TOSHIBA Bi−CD INTEGRATED CIRCUIT SILICON MONOLITHIC

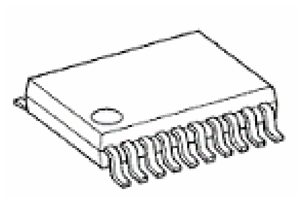
Tentative

TB6608FNG

STEPPING MOTOR DRIVER IC

TB6608FNG is a micro-step one-chip IC, which applies PWM constant current system and drives of sine wave, for stepping motor driver.

It is capable of selecting 2, 1−2, W1-2, and 2W1−2 phase excitation modes and forward and reverse rotation modes. And it can easily control 2 phase bipolar-type stepping motor by only clock signals.



SSOP20-P-225-0.65

Weight: 0.09 g (typ.)

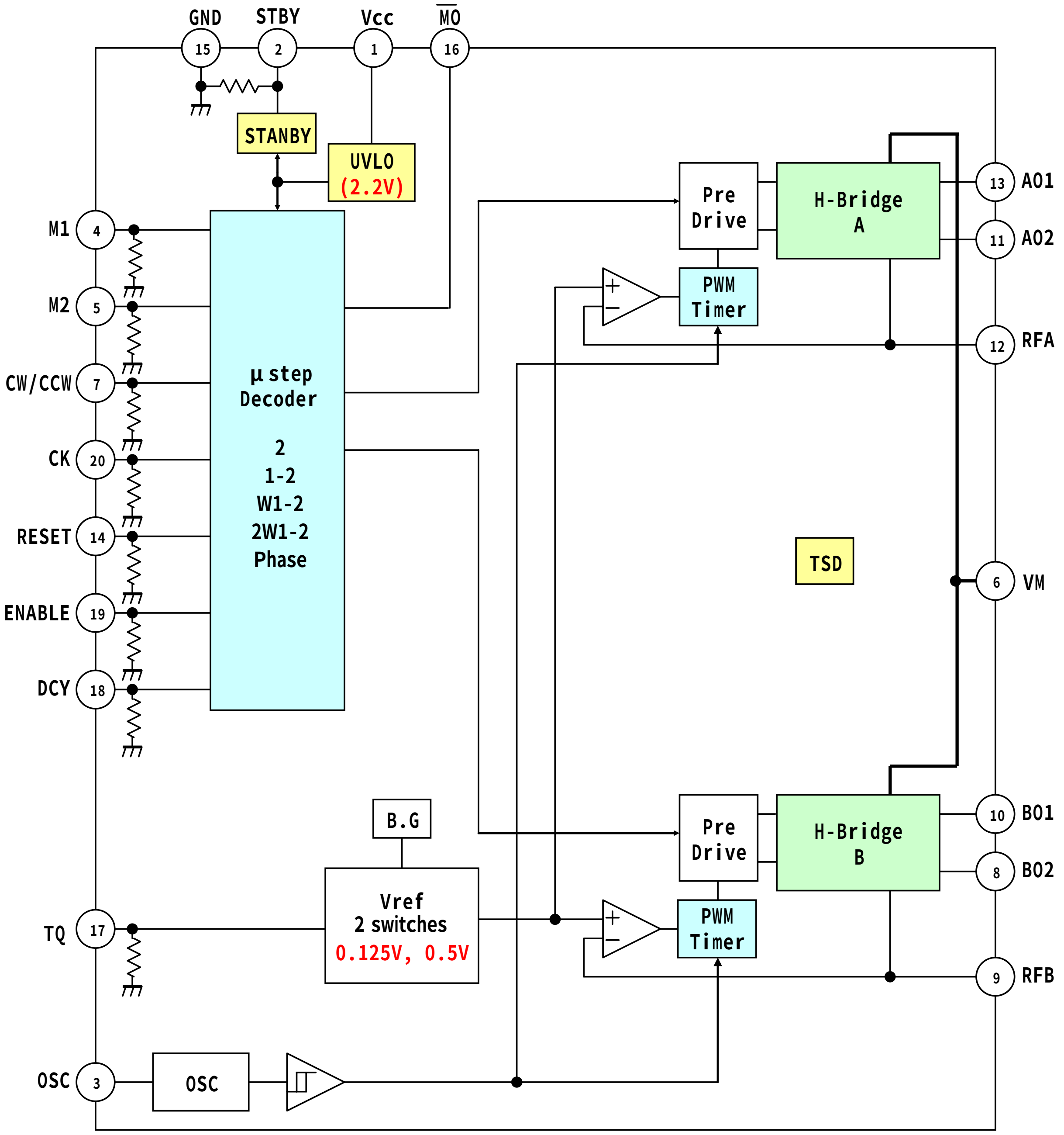
Features

- Motor sypply voltage ; V_M=15V (Max.)
- Control sypply voltage ; Vcc=2.7V～6V
- Output current ; Iout≦0.8A (Max)
- Output ON resistance ; Ron=1.5Ω (Up+Down typ. @V_M = 5 V)
- Built in micro step control encoder circuit (Clock in method)
- Four way excitation modes (2, 1-2, W1-2 and 2W1-2 phase excitation).
- Built in input pull down resistance.: 200 kΩ (typ.)
- With output monitor pin ($\overline{MO}$) .
- Built in thermal shutdown circuit (TSD) and low voltage detection circuit (UVLO) .
- Small surface package (SSOP20 : 0.65mm pitch) .
- Pb free

- This product has a MOS structure and is sensitive to electrostatic discharge. When handling this product, ensure that the environment is protected against electrostatic discharge by using an earth strap, a conductive mat and an ionizer. Ensure also that the ambient temperature and relative humidity are maintained at reasonable levels.
- Install the product correctly to avoid breakdown, damage and/or degradation to the product or equipment.

The TB6608FNG is a Pb-free product.
The following conditions apply to solderability:
*Solderability
1. Use of Sn-37Pb solder bath
   *solder bath temperature = 230°C
   *dipping time = 5 seconds
   *number of times = once
   *use of R-type flux
2. Use of Sn-3.0Ag-0.5Cu solder bath
   *solder bath temperature = 245°C
   *dipping time = 5 seconds
   *number of times = once
   *use of R-type flux

Block Diagram



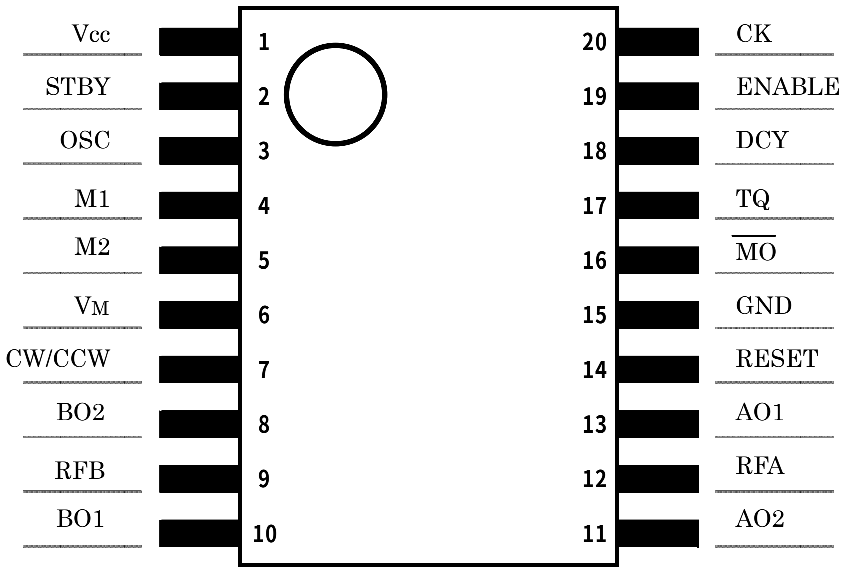
Vref set

Input	Vref
TQ	
L	0.125V
H	0.5V

Pin Function

PIN No.	SYMBOL	FUNCTIONAL DESCRIPTION	Remarks
1	Vcc	Power voltage supply terminal for logic	Vcc(opr)=2.7～5.5V
2	STBY	Stand by signal input terminal	Refer to the table “Input signal and operation mode”.
3	OSC	External condenser terminal for Internal oscillation	
4	M1	Excitation mode setting input terminal 1	Refer to the table “Setting excitation mode”.
5	M2	Excitation mode setting input terminal 2	Refer to the table “Setting excitation mode”.
6	VM	Power voltage supply terminal for output.	VM(opr)=2.5～13.5V
7	CW／CCW	Forward rotation / Reverse rotation signal input	Refer to the table “Input signal and operation mode”.
8	BO2	B phase output terminal 2.	Connecting to motor coil terminal.
9	RFB	Connecting terminal for B phase output current detecting resistance	
10	BO1	B phase output terminal 1.	Connecting to motor coil terminal.
11	AO2	A phase output terminal 2.	Connecting to motor coil terminal.
12	RFA	Connecting terminal for A phase output current detecting resistance	
13	AO1	A phase output terminal 1.	Connecting to motor coil terminal.
14	RESET	Reset signal input terminal.	Refer to the table “Input signal and operation mode”.
15	GND	Ground terminal	
16	$\overline{\text{MO}}$	Monitor signal output terminal.	Initial status; $\overline{\text{MO}}$＝Low (open drain, Pulled up by external resistance)
17	TQ	Vref setting input terminal	Refer to the table “Vref set”.
18	DCY	Decay setting input terminal	Refer to the table”Insert length of fast mode in falling current”.
19	ENABLE	Enable signal input terminal	Refer to the able “Input signal and operation mode”.
20	CK	Clock signal input terminal	

Pin Connection



Input Signal and Operation Mode

Input					Mode
CK	CW/CCW	RESET	ENABLE	STBY	
↑ (rising edge)	L	H	H	H	CW
↑ (rising edge)	H	H	H	H	CCW
X	X	L	H	H	Initial mode
X	X	X	L	H	Enable waiting mode（Output OFF, High impedance）
X	X	X	X	L	Stand by mode（Output OFF, High impedance）

X: Don’t Care

Setting Excitation Mode

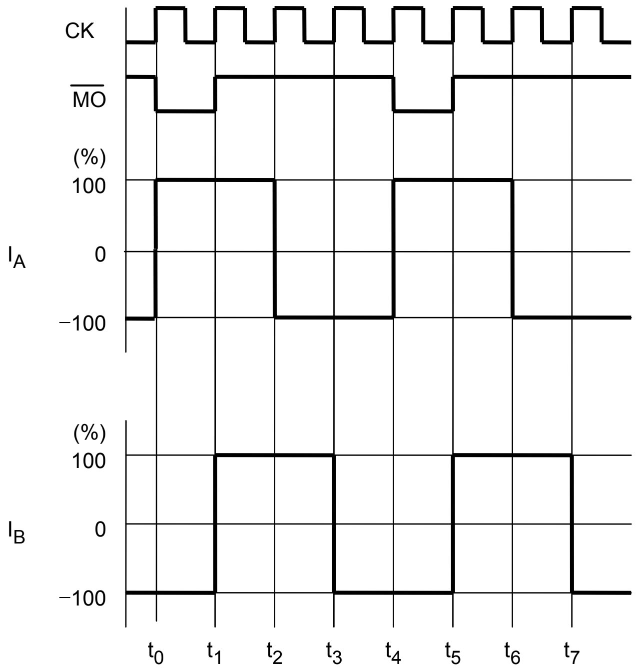
Input		Excitation mode
M1	M2	
L	L	2 phase
H	L	1-2 phase
L	H	W1-2 phase
H	H	2W1-2 phase

Initial status of A and B phase current (The recovering status from STBY mode is also in this initial status.)

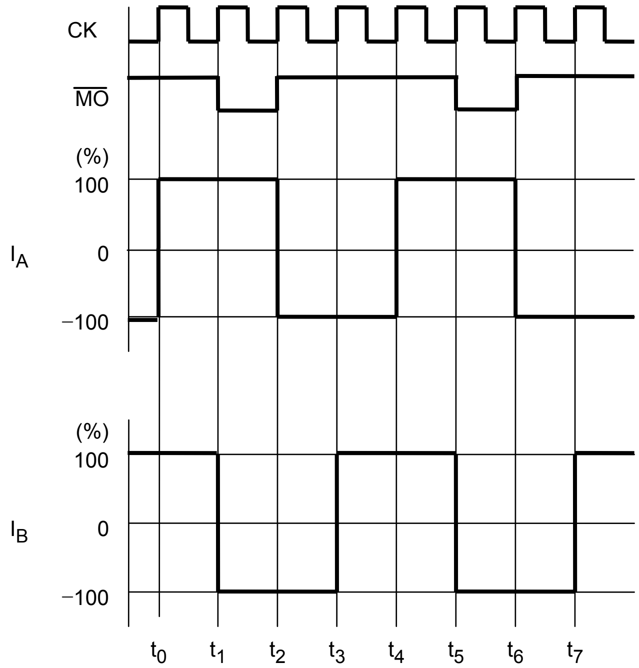
Excitation mode	A phase current	B phase current
2 phase	100%	－100%
1-2 phase	100%	0%
W1-2 phase	100%	0%
2W1-2 phase	100%	0%

In this specification, the direction from AO1 to AO2 and BO1 to BO2 are defined as forward directions.

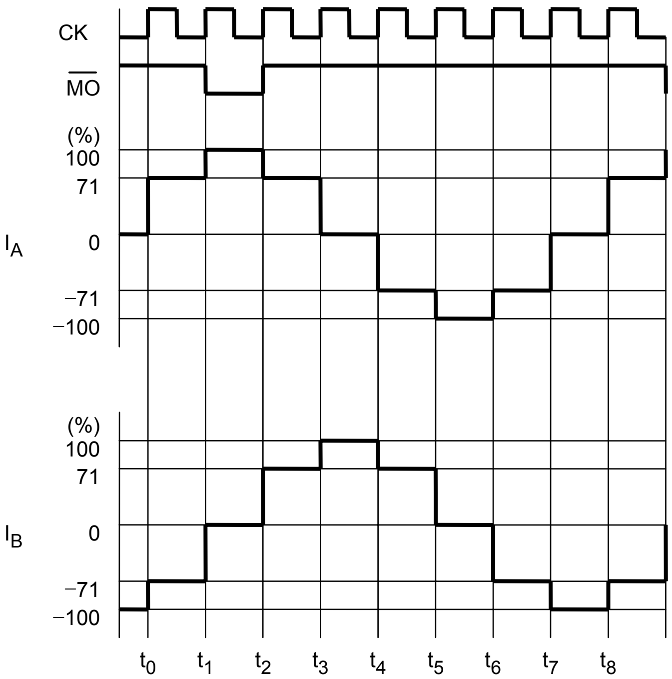
2 phase excitation (M1: L, M2: L, CW mode)



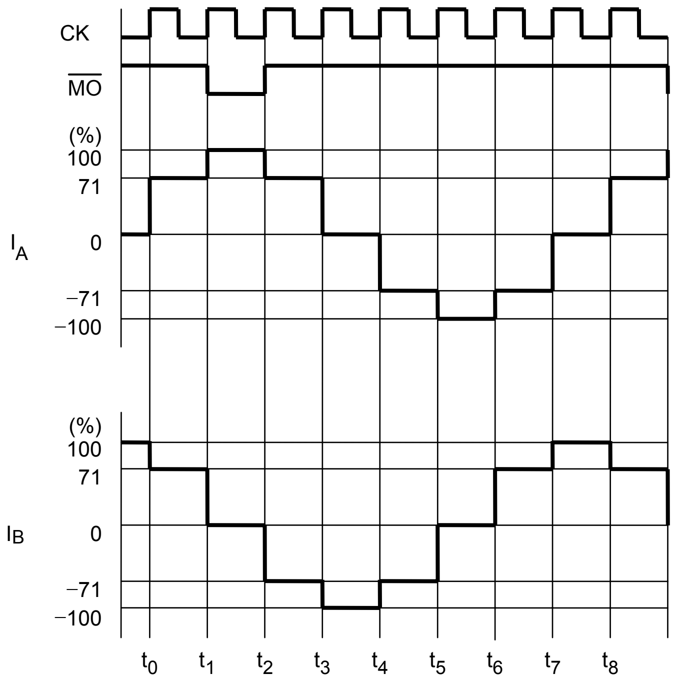
2 phase excitation (M1: L, M2: L, CCW mode)



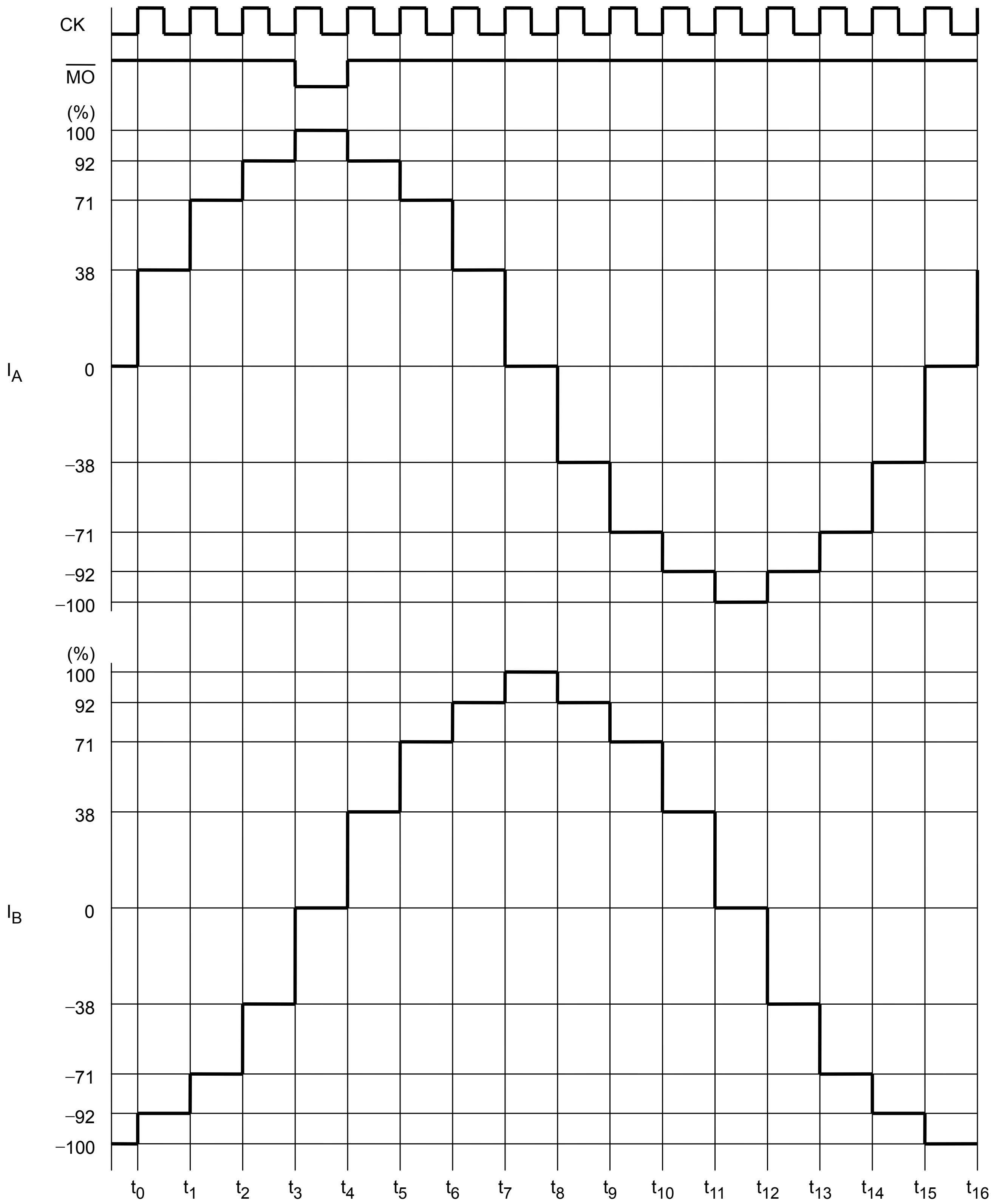
1−2 phase excitation (M1: H, M2: L, CW mode)



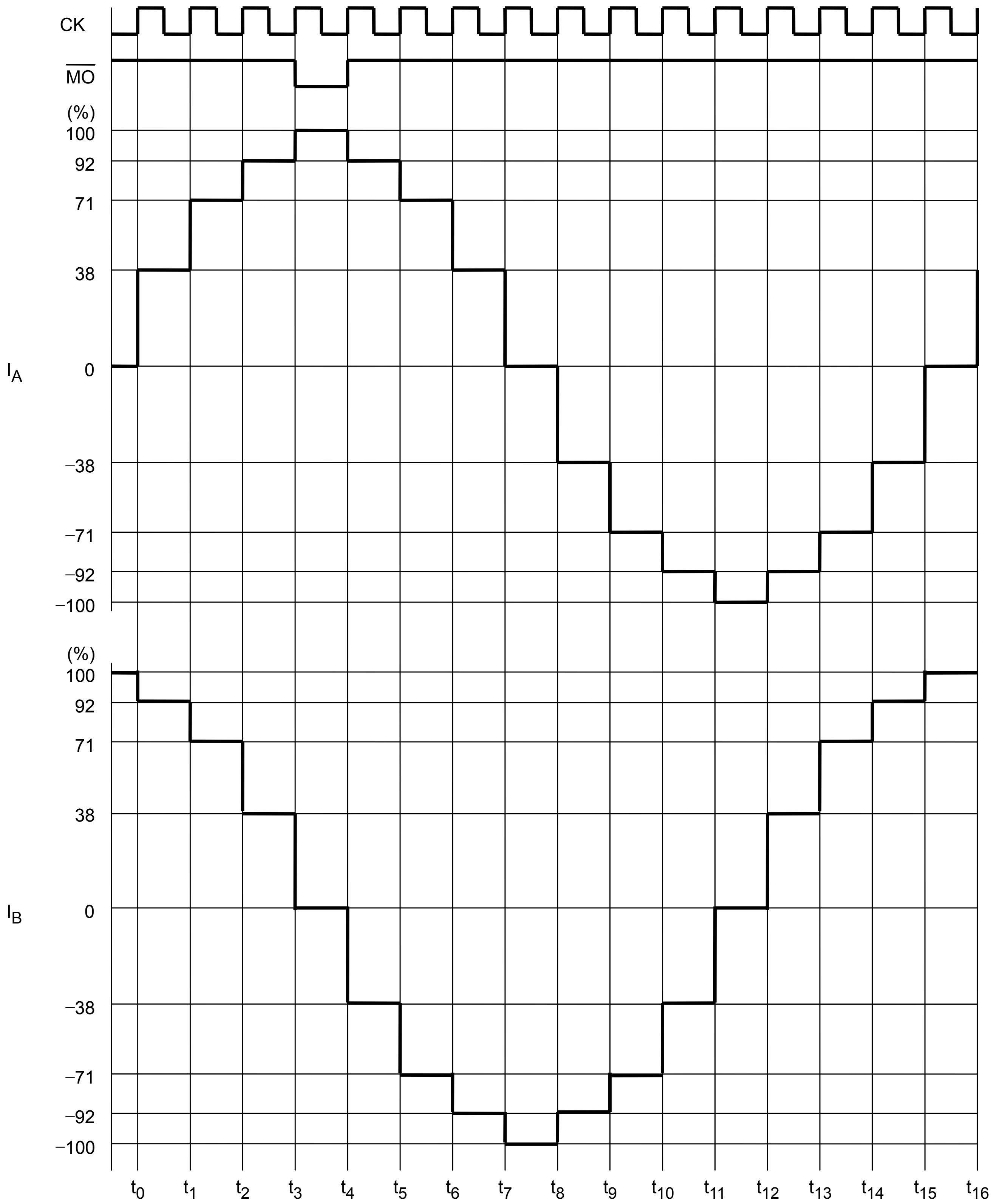
1−2 phase excitaiton (M1: H, M2: L, CCW mode)



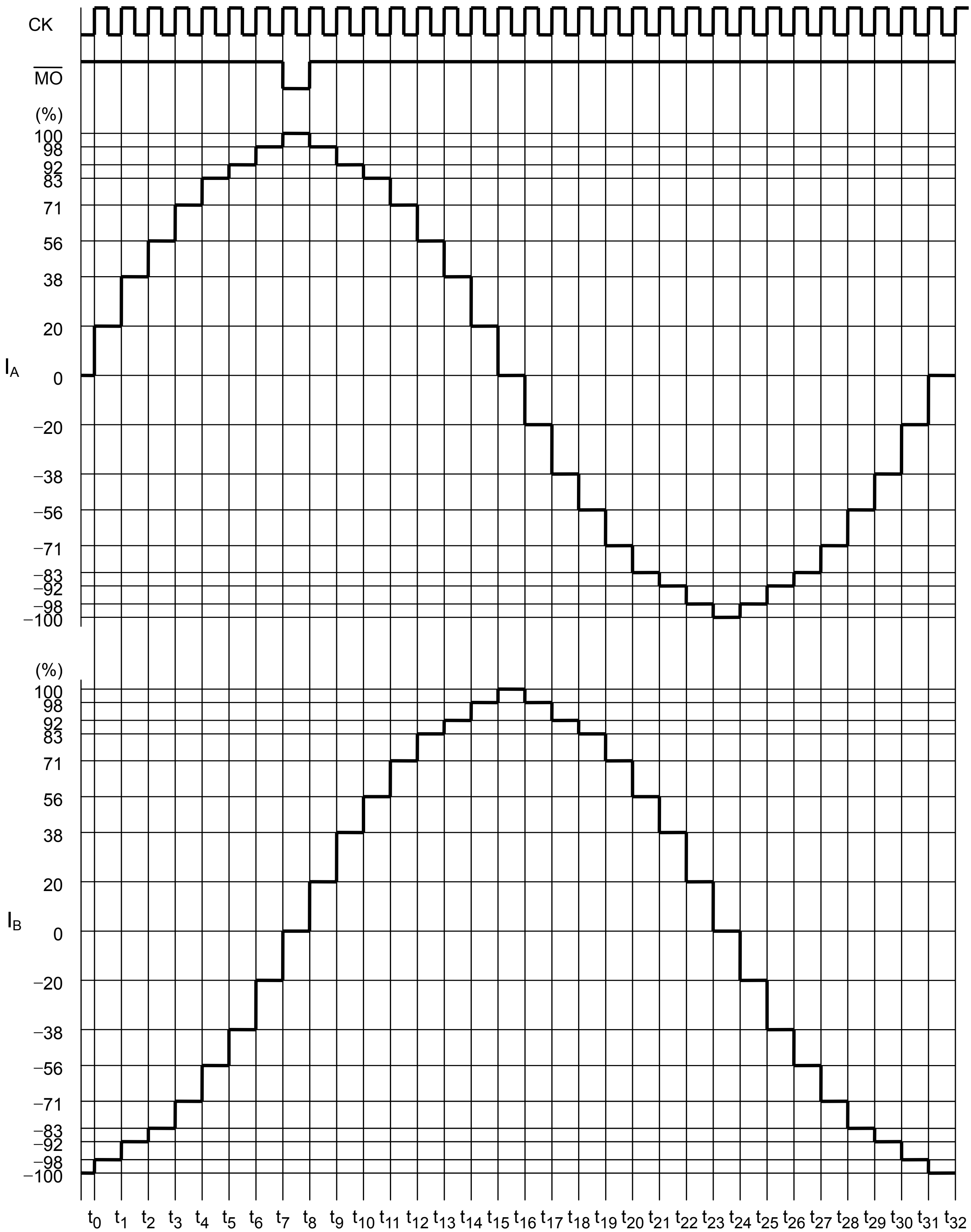
W1−2 phase excitation (M1: L, M2: H, CW mode)



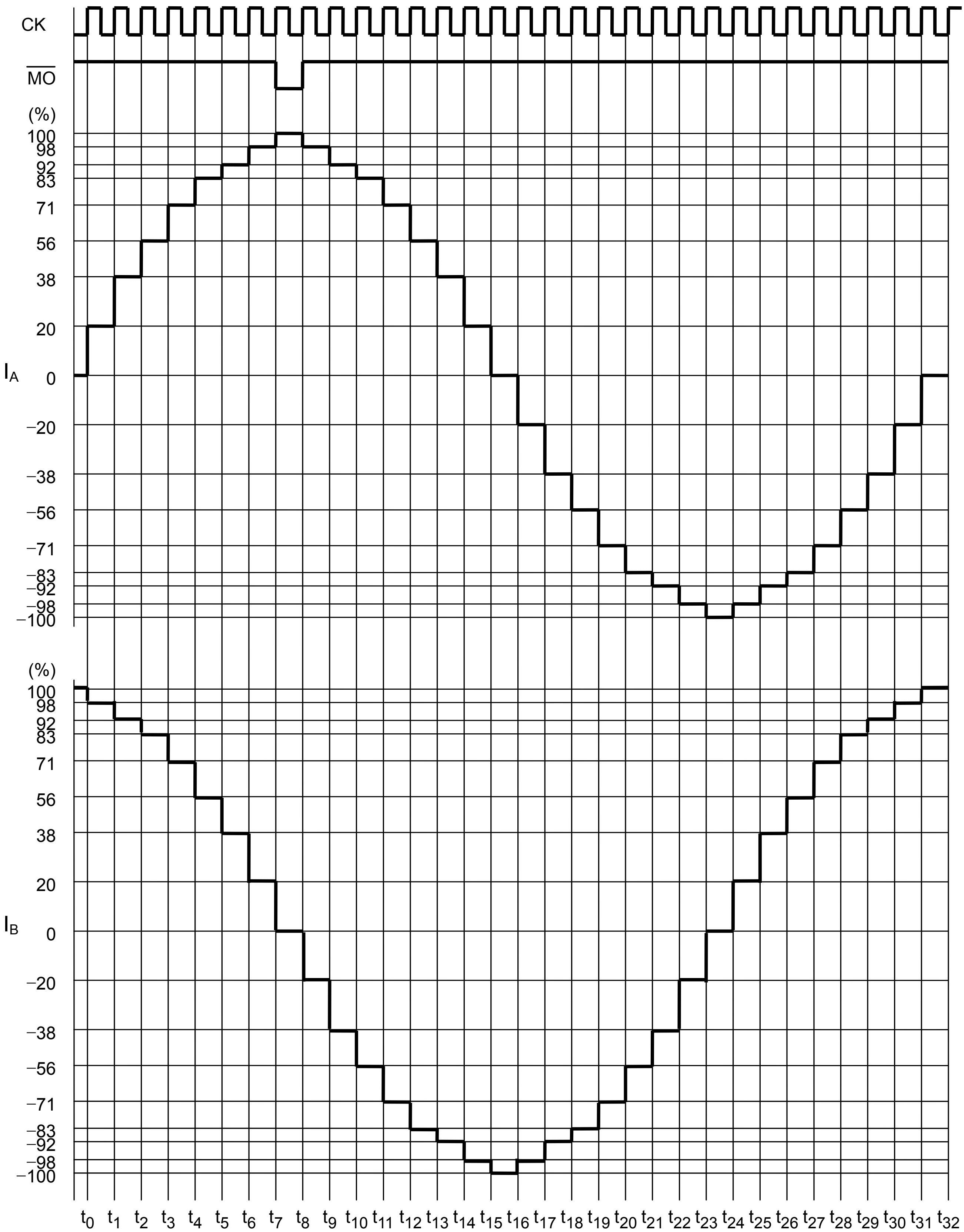
W1−2 phase excitation (M1: L, M2: H, CCW mode)



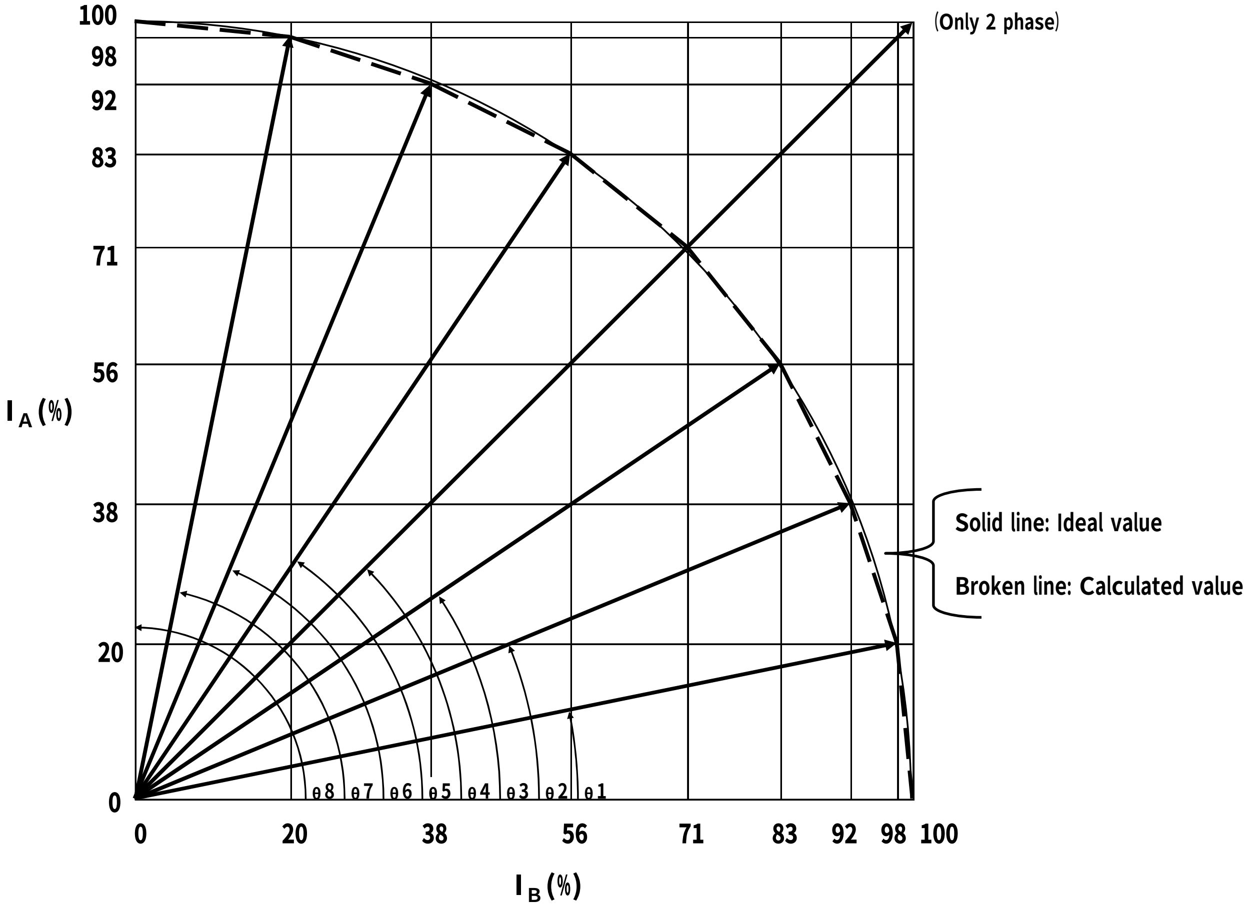
2W1−2 phase excitation (M1: H, M2: H, CW mode)



2W1−2 phase excitation (M1: H, M2: H, CCW mode)



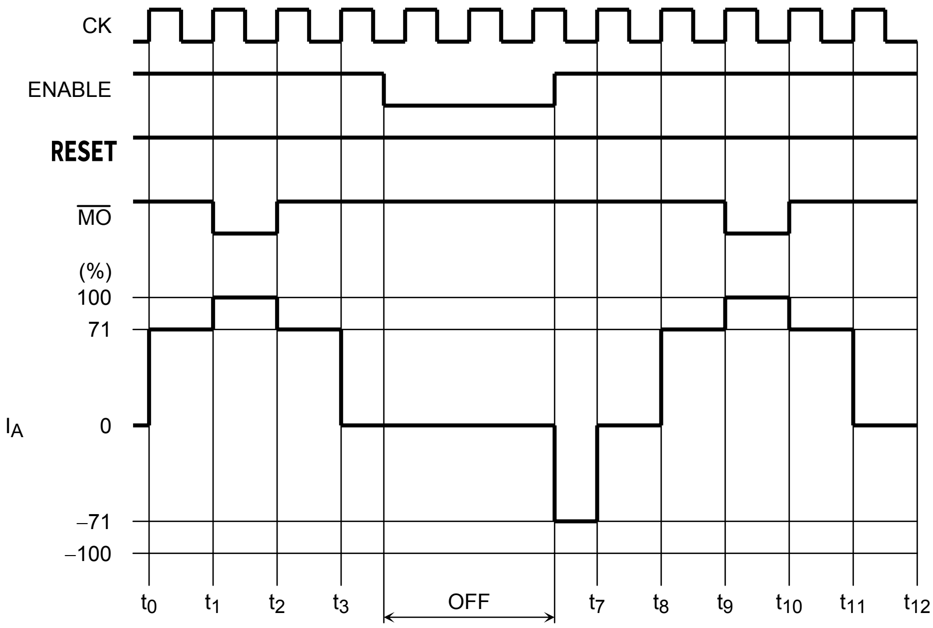
Output Current Vector or Bit (Normalize to 90 deg for each one step)



θ	Rotation angle		Vector length		
	Ideal	Calculated	Ideal	Calculated	
θ0	0.00°	0.00°	100	100.00	—
θ1	11.25°	11.53°	100	100.02	—
θ2	22.50°	22.44°	100	99.54	—
θ3	33.75°	34.01°	100	100.12	—
θ4	45.00°	45.00°	100	100.41	141.42
θ5	56.25°	55.99°	100	100.12	—
θ6	67.50°	67.56°	100	99.54	—
θ7	78.75°	78.47°	100	100.02	—
θ8	90.00°	90.00°	100	100.00	—
				1-2/W1-2/2W1-2 phase	2 phase

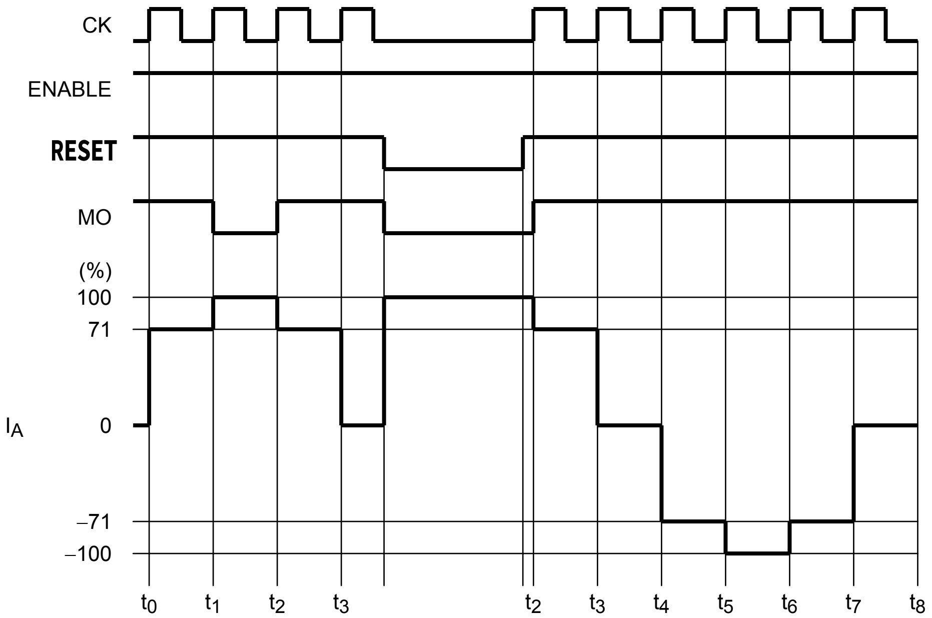
ENABLE, RESET and Outputs (OUT, $\overline{MO}$)

Ex1. ENABLE 1−2 phase excitation (M1: H, M2: L)



$\overline{\text{ENABLE}}$ signal disables only output signal. Internal logic functions are preceded by CK signal without regard to $\overline{\text{ENABLE}}$ signal.
Therefore, Output Current is initiated from the proceeded timing point of internal logic circuit, after release of disable mode.

Ex2. RESET 1−2 phase excitation (M1: H, M2: L)



When $\overline{\text{RESET}}$ is low, the decoder is initialized and $\overline{\text{MO}}$ outputs low level. (Output Current: A−Phase 100 %.) After $\overline{\text{RESET}}$ is high, the motion is resumed from next clock. $\overline{\text{MO}}$ is used as rotation and initial signal for stable rotation checking.

Absolute Maximum Rating (Ta=25°C)

CHARACTERISTIC	SYMBOL	RATING	UNIT
Supply Voltage	V_{CC}	6	V
Output Voltage	$V_{M\ (opr)}$	15	V
	$V_{M\ (max)}$	15	
Output Current	Iout(AO), Iout(BO)	0.8	A
	$I_{\overline{MO}}$	1	mA
Output tolerance of $\overline{MO}$	$V_{\overline{MO}}$	Vcc	V
Input Voltage	V_{IN}	−0.2 ~ V_{CC}+0.2	V
Power Dissipation	P_D	0.71 (Note1)	W
		0.96 (Note2)	
Operating Temperature	T_{opr}	−20 ~ 85	°C
Storage Temperature	T_{stg}	−55 ~ 150	°C

Note1 : IC only

Note2 : 50 × 50 × 1.6 mm, Cu 40%, in mounted on glass epoxy substrate.

Recommended Operating Conditions (Ta= −20 ～ 85°C)

CHARACTERISTIC	SYMBOL	TEST CONDITION	MIN	TYP.	MAX	UNIT
Control Power Supply Voltage	$V_{CC\ (opr)}$	—	2.7	3.3	5.5	V
Motor Power Supply Voltage	$V_{M\ (opr)}$	—	2.5	5	13.5	V
Output Current	I_{OUT}	2.5V ≦ VM ≦ 5V	—	—	0.35	A
Output Current	I_{OUT}	5V ＜ VM ≦ 13.5V	—	—	0.6	A
Input Voltage	V_{IN}	—	—	—	V_{CC}	V
Clock Frequency	f ck	—	—	1	10	kHz
OSC Frequency	f osc	—	80	400	(800)	kHz
Chopping Frequency	f chop	—	15	100	(200)	kHz

Operation Description

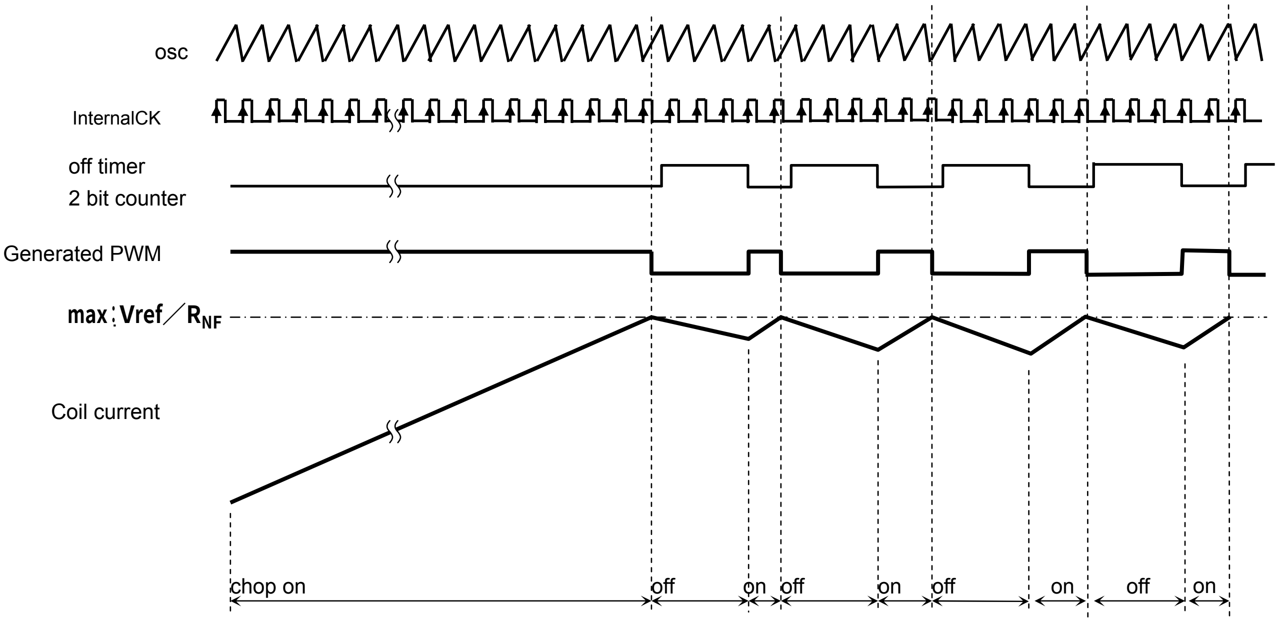
Triangle wave oscillating frequency fosc;

$$fosc = A \cdot \frac{1}{Cosc}$$

Chopping Control Description

1. The coil current flows when chop turns on.
2. V_{RF} reaches Vref and the comparator detects V_{RF} equals Vref.
3. Chop turns off.

Up-edges of internal clock formed by oscillation are counted. Chop turns off at the fourth up-edge and the driving PWM signal is generated.



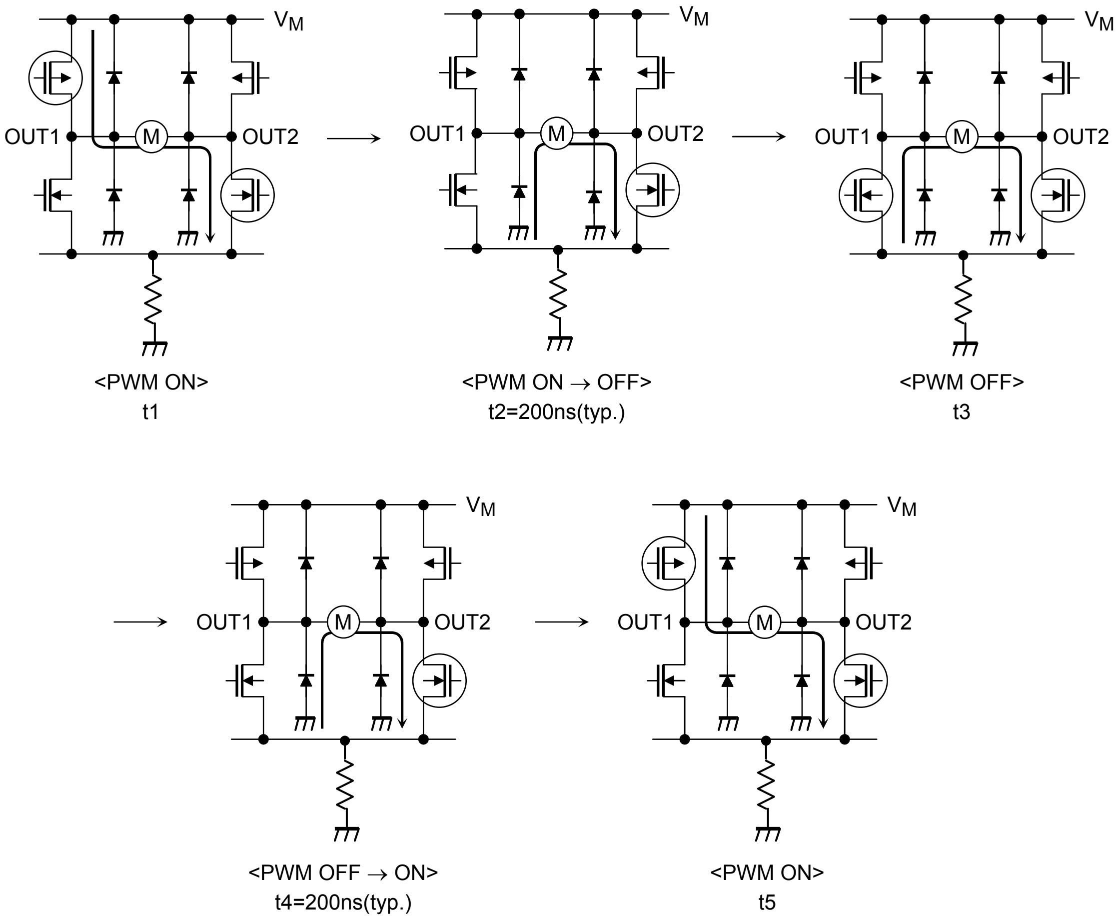
Timing chart may be simplified to explain the IC function and operation clearly.

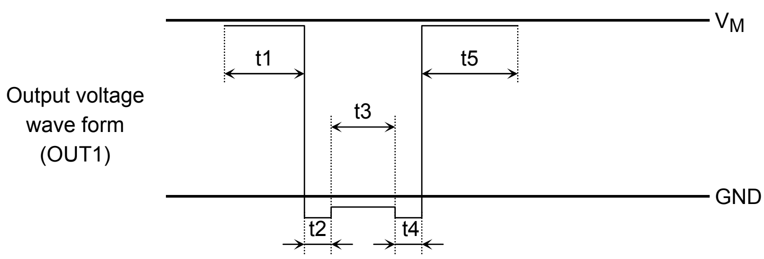
PWM Control

Normal operation and short brake are repeated under PWM control.

To avoid the lead-though current which is generated when up/down power transistors are turned on at the same time on the output circuit, the dead time t2 and t4 (200ns : design marked value) are generated in the IC when each mode is switched.

So, PWM control by synchronized commutation is capable without inserting OFF time by external input.

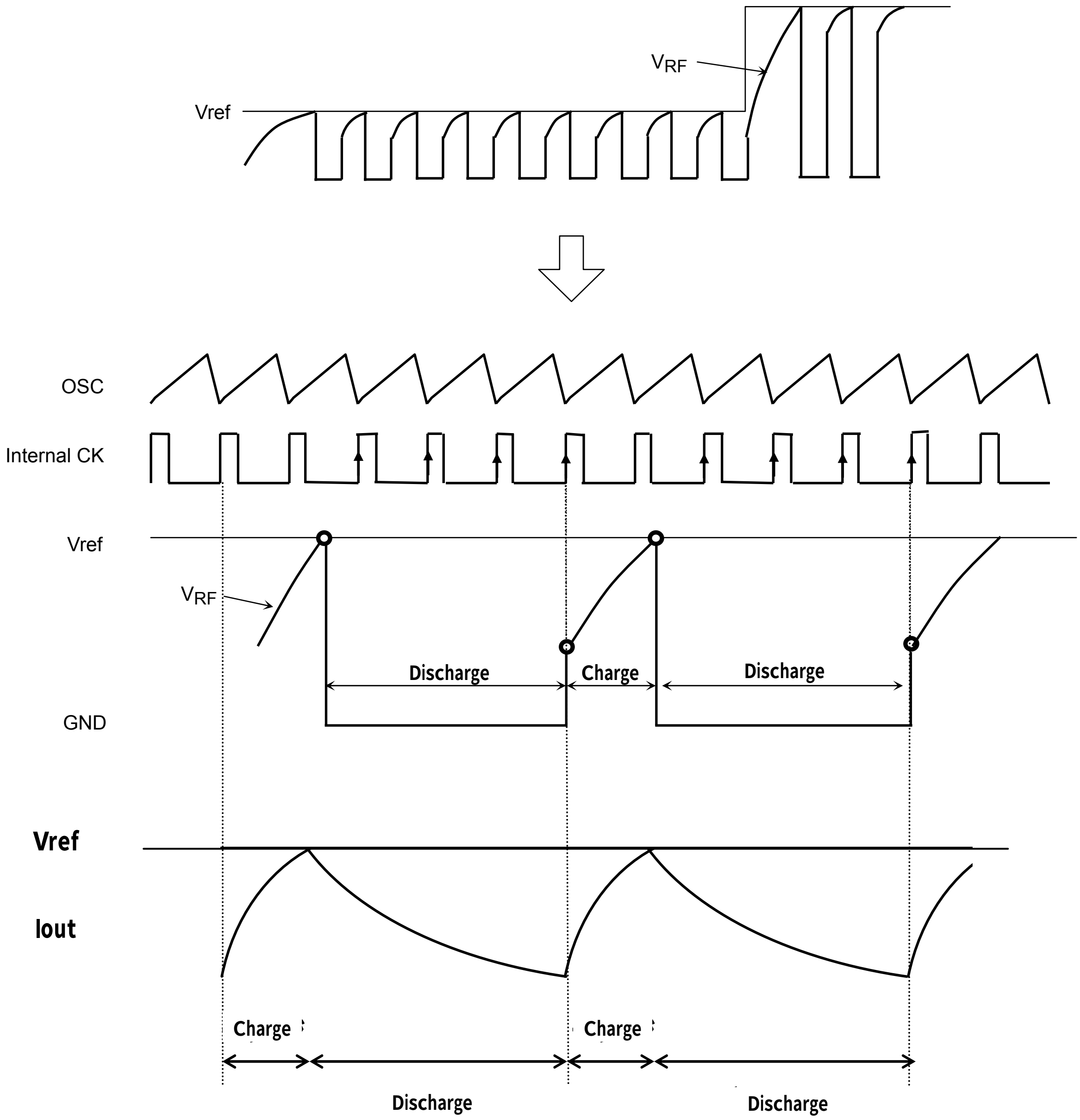




(1) Constant current chopping

It transfers to discharge mode when V_{RF} reaches Vref.

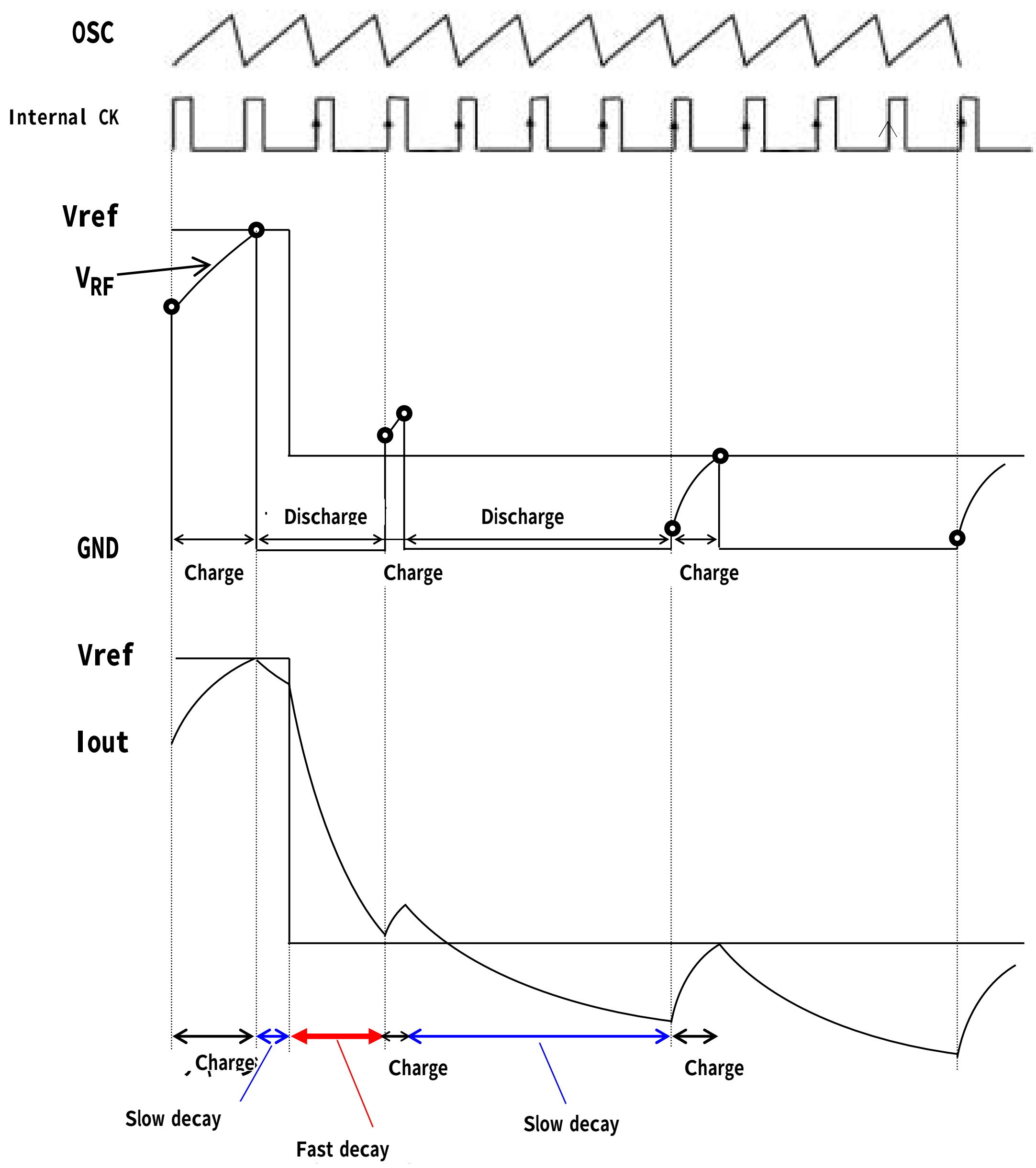
Charge mode drives again after four-count discharge mode of internal clock signal formed from OSC is inserted.



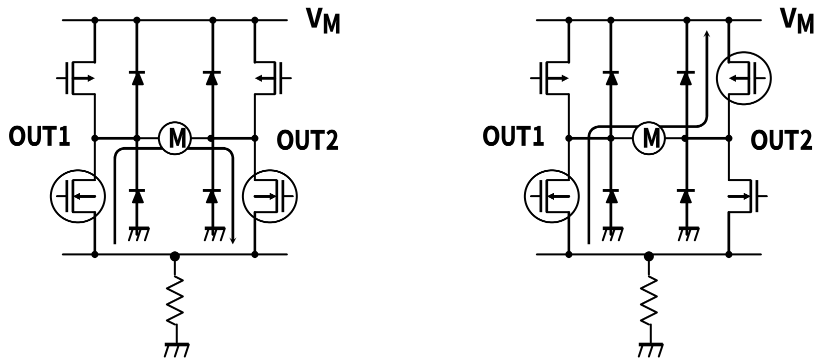
(2) Operation in set current switching (Decay)

In decaying, the fast decay mode drives just after the edge of slopedown is recognized. Deformation of the current wave form is reduced by recovering the coil current to the power supply. Fast decay mode transfers to the charge mode after CK: 2 pulses. (In this section, the length of the fast decay mode is explained in internal CK:2 pulses. Refter to the section "Setting current decay mode"in details.)

Though it transfers to discharge mode when V_{RF} reaches Vref, in the case V_{RF} equals Vref or more when it transfers to charge mode after CK:4 pulses, it transfers to the decay mode again. And the charge mode continues until V_{RF} reaches Vref by comparing V_{RF} and Vref after CK:4 pulses.



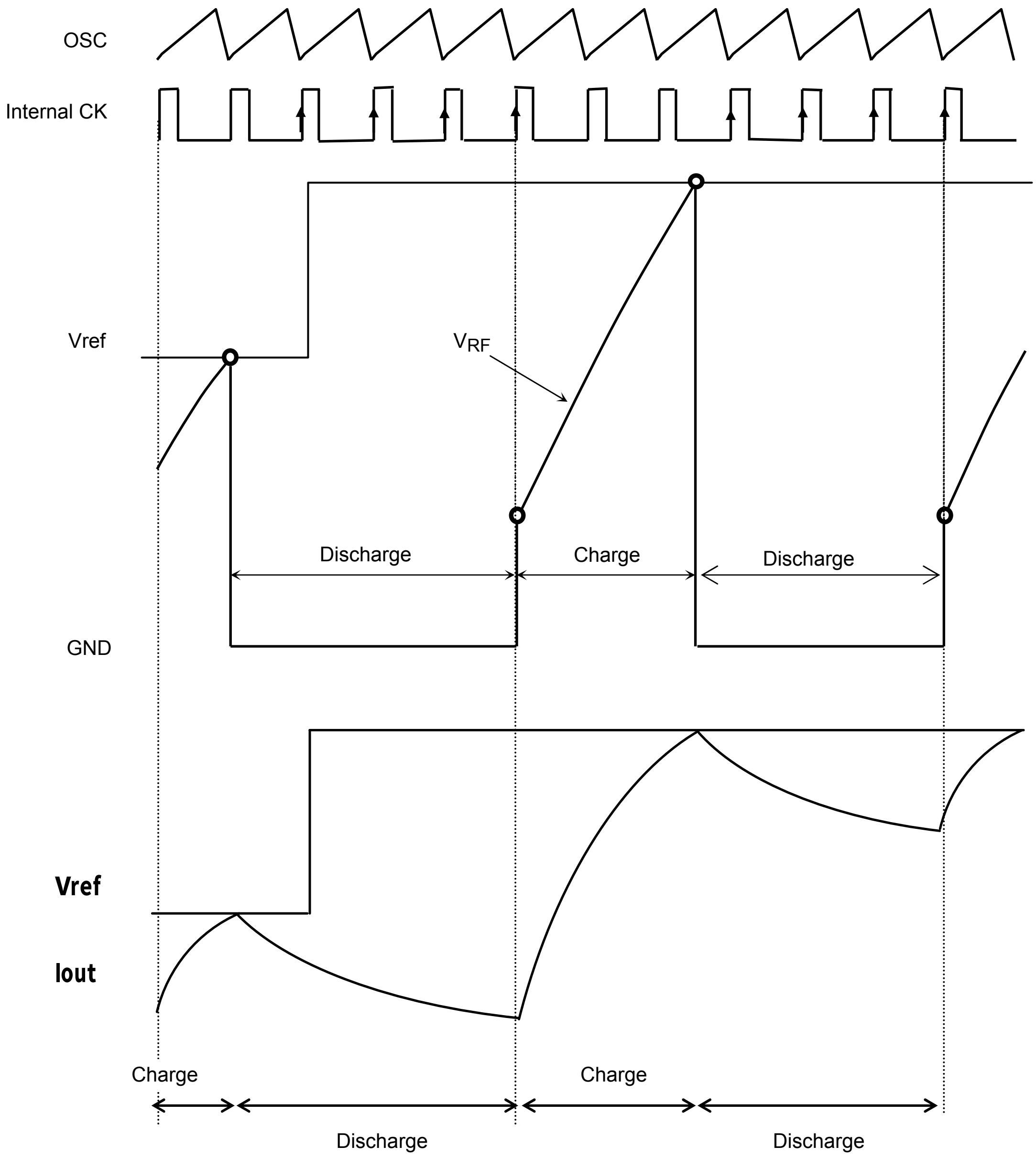
In fast decay mode, coil current regeneraged to the power supply shown below.



(Slow decay mode) (Fast decay mode)

(3) Operation in set current switching (Accerelate)

Discharege mode continues for CK:4 counts though Vref rises. And it transfers to charge mode. In acceralating,discharge mode corresponds to only slow decay mode.



Setting current decay mode

The table below may be changed because it is tentative.

Table Insert length of fast mode in current fall (Defied as multiples of Internal CLK)

Input	2W1-2phase			W1-2phase			1-2phase		
	Set current	CLKnumber		Set current	CLKnumber		Set current	CLKnumber	
DCY	%	100%、75%	50%、25%	%	100%、75%	50%、25%	%	100%、75%	50%、25%
L	100			100			100		
	98	1	1						
	92	1	1	92	1	1			
	83	1	1						
	71	1	1	71	2	1	71	2	1
	56	2	1						
	38	2	1	38	4	2			
	20	2	1						
	0	0	0	0	0	0	0	0	0
H	100			100			100		
	98	4	2						
	92	4	2	92	4	2			
	83	4	2						
	71	4	2	71	8	4	71	8	4
	56	8	4						
	38	8	4	38	8	8			
	20	8	4						
	0	0	0	0	0	0	0	0	0

Thermal shutdown circuit (TSD)

This IC includes a thermal shutdown circuit, which turns the output OFF when the junction temperature (Tj) exceeds 160°C (typ.). The output turns back ON automatically. The thermal hysteresis is 40°C.

T_{SD} = 160°C (design target value)

ΔT_{SD} = 40°C (design target value)

* When the thermal shutdown circuit operates, the conditions of the internal IC and outputs are in the enable waiting mode (output: OFF, high impedance).

Low voltage detection circuit (UVLO)

This IC includes a low voltage detection circuit, which turns the output OFF when Vcc decreases to 2.2V (typ.) or less.

The output turns back ON automatically. It has a hysteresis of 0.2V. It recovers to 2.4V.

* When the low voltage detection circuit operates, the conditions of the internal IC and outputs are in the stand by mode (output: OFF, high impedance).

Electrical Characteristics

(Unless otherwise specified(Ta = 25°C, V_{CC} = 3.3V, VM = 5V, R_{NF} = 1 Ω, C_{OSC} = 220pF)

CHARACTERISTIC	SYMBOL	TEST CIR−CUIT	TEST CONDITION	MIN	TYP.	MAX	UNIT
Input Voltage	$V_{IN (H) (1)}$	1	CW／CCW、CK、RESET、ENABLE、M1、M2 (@ 2.7V□Vcc□5.0V)	2	—	Vcc+0.2	V
	$V_{IN (L) (1)}$			−0.2	—	0.8	V
	$V_{IN (H)(2)}$	1	CW／CCW、CK、RESET、ENABLE、M1、M2 (@ 5.0V<Vcc□5.5V)	2.8	—	Vcc+0.2	V
	$V_{IN (L) (2)}$			−0.2	—	0.8	V
	$V_{IN (H)(3)}$	1	STBY、TQ、DCY	Vcc×0.7	—	Vcc+0.2	V
	$V_{IN (L) (3)}$			−0.2	—	Vcc×0.3	V
Input Hysteresis Voltage	V_H	–	CW／CCW、CK、RESET、ENABLE、M1、M2	—	200	—	mV
Input Current	I_{INH}	1	V_{IN} = 3.0 V	5	15	25	μA
	I_{INL}		V_{IN} = GND	—	—	1	μA
Current Consumption	I_{CC1}	2	Output Open, ENABLE:H, RESET:H	—	0.7	1.5	mA
	I_{CC2}		ENABLE:L	—	0.7	1.5	mA
	I_{CC3}		Stand by mode	—	7	15	μA
	I_{M1}		Output Open, ENABLE:H, RESET:H	—	1	2	mA
	I_{M2}		ENABLE:L	—	1	2	mA
	I_{M3}		Stand by mode	—	—	1	μA
Comparator Reference Voltage Level	$V_{RFA(1)}$,$V_{RFB(1)}$	3	TQ:L、2 phase excitation	(0.11)	0.125	(0.14)	V
	$V_{RFA(2)}$,$V_{RFB(2)}$		TQ:H、2 phase excitation	(0.45)	0.5	(0.55)	
Errors between Output Channels	ΔV_O	—	B/A、TQ:L	(−10)	—	(10)	%
MO Output Voltage	$V_{\overline{MO}}$	—	— I_{MO}=1mA	—	—	0.5	V
OSC Frequency	f_{OSC}	—	C_{OSC} = 220 pF	280	400	520	kHz

Input level and with or without hysteresis of input terminal are shown below.

Input terminal	Input level	Hysteresis
CW／CCW、CK、RESET、ENABLE、M1、M2	TTL	With
STBY、TQ、DCY	CMOS	Without

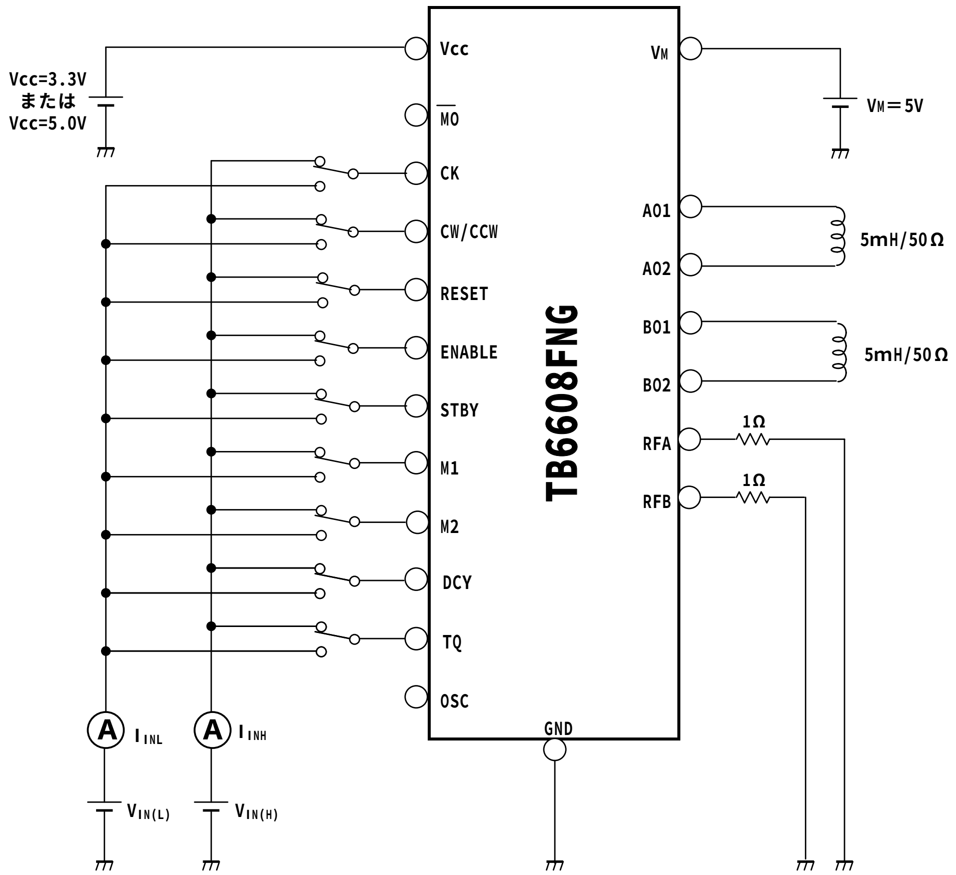
Output section

<table>
<tr><th colspan="4">CHARACTERISTIC</th><th>SYMBOL</th><th>TEST CIR–CUIT</th><th colspan="2">TEST CONDITION</th><th>MIN</th><th>TYP.</th><th>MAX</th><th>UNIT</th></tr>
<tr><td colspan="4" rowspan="2">Saturation Voltage</td><td rowspan="2">$V_{SAT\ (U+L)}$</td><td rowspan="2">4</td><td colspan="2">I_{OUT} = 0.2 A</td><td>—</td><td>0.3</td><td>0.4</td><td rowspan="2">V</td></tr>
<tr><td colspan="2">I_{OUT} = 0.6 A</td><td>—</td><td>0.9</td><td>1.2</td></tr>
<tr><td colspan="4" rowspan="2">Diode Forward Voltage</td><td>$V_{F\ U}$</td><td rowspan="2">5</td><td colspan="2" rowspan="2">I_{OUT} = 0.6 A</td><td>—</td><td>1</td><td>1.2</td><td rowspan="2">V</td></tr>
<tr><td>$V_{F\ L}$</td><td>—</td><td>1</td><td>1.2</td></tr>
<tr><td rowspan="9">A:B Chop-per Current (Note)</td><td>2W1-2 phase excitation</td><td>W1-2 phase excitation</td><td>1-2 phase excitation</td><td rowspan="8">Vector</td><td rowspan="8">3</td><td>θ = 0</td><td rowspan="8">TQ: L
R_{NF} = 2 Ω
C_{OSC} = 220pF</td><td>—</td><td>100</td><td>—</td><td rowspan="9">%</td></tr>
<tr><td>2W1-2 phase excitation</td><td>—</td><td>—</td><td>θ = 1/8</td><td>(93)</td><td>98</td><td>(100)</td></tr>
<tr><td>2W1-2 phase excitation</td><td>W1-2 phase excitation</td><td>—</td><td>θ = 2/8</td><td>(87)</td><td>92</td><td>(97)</td></tr>
<tr><td>2W1-2 phase excitation</td><td>—</td><td>—</td><td>θ = 3/8</td><td>(78)</td><td>83</td><td>(88)</td></tr>
<tr><td>2W1-2 phase excitation</td><td>W1-2 phase excitation</td><td>1-2 phase excitation</td><td>θ = 4/8</td><td>(66)</td><td>71</td><td>(76)</td></tr>
<tr><td>2W1-2 phase excitation</td><td>—</td><td>—</td><td>θ = 5/8</td><td>(51)</td><td>56</td><td>(61)</td></tr>
<tr><td>2W1-2 phase excitation</td><td>W1-2 phase excitation</td><td>—</td><td>θ = 6/8</td><td>(33)</td><td>38</td><td>(43)</td></tr>
<tr><td>2W1-2 phase excitation</td><td>—</td><td>—</td><td>θ = 7/8</td><td>(15)</td><td>20</td><td>(25)</td></tr>
<tr><td colspan="3">2 phase excitation</td><td></td><td>—</td><td colspan="2">—</td><td>—</td><td>100</td><td>—</td></tr>
</table>

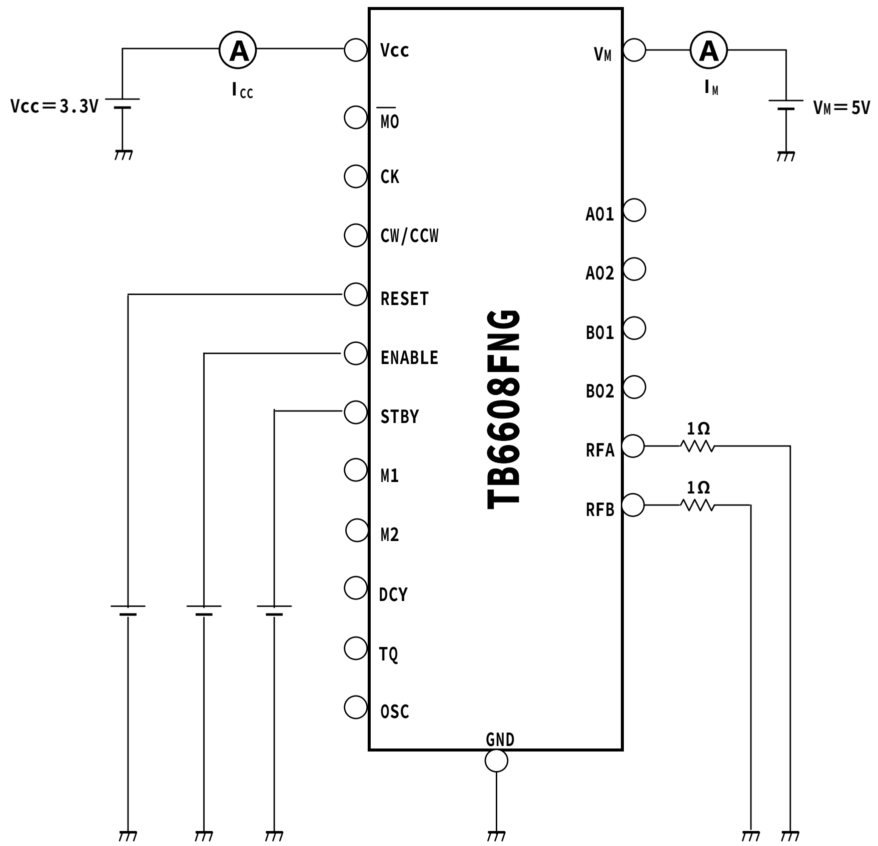
Note: Maximum current θ = 0 is set at 100.

CHARACTERISTIC		SYMBOL	TEST CIR-CUIT	TEST CONDITION		MIN	TYP.	MAX	UNIT
Reference Voltage		ΔV_{NF}	3	$\Delta\theta$ = 0/8 – 1/8	TQ:L R_{NF} = 2 Ω C_{OSC}= 220pF	(2)	5	(8)	mV
				$\Delta\theta$ = 1/8 – 2/8		(6)	15	(24)	
				$\Delta\theta$ = 2/8 – 3/8		(11)	22.5	(34)	
				$\Delta\theta$ = 3/8 – 4/8		(15)	30	(45)	
				$\Delta\theta$ = 4/8 – 5/8		(22)	37.5	(53)	
				$\Delta\theta$ = 5/8 – 6/8		(27)	45	(63)	
				$\Delta\theta$ = 6/8 – 7/8		(27)	45	(63)	
Output Tr Switching		t_r	7	R_L = 25 Ω, V_{NF} = 0 V, C_L = 15 pF		—	(100)	—	ns
		t_f				—	(100)	—	
		t_{pLH}		CK~ Output		—	(150)	—	
		t_{pHL}				—	(150)	—	
		t_{pLH}		OSC~ Output		—	(150)	—	
		t_{pHL}				—	(150)	—	
		t_{pLH}		RESET~ Output		—	(150)	—	
		t_{pHL}				—	(150)	—	
		t_{pLH}		ENABLE~ Output		—	(150)	—	
		t_{pHL}				—	(150)	—	
Output Leakage Current	Upper	I_{OH}	6	V_M = 13V		—	—	1	μA
	Lower	I_{OL}				—	—	1	

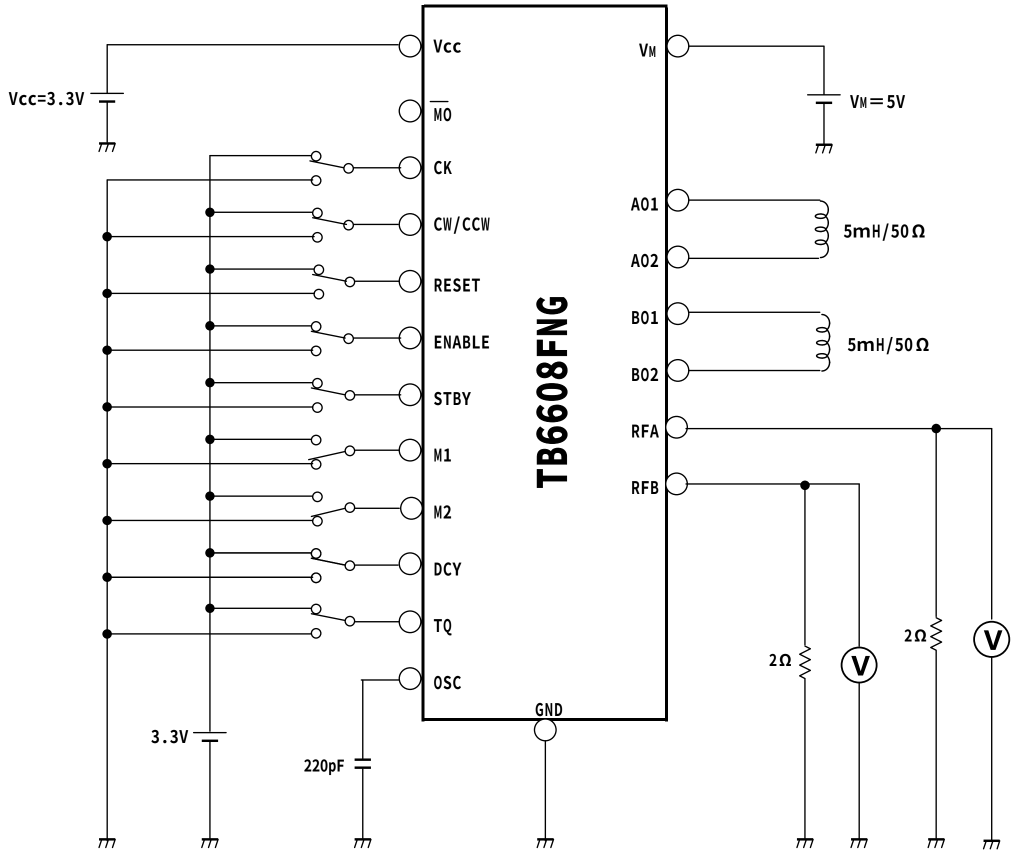
Test Circuit 1 : $V_{IN\ (H)}$, $V_{IN\ (L)}$, I_{INH}, I_{INL}



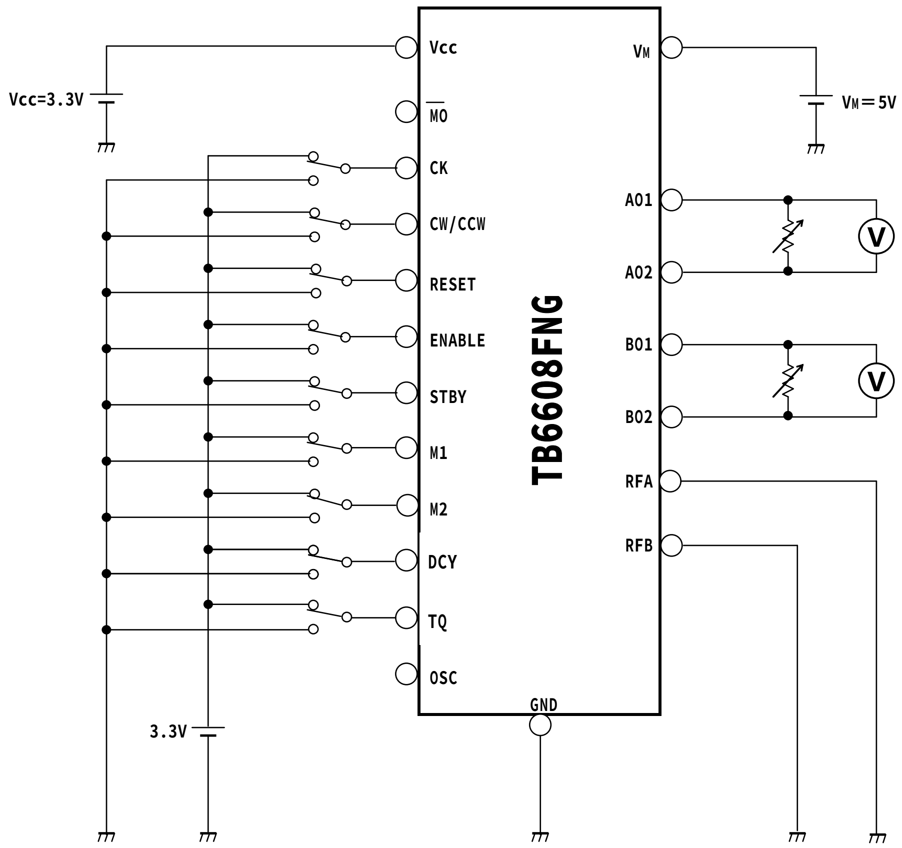
Test Circuit 2 : I_{CC}, I_M



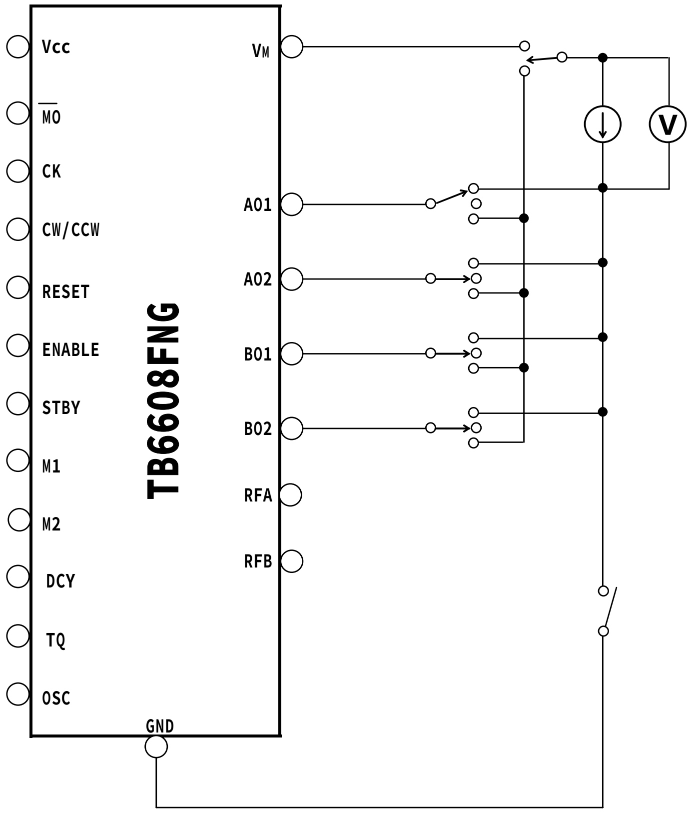
Test Circuit 3 : V_{RFA}, V_{RFB}



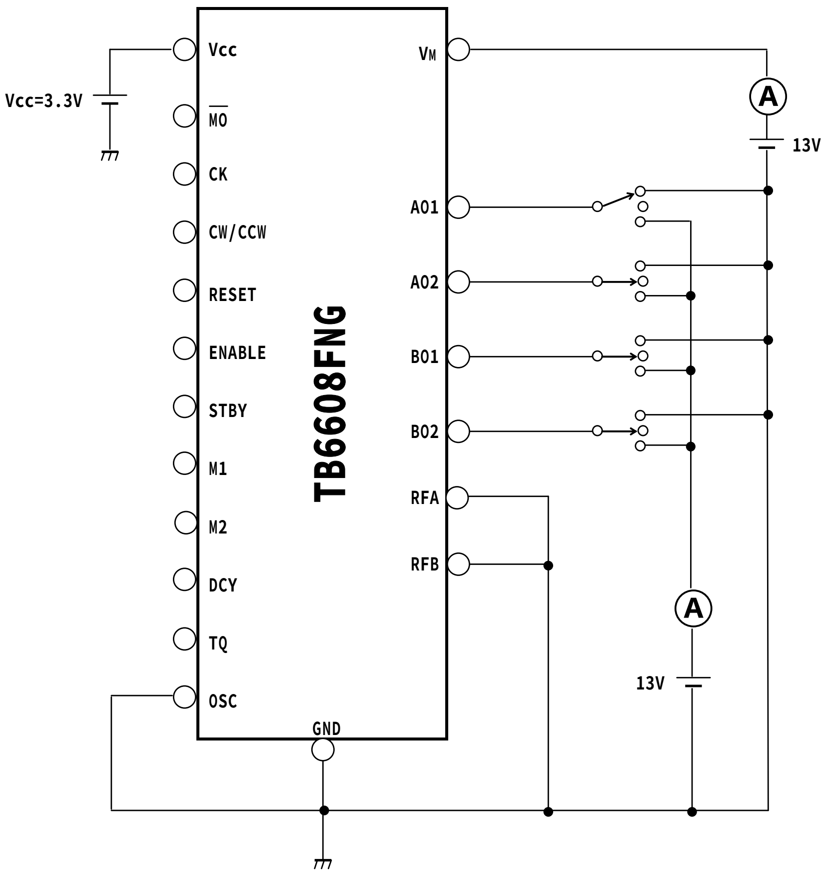
Test Circuit 4 : $V_{SAT(UL)}$



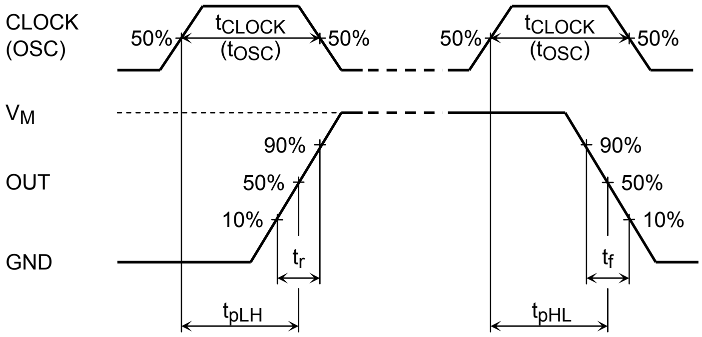
Test Circuit 5 : V_{FU} , V_{FL}



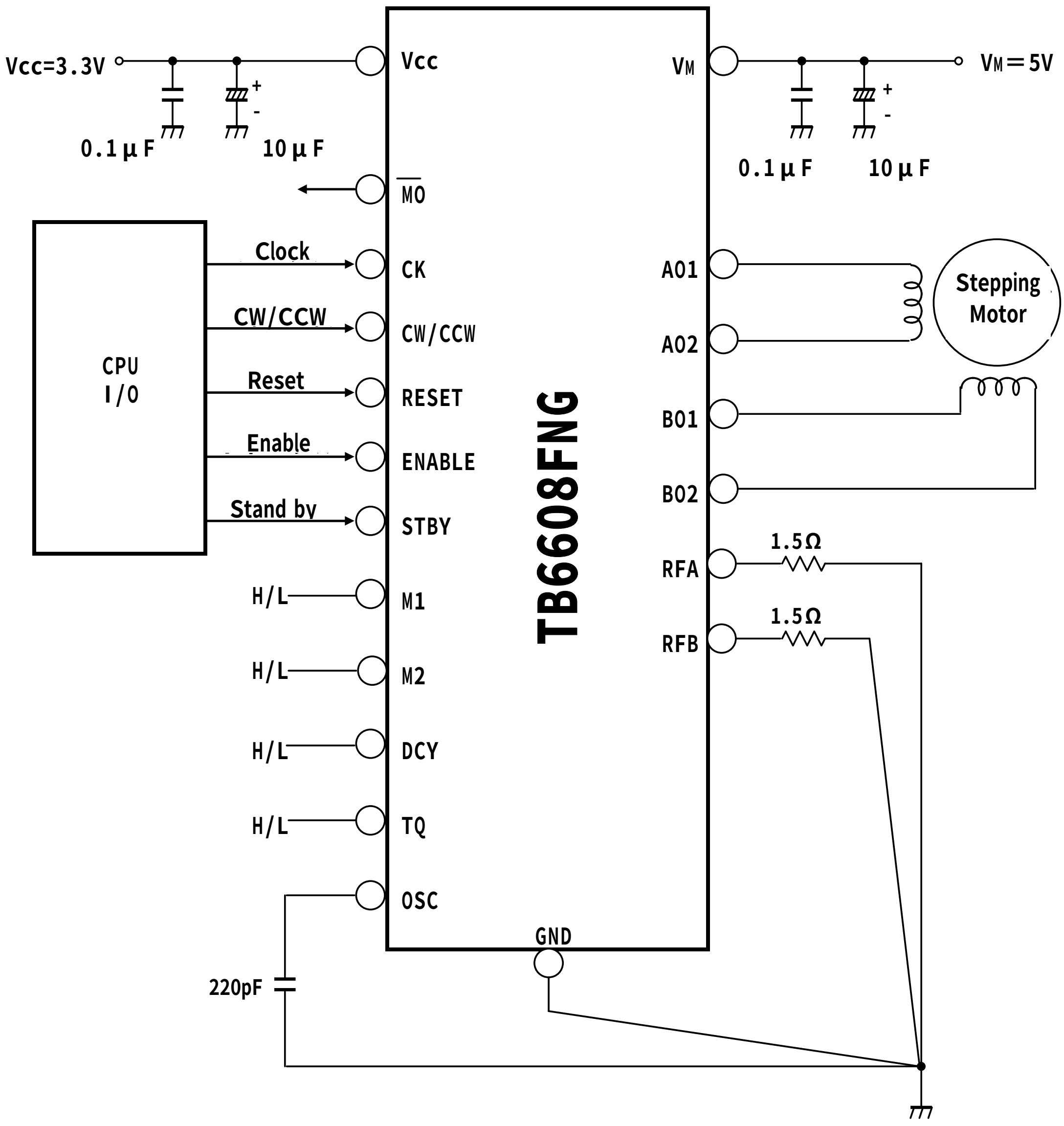
Test Circuit 6 : I_{OH} , I_{OL}



AC Electrical Characteristics, Test Circuit 7：CK(OSC)-OUT



Application Circuit



Note 1: Condensot for supply should be connected to IC as near as possible.

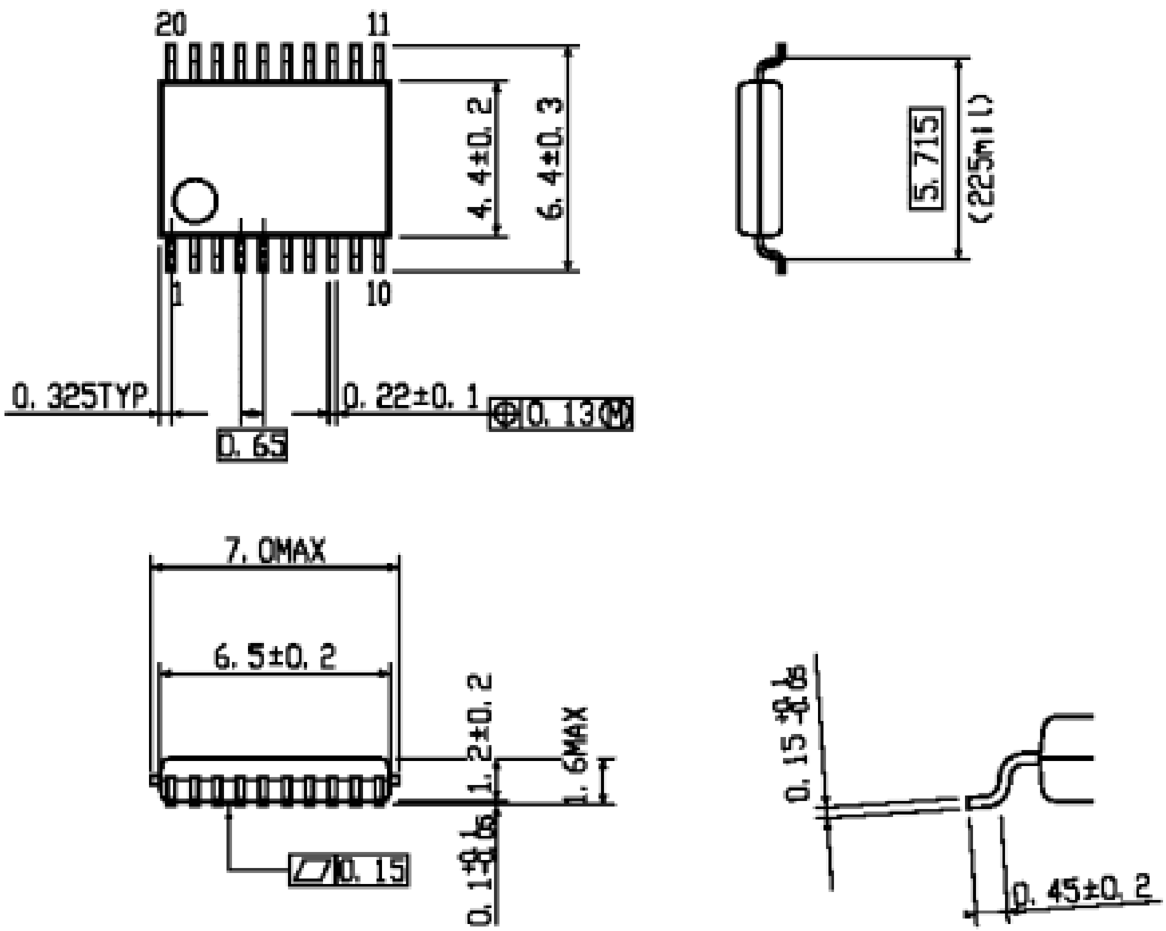
Note 2: In turning on, set STBY low level.

Notes in handling of IC

Utmost care is necessary in the design of the output, V_{CC}, V_M, 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.

Package Dimensions

SSOP20-P-225-0.65 Unit: mm



Weight: 0.09 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) 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.

(2) 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 considerate the effect of IC heat radiation with peripheral components.

(3) 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.