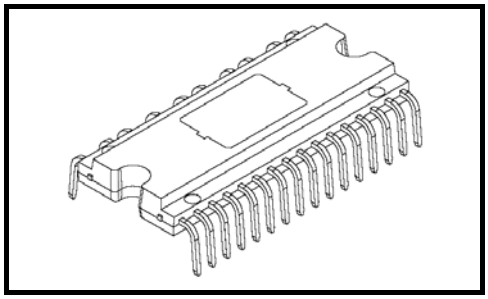
TOSHIBA Intelligent Power Device High Voltage Monolithic Silicon Power IC

# TPD4123AK

The TPD4123AK is a DC brush less motor driver using high voltage PWM control. It is fabricated by high voltage SOI process. It is 3-shunt type. It contains level shift high-side driver, low-side driver, IGBT outputs, FRDs and protective functions for under voltage protection circuits and thermal shutdown circuit. It is easy to control a DC brush less motor by just putting logic inputs from a MPU or motor controller to the TPD4123AK.



Weight
**HDIP26-P-1332-2.0** : 3.8 g (typ.)

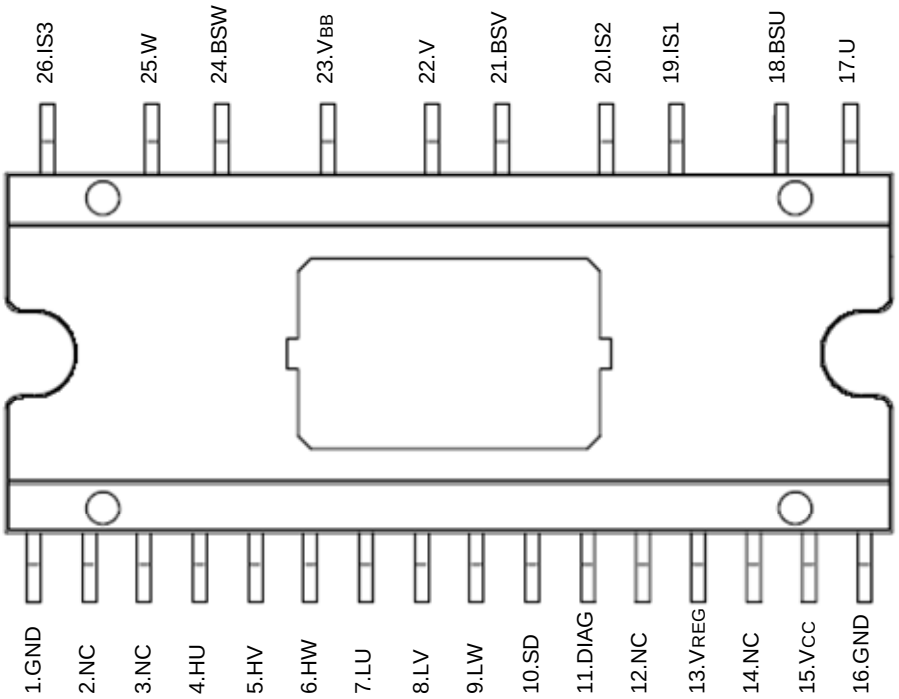
## Features

- Bootstrap circuits give simple high-side supply.
- Bootstrap diodes are built in.
- A dead time can be set as a minimum of 1.4 μs, and it is the best for a Sine-wave from drive.
- 3-phase bridge output using IGBTs.
- FRDs are built in.
- Included under voltage protection and thermal shutdown.
- The regulator of 7V (typ.) is built in.
- Package: 26-pin DIP.

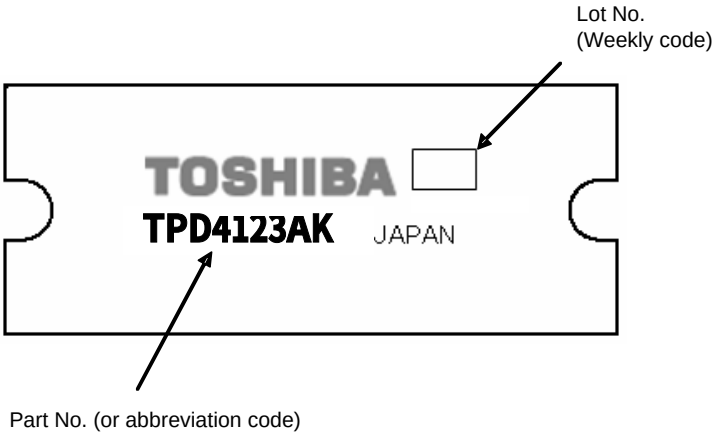
This product has a MOS structure and is sensitive to electrostatic discharge. When handling this product, ensure that the environment is protected against electrostatic discharge.

**This material is technological examination material to aim at the product introduction. The change in the content of the characteristic might be accompanied at the final specification process. The final specification will be able to be gotten in the brokerage department when the product is designed and to get the confirmation.**

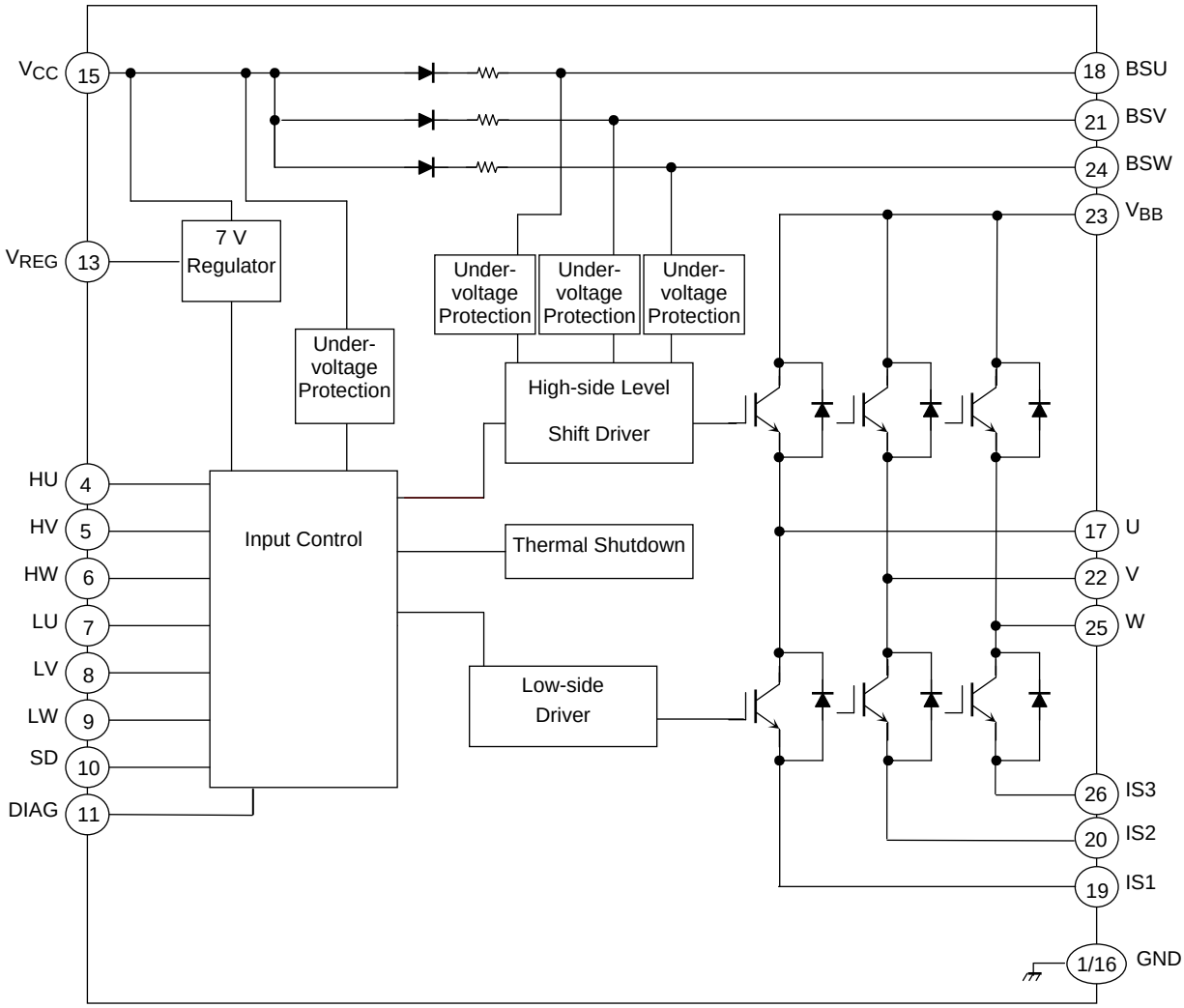
## Pin Assignment




## Marking



## Block Diagram

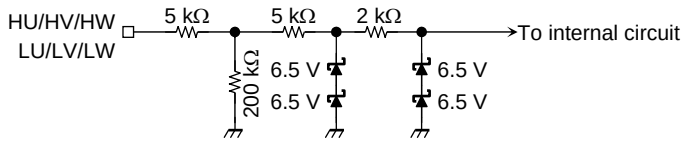


## Pin Description

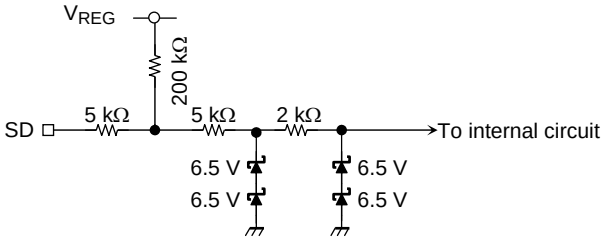
| Pin No. | Symbol | Pin Description |
|---|---|---|
| 1 | GND | Ground pin. |
| 2 | NC | Unused pin, which is not connected to the chip internally. |
| 3 | NC | Unused pin, which is not connected to the chip internally. |
| 4 | HU | The control terminal of IGBT by the side of U top arm. It turns off less than by 1.5V.<br>It turns on more than by 3.5V. |
| 5 | HV | The control terminal of IGBT by the side of V top arm. It turns off less than by 1.5V.<br>It turns on more than by 3.5V. |
| 6 | HV | The control terminal of IGBT by the side of W top arm. It turns off less than by 1.5V.<br>It turns on more than by 3.5V. |
| 7 | HV | The control terminal of IGBT by the side of U bottom arm. It turns off less than by 1.5V.<br>It turns on more than by 3.5V. |
| 8 | HV | The control terminal of IGBT by the side of V bottom arm. It turns off less than by 1.5V.<br>It turns on more than by 3.5V. |
| 9 | HV | The control terminal of IGBT by the side of W bottom arm. It turns off less than by 1.5V.<br>It turns on more than by 3.5V. |
| 10 | SD | Input pin of external protection. (“L” active, No input hysteresis) |
| 11 | DIAG | With the diagnostic output terminal of open drain , a pull-up is carried out by resistance.<br>It turns it on at the time of unusual. |
| 12 | NC | Unused pin, which is not connected to the chip internally. |
| 13 | $V_{REG}$ | 7V regulator output pin. |
| 14 | NC | Unused pin, which is not connected to the chip internally. |
| 15 | $V_{CC}$ | Control power supply pin.(15V typ.) |
| 16 | GND | Ground pin. |
| 17 | U | U-phase output pin. |
| 18 | BSU | U-phase bootstrap capacitor connecting pin. |
| 19 | IS1 | U-phase IGBT emitter and FRD anode pin. |
| 20 | IS2 | V-phase IGBT emitter and FRD anode pin. |
| 21 | BSV | V-phase bootstrap capacitor connecting pin. |
| 22 | V | V-phase output pin. |
| 23 | $V_{BB}$ | High-voltage power supply input pin. |
| 24 | BSW | W-phase bootstrap capacitor connecting pin. |
| 25 | W | W-phase output pin. |
| 26 | IS3 | W-phase IGBT emitter and FRD anode pin. |

## Equivalent Circuit of Input Pins

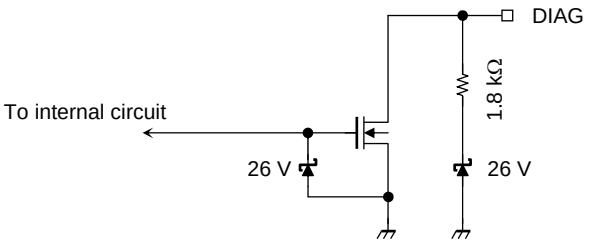
### Internal circuit diagram of HU, HV, HW, LU, LV, LW input pins



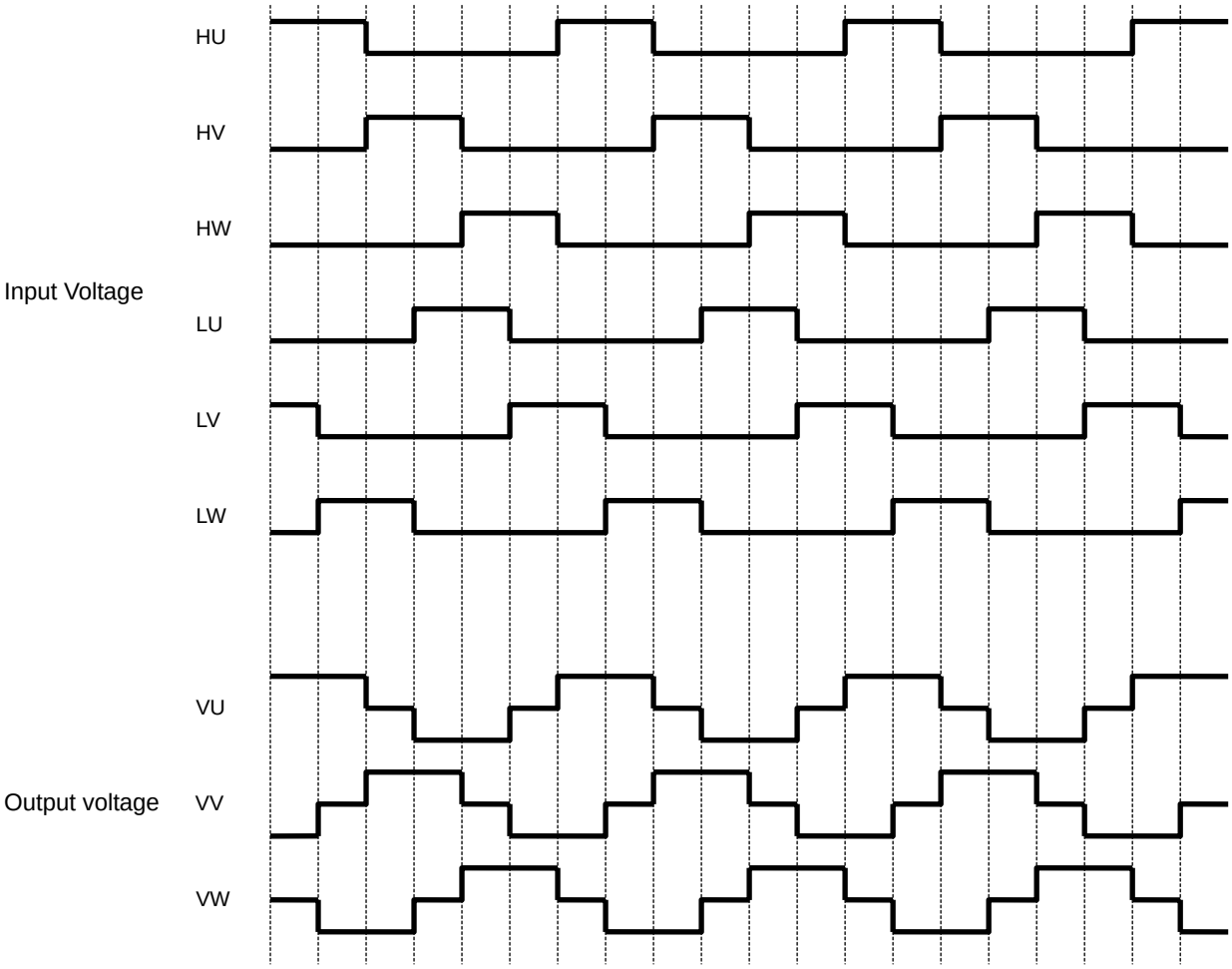

### Internal circuit diagram of SD pin




### Internal circuit diagram of DIAG pin



## Timing Chart



## Truth Table

| Mode | Input | | | | | | | Top arm | | | Bottom arm | | | DIAG |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | HU | HV | HW | LU | LV | LW | SD | U phase | V phase | W phase | U phase | V phase | W phase | |
| Normal | H | L | L | L | H | L | H | ON | OFF | OFF | OFF | ON | OFF | OFF |
| | H | L | L | L | L | H | **H** | ON | OFF | OFF | OFF | OFF | ON | OFF |
| | L | H | L | L | L | H | H | OFF | ON | OFF | OFF | OFF | ON | OFF |
| | L | H | L | H | L | L | H | OFF | ON | OFF | ON | OFF | OFF | OFF |
| | L | L | H | H | L | L | H | OFF | OFF | ON | ON | OFF | OFF | OFF |
| | L | L | H | L | H | L | H | OFF | OFF | ON | OFF | ON | OFF | OFF |
| Thermal shutdown | H | L | L | L | H | L | H | OFF | OFF | OFF | OFF | OFF | OFF | ON |
| | H | L | L | L | L | H | H | OFF | OFF | OFF | OFF | OFF | OFF | ON |
| | L | H | L | L | L | H | H | OFF | OFF | OFF | OFF | OFF | OFF | ON |
| | L | H | L | H | L | L | H | OFF | OFF | OFF | OFF | OFF | OFF | ON |
| | L | L | H | H | L | L | H | OFF | OFF | OFF | OFF | OFF | OFF | ON |
| | L | L | H | L | H | L | H | OFF | OFF | OFF | OFF | OFF | OFF | ON |
| $V_{CC}$ Under-voltage | H | L | L | L | H | L | H | OFF | OFF | OFF | OFF | OFF | OFF | ON |
| | H | L | L | L | L | H | H | OFF | OFF | OFF | OFF | OFF | OFF | ON |
| | L | H | L | L | L | H | H | OFF | OFF | OFF | OFF | OFF | OFF | ON |
| | L | H | L | H | L | L | H | OFF | OFF | OFF | OFF | OFF | OFF | ON |
| | L | L | H | H | L | L | H | OFF | OFF | OFF | OFF | OFF | OFF | ON |
| | L | L | H | L | H | L | H | OFF | OFF | OFF | OFF | OFF | OFF | ON |
| $V_{BS}$ Under-voltage | H | L | L | L | H | L | H | OFF | OFF | OFF | OFF | ON | OFF | OFF |
| | H | L | L | L | L | H | H | OFF | OFF | OFF | OFF | OFF | ON | OFF |
| | L | H | L | L | L | H | H | OFF | OFF | OFF | OFF | OFF | ON | OFF |
| | L | H | L | H | L | L | H | OFF | OFF | OFF | ON | OFF | OFF | OFF |
| | L | L | H | H | L | L | H | OFF | OFF | OFF | ON | OFF | OFF | OFF |
| | L | L | H | L | H | L | H | OFF | OFF | OFF | OFF | ON | OFF | OFF |
| **S D** | * | * | * | * | * | * | L | OFF | OFF | OFF | OFF | OFF | OFF | ON |

Notes: Release of thermal shutdown protection and under voltage protection is based on a self-return.
An output is turned off when SD terminal is detected . This state is latched and is canceled by input ALL"L."

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

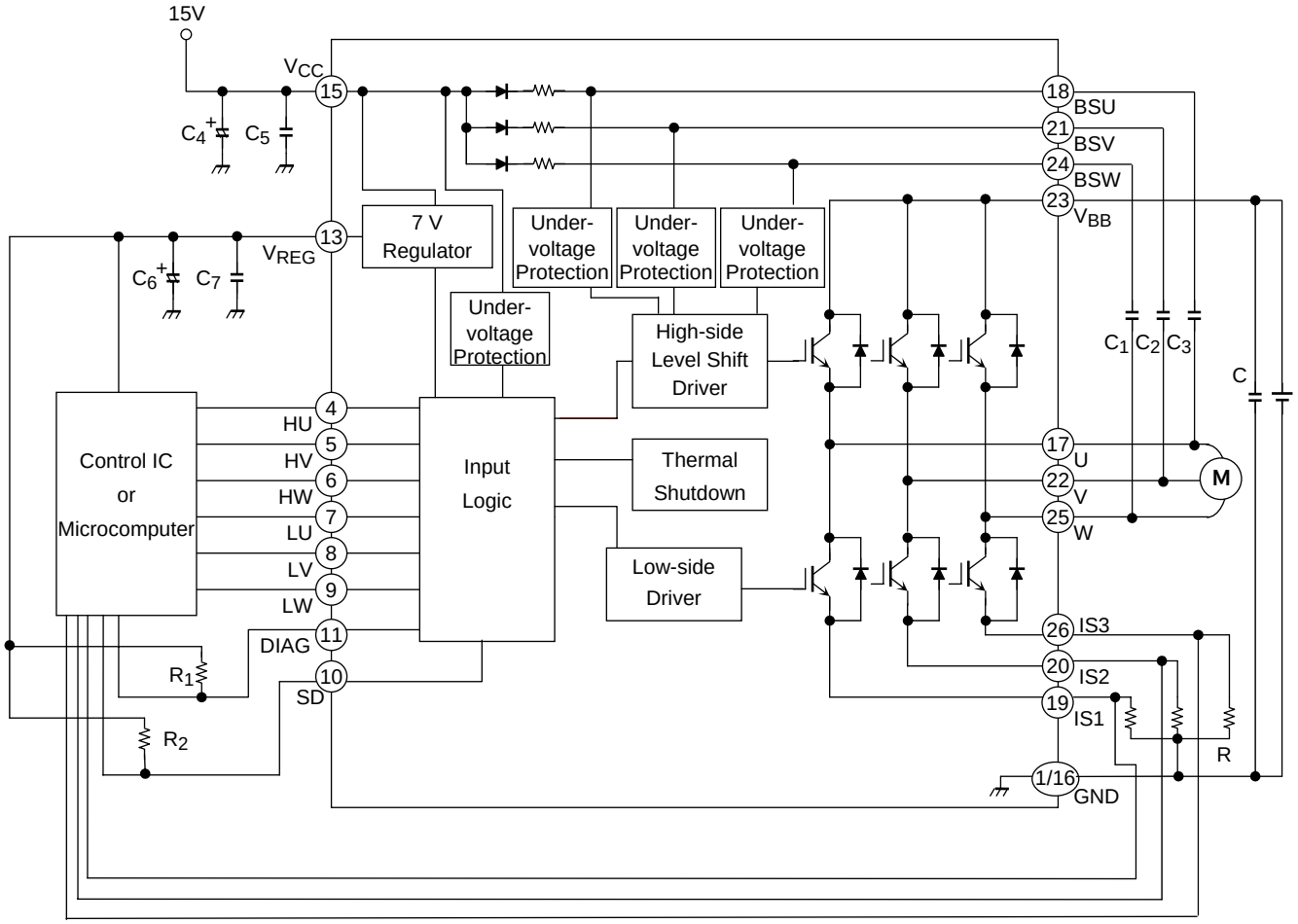
| Characteristics | Symbol | Rating | Unit |
|---|---|---|---|
| Power supply voltage | $V_{BB}$ | 500 | V |
| | $V_{CC}$ | 18 | V |
| Output current (DC) | $I_{out}$ | 1 | A |
| Output current (pulse) | $I_{out}$ | 2 | A |
| Input voltage | $V_{IN}$ | -0.5~7 | V |
| $V_{REG}$ current | $I_{REG}$ | 50 | mA |
| Power dissipation (Tc = 25°C ) | $P_C$ | 23 | W |
| Operating temperature | $T_{jopr}$ | -40~135 | °C |
| Junction temperature | $T_j$ | 150 | °C |
| Storage temperature | $T_{stg}$ | -55~150 | °C |

Note: Using continuously under heavy loads (e.g. the application of high temperature/current/voltage and the significant change in temperature, etc.) may cause this product to decrease in the reliability significantly even if the operating conditions (i.e. operating temperature/current/voltage, etc.) are within the absolute maximum ratings and the operating ranges.
Please design the appropriate reliability upon reviewing the Toshiba Semiconductor Reliability Handbook (“Handling Precautions”/Derating Concept and Methods) and individual reliability data (i.e. reliability test report and estimated failure rate, etc).

## Electrical Characteristics (Ta = 25°C)

| Characteristics | Symbol | Test Condition | Min | Typ. | Max | Unit |
|---|---|---|---|---|---|---|
| Operating power supply voltage | $V_{BB}$ | — | 50 | 280 | 450 | V |
| | $V_{CC}$ | — | 13.5 | 15 | 16.5 | |
| Current dissipation | $I_{BB}$ | $V_{BB}$ = 450V | — | — | 0.5 | mA |
| | $I_{CC}$ | $V_{CC}$ = 15 V | — | 1.0 | 5 | |
| | $I_{BS\ (ON)}$ | $V_{BS}$ = 15 V, high side ON | — | 260 | 410 | μA |
| | $I_{BS\ (OFF)}$ | $V_{BS}$ = 15 V, high side OFF | — | 230 | 370 | |
| Input voltage | $V_{IH}$ | $V_{IN}$ = “H”, $V_{CC}$ = 15 V | 2.5 | — | — | V |
| | $V_{IL}$ | $V_{IN}$ = “L” , $V_{CC}$ = 15 V | — | — | 1.5 | |
| SD input voltage | $V_{SD}$ | $V_{CC}$ = 15 V | — | 2.5 | — | V |
| Input current | $I_{IH}$ | $V_{IN}$ = 5 V | — | — | 150 | μA |
| | $I_{IL}$ | $V_{IN}$ = 0 V | — | — | 100 | |
| SD Input current | $I_{SDR}$ | $V_{IN}$ = 5 V | — | — | 100 | μA |
| | $I_{SDR}$ | $V_{IN}$ = 0 V | — | — | 150 | |
| Output saturation voltage | $V_{CEsat}H$ | $V_{CC}$ = 15 V, $I_C$ = 0.5 A | — | 2.4 | 3 | V |
| | $V_{CEsat}L$ | $V_{CC}$ = 15 V, $I_C$ = 0.5 A | — | 2.4 | 3 | |
| FRD forward voltage | $V_F H$ | $I_F$ = 0.5 A, high side | — | 1.6 | 2.0 | V |
| | $V_F L$ | $I_F$ = 0.5 A, low side | — | 1.6 | 2.0 | |
| BSD forward voltage | $V_{F\ (BSD)}$ | $I_F$ = 500 μA | — | 0.9 | 1.2 | V |
| Regulator voltage | $V_{REG}$ | $V_{CC}$ = 15 V, $I_O$ = 30 mA | 6.5 | 7 | 7.5 | V |
| Thermal shutdown temperature | TSD | $V_{CC}$ = 15 V | 135 | — | 185 | °C |
| Thermal shutdown hysteresis | ΔTSD | $V_{CC}$ = 15 V | — | 50 | — | °C |
| $V_{CC}$ under voltage protection | $V_{CC}UVD$ | — | 10 | 11 | 12 | V |
| $V_{CC}$ under voltage protection recovery | $V_{CC}UVR$ | — | 10.5 | 11.5 | 12.5 | V |
| $V_{BS}$ under voltage protection | $V_{BS}UVD$ | — | 8 | 9 | 9.5 | V |
| $V_{BS}$ under voltage protection recovery | $V_{BS}UVR$ | — | 8.5 | 9.5 | 10.5 | V |
| DIAG saturation voltage | $V_{DIAGsat}$ | $I_{DIAG}$ = 5 mA | — | — | 0.5 | V |
| Output on delay time | $t_{on}$ | $V_{BB}$ = 280 V, $V_{CC}$ = 15 V, $I_C$ = 0.5 A | — | 1.5 | 3 | μs |
| Output off delay time | $t_{off}$ | $V_{BB}$ = 280 V, $V_{CC}$ = 15 V, $I_C$ = 0.5 A | — | 1.2 | 3 | μs |
| Dead time | $t_{dead}$ | $V_{BB}$ = 280 V, $V_{CC}$ = 15 V, $I_C$ = 0.5 A | 1.4 | — | — | μs |
| FRD reverse recovery time | $t_{rr}$ | $V_{BB}$ = 280 V, $V_{CC}$ = 15 V, $I_C$ = 0.5 A | — | 200 | — | ns |

## Application Circuit Example



## External Parts

Typical external parts are shown in the following table.

| Part | Typical | Purpose | Remarks |
|---|---|---|---|
| $C_1$, $C_2$, $C_3$ | 25 V/2.2 μF | Bootstrap capacitor | (Note 1) |
| $C_4$ | 25 V/10 μF | $V_{CC}$ power supply stability | (Note 2) |
| $C_5$ | 25 V/0.1μF | $V_{CC}$ for surge absorber | (Note 2) |
| $C_6$ | 25 V/1 μF | $V_{REG}$ power supply stability | (Note 2) |
| $C_7$ | 25 V/1000 pF | $V_{REG}$ for surge absorber | (Note 2) |
| $R_1$ | 5.1 kΩ | DIAG pin pull-up resistor | (Note 3) |
| $R_2$ | 10 kΩ | SD pin pull-up resistor | |

Note 1: The required bootstrap capacitance value varies according to the motor drive conditions. The capacitor is biased by $V_{CC}$ and must be sufficiently derated for it.

Note 2: When using this product, adjustment is required in accordance with the use environment. When mounting, place as close to the base of this product leads as possible to improve the ripple and noise elimination.

Note 3: The DIAG pin is open drain. If not using the DIAG pin, connect to the GND.

## Handling precautions

(1) Please control the input signal in the state to which the $V_{CC}$ voltage is steady. Both of the order of the $V_{BB}$ power supply and the $V_{CC}$ power supply are not cared about either.
Note that if the power supply is switched off as described above, this product may be destroyed if the current regeneration route to the $V_{BB}$ power supply is blocked when the $V_{BB}$ line is disconnected by a relay or similar while the motor is still running.

(2) The excess voltage such as the voltage surge which exceed the maximum rating is added, for example, may destroy the circuit. Accordingly, be careful of handling this product or of surge voltage in its application environment.

## Description of Protection Function

(1) Under voltage protection

This product incorporates the under voltage protection circuit to prevent the IGBT from operating in unsaturated mode when the $V_{CC}$ voltage or the $V_{BS}$ voltage drops.

When the $V_{CC}$ power supply falls to this product internal setting $V_{CC}$UVD (= 11 V typ.), all IGBT outputs shut down regardless of the input. This protection function has hysteresis. When the $V_{CC}$UVR (= 11.5 V typ.) reaches 0.5 V higher than the shutdown voltage, this product is automatically restored and the IGBT is turned on again by the input.

When the $V_{BS}$ supply voltage drops $V_{BS}$UVD (= 9 V typ.), the high-side IGBT output shuts down. When the $V_{BS}$UVR (= 9.5 V typ.) reaches 0.5 V higher than the shutdown voltage, the IGBT is turned on again by the input signal.

(2) Thermal shutdown

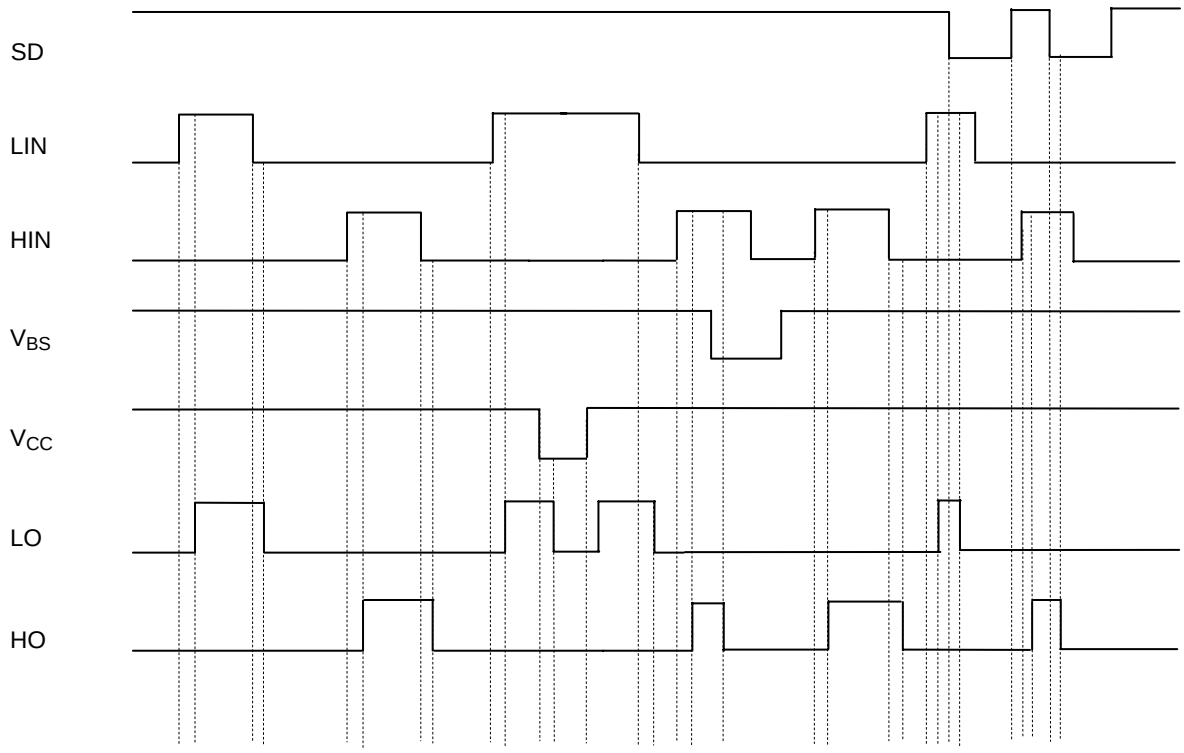
This product incorporates the thermal shutdown circuit to protect itself against the abnormal state when its temperature rises excessively.

When the temperature of this chip rises to the internal setting TSD due to external causes or internal heat generation , all IGBT outputs shut down regardless of the input. This protection function has hysteresis ΔTSD (= 50°C typ.). When the chip temperature falls to TSD − ΔTSD, the chip is automatically restored and the IGBT is turned on again by the input.

Because the chip contains just one temperature detection location, when the chip heats up due to the IGBT, for example, the differences in distance from the detection location in the IGBT (the source of the heat) cause differences in the time taken for shutdown to occur. Therefore, the temperature of the chip may rise higher than the thermal shutdown temperature when the circuit started to operate.

(3) SD pin

SD pin is the input signal pin to shut down the internal output IGBT. Output of all IGBT is shuted down after delay times (2μs(typ.)) when "L" signal is inputed to the SD pin from external circuit(MCU etc.). It is possible to shut down IC when overcurrent and others is detected by external circuit. Shut down state is released by all of IC input signal "L". At open state of SD pin, shut down function can not operate.



## Safe Operating Area

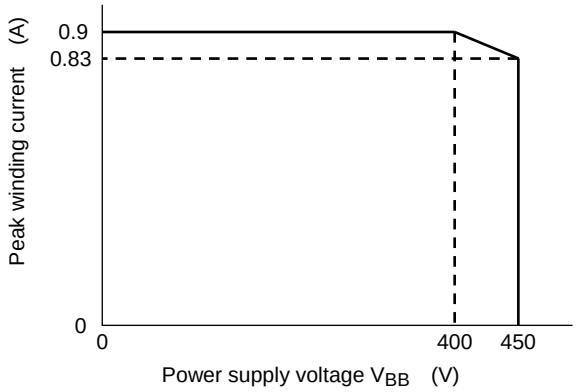
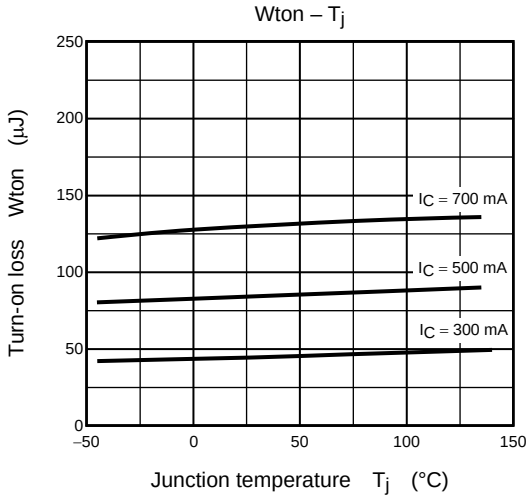
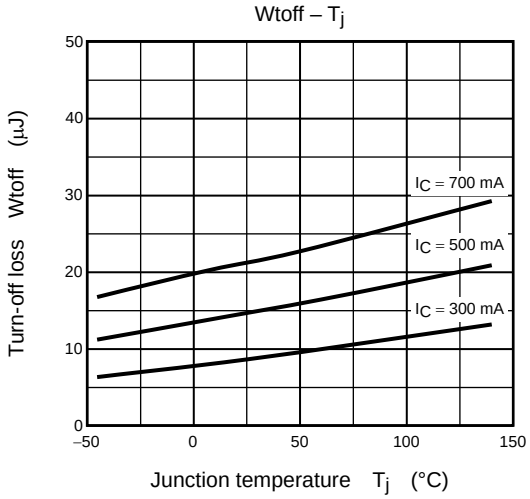


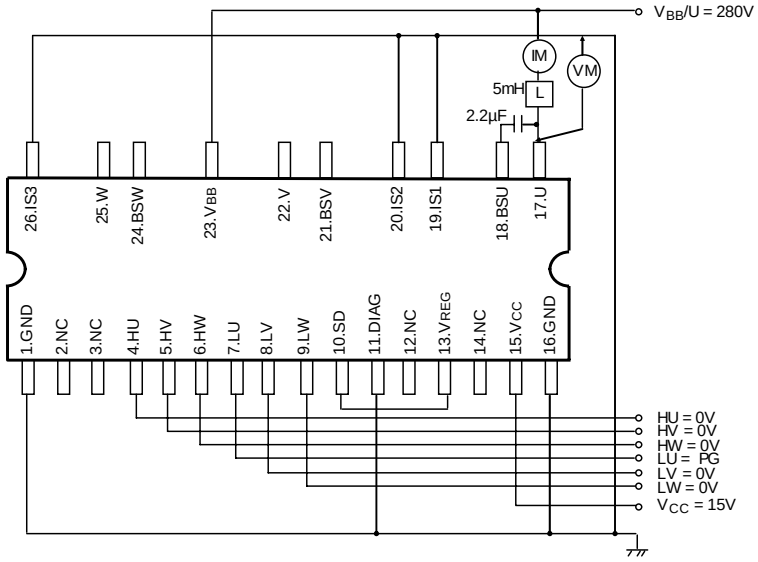

Figure 1 SOA at Tj = 135°C

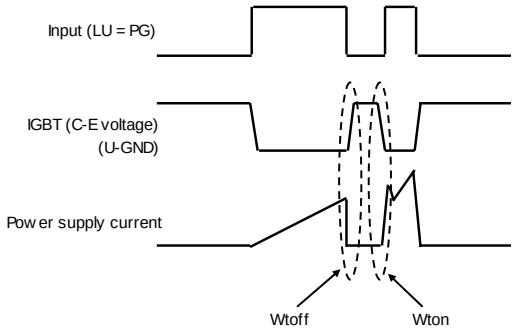
Note 1: The above safe operating areas are Tj = 135°C (Figure 1).



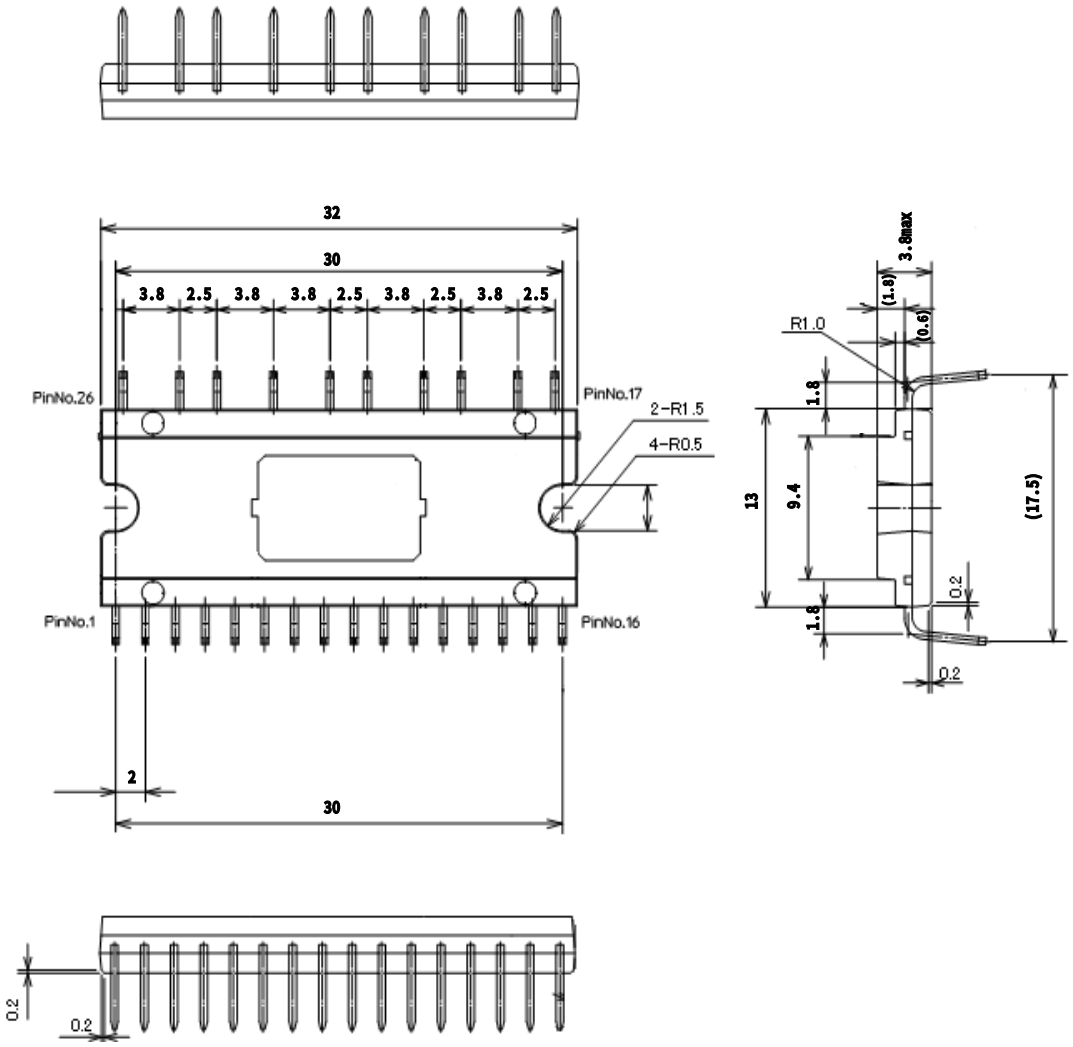

## Turn-On/Off Loss (low side IGBT + high side FRD)



## Package Dimensions

**HDIP26-P-1332-2.0** **Unit:mm**




Weight: 3.8 g (typ.)

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