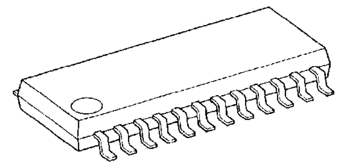
TOSHIBA Bi−CMOS INTEGRATED CIRCUIT   MULTICHIP

TB6512AF/AFG

PWM CHOPPER TYPE BIPOLAR STEPPING MOTOR DRIVER

The TB6512AF/AFG is PWM chopper type sinusoidal micro step bipolar stepping motor driver.
Sinusoidal micro step operation is accomplished only a clock signal inputting by means of built−in hard ware.



Weight: 0.27 g (Typ.)

FEATURES

- 1 chip bipolar sinusoidal micro step stepping motor driver.
- Output Current up to 150 mA
- PWM chopper type.
- Structured by high voltage Bi−CMOS process technology.
- Forward and reverse rotation are available.
- 1−2, 2W1−2 phase 1 or 2 clock drives are selectable.
- Package : SSOP24−P−300B
- Input Pull−Up Resistor equipped with RESET and ENABLE Terminal : R = 500 kΩ (Typ.)
- Output Monitor available with $\overline{MO}$.$I_{O(\overline{MO})}$= ±2 mA MAX.
- Reset and Enable are available with $\overline{RESET}$ and $\overline{ENABLE}$.

TB6512AFG:
The TB6512AFG 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
   *the number of times = once
   *use of R-type flux

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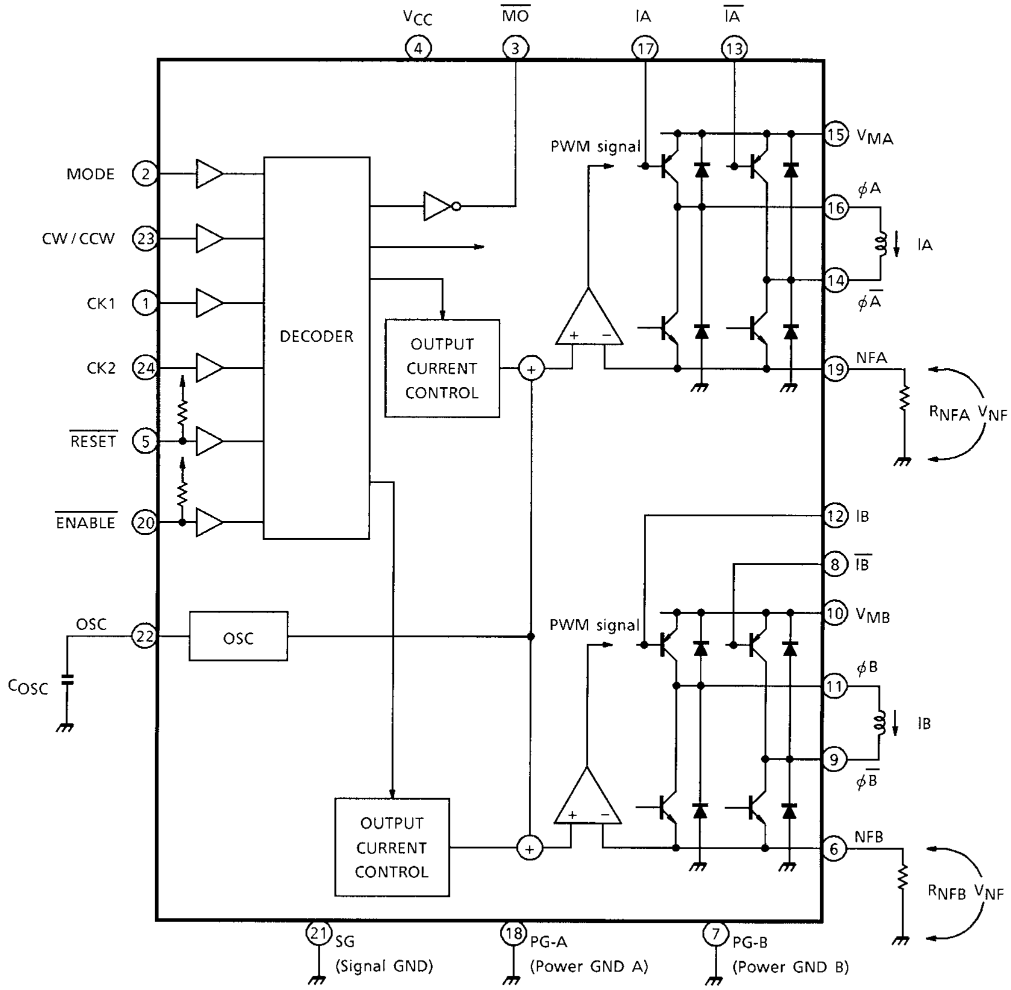
BLOCK DIAGRAM



(5), (20) : Pull-up Resistor 500 kΩ (Typ.)

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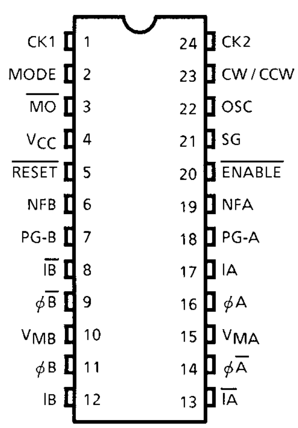
PIN FUNCTION

PIN No.	SYMBOL	FUNCTIONAL DESCRIPTION	
1	CK1	CLOCK Signal Input terminal	Truth table A
2	MODE	Excitation Mode Setting terminal	Truth table B
3	$\overline{MO}$	Monitor Output terminal	
4	V_{CC}	Power voltage supply terminal for Logic	
5	$\overline{RESET}$	Reset Signal Input terminal	Truth table A
6	NFB	B Channel current detective terminal	
7	PG−B	Power GND B terminal	
8	$I\overline{B}$	Upper PNP Transistor Base terminal	
9	$\varphi\overline{B}$	Output $\overline{B}$ terminal	
10	V_{MB}	Power voltage supply terminal for Motor B	
11	φB	Output B terminal	
12	IB	Upper PNP Transistor Base terminal	
13	$I\overline{A}$	Upper PNP Transistor Base terminal	
14	$\varphi\overline{A}$	Output $\overline{A}$ terminal	
15	V_{MA}	Power voltage supply terminal for Motor A	
16	φA	Output A terminal	
17	IA	Upper side PNP Transistor Base terminal	
18	PG−A	Power GND $\overline{A}$ terminal	
19	NFA	A Channel current detective terminal	
20	$\overline{ENABLE}$	ENABLE Signal Input terminal	Truth table A
21	SG	Signal GND terminal	
22	OSC	Internal Oscillation frequency detective terminal	
23	CW / CCW	Forward rotation / Reverse rotation signal Input	Truth table A
24	CK2	Clock signal Input terminal	

PIN CONNECTION



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TRUTH TABLE A

INPUT					MODE
CK1	CK2	CW / CCW	$\overline{\text{RESET}}$	$\overline{\text{ENABLE}}$	
↑	H	L	H	L	CW
⊓	L	L	H	L	INHIBIT
H	↑	L	H	L	CCW
L	⊓	L	H	L	INHIBIT
↑	H	H	H	L	CCW
⊓	L	H	H	L	INHIBIT
H	↑	H	H	L	CW
L	⊓	H	H	L	INHIBIT
X	X	X	L	L	INITIAL
X	X	X	X	H	Z

Z : High impedance
X : Don't care
Note: Do not use INHIBIT mode.

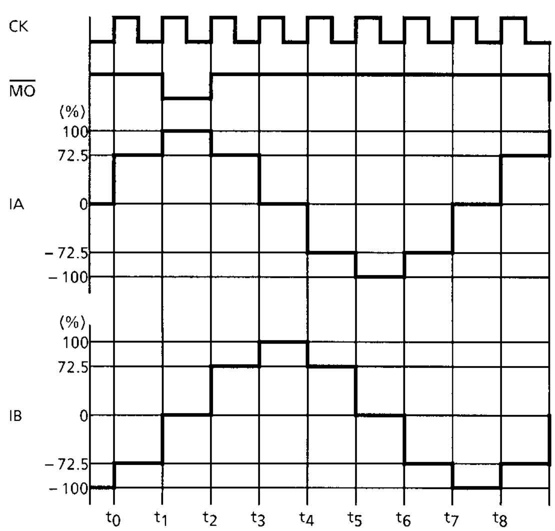
TRUTH TABLE B

INPUT	MODE (EXCITATION)
MODE	
L	1−2 phase
H	2W1−2 phase

INITIAL MODE

EXCITATION MODE	I_{OUT} (A)	I_{OUT} (B)
1−2 phase	100%	0%
2W1−2 phase	100%	0%

1−2 PHASE EXCITATION (MODE : L, CW mode)



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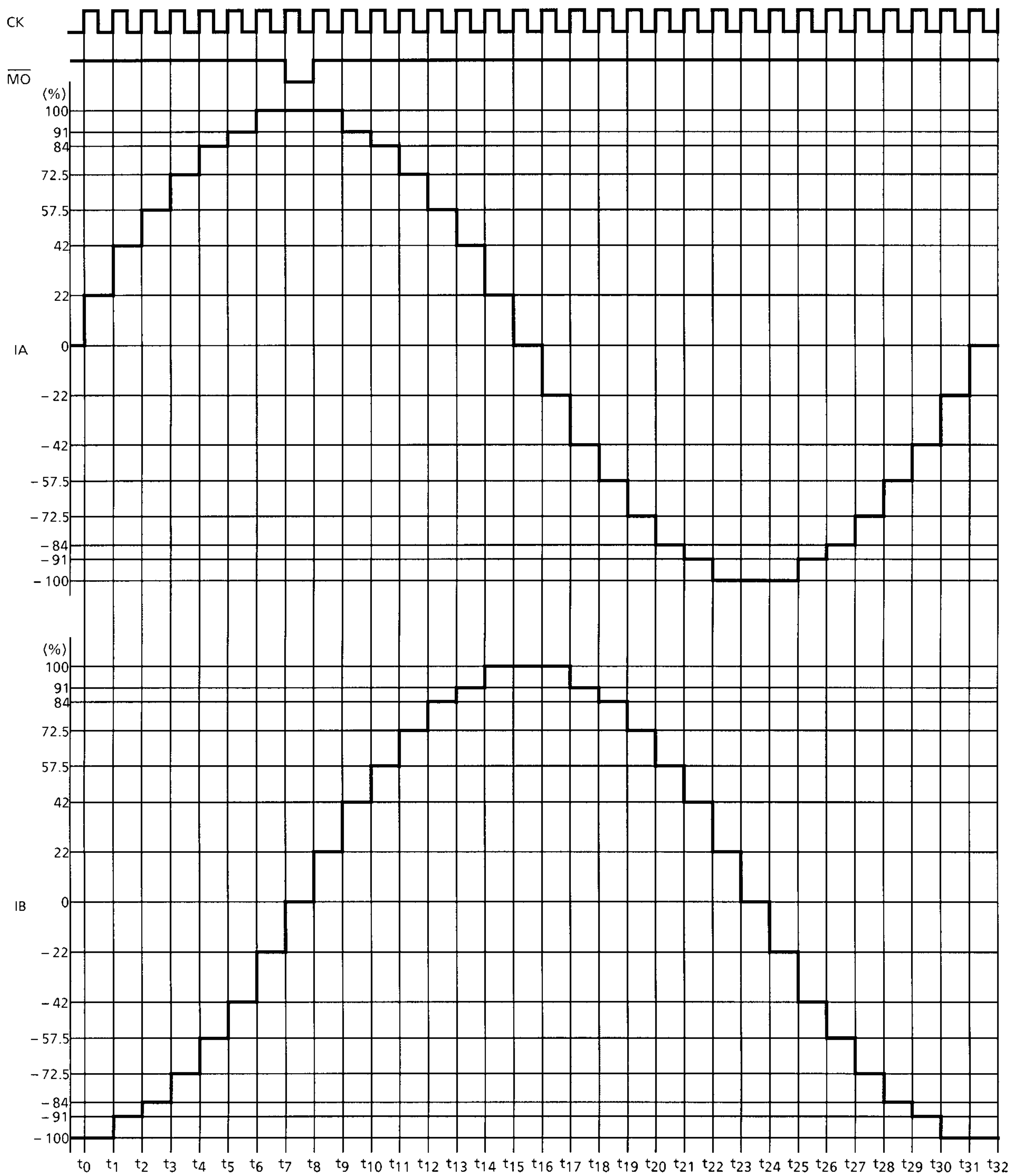
2W1−2 PHASE EXCITATION (MODE : H, CW mode)



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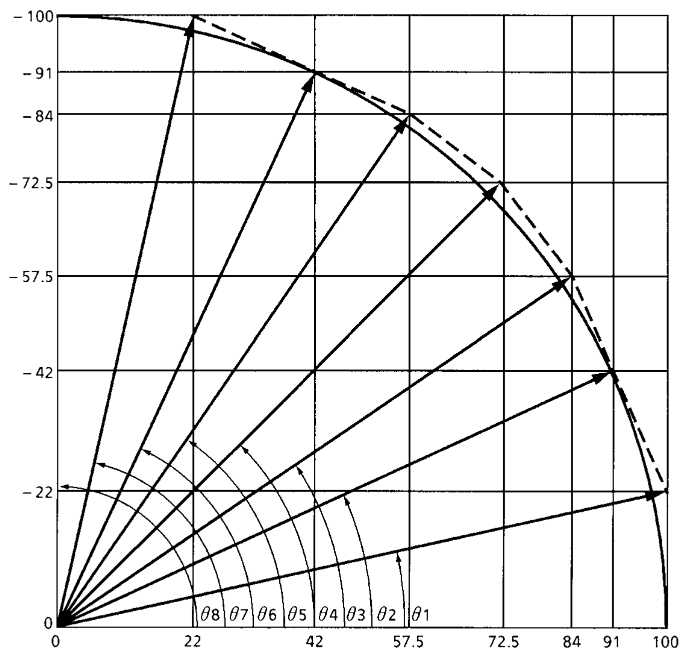
OUTPUT CURRENT VECTOR OR BIT (Normalize to 90 deg for each one step)



θ	ROTATION ANGLE		VECTOR LENGTH	
	IDEAL	TB6512AF/AFG	IDEAL	TB6512AF/AFG
θ0	0°	0°	100	100.00
θ1	11.25°	12.41°	100	102.39
θ2	22.5°	27.78°	100	100.22
θ3	33.75°	34.39°	100	101.80
θ4	45°	45°	100	102.53
θ5	56.25°	55.61°	100	101.81
θ6	67.5°	65.22°	100	100.22
θ7	78.75°	77.59°	100	102.39
θ8	90°	90°	100	100.00
			1−2 / 2W1−2 Phase	

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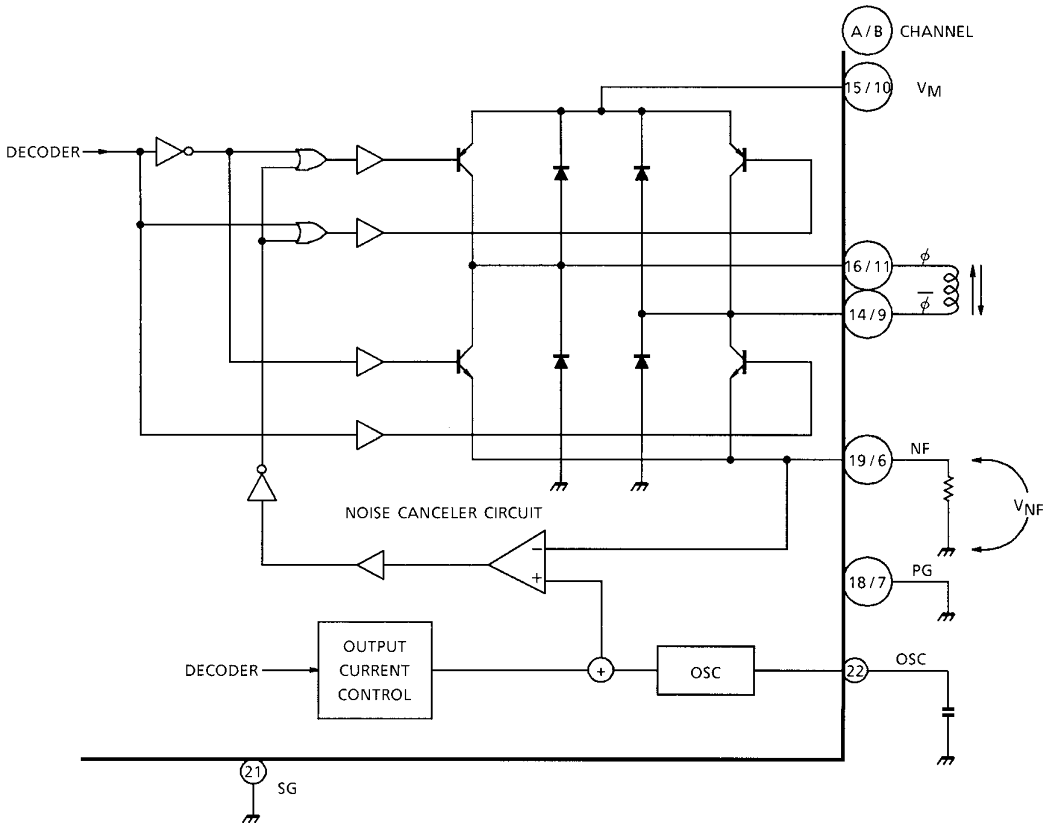
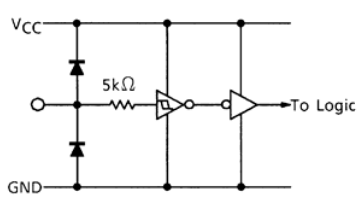
OUTPUT CIRCUIT

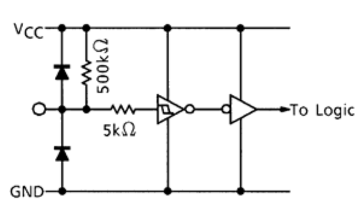


INPUT CIRCUIT

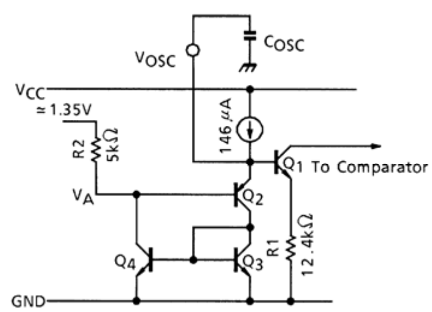
CK1, CK2, CW / CCW,
MODE Terminals



$\overline{\text{RESET}}$, $\overline{\text{ENABLE}}$ Terminals



OSC Terminals



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- OSC frequency calculation

Sawtooth OSC circuit consists of Q_1 through Q_4 and R_1 through R_4.
Q_2 is turned "off" when V_{OSC} is less than the voltage of 2.5 V + V_{BE} Q_2 approximately equal to 2.05 V.
V_{OSC} is increased by C_{OSC} charging through R_1.
Q_3 and Q_4 are turned "on" when V_{OSC} becomes 2.05 V (Higher level.)
Lower level of $V_{(22)}$ pin is equal to V_{BE} Q_2 + V_{SAT} Q_4 approximately equal to 1.4 V.
V_{OSC} is calculated by following equation.
Assuming that V_{OSC} = 1.4 V ($t = t_1$) and = 2.05 ($t = t_2$)
C_{OSC} is external capacitance connected to pin(22) and R_1 is on−chip 10 kΩ resistor.
Therefore, OSC frequency is calculated as follows.

$$t_1 = \frac{1.0 \times C_{OSC}}{146 \times 10^{-6}}$$

$$t_2 = \frac{2.05 \times C_{OSC}}{146 \times 10^{-6}}$$

$$f_{OSC} = \frac{1}{t_2 - t_1} = \frac{146 \times 10^{-6}}{C_{OSC}\ (2.05 - 1.0)}$$

$$= \frac{0.139}{C_{OSC}}\ (\text{kHz})\ \ (C_{OSC}\ \text{unit} = \mu\text{F})$$

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$\overline{\text{ENABLE}}$ AND $\overline{\text{RESET}}$ FUNCTION AND $\overline{\text{MO}}$ SIGNAL

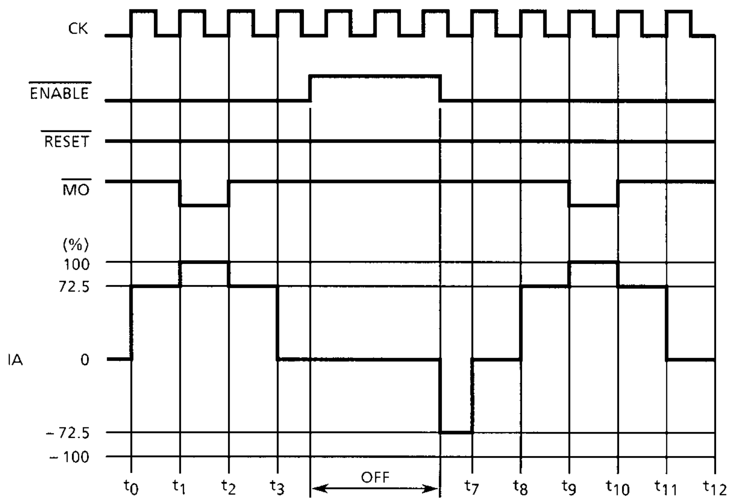

Fig.1. 1−2 phase drive mode (MODE : L)

$\overline{\text{ENABLE}}$ signal disables only Output signal. Internal logic functions are proceeded 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.
Fig.1 shows the $\overline{\text{ENABLE}}$ functions, when the system is selected in 1−2 phase drive mode.

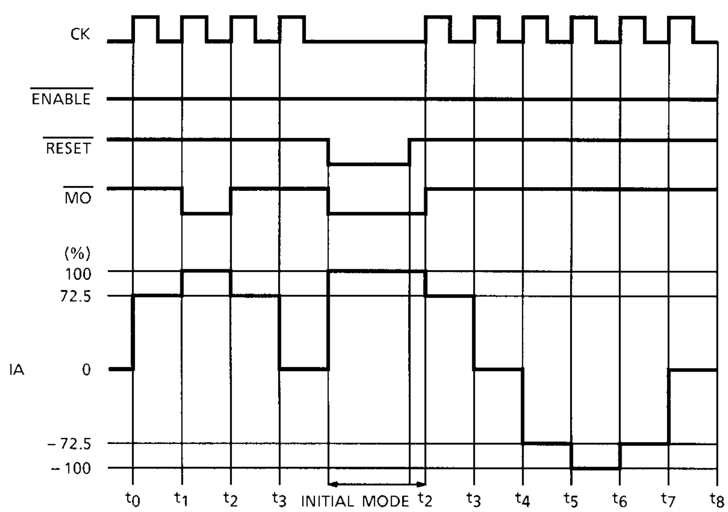

Fig.2. 1−2 phase drive mode (MODE : L)

As $\overline{\text{RESET}}$ is low, the decoder is initialized and $\overline{\text{MO}}$ is low.
After $\overline{\text{RESET}}$ is high, the motion is resumed from next clock as show in Fig.2.
$\overline{\text{MO}}$ (Monitor Output) signals is used as rotation and initial signal for stable. rotation checking.

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ABSOLUTE MAXIMUM RATINGS (Ta = 25°C)

CHARACTERISTIC		SYMBOL	RATING	UNIT
Supply Voltage		V_{CC}	5.5	V
Output Voltage		$V_{M\ (opr.)}$	4.0~10.0	V
		$V_{M\ (MAX.)}$	12.0	
Output Current		$I_{O\ (MAX.)}$	120	mA
	AVE.	$I_{O(\overline{MO})}$	±2	
Input Voltage		V_{IN}	~V_{CC}	V
Power Dissipation		P_D	0.83 (Note 1)	W
			1.04 (Note 2)	
Operating Temperature		T_{opr}	−30~85	°C
Storage Temperature		T_{stg}	−55~150	°C
Feed Back Voltage		V_I	1.0	V

Note 1: No heat sink
Note 2: With heat sink (50 × 50 × 1.6 mm Cu 10%)

RECOMMENDED OPERATING CONDITIONS (Ta = −30~85°C)

CHARACTERISTIC	SYMBOL	TEST CONDITION	MIN	TYP.	MAX	UNIT
Supply Voltage	$V_{CC\ (opr.)}$		2.7	3.0	5.5	V
Output Voltage	$V_{M\ (opr.)}$		4.0	—	10.0	V
Output Current	I_{OUT}		—	—	100	mA
Input Voltage	V_{IN}		—	—	V_{CC}	V
Clock Frequency	f_{CLOCK}		—	—	5	kHz
OSC Frequency	f_{OSC}		15	—	80	kHz

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ELECTRICAL CHARACTERISTICS

Unless otherwise specified, (Ta = 25°C, V_{CC} = 3 V, V_M = 5 V, L = 20 mH / R = 0.5 Ω)

CHARACTERISTIC		SYMBOL	TEST CIR-CUIT	TEST CONDITION	MIN	TYP.	MAX	UNIT
Input Voltage	High	$V_{IN (H)}$	1	MODE, CW / CCW, $\overline{\text{ENABLE}}$ CK1, CK2, $\overline{\text{RESET}}$	V_{CC} ×0.7	—	V_{CC} +0.4	V
	Low	$V_{IN (L)}$			GND −0.4	—	GND ×0.3	
Input Hysteresis Voltage		V_H			—	600	—	mV
Input Current		$I_{IN-1 (H)}$	1	M1, M2, REF IN, V_{IN} = 5.0 V	—	—	100	nA
		$I_{IN-1 (L)}$		$\overline{\text{RESET}}$, V_{IN} = 0 V, $\overline{\text{ENABLE}}$ Internal pull−up resistor	3	6	12	μA
		$I_{IN-2 (L)}$		V_{IN} = 0 V	—	—	100	nA
Quiescent Current V_{CC}		I_{CC1}	2	Output open, $\overline{\text{RESET}}$: H, $\overline{\text{ENABLE}}$: L, (1−2 phase excitation)	—	5	9	mA
		I_{CC2}		Output open, $\overline{\text{RESET}}$: H, $\overline{\text{ENABLE}}$: L (2W1−2 phase excitation)	—	5	9	
		I_{CC3}		$\overline{\text{RESET}}$: L, $\overline{\text{ENABLE}}$: H	—	1.3	—	
		I_{CC4}		$\overline{\text{RESET}}$: H, $\overline{\text{ENABLE}}$: H	—	1.3	—	
Comparator Reference Voltage		V_{NF}	3	R_{NF} = 2.5 Ω, C_{OSC} = 0.0033 μF	0.22	0.25	0.28	V
Output Diffirencial		ΔV_O	—	B / A, C_{OSC} = 0.0033 μF R_{NF} = 2.5 Ω	−10	—	10	%
Maximum OSC Frequency		$f_{OSC (MAX.)}$	—		100	—	—	kHz
Minimum OSC Frequency		$f_{OSC (MIN.)}$	—		—	—	10	kHz
OSC Frequency		f_{OSC}	—	C_{OSC} = 0.0033 μF	31	44	70	kHz
Output Voltage		$V_{OH (MO)}$	—	I_{OH} = −40 μA	2.5	—	V_{CC}	V
		$V_{OL (MO)}$	—	I_{OL} = 40 μA	GND	0.1	0.5	

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Output block

CHARACTERISTIC			SYMBOL	TEST CIRCUIT	TEST CONDITION		MIN	TYP.	MAX	UNIT
Output Saturation Voltage	Upper Side		$V_{SAT\ U1}$	4	I_{OUT} = 0.12 A		—	0.08	0.23	V
	Lower Side		$V_{SAT\ L1}$				—	0.16	0.43	
	Upper Side		$V_{SAT\ U2}$		I_{OUT} = 0.06 A		—	0.06	—	
	Lower Side		$V_{SAT\ L2}$				—	0.10	—	
Diode Forward Voltage	Upper Side		$V_{F\ U1}$	5	I_{OUT} = 0.12 A		—	1.13	1.8	V
	Lower Side		$V_{F\ L1}$				—	0.95	1.6	
Output Dark Current (A+B Channels)			I_{M1}	2	$\overline{ENABLE}$: "H" Level $\overline{RESET}$: "L" Level Output Open		—	—	50	μA
			I_{M2}		$\overline{ENABLE}$: "L" Level $\overline{RESET}$: "H" Level Output Open,		—	17	28	mA
NF Terminal Current (1 Channels)			I_{NF}		$\overline{ENABLE}$: "L" Level $\overline{RESET}$: "H" Level Output Open		1	2.5	7	
A−B Chopping Current (Note)	2W1−2φ	1−2φ	VECTOR	3	θ = 0	R_{NF} = 2.5 Ω C_{OSC} = 0.0033 μF	—	100	—	%
	2W1−2φ	—			θ = 1 / 8		—	100	—	
	2W1−2φ	—			θ = 2 / 8		86	91	96	
	2W1−2φ	—			θ = 3 / 8		79	84	89	
	2W1−2φ	1−2φ			θ = 4 / 8		67.5	72.5	77.5	
	2W1−2φ	—			θ = 5 / 8		52.5	57.5	62.5	
	2W1−2φ	—			θ = 6 / 8		37	42	47	
	2W1−2φ	—			θ = 7 / 8		17	22	27	

Note: Maximum current (θ = 0) : 100%
2W1−2φ : 2W1, 2 phase excitation mode
W1−2φ : W1, 2 phase excitation mode
1−2φ : 1, 2 phase excitation mode

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ELECTRICAL CHARACTERISTICS

Unless otherwise specified, (Ta = 25°C, V_{CC} = 3 V, V_M = 5 V, L = 20mH / R = 0.5 Ω)

CHARACTERISTIC			SYMBOL	TEST CIR−CUIT	TEST CONDITION		MIN	TYP.	MAX	UNIT
A−B Chopping Current (Note)	2W1−2φ	1−2φ	VECTOR	3	θ = 0	R_{NF} = 3.3 Ω, C_{OSC} = 0.0033 μF, L = 5mH / R = 50 Ω	—	100	—	%
	2W1−2φ	—			θ = 1 / 8		—	100	—	
	2W1−2φ	—			θ = 2 / 8		—	91.1	—	
	2W1−2φ	—			θ = 3 / 8		—	83.6	—	
	2W1−2φ	1−2φ			θ = 4 / 8		—	72.6	—	
	2W1−2φ	—			θ = 5 / 8		—	60.0	—	
	2W1−2φ	—			θ = 6 / 8		—	44.5	—	
	2W1−2φ	—			θ = 7 / 8		—	24.3	—	
Reference Voltage			ΔV_{NF}		Δθ = 0 / 8−1 / 8	R_{NF} = 2.5 Ω, C_{OSC} = 0.0033 μF	—	0	—	mV
					Δθ = 1 / 8−2 / 8		10	22.5	35	
					Δθ = 2 / 8−3 / 8		5	17.5	30	
					Δθ = 3 / 8−4 / 8		16.25	28.75	41.25	
					Δθ = 4 / 8−5 / 8		25	37.5	50	
					Δθ = 5 / 8−6 / 8		26.25	38.75	51.25	
					Δθ = 6 / 8−7 / 8		37.5	50	62.5	
Output Tr Switching Characteristics			t_r	7	R_L = 2 Ω, V_{NF} = 0 V, C_L = 15 pF		—	0.3	—	μs
			t_f				—	2.2	—	
			t_{pLH}		CK ~ Output		—	1.5	—	
			t_{pHL}				—	2.7	—	
			t_{pLH}		OSC ~ Output		—	5.4	—	
			t_{pHL}				—	6.3	—	
			t_{pLH}		$\overline{\text{RESET}}$ ~ Output		—	2.0	—	
			t_{pHL}				—	2.5	—	
			t_{pLH}		$\overline{\text{ENABLE}}$ ~ Output		—	5.0	—	
			t_{pHL}				—	6.0	—	
Output Leakage Current	Upper Side		I_{OH}	6	V_M = 12 V		—	—	50	μA
	Upper Side		I_{OL}				—	—	50	

Note: Maximum current (θ = 0) : 100%
2W1−2φ : 2W1, 2 phase excitation mode
W1−2φ : W1, 2 phase excitation mode
1−2φ : 1,2 phase excitation mode

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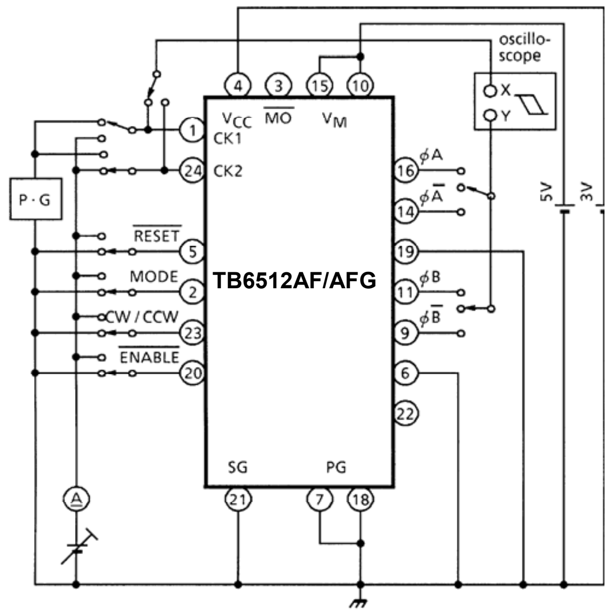
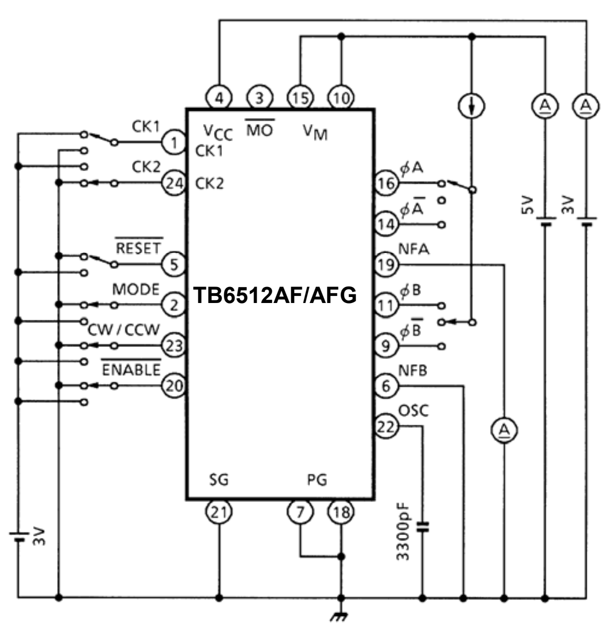
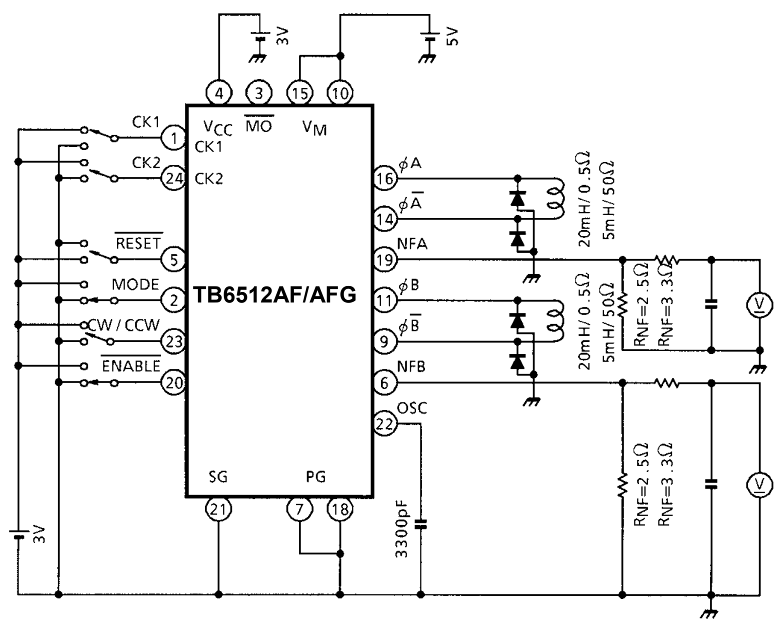
TEST CIRCUIT 1 : V_{IN} (H), (L), I_{IN} (H), (L)



TEST CIRCUIT 2 : I_{CC}, I_M, I_{NF}



TEST CIRCUIT 3 : V_{NF}



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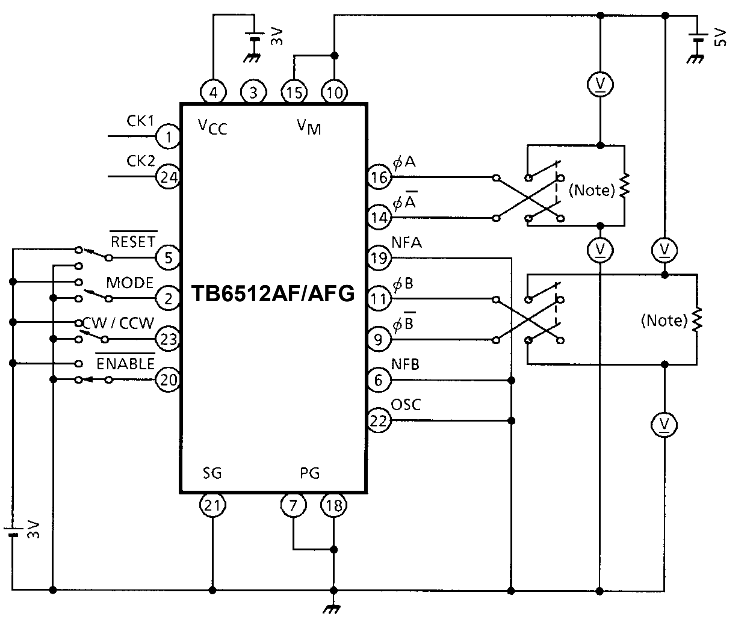
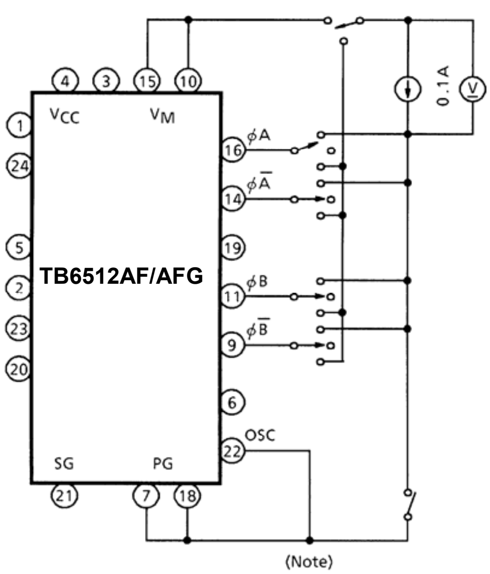
TEST CIRCUIT 4 : $V_{CE\ (SAT)}$ Upper, lower

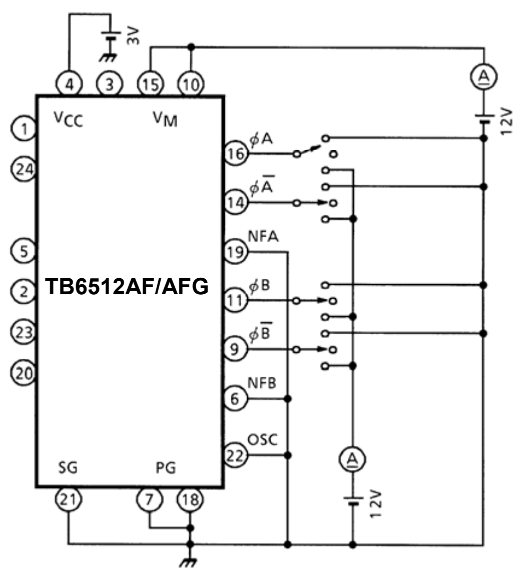


Note: Calibrate Output Current becomes 0.06 A (or 0.10 A) with this resistor.

TEST CIRCUIT 5 : V_{F-U}, V_{F-L}



TEST CIRCUIT 6 : I_{OH}, I_{OL}



Note: Not to take a GND with any non−connecting Pins.

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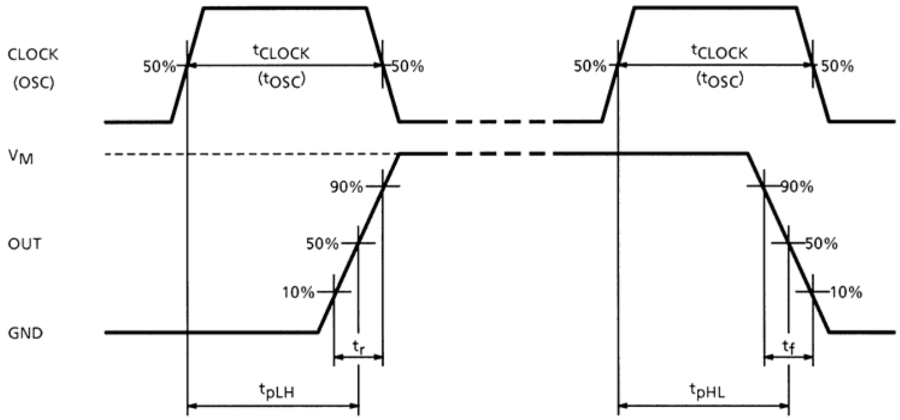
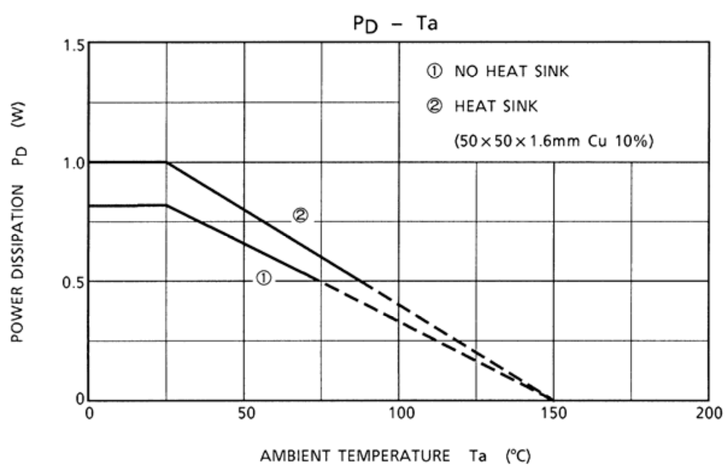
AC ELECTRICAL, CHARACTERICAL

CK (OSC) − OUT





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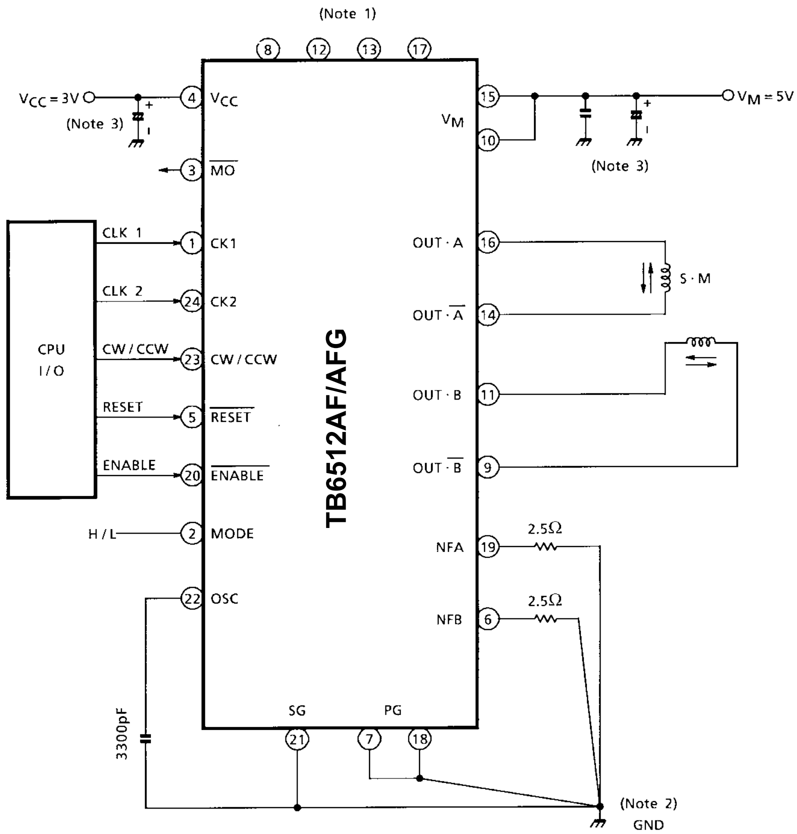
APPLICATION CIRCUIT



Note 1: (8), (12), (13), (17) pin : open

Note 2: GND pattern to be laid out at one point in order to prevent common impedance.

Note 3: Capacitor for noise suppression to be connected between the Power Supply (V_{CC}, V_M) and GND to stabilize the operation.

Note 4: 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.

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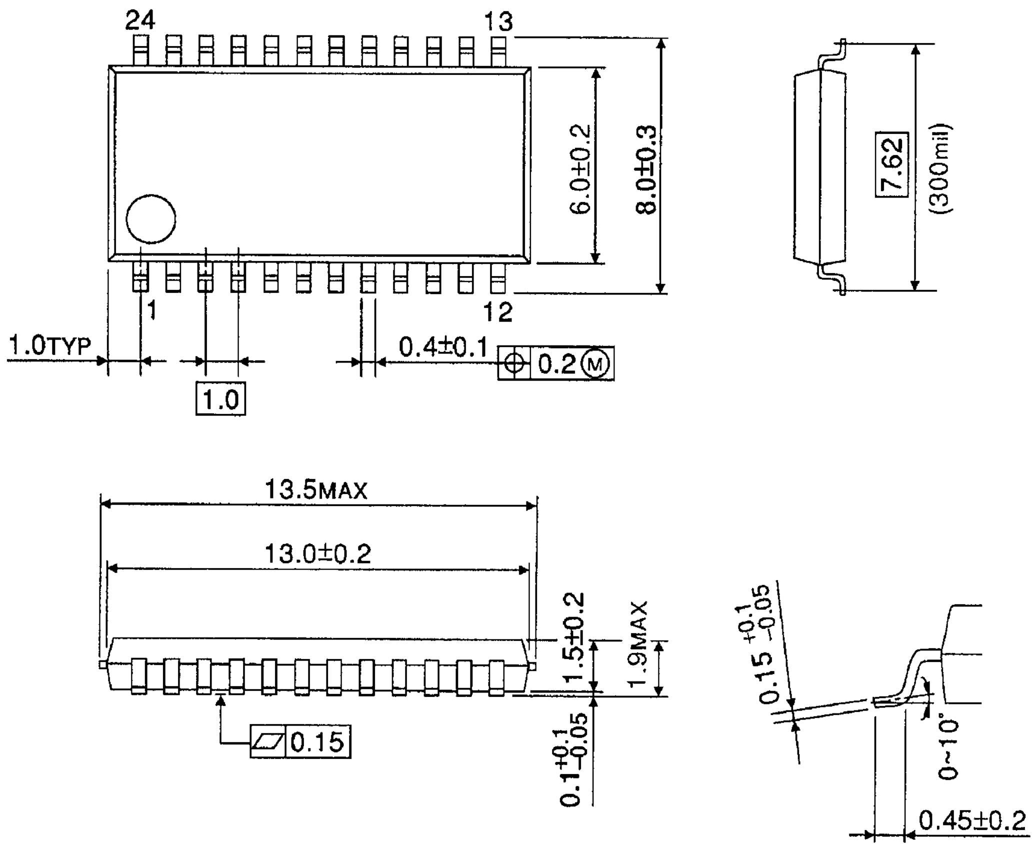
PACKAGE DIMENSIONS

SSOP24−P−300−1.00B Unit: mm



Weight: 0.27 g (Typ.)

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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.

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Points to remember on handling of ICs

(1) 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.

(2) 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.

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