

Intelligent Power Device

# TPD4164F

High Voltage Monolithic Silicon Power IC

## 1. Description

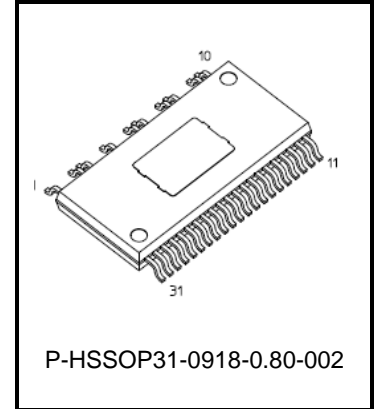
The TPD4164F is a DC brush less motor driver using high voltage PWM control. It is fabricated by high voltage SOI process. It is three-shunt resistor circuit for current sensing. It contains level shift high-side driver, low-side driver, IGBT outputs, FRDs and protective functions for over-current circuit and 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 MCU or motor controller to the TPD4164F.

## 2. Applications

DC brushless motor driver IC

## 3. Features

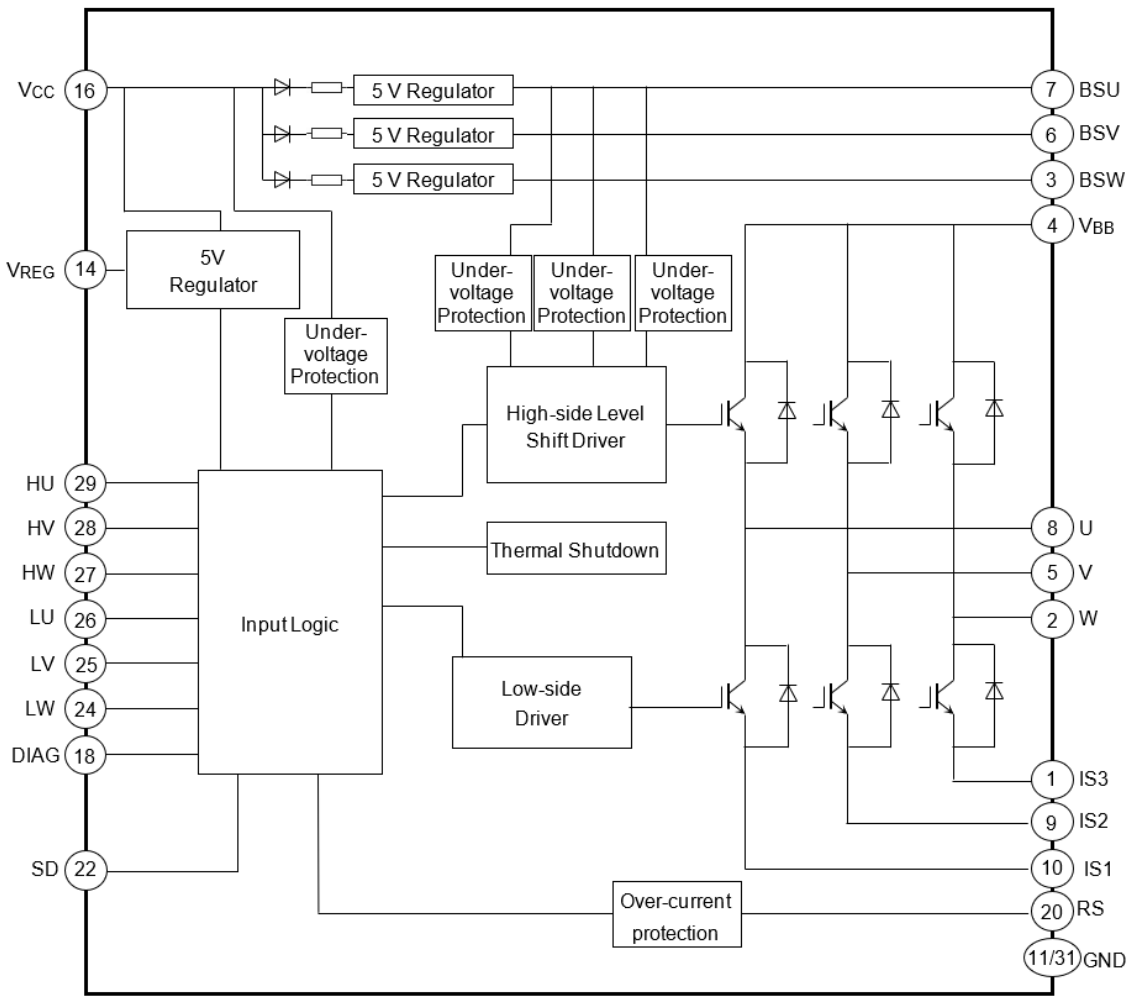
- High voltage power side and low voltage signal side terminal are separated.
- It is the best for current sensing in three shunt resistance.
- Bootstrap circuit gives simple high-side supply.
- Bootstrap diodes are built in.
- A dead time can be set as a minimum of 1  $\mu$ s, and it is suitable for a Sine-wave from drive.
- 3-phase bridge output using IGBTs.
- Included over-current and under-voltage protection, shutdown function controlled by SD pin, and thermal shutdown.
- The regulator of 5 V (typ.) is built in.
- The package is a surface mount type with 31 pin.



Weight: 0.7 g (typ.)

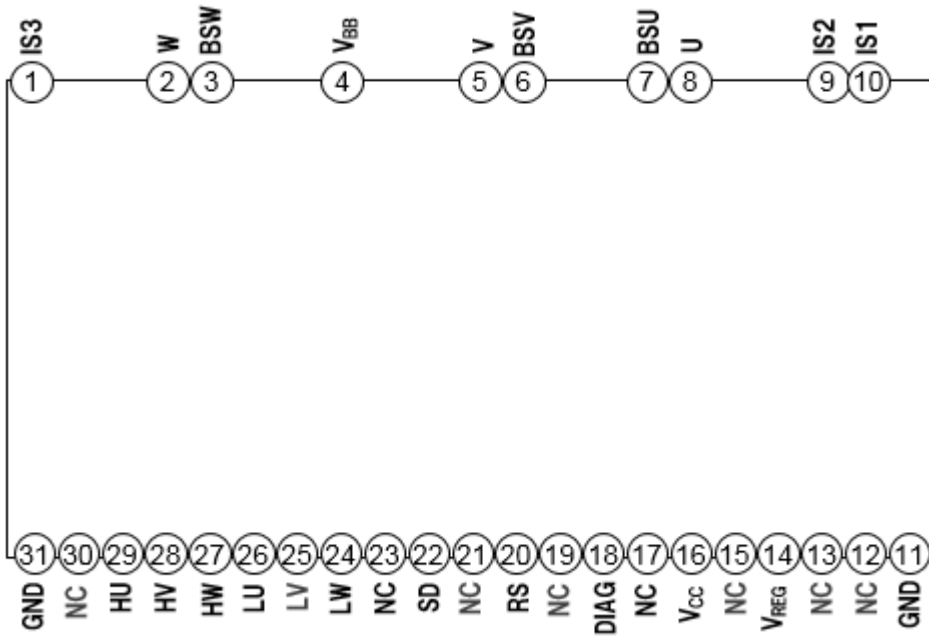
Start of commercial production  
2023-03

**4. Block Diagram**



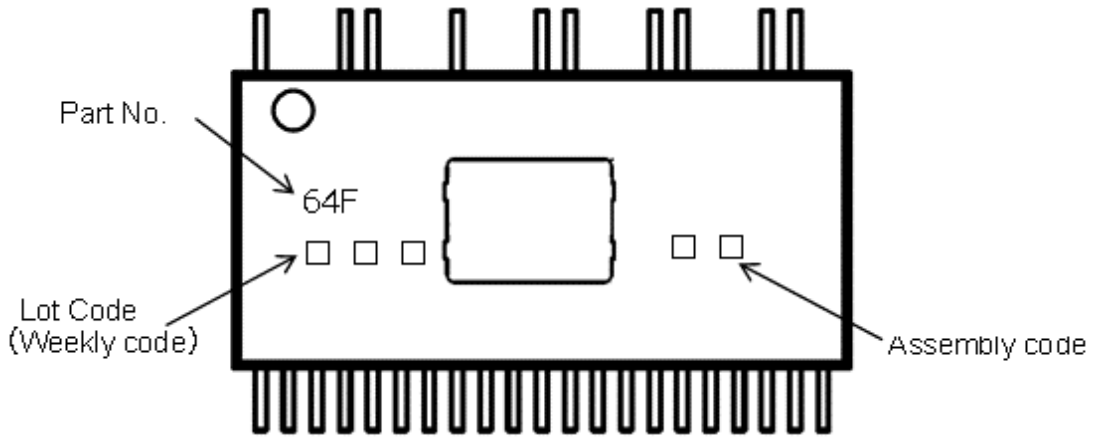
**Figure 4.1 Block Diagram**

**5. Pin Assignments**



**Figure 5.1 Pin Assignments**

**Marking**



**Figure 5.2 Marking**

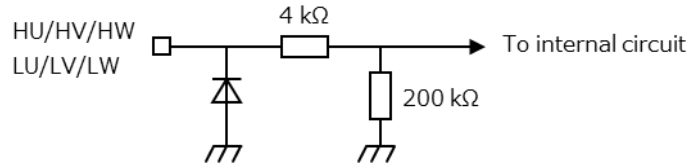
**6. Pin Description**

**Table 6.1 Pin Description**

| Pin No. | Symbol           | Pin Description  |
|---------|------------------|--|
| 1       | IS3              | W-phase IGBT emitter and FRD anode pin.  |
| 2       | W                | W-phase output pin.  |
| 3       | BSW              | W-phase bootstrap capacitor connecting pin.  |
| 4       | V <sub>BB</sub>  | High-voltage power supply input pin.   |
| 5       | V                | V-phase output pin.  |
| 6       | BSV              | V-phase IGBT emitter and FRD anode pin.  |
| 7       | BSU              | U-phase IGBT emitter and FRD anode pin.  |
| 8       | U                | U-phase output pin.  |
| 9       | IS2              | V-phase IGBT emitter and FRD anode pin.  |
| 10      | IS1              | U-phase IGBT emitter and FRD anode pin.  |
| 11      | GND              | Ground pin.  |
| 12      | NC               | Unused pin, which is not connected to the chip internally.   |
| 13      | NC               | Unused pin, which is not connected to the chip internally.   |
| 14      | V <sub>REG</sub> | 5 V regulator output pin.  |
| 15      | NC               | Unused pin, which is not connected to the chip internally.   |
| 16      | V <sub>CC</sub>  | Control power supply pin. (15 V typ.)  |
| 17      | NC               | Unused pin, which is not connected to the chip internally.   |
| 18      | DIAG             | With the diagnostic output terminal of open drain, a pull-up is carried out by resistance. It turns on at the time of unusual. |
| 19      | NC               | Unused pin, which is not connected to the chip internally.   |
| 20      | RS               | Over current detection pin.  |
| 21      | NC               | Unused pin, which is not connected to the chip internally.   |
| 22      | SD               | Input pin of external protection. ("L" active, It doesn't have hysteresis.)  |
| 23      | NC               | Unused pin, which is not connected to the chip internally.   |
| 24      | LW               | The control terminal of IGBT by the low side of W. It turns off less than 1.5 V. It turns on more than 2.5 V.                  |
| 25      | LV               | The control terminal of IGBT by the low side of V. It turns off less than 1.5 V. It turns on more than 2.5 V.                  |
| 26      | LU               | The control terminal of IGBT by the low side of U. It turns off less than 1.5 V. It turns on more than 2.5 V.                  |
| 27      | HW               | The control terminal of IGBT by the high side of W. It turns off less than 1.5 V. It turns on more than 2.5 V.                 |
| 28      | HV               | The control terminal of IGBT by the high side of V. It turns off less than 1.5 V. It turns on more than 2.5 V.                 |
| 29      | HU               | The control terminal of IGBT by the high side of U. It turns off less than 1.5 V. It turns on more than 2.5 V.                 |
| 30      | NC               | Unused pin, which is not connected to the chip internally.   |
| 31      | GND              | Ground pin.  |

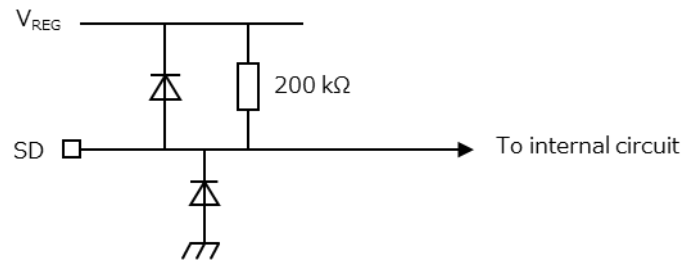
## Equivalent circuit of input and output pins

### HU, HV, HW, LU, LV, LW input pins



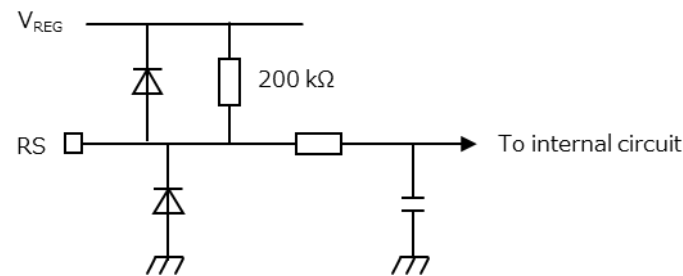
**Figure 6.1 Equivalent circuit (1)**

### SD input pin



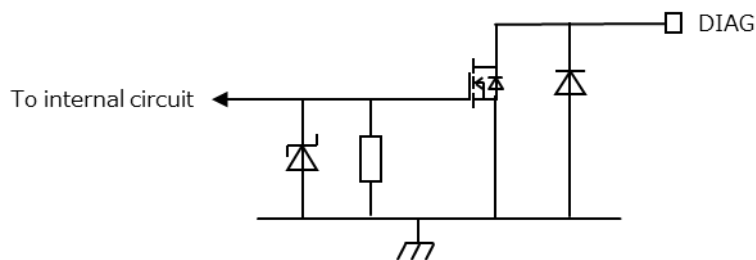
**Figure 6.2 Equivalent circuit (2)**

### RS input pin



**Figure 6.3 Equivalent circuit (3)**

### DIAG output pin



**Figure 6.4 Equivalent circuit (4)**

## 7. Functional Description

### 7.1. Basic Operation

#### 7.1.1. Timing Chart

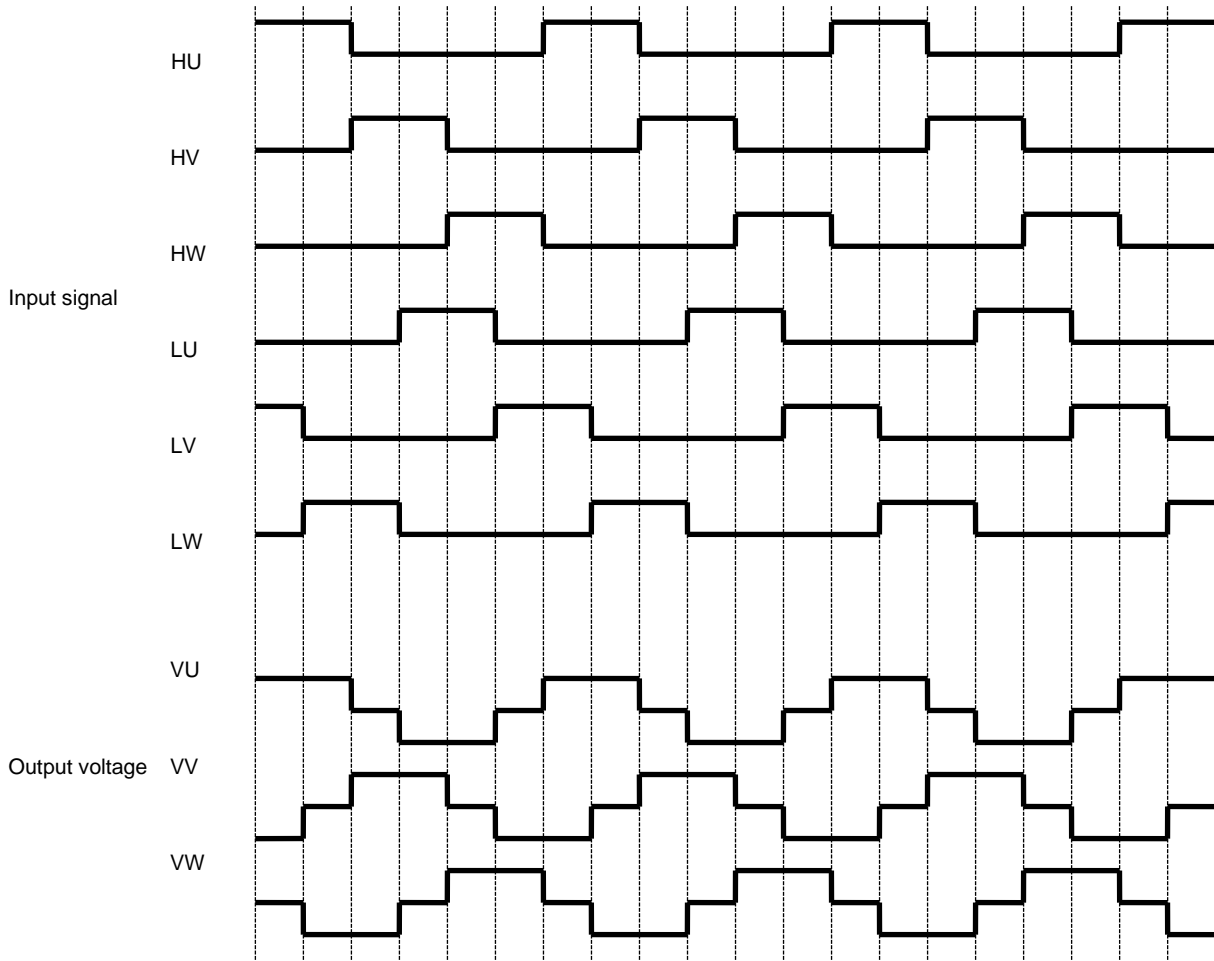


Figure 7.1.1 Timing Chart

## 7.1.2. Truth Table

**Table 7.1.2 Truth Table**

| Mode                          | Input |    |    |    |    |    |    | High side |         |         | Low side |         |         | 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  |
| Over-current                  | 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   |
| 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   |
| Vcc 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 <sub>BS</sub> 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  |
| Irregular (Note)              | H     | L  | L  | H  | L  | L  | H  | OFF       | OFF     | OFF     | OFF      | OFF     | OFF     | OFF  |
|                               | L     | H  | L  | L  | H  | L  | H  | OFF       | OFF     | OFF     | OFF      | OFF     | OFF     | OFF  |
|                               | L     | L  | H  | L  | L  | H  | H  | OFF       | OFF     | OFF     | OFF      | OFF     | OFF     | OFF  |
| SD                            | X     | X  | X  | X  | X  | X  | L  | OFF       | OFF     | OFF     | OFF      | OFF     | OFF     | ON   |

X: Don't care

Note: Each phases of U, V and W turns OFF when the control signals of both high side and low side are "H" at the same time.

(HU = "H" and LU = "H", HV = "H" and LV = "H", or HW = "H" and LW = "H")

## 7.2. Description of Protection Function

- (1) Under voltage protection  
This product incorporates under voltage protection circuits to prevent the IGBT from operating in unsaturated mode when the VCC voltage or the VBS voltage drops.  
When the VCC power supply falls to this product internal setting VCCUVD (=11 V typ.), all IGBT outputs shut down regardless of the input. This protection function has hysteresis. When the VCC power supply reaches 0.5 V higher than the shutdown voltage (VCCUVR (=11.5 V typ.)), this product is automatically restored and the IGBT is turned on again by the input. DIAG output is reversed at the time of VCC under-voltage protection. When the VCC power supply is less than 7 V, DIAG output isn't sometimes reversed. When the VBS supply voltage drops VBSUVD (=3 V typ.), the high-side IGBT output shuts down. When the VBS supply voltage reaches 0.5 V higher than the shutdown voltage (VBSUVR (=3.5V typ.)), the IGBT is turned on again by the input signal.
- (2) Over-current protection  
This product incorporates a over-current protection circuit to protect itself against over-current at startup or when a motor is locked. This protection function detects voltage generated in the current detection resistor connected to the RS pin. When this voltage exceeds VR (=0.5 V typ.), the IGBT output, which is on, temporarily shuts down after a delay time, preventing any additional current from flowing to this product. The next all "L" signal releases the shutdown state.
- (3) Thermal shutdown  
This product incorporates a 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  $\Delta TSD$  (= 50°C typ.). When the chip temperature falls to  $TSD - \Delta TSD$ , 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.
- (4) SD function  
SD pin is the input signal pin to shut down the internal output IGBT. Output of all IGBT is shut down after delay times (2  $\mu$ s (typ.)) when "L" signal is input 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.



**8. Absolute Maximum Ratings**

**Table 8.1 Absolute Maximum Ratings**  
( $T_a = 25^\circ\text{C}$  unless otherwise specified)

| Characteristics  | Symbol        | Rating                   | Unit             |
|--|---------------|--------------------------|------------------|
| Power supply voltage   | $V_{BB}$      | 600                      | V                |
|  | $V_{CC}$      | 20                       | V                |
| Output current (DC)  | $I_{out}$     | 2                        | A                |
| Output current (pulse 1ms)   | $I_{outp}$    | 3                        | A                |
| Bootstrap pin voltage (Note1)                                      | $V_{BSX}$     | 600                      | V                |
|  | $V_{BSX-X}$   | - 0.5 to 6               | V                |
| Input voltage (Note2)  | $V_{IN}$      | - 0.5 to 6               | V                |
| $V_{REG}$ current  | $I_{REG}$     | 50                       | mA               |
| DIAG voltage   | $V_{DIAG}$    | 20                       | V                |
| DIAG current   | $I_{DIAG}$    | 20                       | mA               |
| SD pin voltage   | $V_{SD}$      | - 0.5 to $V_{REG} + 0.5$ | V                |
| RS pin voltage   | $V_{RS}$      | - 0.5 to $V_{REG} + 0.5$ | V                |
| IS pin voltage (Note3)   | $V_{IS}$      | $\pm 0.7$                | V                |
| Power dissipation<br>( IGBT 1-phase ( $T_c = 25^\circ\text{C}$ ) ) | $P_{C(IGBT)}$ | 27                       | W                |
| Power dissipation<br>( FRD 1-phase ( $T_c = 25^\circ\text{C}$ ) )  | $P_{C(FRD)}$  | 9                        | W                |
| Operating junction temperature                                     | $T_{jopr}$    | - 40 to 135              | $^\circ\text{C}$ |
| Junction temperature   | $T_j$         | 150                      | $^\circ\text{C}$ |
| Storage temperature  | $T_{stg}$     | - 55 to 150              | $^\circ\text{C}$ |

Note1:  $V_{BSX-X}$ : BSU-U, BSV-V, BSW-W

Note2:  $V_{IN}$ : HU, HV, HW, LU, LV, LW

Note3: Except for the peak voltage occurred in switching outputs including within the delay time of over current protection.

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

If any of these rating would be exceeded during operation, the device electrical characteristics may be irreparably altered and the reliability and lifetime of the device can no longer be guaranteed. Moreover, these operations with exceeded ratings may cause break down, damage, and/or degradation to any other equipment. Applications using the device should be designed such that each maximum rating will never be exceeded in any operating conditions.

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).

## 9. Operating Ranges

**Table 9.1 Operating Ranges ( $T_a = 25^\circ\text{C}$  unless otherwise specified)**

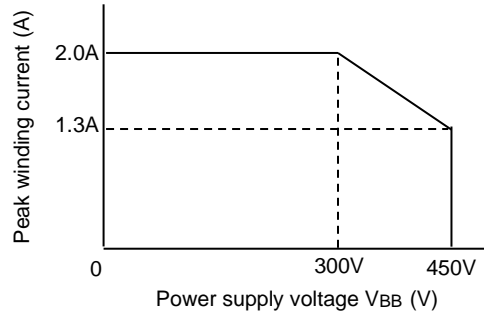
| Characteristics                | Symbol   | Test Condition | Min  | Typ. | Max  | Unit |
|--------------------------------|----------|----------------|------|------|------|------|
| Operating power supply voltage | $V_{BB}$ | —              | 50   | 280  | 450  | V    |
|                                | $V_{CC}$ | —              | 13.5 | 15   | 16.5 |      |

## 10. Electrical Characteristics

**Table 10.1 Electrical Characteristics ( $T_a = 25^\circ\text{C}$  unless otherwise specified)**

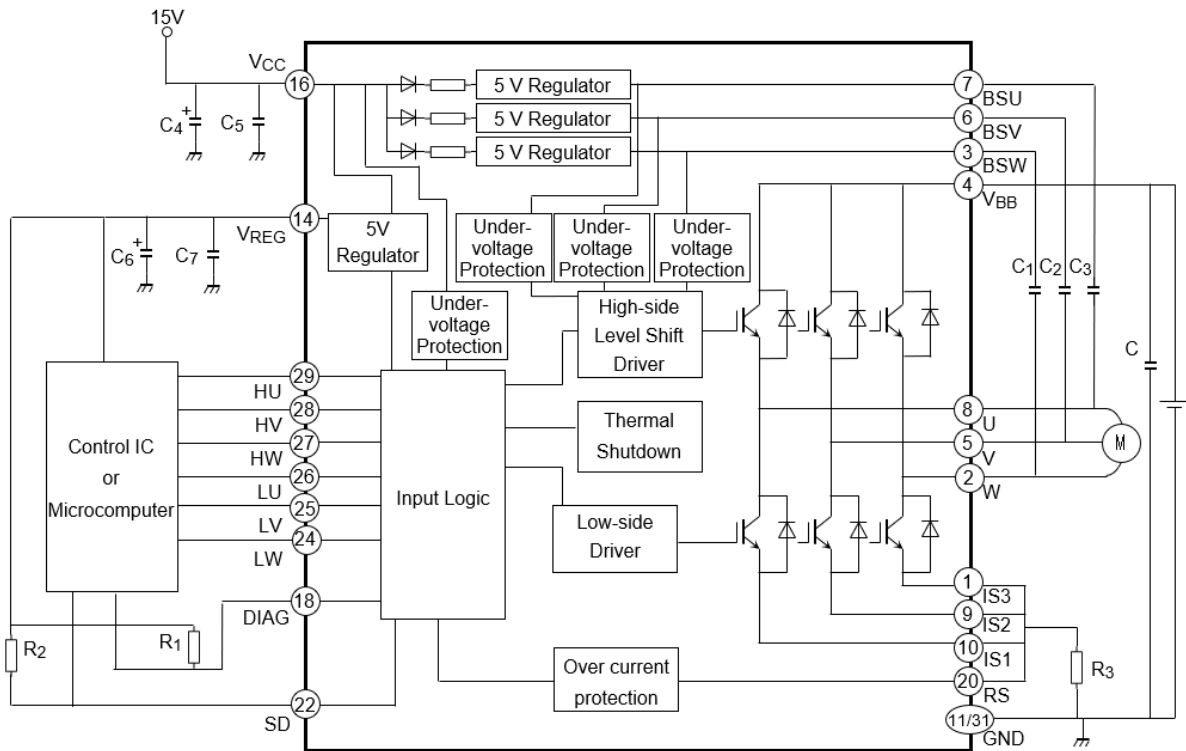
| Characteristics                            | Symbol               | Test Condition  | Min  | Typ. | Max  | Unit             |
|--|----------------------|---|------|------|------|------------------|
| Current dissipation                        | $I_{BB}$             | $V_{BB} = 450\text{ V}$   | —    | —    | 0.5  | mA               |
|  | $I_{CC}$             | $V_{CC} = 15\text{ V}$  | —    | 0.8  | 1.5  |                  |
| Bootstrap Current dissipation              | $I_{BS}(\text{ON})$  | $V_{BS} = 5\text{ V}$ , high side ON                                  | —    | 90   | 150  | $\mu\text{A}$    |
|  | $I_{BS}(\text{OFF})$ | $V_{BS} = 5\text{ V}$ , high side OFF                                 | —    | 80   | 140  |                  |
| Input voltage                              | $V_{IH}$             | $V_{IN} = \text{"H"}$ , $V_{CC} = 15\text{ V}$                        | 2.5  | —    | —    | V                |
|  | $V_{IL}$             | $V_{IN} = \text{"L"}$ , $V_{CC} = 15\text{ V}$                        | —    | —    | 1.5  |                  |
| Input current                              | $I_{IH}$             | $V_{IN} = 5\text{ V}$   | —    | —    | 50   | $\mu\text{A}$    |
|  | $I_{IL}$             | $V_{IN} = 0\text{ V}$   | —    | —    | 10   |                  |
| Output saturation voltage                  | $V_{CEsatH}$         | $V_{CC} = 15\text{ V}$ , $I_C = 1\text{ A}$ , high side               | —    | 3.0  | 3.7  | V                |
|  | $V_{CEsatL}$         | $V_{CC} = 15\text{ V}$ , $I_C = 1\text{ A}$ , low side                | —    | 3.0  | 3.7  |                  |
| FRD forward voltage                        | $V_{FH}$             | $I_F = 1\text{ A}$ , high side  | —    | 2.5  | 3.2  | V                |
|  | $V_{FL}$             | $I_F = 1\text{ A}$ , low side   | —    | 2.5  | 3.2  |                  |
| Regulator voltage                          | $V_{REG}$            | $V_{CC} = 15\text{ V}$ , $I_{REG} = 30\text{ mA}$                     | 4.5  | 5    | 5.5  | V                |
| Over current protection voltage            | $V_R$                | —   | 0.46 | 0.5  | 0.54 | V                |
| Over current protection delay time         | $D_t$                | —   | —    | 2    | 3    | $\mu\text{s}$    |
| Thermal shutdown temperature               | TSD                  | $V_{CC} = 15\text{ V}$  | 135  | —    | 165  | $^\circ\text{C}$ |
| Thermal shutdown hysteresis                | $\Delta\text{TSD}$   | $V_{CC} = 15\text{ V}$  | —    | 50   | —    | $^\circ\text{C}$ |
| $V_{CC}$ under voltage protection          | $V_{CCUVD}$          | —   | 10   | 11   | 12   | V                |
| $V_{CC}$ under voltage protection recovery | $V_{CCUVR}$          | —   | 10.5 | 11.5 | 12.5 | V                |
| $V_{BS}$ under voltage protection          | $V_{BSUVD}$          | —   | 2    | 3    | 4    | V                |
| $V_{BS}$ under voltage protection recovery | $V_{BSUVR}$          | —   | 2.5  | 3.5  | 4.5  | V                |
| DIAG saturation voltage                    | $V_{DIAGsat}$        | $I_{DIAG} = 5\text{ mA}$  | —    | —    | 0.5  | V                |
| Minimum operating pulse width              | $PW_{min}$           | $V_{BB} = 280\text{ V}$ , $V_{CC} = 15\text{ V}$                      | 0.8  | —    | —    | $\mu\text{s}$    |
| SD Input voltage                           | $V_{SD}$             | $V_{CC} = 15\text{ V}$  | —    | 2.5  | —    | V                |
| Output on delay time                       | $t_{on}$             | $V_{BB} = 280\text{ V}$ , $V_{CC} = 15\text{ V}$ , $I_C = 1\text{ A}$ | —    | 1.0  | 1.5  | $\mu\text{s}$    |
| Output off delay time                      | $t_{off}$            | $V_{BB} = 280\text{ V}$ , $V_{CC} = 15\text{ V}$ , $I_C = 1\text{ A}$ | —    | 1.2  | 1.7  | $\mu\text{s}$    |
| Dead time                                  | $t_{dead}$           | $V_{BB} = 280\text{ V}$ , $V_{CC} = 15\text{ V}$ , $I_C = 1\text{ A}$ | 1    | —    | —    | $\mu\text{s}$    |
| FRD reverse recovery time                  | $t_{rr}$             | $V_{BB} = 280\text{ V}$ , $V_{CC} = 15\text{ V}$ , $I_C = 1\text{ A}$ | —    | 200  | —    | ns               |

**11. Safe Operating Area**



**Figure 11.1 SOA at  $T_j = 135\text{ }^\circ\text{C}$**

**12. Application Circuit Example**



**Figure 12.1 Application Circuit Example**

Typical external parts are shown in the following table.

**Table 12.1 Typical external parts**

| Part       | Typical                     | Purpose                     | Remarks  |
|------------|-----------------------------|-----------------------------|----------|
| C1, C2, C3 | 25 V/2.2 $\mu$ F            | Bootstrap capacitor         | (Note 1) |
| C4         | 25 V/10 $\mu$ F             | VCC power supply stability  | (Note 2) |
| C5         | 25 V/0.1 $\mu$ F            | VCC for surge absorber      | (Note 2) |
| C6         | 25 V/10 $\mu$ F             | VREG power supply stability | (Note 2) |
| C7         | 25 V/0.1 $\mu$ F            | VREG for surge absorber     | (Note 2) |
| R1         | 5.1 k $\Omega$              | DIAG pin pull-up resistor   | (Note 3) |
| R2         | 10 k $\Omega$               | SD pin pull-up resistor     | -        |
| R3         | 0.35 $\Omega \pm 1\%$ (1 W) | Over current detection      | (Note 4) |

Note 1: The required bootstrap capacitance value varies according to the motor drive conditions. The capacitor is biased by 5V(typ.) 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.

Note 4: The following formula shows the detection current:  $I_O = V_R / R_3$  (For  $V_R = 0.5$  V typ.)

### 13. Handling precautions

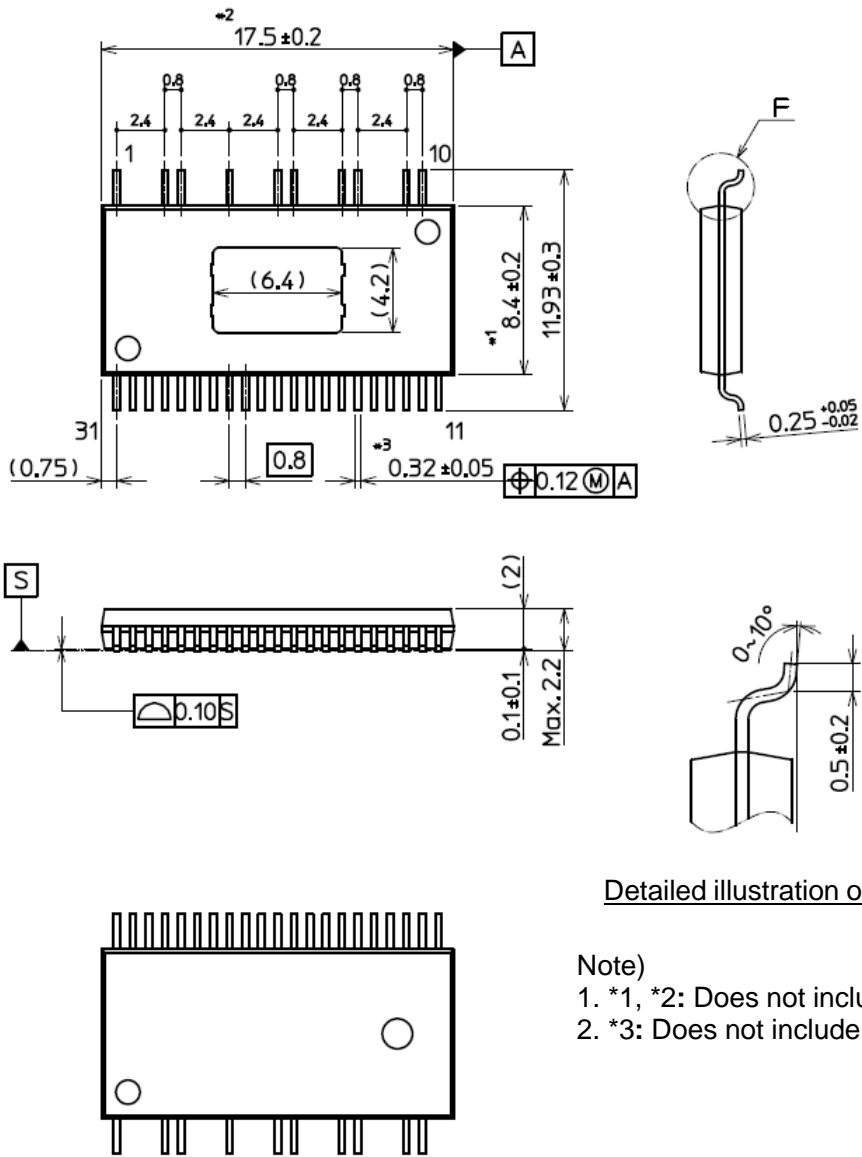
- (1) Please control the input signal in the state to which the VCC voltage is steady. Both of the order of the VBB power supply and the VCC power supply are not cared about either. Note that if the power supply is switched off as described above, this product may be destroyed if the current regeneration route to the VBB power supply is blocked when the VBB line is disconnected by a relay or similar while the motor is still running.
- (2) Over voltage caused by a surge voltage over the absolute maximum ratings may destroy the circuit. Accordingly, be careful of handling the IC or of surge voltage in its application environment.

## 14. Package Information

### 14.1. Package Dimensions

P-HSSOP31-0918-0.80-002

Unit: mm



Detailed illustration of Part F.

Note)

- \*1, \*2: Does not include leftover resin.
- \*3: Does not include leftover tiebar.

Weight: 0.7 g (typ.)

Figure 14.1 Package Dimensions

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