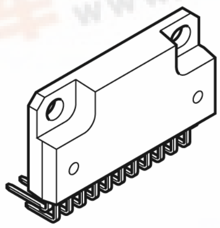
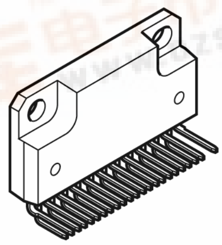
TOSHIBA Intelligent Power Device High Voltage Monolithic Silicon Power IC

TPD4113K

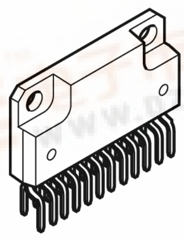
The TPD4113K is a DC brushless motor driver using high- voltage PWM control. It is fabricated using a high-voltage SOI process. The device contains a level shift high side driver, low side driver, IGBT outputs, FRDs and protective functions for over-current and under-voltage protection circuits, and 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 TPD4113K.



HZIP23-P-1.27F (LBR)



HZIP23-P-1.27G (LBF)



HZIP23-P-1.27H (LB2)

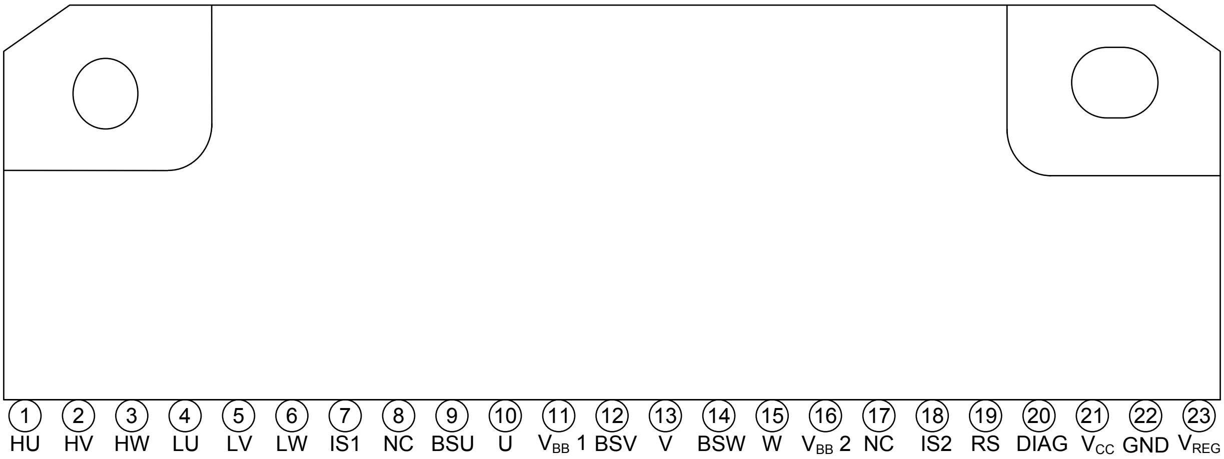
Weight
HZIP23-P-1.27F : 6.1 g (typ.)
HZIP23-P-1.27G : 6.1 g (typ.)
HZIP23-P-1.27H : 6.1 g (typ.)

Features

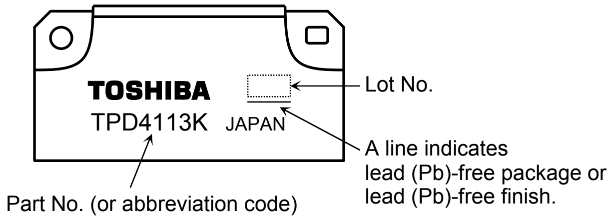
- Bootstrap circuit gives simple high-side supply.
- Bootstrap diodes are built in.
- A dead time can be set as a minimum of 1.4 μs and it is the best for a Sine-wave from drive.
- 3-phase bridge output using IGBTs
- FRDs are built in
- Included over-current and under-voltage protection, and thermal 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.

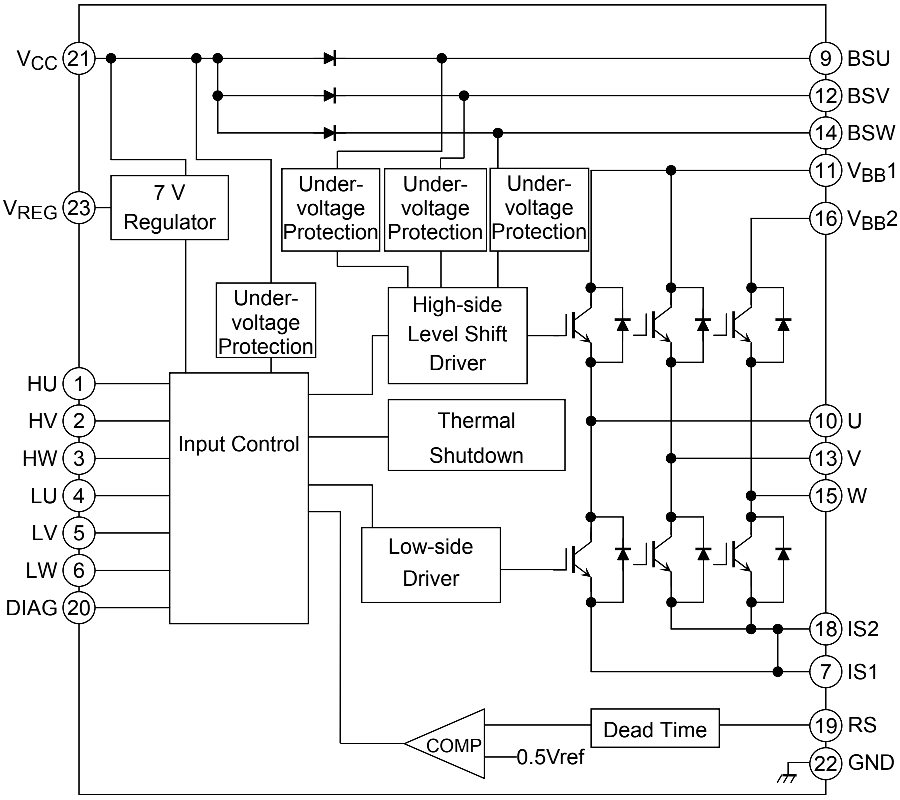
Pin Assignment



Marking



Block Diagram

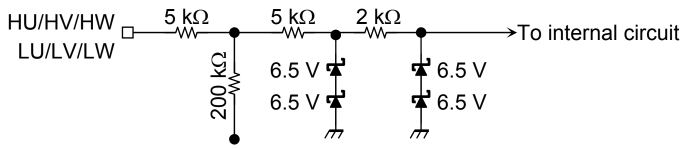


Pin Description

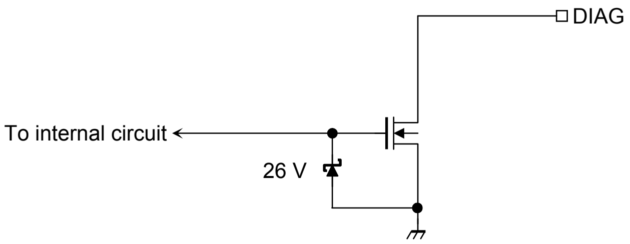
Pin No.	Symbol	Pin Description
1	HU	The control terminal of IGBT by the side of U top arm. It turns off more than by 1.5V. It turns on more than by 3.5V.
2	HV	The control terminal of IGBT by the side of V top arm. It turns off more than by 1.5V. It turns on more than by 3.5V.
3	HW	The control terminal 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	$V_{BB}1$	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	$V_{BB}2$	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	RS	Over current detection pin. (Connect a current-detecting resistor to this pin.)
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_{CC}	Control power supply pin.(15V typ.)
22	GND	Ground pin.
23	V_{REG}	7V regulator output pin.

Equivalent Circuit of Input Pins

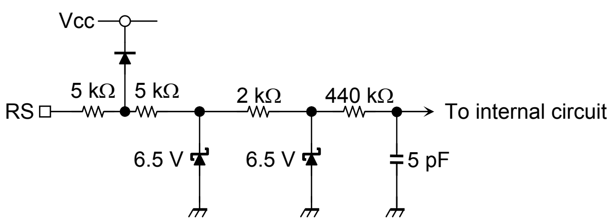
Internal circuit diagram of HU, HV, HW, LU, LV, LW input pins



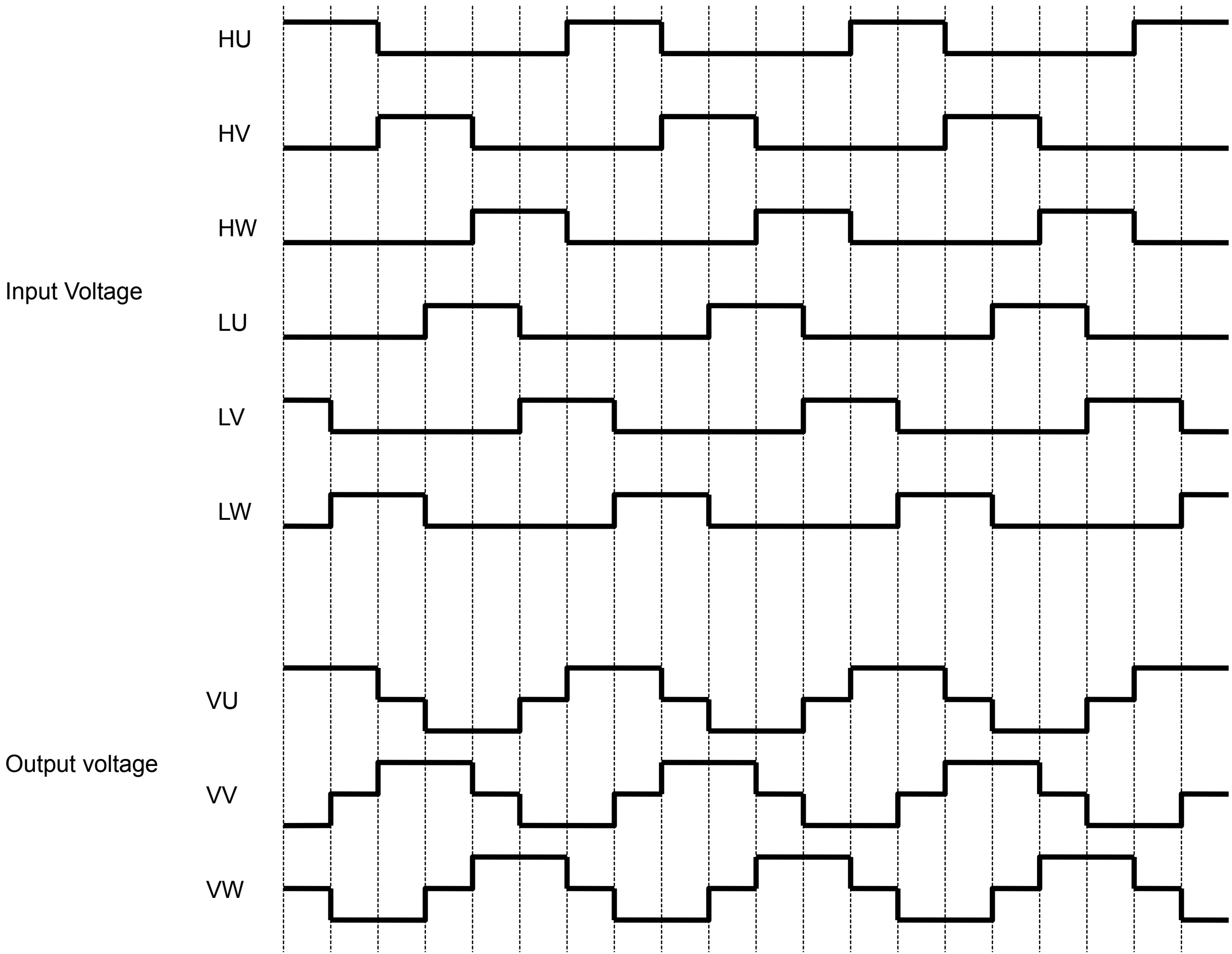
Internal circuit diagram of DIAG pin



Internal circuit diagram of RS pin



Timing Chart



Truth Table

Mode	Input						Top arm			Bottom arm			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
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 and over current protection on an all "L" input.

Absolute Maximum Ratings (Ta = 25°C)

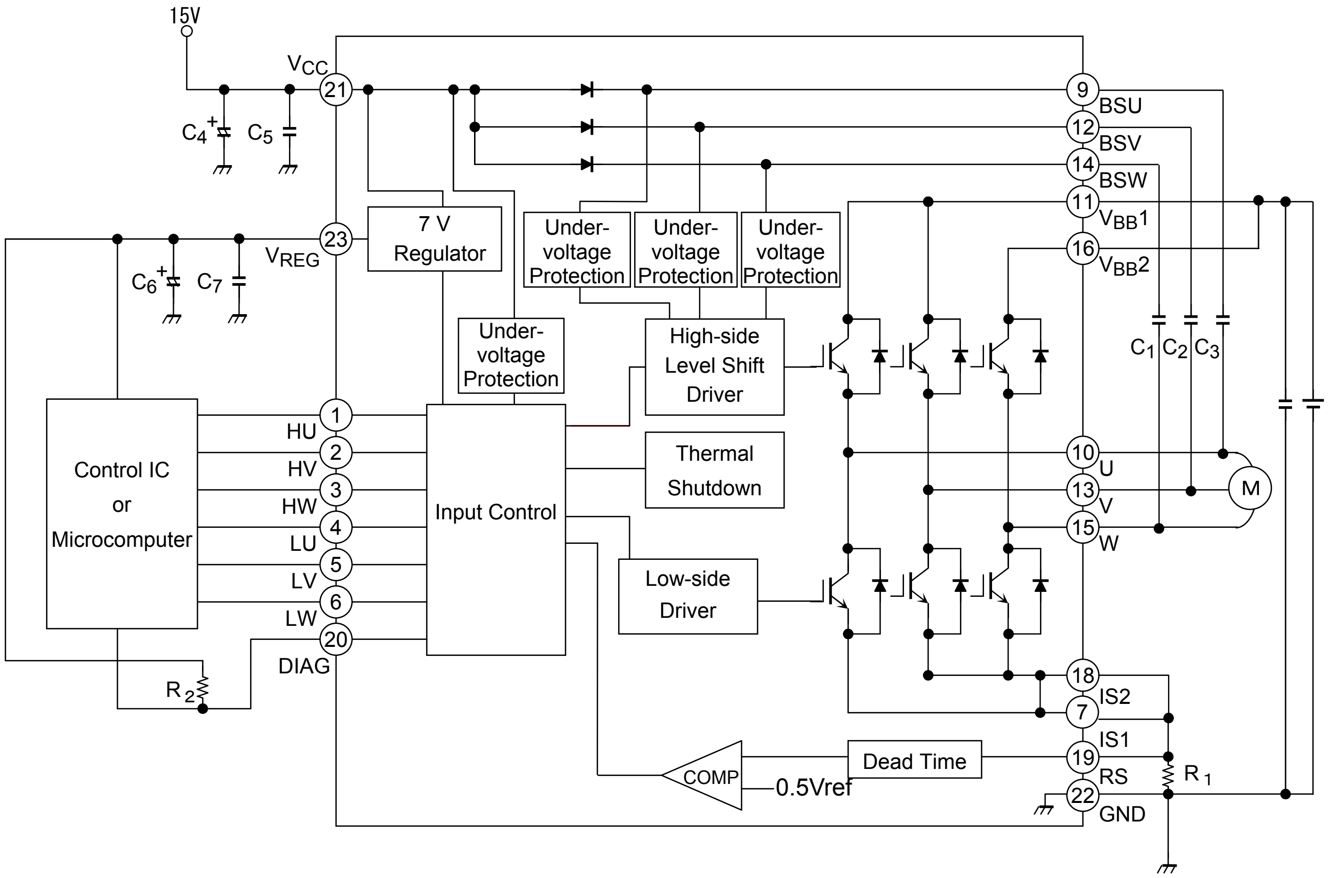
Characteristics	Symbol	Rating	Unit
Power supply voltage	V_{BB}	500	V
	V_{CC}	18	V
Output current (DC)	I_{out}	1	A
Output current (pulse)	I_{out}	2	A
Input voltage	V_{IN}	−0.5~7	V
V_{REG} current	I_{REG}	50	mA
Power dissipation (Ta = 25°C)	P_C	4	W
Power dissipation (Tc = 25°C)	P_C	20	W
Operating temperature	T_{jopr}	−20~135	°C
Junction temperature	T_j	150	°C
Storage temperature	T_{stg}	−55~150	°C
Lead-heat sink isolation voltage	Vhs	1000 (1 min)	Vrms

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} = 450 V	—	—	0.5	mA
	I_{CC}	V_{CC} = 15 V	—	1.1	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”	3.5	—	—	V
	V_{IL}	V_{IN} = “L”	—	—	1.5	
Input current	I_{IH}	V_{IN} = 5 V	—	—	150	μA
	I_{IL}	V_{IN} = 0 V	—	—	100	
Output saturation voltage	$V_{CEsat}H$	V_{CC} = 15 V, IC = 0.5 A	—	2.4	3	V
	$V_{CEsat}L$	V_{CC} = 15 V, IC = 0.5 A	—	2.4	3	
FRD forward voltage	V_FH	IF = 0.5 A, high side	—	1.6	2.0	V
	V_FL	IF = 0.5 A, low side	—	1.6	2.0	
Regulator voltage	V_{REG}	IF = 500 μA	—	0.9	1.2	V
BSD forward voltage	V_F (BSD)	V_{CC} = 15 V, I_O = 30 mA	6.5	7	7.5	V
Current limiting voltage	V_R	—	0.46	0.5	0.54	V
Current limiting dead time	Dt	—	2.3	3.3	4.4	μs
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}=5mA	—	—	0.5	V
Output-on delay time	t_{on}	V_{BB} = 280 V, IC = 0.5 A	—	1.5	3	μs
Output-off delay time	t_{off}	V_{BB} = 280 V, IC = 0.5 A	—	1.2	3	μs
Dead time	tdead	V_{BB} = 280 V, IC = 0.5 A	1.4	—	—	μs
FRD reverse recovery time	t_{rr}	V_{BB} = 280 V, IC = 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_1, C_2, C_3	25 V/2.2 μF	Bootstrap capacitor	(Note 1)
R_1	0.62 Ω ± 1% (1 W)	Current detection	(Note 2)
C_4	25 V/10 μF	V_{CC} power supply stability	(Note 3)
C_5	25 V /0.1μF	V_{CC} for surge absorber	(Note 3)
C_6	16 V/1 μF	V_{REG} power supply stability	(Note 3)
C_7	16 V/1000 pF	V_{REG} for surge absorber	(Note 3)
R_2	5.1 kΩ	FG 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_{CC} 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)
Do not exceed a detection current of 1 A when using this product.

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_{CC}, 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_{CC} voltage is steady. Both of the order of the VBB 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 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 the 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 dead 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 an 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/off 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/off again by the input signal.

(3) 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 (ΔTSD = 50°C typ.). When the chip temperature falls to TSD – ΔTSD, 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

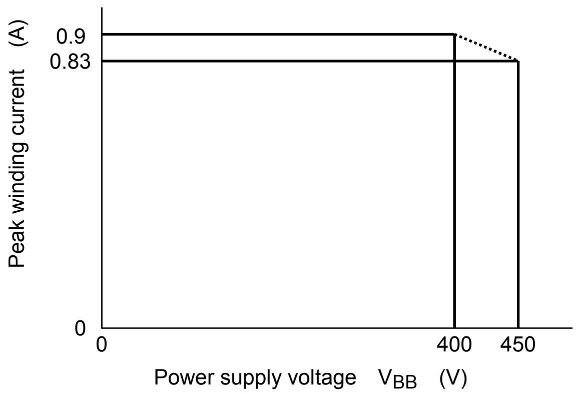


Figure 1 SOA at Tj = 135°C

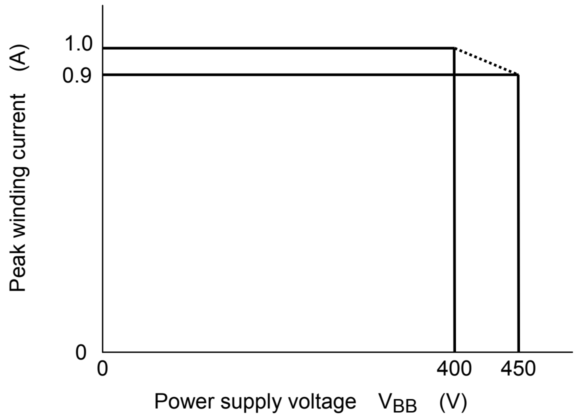
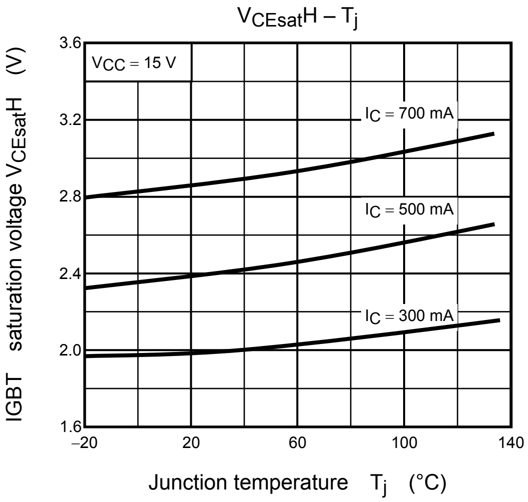
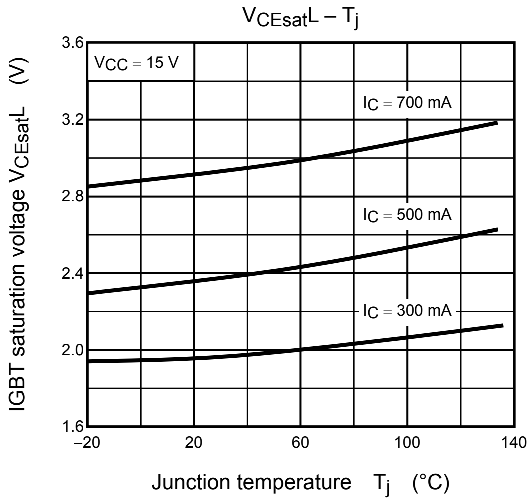


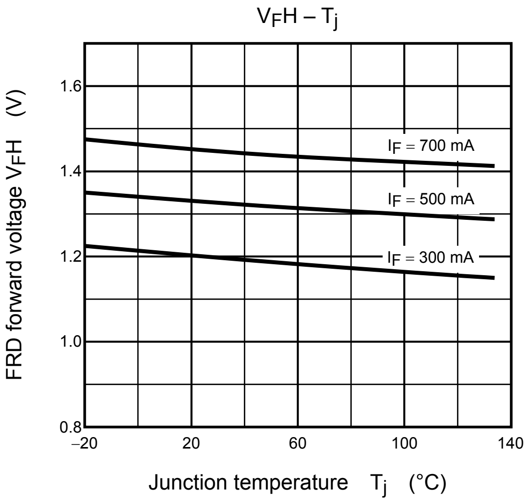
Figure 2 SOA at Tc = 95°C

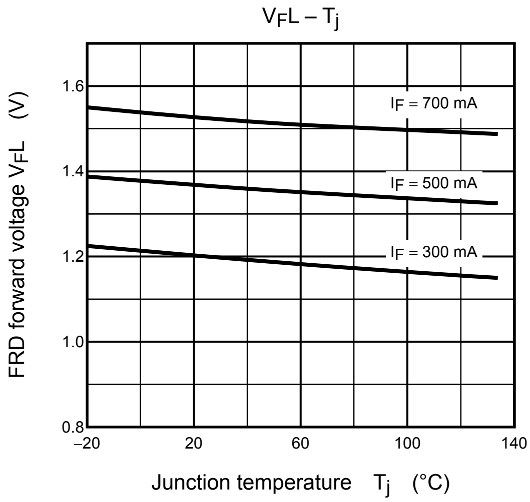
Note 1: The above safe operating areas are at Tj = 135°C (Figure 1) and Tc = 95°C (Figure 2). If the temperature exceeds these, the safe operation areas are reduced.

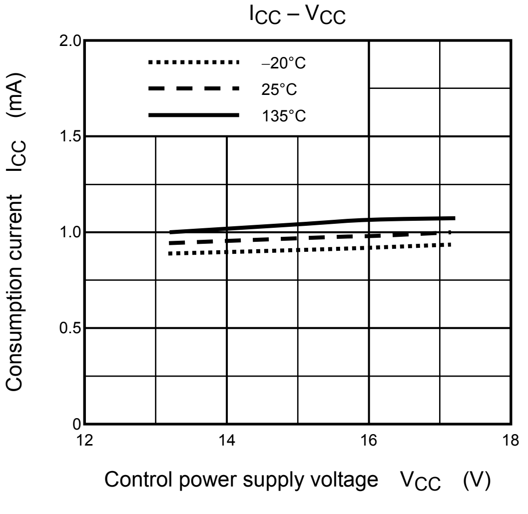
Note 2: The above safe operating areas include the over-current protection operation area.

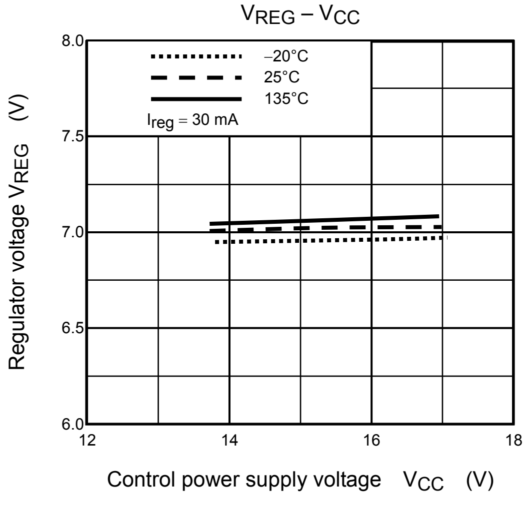

$V_{CEsat}H – T_j$
V_{CC} = 15 V
I_C = 700 mA
I_C = 500 mA
I_C = 300 mA
IGBT saturation voltage $V_{CEsat}H$ (V)
Junction temperature T_j (°C)
3.6
3.2
2.8
2.4
2.0
1.6
–20
20
60
100
140

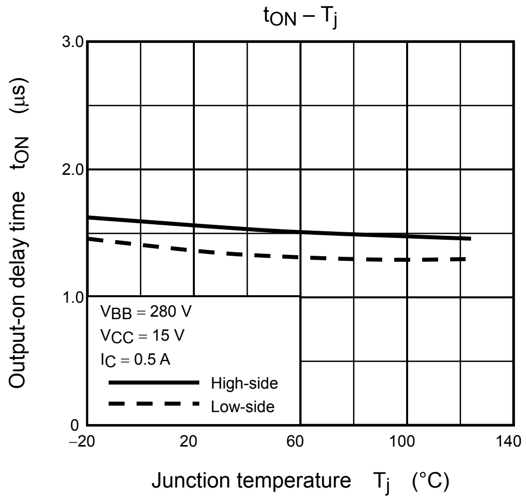

$V_{CEsat}L – T_j$
V_{CC} = 15 V
I_C = 700 mA
I_C = 500 mA
I_C = 300 mA
IGBT saturation voltage $V_{CEsat}L$ (V)
Junction temperature T_j (°C)
3.6
3.2
2.8
2.4
2.0
1.6
–20
20
60
100
140

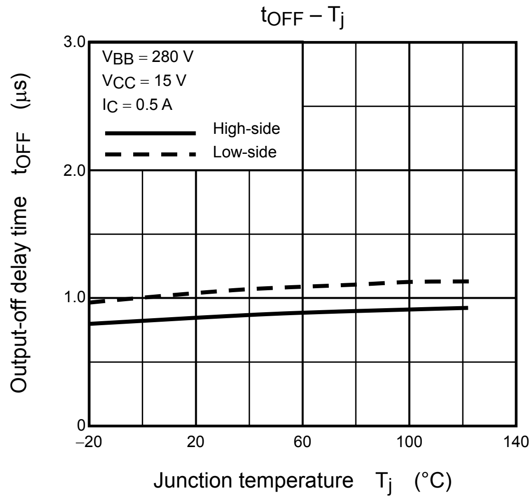

$V_FH – T_j$
I_F = 700 mA
I_F = 500 mA
I_F = 300 mA
FRD forward voltage V_FH (V)
Junction temperature T_j (°C)
1.6
1.4
1.2
1.0
0.8
–20
20
60
100
140

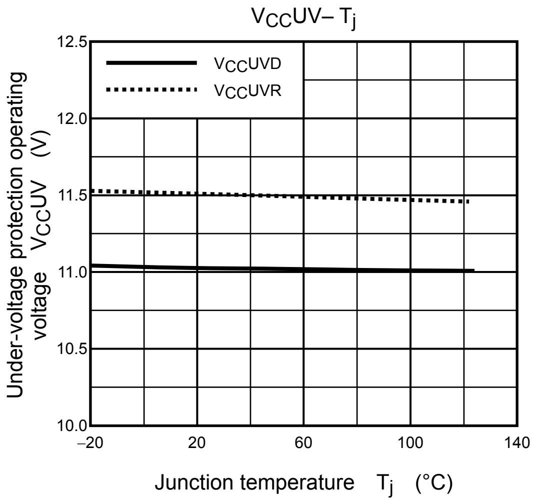

$V_FL – T_j$
I_F = 700 mA
I_F = 500 mA
I_F = 300 mA
FRD forward voltage V_FL (V)
Junction temperature T_j (°C)
1.6
1.4
1.2
1.0
0.8
–20
20
60
100
140

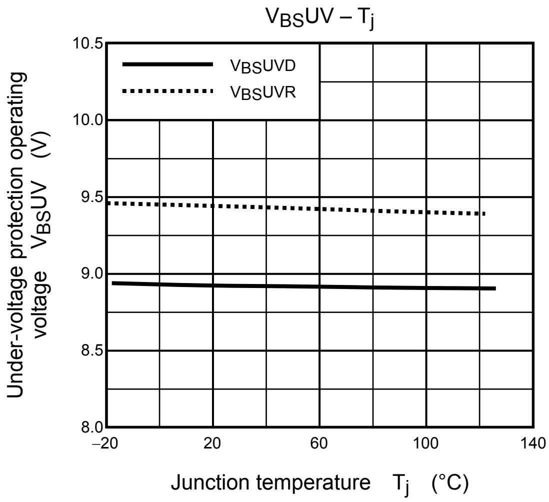

$I_{CC} – V_{CC}$
–20°C
25°C
135°C
Consumption current I_{CC} (mA)
Control power supply voltage V_{CC} (V)
2.0
1.5
1.0
0.5
0
12
14
16
18

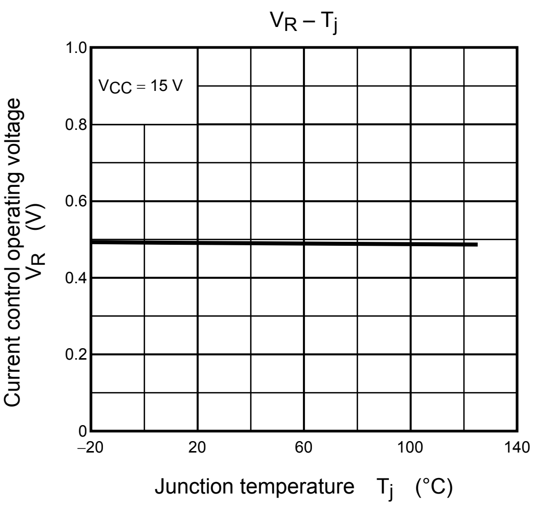

$V_{REG} – V_{CC}$
–20°C
25°C
135°C
I_{reg} = 30 mA
Regulator voltage V_{REG} (V)
Control power supply voltage V_{CC} (V)
8.0
7.5
7.0
6.5
6.0
12
14
16
18

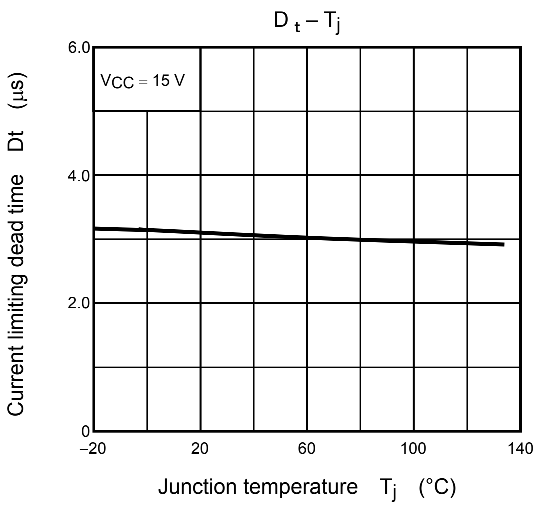

tON – Tj
VBB = 280 V
VCC = 15 V
IC = 0.5 A
High-side
Low-side
Output-on delay time tON (µs)
Junction temperature Tj (°C)

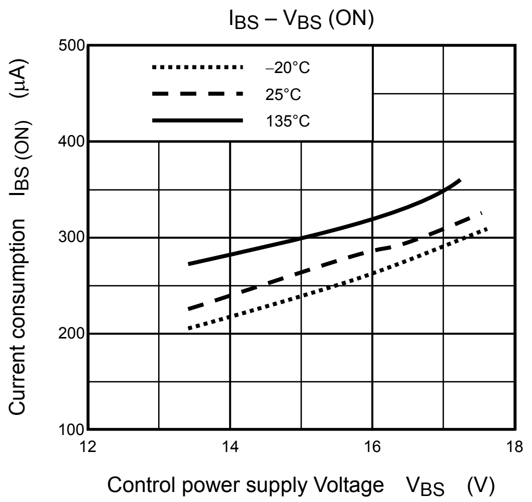

tOFF – Tj
VBB = 280 V
VCC = 15 V
IC = 0.5 A
High-side
Low-side
Output-off delay time tOFF (µs)
Junction temperature Tj (°C)


VCCUV– Tj
VCCUVD
VCCUVR
Under-voltage protection operating voltage VCCUV (V)
Junction temperature Tj (°C)

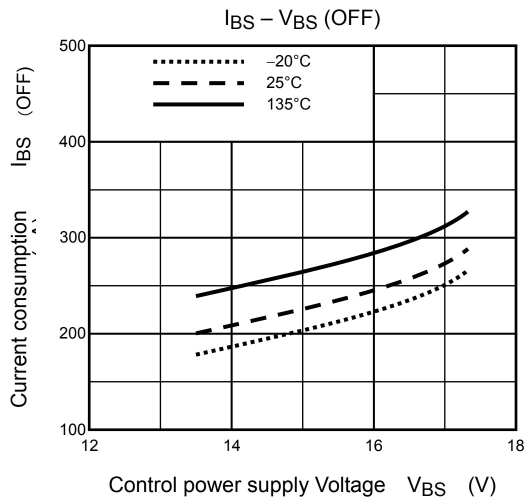

VBSUV – Tj
VBSUVD
VBSUVR
Under-voltage protection operating voltage VBSUV (V)
Junction temperature Tj (°C)


VR – Tj
VCC = 15 V
Current control operating voltage VR (V)
Junction temperature Tj (°C)

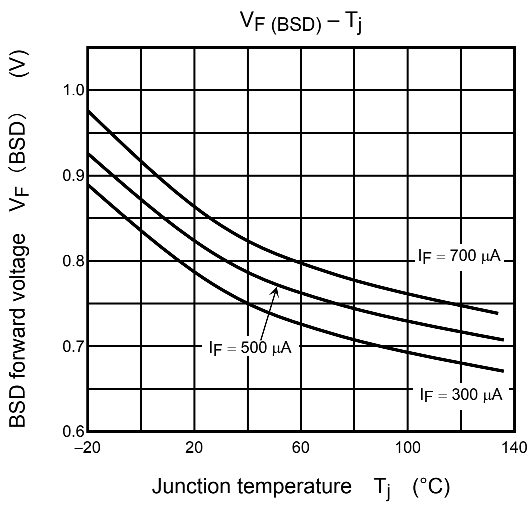

D t – Tj
VCC = 15 V
Current limiting dead time Dt (µs)
Junction temperature Tj (°C)



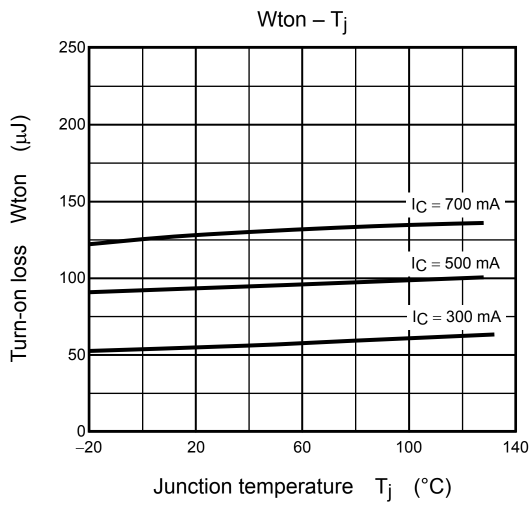
I_{BS} – V_{BS} (ON)
–20°C
25°C
135°C
Current consumption $I_{BS (ON)}$ (μA)
Control power supply Voltage V_{BS} (V)



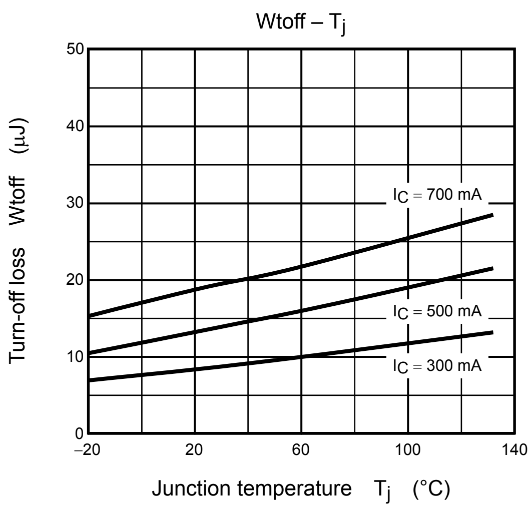
I_{BS} – V_{BS} (OFF)
–20°C
25°C
135°C
Current consumption I_{BS} (OFF)
Control power supply Voltage V_{BS} (V)



$V_{F (BSD)}$ – T_j
I_F = 700 μA
I_F = 500 μA
I_F = 300 μA
BSD forward voltage V_F (BSD) (V)
Junction temperature T_j (°C)



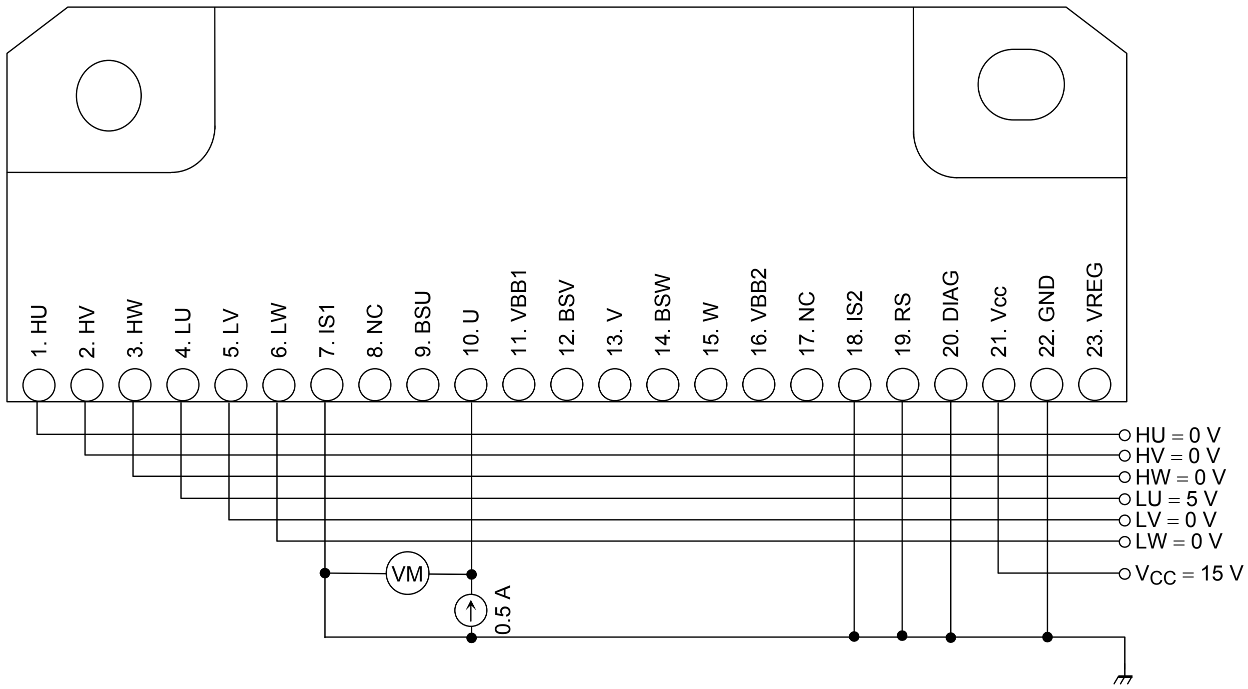
Wton – T_j
I_C = 700 mA
I_C = 500 mA
I_C = 300 mA
Turn-on loss Wton (μJ)
Junction temperature T_j (°C)



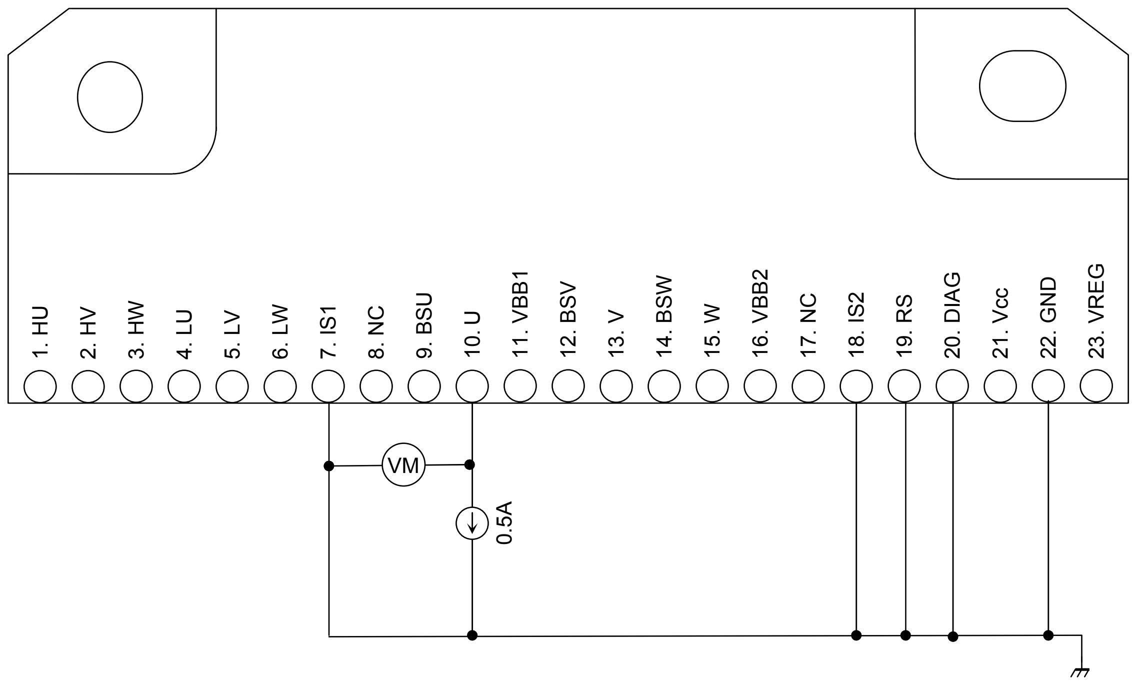
Wtoff – T_j
I_C = 700 mA
I_C = 500 mA
I_C = 300 mA
Turn-off loss Wtoff (μJ)
Junction temperature T_j (°C)

Test Circuits

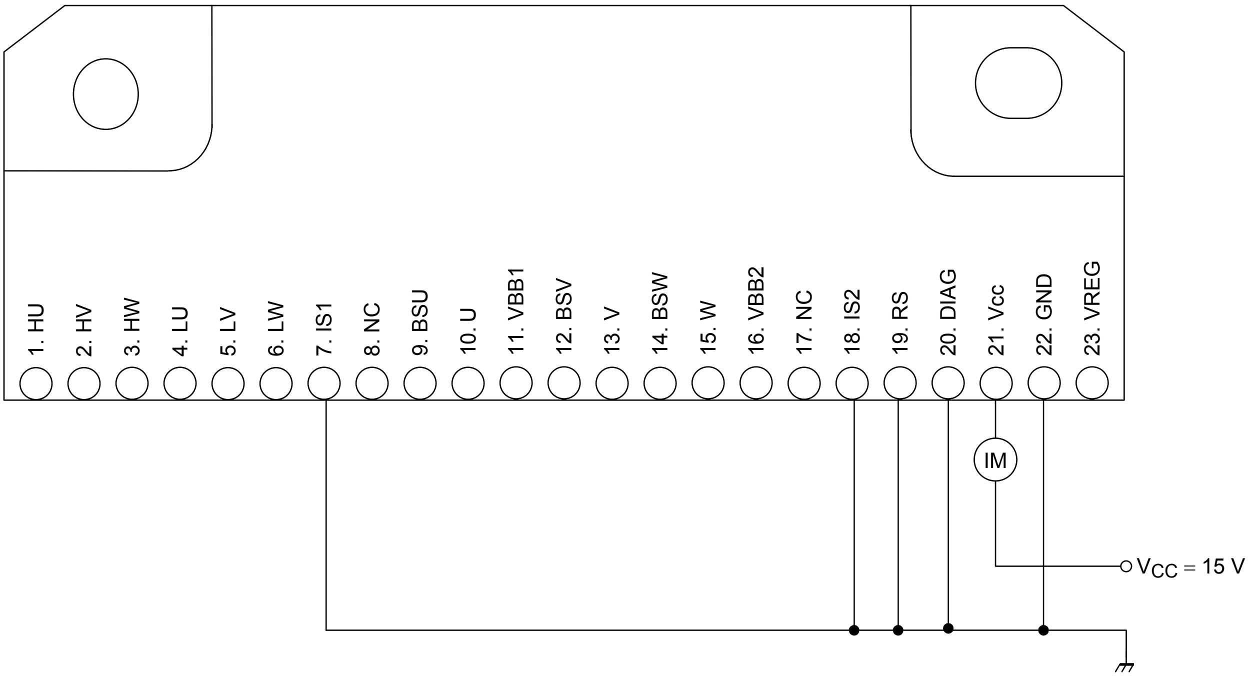
IGBT Saturation Voltage (U-phase low side)



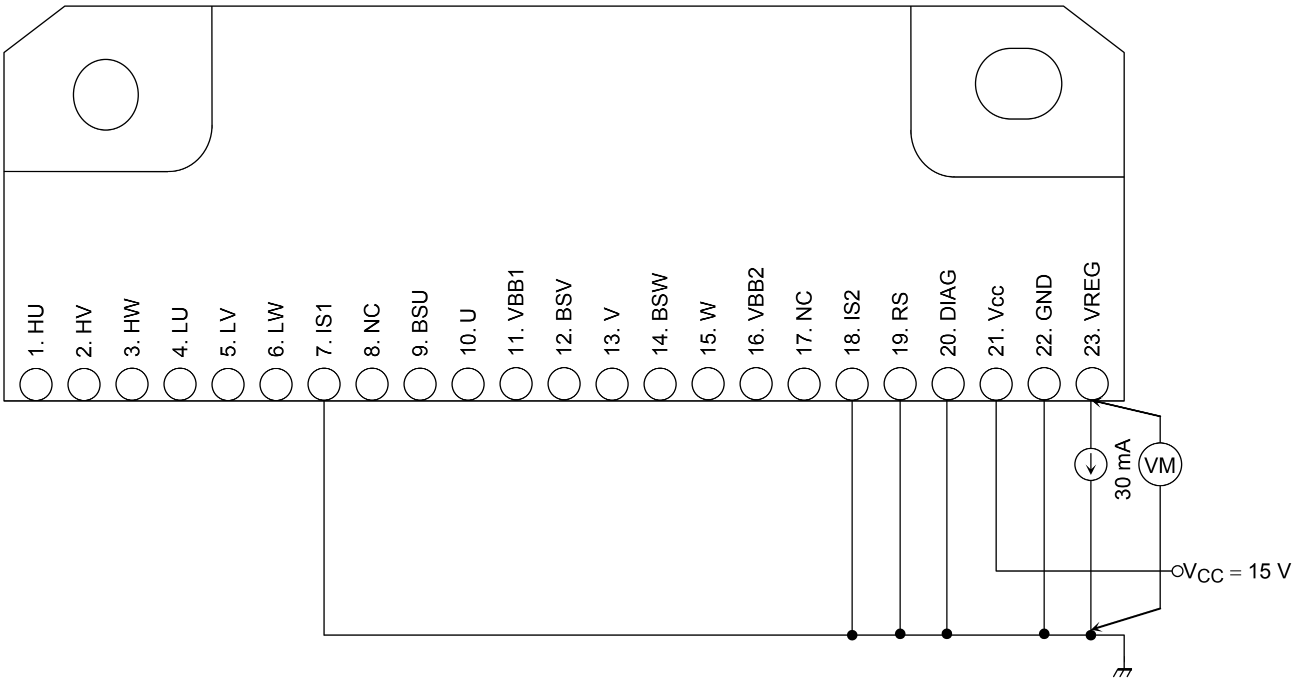
FRD Forward Voltage (U-phase low side)



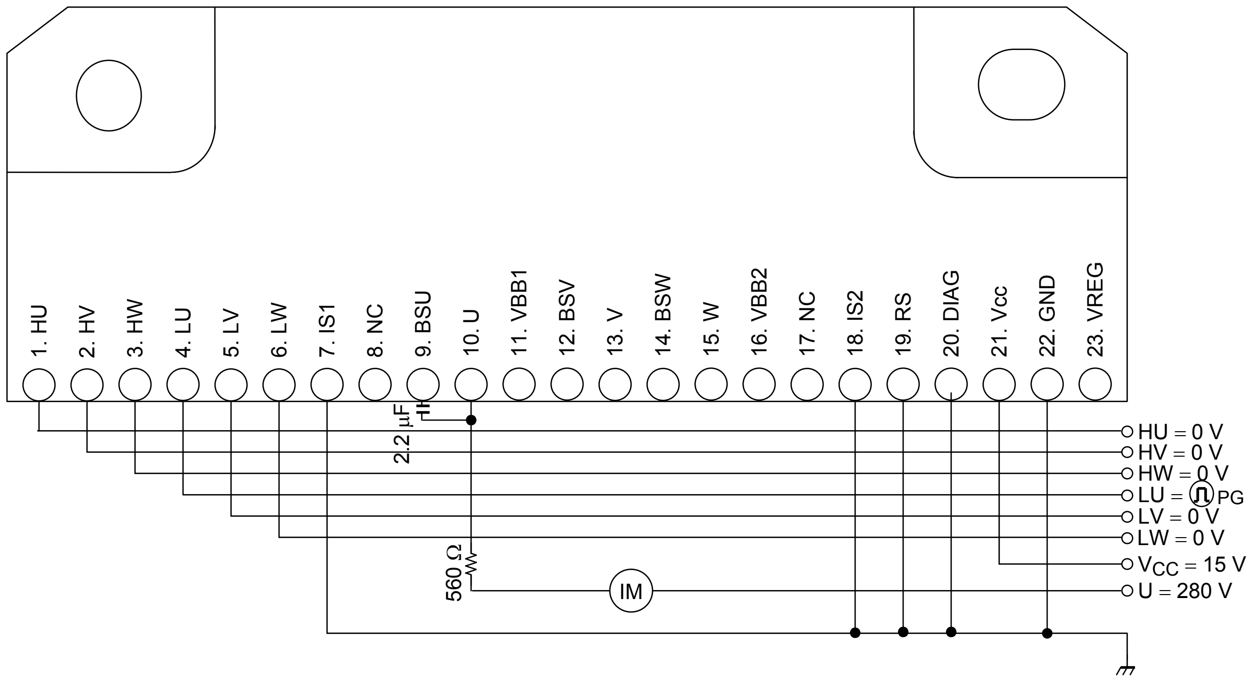
V_{CC} Current Dissipation

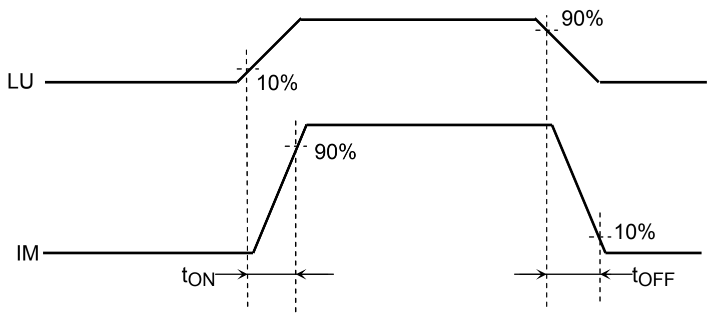


Regulator Voltage

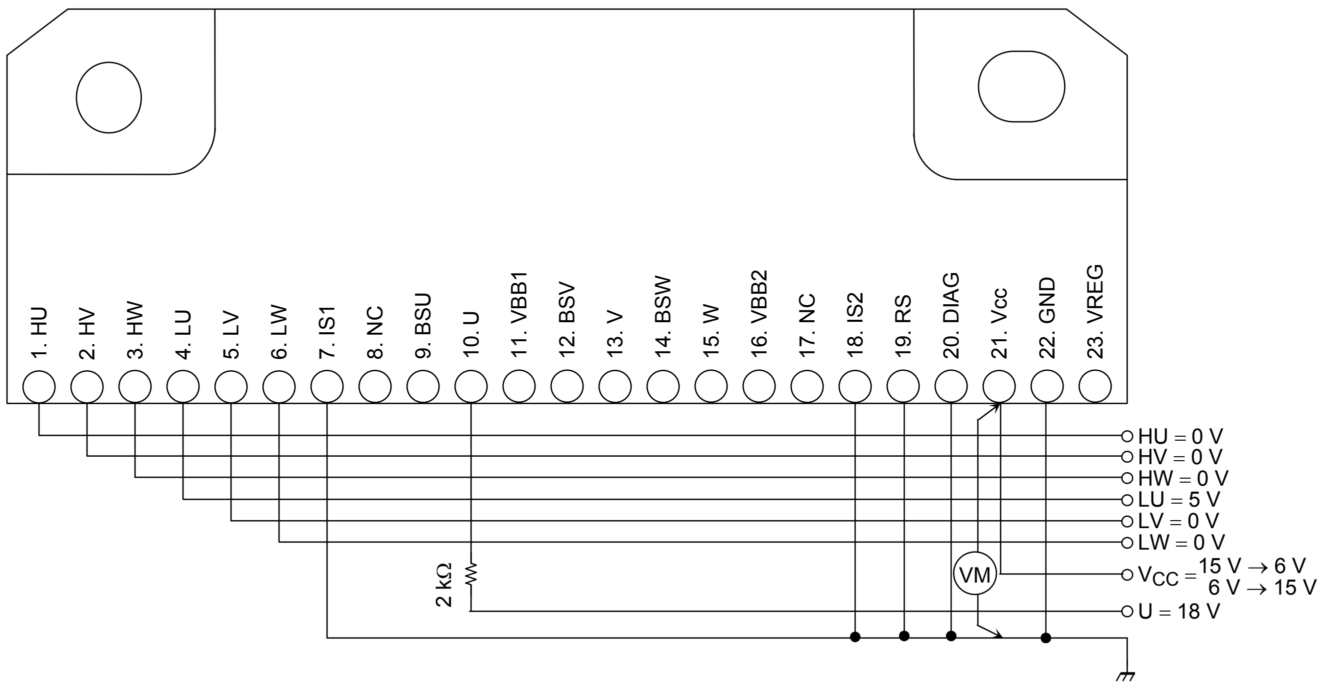


Output ON/OFF Delay Time (U-phase low side)



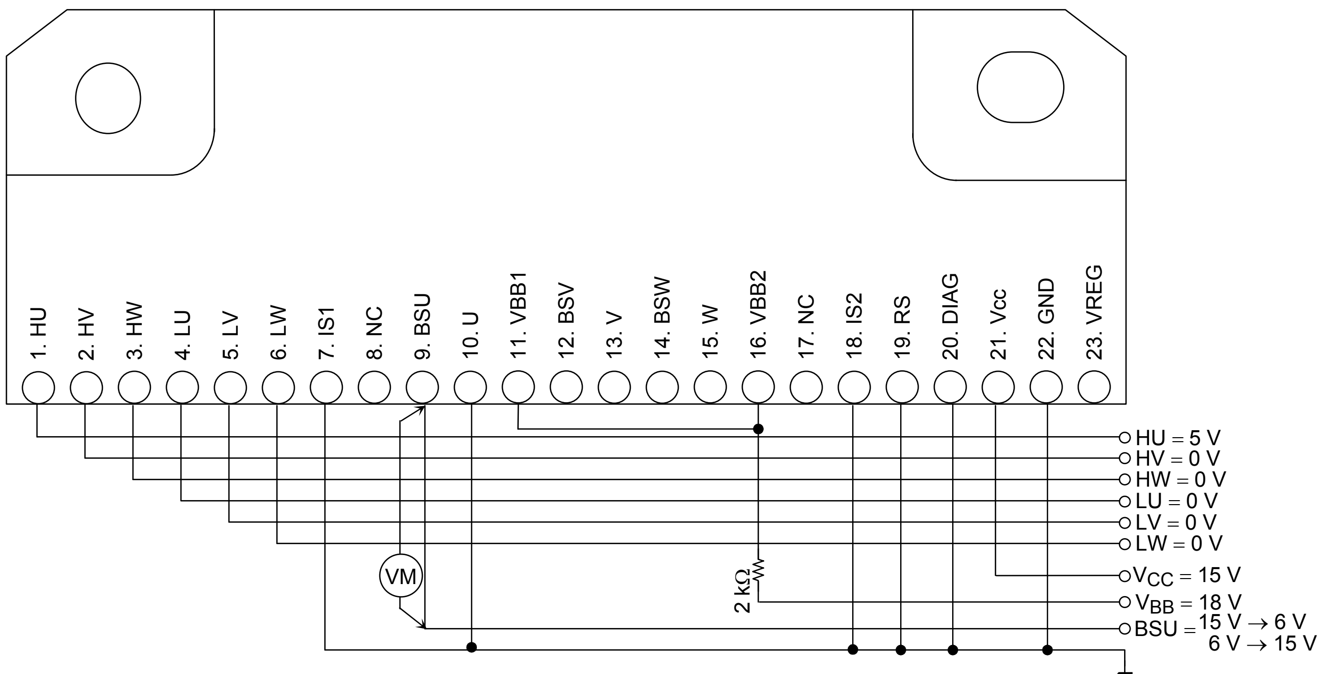


V_{CC} Under-voltage Protection Operation/Recovery Voltage (U-phase low side)



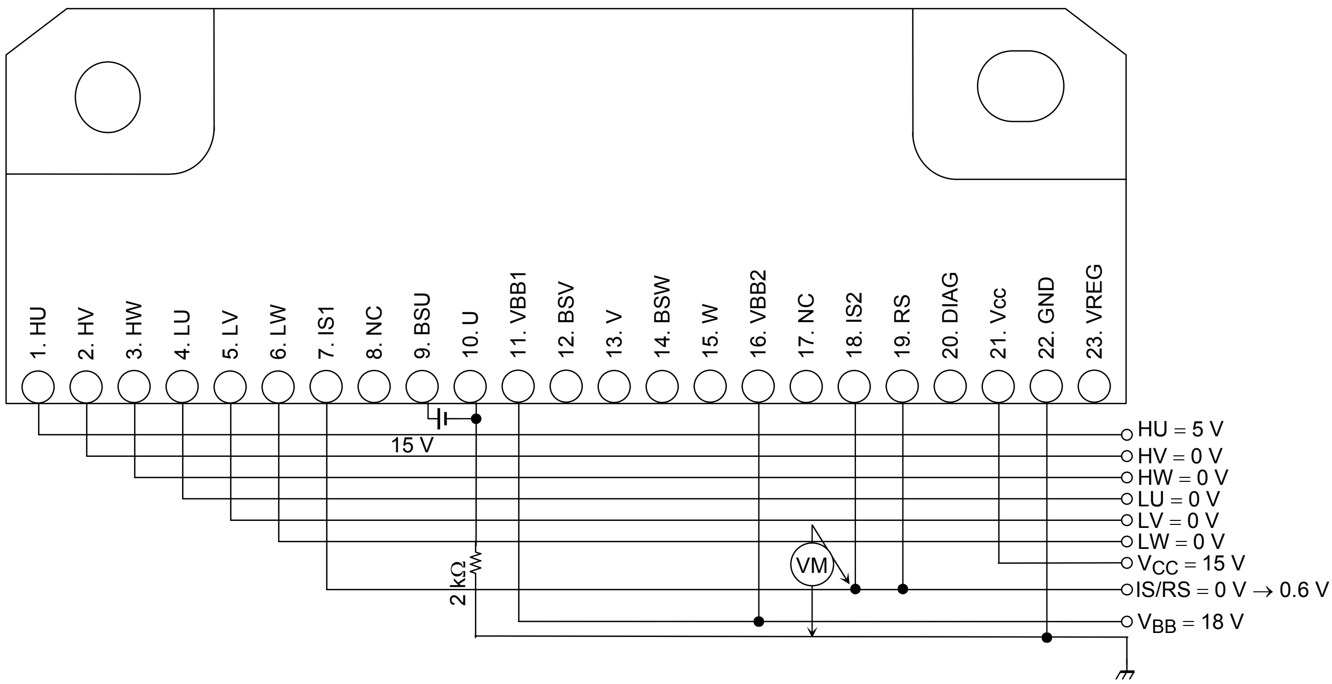
*:Note: Sweeps the V_{CC} pin voltage from 15 V and monitors the U pin voltage.
The V_{CC} pin voltage when output is off defines the under-voltage protection operating voltage.
Also sweeps from 6 V to increase. The V_{CC} pin voltage when output is on defines the under voltage protection recovery voltage.

V_{BS} Under-voltage Protection Operation/Recovery Voltage (U-phase high side)



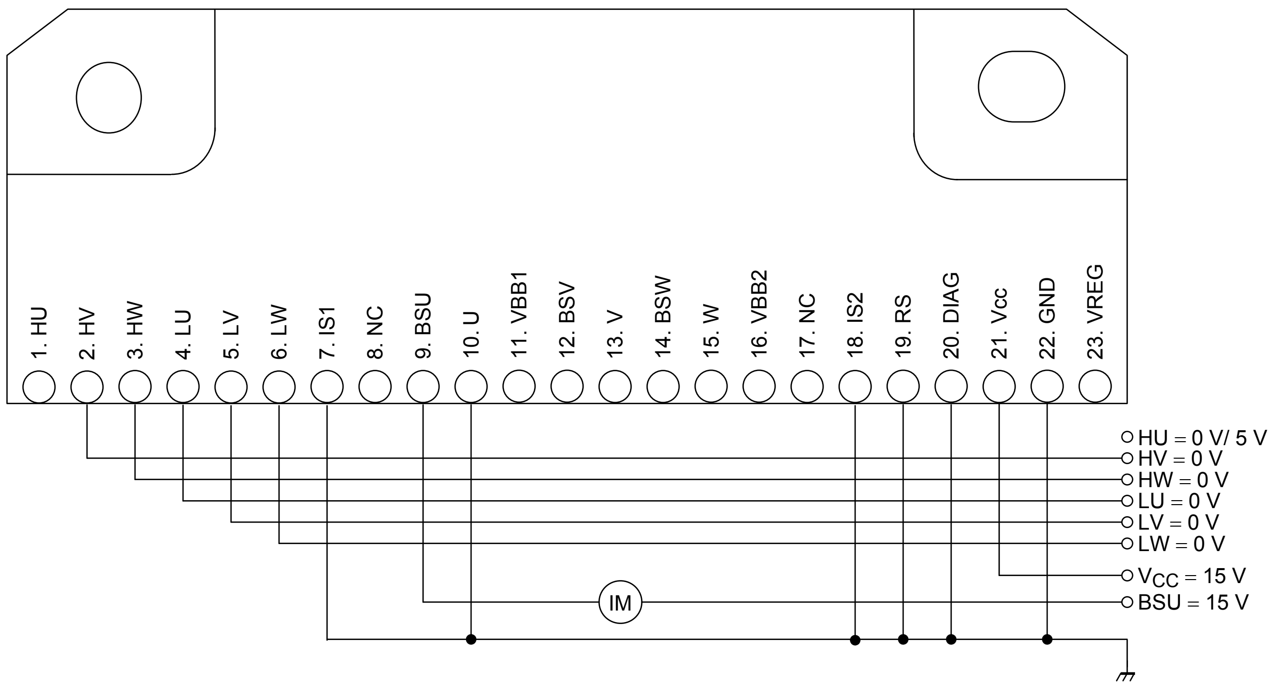
*:Note: Sweeps the BSU pin voltage from 15 V and monitors the V_{BB} pin voltage.
The BSU pin voltage when output is off defines the under-voltage protection operating voltage.
Also sweeps the BSU pin voltage from 6 V and changes from the HU pin voltage at 0 V → 5 V → 0 V.
The BSU pin voltage when output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

Current Control Operating Voltage (U-phase high side)

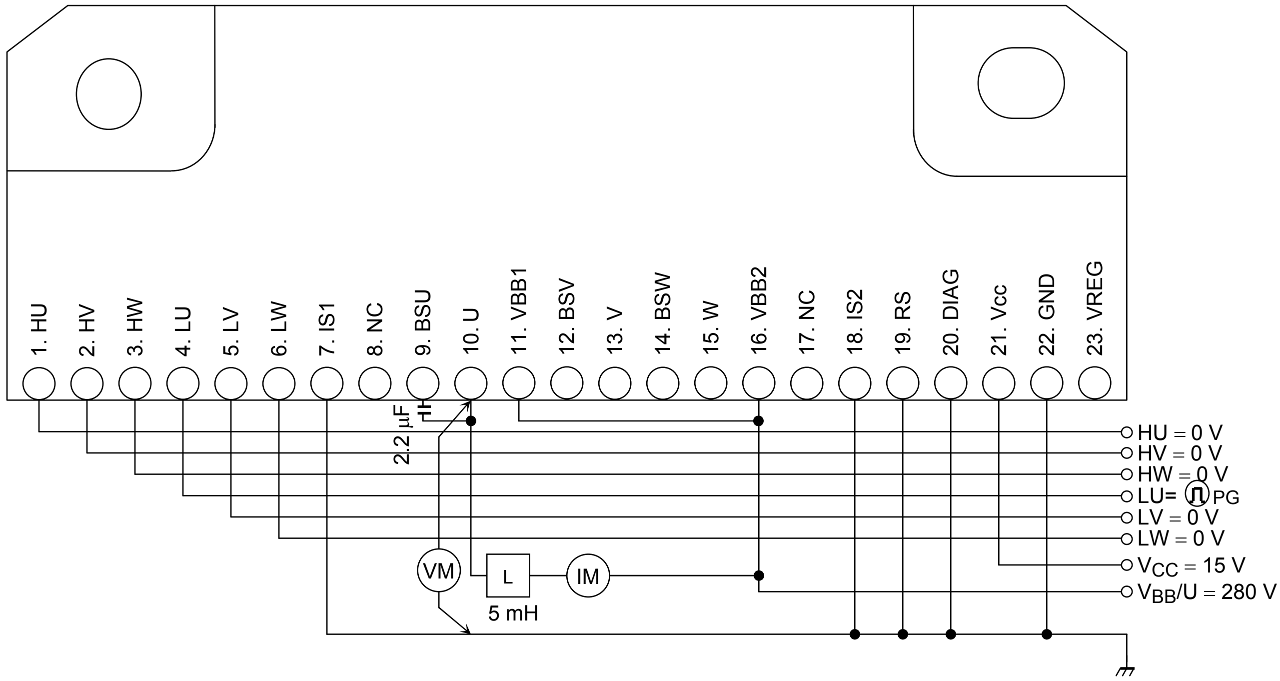


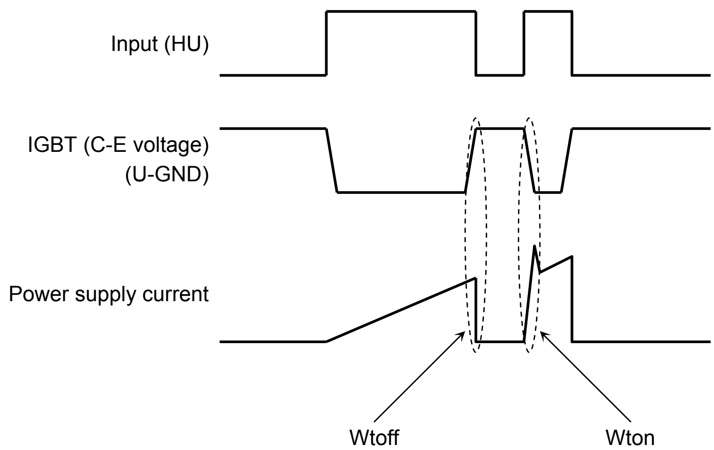
*: Note:Sweeps the IS/ RS pin voltage and monitors the U pin voltage.
The IS/ RS pin voltage when output is off defines the current control operating voltage.

V_{BS} Current Consumption (U-phase high side)

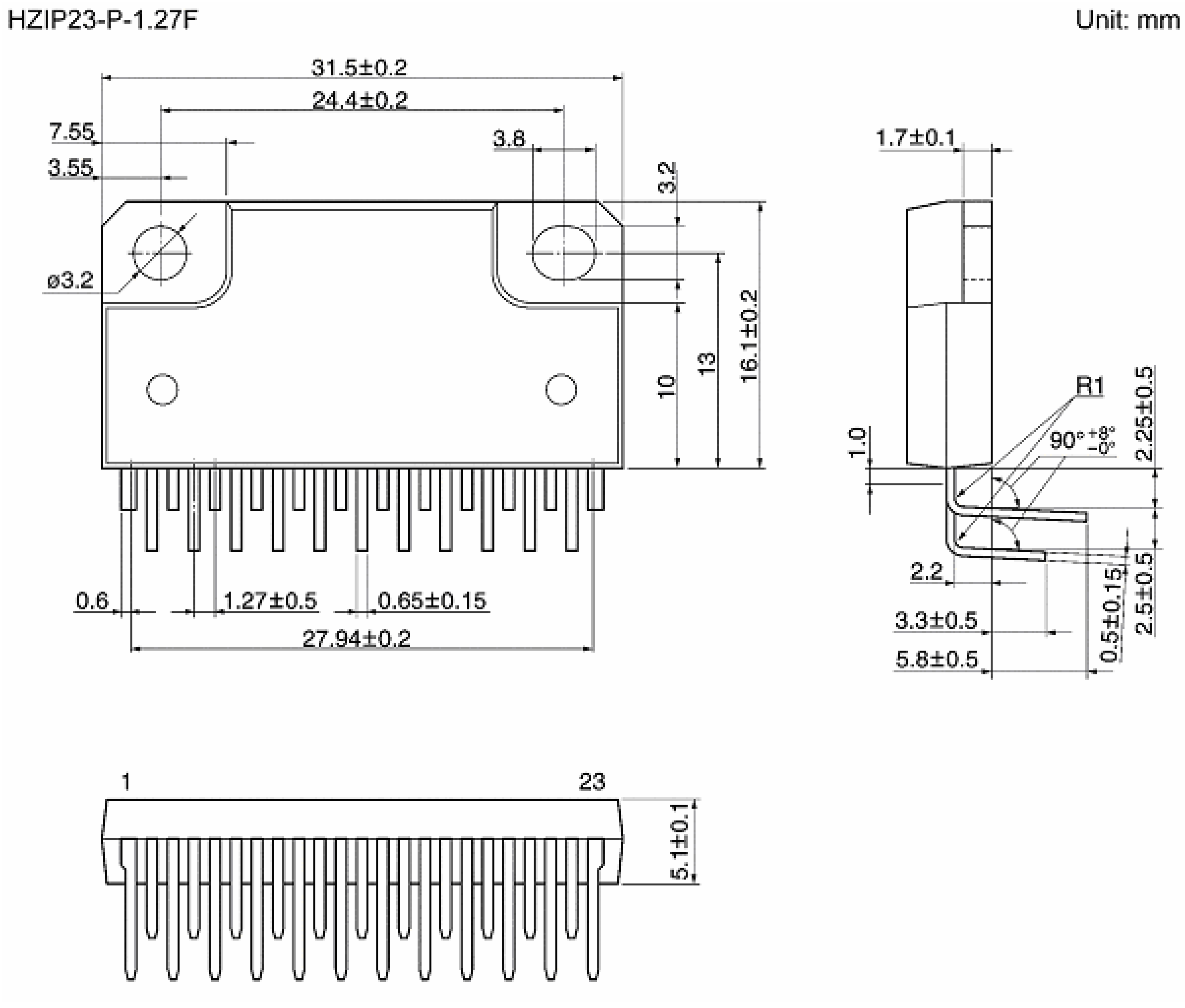


Turn-On/Off Loss (low-side IGBT + high-side FRD)





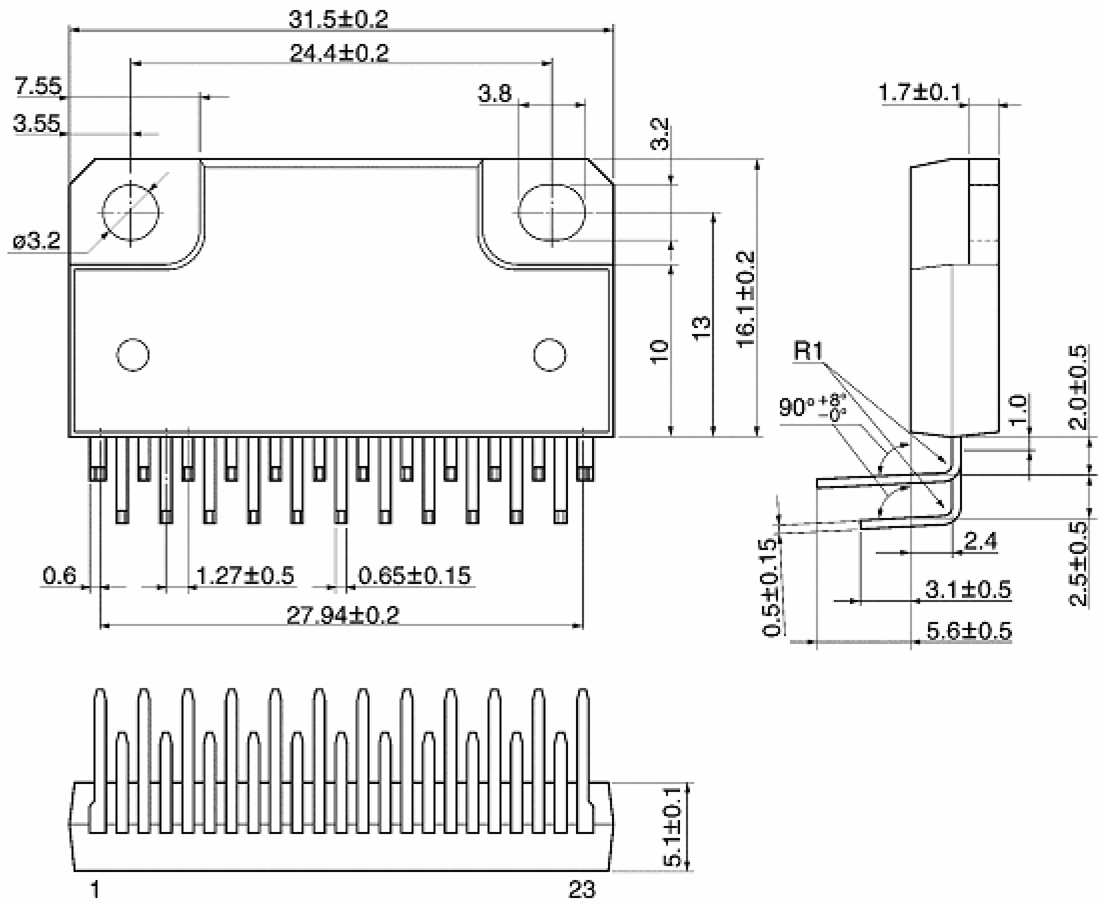
Package Dimensions



Weight: 6.1 g (typ.)

Package Dimensions

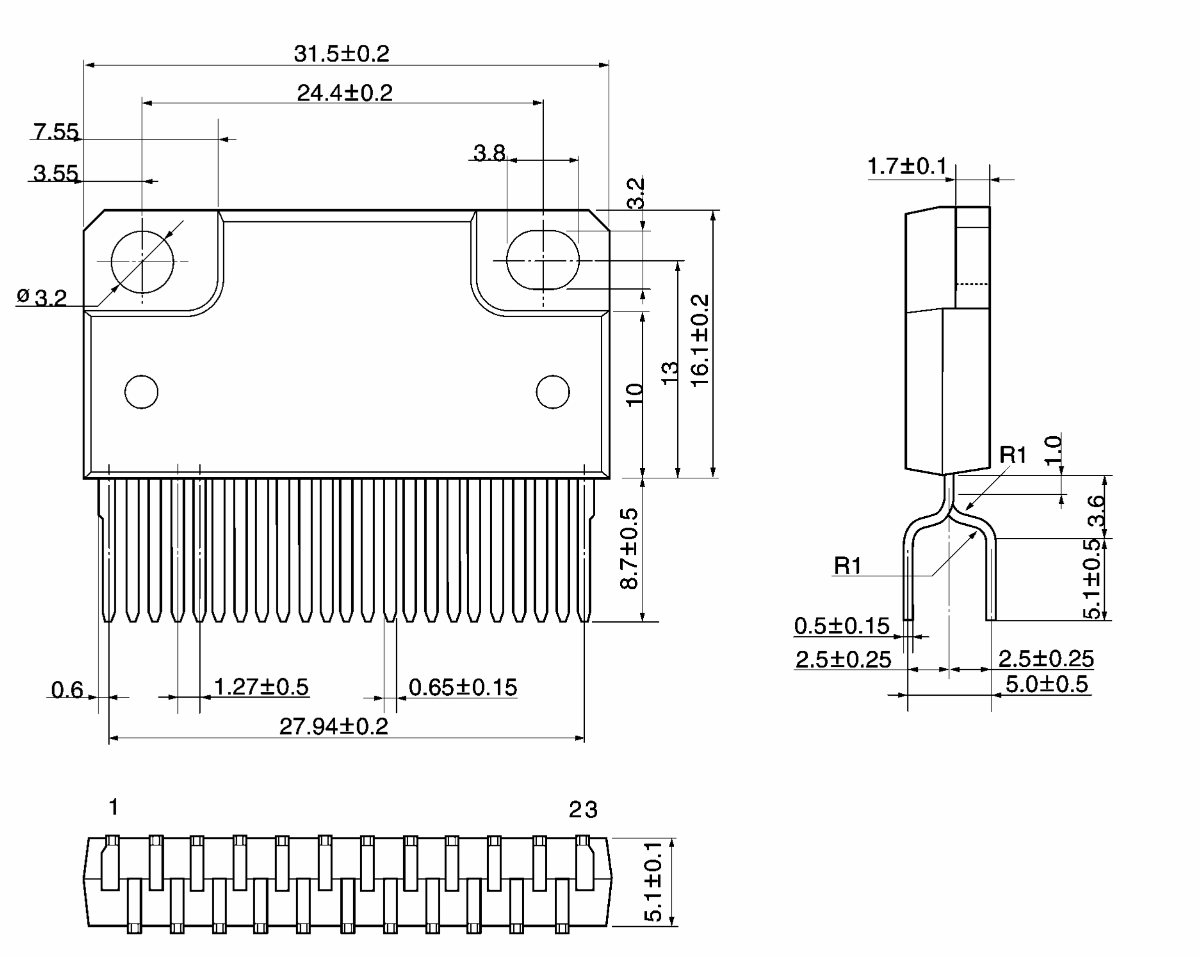
HZIP23-P-1.27G Unit: mm



Weight: 6.1 g (typ.)

Package Dimensions

HZIP23-P-1.27H Unit: mm



Weight: 6.1 g (typ.)

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20070701-EN

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