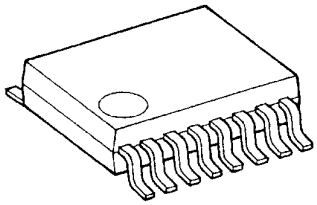
**TENTATIVE** TOSHIBA Bi-CMOS Integrated Circuit Silicon Monolithic

# TB6598FN/FNG

Dual Full-Bridge Driver for Stepping Motors

The TB6598FN/FNG is a 2-phase bipolar stepping motor driver employing an LDMOS structure with low ON-resistance for output drive transistors. By applying four input signals (EN1, EN2, IN1, IN2), it is possible to control the rotation direction (forward/reverse) of 2-phase/1-2-phase stepper motor.

It is also possible to achieve constant-current drive (PWM chopper drive).



SSOP16-P-225-0.65B

Weight: 0.07 g (typ.)

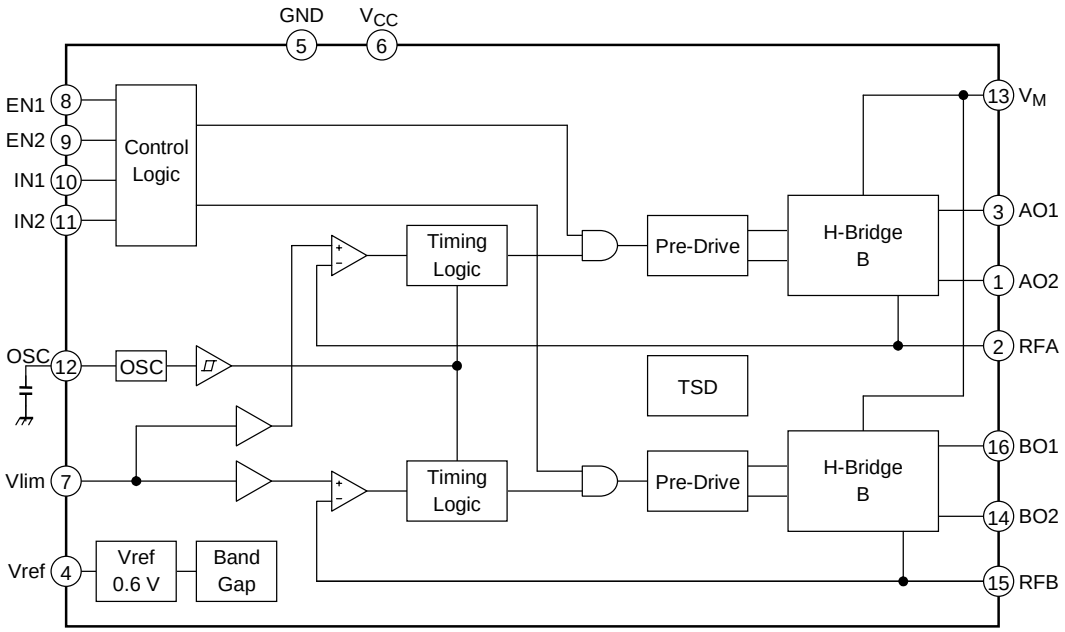
## Features

- Motor supply voltage: $V_M \leq 15$ V (max)
- Control supply voltage: $V_{CC}$ = 2.7 V to 6 V
- Output current: $I_{out} \leq 0.8$ A (max)
- Low ON-resistance: 1.5 Ω (upper side + lower side typ. @ $V_M$ = 5 V)
- Constant-current control (PWM chopper drive)
- Standby (power-saving) mode
- On-chip thermal shutdown circuit (TSD)
- Compact package: SSOP-16

TB6598FNG:
TB6598FNG is a Pb-free product.
The following conditions apply to solderability:
*Solderability
1. Use of Sn-63Pb 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

- This product has a MOS structure and is sensitive to electrostatic discharge. When handling the 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. Otherwise, breakdown, damage and/or degradation in the product or equipment may result.

## Block Diagram




Some functional blocks, circuits, or constants may be omitted or simplified in the block diagram for explanatory purposes.

## Pin Functions

| Pin Name | Pin No. | Functional Description | Remarks |
|---|---|---|---|
| AO2 | 1 | Output 2 (Ch. A) | Ch. A motor winding connection pin |
| RFA | 2 | Winding current detection pin (Ch. A) | |
| AO1 | 3 | Output 1 (Ch. A) | Ch. A motor winding connection pin |
| Vref | 4 | Internal reference voltage | +0.6 V (typ.) |
| GND | 5 | Ground pin | |
| $V_{CC}$ | 6 | Small-signal power supply pin | $V_{CC\ (ope)}$ = 2.7 V to 5.5 V |
| Vlim | 7 | Winding current setting pin | Icoil (A) = Vlimit (V)/external RF (Ω) |
| EN1 | 8 | Enable input 1 | |
| EN2 | 9 | Enable input 2 | |
| IN1 | 10 | Control input 1 | |
| IN2 | 11 | Control input 2 | |
| OSC | 12 | Internal oscillation frequency setting pin | Connect an oscillator capacitor externally |
| $V_M$ | 13 | Motor power supply pin | $V_{M\ (ope)}$ = 4.5 V to 13.5 V |
| BO2 | 14 | Output 2 (Ch. B) | Ch. B motor winding connection pin |
| RFB | 15 | Winding current detection pin (Ch. B) | |
| BO1 | 16 | Output 1 (Ch. B) | Ch. B motor winding connection pin |

## Truth Table 1

| EN1 (EN2) | IN1 (IN2) | AO1 (BO1) | AO2 (BO2) | Mode |
|---|---|---|---|---|
| L | * | OFF | OFF | ALL OFF |
| H | H | L | H | Reverse |
| | L | H | L | Forward |

"*" indicates "don't care."

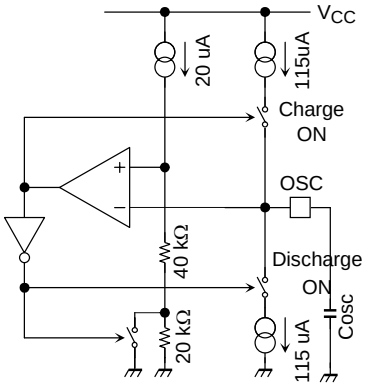
## Truth Table 2

| EN1 | EN2 | Mode |
|---|---|---|
| L (Note) | L (Note) | Standby |
| L | H | Operation |
| H | L | |
| H | H | |

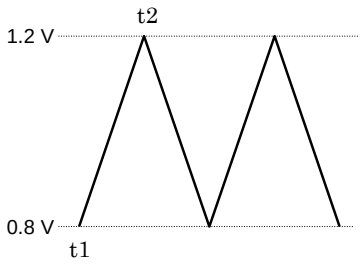
Note: VINL (EN1 = EN2) ≦ 0.5 V.

## Operating Description

The equivalent circuit diagrams may be simplified or some parts of them may be omitted for explanatory purposes.




**Oscillator circuit**




**Vosc waveform**

- The internal oscillation frequency is determined by charging and discharging an external capacitor (Cosc).

$$\mathrm{Vosc} = \frac{1}{\mathrm{Cosc}} \int \mathrm{i}\, \mathrm{dt}\ ,$$

$$\Delta\mathrm{Vosc} = \mathrm{I} \times\ (\mathrm{t1} - \mathrm{t2})/\mathrm{Cosc},$$

$$\frac{1}{\mathrm{t1} - \mathrm{t2}} = \frac{\mathrm{I}}{\Delta\mathrm{Vosc} \cdot \mathrm{Cosc}}\ ,$$

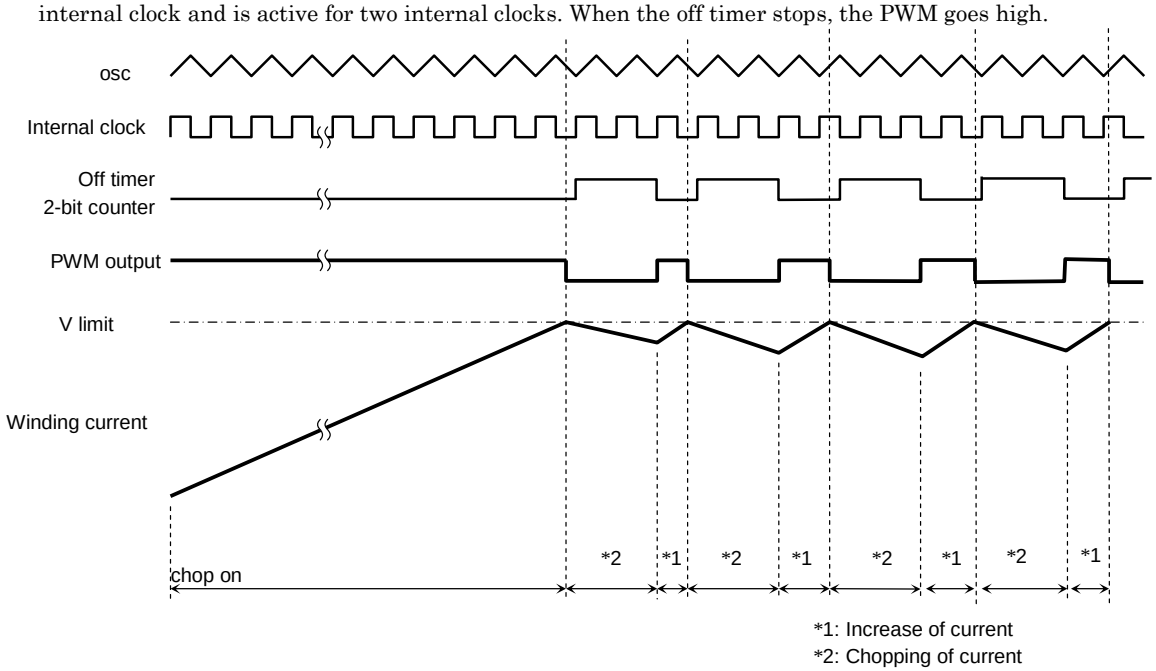
$$\mathrm{fosc} = \frac{1}{2\,(\mathrm{t1} - \mathrm{t2})} = \frac{\mathrm{I}}{2 \cdot \Delta\mathrm{Vosc} \cdot \mathrm{Cosc}}\ ,$$

$$= \frac{1}{2 \times 0.4/115\ \mu\mathrm{A} \times \mathrm{Cosc}} = \frac{1}{6.957 \times 10^{3} \times \mathrm{Cosc}}$$ (theoretical formula).

- Chopper control

The winding current flows while the output drive transistor is On. When the $V_{RF}$ reaches the limit voltage level (Vlimit), the comparator detects it and turns off the output drive transistor.

The oscillator output is squared to generate an internal clock. The off timer starts on the edge of the internal clock and is active for two internal clocks. When the off timer stops, the PWM goes high.



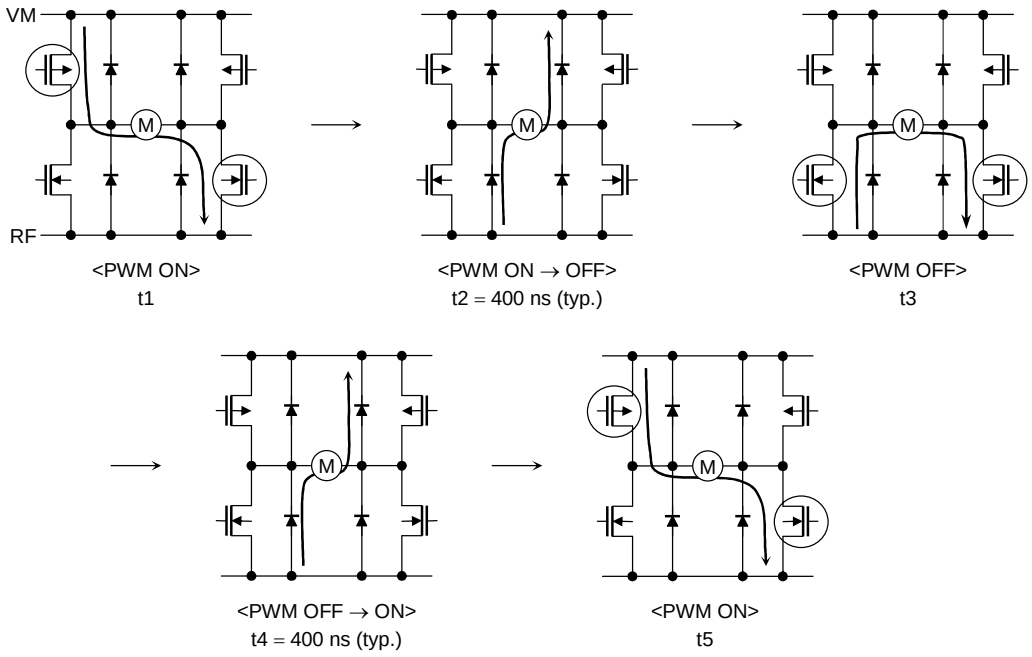

*1: Increase of current
*2: Chopping of current

The PWM control limits the winding current to a level determined by the current value ($I_O$) as expressed in the equation below:

$$I_O = Vlimt/RNF.$$

- PWM control function

When PWM control is provided, normal operation and short brake operation are repeated.
To prevent penetrating current, dead time t2 and t4 are provided in the IC.



## Maximum Ratings (Ta = 25°C)

| Characteristics | Symbol | Rating | Unit | Remarks |
|---|---|---|---|---|
| Power supply voltage | $V_M$ | 15 | V | |
| | $V_{CC}$ | 6 | | |
| Input voltage | $V_{IN}$ | −0.2 to 6 | V | IN1, IN2, EN1 and EN2 pins |
| Output current | $I_{OUT}$ | 0.8 | A | |
| Power dissipation | $P_D$ | 0.78 (Note 1) | W | |
| Operating temperature | $T_{opr}$ | −20 to 85 | °C | |
| Storage temperature | $T_{stg}$ | −55 to 150 | °C | |

Note 1: When mounted on a glass-epoxy PCB (50 mm × 30 mm × 1.6 mm, Cu area: 40%)

The absolute maximum ratings of a semiconductor device are a set of specified parameter values that must not be exceeded during operation, even for an instant.

If any of these ratings are exceeded during operation, the electrical characteristics of the device may be irreparably altered, in which case the reliability and lifetime of the device can no longer be guaranteed.

Moreover, any exceeding of the ratings during operation may cause breakdown, damage and/or degradation in other equipment. Applications using the device should be designed so that no maximum rating will ever be exceeded under any operating conditions.

Before using, creating and/or producing designs, refer to and comply with the precautions and conditions set forth in this document.

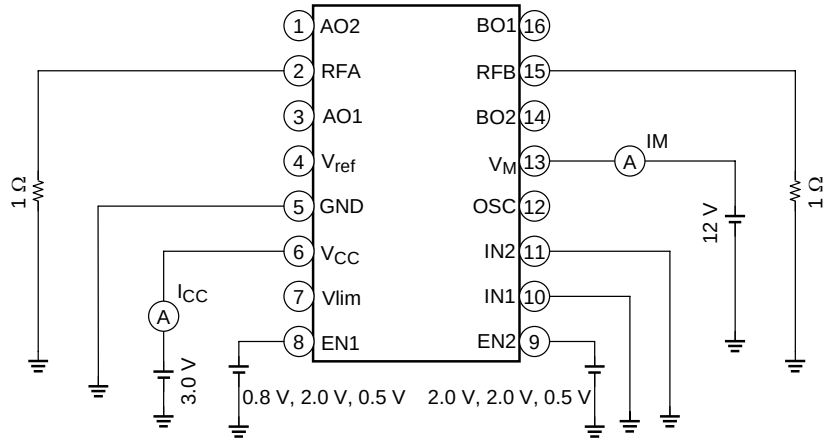
## Operating Range (Ta = −20 to 85°C)

| Characteristics | Symbol | Min | Typ. | Max | Unit |
|---|---|---|---|---|---|
| Power supply voltage ($V_{CC}$) | $V_{CC}$ | 2.7 | 3 | 5.5 | V |
| Power supply voltage ($V_M$) | $V_M$ | 2.5 | 5 | 13.5 | V |
| Output current | $I_{OUT}$ | — | — | 0.6 | A |
| Limit voltage | $V_{limit}$ | GND | — | Vref | V |
| OSC frequency | f osc | — | — | 1 | MHz |
| Chopping frequency | $f_{chop}$ | 20 | — | 250 | kHz |

## Electrical Characteristics (unless otherwise specified, $V_{CC}$ = 3 V, $V_M$ = 12 V, Ta = 25°C)

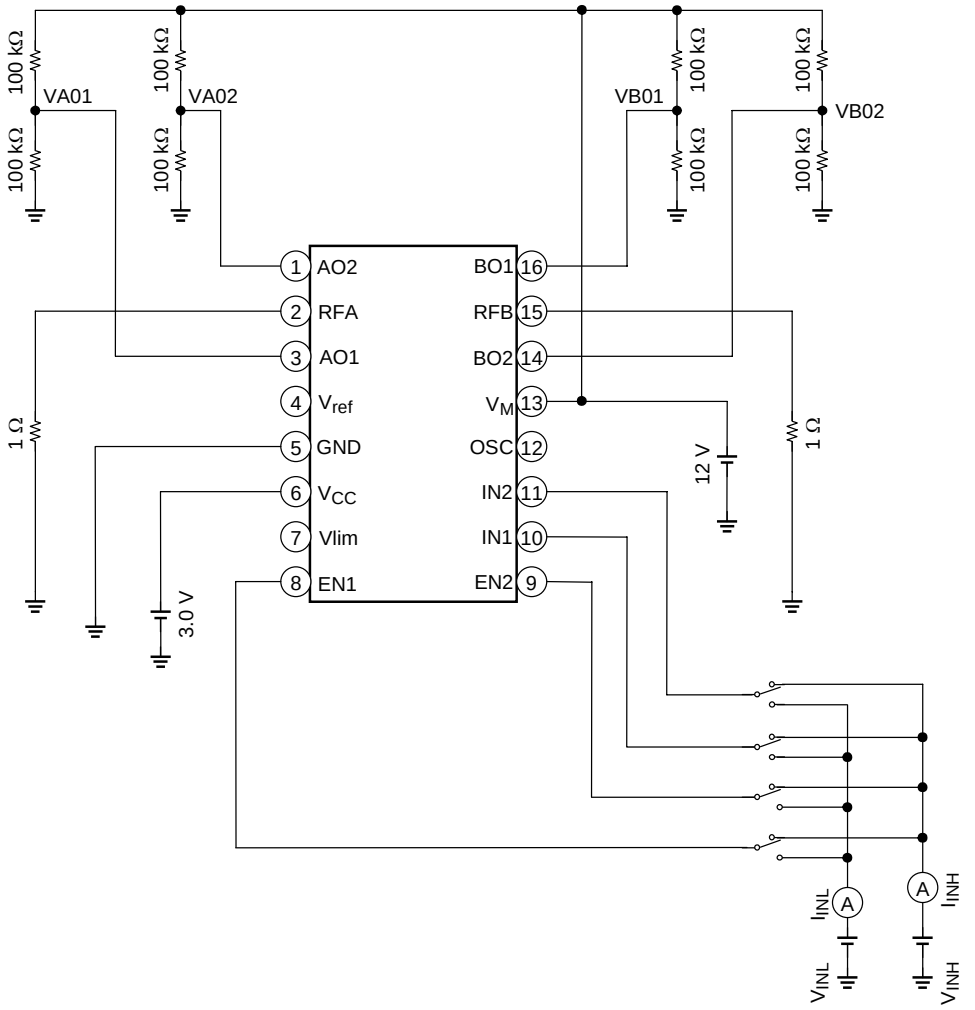
| Characteristics | | Symbol | Test Circuit | Test Condition | Min | Typ. | Max | Unit |
|---|---|---|---|---|---|---|---|---|
| Supply current | | $I_{CC1}$ | 1 | 1ch ON<br>EN1 = 0.8 V, EN2 = 2.0 V | — | 1.4 | 3 | mA |
| | | $I_{CC2}$ | 1 | 2ch ON<br>EN1 = EN2 = 2.0 V | — | 1.4 | 3 | mA |
| | | $I_{CC3}$ | 1 | Standby mode<br>EN1 = EN2 = 0.5 V | — | 7 | 15 | μA |
| | | $I_{M1}$ | 1 | 1ch ON, Output open<br>EN1 = 0.8 V, EN2 = 2.0 V | — | 1.9 | 3.0 | mA |
| | | $I_{M2}$ | 1 | 2ch ON, Output open<br>EN1 = EN2 = 2.0 V | — | 1.9 | 3.0 | |
| | | $I_{M3}$ | 1 | Standby mode<br>EN1 = EN2 = 0.5 V | — | — | 1 | μA |
| Control circuit | Input voltage | $V_{INH}$ | 2 | | 2 | — | $V_{CC}$ + 0.2 | V |
| | | $V_{INL1}$ | 2 | | −0.2 | — | 0.8 | |
| | | $V_{INL2}$ | 2 | Standby mode | −0.2 | — | 0.5 | |
| | Hysteresis voltage | $V_{IN\ (HIS)}$ | — | (Design target value) | — | 0.2 | — | |
| | Input current | $I_{INH}$ | 2 | VIN = 3 V | 5 | 15 | 30 | μA |
| | | $I_{INL}$ | 2 | VIN = GND | — | — | 1 | μA |
| Output saturating voltage | | $V_{sat\ (U+L)}$ | 3 | $I_O$ = 0.2 A | — | 0.3 | 0.4 | V |
| | | | | $I_O$ = 0.6 A | — | 0.9 | 1.2 | |
| Output constant-current detection level | | $V_{RF}$ | 4 | $R_{RF}$ = 0.1 Ω, $V_{ref}$ = 0.6 V | 0.565 | 0.6 | 0.635 | V |
| Reference voltage | | $V_{ref}$ | 5 | No load | 0.57 | 0.6 | 0.63 | V |
| Reference voltage current capacity | | $I_{ref}$ | 5 | Source ($\Delta V_{ref}$ = 50 mV) | — | — | 100 | μA |
| Input current at winding current setting pin | | $I_{IN\ (limit)}$ | 6 | $V_{limit}$ = GND | — | — | 1 | μA |
| Output leakage current | | $I_{L\ (U)}$ | 7 | $V_M$ = 15 V | — | — | 1 | μA |
| | | $I_{L\ (L)}$ | 7 | | — | — | 1 | |
| Diode forward voltage | | $V_{F\ (U)}$ | 8 | $I_O$ = 0.6 A | — | 1 | 1.2 | V |
| | | $V_{F\ (L)}$ | 9 | $I_O$ = 0.6 A | — | 1 | 1.2 | |
| Oscillation frequency | | f osc | 10 | $C_{osc}$ = 220 pF | 430 | 530 | 630 | kHz |
| Capacitor charge current | | $I_{C1}$ | 11 | $V_{osc}$ = 0 V | — | 115 | — | μA |
| Capacitor discharge current | | $I_{C2}$ | 11 | $V_{osc}$ = 2 V | — | 115 | — | μA |
| Thermal shutdown circuit operating temperature | | $T_{SD}$ | — | (Design target value) | — | 170 | — | °C |
| Thermal shutdown hysterisis | | $\Delta T_{SD}$ | — | | — | 20 | — | °C |

**Test Circuit 1: $I_{CC}1$, $I_{CC}2$, $I_{CC}3$, IM1, IM2, IM3**

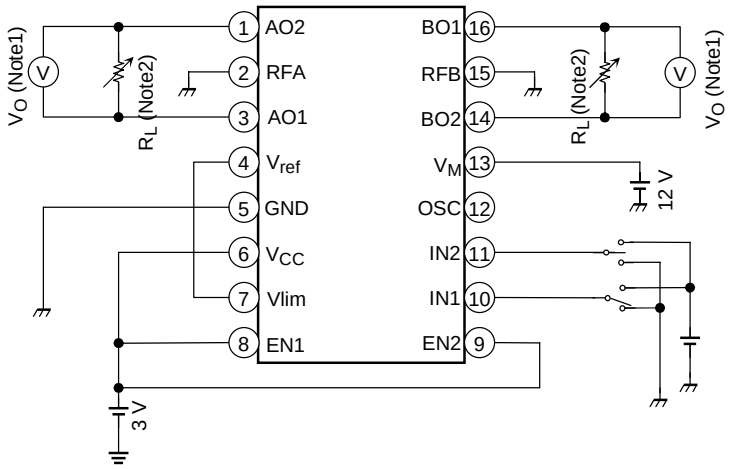



$I_{CC1}$, IM1: EN1 = 0.8 V, EN2 = 2.0 V
$I_{CC2}$, IM2: EN1 = 2.0 V, EN2 = 2.0 V
$I_{CC3}$, IM3: EN1 = 0.5 V, EN2 = 0.5 V

**Test Circuit 2: $V_{INH}$, $V_{INL1}$, $V_{INL2}$, $I_{INH}$, $I_{INL}$**



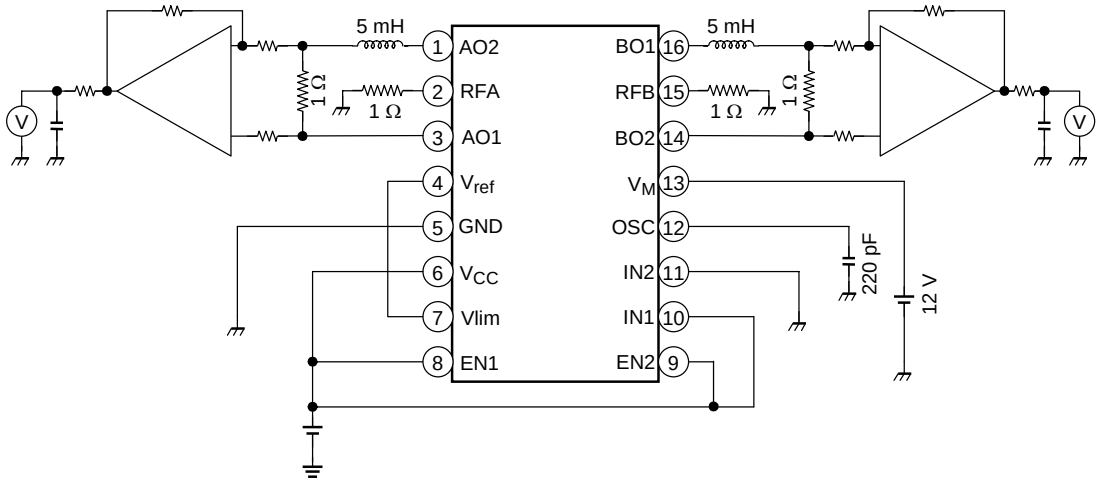
### Test Circuit 3: $V_{SAT\ (U+L)}$



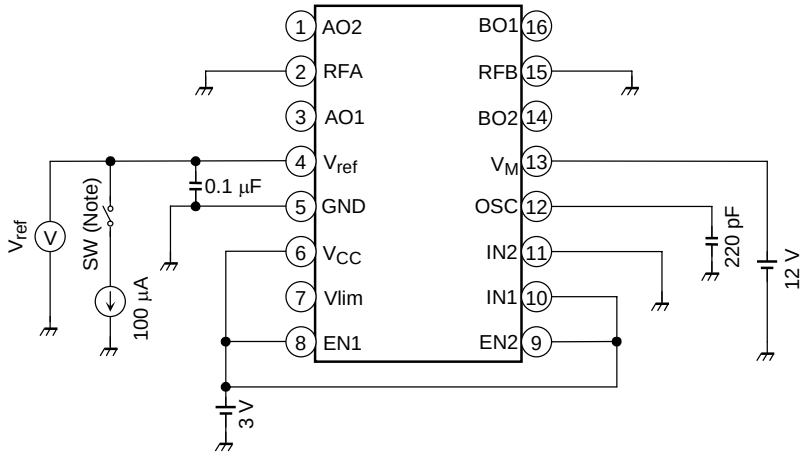

Note1: $V_{SAT\ (U+L)} = 12 - V_O$

Note2: Calibrate $I_O$ to 0.2 A / 0.6 A by RL.

### Test Circuit 4: $V_{RF}$

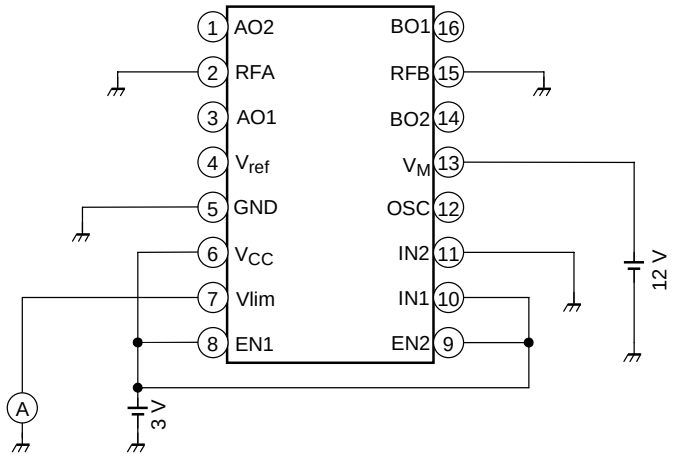


### Test Circuit 5: $V_{ref}$, Iref

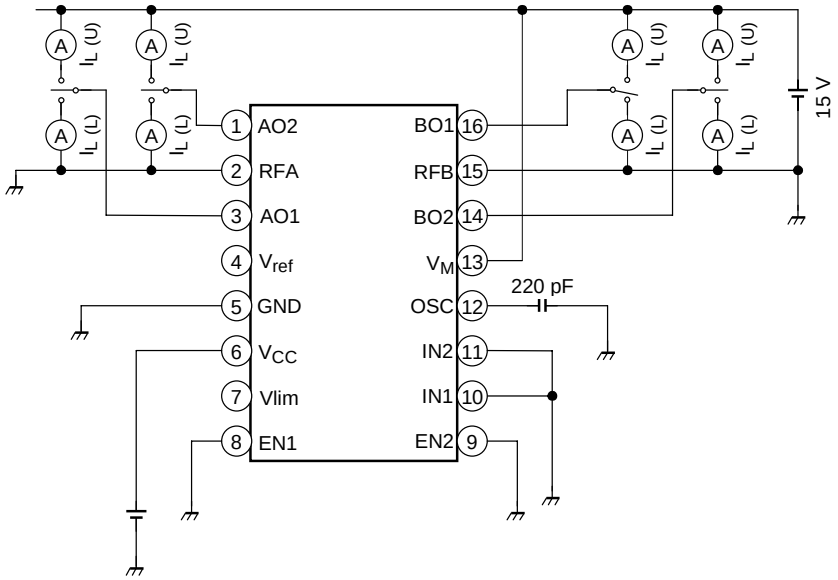



Note: 1. Vref: SW = OFF
2. Iref: The Vref voltage descent at the time of SW = ON checks below 50 mV.

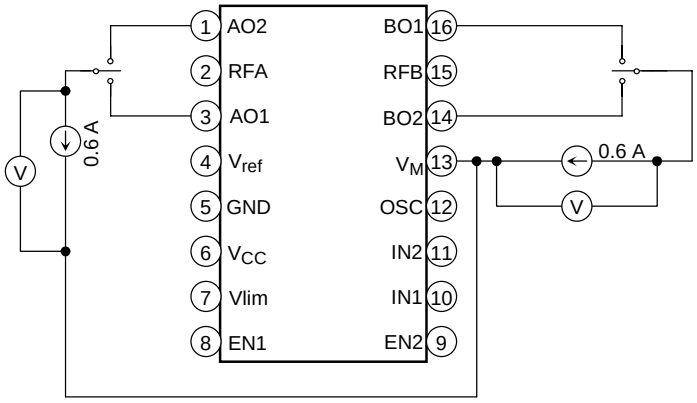
### Test Circuit 6: $I_{IN\ (limit)}$



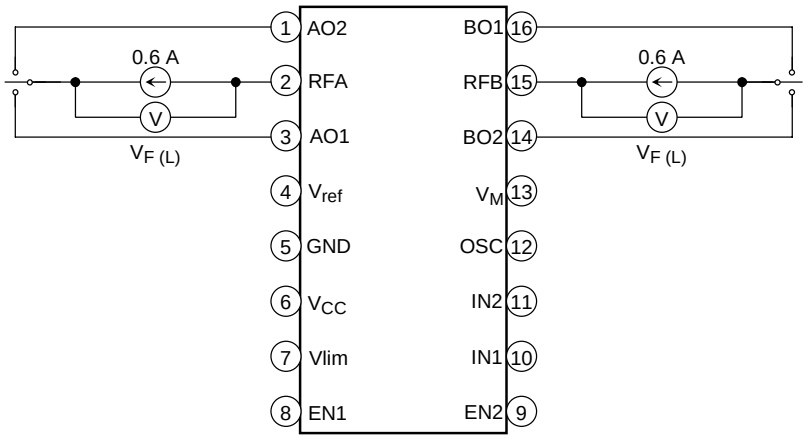
**Test Circuit 7: $I_{L\ (U)}$, $I_{L\ (L)}$**



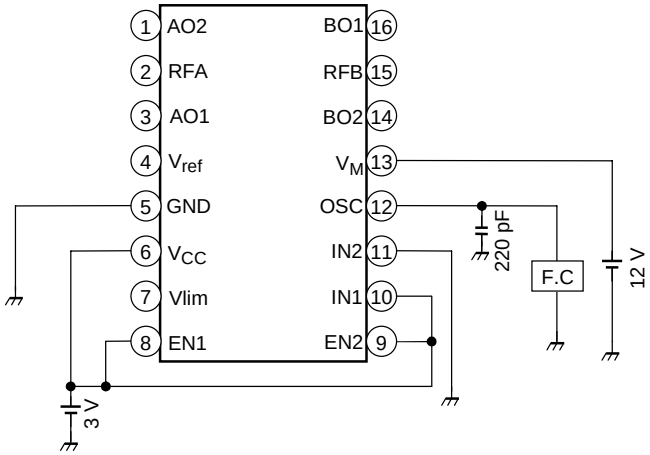

**Test Circuit 8: $V_{F\ (U)}$**



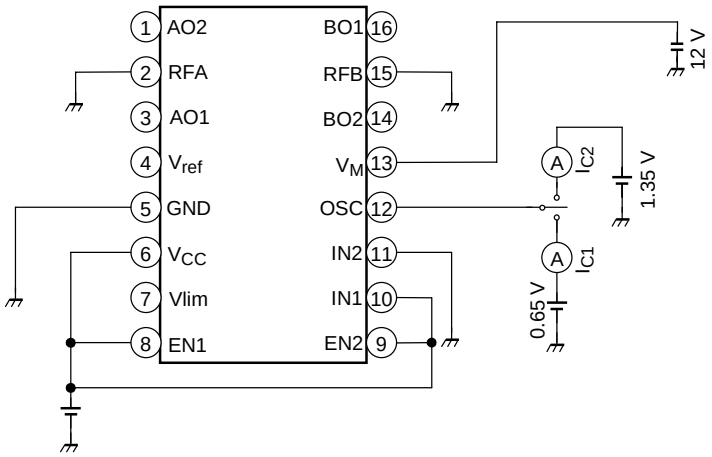
**Test Circuit 9: $V_{F\ (L)}$**



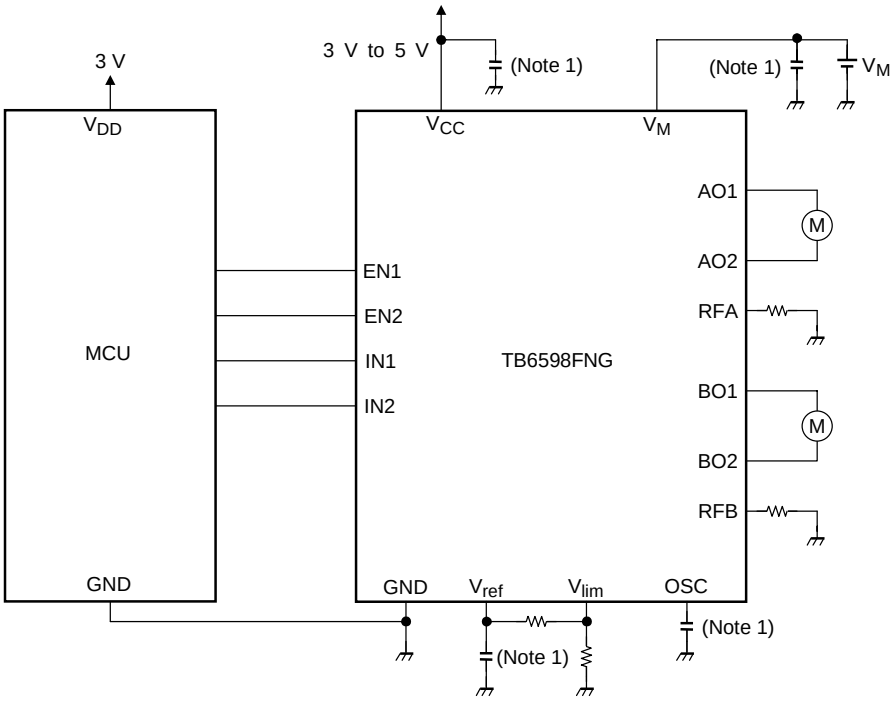

**Test Circuit 10: $f_{OSC}$**



**Test Circuit 11: $I_{C1}$, $I_{C2}$**

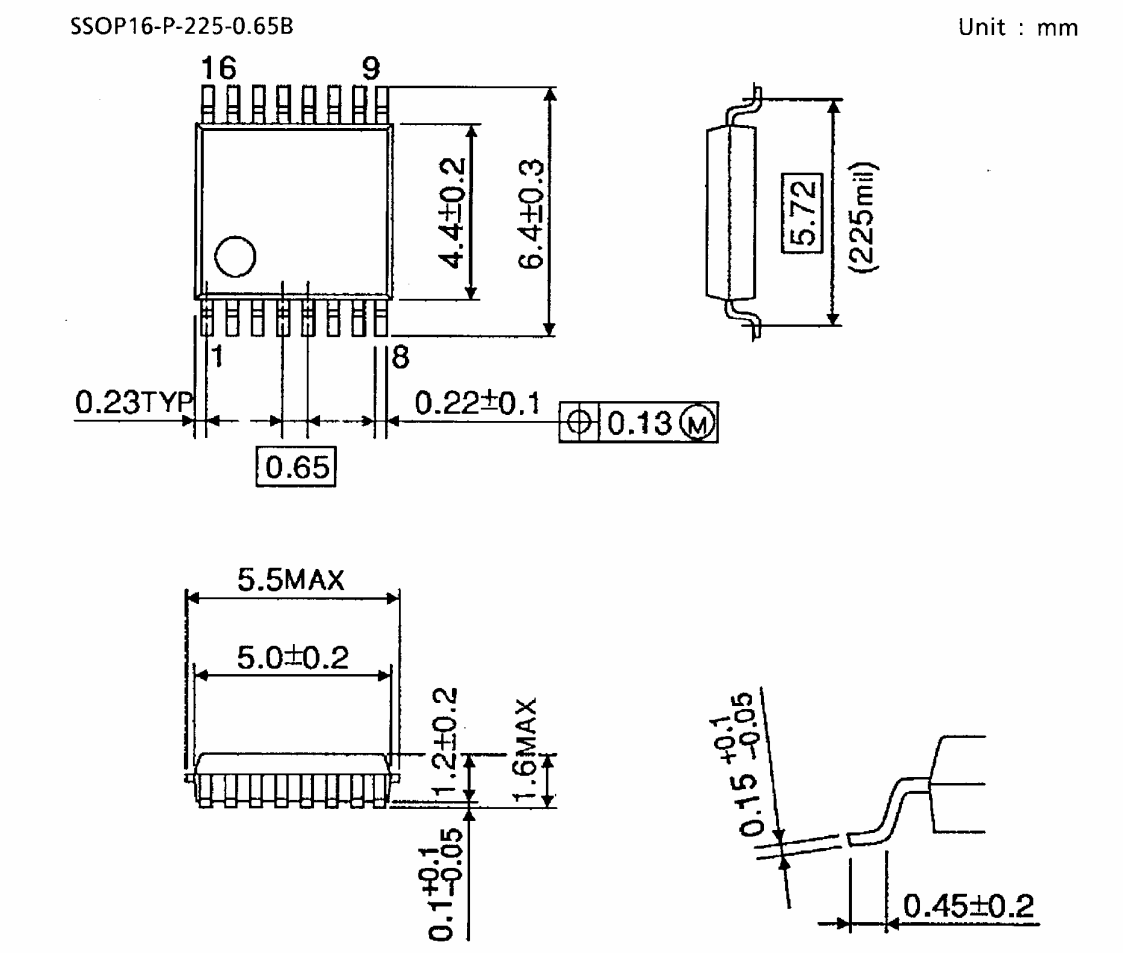


## Application Circuit Example




Note 1: Noise suppression capacitors and oscillator capacitors should be connected as close as possible to the IC.

**Package Dimensions**




Weight: 0.07 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. Maximum Ratings

The absolute maximum ratings of a semiconductor device are a set of specified parameter values that must not be exceeded during operation, even for an instant.

If any of these ratings are exceeded during operation, the electrical characteristics of the device may be irreparably altered, in which case the reliability and lifetime of the device can no longer be guaranteed.

Moreover, any exceeding of the ratings during operation may cause breakdown, damage and/or degradation in other equipment. Applications using the device should be designed so that no maximum rating will ever be exceeded under any operating conditions.

Before using, creating and/or producing designs, refer to and comply with the precautions and conditions set forth in this document.

### 5. Application Circuits

The application circuits shown in this document are provided for reference purposes only. Thorough evaluation is required in the mass production design phase.

In furnishing these examples of application circuits, Toshiba does not grant the use of any industrial property rights.

### 6. Test Circuits

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

### Handling of the IC

Ensure that the product is installed correctly to prevent breakdown, damage and/or degradation in the product or equipment.

### Overcurrent Protection and Heat Protection Circuits

These protection functions are intended only as a temporary means of preventing output short circuits or other abnormal conditions and are not guaranteed to prevent damage to the IC.

If the guaranteed operating ranges of this product are exceeded, these protection features may not operate and some output short circuits may result in the IC being damaged.

The over-current protection feature is intended to protect the IC from temporary short circuits only.

Short circuits persisting over long periods may cause excessive stress and damage the IC. Systems should be configured so that any over-current condition will be eliminated as soon as possible.

### Counter-Electromotive force

When the motor reverses or stops, the effect of counter-electromotive force may cause the current to flow to the power source.

If the power supply is not equipped with sink capability, the power and output pins may exceed the maximum rating.

The counter-electromotive force of the motor will vary depending on the conditions of use and the features of the motor. Therefore make sure there will be no damage to or operational problem in the IC, and no damage to or operational errors in peripheral circuits caused by counter-electromotive force.

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