF point, the current control mode is briefly switched to Charge mode for current sensing.

**Current Draw-out Path when ENABLE is Input in Mid Operation**

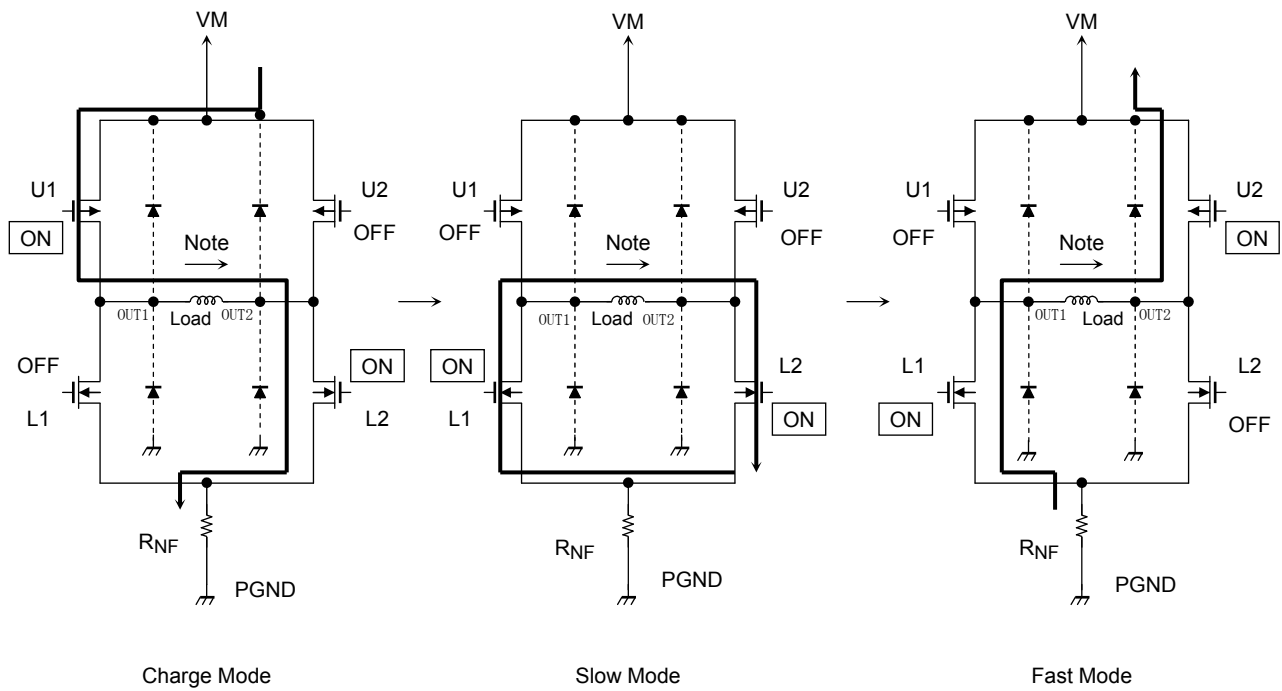
When all the output transistors are forced OFF during Slow mode, the coil energy is drawn out in the following modes:

Note: Parasitic diodes are indicated on the designed lines. However, these are not normally used in Mixed Decay mode.



As shown in the figure above, an output transistor has parasitic diodes. Normally, when the energy of the coil is drawn out, each transistor is turned ON and the power flows in the opposite-to-normal direction; as a result, the parasitic diode is not used. However, when all the output transistors are forced OFF, the coil energy is drawn out via the parasitic diode.

## Output Stage Transistor Operation Mode



## Output Stage Transistor Operation Functions

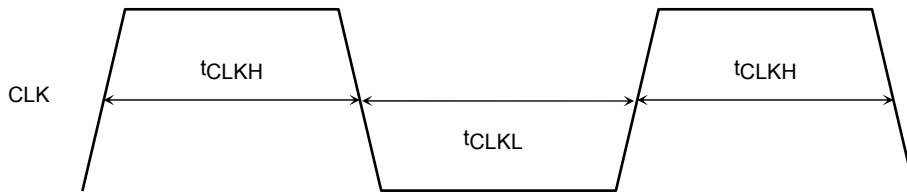
| CLK    | U1  | U2  | L1  | L2  |
|--------|-----|-----|-----|-----|
| CHARGE | ON  | OFF | OFF | ON  |
| SLOW   | OFF | OFF | ON  | ON  |
| FAST   | OFF | ON  | ON  | OFF |

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:

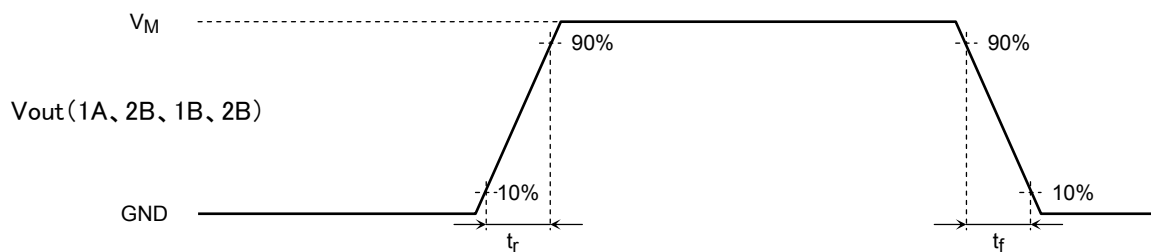
| CLK    | U1  | U2  | L1  | L2  |
|--------|-----|-----|-----|-----|
| CHARGE | OFF | ON  | ON  | OFF |
| SLOW   | OFF | OFF | ON  | ON  |
| FAST   | ON  | OFF | OFF | ON  |

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

**Measurement Waveform**



**Figure 1 Timing Waveforms and Names**



**Figure 2 Timing Waveforms and Names**

**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  $V_{CC}$  is less than 8V, TSD function cannot operate regardless of the state of the Latch/Auto pin.

**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.

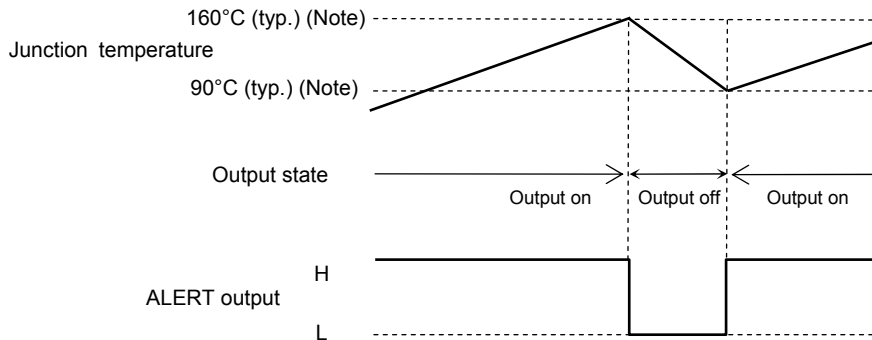
When power supply voltage  $V_{CC}$  is less than 8V, TSD function cannot operate.

## Thermal Shut-Down circuit (TSD)

### (1) Automatic return

TSD = 160°C (typ.) (Note)

TSD<sub>hys</sub> = 70°C (typ.) (Note)

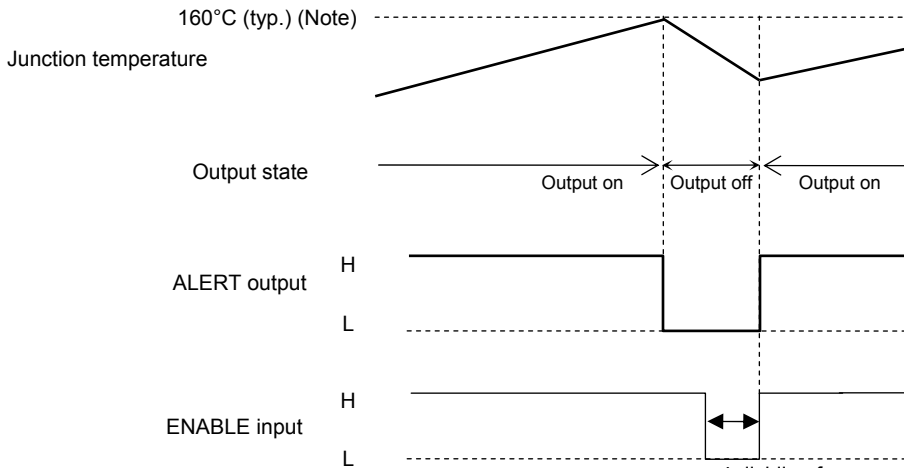


Automatic return has a temperature hysteresis shown in the above figure.

In case of automatic return, the return timing is adjusted at charge start of fchop after the temperature falls to the return temperature (It is 90(typ.) in the above figure). It returns after time passes between 1st and 2nd frequency (fchop).

### (2) Latch return

TSD = 160°C (typ.) (Note)



4 dividing frequency of OSC: 150 CLK  
0.15 ms (typ.), Term of L level should be 0.3 ms (max.) or more.

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 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.

States of internal IC and output correspond to the state in ENABLE mode.

After a return, the timing of output is not determined. It is the same as the case that ENABLE mode is reset. Operation can start from initial mode by setting the reset low level.

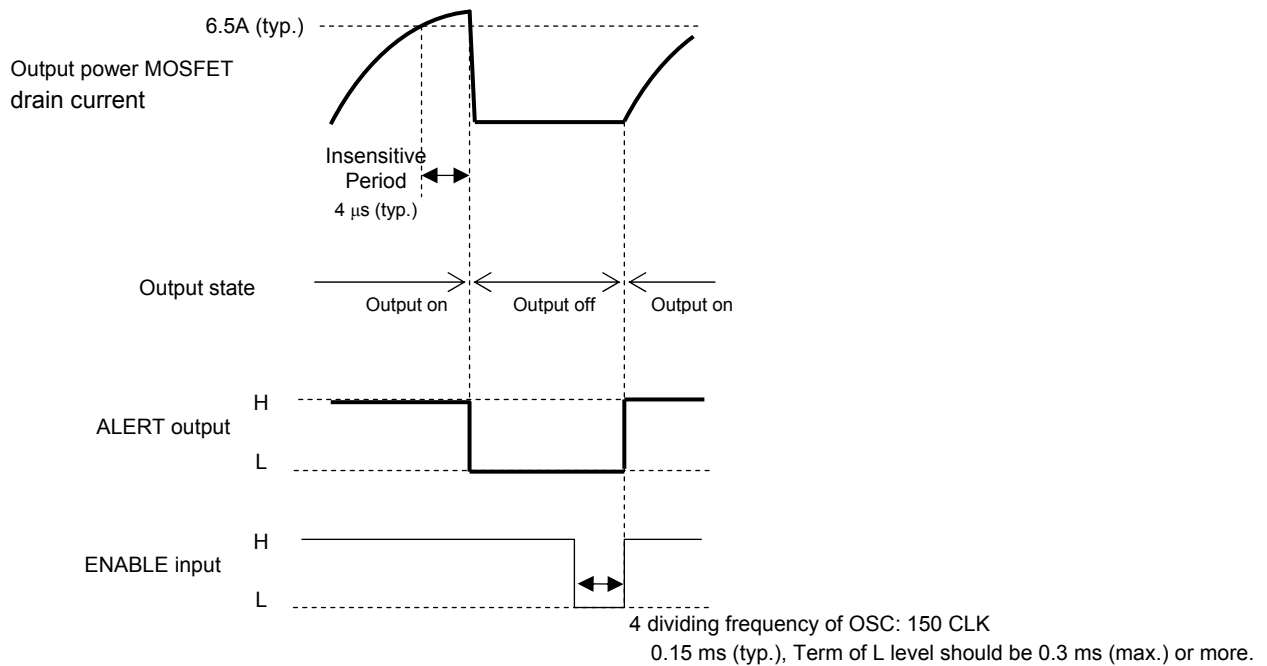
## ISD (Over current detection)

Current that flows through output power MOSFETs are monitored individually. If over-current is detected in at least one of all 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 4 $\mu$ s (typ.) should be provided in order to protect detection error by noise.

ISD=6.5 A  $\pm$  0.15 A (Note)

### Latch return



The operation returns by programming the ENABLE as H  $\rightarrow$  L  $\rightarrow$  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.

States of internal IC and output correspond to the state in ENABLE mode.

After a return, the timing of output is not determined. It is the same as the case that ENABLE mode is reset.

Operation can start from initial mode by setting the reset low level.

## 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.).

### •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 either of VCCA or VCCB 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.



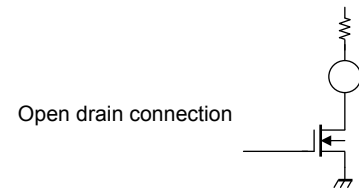
**ALERT output**

ALERT terminal outputs in detecting either TSD or ISD.

ALERT terminal is connected to power supply externally via pull-up resistance.

$V_{ALERT} = 0.5 \text{ V (max.) at } 1 \text{ mA}$

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



Applied voltage to pull-up resistance is up to 5.5 V. And conducted current is up to 1 mA.

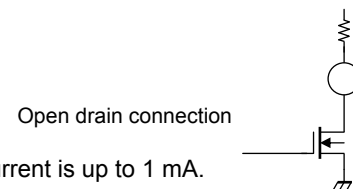
**MO output**

MO turns on at the predetermined state and output low.

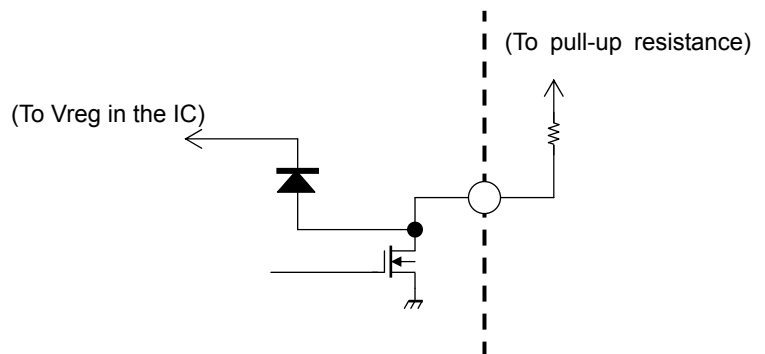
MO terminal is connected to power supply externally via pull-up resistance.

$V_{MO} = 0.5 \text{ V (max.) at } 1 \text{ mA}$

| 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.

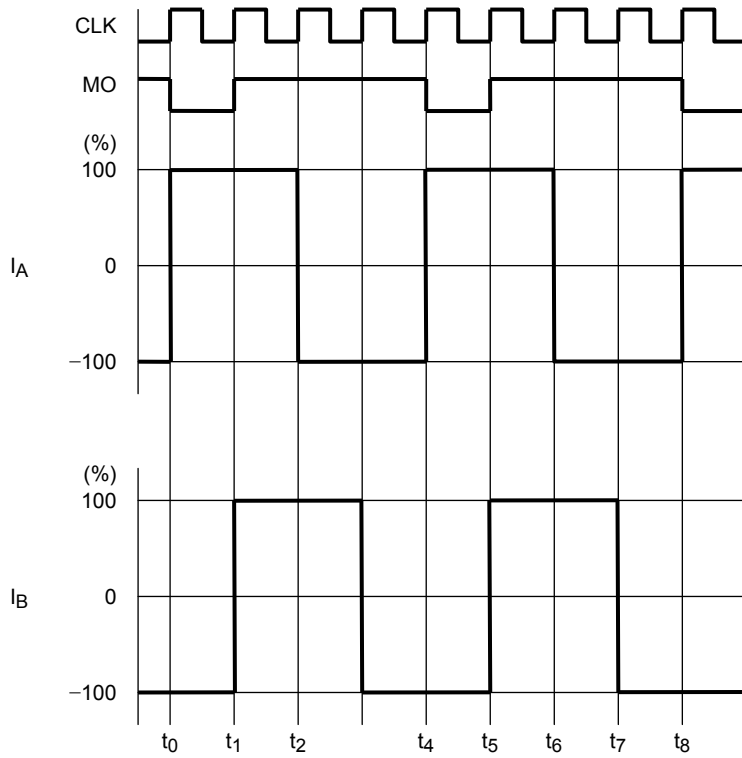


**Voltage pull-up of MO and ALERT pins**

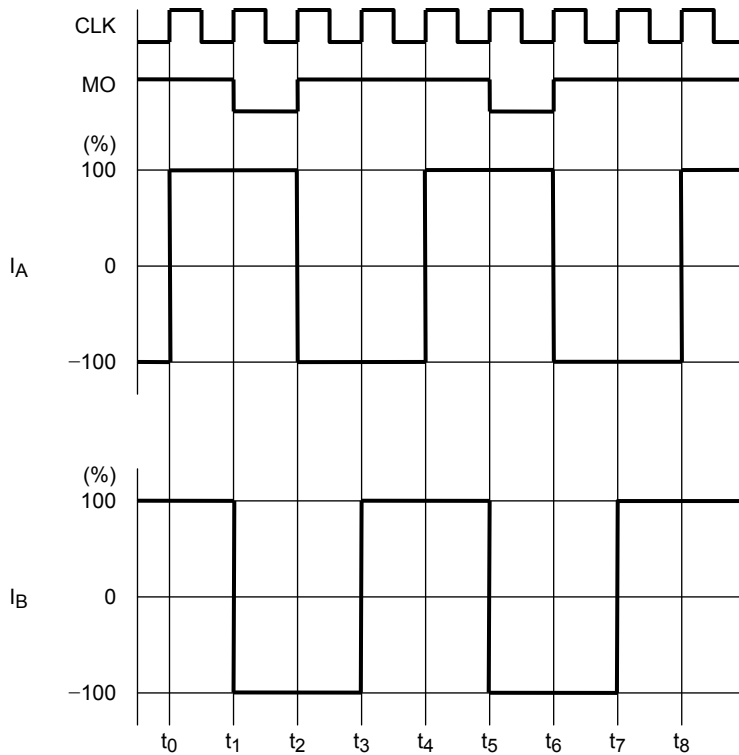
- It is recommended to pull-up voltage to Vreg pin.
  - In case of pull-up to except 5 V (for instance, 3.3 V etc.), it is recommended to use other power supply (ex. 3.3 V) while VCCA and VCCB output between the operation range. When VCCA and VCCB decrease lower than the operation range and Vreg decreases 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 in each excitation mode

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

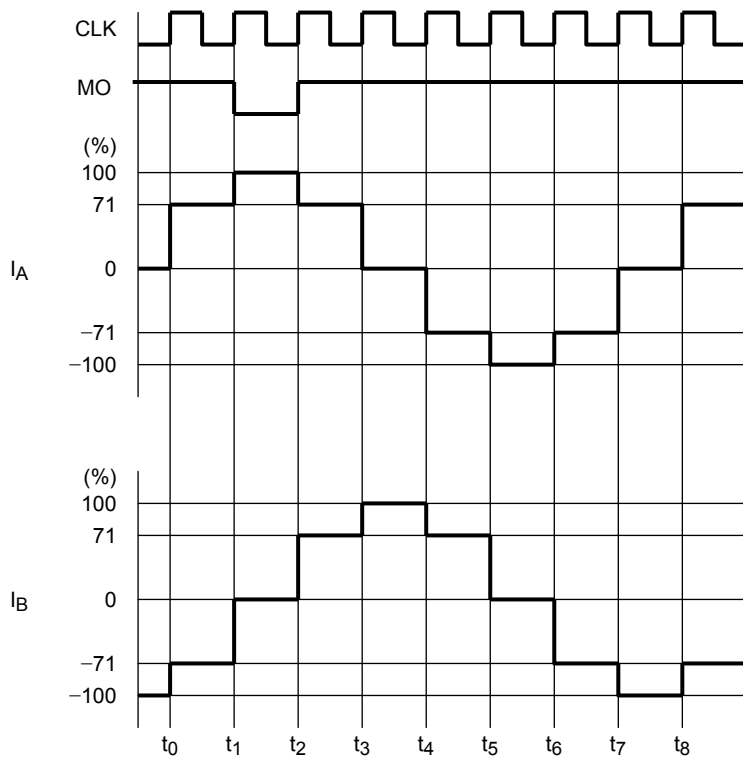


#### 1/1-step Excitation Mode (M1: L, M2: L, M3: H, CCW Mode)

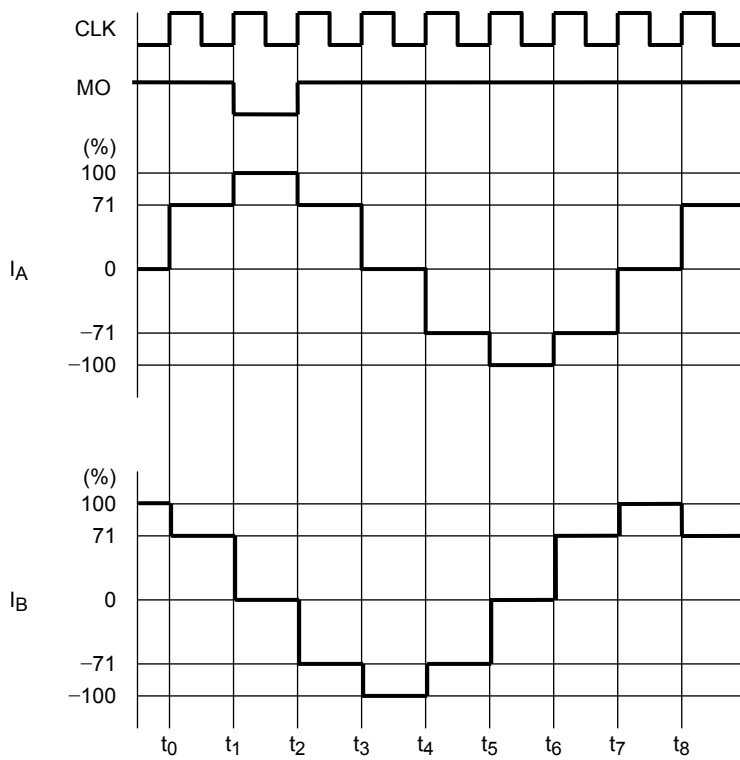


It operates from the initial state after the excitation mode is switched.

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

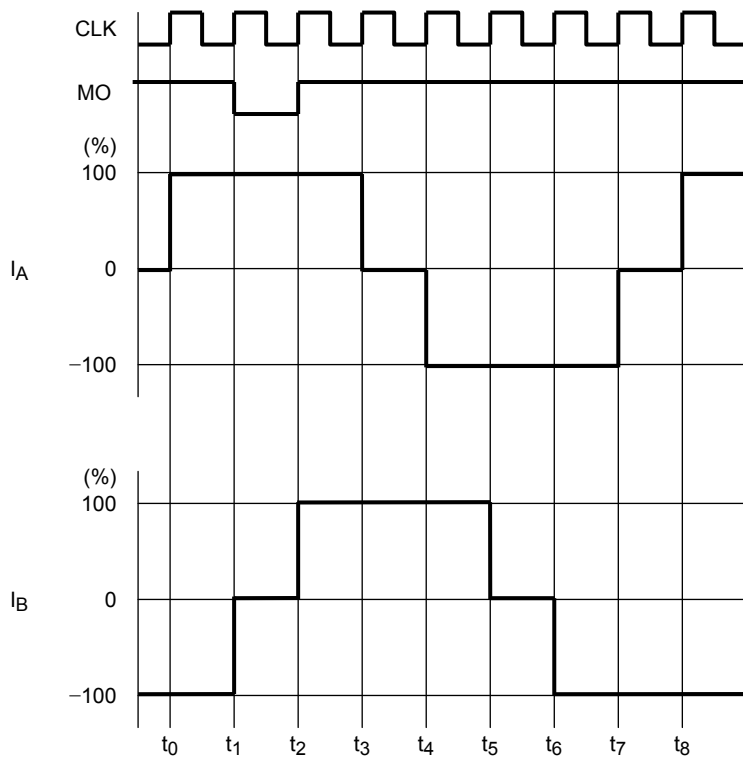


**1/2-step Excitation Mode (A type) (M1: L, M2: H, M3: L, CCW Mode)**

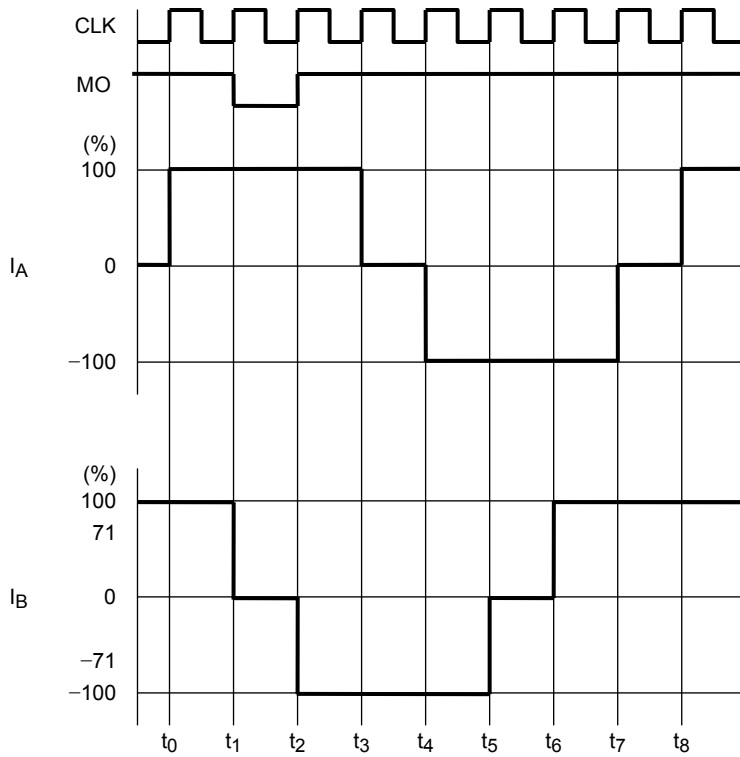


It operates from the initial state after the excitation mode is switched.

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

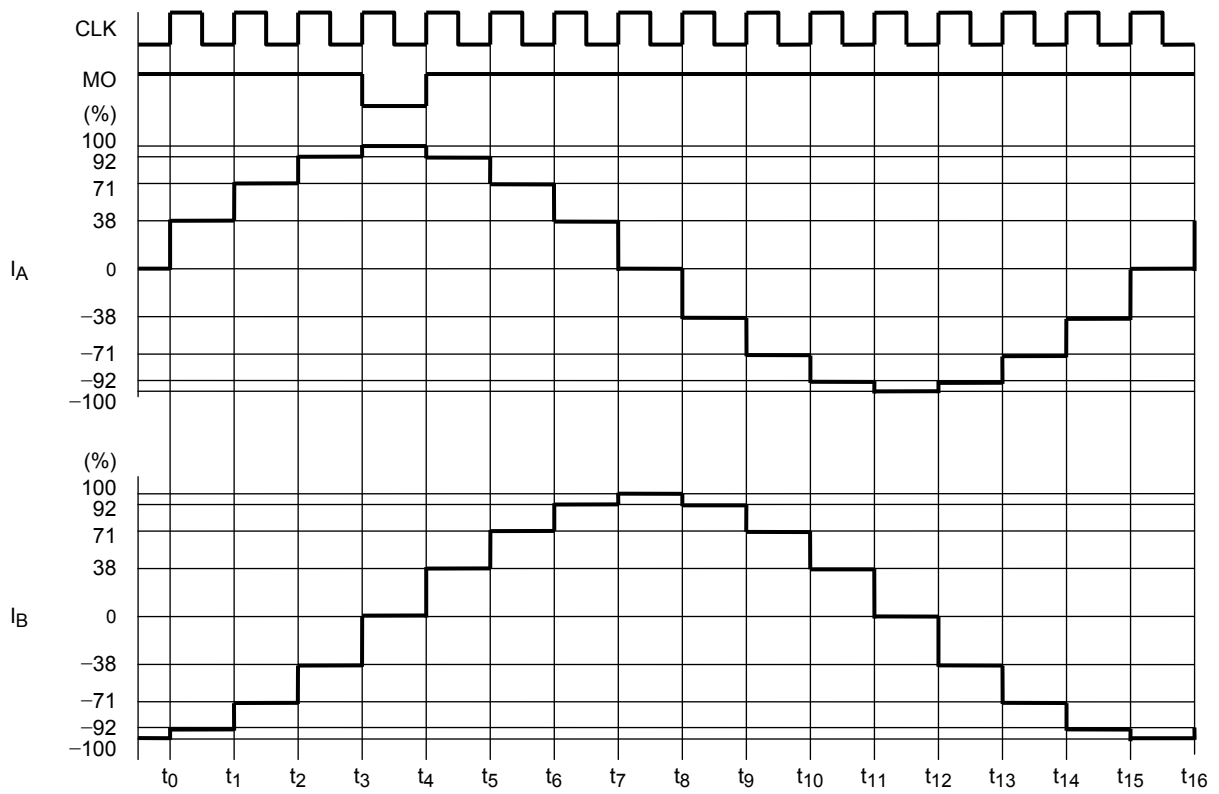


**1/2-step Excitation Mode (B type) (M1: L, M2: H, M3: H, CCW Mode)**

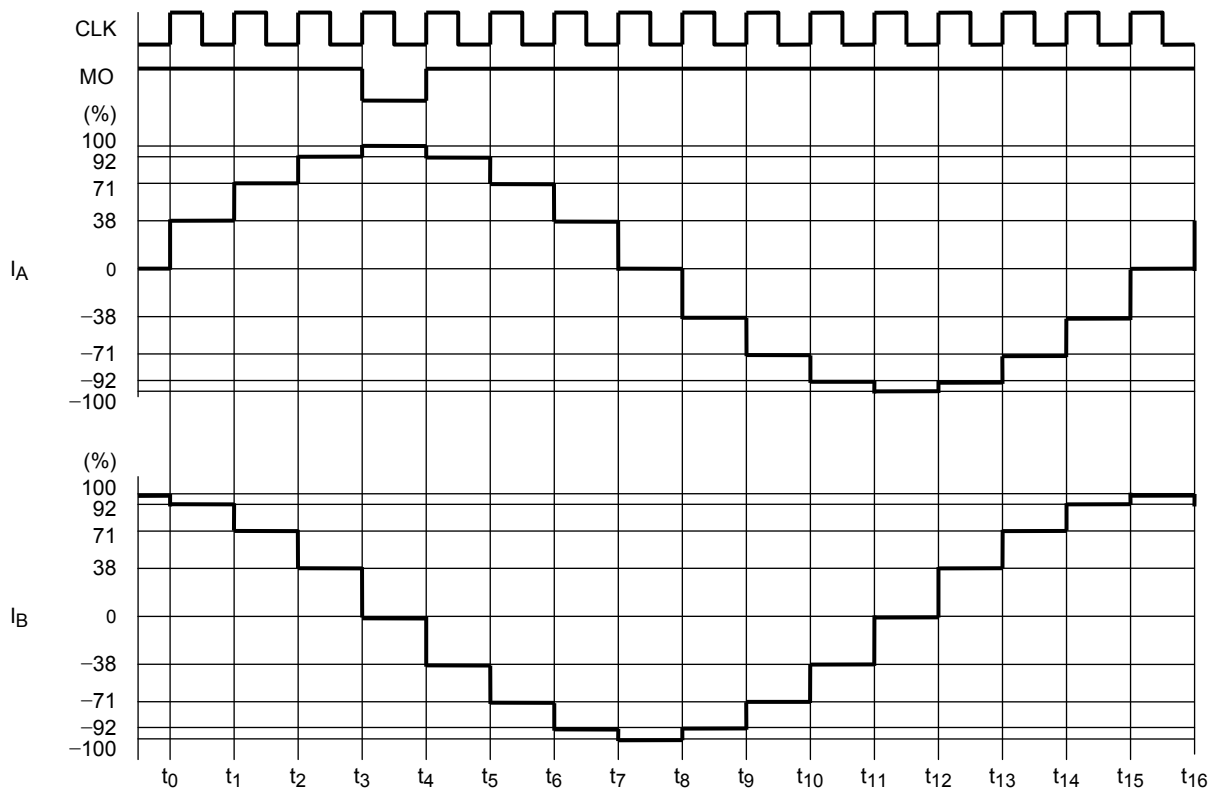


It operates from the initial state after the excitation mode is switched.

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

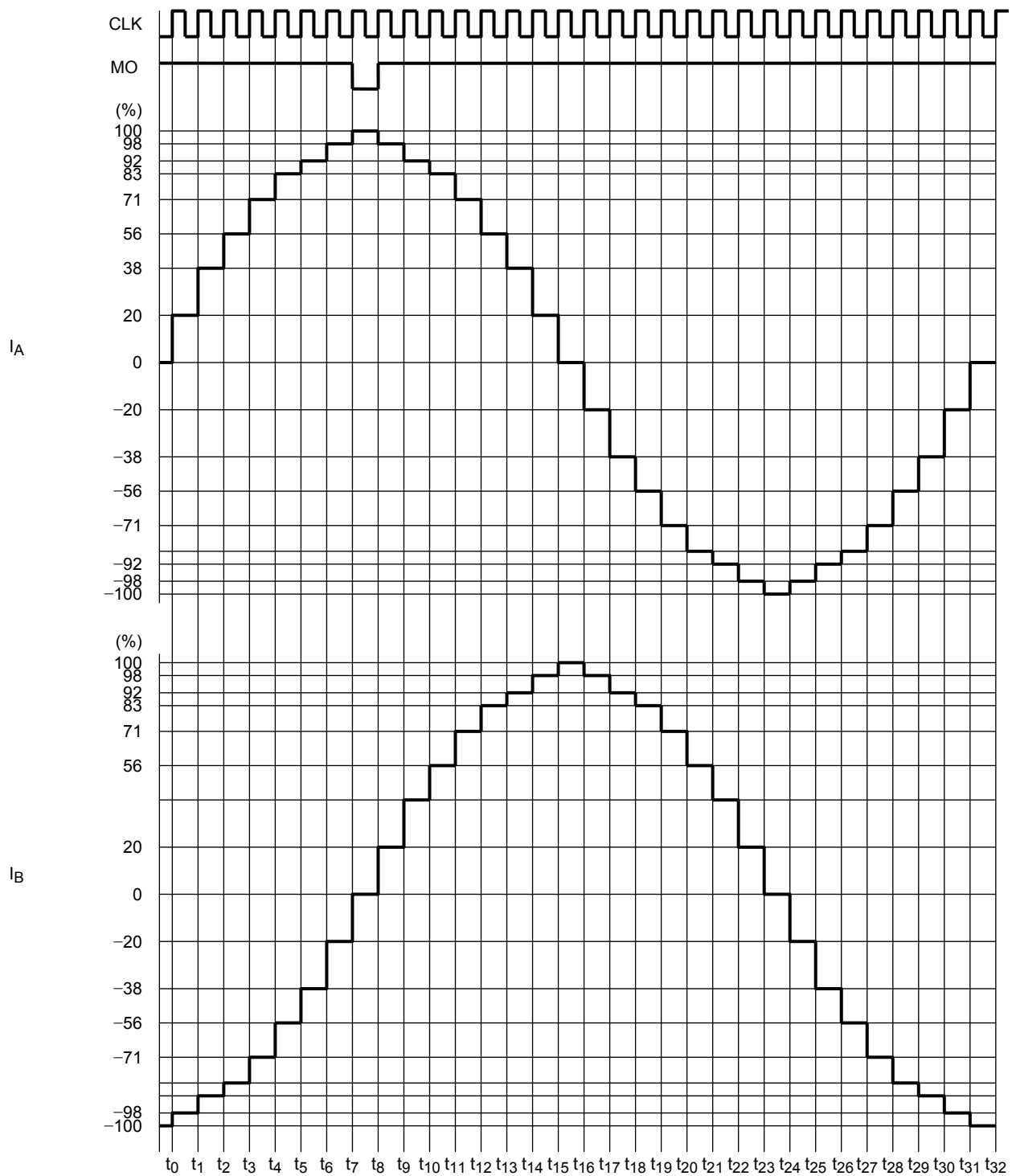


**1/4-step Excitation Mode (M1: H, M2: L, M3: L, CCW Mode)**



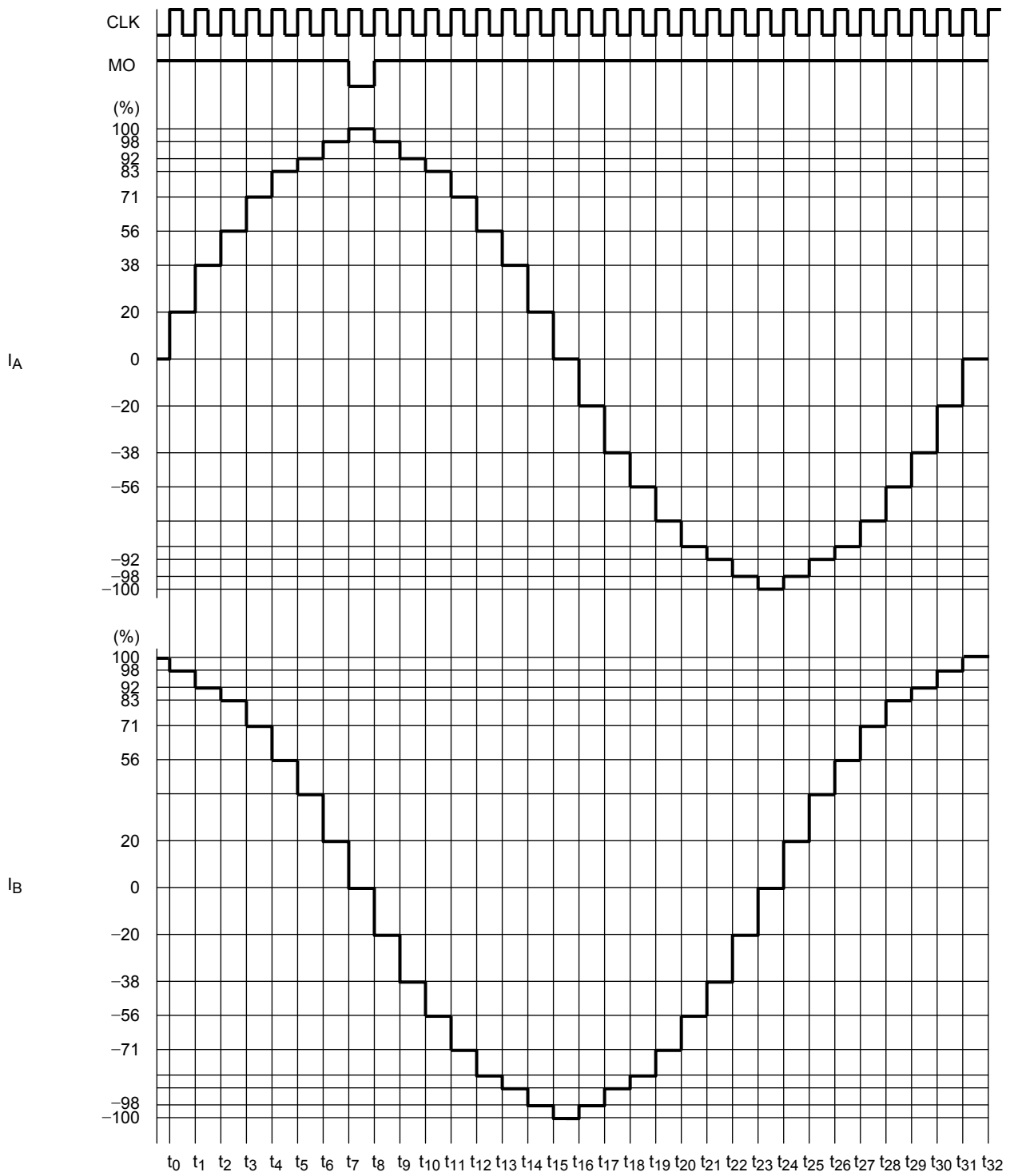
It operates from the initial state after the excitation mode is switched.

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



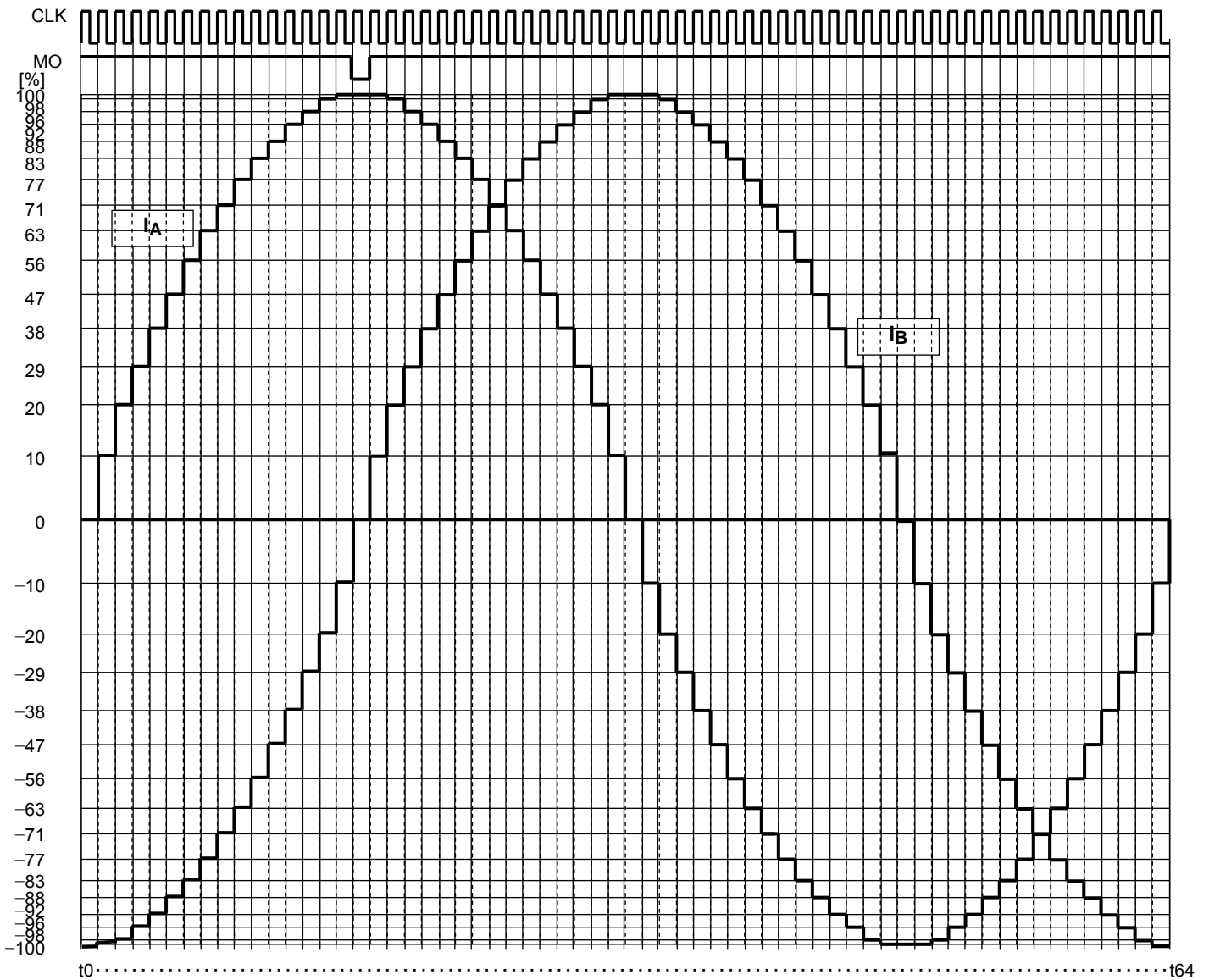
It operates from the initial state after the excitation mode is switched.

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.

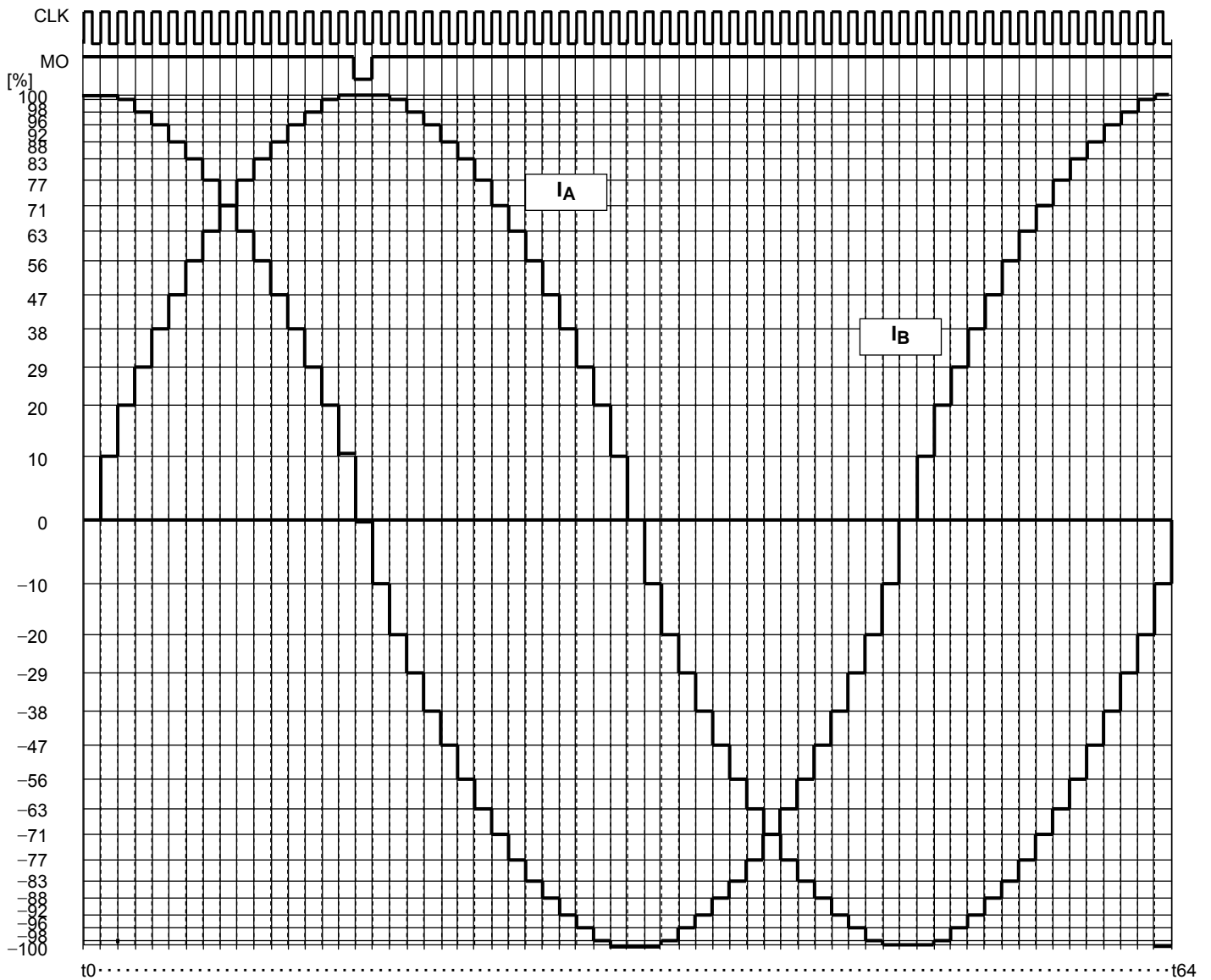
## 1/16-step Excitation Mode (M1: H, M2: H, M3: L, CW Mode)



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

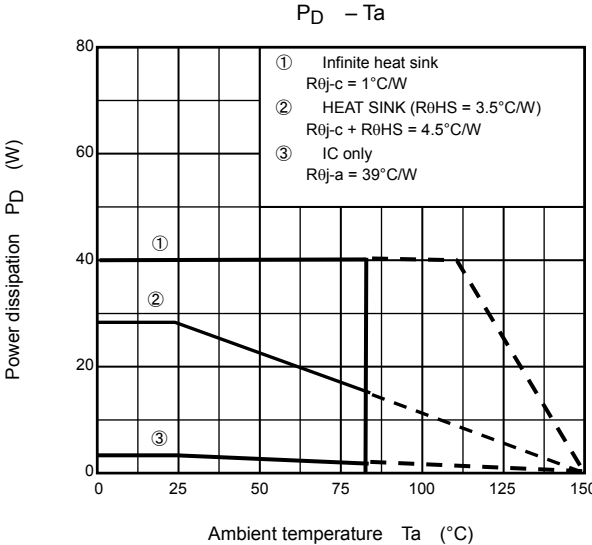
2-phase, 1-2-phase, W1-2-phase, 2W1-2-phase, 4W1-2-phase excitation (unit: %)

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

| 1/16,<br>1/8, 1/4,<br>1/2, 1/1 | Min. | Typ.  | Max.  | Unit |
|--------------------------------|------|-------|-------|------|
| $\theta$ 16                    | ---  | 100.0 | ---   | %    |
| $\theta$ 15                    | 95.5 | 99.5  | 100.0 |      |
| $\theta$ 14                    | 94.1 | 98.1  | 100.0 |      |
| $\theta$ 13                    | 91.7 | 95.7  | 99.7  |      |
| $\theta$ 12                    | 88.4 | 92.4  | 96.4  |      |
| $\theta$ 11                    | 84.2 | 88.2  | 92.2  |      |
| $\theta$ 10                    | 79.1 | 83.1  | 87.1  |      |
| $\theta$ 9                     | 73.3 | 77.3  | 81.3  |      |
| $\theta$ 8                     | 66.7 | 70.7  | 74.7  |      |
| $\theta$ 7                     | 59.4 | 63.4  | 67.4  |      |
| $\theta$ 6                     | 51.6 | 55.6  | 59.6  |      |
| $\theta$ 5                     | 43.1 | 47.1  | 51.1  |      |
| $\theta$ 4                     | 34.3 | 38.3  | 42.3  |      |
| $\theta$ 3                     | 25.0 | 29.0  | 33.0  |      |
| $\theta$ 2                     | 15.5 | 19.5  | 23.5  |      |
| $\theta$ 1                     | 5.8  | 9.8   | 13.8  |      |
| $\theta$ 0                     | ---  | 0.0   | ---   |      |

Power Dissipation

TB6600HG



## 1. How to Turn on the Power

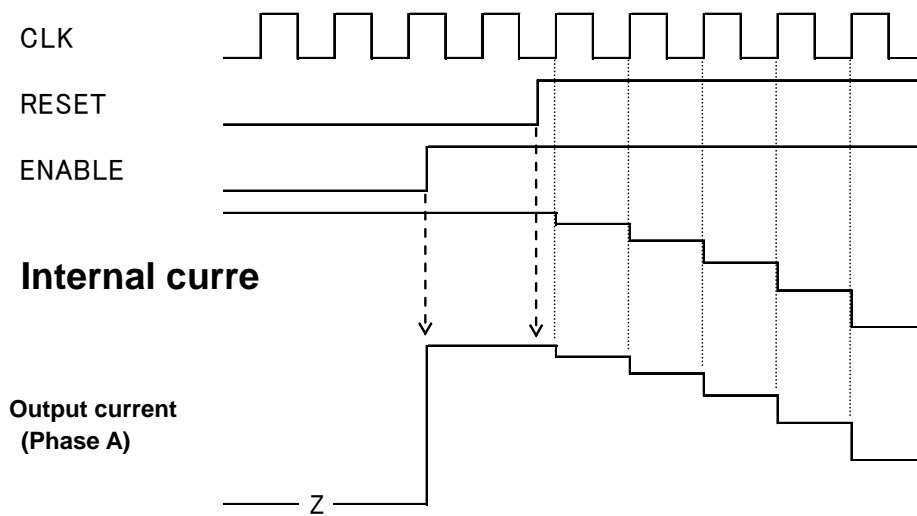
In applying Vcc or shutdown, ENABLE should be Low.

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.

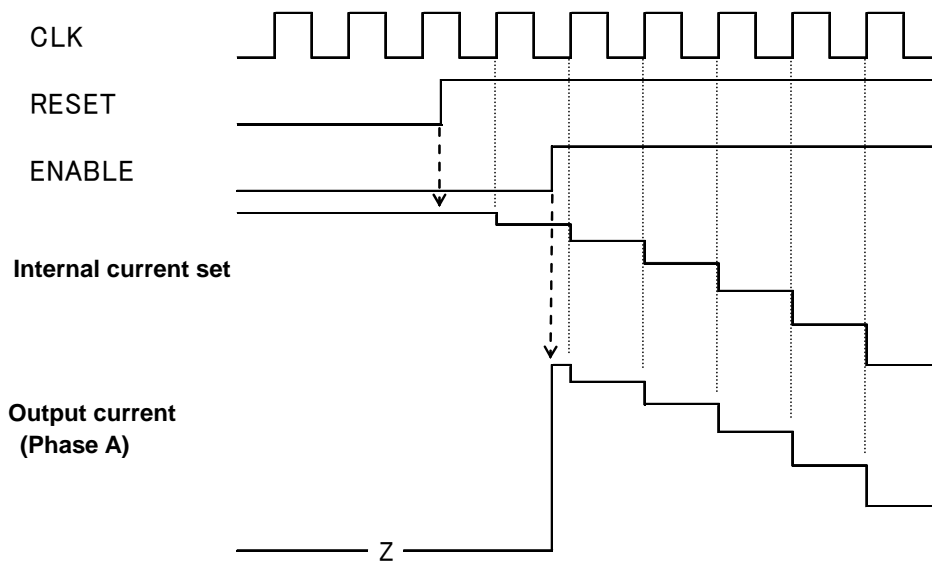
- (1) CLK: Current step proceeds to the next mode with respect to every rising edge of CLK.
  - (2) ENABLE: It is in Hi-Z state in low level. It is output in high level.
- RESET: It is in the initial mode (Phase A100% and Phase B %) in low level.
- ① ENABLE=Low and RESET=Low: Hi-Z. Internal current setting is in initial mode.
  - ② ENABLE=Low and RESET=High: Hi-Z. Internal current setting proceeds by internal counter.
  - ③ ENABLE=High and RESET=Low: Output in the initial mode (Phase A100% and Phase B%).
  - ④ ENABLE=High and RESET=High: Output at the value which is determined by the internal counter.

<Recommended control input sequence>

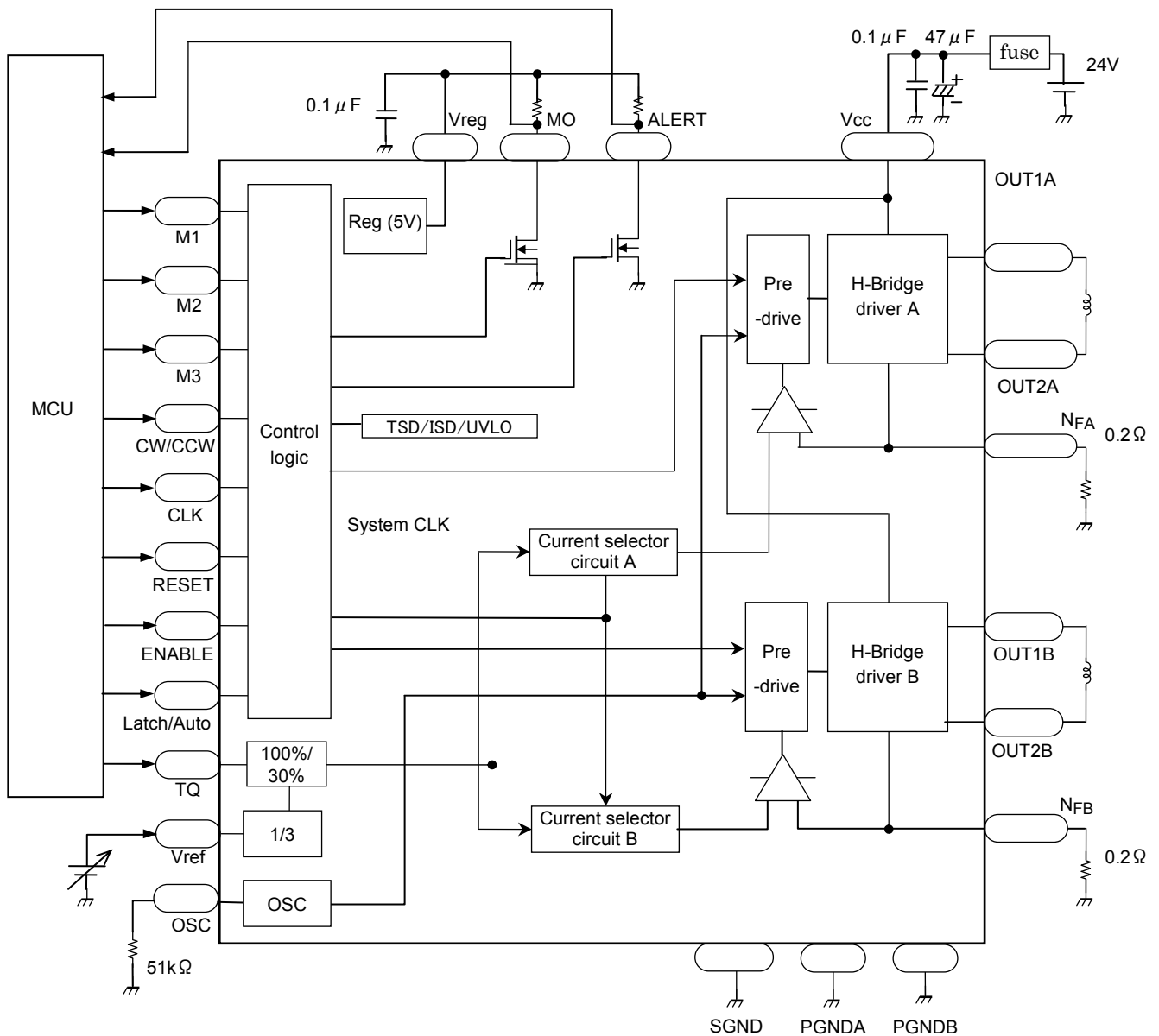
**(Example 1)**



**(Example 2)**



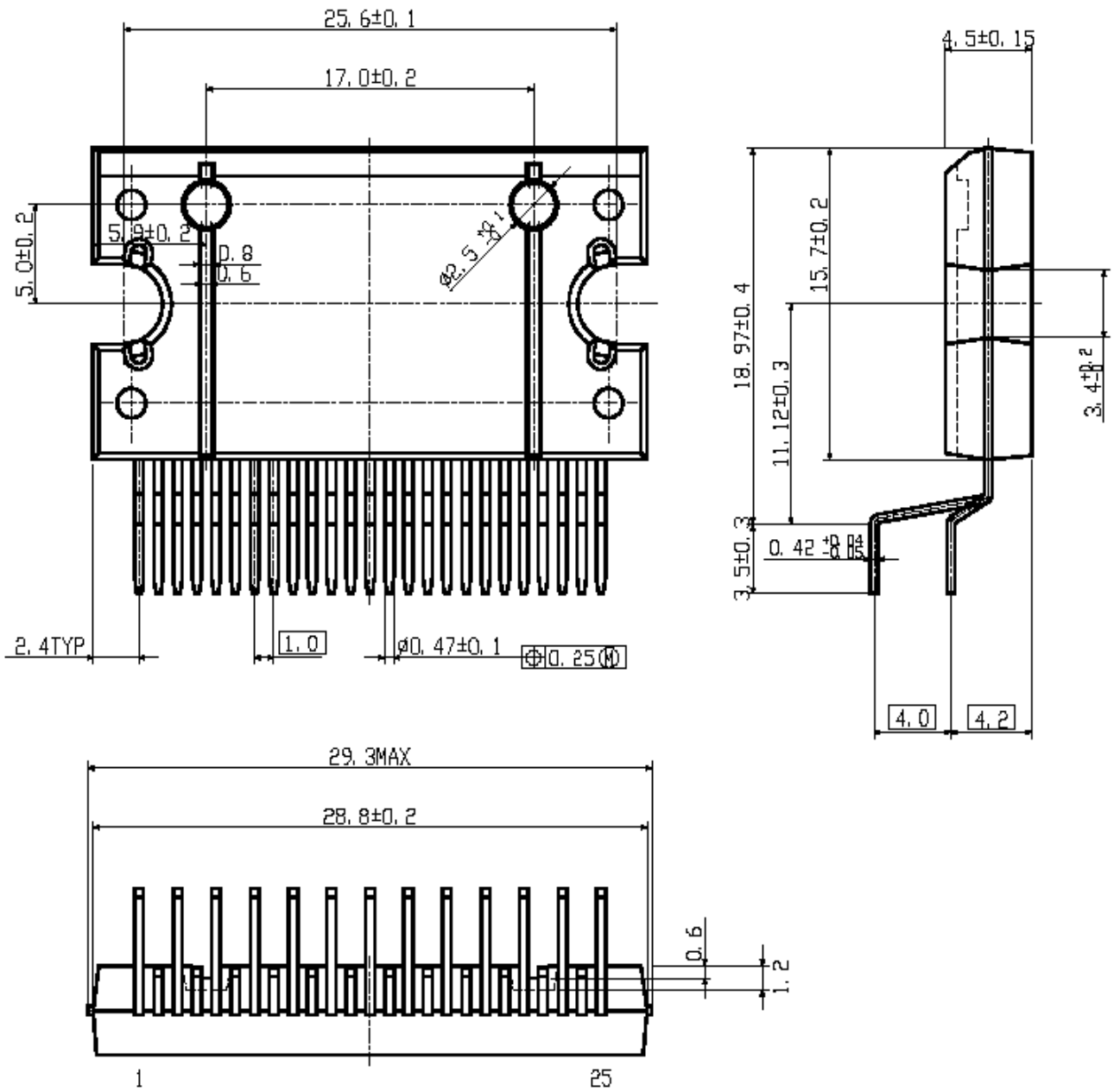
## Application Circuit



- 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 0.1 $\mu$ F. 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.

**Package Dimensions**

Unit: mm



Weight: 7.7 g (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.

Toshiba does not grant any license to any industrial property rights by providing these examples of application circuits.

### 5. Test Circuits

Components in the test circuits are used only to obtain and confirm the device characteristics. These components and circuits are not guaranteed to prevent malfunction or failure from occurring in the application equipment.

## 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.

**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 ( $T_j$ ) 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 consideration the effect of IC heat radiation with peripheral components.

**(4) Back-EMF**

When a motor rotates in the reverse 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 maximum ratings. To avoid this problem, take the effect of back-EMF into consideration in system design.

**(5) Others**

Utmost care is necessary in the design of the output, V<sub>CC</sub>, VM, and GND lines since the IC may be destroyed by short-circuiting between outputs, air contamination faults, or faults due to improper grounding, or by short-circuiting between contiguous pins.



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