

TOSHIBA Intelligent Power Device High Voltage Monolithic Silicon Power IC

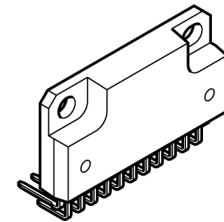
# TPD4113AK

The TPD4113AK is a DC brush less motor driver using high-voltage PWM control. It is fabricated using a high-voltage SOI process. The device contains a level shift high side driver, low side driver, IGBT outputs, FRDs and protective functions for under-voltage protection circuits, and a 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 TPD4113AK.

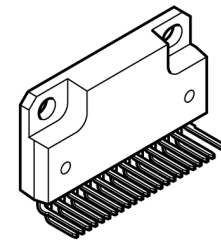
## Features

- Bootstrap circuit gives simple high-side power supply.
- Bootstrap diodes are built in.
- A dead time can be set as a minimum of 1.4  $\mu$ s, 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: 23-pin HZIP.

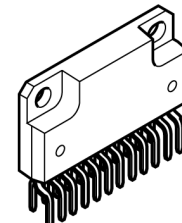
This product has a MOS structure and is sensitive to electrostatic discharge. When handling this product, ensure that the environment is protected against electrostatic discharge.



HZIP23-P-1.27F (LBR)



HZIP23-P-1.27G (LBF)



HZIP23-P-1.27H (LB2)

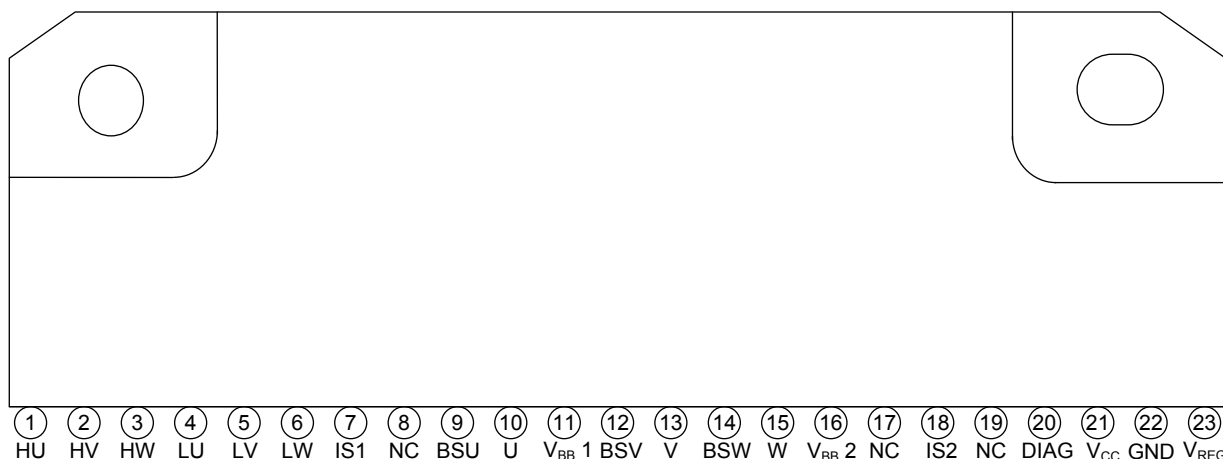
### Weight

HZIP23-P-1.27F : 6.1 g (typ.)

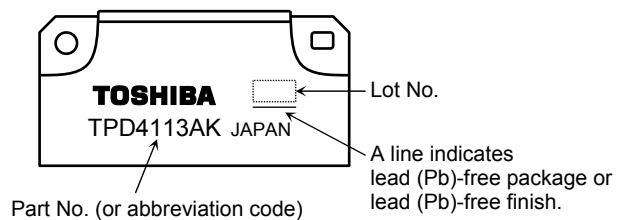
HZIP23-P-1.27G : 6.1 g (typ.)

HZIP23-P-1.27H : 6.1 g (typ.)

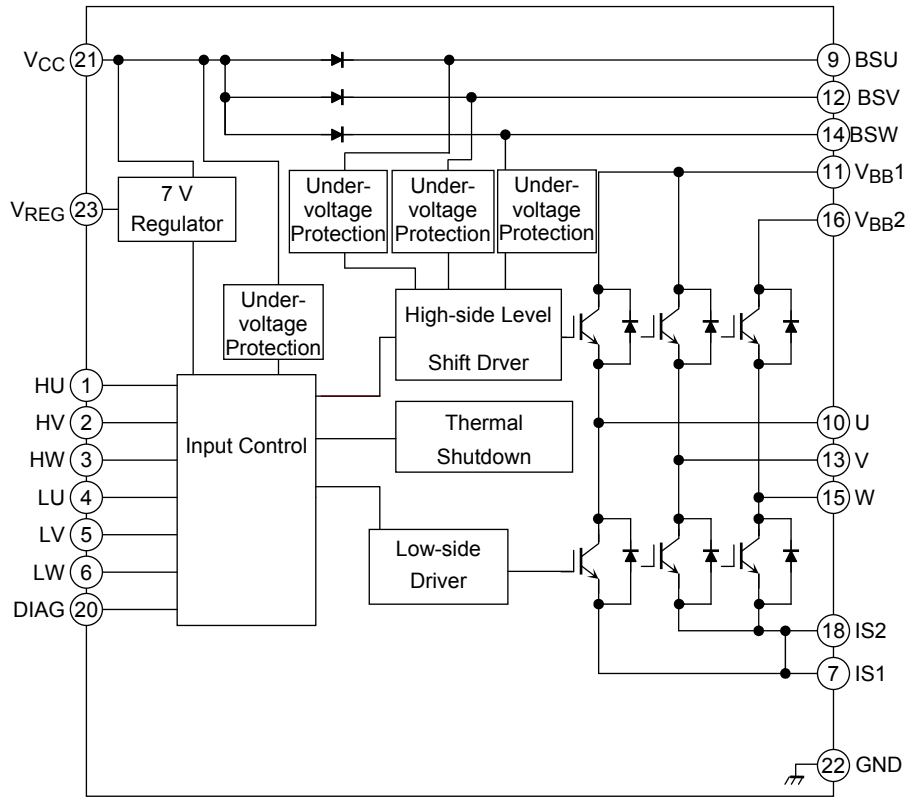
## Pin Assignment



## Marking



Block Diagram

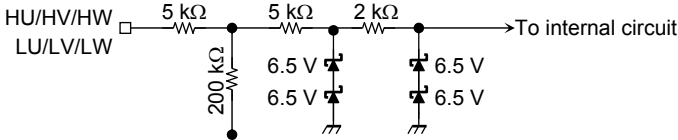


## Pin Description

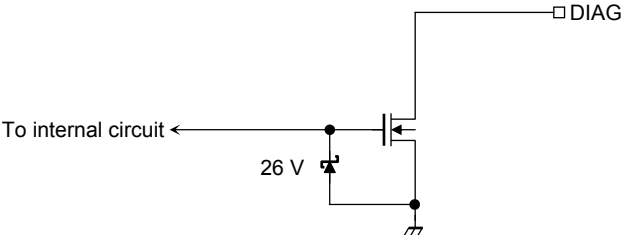
Pin No.	Symbol	Pin Description
1	HU	The control terminal of IGBT by the side of U top arm. It turns off more than by 1.5V. It turns on more than by 3.5V.
2	HV	The control terminal of IGBT by the side of V top arm. It turns off more than by 1.5V. It turns on more than by 3.5V.
3	HW	The control terminal of IGBT by the side of W top arm. It turns off more than by 1.5V. It turns on more than by 3.5V.
4	LU	The control terminal of IGBT by the side of U bottom arm. It turns off more than by 1.5V. It turns on more than by 3.5V.
5	LV	The control terminal of IGBT by the side of V bottom arm. It turns off more than by 1.5V. It turns on more than by 3.5V.
6	LW	The control terminal of IGBT by the side of W bottom arm. It turns off more than by 1.5V. It turns on more than by 3.5V.
7	IS1	IGBT emitter and FRD anode pin.
8	NC	Unused pin, which is not connected to the chip internally.
9	BSU	U-phase bootstrap capacitor connecting pin.
10	U	U-phase output pin.
11	V <sub>BB1</sub>	U and V-phase high-voltage power supply input pin.
12	BSV	V-phase bootstrap capacitor connecting pin.
13	V	V-phase output pin.
14	BSW	W-phase bootstrap capacitor connecting pin.
15	W	W-phase output pin.
16	V <sub>BB2</sub>	W-phase high-voltage power supply input pin.
17	NC	Unused pin, which is not connected to the chip internally.
18	IS2	IGBT emitter and FRD anode pin.
19	NC	Unused pin, which is not connected to the chip internally.
20	DIAG	With the diagnostic output terminal of open drain , a pull-up is carried out by resistance. It turns it on at the time of unusual.
21	V <sub>CC</sub>	Control power supply pin.(15V typ.)
22	GND	Ground pin.
23	V <sub>REG</sub>	7V regulator output pin.

**Equivalent Circuit of Input Pins**

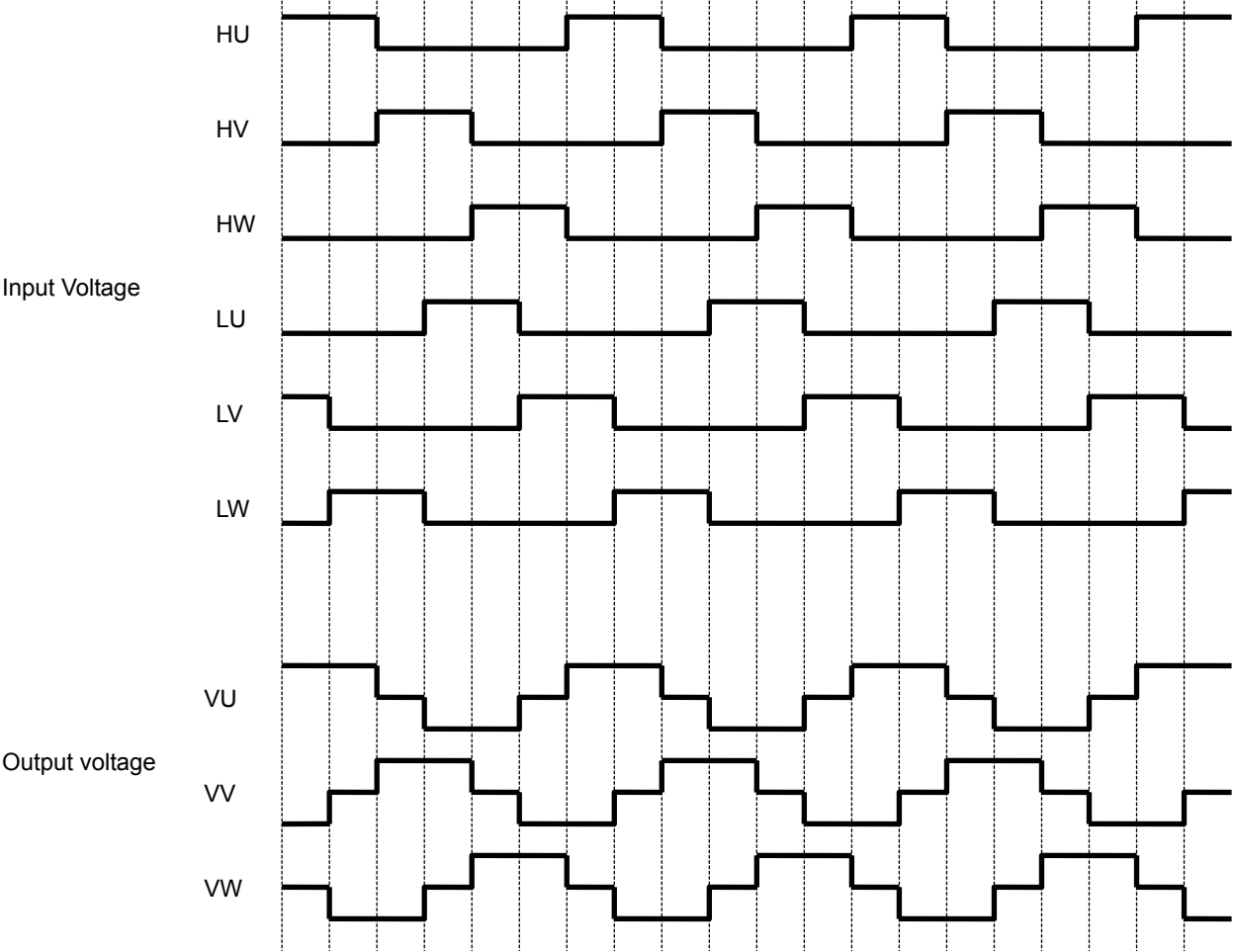
Internal circuit diagram of HU, HV, HW, LU, LV, LW input pins



**Internal circuit diagram of DIAG pin**



**Timing Chart**



## Truth Table

Mode	Input						Top arm			Bottom arm			DIAG
	H U	H V	H W	L U	L V	L W	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
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
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

Notes: Release of Thermal shutdown protection and under voltage protection depends release of a self-reset .

## 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>	1	A
Output current (pulse)	I <sub>out</sub>	2	A
Input voltage	V <sub>IN</sub>	-0.5~7	V
V <sub>REG</sub> current	I <sub>REG</sub>	50	mA
V <sub>DIAG</sub> current	I <sub>DIAG</sub>	20	mA
Power dissipation (Ta = 25°C)	P <sub>C</sub>	4	W
Power dissipation (Tc = 25°C)	P <sub>C</sub>	20	W
Operating temperature	T <sub>jopr</sub>	-20~135	°C
Junction temperature	T <sub>j</sub>	150	°C
Storage temperature	T <sub>stg</sub>	-55~150	°C
Lead-heat sink isolation voltage	V <sub>hs</sub>	1000 (1 min)	V <sub>rms</sub>

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.

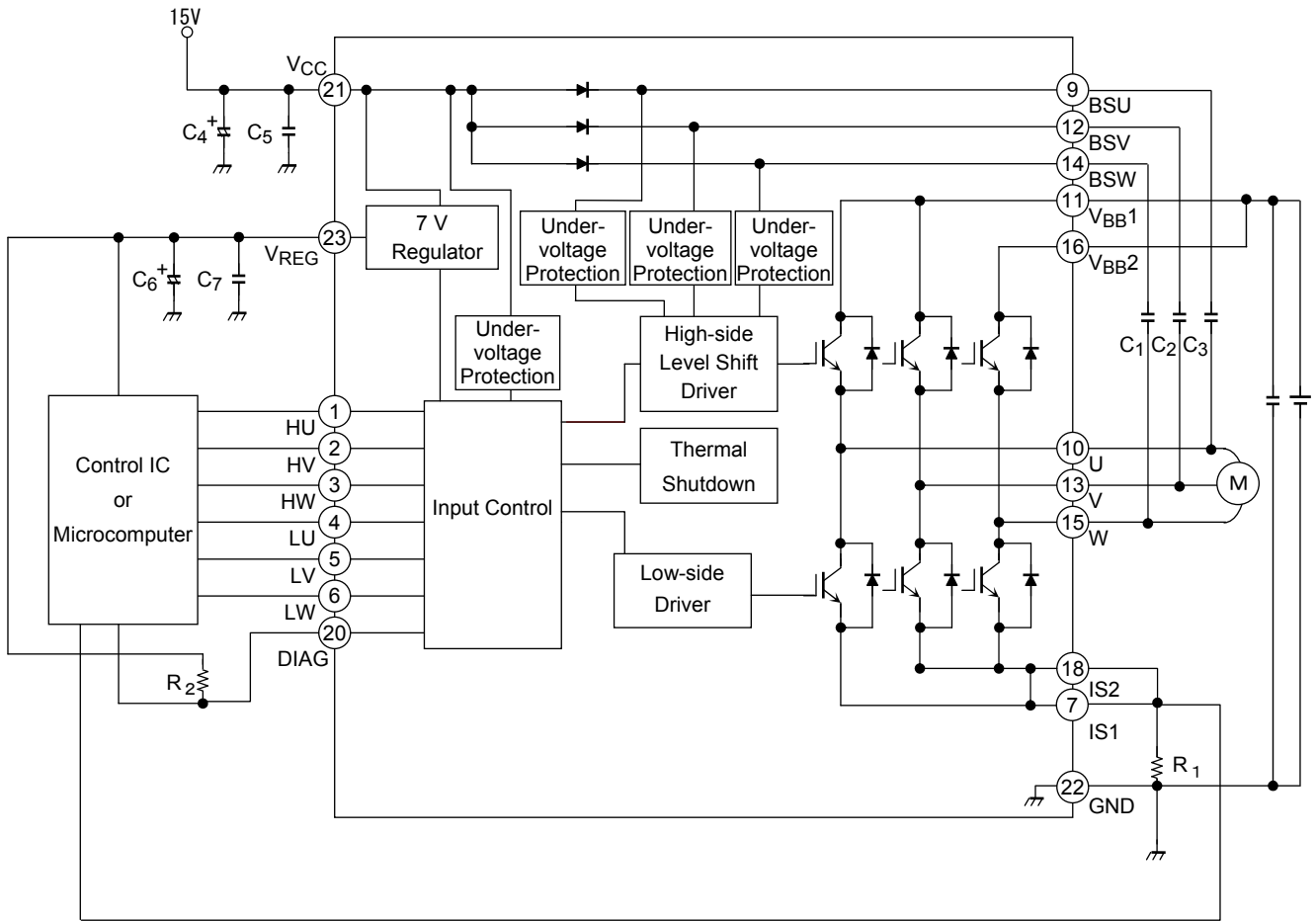
Please design the appropriate reliability upon reviewing the Toshiba Semiconductor Reliability Handbook ("Handling Precautions"/Derating Concept and Methods) and individual reliability data (i.e. reliability test report and estimated failure rate, etc).

## 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	—	1.1	5	
	I <sub>BS (ON)</sub>	V <sub>BS</sub> = 15 V, high side ON	—	260	410	μA
	I <sub>BS (OFF)</sub>	V <sub>BS</sub> = 15 V, high side OFF	—	230	370	
Input voltage	V <sub>IH</sub>	V <sub>IN</sub> = "H"	3.5	—	—	V
	V <sub>IL</sub>	V <sub>IN</sub> = "L"	—	—	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> = 0.5 A	—	2.4	3	V
	V <sub>CEsatL</sub>	V <sub>CC</sub> = 15 V, I <sub>C</sub> = 0.5 A	—	2.4	3	
FRD forward voltage	V <sub>FH</sub>	I <sub>F</sub> = 0.5 A, high side	—	1.6	2.0	V
	V <sub>FL</sub>	I <sub>F</sub> = 0.5 A, low side	—	1.6	2.0	
Regulator voltage	V <sub>REG</sub>	V <sub>CC</sub> = 15 V, I <sub>O</sub> = 30 mA	6.5	7	7.5	V
BSD forward voltage	V <sub>F (BSD)</sub>	I <sub>F</sub> = 500 μA	—	0.9	1.2	V
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, I <sub>C</sub> = 0.5 A	—	1.5	3	μs
Output-off delay time	t <sub>off</sub>	V <sub>BB</sub> = 280 V, I <sub>C</sub> = 0.5 A	—	1.2	3	μs
Dead time	t <sub>dead</sub>	V <sub>BB</sub> = 280 V, I <sub>C</sub> = 0.5 A	1.4	—	—	μs
FRD reverse recovery time	t <sub>rr</sub>	V <sub>BB</sub> = 280 V, I <sub>C</sub> = 0.5 A	—	200	—	ns



Application Circuit Example



## External Parts

Standard external parts are shown in the following table.

Part	Recommended Value	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>	0.62 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>	16 V/1 μF	V <sub>REG</sub> power supply stability	(Note 3)
C <sub>7</sub>	16 V/1000 pF	V <sub>REG</sub> for surge absorber	(Note 3)
R <sub>2</sub>	5.1 kΩ	DIAG pin 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:  $I_O = V_R \div R_1$   
Do not exceed a detection current of 1A when using this product.  
(Please go from the outside in the over current protection.)

Note 3: When using this product, some 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. Note that when the DIAG pin is connected to a power supply with a voltage higher than or equal to the V<sub>CC</sub>, a protection circuit is triggered so that the current flows continuously. If the DIAG pin is not used, 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 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 an under-voltage protection circuit 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 ( $V_{CCUVD} = 11\text{ V typ.}$ ), all IGBT outputs shut down regardless of the input. This protection function has hysteresis. When the  $V_{CCUVR}$  ( $= 11.5\text{ V typ.}$ ) reaches 0.5 V higher than the shutdown voltage, this product is automatically restored and the IGBT is turned on/off again by the input.

When the VBS supply voltage drops ( $V_{BSUVD} = 9\text{ V typ.}$ ), the high-side IGBT output shuts down. When the  $V_{BSUVR}$  ( $= 9.5\text{ V typ.}$ ) reaches 0.5 V higher than the shutdown voltage, the IGBT is turned on/off again by the input signal.

(2) Thermal shutdown

This product incorporates a thermal shutdown circuit to protect itself against excessive rise in temperature. 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 ( $\Delta T_{SD} = 50^\circ\text{C typ.}$ ). When the chip temperature falls to  $T_{SD} - \Delta T_{SD}$ , the chip is automatically restored and the IGBT is turned on/off 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 between the detection location and the IGBT (the source of the heat) can cause differences in the time taken for shutdown to occur. Therefore, the temperature of the chip may rise higher than the initial thermal shutdown temperature.

**Safe Operating Area**

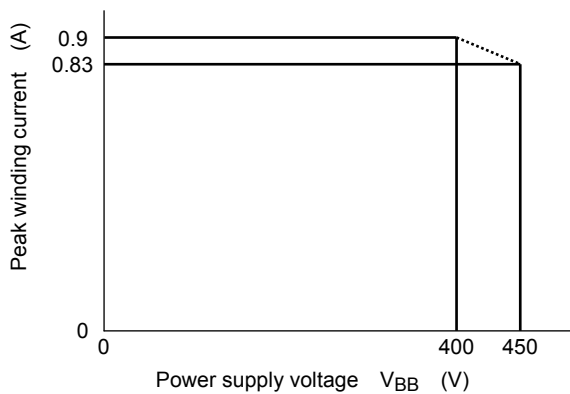


Figure 1 SOA at Tj = 135°C

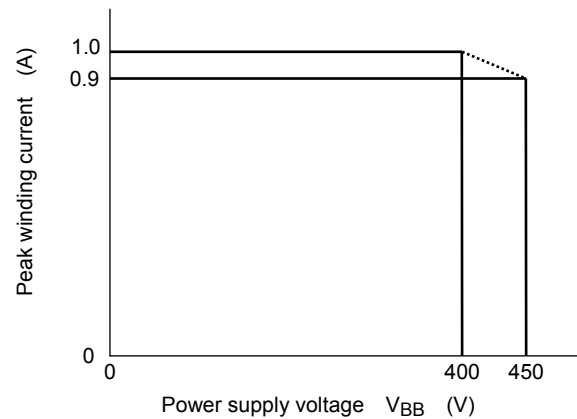
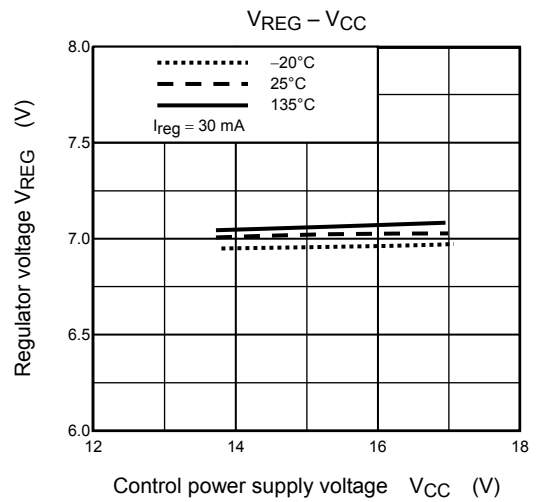
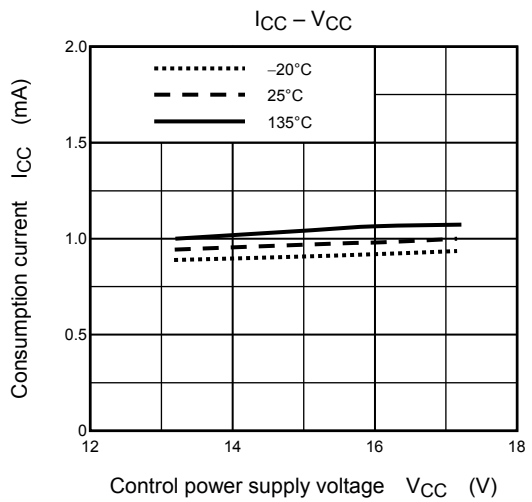
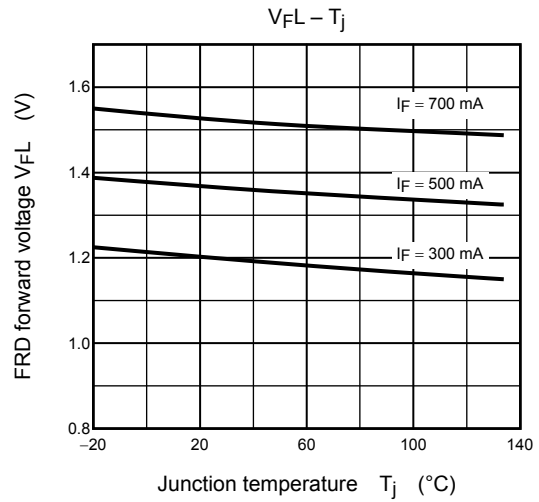
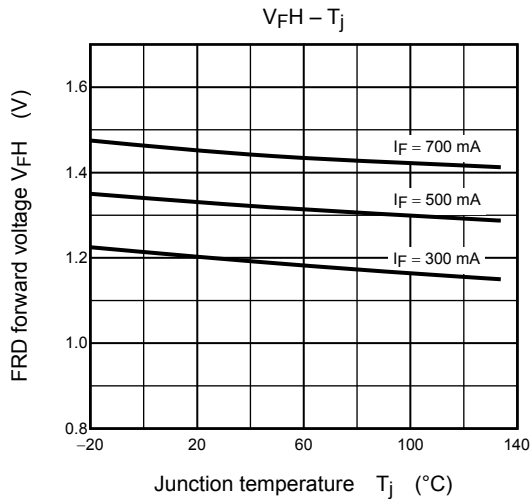
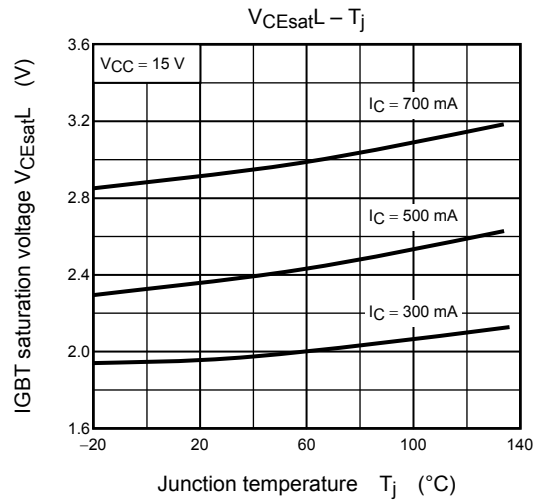
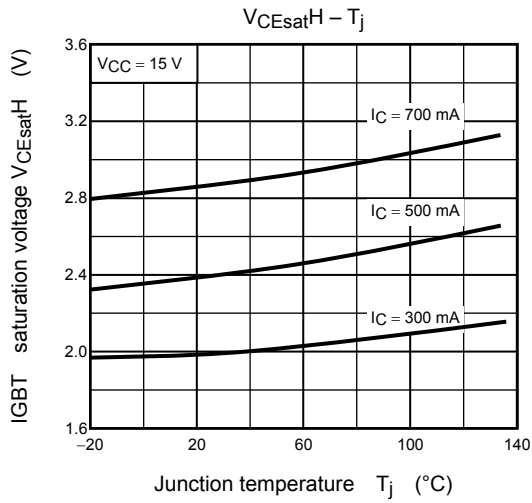
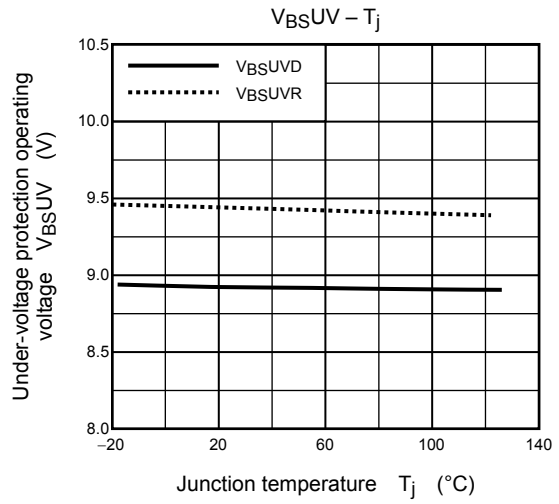
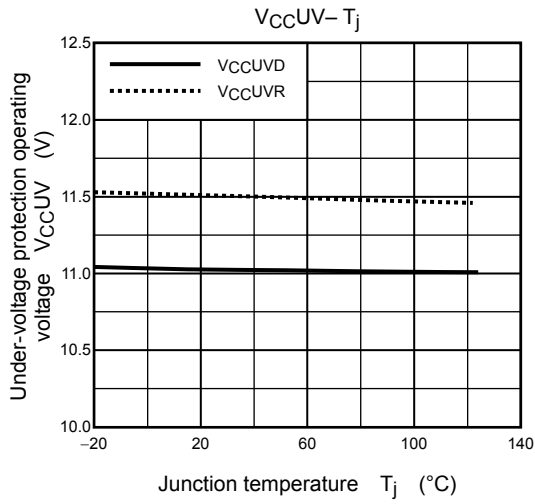
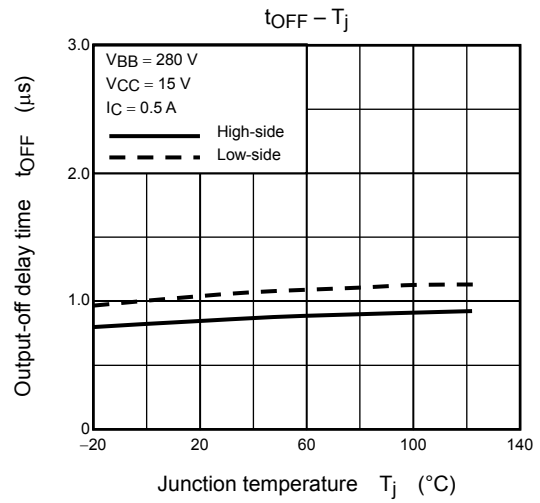
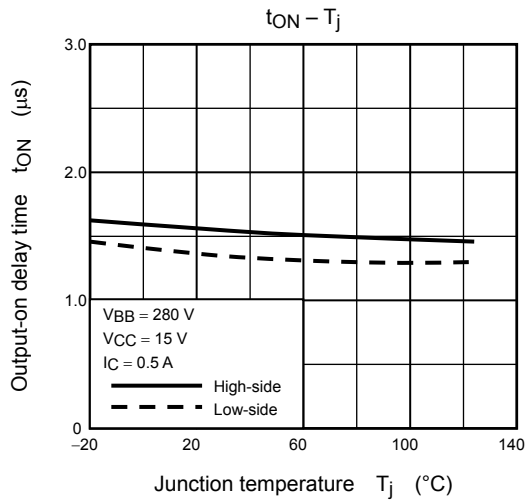


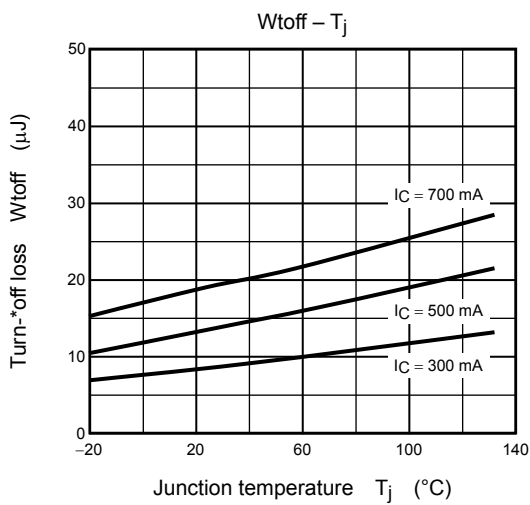
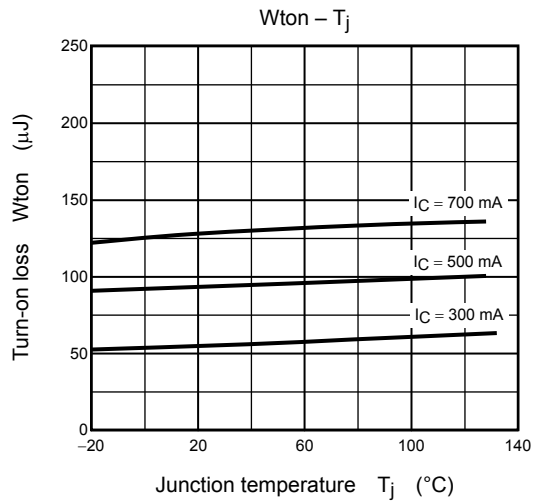
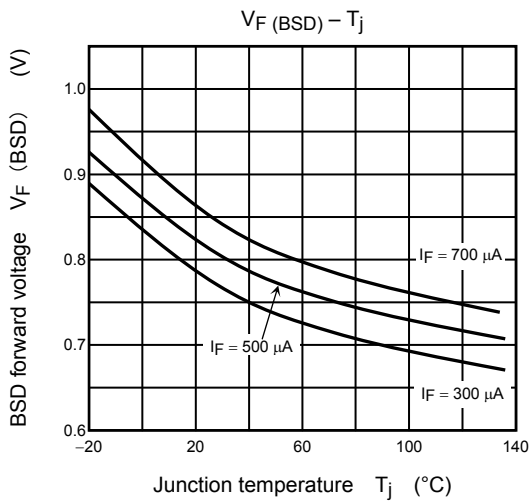
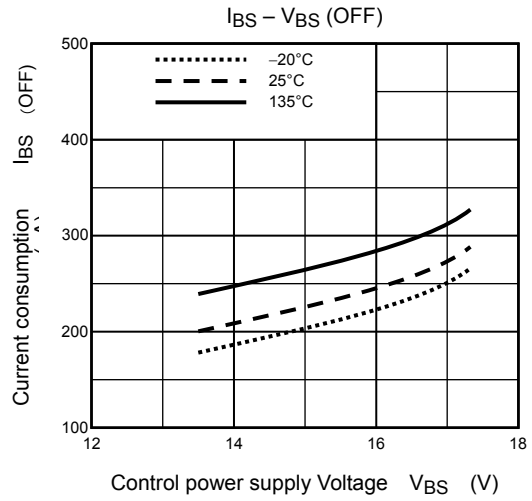
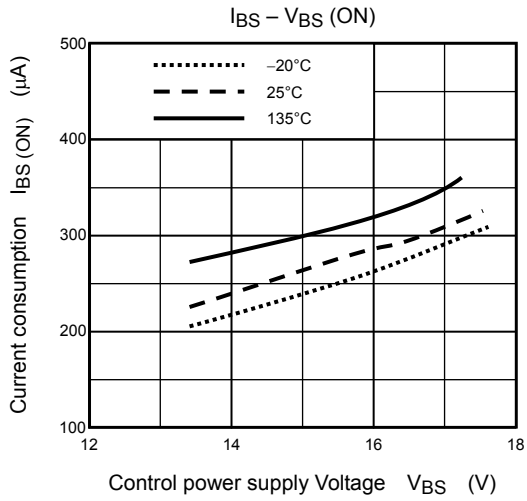
Figure 2 SOA at Tc = 95°C

Note 1: The above safe operating areas are at Tj = 135°C (Figure 1) and Tc = 95°C (Figure 2). If the temperature exceeds these, the safe operation areas reduce.

Note 2: The above safe operating areas include the over current protection operation area.

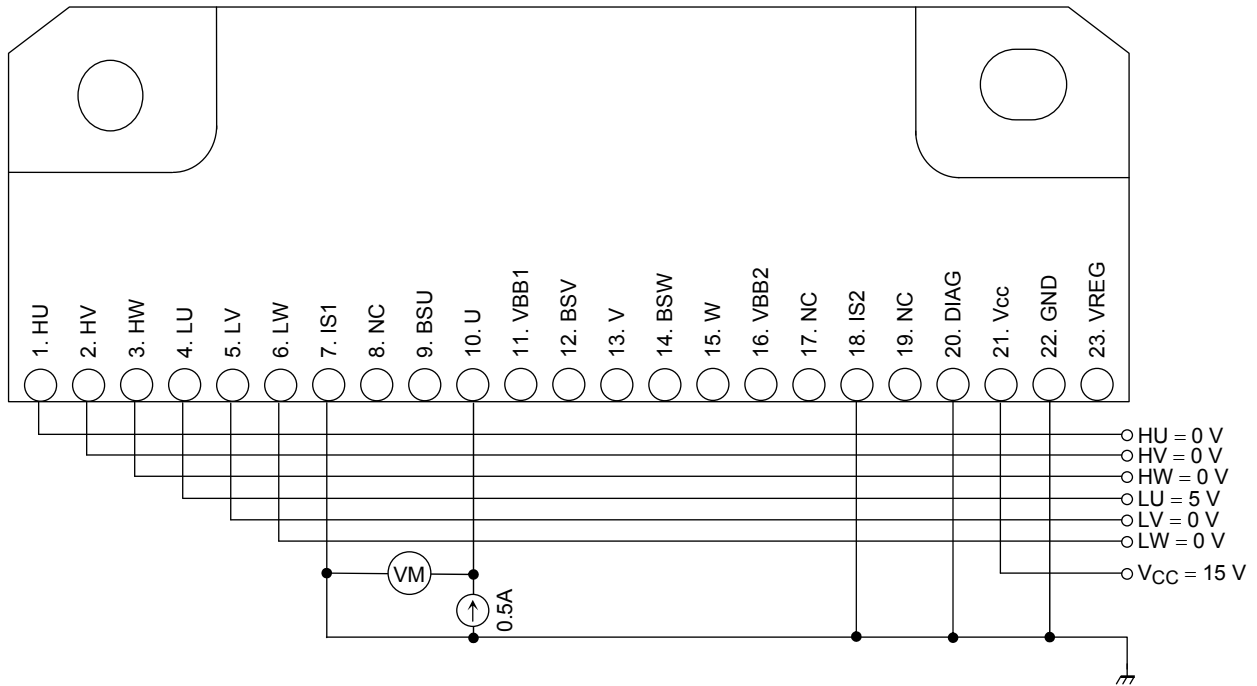




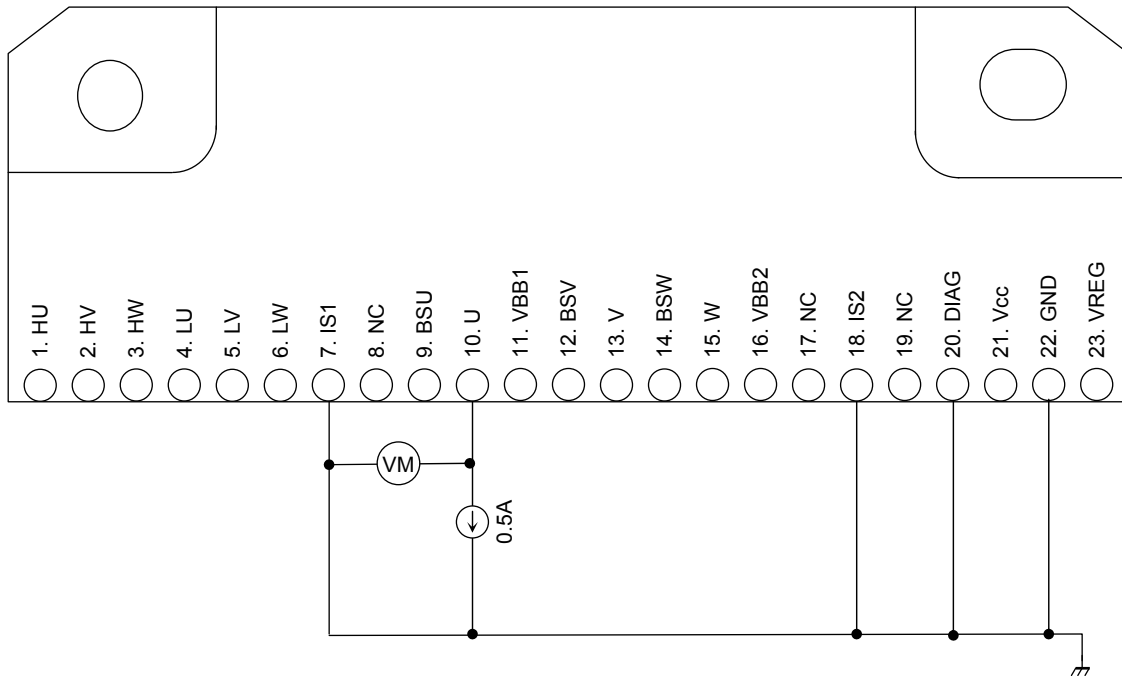


## Test Circuits

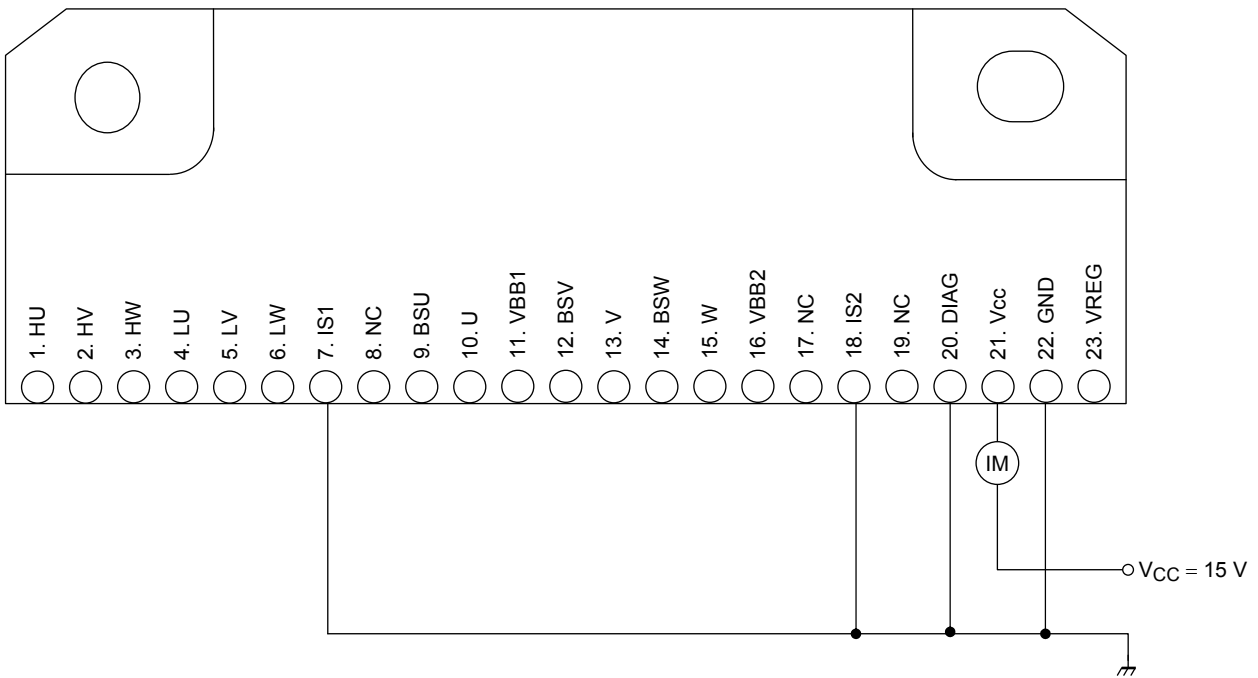
### IGBT Saturation Voltage (U-phase low side)



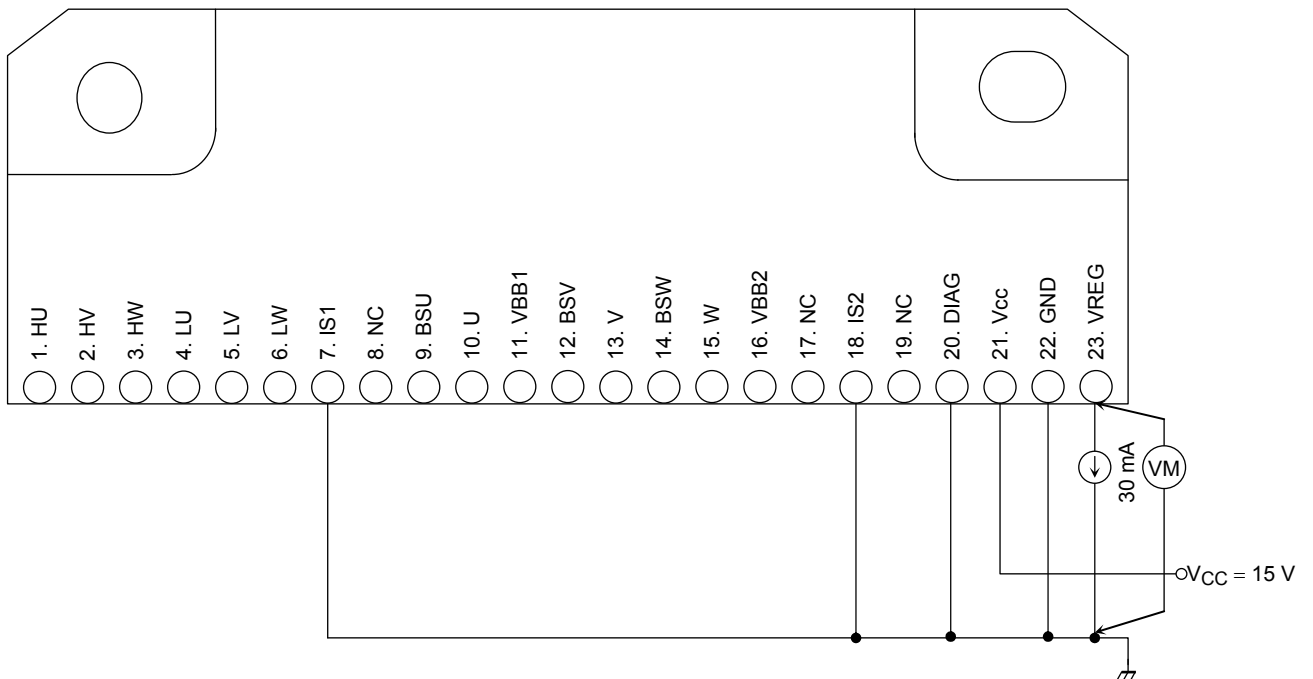
### FRD Forward Voltage (U-phase low side)



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

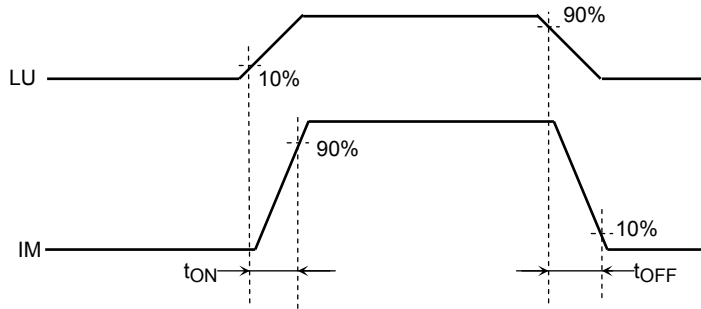
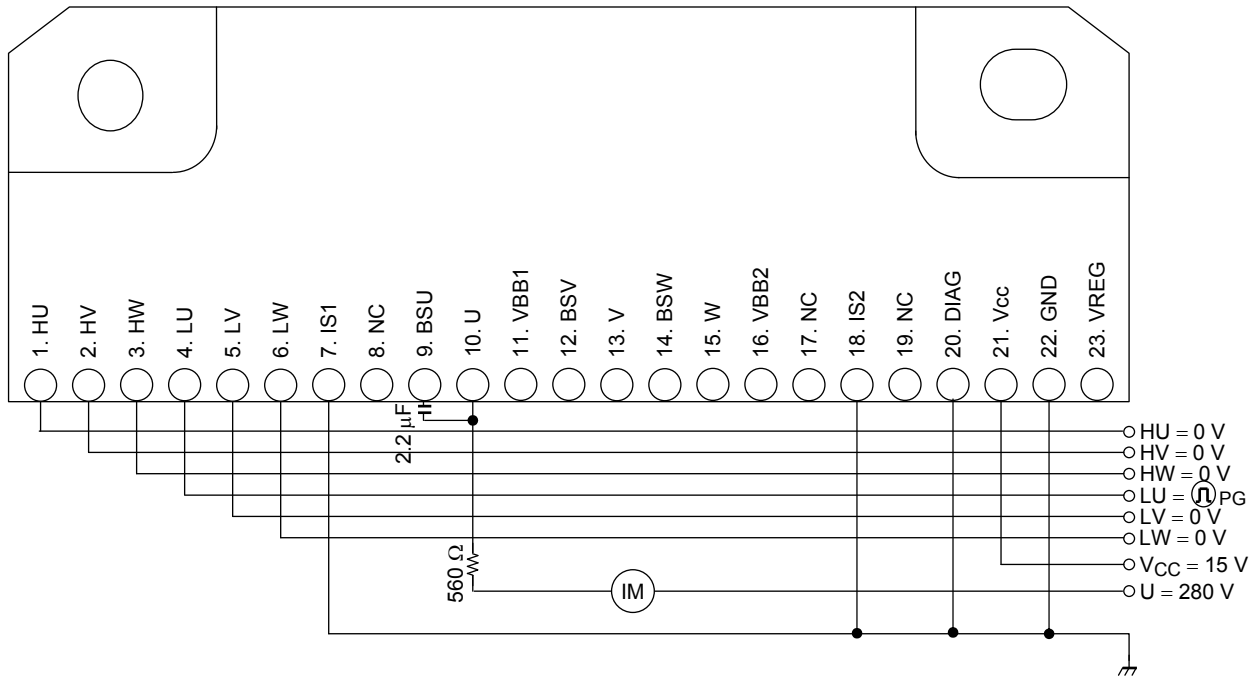


## Regulator Voltage

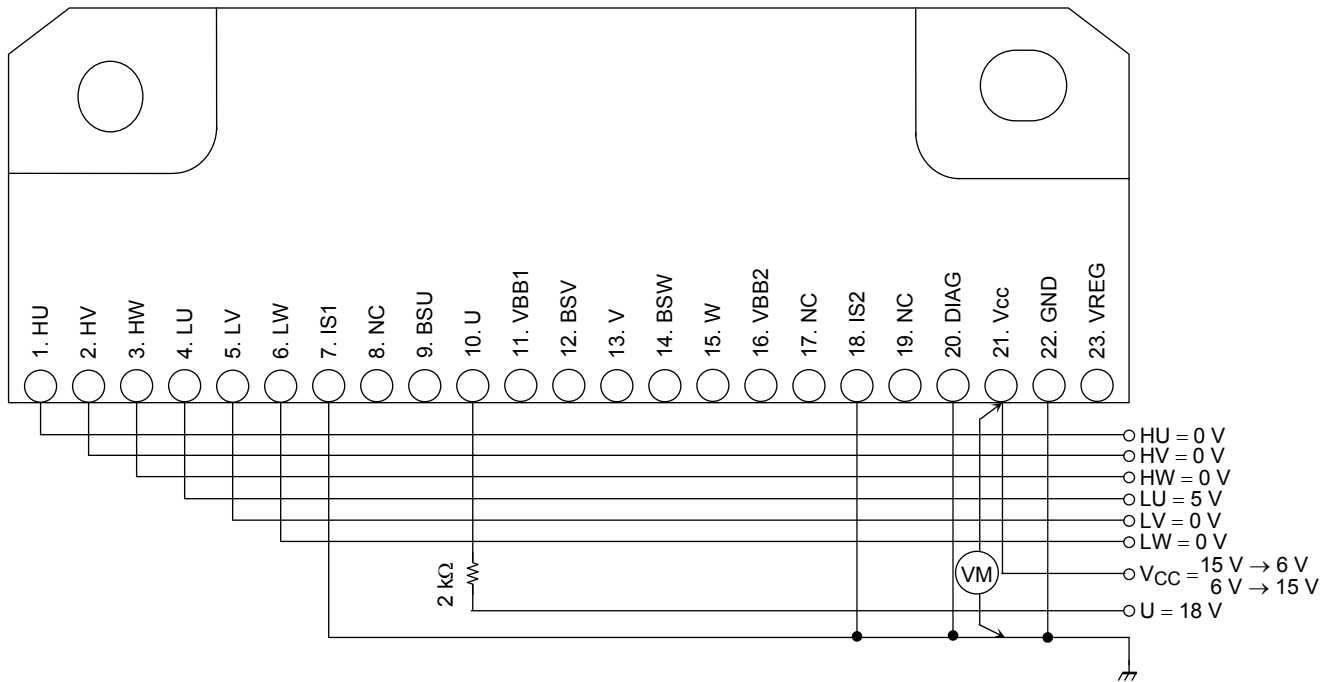




## Output ON/OFF Delay Time (U-phase low side)

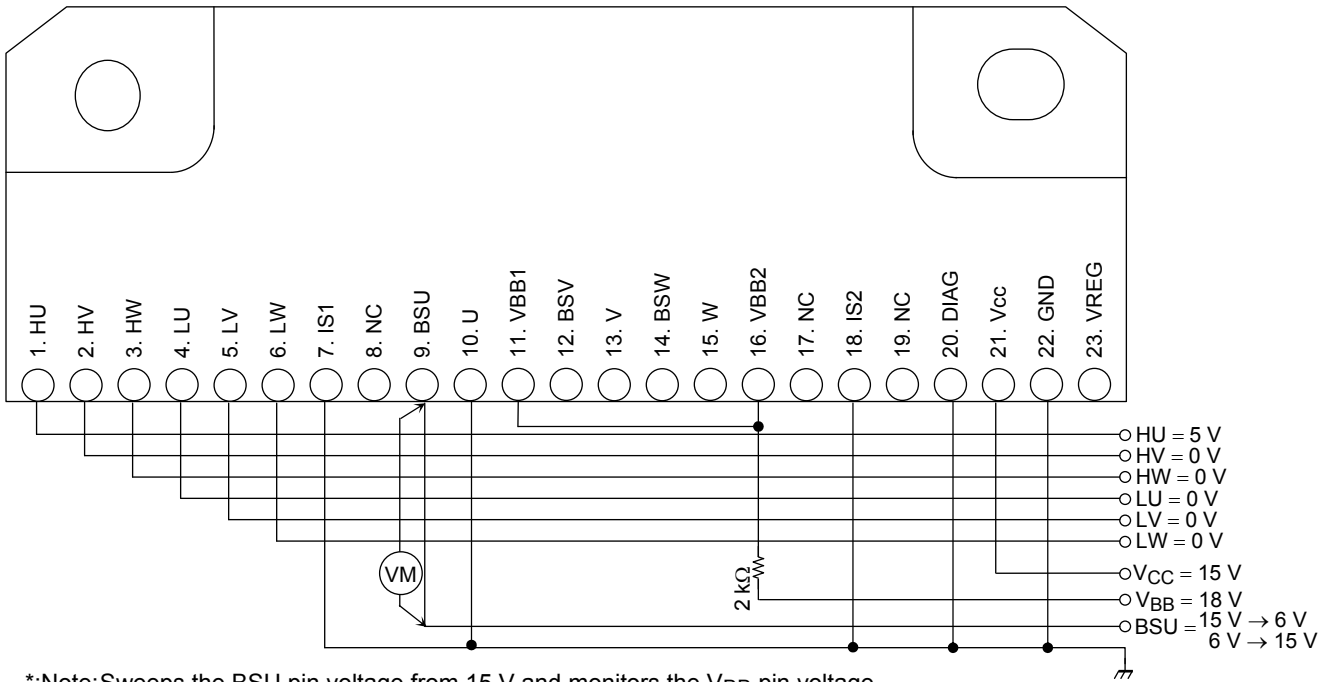


**V<sub>CC</sub> Under-voltage Protection Operation/Recovery Voltage (U-phase low side)**



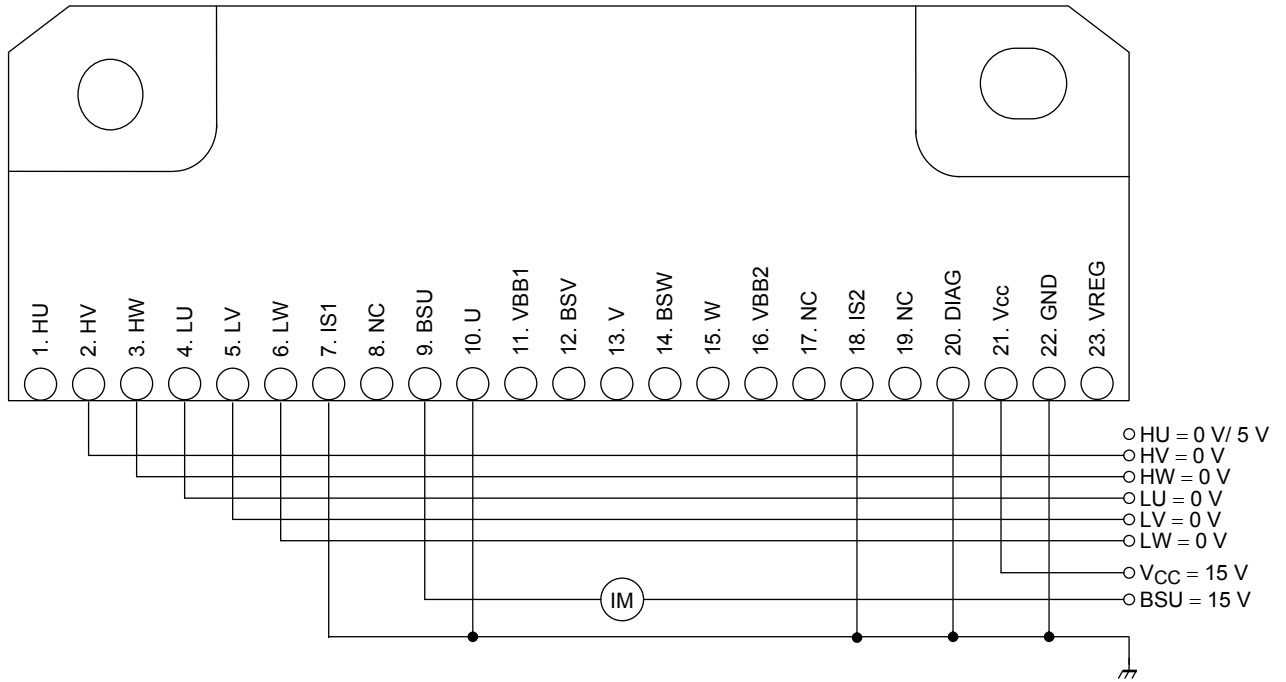
\*:Note:Sweeps the V<sub>CC</sub> pin voltage from 15 V and monitors the U pin voltage.  
 The V<sub>CC</sub> pin voltage when output is off defines the under voltage protection operating voltage.  
 Also sweeps from 6 V to increase. The V<sub>CC</sub> pin voltage when output is on defines the under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

**V<sub>BS</sub> Under-voltage Protection Operation/Recovery Voltage (U-phase high side)**

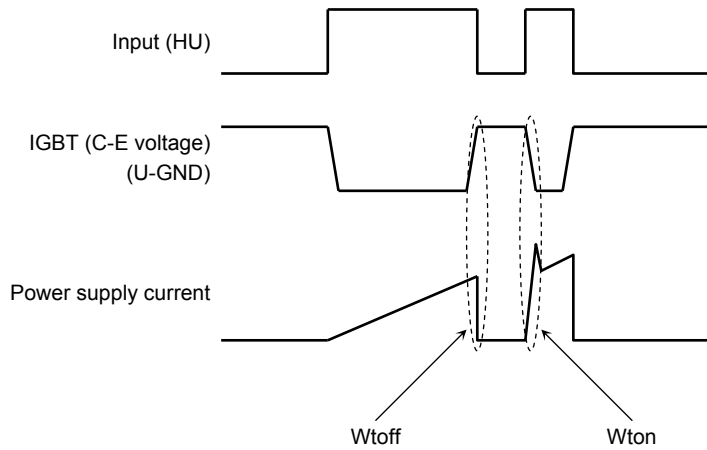
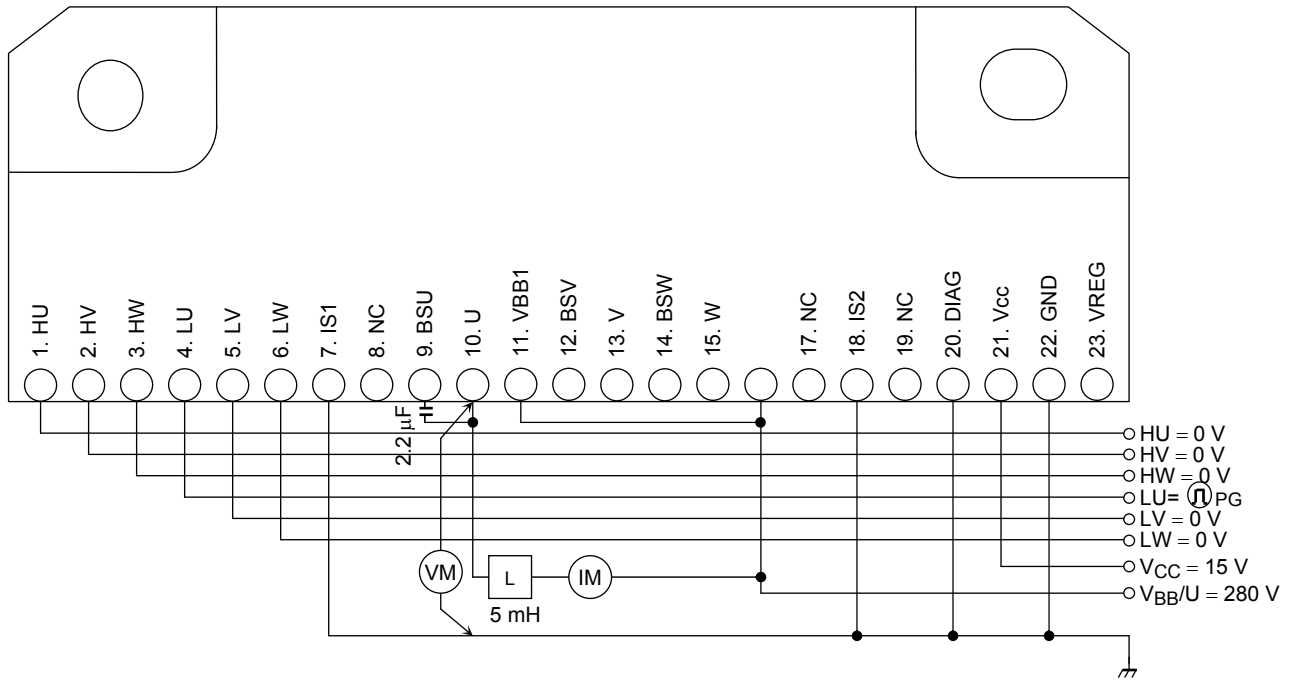


\*:Note:Sweeps the BSU pin voltage from 15 V and monitors the V<sub>BB</sub> pin voltage.  
 The BSU pin voltage when output is off defines the under-voltage protection operating voltage.  
 Also sweeps the BSU pin voltage from 6 V and changes from the HU pin voltage at 0 V → 5 V → 0 V.  
 The BSU pin voltage when output is on defines the under-voltage protection recovery voltage.

**V<sub>BS</sub> Current Consumption (U-phase high side)**



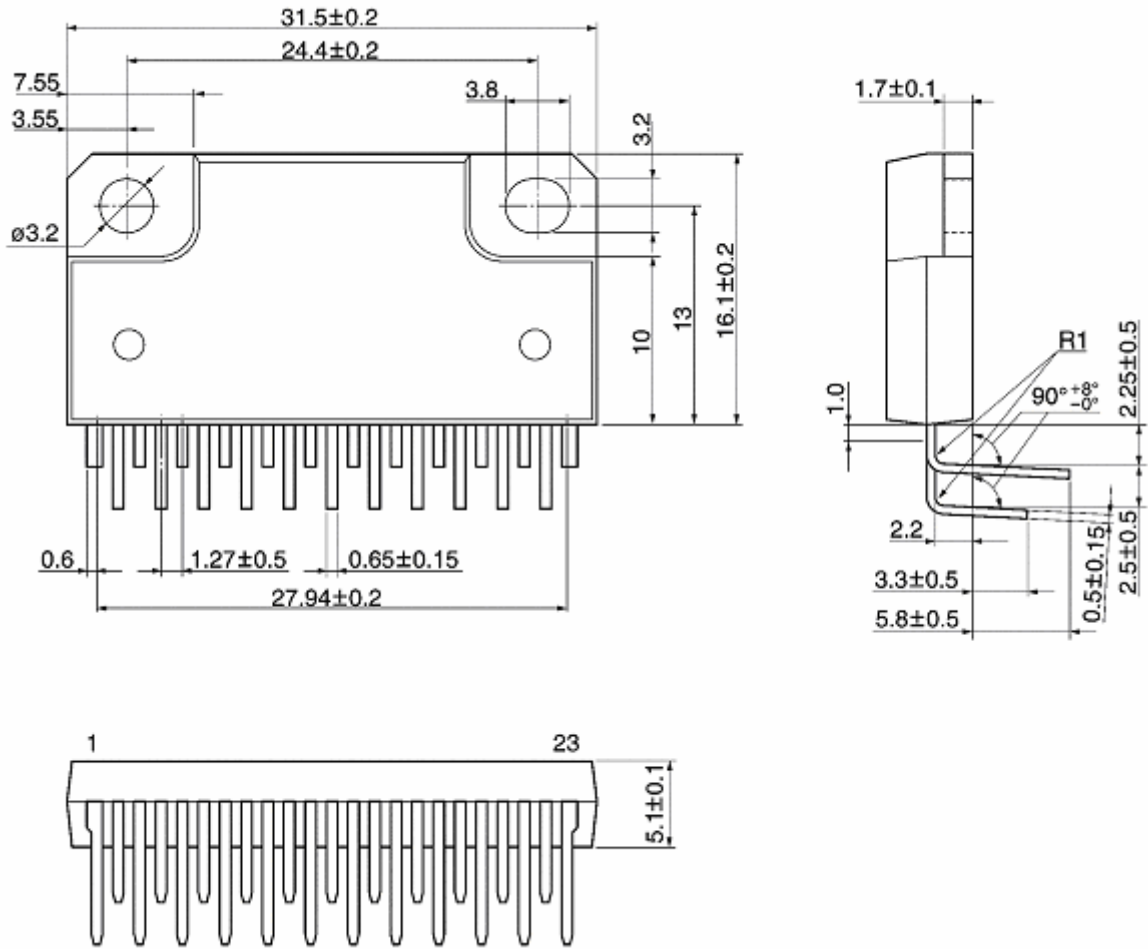
## Turn-On/Off Loss (low-side IGBT + high-side FRD)



Package Dimensions

HZIP23-P-1.27F

Unit: mm

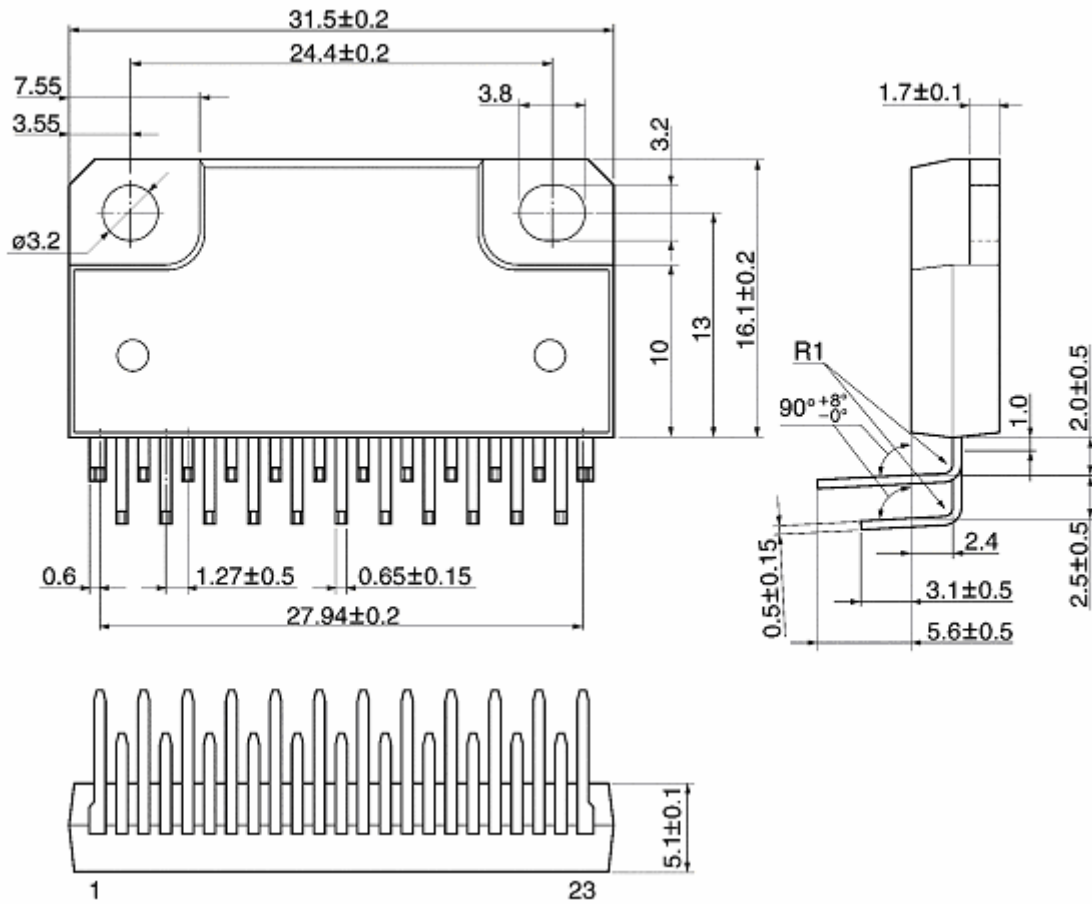


Weight: 6.1 g (typ.)

**Package Dimensions**

HZIP23-P-1.27G

Unit: mm

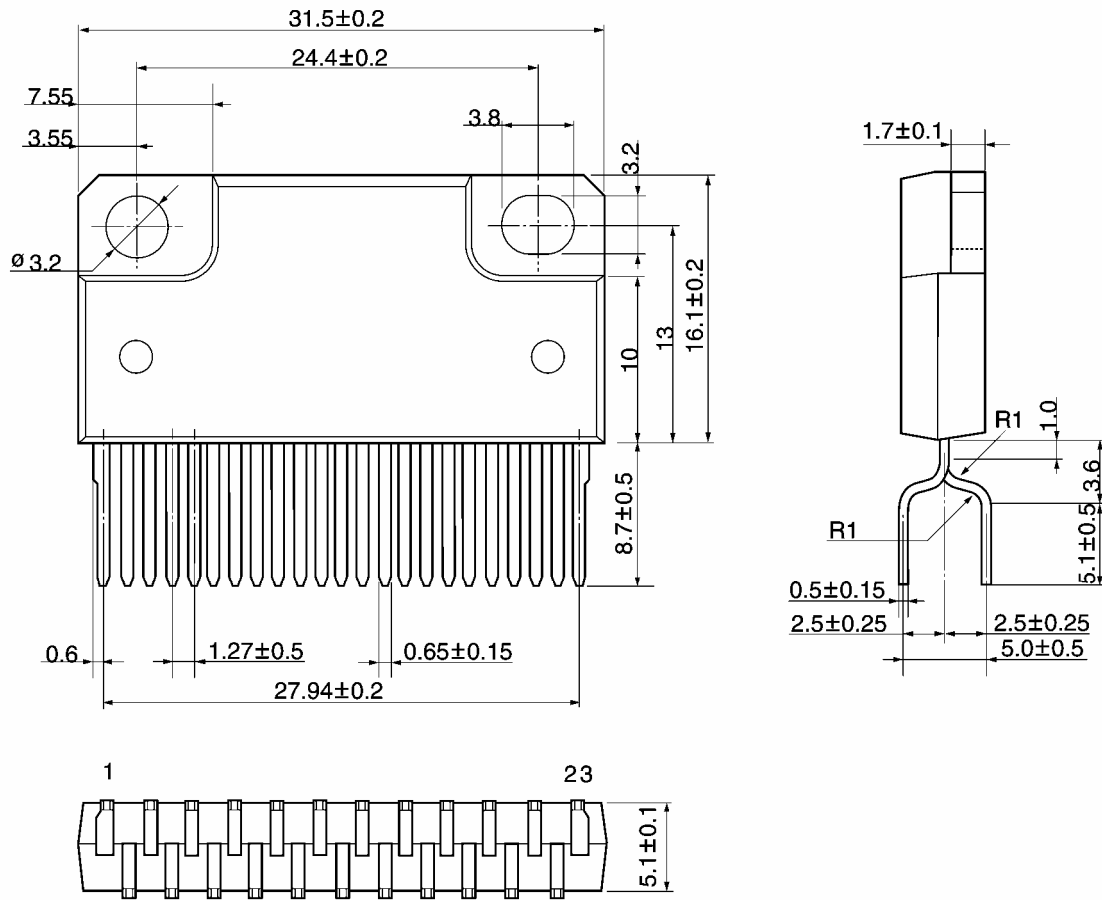


Weight: 6.1 g (typ.)

**Package Dimensions**

HZIP23-P-1.27H

Unit: mm



Weight: 6.1 g (typ.)

**RESTRICTIONS ON PRODUCT USE**

20070701-EN

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