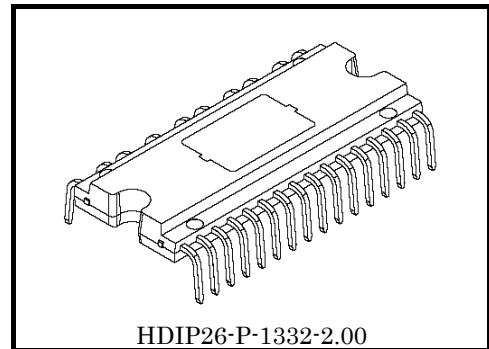


TOSHIBA Intelligent Power Device  
High Voltage Monolithic Silicon Power IC

# TPD4144K

The TPD4144K 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 MPU or motor controller to the TPD4144K.



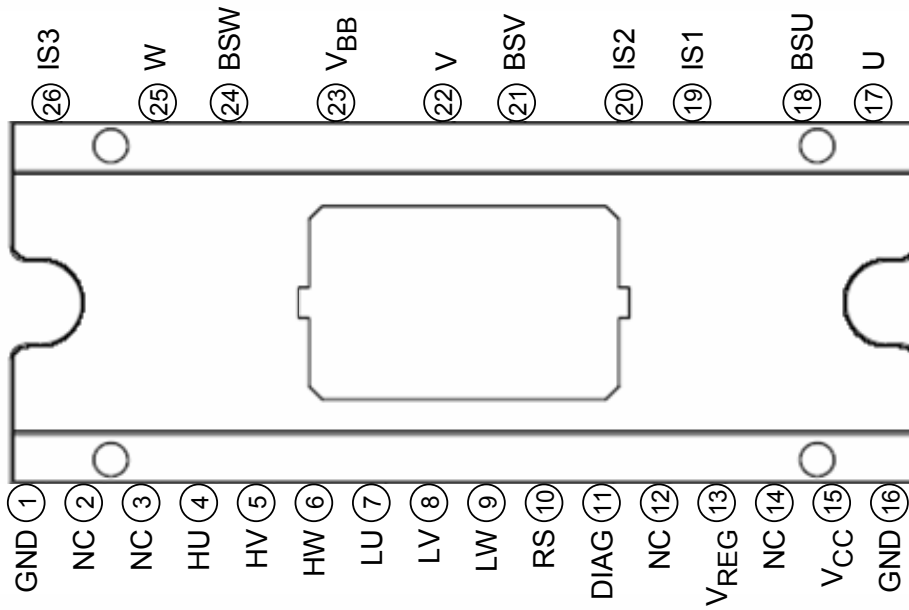
Weight: 3.8 g (typ.)

## Features

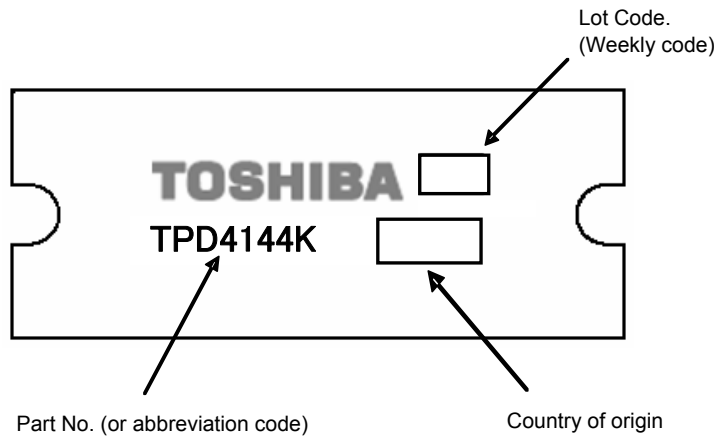
- High voltage power side and low voltage signal side terminal are separated.
- It is the best for current sensing in three shunt resistance.
- Bootstrap circuit gives simple high-side supply.
- Bootstrap diodes are built in.
- A dead time can be set as a minimum of 1.4  $\mu$ s, and it is suitable for a Sine-wave from drive.
- 3-phase bridge output using IGBTs.
- FRDs are built in.
- Included over-current and under-voltage protection, and thermal shutdown.
- The regulator of 7 V (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.

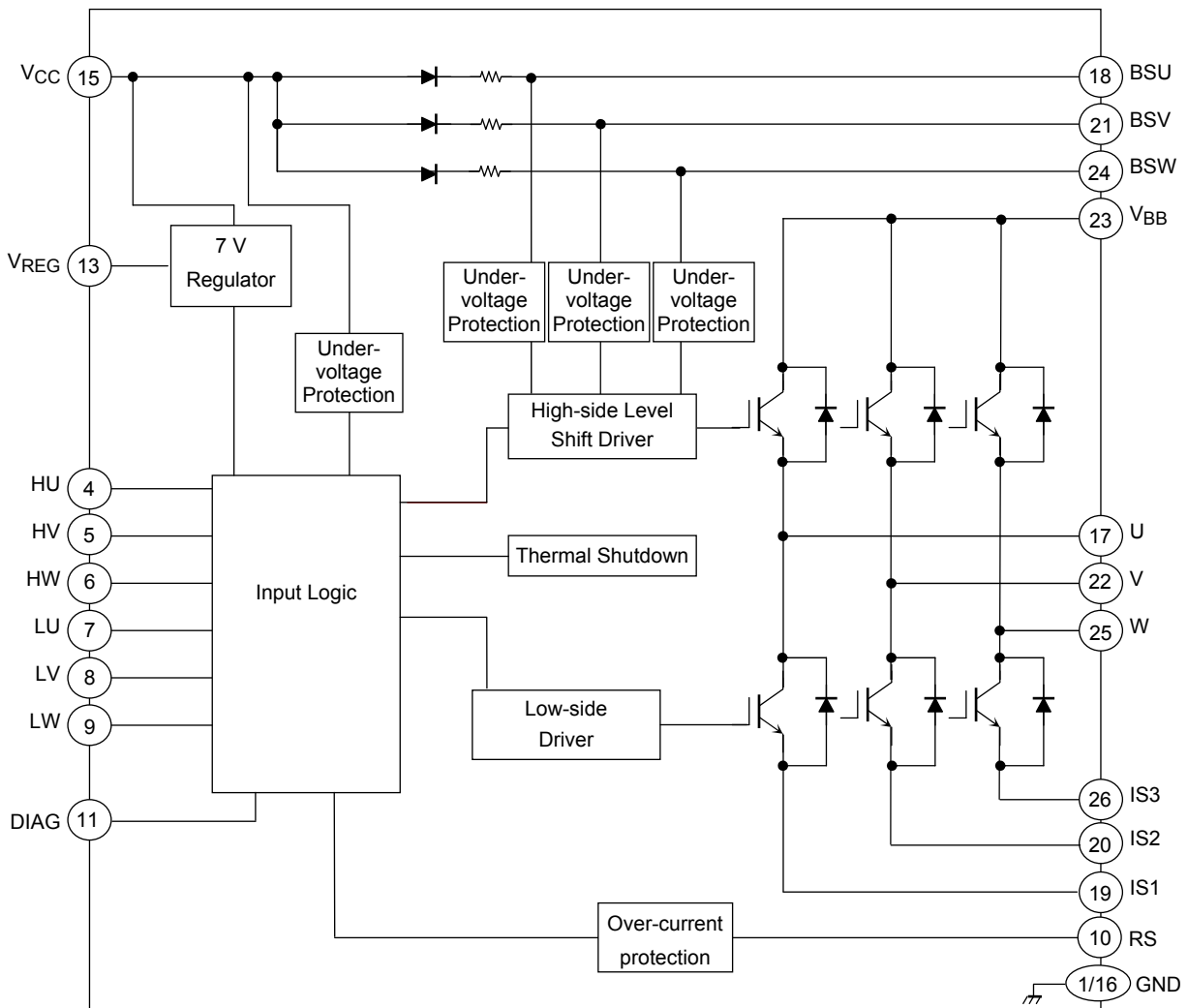
**Pin Assignment**



**Marking**



**Block Diagram**

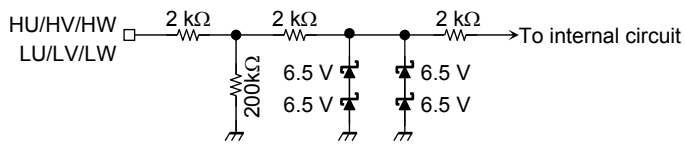


## Pin Description

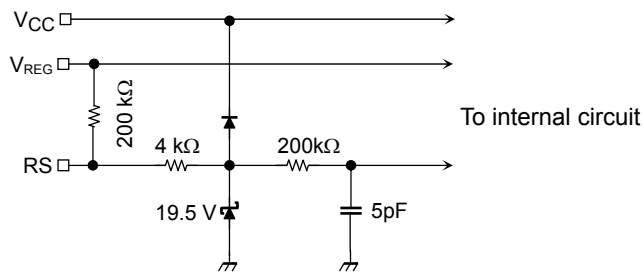
| Pin No. | Symbol           | Pin Description   |
|---------|------------------|---|
| 1       | GND              | Ground pin.   |
| 2       | NC               | Unused pin, which is not connected to the chip internally.  |
| 3       | NC               | Unused pin, which is not connected to the chip internally.  |
| 4       | HU               | The control terminal of IGBT by the high side of U. It turns off less than 1.5 V. It turns on more than 2.5 V.                  |
| 5       | 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.                  |
| 6       | 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.                  |
| 7       | 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.                   |
| 8       | 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.                   |
| 9       | 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.                   |
| 10      | RS               | Over current detection pin.   |
| 11      | 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. |
| 12      | NC               | Unused pin, which is not connected to the chip internally.  |
| 13      | V <sub>REG</sub> | 7 V regulator output pin.   |
| 14      | NC               | Unused pin, which is not connected to the chip internally.  |
| 15      | V <sub>CC</sub>  | Control power supply pin. (15 V 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 <sub>BB</sub>  | 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**

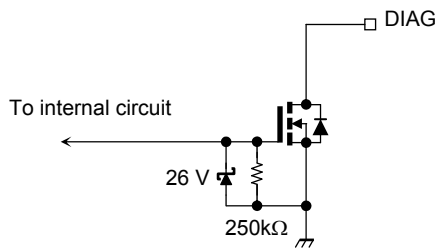
**Internal circuit diagram of HU, HV, HW, LU, LV, LW input pins**



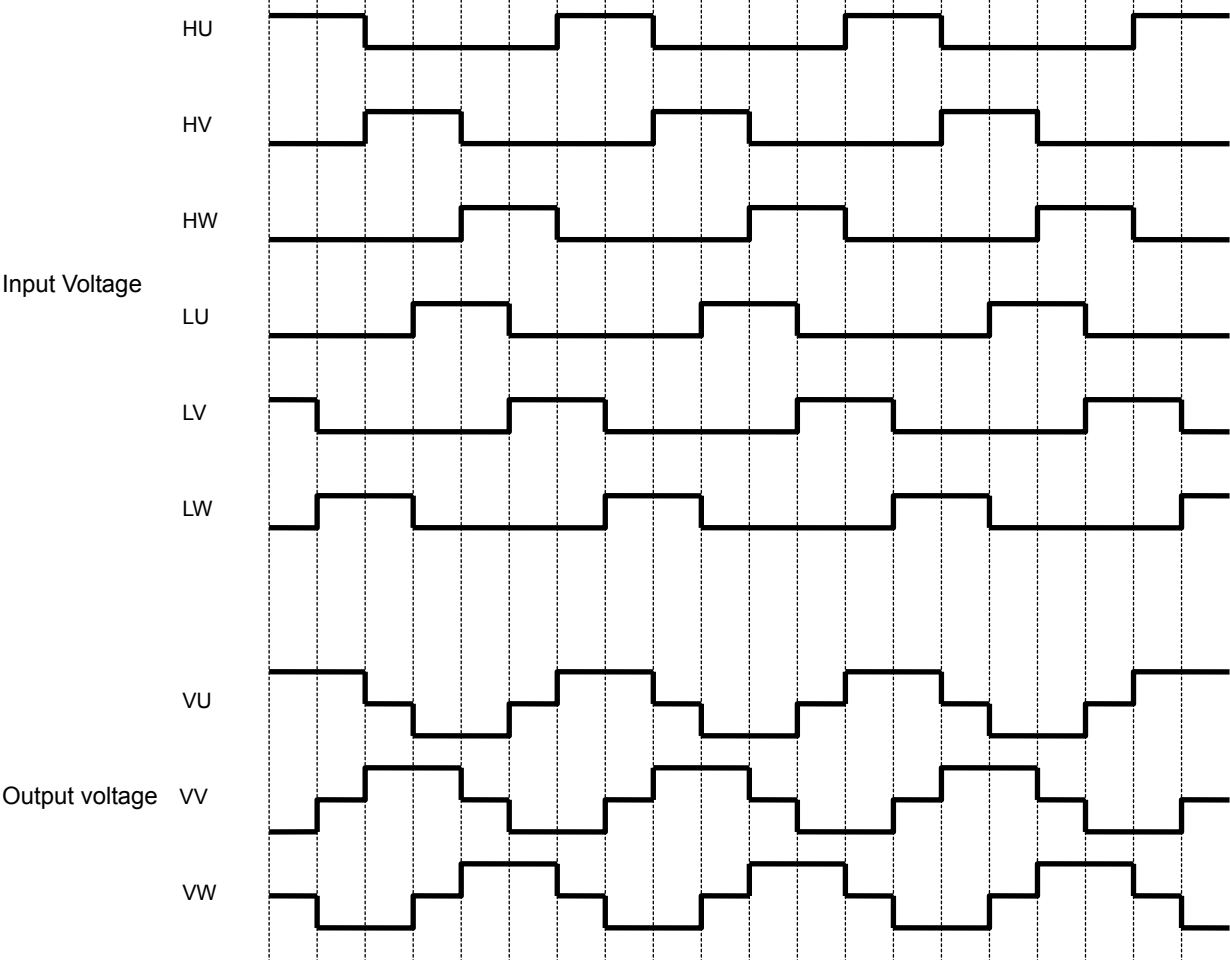
**Internal circuit diagram of RS pin**



**Internal circuit diagram of DIAG pin**



Timing Chart



## Truth Table

| Mode                          | Input |    |    |    |    |    | High side |         |         | Low side |         |         | DIAG |
|-------------------------------|-------|----|----|----|----|----|-----------|---------|---------|----------|---------|---------|------|
|                               | HU    | HV | HW | LU | LV | LW | U phase   | V phase | W phase | U phase  | V phase | W phase |      |
| Normal                        | H     | L  | L  | L  | H  | L  | ON        | OFF     | OFF     | OFF      | ON      | OFF     | OFF  |
|                               | H     | L  | L  | L  | L  | H  | ON        | OFF     | OFF     | OFF      | OFF     | ON      | OFF  |
|                               | L     | H  | L  | L  | L  | H  | OFF       | ON      | OFF     | OFF      | OFF     | ON      | OFF  |
|                               | L     | H  | L  | H  | L  | L  | OFF       | ON      | OFF     | ON       | OFF     | OFF     | OFF  |
|                               | L     | L  | H  | H  | L  | L  | OFF       | OFF     | ON      | ON       | OFF     | OFF     | OFF  |
|                               | L     | L  | H  | L  | H  | L  | OFF       | OFF     | ON      | OFF      | ON      | OFF     | OFF  |
| Over-current                  | H     | L  | L  | L  | H  | L  | OFF       | OFF     | OFF     | OFF      | OFF     | OFF     | ON   |
|                               | H     | L  | L  | L  | L  | H  | OFF       | OFF     | OFF     | OFF      | OFF     | OFF     | ON   |
|                               | L     | H  | L  | L  | L  | H  | OFF       | OFF     | OFF     | OFF      | OFF     | OFF     | ON   |
|                               | L     | H  | L  | H  | L  | L  | OFF       | OFF     | OFF     | OFF      | OFF     | OFF     | ON   |
|                               | L     | L  | H  | H  | L  | L  | OFF       | OFF     | OFF     | OFF      | OFF     | OFF     | ON   |
|                               | L     | L  | H  | L  | H  | L  | OFF       | OFF     | OFF     | OFF      | OFF     | OFF     | ON   |
| Thermal shutdown              | H     | L  | L  | L  | H  | L  | OFF       | OFF     | OFF     | OFF      | OFF     | OFF     | ON   |
|                               | H     | L  | L  | L  | L  | H  | OFF       | OFF     | OFF     | OFF      | OFF     | OFF     | ON   |
|                               | L     | H  | L  | L  | L  | H  | OFF       | OFF     | OFF     | OFF      | OFF     | OFF     | ON   |
|                               | L     | H  | L  | H  | L  | L  | OFF       | OFF     | OFF     | OFF      | OFF     | OFF     | ON   |
|                               | L     | L  | H  | H  | L  | L  | OFF       | OFF     | OFF     | OFF      | OFF     | OFF     | ON   |
|                               | L     | L  | H  | L  | H  | L  | OFF       | OFF     | OFF     | OFF      | OFF     | OFF     | ON   |
| V <sub>CC</sub> Under-voltage | H     | L  | L  | L  | H  | L  | OFF       | OFF     | OFF     | OFF      | OFF     | OFF     | ON   |
|                               | H     | L  | L  | L  | L  | H  | OFF       | OFF     | OFF     | OFF      | OFF     | OFF     | ON   |
|                               | L     | H  | L  | L  | L  | H  | OFF       | OFF     | OFF     | OFF      | OFF     | OFF     | ON   |
|                               | L     | H  | L  | H  | L  | L  | OFF       | OFF     | OFF     | OFF      | OFF     | OFF     | ON   |
|                               | L     | L  | H  | H  | L  | L  | OFF       | OFF     | OFF     | OFF      | OFF     | OFF     | ON   |
|                               | L     | L  | H  | L  | H  | L  | OFF       | OFF     | OFF     | OFF      | OFF     | OFF     | ON   |
| V <sub>BS</sub> Under-voltage | H     | L  | L  | L  | H  | L  | OFF       | OFF     | OFF     | OFF      | ON      | OFF     | OFF  |
|                               | H     | L  | L  | L  | L  | H  | OFF       | OFF     | OFF     | OFF      | OFF     | ON      | OFF  |
|                               | L     | H  | L  | L  | L  | H  | OFF       | OFF     | OFF     | OFF      | OFF     | ON      | OFF  |
|                               | L     | H  | L  | H  | L  | L  | OFF       | OFF     | OFF     | ON       | OFF     | OFF     | OFF  |
|                               | L     | L  | H  | H  | L  | L  | OFF       | OFF     | OFF     | ON       | OFF     | OFF     | OFF  |
|                               | L     | L  | H  | L  | H  | L  | OFF       | OFF     | OFF     | OFF      | ON      | OFF     | OFF  |

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

| Characteristics                                 | Symbol               | Rating     | Unit |
|---|----------------------|------------|------|
| Power supply voltage                            | V <sub>BB</sub>      | 500        | V    |
|   | V <sub>CC</sub>      | 18         | V    |
| Output current (DC)                             | I <sub>out</sub>     | 2          | A    |
| Output current (pulse 1ms)                      | I <sub>outp</sub>    | 3          | A    |
| Input voltage                                   | V <sub>IN</sub>      | -0.5 to 7  | V    |
| V <sub>REG</sub> current                        | I <sub>REG</sub>     | 50         | mA   |
| DIAG voltage                                    | V <sub>DIAG</sub>    | 20         | V    |
| DIAG current                                    | I <sub>DIAG</sub>    | 20         | mA   |
| Power dissipation<br>(IGBT1 phase (Tc = 25°C) ) | P <sub>C(IGBT)</sub> | 36         | W    |
| Power dissipation<br>(FRD1 phase (Tc = 25°C) )  | P <sub>C(FRD)</sub>  | 22         | W    |
| Operating junction temperature                  | T <sub>jopr</sub>    | -40 to 135 | °C   |
| Junction temperature                            | T <sub>j</sub>       | 150        | °C   |
| Storage temperature                             | T <sub>stg</sub>     | -55 to 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.

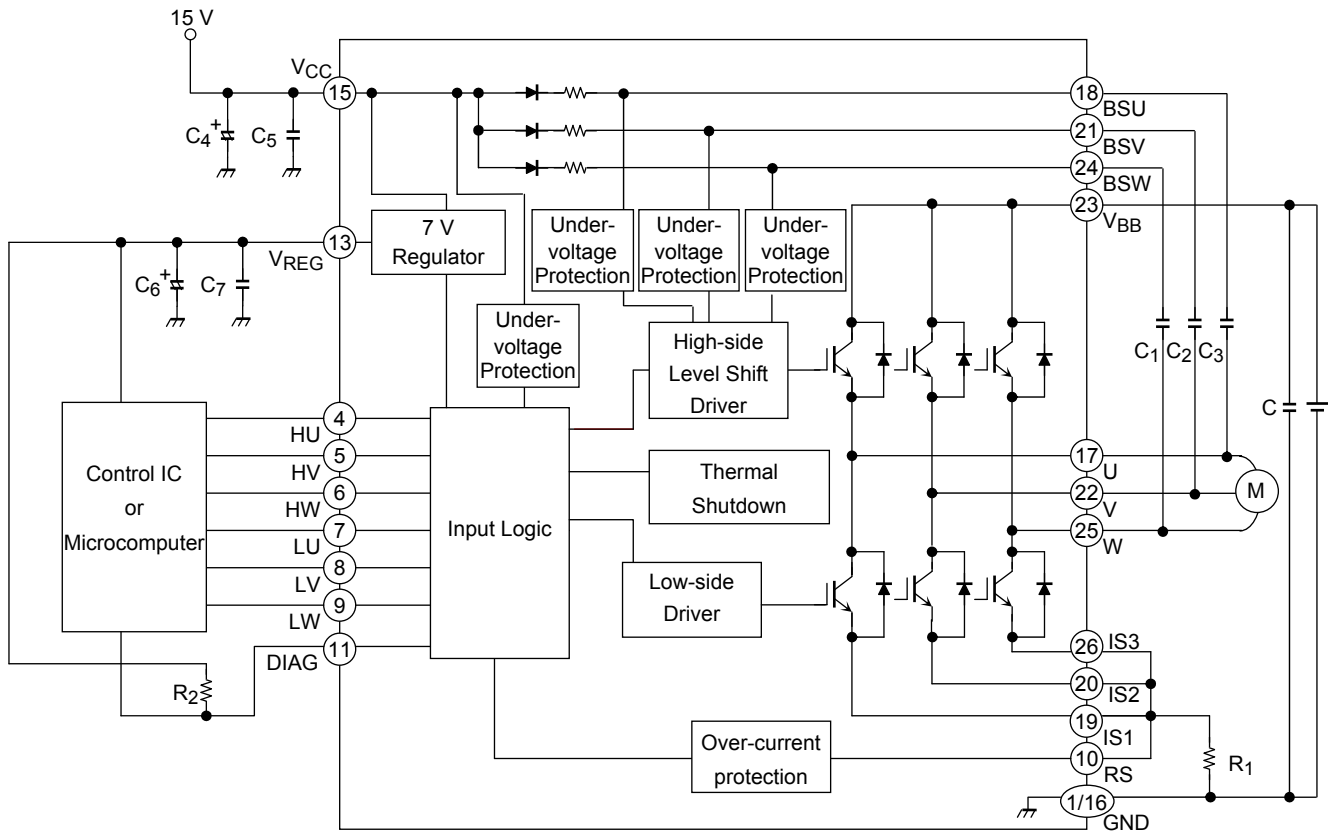
Please design the appropriate reliability upon reviewing the Toshiba Semiconductor Reliability Handbook (“Handling Precautions”/“Derating Concept and Methods”) and individual reliability data (i.e. reliability test report and estimated failure rate, etc).



## Electrical Characteristics (Ta = 25°C)

| Characteristics                                   | Symbol                | Test Condition  | Min  | Typ. | Max  | Unit |
|---|-----------------------|---|------|------|------|------|
| Operating power supply voltage                    | V <sub>BB</sub>       | —   | 50   | 280  | 450  | V    |
|   | V <sub>CC</sub>       | —   | 13.5 | 15   | 16.5 |      |
| Current dissipation                               | I <sub>BB</sub>       | V <sub>BB</sub> = 450 V   | —    | —    | 0.5  | mA   |
|   | I <sub>CC</sub>       | V <sub>CC</sub> = 15 V  | —    | 0.8  | 5    |      |
| Bootstrap Current dissipation                     | I <sub>BS</sub> (ON)  | V <sub>BS</sub> = 15 V, high side ON                                  | —    | 210  | 410  | μA   |
|   | I <sub>BS</sub> (OFF) | V <sub>BS</sub> = 15 V, high side OFF                                 | —    | 180  | 370  |      |
| Input voltage                                     | V <sub>IH</sub>       | V <sub>IN</sub> = "H", V <sub>CC</sub> = 15 V                         | 2.5  | —    | —    | V    |
|   | V <sub>IL</sub>       | V <sub>IN</sub> = "L", V <sub>CC</sub> = 15 V                         | —    | —    | 1.5  |      |
| Input current                                     | I <sub>IH</sub>       | V <sub>IN</sub> = 5 V   | —    | —    | 150  | μA   |
|   | I <sub>IL</sub>       | V <sub>IN</sub> = 0 V   | —    | —    | 100  |      |
| Output saturation voltage                         | V <sub>CEsatH</sub>   | V <sub>CC</sub> = 15 V, I <sub>C</sub> = 1 A, high side               | —    | 2.3  | 3.2  | V    |
|   | V <sub>CEsatL</sub>   | V <sub>CC</sub> = 15 V, I <sub>C</sub> = 1 A, low side                | —    | 2.3  | 3.2  |      |
| FRD forward voltage                               | V <sub>FH</sub>       | I <sub>F</sub> = 1 A, high side                                       | —    | 2.1  | 3.1  | V    |
|   | V <sub>FL</sub>       | I <sub>F</sub> = 1 A, low side  | —    | 2.1  | 3.1  |      |
| BSD forward voltage                               | V <sub>F</sub> (BSD)  | I <sub>F</sub> = 500 μA   | —    | 0.8  | 1.2  | V    |
| Regulator voltage                                 | V <sub>REG</sub>      | V <sub>CC</sub> = 15 V, I <sub>REG</sub> = 30 mA                      | 6.5  | 7    | 7.5  | V    |
| Current limiting voltage                          | V <sub>R</sub>        | —   | 0.46 | 0.5  | 0.54 | V    |
| Current limiting delay time                       | Dt                    | —   | 1.5  | 3    | 5    | μs   |
| Thermal shutdown temperature                      | TSD                   | V <sub>CC</sub> = 15 V  | 135  | —    | 185  | °C   |
| Thermal shutdown hysteresis                       | ΔTSD                  | V <sub>CC</sub> = 15 V  | —    | 50   | —    | °C   |
| V <sub>CC</sub> under voltage protection          | V <sub>CCUVD</sub>    | —   | 10   | 11   | 12   | V    |
| V <sub>CC</sub> under voltage protection recovery | V <sub>CCUVR</sub>    | —   | 10.5 | 11.5 | 12.5 | V    |
| V <sub>BS</sub> under voltage protection          | V <sub>BSUVD</sub>    | —   | 8    | 9    | 9.5  | V    |
| V <sub>BS</sub> under voltage protection recovery | V <sub>BSUVR</sub>    | —   | 8.5  | 9.5  | 10.5 | V    |
| DIAG saturation voltage                           | V <sub>DIAGsat</sub>  | I <sub>DIAG</sub> = 5 mA  | —    | —    | 0.5  | V    |
| Output on delay time                              | t <sub>on</sub>       | V <sub>BB</sub> = 280 V, V <sub>CC</sub> = 15 V, I <sub>C</sub> = 1 A | —    | 1.2  | 3    | μs   |
| Output off delay time                             | t <sub>off</sub>      | V <sub>BB</sub> = 280 V, V <sub>CC</sub> = 15 V, I <sub>C</sub> = 1 A | —    | 1    | 3    | μs   |
| Dead time   | t <sub>dead</sub>     | V <sub>BB</sub> = 280 V, V <sub>CC</sub> = 15 V, I <sub>C</sub> = 1 A | 1.4  | —    | —    | μs   |
| FRD reverse recovery time                         | t <sub>rr</sub>       | V <sub>BB</sub> = 280 V, V <sub>CC</sub> = 15 V, I <sub>C</sub> = 1 A | —    | 150  | —    | ns   |

Application Circuit Example



## External Parts

Typical external parts are shown in the following table.

| Part   | Typical            | Purpose                                 | Remarks  |
|--|--------------------|---|----------|
| C <sub>1</sub> , C <sub>2</sub> , C <sub>3</sub> | 25 V/2.2 μF        | Bootstrap capacitor                     | (Note 1) |
| R <sub>1</sub>                                   | 0.35 Ω ± 1 % (1 W) | Current detection                       | (Note 2) |
| C <sub>4</sub>                                   | 25 V/10 μF         | V <sub>CC</sub> power supply stability  | (Note 3) |
| C <sub>5</sub>                                   | 25 V/0.1 μF        | V <sub>CC</sub> for surge absorber      | (Note 3) |
| C <sub>6</sub>                                   | 25 V/1 μF          | V <sub>REG</sub> power supply stability | (Note 3) |
| C <sub>7</sub>                                   | 25 V/1000 pF       | V <sub>REG</sub> for surge absorber     | (Note 3) |
| R <sub>2</sub>                                   | 5.1 kΩ             | DIAG pull-up resistor                   | (Note 4) |

Note 1: The required bootstrap capacitance value varies according to the motor drive conditions. The capacitor is biased by V<sub>CC</sub> and must be sufficiently derated for it.

Note 2: The following formula shows the detection current:  $I_O = V_R \div R_1$  (For  $V_R = 0.5$  V typ.)  
Do not exceed a detection current of 2 A when using this product.  
(Please go from the outside in the over current protection.)

Note 3: 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 4: The DIAG pin is open drain. If not using the DIAG pin, connect to the GND.

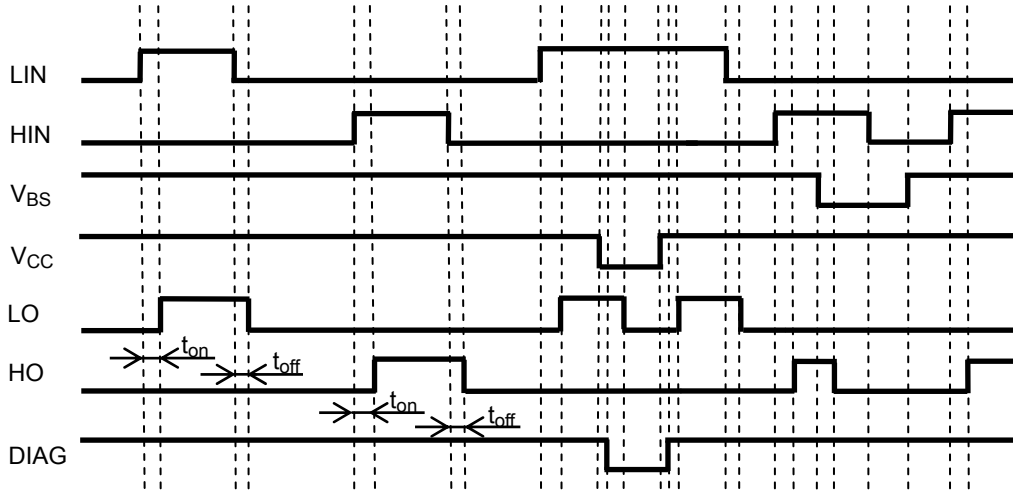
### Handling precautions

- (1) Please control the input signal in the state to which the V<sub>CC</sub> voltage is steady. Both of the order of the V<sub>BB</sub> power supply and the V<sub>CC</sub> 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<sub>BB</sub> power supply is blocked when the V<sub>BB</sub> line is disconnected by a relay or similar while the motor is still running.
- (2) The RS pin connecting the current detection resistor is connected to a comparator in the IC and also functions as a sensor pin for detecting over current. As a result, over voltage caused by a surge voltage, for example, may destroy the circuit. Accordingly, be careful of handling the IC or of surge voltage in its application environment.

**Description of Protection Function**

- (1) 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  $V_R$  (=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.
- (2) 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  $V_{CCUVD}$  (=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 ( $V_{CCUVR}$  (=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  $V_{BSUVD}$  (=9 V typ.), the high-side IGBT output shuts down. When the VBS supply voltage reaches 0.5 V higher than the shutdown voltage ( $V_{BSUVR}$  (=9.5 V typ.)), the IGBT is turned on again by the input signal.
- (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.

**Timing Chart of Under voltage protection**



Note: The above timing chart is considering the delay time

**Safe Operating Area**

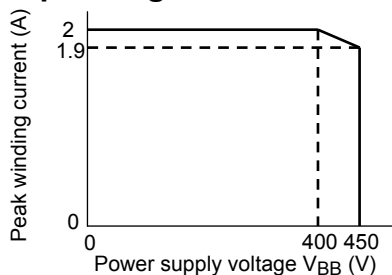
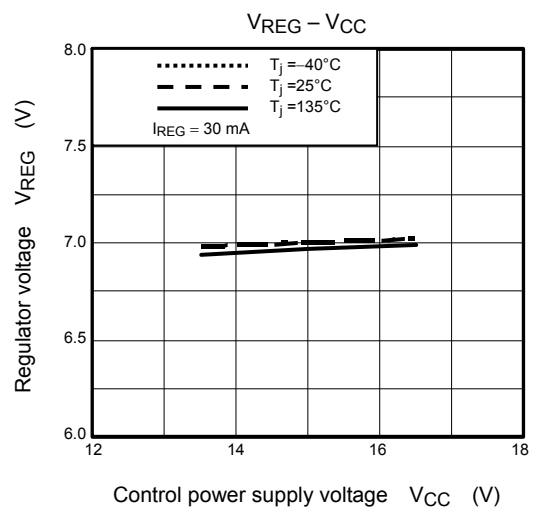
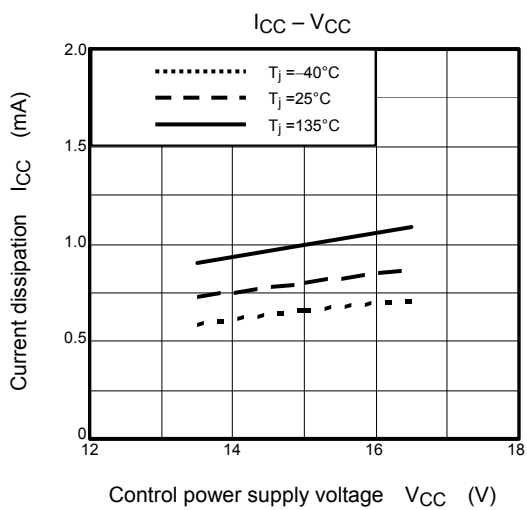
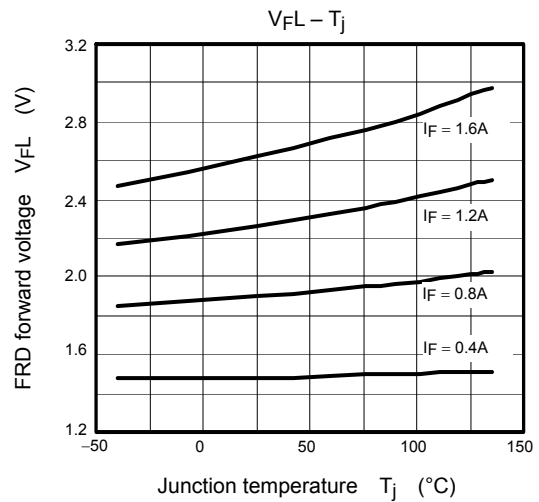
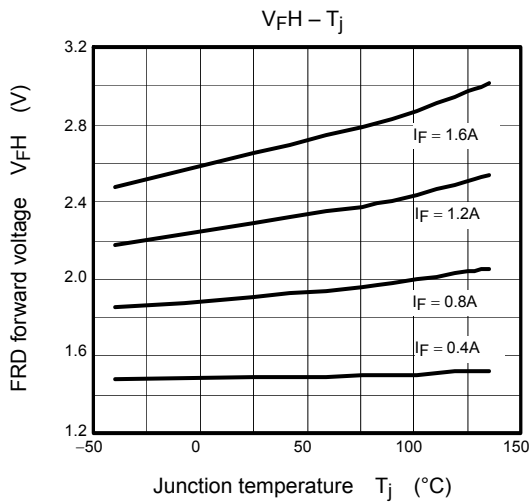
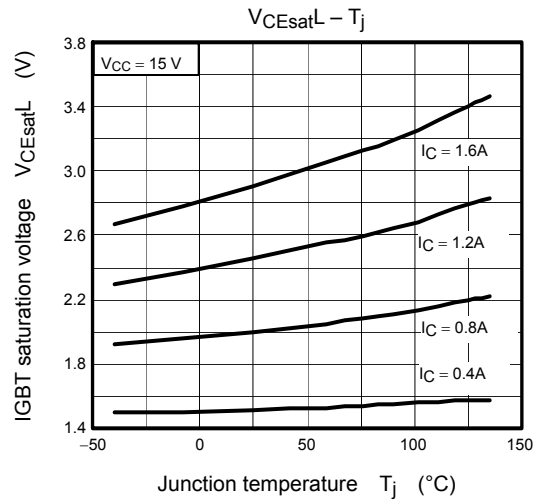
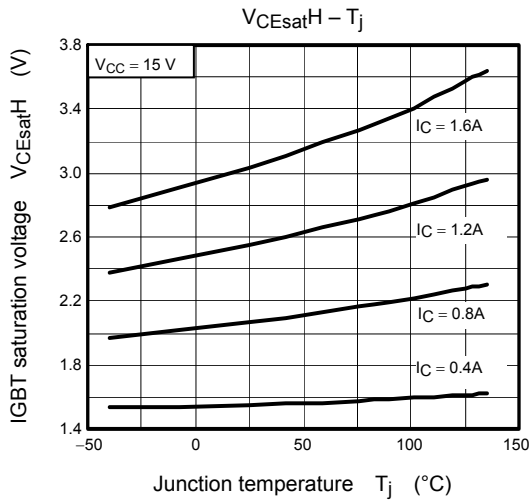
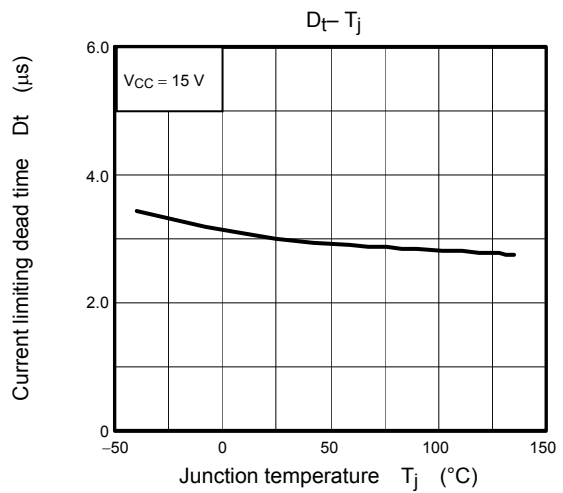
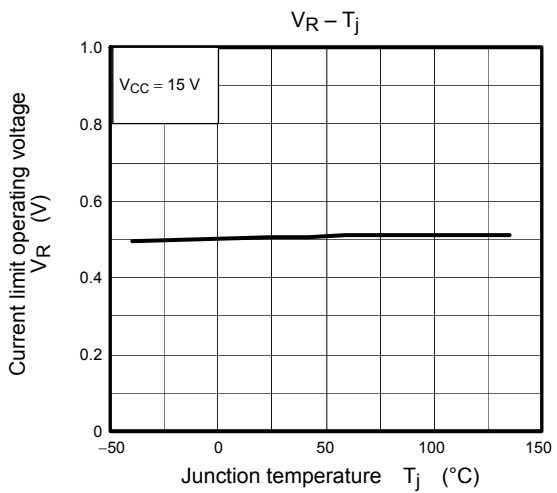
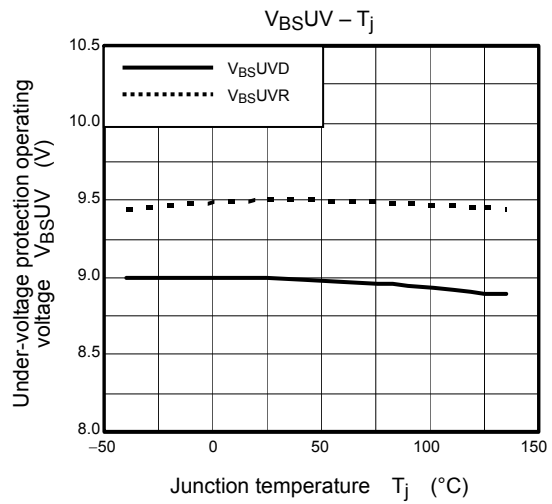
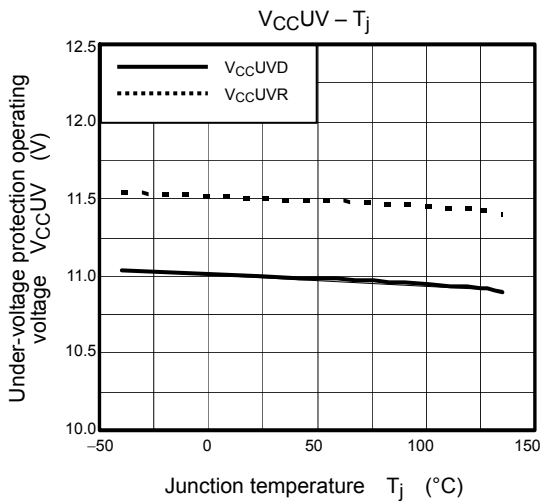
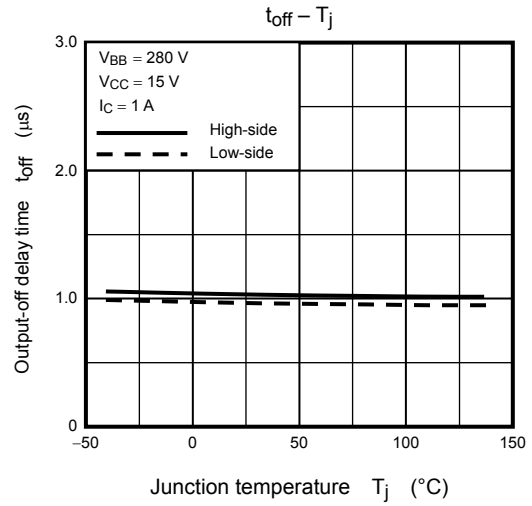
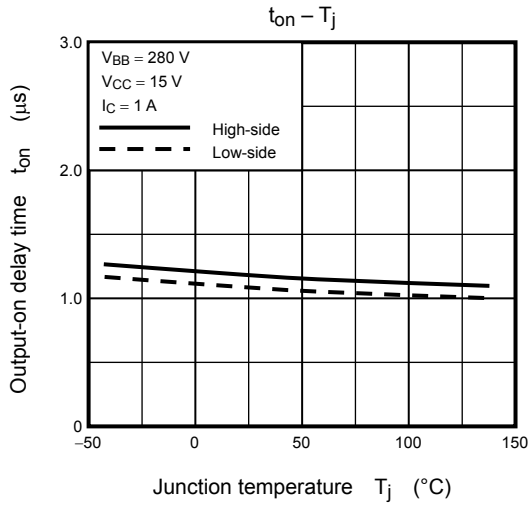
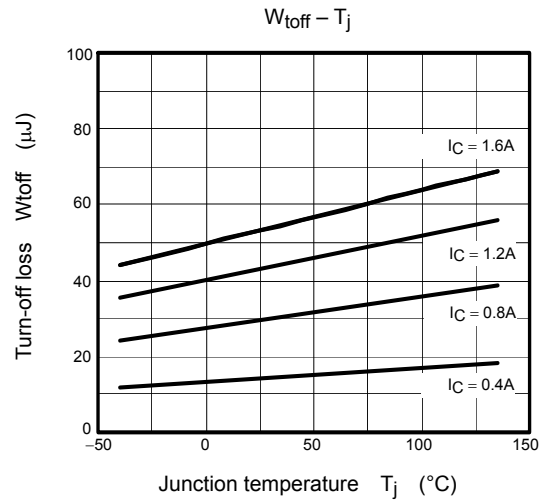
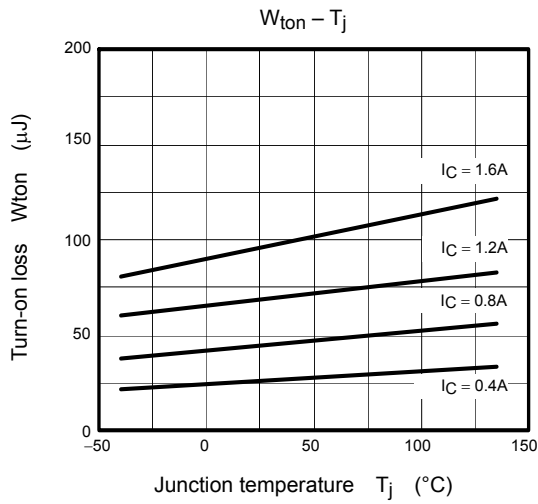
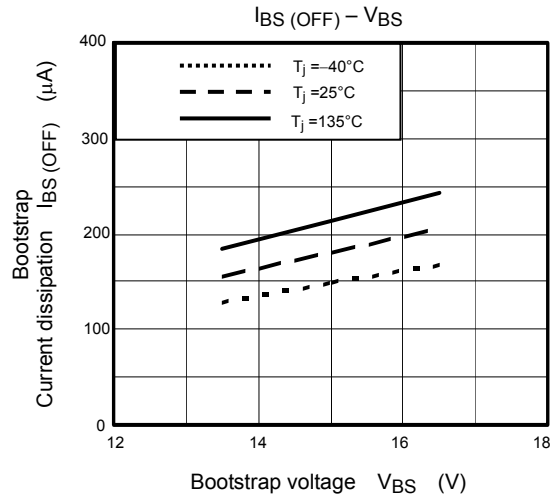
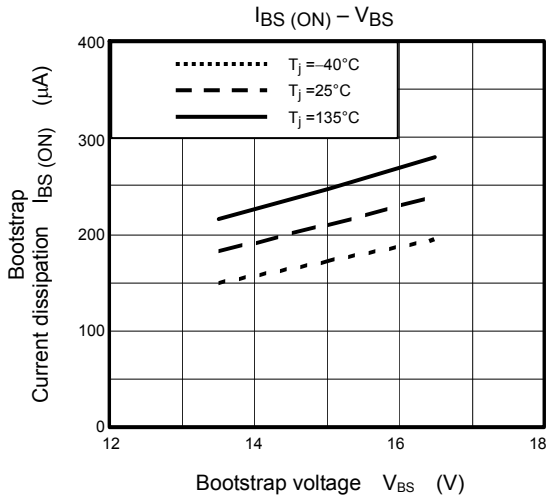


Figure 1 SOA at  $T_j = 135^\circ\text{C}$

Note 1: The above safe operating areas are  $T_j = 135^\circ\text{C}$  (Figure 1).

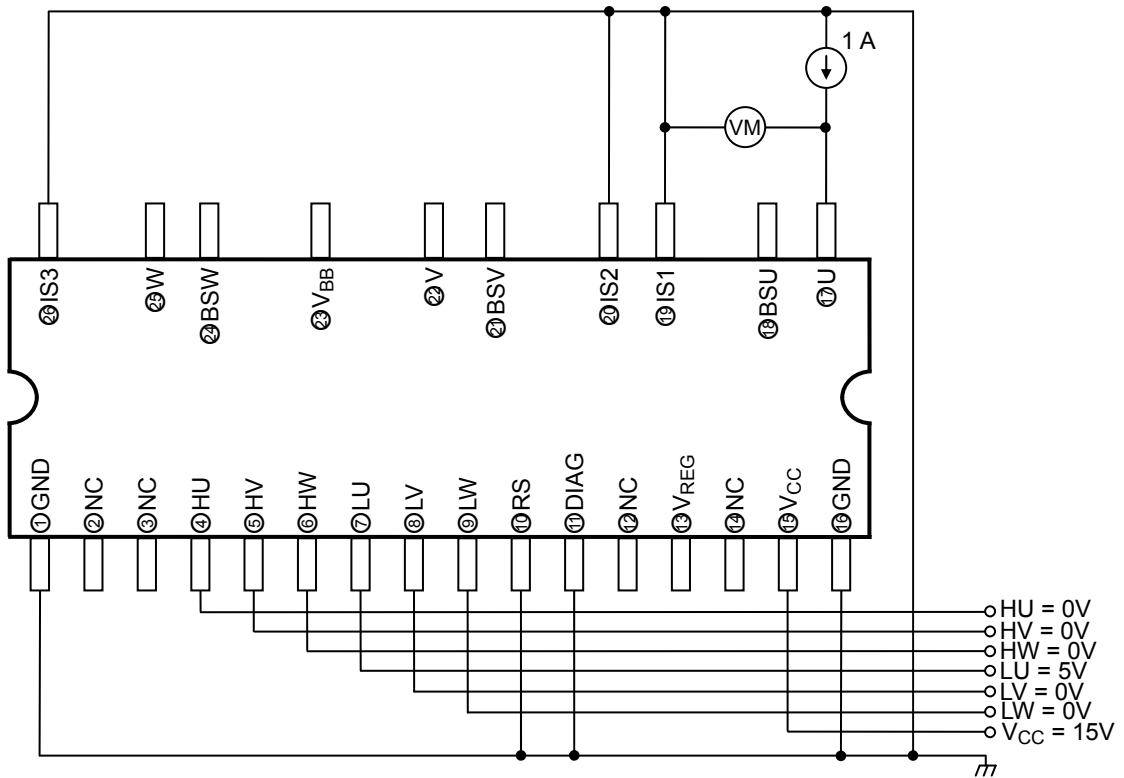




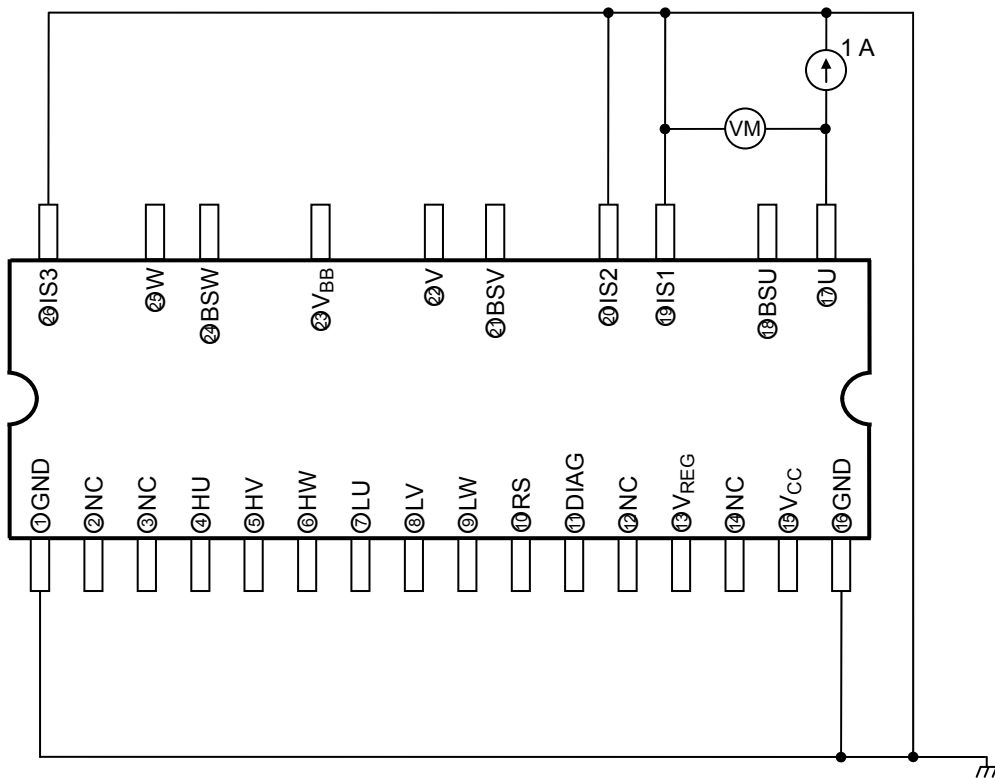


**Test Circuits**

**IGBT Saturation Voltage (U-phase low side)**

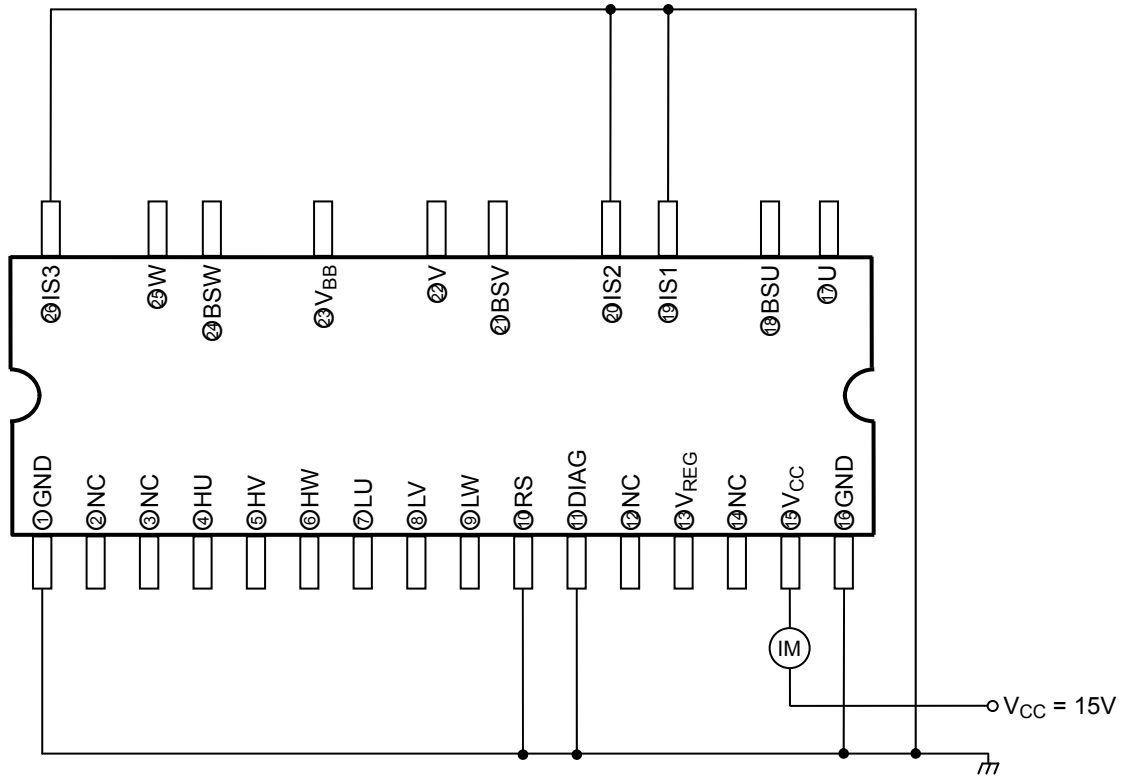


**FRD Forward Voltage (U-phase low side)**

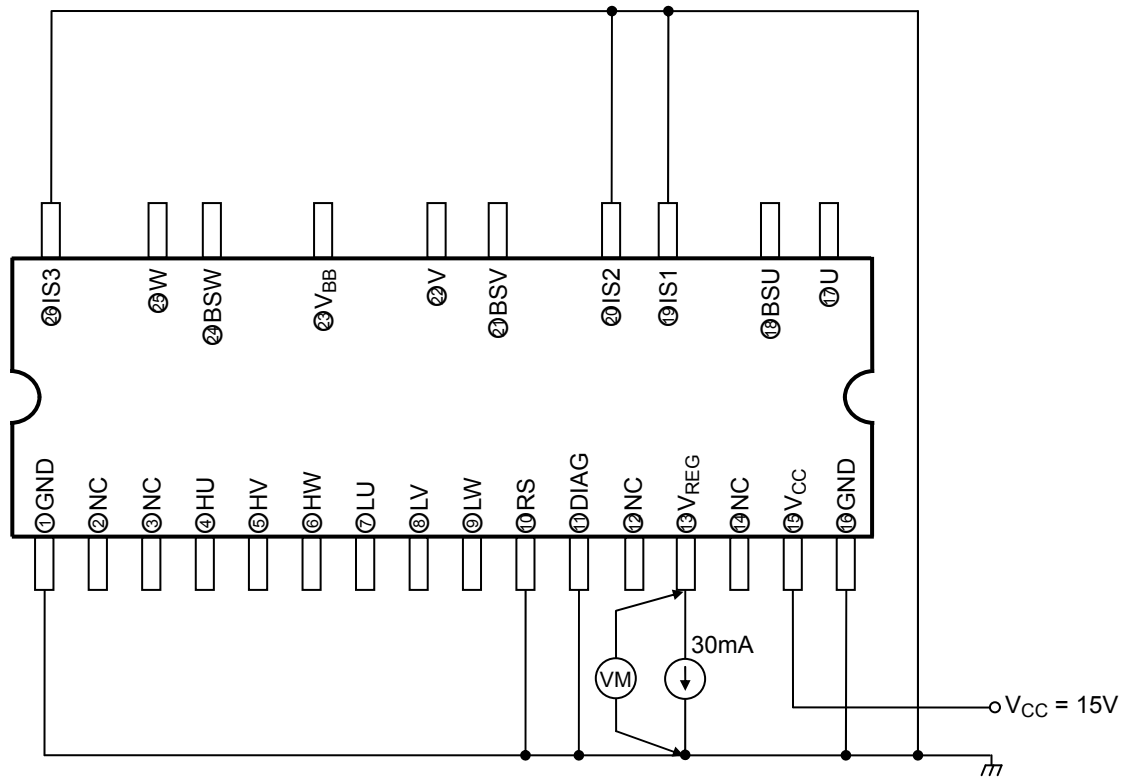




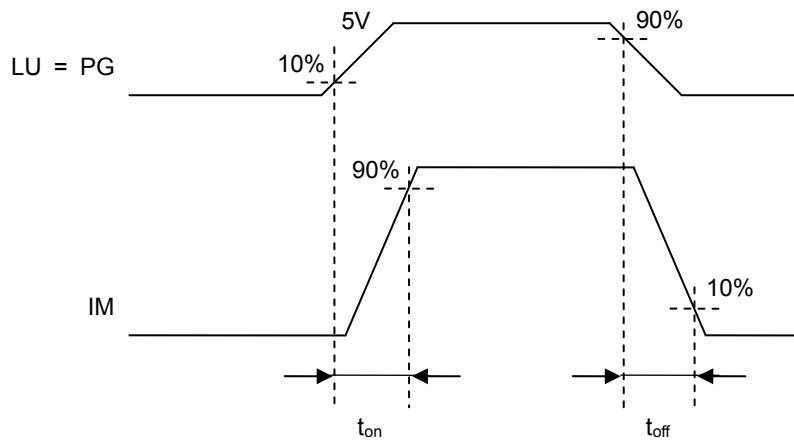
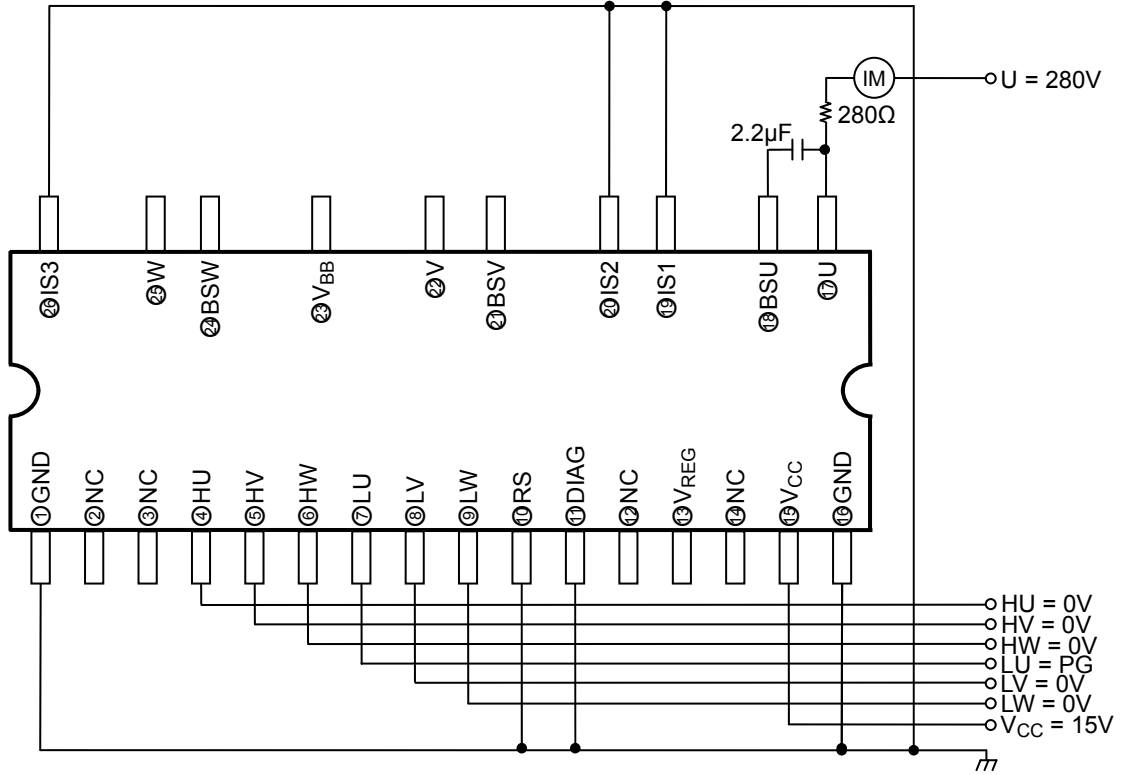
**V<sub>CC</sub> Current Dissipation**



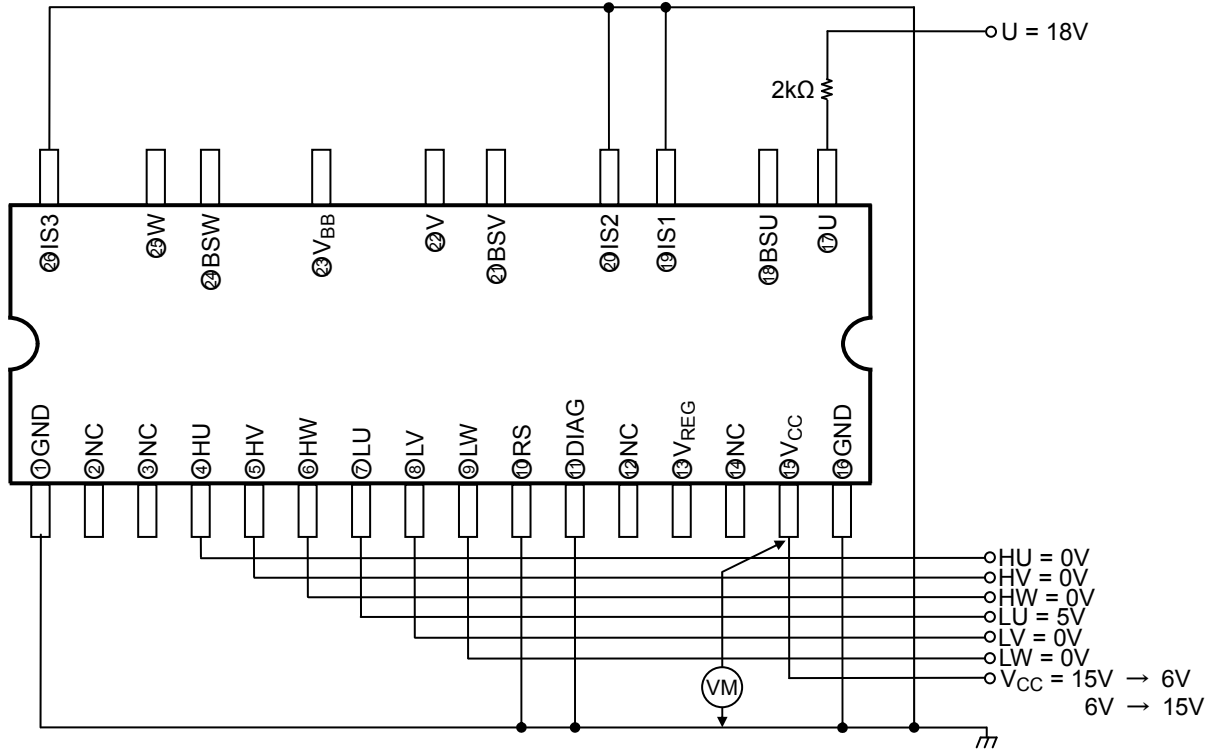
**Regulator Voltage**



Output ON/OFF Delay Time (U-phase low side)

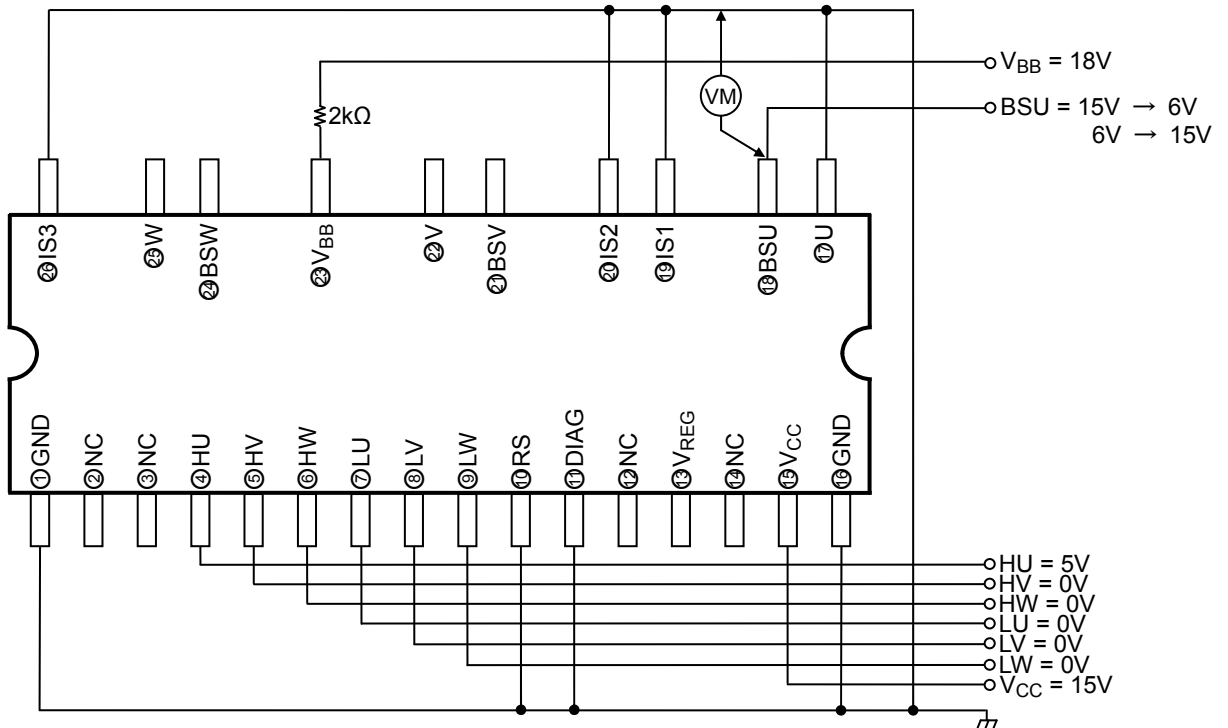


**VCC Under-voltage Protection Operating/Recovery Voltage (U-phase low side)**



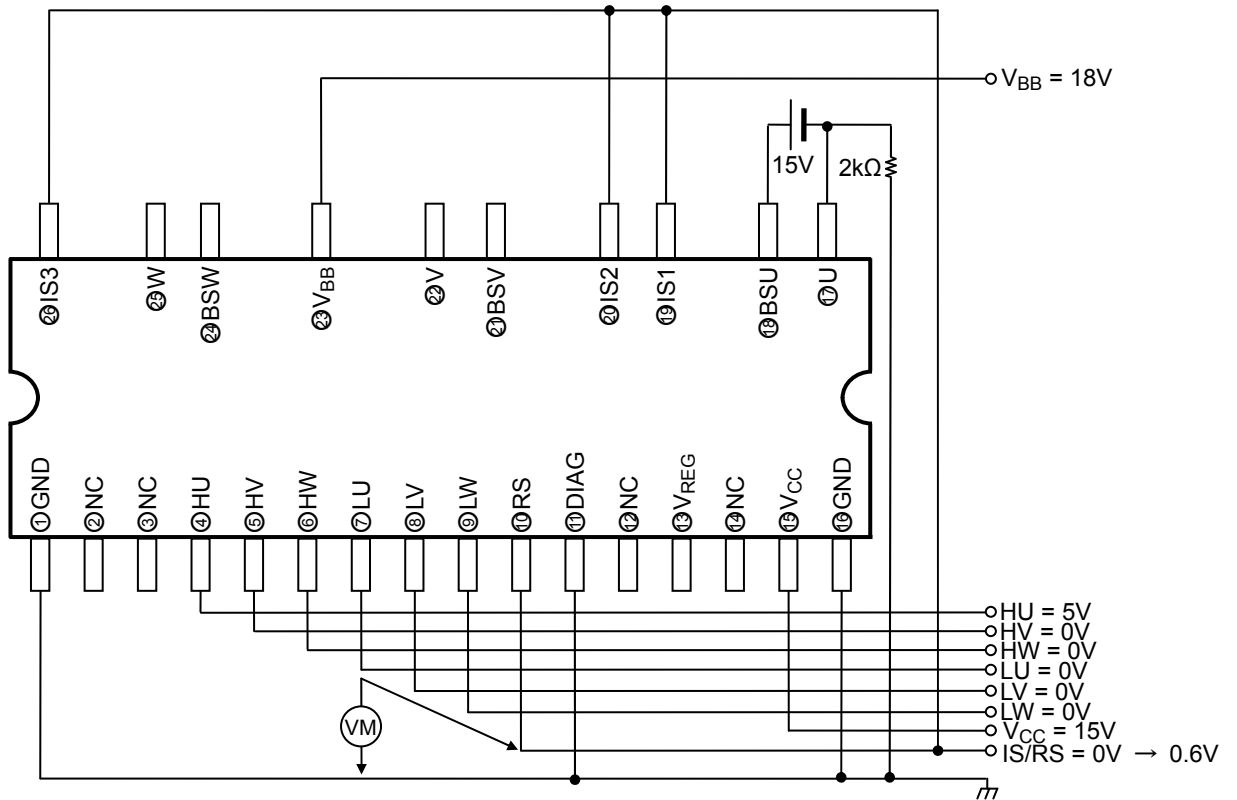
\*Note: Sweeps the VCC pin voltage from 15 V and monitors the U pin voltage. The VCC pin voltage when output is off defines the under-voltage protection operating voltage. Also sweeps from 6 V to increase. The VCC pin voltage when output is on defines the under voltage protection recovery voltage.

**VBS Under-voltage Protection Operating/Recovery Voltage (U-phase high side)**



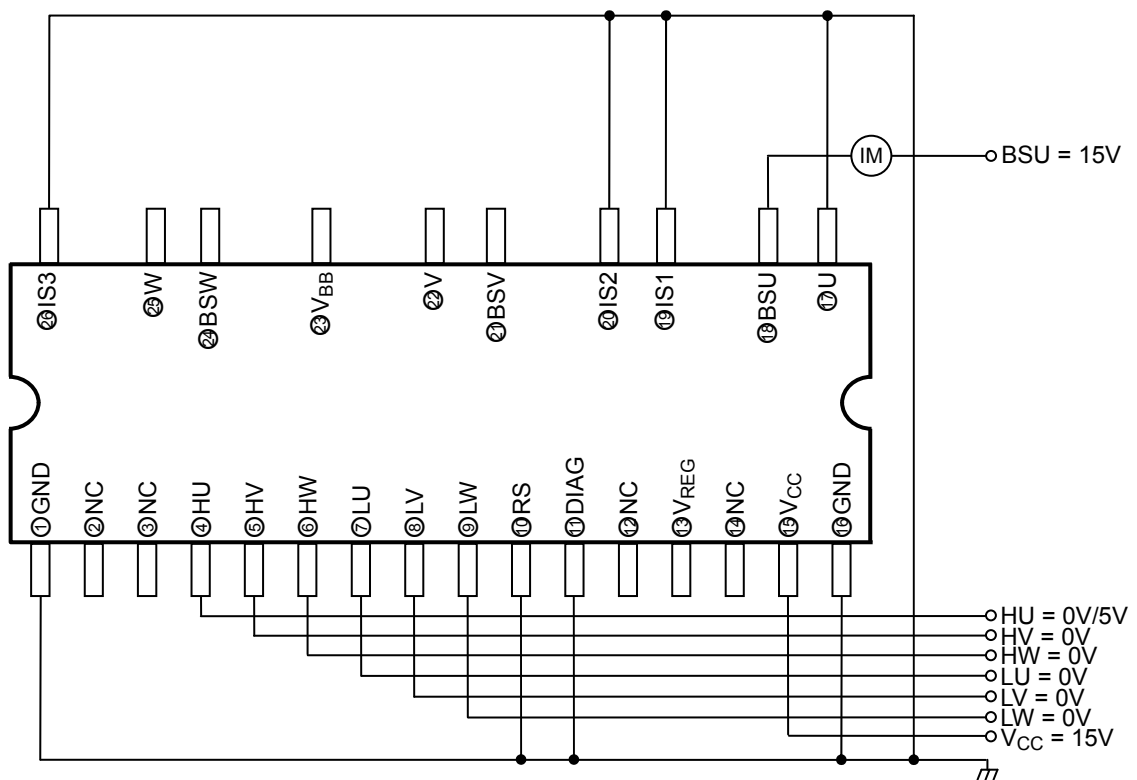
\*Note: Sweeps the BSU pin voltage from 15 V to decrease and monitors the VBB pin voltage. The BSU pin voltage when output is off defines the under voltage protection operating voltage. Also sweeps the BSU pin voltage from 6V to increase and change the HU pin voltage at 5 V→0 V→5 V each time. It repeats similarly output is on. When the BSU pin voltage when output is on defines the under voltage protection recovery voltage.

**Current Limit Operating Voltage (U-phase high side)**

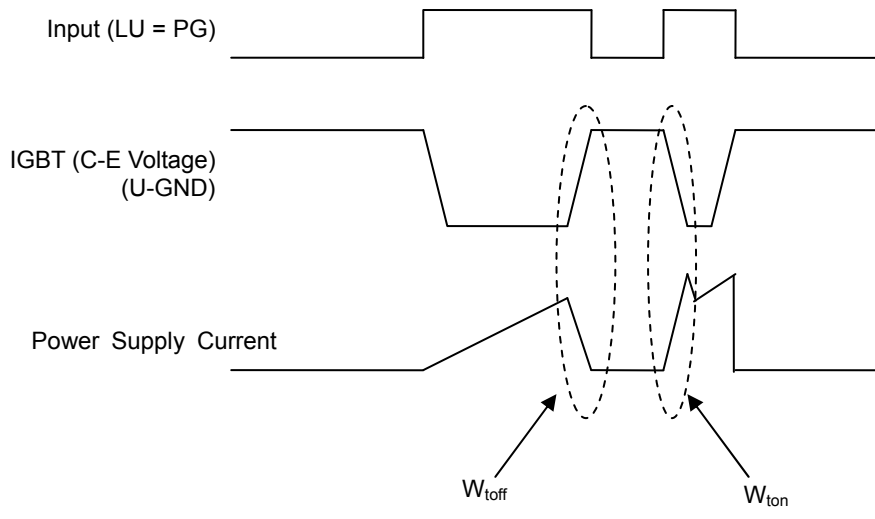
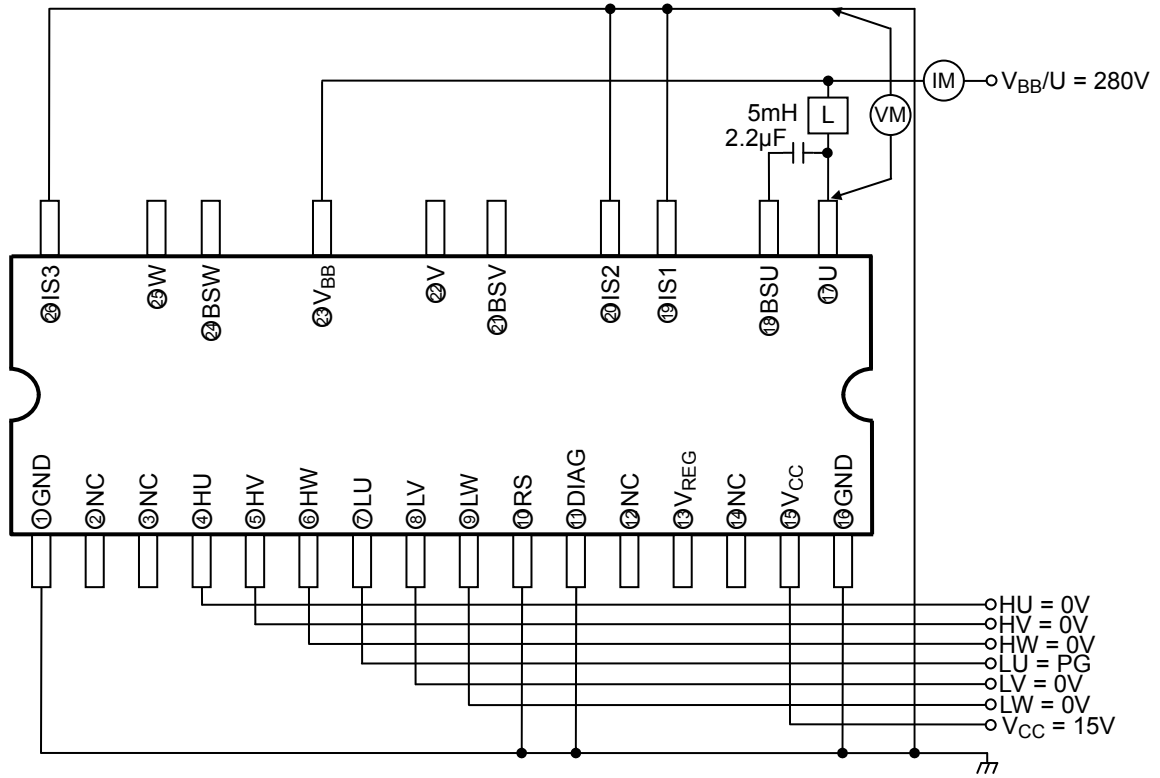


\*Note: Sweeps the IS/RS pin voltage and monitors the U pin voltage.  
 The IS/RS pin voltage when output is off defines the current control operating voltage.

**Bootstrap Current Dissipation (U-phase high side)**



## Turn-ON/OFF Loss (low side IGBT + high side FRD)





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