

CD Integrated Circuit Silicon Monolithic

# TC78H600FNG/FTG

## DUAL-BRIDGE DRIVER IC FOR DC MOTORS

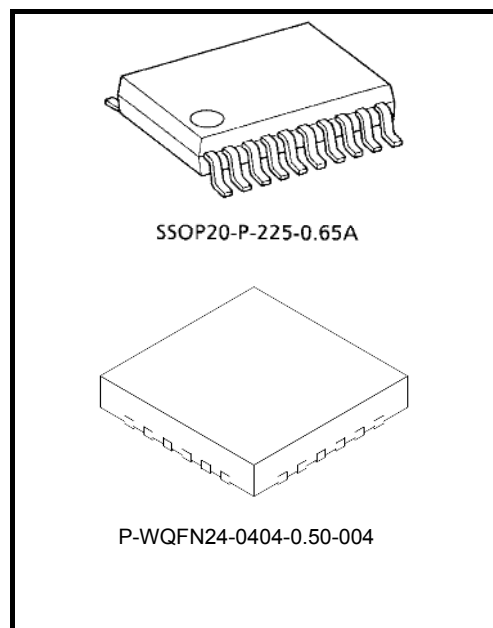
The TC78H600FNG/FTG is a dual-bridge driver IC for DC motors which incorporates DMOS in output transistors. DMOS output driver with low ON-resistance and PWM drive system are applied to realize high efficiency driving.

### Features

- Power supply voltage for motor:  $V_M=15V$  (max)
- Power supply voltage for control:  $V_{CC}=2.7V$  to  $5.5V$  (Operation range)
- Output current:  $I_{out} \leq 0.8A$  (max)
- Output ON resistance:  $R_{on}=1.2\Omega$  (upper and lower sum)
- Internal pull-down resistors on inputs:  $200\text{ k}\Omega$  (typ.)
- Built-in over current detection (ISD), thermal shutdown (TSD) circuit, and under voltage lockout (UVLO) circuit.
- ALERT output pin
- Package: TC78H600FNG;SSOP20, TC78H600FTG; QFN24
- Built-in cross conduction protection circuit

\*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.

\*The IC should be installed correctly. Otherwise, the IC or peripheral parts and devices may be degraded or permanently damaged.



Weight: SSOP20-P-225-0.65A: 0.09g(typ.)  
P-WQFN24-0404-0.50-004: 0.03g(typ.)

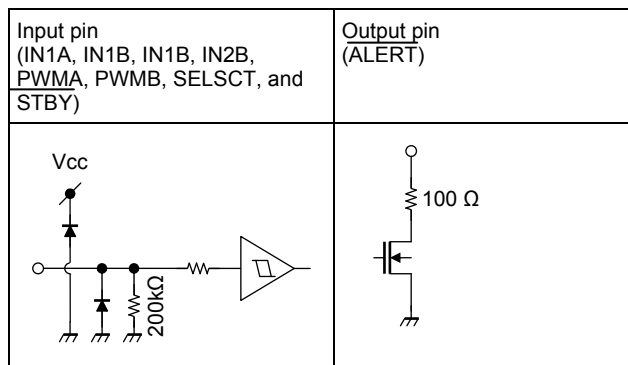


## Pin Functions

Pin No.		Pin name	Functional description	Remarks
TC78H 600 FNG	TC78H 600 FTG			
1	4, 5	Vcc	Power supply pin for logic block	Vcc(opr)=2.7 to 5.5V
2	6	$\overline{\text{STBY}}$	Standby input	Refer to "Input/Output functions".
3	7	OSC	Connection pin for an external capacitor used for internal oscillation	
4	8	IN2B	Control input pin for Bch (2)	Refer to "Input/Output functions".
5	9	IN1B	Control input pin for Bch (1)	Refer to "Input/Output functions".
6	10, 11	VM	Power supply pin for output	VM(opr) = 2.5 to 15.0 V
7	12	PWMB	PWM signal input pin for Bch	Refer to "Input/Output functions".
8	13	BO2	Output pin of B phase (2)	Connect BO2 to a motor coil pin.
9	14	RSGNDB	Connection pin for a B-phase output current detection resistor	Refer to "Select Direct PWM or Constant current PWM".
10	15	BO1	Output pin of B phase (1)	Connect BO1 to a motor coil pin.
11	16	AO2	Output pin of A phase (2)	Connect AO2 to a motor coil pin.
12	17	RSGNDA	Connection pin for an A-phase output current detection resistor	Refer to "Select Direct PWM or Constant current PWM".
13	18	AO1	Output pin of A phase (1)	Connect AO1 to a motor coil pin.
14	19	SELECT	Constant PWM, Direct PWM select pin	
15	20, 21	GND	Ground pin	
16	22	$\overline{\text{ALERT}}$	Monitor signal pin for TSD and ISD (output)	Open drain, Pulled up by an external resistor
17	23	PWMA	PWM signal input pin for Ach	Refer to "Input/Output functions".
18	1	Vref	External set terminal for A-phase and B-phase reference voltage	Refer to "Select Direct PWM or Constant current PWM".
19	2	IN2A	Control input pin for Ach (2)	Refer to "Input/Output functions".
20	3	IN1A	Control input pin for Ach (1)	Refer to "Input/Output functions".

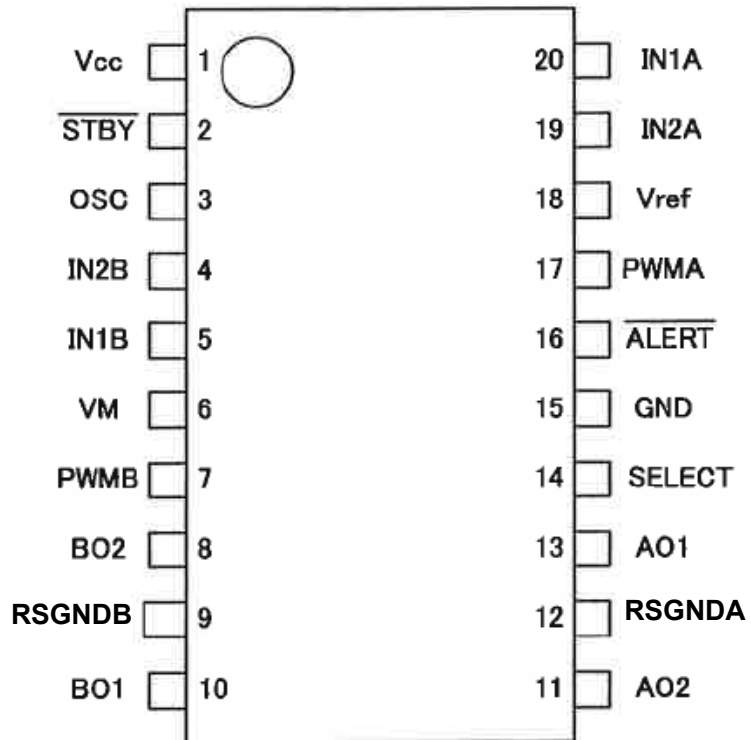
TC78H600FTG: Pin No. 24 of QFN24: N.C.

<Pin circuit>

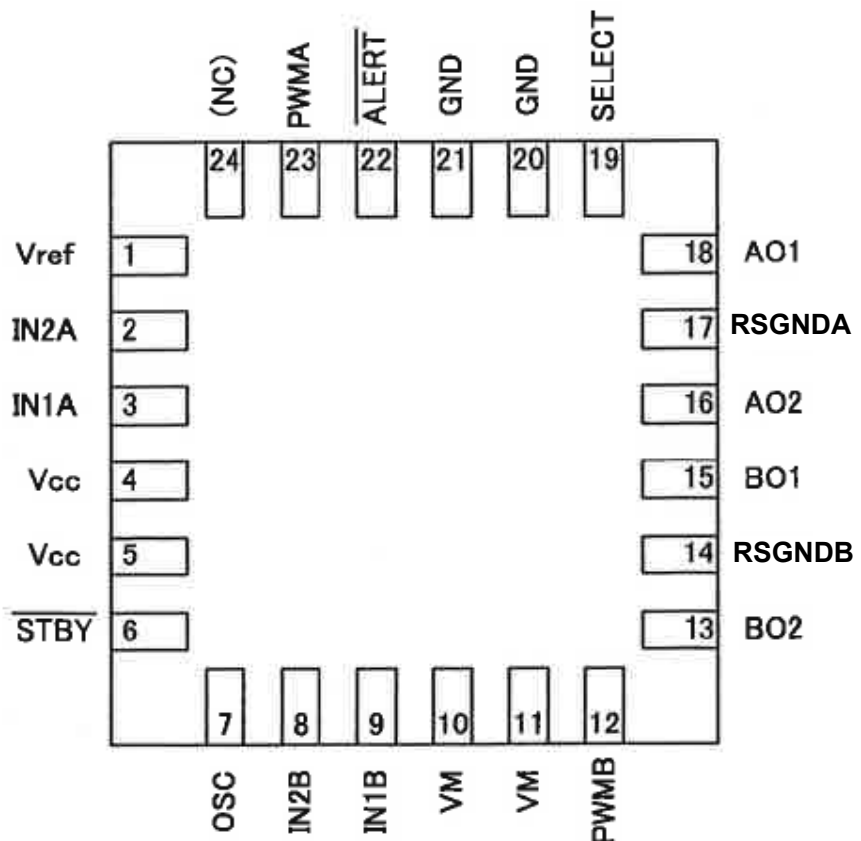


### Pin Assignment (Top view)

TC78H600FNG  
SSOP20



TC78H600FTG  
P-WQFN24



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

Characteristics	Symbol	Rating	Unit	
Power supply voltage	V <sub>CC</sub>	6	V	
	V <sub>M</sub>	18	V	
Output current	Peak, I <sub>out</sub> (AO), I <sub>out</sub> (BO), per one phase, tw ≤ 10ms, duty 20%	1.0	A	
	Continuously, I <sub>out</sub> (AO), I <sub>out</sub> (BO), per one phase	0.8	A	
	I <sub>ALERT</sub>	4	mA	
Output voltage of $\overline{\text{ALERT}}$	V <sub>ALERT</sub>	6	V	
Input voltage	V <sub>IN</sub>	-0.2 to V <sub>CC</sub> +0.2	V	
Power dissipation	P <sub>D</sub>	TC78H600FNG	0.71 (Note 1)	W
			0.96 (Note 2)	
		TC78H600FTG	3.17 (Note 3)	
Operation temperature	T <sub>opr</sub>	-20 to 85	°C	
Storage temperature	T <sub>stg</sub>	-55 to 150	°C	

Note 1: IC only

Note 2: When mounted on a glass epoxy board (50 mm × 50 mm × 1.6 mm, Cu area: 40 %)

Note 3: Mounted on the board (76 mm × 114 mm × 1.6 mm, 4 layers in accordance with the relevant JESD-51)

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 absolute maximum rating will ever be exceeded under any operating condition.

## Operating Range (Ta = -20 to 85°C)

Characteristics	Symbol	Conditions	Min	Typ.	Max	Unit
Controlled power supply voltage	V <sub>CC(opr)</sub>	—	2.7	3.3	5.5	V
Motor power supply voltage	V <sub>M(opr)</sub>	—	2.5	5	15	V
Output current	I <sub>OUT</sub>	—	—	—	0.8	A
Input voltage	V <sub>IN</sub>	—	—	—	5.5	V
Input voltage	V <sub>ref</sub>	—	0.4	2.5	V <sub>CC</sub> - 1.8	V
PWM frequency (Input in direct PWM drive)	f <sub>PWM</sub>	duty50% IN1A, IN2A, PWMA, IN1B, IN2B, PWMB	1	—	500	kHz
Oscillation frequency	f <sub>osc</sub>	C <sub>osc</sub> =220pF	160	320	480	kHz
Chopping frequency	f <sub>chop</sub>	In constant current PMW mode 180pF ≤ C <sub>osc</sub> ≤ 260pF	20	40	60	kHz

Maximum current is limited by power dissipation. It depends on the ambient temperature, excitation mode, and heat radiation of the board.

**Electrical Characteristics** ( $T_a=25^{\circ}\text{C}$ ,  $V_{CC}=3.3\text{V}$ ,  $V_M=5\text{V}$ ,  $R_{NF}=2\Omega$ ,  $C_{OSC}=220\text{pF}$ , unless otherwise specified.)

Characteristics	Symbol	Test Condition	Min	Typ.	Max	Unit
Input voltage (Note)	$V_{IN(H)}$	SELECT, PWMA, PWMB, IN1A, IN1B, IN2A, IN2B, RESET, $\overline{\text{STBY}}$	2	—	5.5	V
	$V_{IN(L)}$		-0.2	—	0.8	V
Hysteresis voltage	$V_{Hys}$	SELECT, PWMA, PWMB, IN1A, IN1B, IN2A, IN2B, RESET, $\overline{\text{STBY}}$	—	200	—	mV
Input current	$I_{INH}$	$V_{IN} = 3.3\text{V}$	11	16.5	22	$\mu\text{A}$
	$I_{INL}$	$V_{IN} = \text{GND}$	2	4	8	$\mu\text{A}$
Consumption current	$I_{CC1}$	Stop mode	—	4	6	mA
	$I_{CC2}$	Forward/Reverse mode	—	4	6	mA
	$I_{CC3}$	Standby mode	—	5	10	$\mu\text{A}$
	$I_{M1}$	Stop mode	—	1	2	mA
	$I_{M2}$	Forward/Reverse mode	—	0.5	1	mA
	$I_{M3}$	Standby mode	—	—	1	$\mu\text{A}$
Undervoltage lockout threshold at $V_{CC}$	Lower threshold UVLD	Design target value	—	2.2	—	V
	Upper threshold UVLC	Design target value	—	2.3	—	V
Undervoltage lockout threshold at $V_M$	Lower threshold UVLD	Design target value	—	2.0	—	V
	Upper threshold UVLC	Design target value	—	2.1	—	V
ALERT output voltage	$V_{\overline{\text{ALERT}}}$	$I_{\overline{\text{ALERT}}}=1\text{mA}$	—	—	0.5	V
TSD operating temperature (Note)	TSD	Design target value	—	170	—	$^{\circ}\text{C}$
TSD recovery temperature (Note)	TSDhys	Design target value	—	40	—	$^{\circ}\text{C}$
OSC frequency	$f_{OSC}$	$C_{OSC} = 220\text{pF}$	210	320	430	kHz

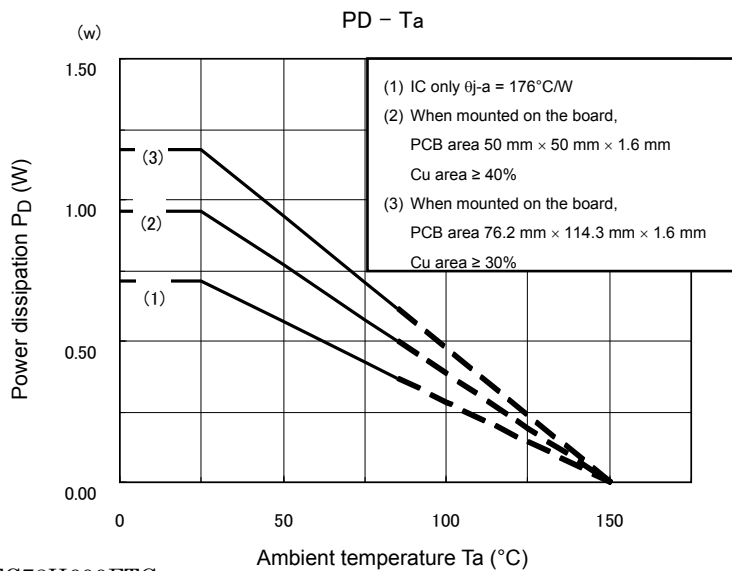
(Note) As for the design target value, Toshiba does not implement testing before shipping.

## Output Block

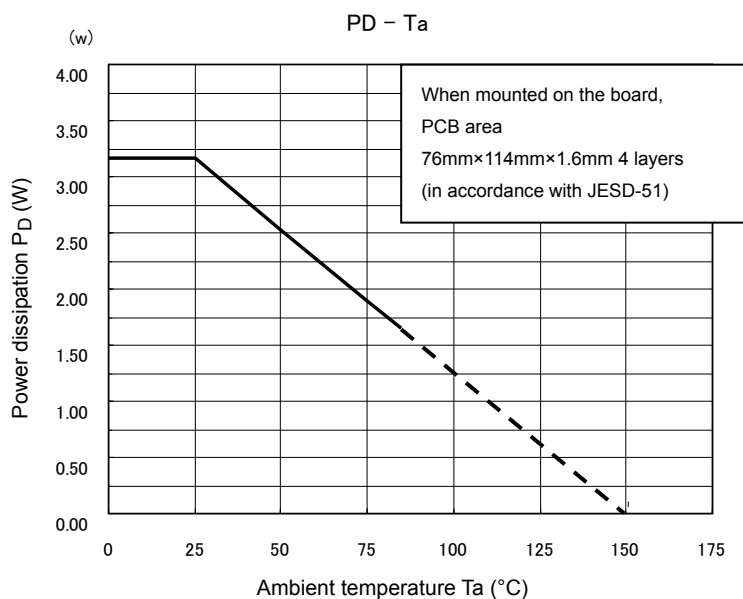
Characteristics		Symbol	Test Condition	Min	Typ.	Max	Unit
Output saturation voltage		$V_{SAT(U+L)}$	$I_{OUT} = 0.2\text{ A}$	—	0.24	0.32	V
			$I_{OUT} = 0.6\text{ A}$	—	0.72	0.96	
Diode forward voltage		$V_{FU}$	$I_{OUT} = 0.6\text{ A}$	—	1	1.2	V
		$V_{FL}$		—	1	1.2	
Output transistor switching characteristics		$t_r$	Design target value	—	20	—	ns
		$t_f$	Output load $25\ \Omega + 15\text{ pF}$	—	20	—	
		$t_{pLH(PWM)}$	Design target value	—	500	—	
		$t_{pHL(PWM)}$		—	500	—	
Output leakage current	Upper	$I_{OH}$	$V_M = 15\text{ V}$	—	—	1	$\mu\text{A}$
	Lower	$I_{OL}$		—	—	1	

## $P_D - T_a$ characteristics

·TC78H600FNG



·TC78H600FTG



## Input/Output functions

### SELECT=L (Direct PWM mode)

Input				Output		
STBY	IN1	IN2	PWM	O1	O2	Mode
H	H	H	H	L	L	Short brake
			L			
H	L	H	H	L	H	Forward/Reverse
			L	L	L	Short brake
H	H	L	H	H	L	Reverse/Forward
			L	L	L	Short brake
H	L	L	H	OFF (High impedance)		Stop
			L			
L	-	-	H	OFF (High impedance)		Standby
			L			

### SELECT=H (Constant current PWM Mode)

Input				Output		
STBY	IN1	IN2	PWM	O1	O2	Mode
H	H	H	H	L	L	Short brake
			L			
H	L	H	H	L	H	Constant current PWM, CW (OUT2→OUT1)
			L	L	L	Short brake
H	H	L	H	H	L	Constant current PWM, CCW (OUT1→OUT2)
			L	L	L	Short brake
H	L	L	H	OFF (High impedance)		Stop
			L			
L	-	-	H	OFF (High impedance)		Standby
			L			

### Select Direct PWM or Constant current PWM

#### (1) Constant current PWM

Connect the current detection resistor (RNF) to RSGNDA and RSGNDB.

Configuration of output current is as follows;

$$I_{out} (A) = (1/5 \times V_{ref} (V)) \div RNF (\Omega)$$

The setting range of Vref: 0.4V to 3.4V, (Vcc - 1.8) V or less. The voltage of less than 0.4V decreases operation accuracy.

Use the IC by connecting the resistance (RNF) of 0.3Ω or more.

#### (2) Direct PWM

Connect RSGNDA, RSGNDB, and Vref to GND pin.

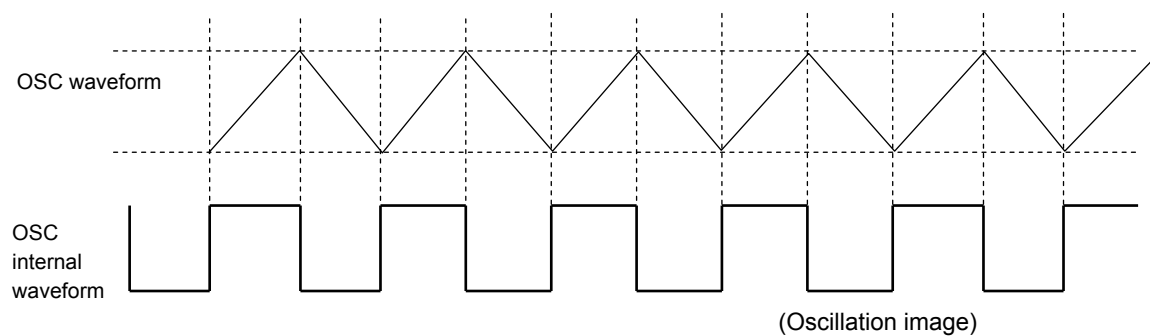


**Stand by Mode**

All functions are turned off to reduce the power consumption.

**OSC**

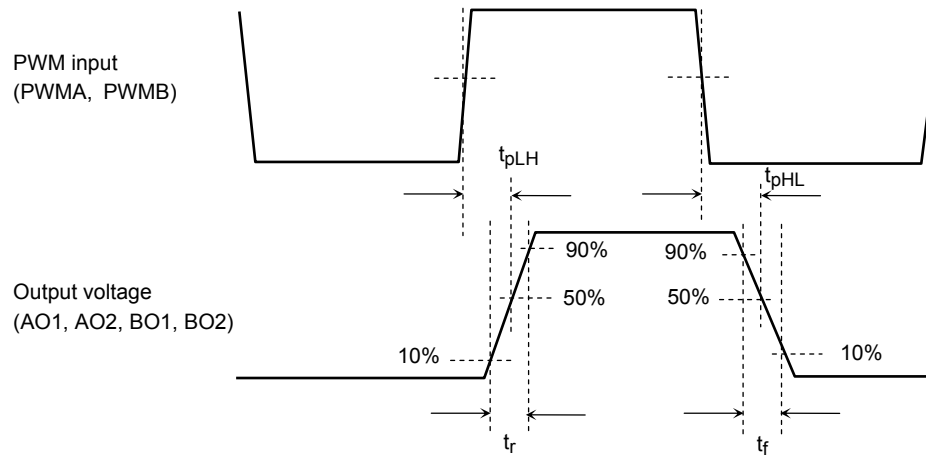
1. Triangle wave is generated internally by connecting the external capacitor to OSC terminal and CR oscillates.
2.  $180 \text{ pF} \leq C_{osc} \leq 260 \text{ pF}$



## Test waveform

- Switching characteristics of output transistor

Relation of PWM input and switching characteristics of output transistor is shown below.



<Design target value>

Symbol	Typical value	Unit
$t_{pLH}$	500	ns
$t_{pHL}$	500	
$t_r$	20	
$t_f$	20	

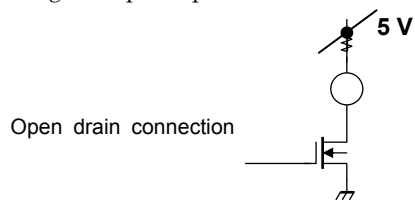
## ALERT (output pin)

TSD or either ISD operates:  $\overline{\text{ALERT}} = \text{Low}$

$\overline{\text{ALERT}}$  pin should be connected to the power supply externally through the pull-up resistor.

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

TSD	ISD	$\overline{\text{ALERT}}$ pin
Detecting	Detecting	Low
No detecting	Detecting	
Detecting	No detecting	
No detecting	No detecting	Z



## PWM control function

Applying a PWM signal to the PWM pin allows motor speed control.

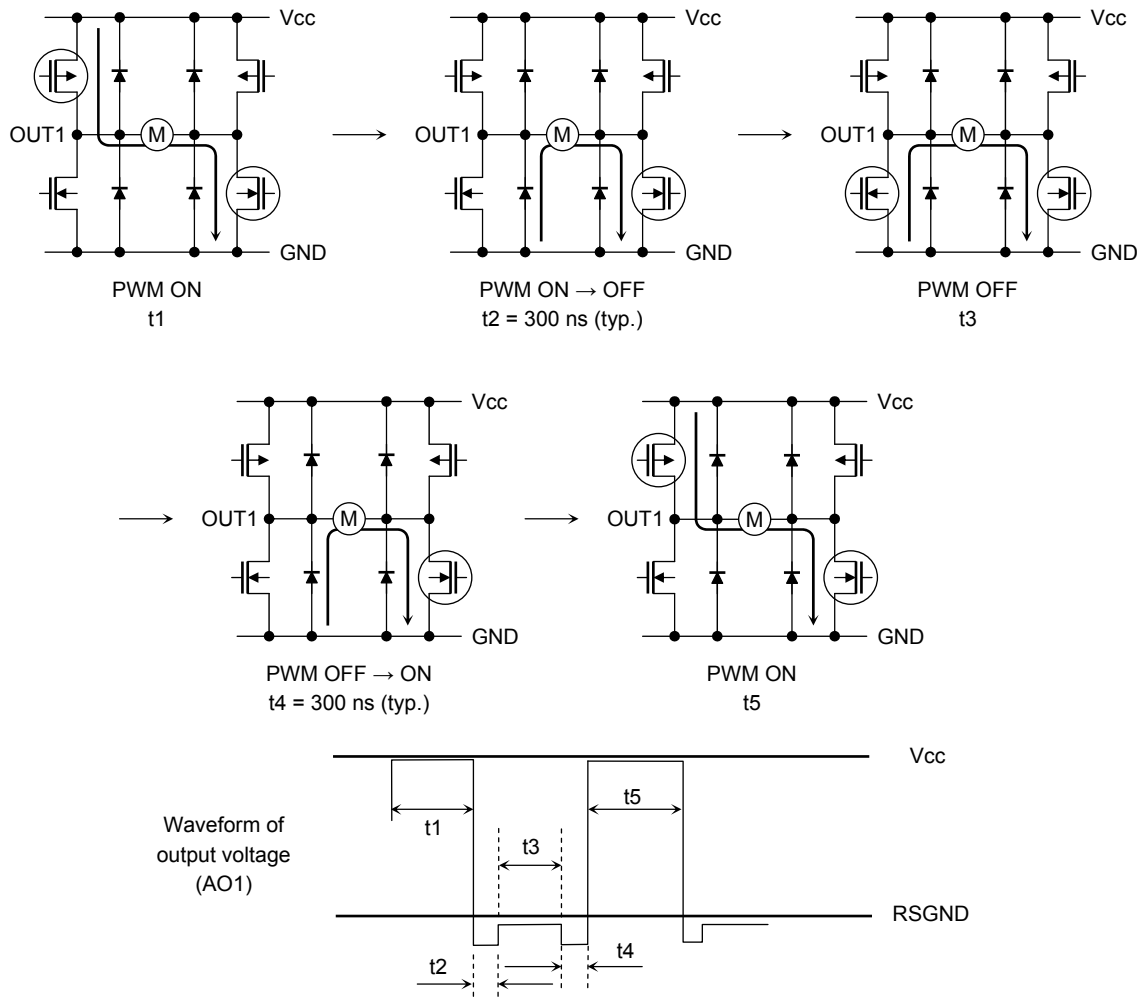
(PWM drive can be operated by inputting PWM signal to IN1 and IN2 pins without using PWM pin.)

The IC enters CW (CCW) mode and short brake mode alternately in PWM current control.

To prevent shoot-through current caused by simultaneous conduction of upper and lower transistors in the output stage, a dead time is internally generated when switching the upper and lower transistors.

Therefore, synchronous rectification for high efficiency in PWM current control can be achieved without an off-time that is generated via an external input.

Even when toggling between each mode (CW, CCW, and short brake), the off-time is not required due to the internally generated dead time.



Design target value:

Dead time, PWM ON→OFF:  $t_2=300\text{ns}$

PWM OFF→ON:  $t_4=300\text{ns}$

**Constant current PWM control**

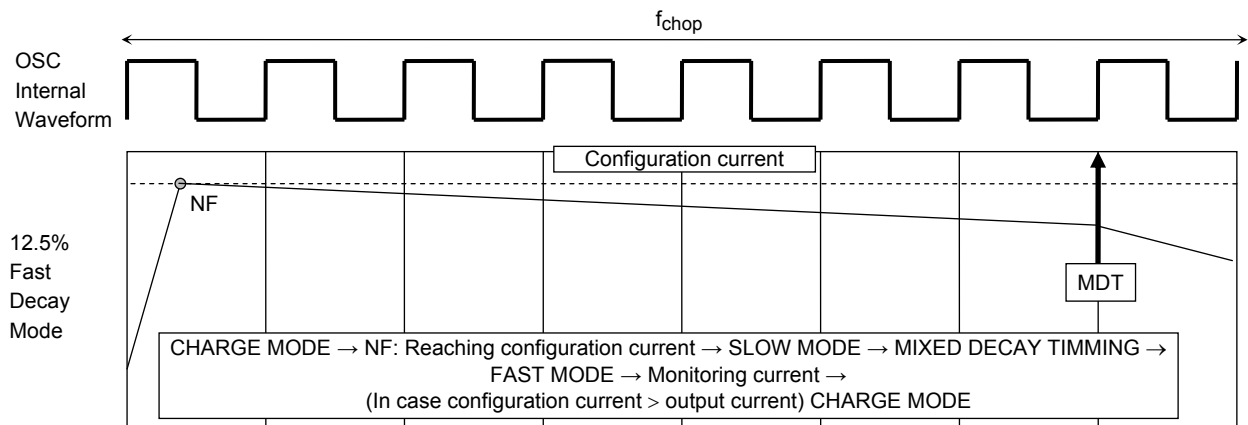
The operation moves to constant current PWM control mode when SELECT pin outputs high.

This circuit operates with peak current detection method. The current outputs constantly by inputting constant voltage from VREF pin.

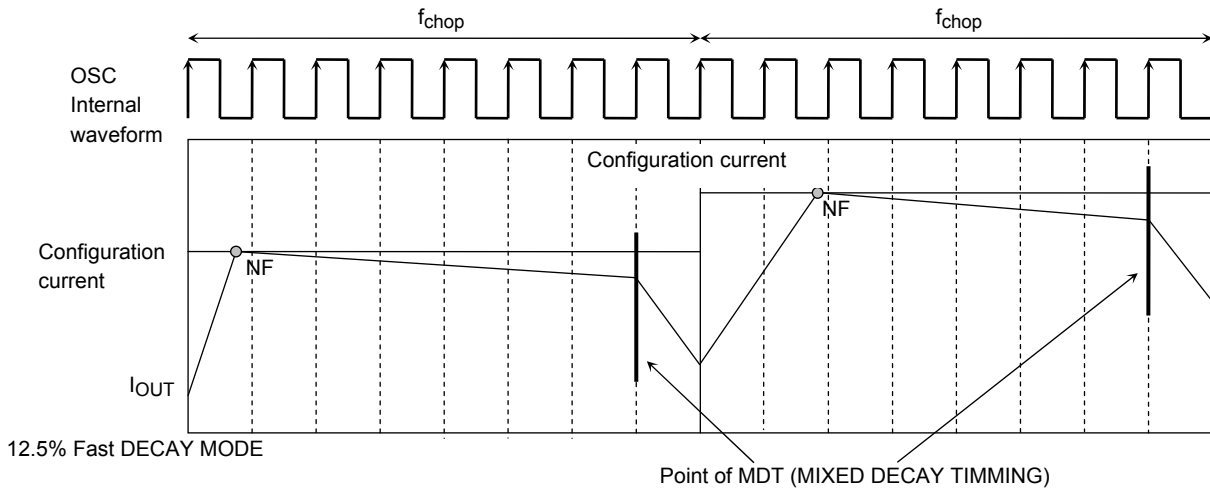
Frequency is fixed. It is fixed to 12.5% fast Decay mode. Charge-discharge frequency of the PWM drive corresponds to 8 cycles of OSC. Only the length of the last cycle of OSC is decayed by the Fast mode. Zero cross point is detected.

\*NF: The point that output current reaches configuration current.

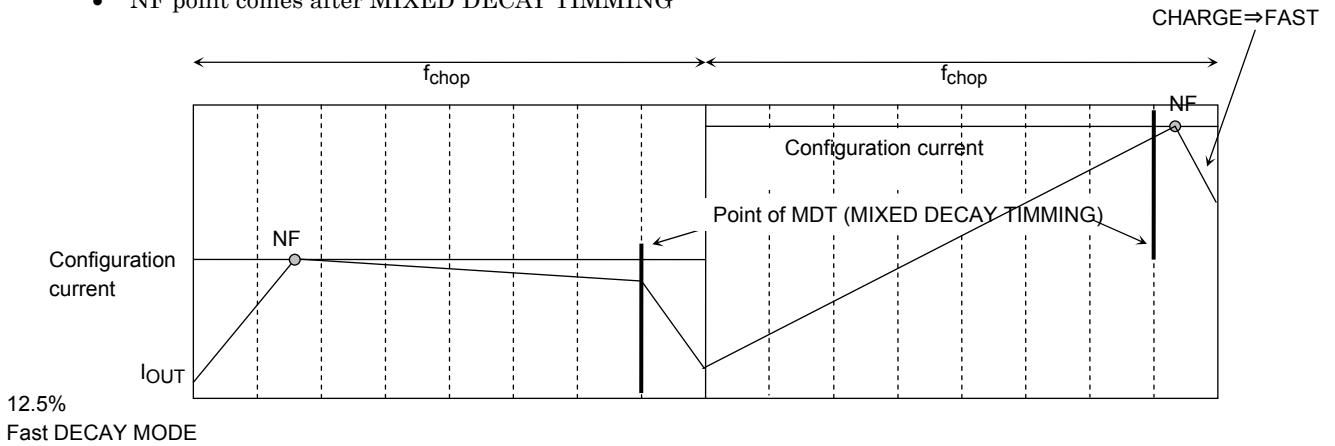
In below figure, MDT means the point of MDT (MIXED DECAY TIMMING).



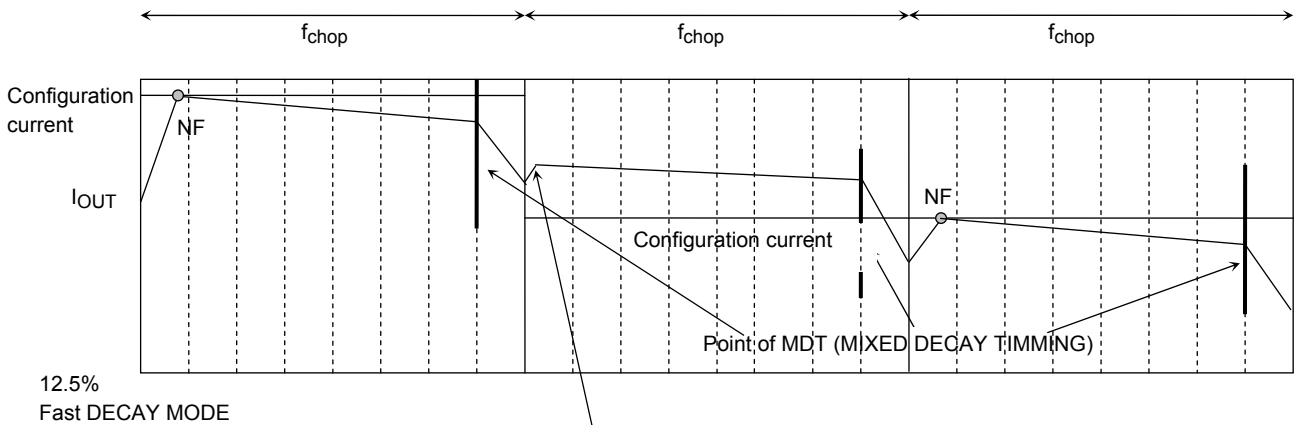
**Constant current PWM control mode: Current waveform when configuration current changes by changing Vref**



- NF point comes after MIXED DECAY TIMMING



- MIXED DECAY MODE: Output current > Configuration current



Though  $I_{OUT}$  is higher than the configuration current, charging current flows instantly for confirming the current.

## Thermal shut down (TSD) circuit

The TC78H600FNG/FTG includes a thermal shutdown circuit, which turns the output transistors off when the junction temperature ( $T_j$ ) exceeds  $170^\circ\text{C}$  (typ.).

The output transistors are automatically turned on when  $T_j$  cools past the shutdown threshold, which is lowered by a hysteresis of  $40^\circ\text{C}$ .

$TSD = 170^\circ\text{C}$  (design target value) (Note.)

$\Delta TSD = 40^\circ\text{C}$  (design target value) (Note.)

Note. Toshiba does not implement testing before shipping.

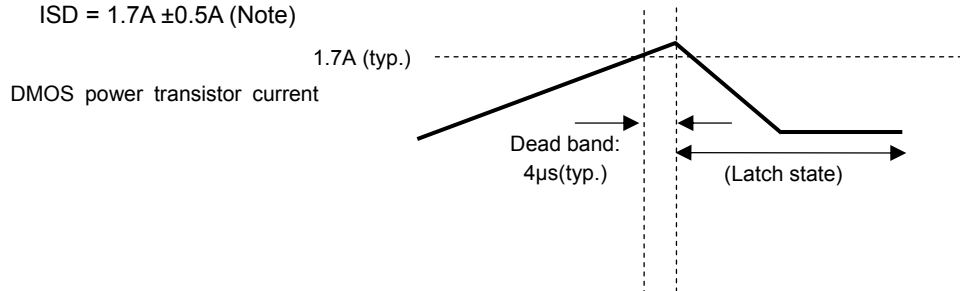
\*In thermal shutdown mode, the internal circuitry and outputs assume the same states as in stop mode ( $IN1=IN2=L$ ).

## ISD (Over current protection)

When any of current which flows in 8 DMOS transistors exceeds  $1.7\text{ A}$  (typ.), all outputs are turned off. It does not resume automatically but latches. It resumes when UVLO operates.

However, masking term of  $4\mu\text{s}$  (typ.) should be added in order to avoid detection error by the noise.

$ISD = 1.7\text{ A} \pm 0.5\text{ A}$  (Note)



Note. Toshiba does not implement testing before shipping.

**Under voltage lockout (UVLO) circuit**

The TC78H600FNG/FTG includes an undervoltage lockout circuit, which puts the output transistors in the high-impedance state when  $V_{CC}$  decreases to 2.2 V (typ.) or lower.

The output transistors are automatically turned on when  $V_{CC}$  increases past the lockout threshold, which is raised to 2.3 V (typ.) by a hysteresis of 0.1 V (typ.).

The TC78H600FNG/FTG includes an undervoltage lockout circuit, which puts the output transistors in the high-impedance state when  $V_M$  decreases to 2.0 V (typ.) or lower.

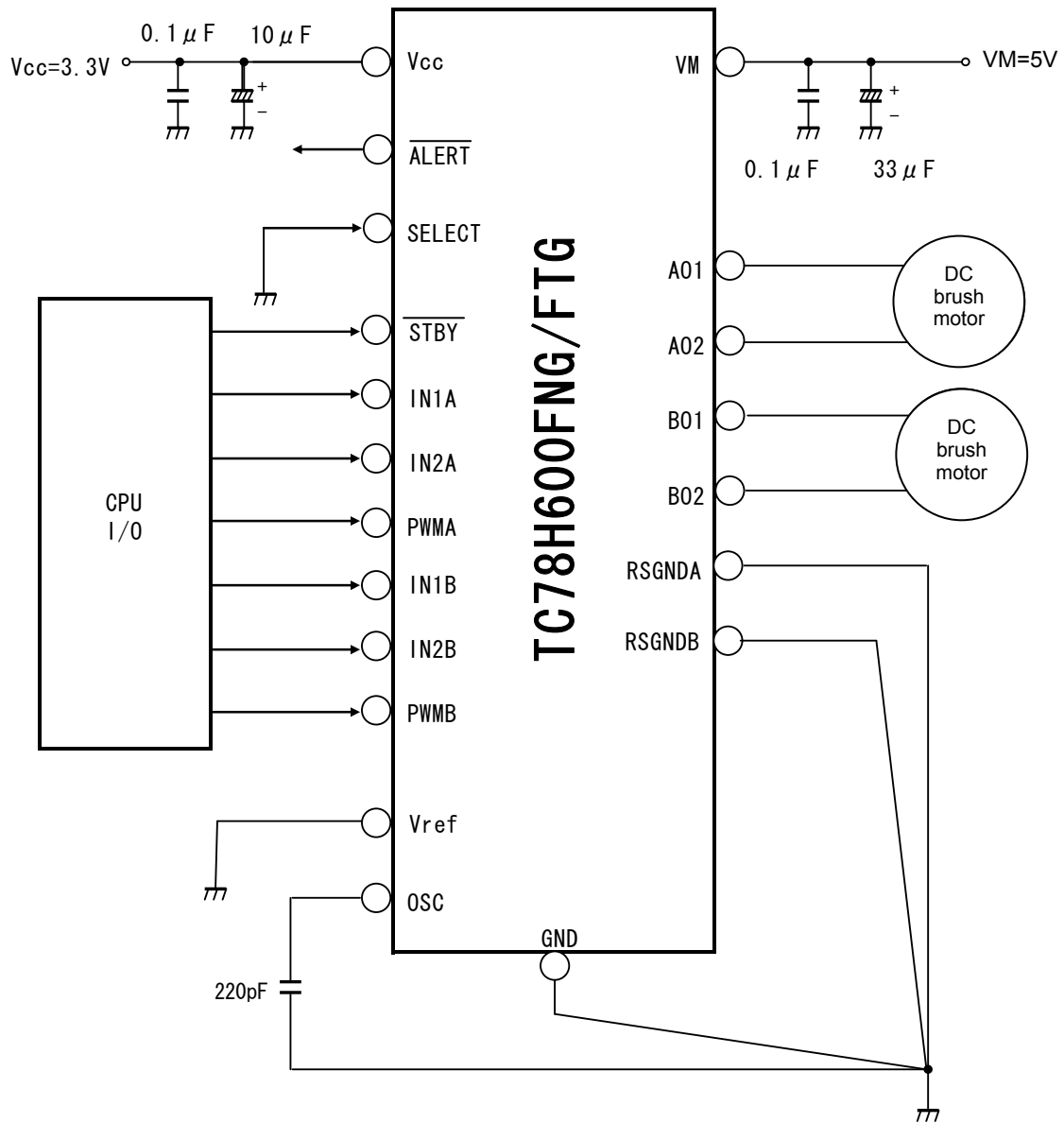
The output transistors are automatically turned on when  $V_M$  increases past the lockout threshold, which is raised to 2.1 V (typ.) by a hysteresis of 0.1 V (typ.).

State of the internal IC and output state when UVLO function operates are same as that of the stop mode ( $IN1=IN2=L$ ).

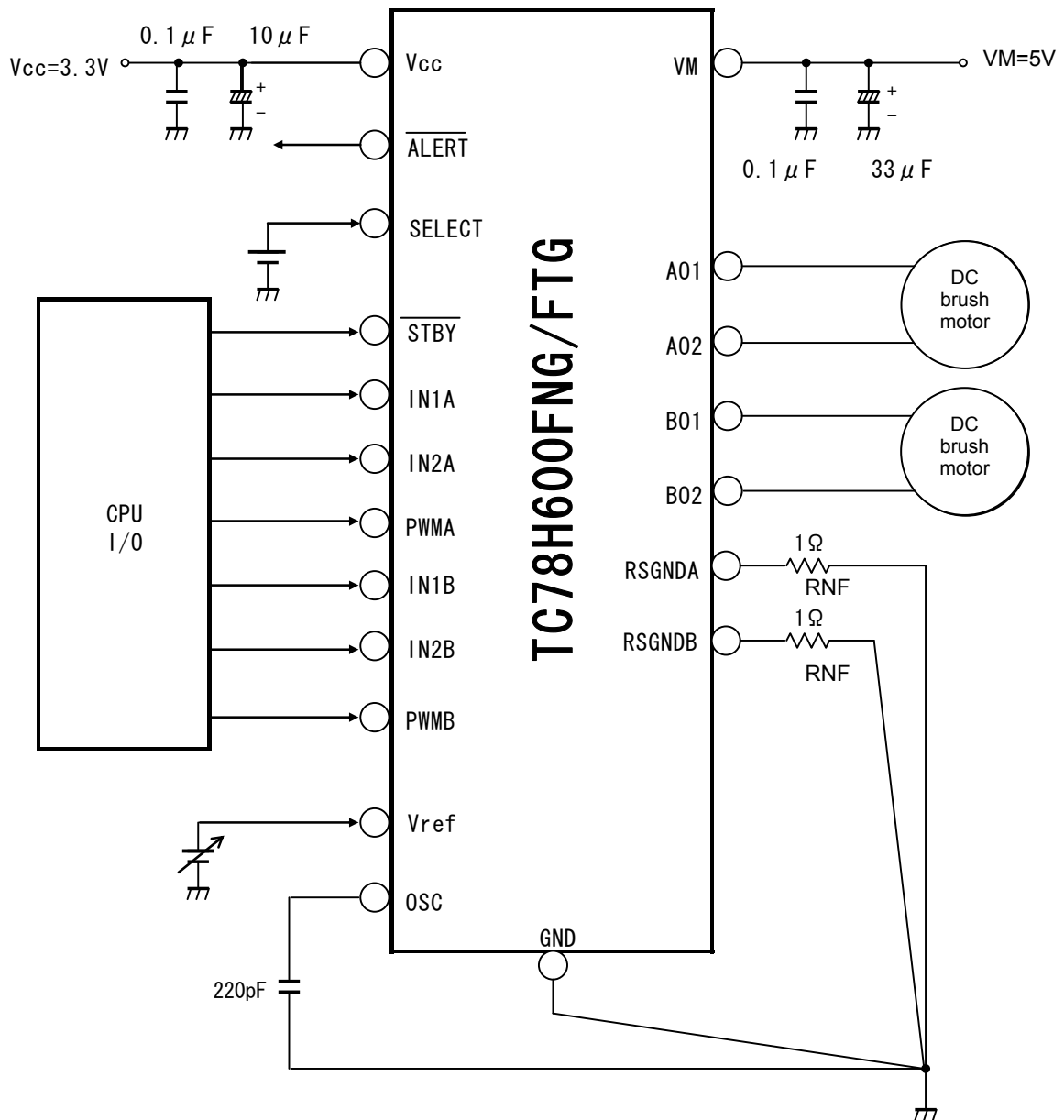


**Application circuit**

(1) Direct PWM



(2) Constant current PWM



Note 1: A power supply capacitor should be connected as close as possible to the IC.

Note 2: When the power is turned on and off, set IN1 and IN2 for low. If IN1 and IN2 are set high in turning on and off the power, unexpected current may be flown in the output pin depending on the situation.

**Caution for using**

Utmost care is necessary in the design of the output, V<sub>CC</sub>, 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.

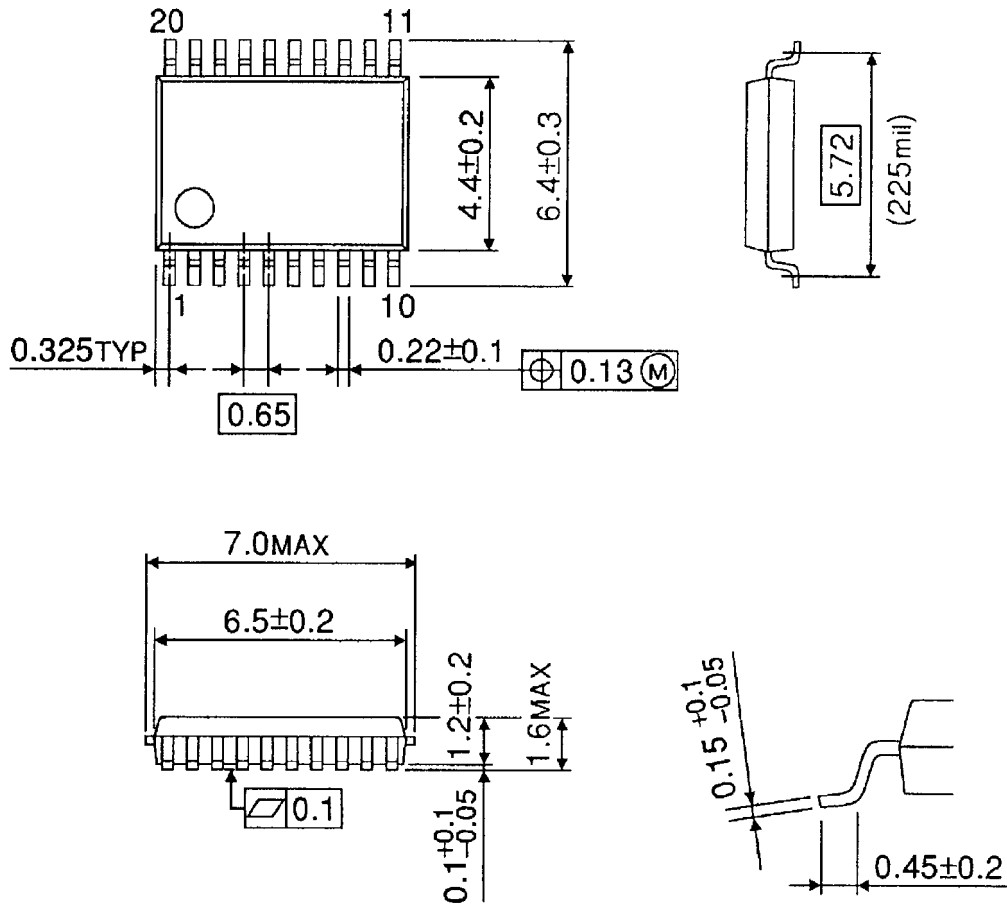
Especially, power supply pins (V<sub>CC</sub>, VM) and output pins (AO1, AO2, BO1, and BO2) might destroy the IC and the peripheral parts, cause smoke and ignition, and also do injury when they short-circuit an adjacent pin and other pins.

The IC may be destroyed when mounted in the wrong orientation. Thus, please mount it with great care. Please use the power supply fuse.

## Package Dimensions

SSOP20-P-225-0.65A

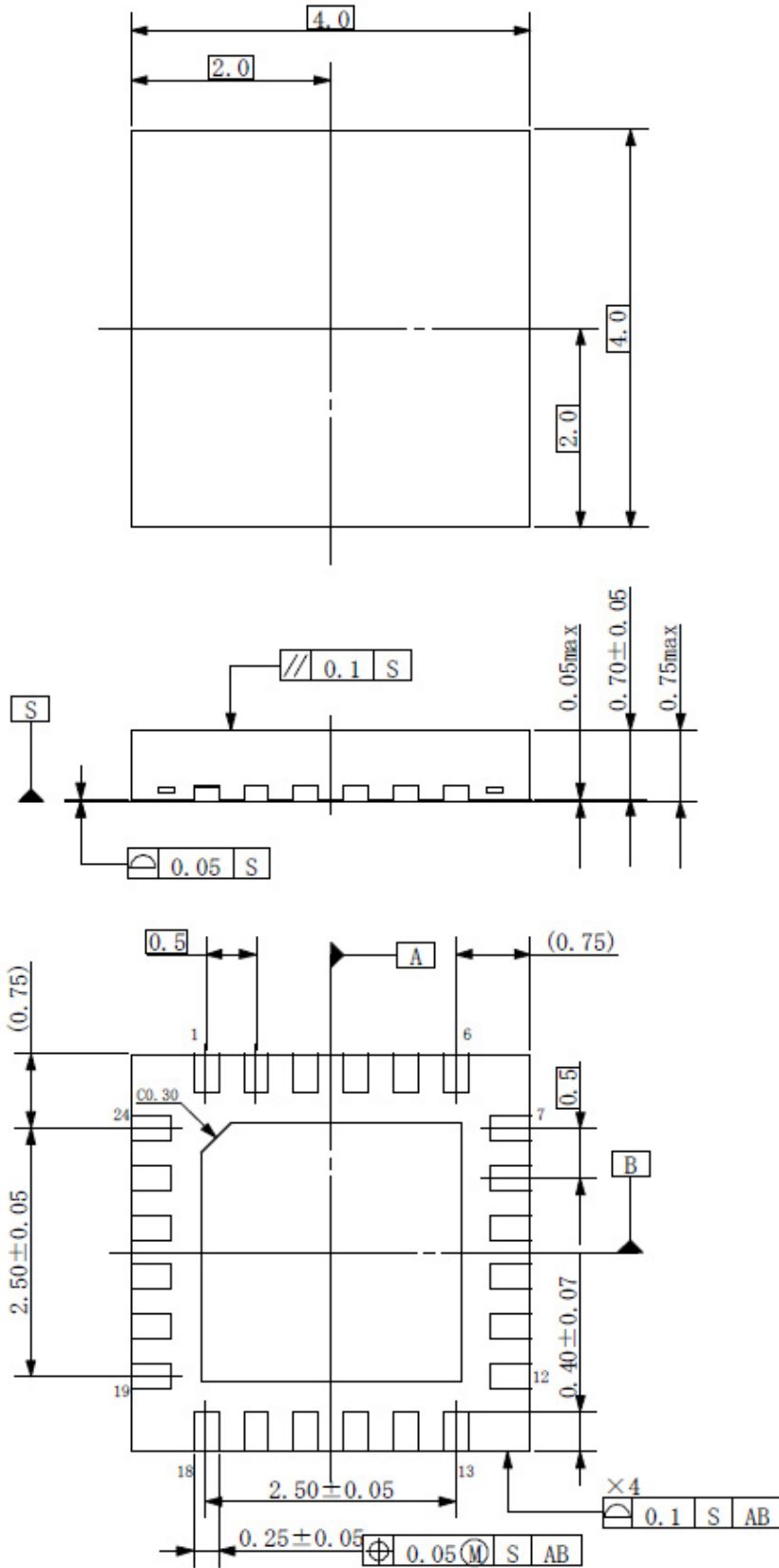
Unit : mm



Weight: 0.09g (typ.)

P-WQFN24-0404-0.50-004

Unit: mm



Weight: 0.03g (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 absolute maximum ratings. To avoid this problem, take the effect of back-EMF into consideration in system design.

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