TOSHIBA Intelligent Power Device High Voltage Monolithic Silicon Power IC

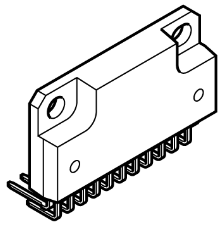
TPD4008K

The TPD4008K is a DC brush less motor driver using high voltage PWM control. It is fabricated by high voltage SOI process. It contains PWM circuit, 3 phase decode logic, level shift high side driver, low side driver, IGBT outputs, FRDs and protective functions for overcurrent, overheat and undervoltage. It is easy to control a DC brush less motor by just putting logic inputs from a micro computer and hole IC into the TPD4008K.

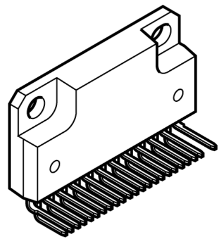
Features

- Bootstrap circuit gives simple high side supply
- Bootstrap diode is built in
- PWM and 3-phase decoder circuit are built in
- Outputs Rotation pulse signals
- 3-phase bridge output using IGBTs
- FRDs are built in
- Protective functions for overcurrent, overheating and undervoltage

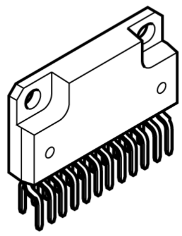
Since this IC is a MOS product, pay attention to static charges when handling it.



HZIP23-P-1.27F (LBR)



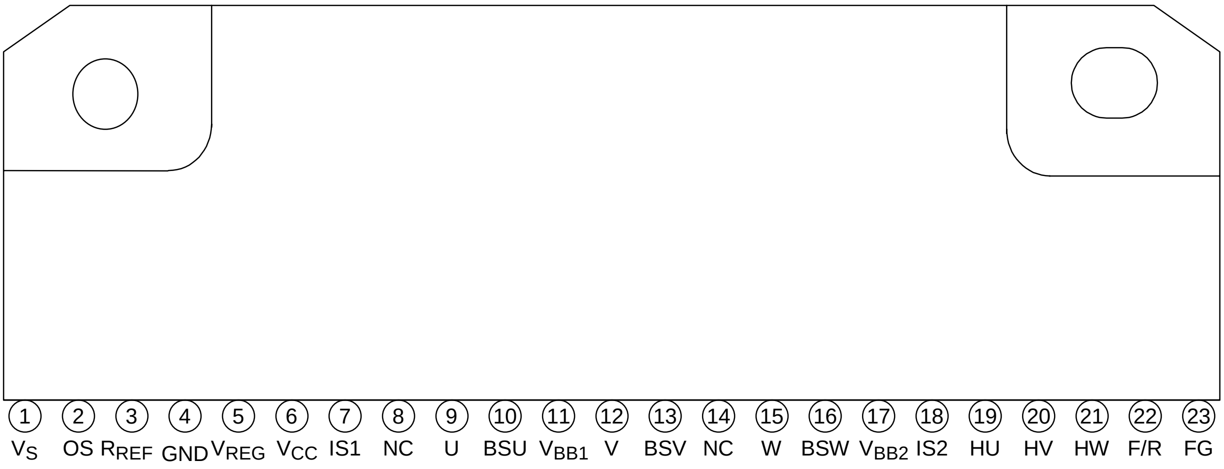
HZIP23-P-1.27G (LBF)



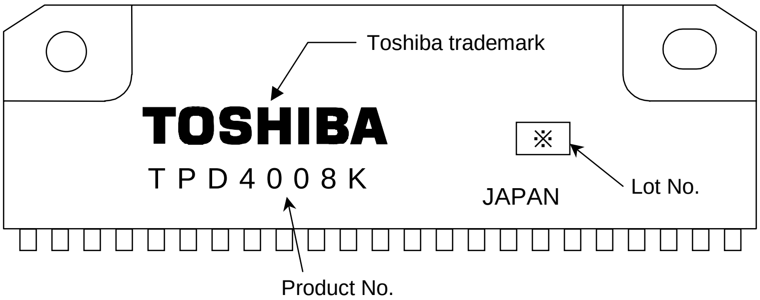
HZIP23-P-1.27H (LB2)

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



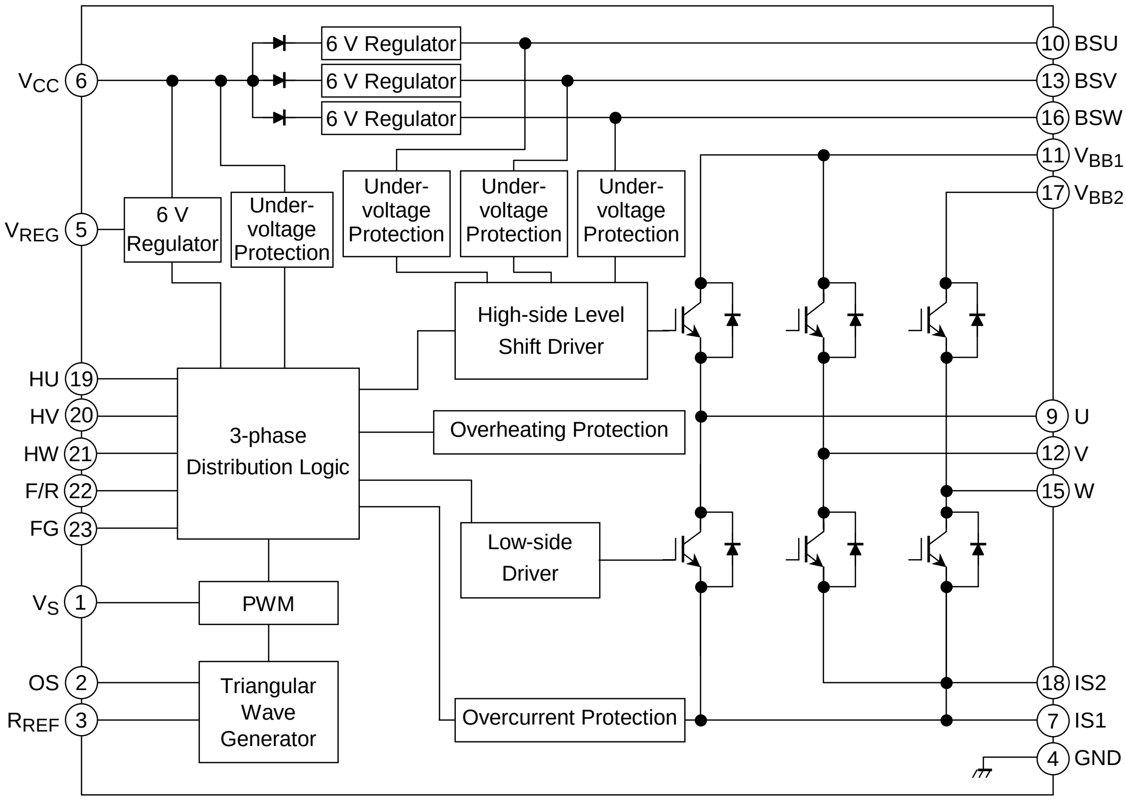
Marking



※ Lot No.

Last decimal digit of the current year and starting from alphabet “A”.

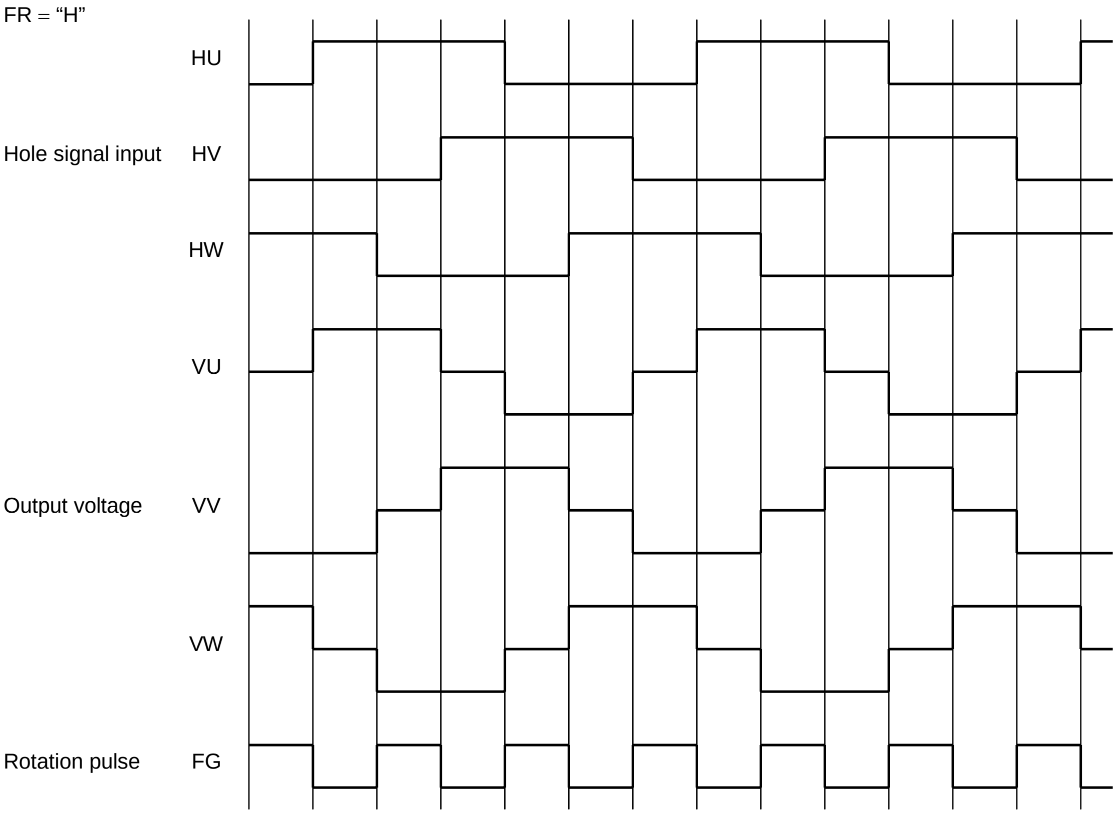
Block Diagram



Pin Description

Pin No.	Symbol	Pin Description
1	V_S	Speed control signal input pin. (PWM reference voltage input pin)
2	OS	PWM triangular wave oscillation frequency setup pin. (Connect a capacitor to this pin.)
3	R_{REF}	PWM triangular wave oscillation frequency setup pin. (Connect a resistor to this pin.)
4	GND	Ground pin.
5	V_{REG}	6 V regulator output pin.
6	V_{CC}	Control power supply pin.
7	IS1	IGBT emitter and FRD anode pin. (Connect a current detecting resistor to this pin.)
8	NC	Unused pin, which is not connected to the chip internally.
9	U	U-phase output pin.
10	BSU	U-phase bootstrap capacitor connecting pin.
11	V_{BB1}	U and V-phase high-voltage power supply input pin.
12	V	V-phase output pin.
13	BSV	V-phase bootstrap capacitor connecting pin.
14	NC	Unused pin, which is not connected to the chip internally.
15	W	W-phase output pin.
16	BSW	W-phase bootstrap capacitor connecting pin.
17	V_{BB2}	W-phase high-voltage power supply input pin.
18	IS2	Connected to the IS1 pin internally.
19	HU	U-phase hole IC signal input pin.
20	HV	V-phase hole IC signal input pin.
21	HW	W-phase hole IC signal input pin.
22	F/R	Forward/reverse select input pin.
23	FG	Rotation pulse output pin. (open drain)

Timing Chart



Truth Table

	Hole Signal Input			U Phase		V Phase		W Phase		
FR	HU	HV	HW	Upper Arm	Lower Arm	Upper Arm	Lower Arm	Upper Arm	Lower Arm	FG
H	H	L	H	ON	OFF	OFF	ON	OFF	OFF	L
H	H	L	L	ON	OFF	OFF	OFF	OFF	ON	H
H	H	H	L	OFF	OFF	ON	OFF	OFF	ON	L
H	L	H	L	OFF	ON	ON	OFF	OFF	OFF	H
H	L	H	H	OFF	ON	OFF	OFF	ON	OFF	L
H	L	L	H	OFF	OFF	OFF	ON	ON	OFF	H
L	H	L	H	OFF	ON	ON	OFF	OFF	OFF	H
L	H	L	L	OFF	ON	OFF	OFF	ON	OFF	L
L	H	H	L	OFF	OFF	OFF	ON	ON	OFF	H
L	L	H	L	ON	OFF	OFF	ON	OFF	OFF	L
L	L	H	H	ON	OFF	OFF	OFF	OFF	ON	H
L	L	L	H	OFF	OFF	ON	OFF	OFF	ON	L
*	L	L	L	OFF	OFF	OFF	OFF	OFF	OFF	L
*	H	H	H	OFF	OFF	OFF	OFF	OFF	OFF	L

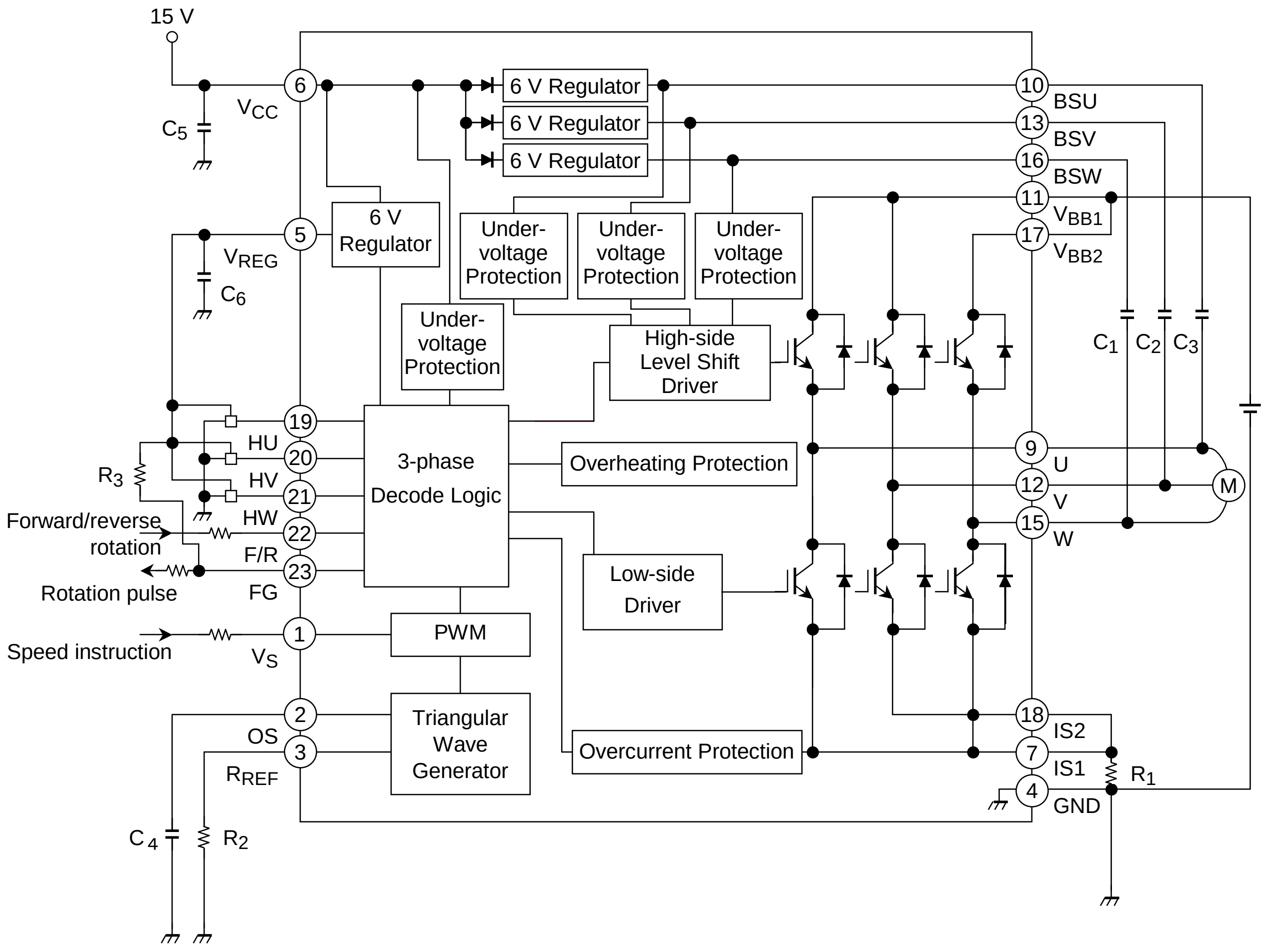
Absolute Maximum Ratings (Ta = 25°C)

Characteristics	Symbol	Rating	Unit
Power supply voltage	V_{BB}	250	V
	V_{CC}	18	V
Output current (DC)	I_{out}	1	A
Output current (pulse)	I_{out}	2	A
Input voltage (except VS)	V_{IN}	−0.5~V_{REG} + 0.5	V
Input voltage (only VS)	VV_S	6.5	V
Power dissipation (Ta = 25°C)	P_C	4	W
Power dissipation (Tc = 25°C)	P_C	20	W
Operating temperature	T_{opr}	−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)	V

Electrical Characteristics (Ta = 25°C)

Characteristics	Symbol	Test Condition	Min	Typ.	Max	Unit
Operating power supply voltage	V_{BB}	—	50	—	165	V
	V_{CC}	—	9	12	16.5	
Current dissipation	I_{BB}	V_{BB} = 165 V duty = 0%	—	0.1	1	mA
	I_{CC}	V_{CC} = 12 V duty = 0%	—	1.8	10	
	$I_{BS (ON)}$	V_{BS} = 6 V, high side ON	—	280	430	μA
	$I_{BS (OFF)}$	V_{BS} = 6 V, high side OFF	—	230	350	
Input voltage	V_{IH}	V_{IN} = “H”	3.5	—	—	V
	V_{IL}	V_{IN} = “L”	—	—	1.5	
Input current	I_{IH}	V_{IN} = V_{REG}	—	—	100	μA
	I_{IL}	V_{IN} = 0 V	—	—	100	
Output saturation voltage	$V_{CEsat}H$	V_{CC} = 12 V, IC = 0.5 A	—	2.0	3.0	V
	$V_{CEsat}L$	V_{CC} = 12 V, IC = 0.5 A	—	2.0	3.0	
FRD forward voltage	V_FH	IF = 0.5 A, high side	—	1.4	2.1	V
	V_FL	IF = 0.5 A, low side	—	1.2	1.8	
PWM ON-duty ratio	PWMMIN	—	0	—	—	%
	PWMMAX	—	—	—	100	
PWM ON-duty ratio, 0%	VV_S0%	PWM = 0%	1.7	2.1	2.5	V
PWM ON-duty ratio, 100%	VV_S100%	PWM = 100%	4.9	5.4	6.1	V
PWM ON-duty voltage range	VV_SW	VV_S100% – VV_S0%	2.8	3.3	3.8	V
Output all-OFF voltage	VV_SOFF	Output all-OFF	1.1	1.3	1.5	V
Regulator voltage	V_{REG}	V_{CC} = 12 V, I_O = 30 mA	5	5.6	7	V
Speed control voltage range	V_S	—	0	—	6.5	V
FG output saturation voltage	VFGsat	IFG = 20 mA	—	—	0.5	V
Current limiting voltage	V_R	—	0.45	0.5	0.55	V
Overheat protection temperature	TSD	—	150	165	200	°C
Overheat protection hysteresis	ΔTSD	—	—	10	—	°C
V_{CC} under voltage protection	V_{CC}UVD	—	6.5	7.5	8.5	V
V_{CC} under voltage protection recovery	V_{CC}UVR	—	7.0	8.0	9.0	V
V_{BS} under voltage protection	V_{BS}UVD	—	3.2	3.8	4.2	V
V_{BS} under voltage protection recovery	V_{BS}UVR	—	3.8	4.4	4.9	V
Refresh operating ON voltage	T_{RFON}	Refresh operation	1.1	1.3	1.5	V
Refresh operating OFF voltage	T_{RFOFF}	OFF refresh operation	3.1	3.8	4.6	V
Triangular wave frequency	f_c	R = 27 kΩ, C = 1000 pF	16.5	20	25	kHz
Output on delay time	t_{on}	V_{BB} = 141 V, IC = 0.5 A	—	2.0	3	μs
Output off delay time	t_{off}	V_{BB} = 141 V, IC = 0.5 A	—	1.5	3	μs
FRD reverse recovery time	t_{rr}	V_{BB} = 141 V, IC = 0.5 A	—	100	—	ns

Application Circuit Example



External Parts

Standard external parts are shown in the following table.

Part	Recommended Value	Purpose	Other
C_1, C_2, C_3	2.2 μF	Bootstrap capacitor	(Note 1)
R_1	0.62 Ω ± 1% (1 W)	Current detection	(Note 2)
C_4	1000 pF ± 5%	PWM frequency setup	(Note 3)
R_2	27 kΩ ± 5%	PWM frequency setup	(Note 3)
C_5	10 μF	Control power supply stability	(Note 4)
C_6	0.1 μF	V_{REG} power supply stability	(Note 4)
R_3	5.1 kΩ	FG pin pull-up resistor	(Note 5)

Note 1: Although the required bootstrap capacitance value with the motor drive conditions, care must be taken to keep the capacitor voltage greater than or equal to 4.8 V for 20 ms after the start-up and during drive. The capacitor is biased by 6 V (typ.) and must be sufficiently derated for it.

Note 2: The following formula shows the detection current: $I_O = V_R \div RIS$ ($V_R = 0.5$ V typ.)
Do not exceed a detection current of 900 mA when using the IC.

Note 3: With the combination of Cos and R_{REF} shown in the table, the PWM frequency is around 20 kHz. The IC intrinsic error factor is around 10%.
The PWM frequency is broadly expressed by the following formula. (In this case, the stray capacitance of the printed circuit board needs to be considered.)

$$f_{PWM} = 0.65 \div \{Cos \times (R_{REF} + 4.25\ k\Omega)\}\ [Hz]$$

R_{REF} creates the reference current of the PWM triangular wave charge/discharge circuit. If R_{REF} is set too small it exceeds the current capacity of the IC internal circuits and the triangular wave distorts. Set R_{REF} to at least 9 k Ω.

Note 4: When using the IC, some adjustment is required in accordance with the use environment. When mounting, place as close to the base of the IC leads as possible to improve the noise elimination.

Note 5: The FG pin is open drain. When using the FG pin, connect it to, for example, the CPU power supply (5 V) via a pull-up resistor. Note that when the FG pin is connected to a power supply with an voltage equal or higher than the V_{CC}, a protector circuit is triggered so that the current flows continuously. If not using the FG pin, connect to the GND.

Note 6: If noise is detected on the Hall signal pin, add a CR filter.
(recommended 0.1 μF capacitor and 1 kΩ resistor)

Handling precautions

(1) When switching the power supply to the circuit on/off, ensure that $V_S < VV_SOFF$ (all IGBT outputs off). At that time, either the V_{CC} or the V_{BB} can be turned on/off first. Note that if the power supply is switched off as described above, the IC 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 IS pin connecting the current detection resistor is connected to a comparator in the IC and also functions as a sensor pin for detecting overcurrent. As a result, overvoltage caused by a surge, for example, may destroy the circuit. Accordingly, be careful of handling the IC or of surges in its application environment.

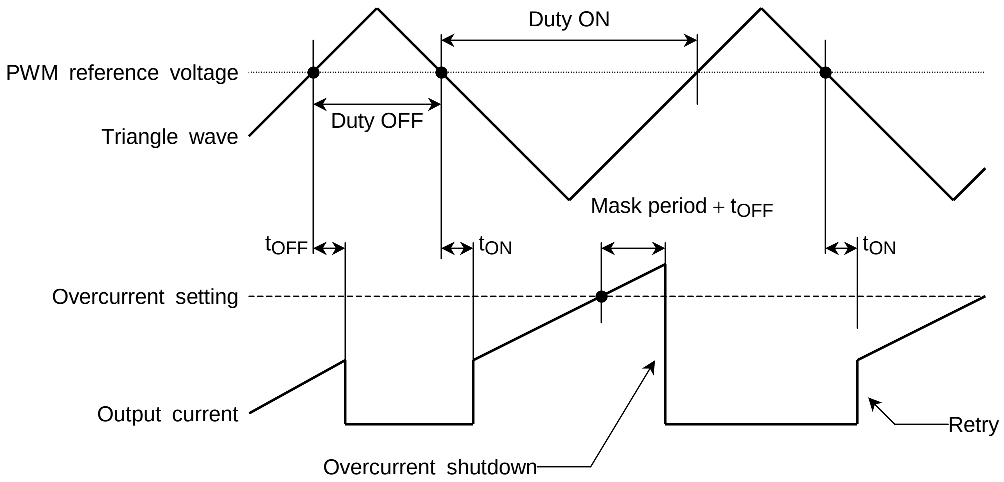
(3) The triangular wave oscillator circuit, with externally connected C_{OS} and R_{REF}, charges and discharges minute amounts of current. Therefore, subjecting the IC to noise when mounting it on the board may distort the triangular wave or cause malfunction. To avoid this, attach external components to the base of the IC leads or isolate them from any tracks or wiring which carries large current.

(4) The PWM of this IC is controlled by the ON/OFF state of the high-side IGBT.

Description of Protection Function

(1) Overcurrent

Overcurrent protection function in this IC detects voltage generated in the current detection resistor connected to the IS pin. When this voltage exceeds V_R = 0.5 V (typ.), the high-side IGBT output, which is on, temporarily shuts down after a mask period (approx. 1 μs), preventing any additional current from flowing to the IC. The next PWM ON signal releases the shutdown state.



(2) Undervoltage

When the V_{CC} power supply falls to the IC internal setting (V_{CC}UVD = 7.5 V typ.), all IGBT outputs shut down regardless of the input. This protection function has hysteresis. When the V_{CC}UVR (= 8.0 V typ.) reaches 0.5 V higher than the shutdown voltage, the IC is automatically restored and the IGBT is turned on again by the input.

(3) Overheating

When the temperature of this chip rises due to external causes or internal heat generation and the internal setting TSD reaches 165°C, all IGBT outputs shut down regardless of the input. This protection function has hysteresis (ΔTSD = 10°C typ.). When the chip temperature falls to TSD − ΔTSD, the chip is automatically restored and the IGBT is turned on again by the input.

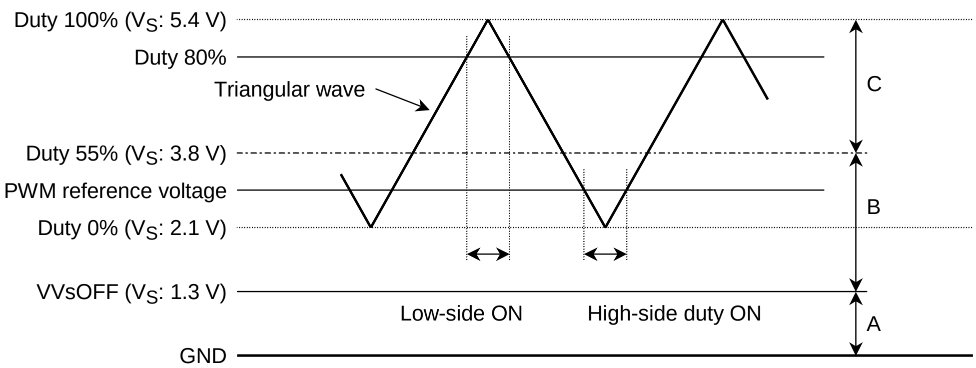
Because the chip contains just one temperature detection location, when the chip heats up due to the IGBT, for example, the differences in distance from the detection location in the IGBT (the source of the heat) cause differences in the time taken for shutdown to occur.

Description of Bootstrap Capacitor Charging

The IC uses bootstrapping for the power supply for high-side drivers.
The bootstrap capacitor is charged by turning on the low-side IGBT of the same arm (approximately 1/5 of PWM cycle) while the high-side IGBT controlled by PWM is off.

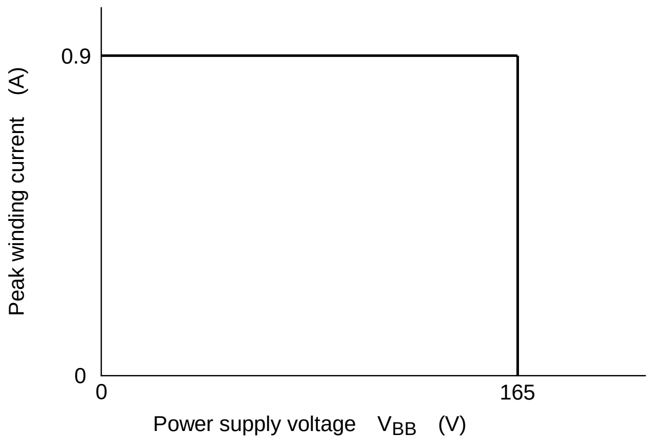
When the V_S voltage exceeds 3.8 V (duty 55%), the low-side IGBT is continuously in the off state. This is because when the PWM on-duty becomes larger, the arm is short-circuited while the low-side IGBT is on. Even in this state, because PWM control is being performed on the high-side IGBT, the regenerative current of the diode flows to the low-side FRD of the same arm, and bootstrap capacitor is charged. Note that when the on-duty is 100%, diode regenerative current does not flow; thus, the bootstrap capacitor is not charged.

To determine the capacitance of the bootstrap capacitor, take the voltage drop at 100% duty into consideration.
(For example, to drive at 20 kHz, it takes approximately 10 μs per cycle to charge the capacitor.)



V_S Range	IGBT Operation
A	Both high- and low-side off.
B	Charging range. Low-side IGBT turns on at the phase when the high-side IGBT turns on in the timing chart.
C	No charging range. High-side at PWM; low-side continues on according to the timing chart.

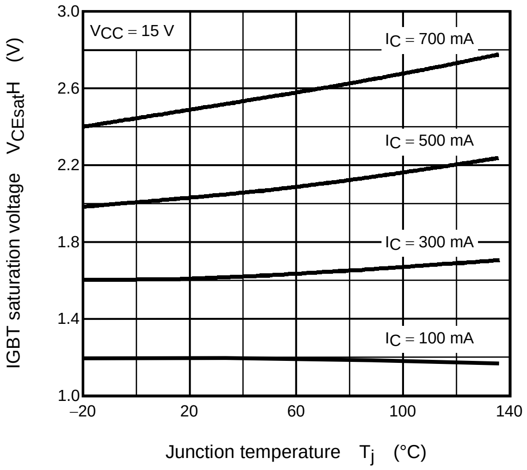
Safe Operating Area



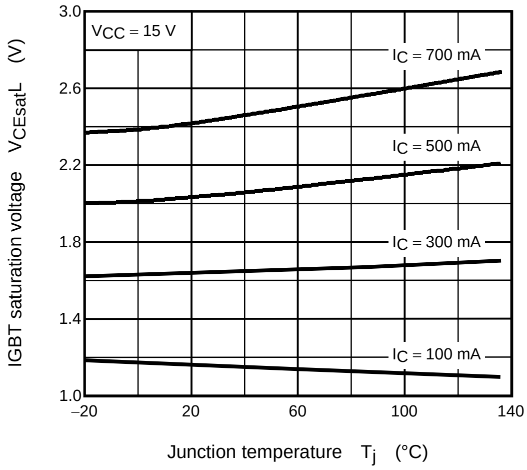
*: The above safe operating area is Tc = 95°C. If the temperature exceeds this, the safe operation area reduces.

*: The above safe operating area includes the overcurrent protection operation area. If the overcurrent protection operation continues, depending on the heat discharge conditions, an overheating protection operation may result.

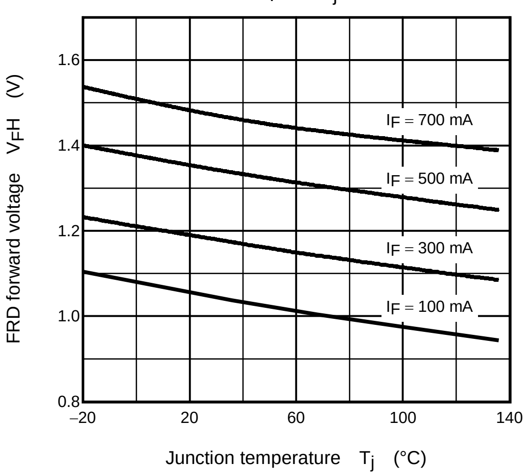
$V_{CEsat}H – T_j$



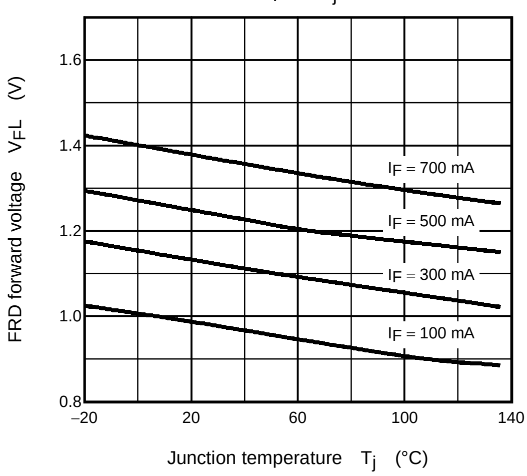
$V_{CEsat}L – T_j$



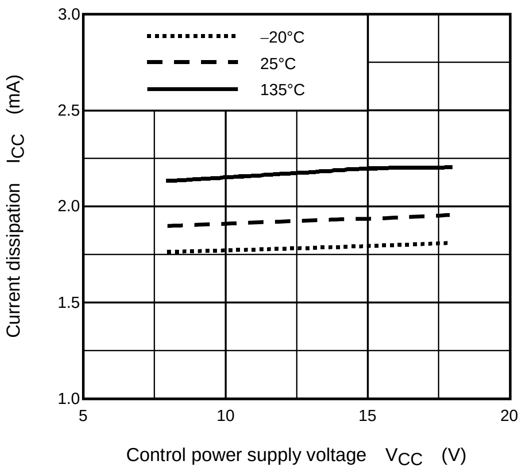
$V_FH – T_j$



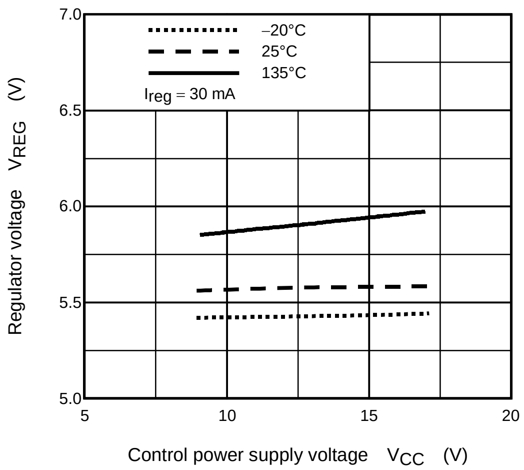
$V_FL – T_j$

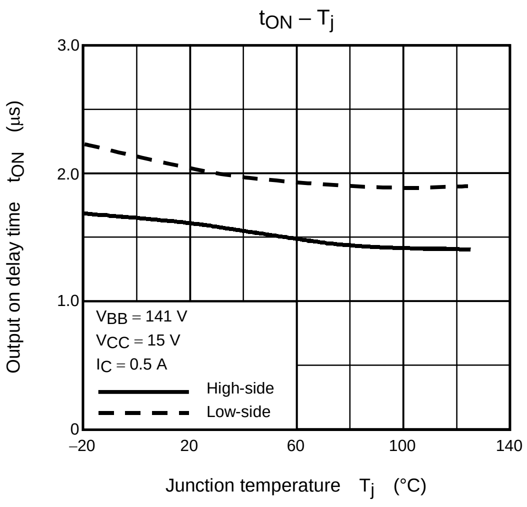


$I_{CC} – V_{CC}$

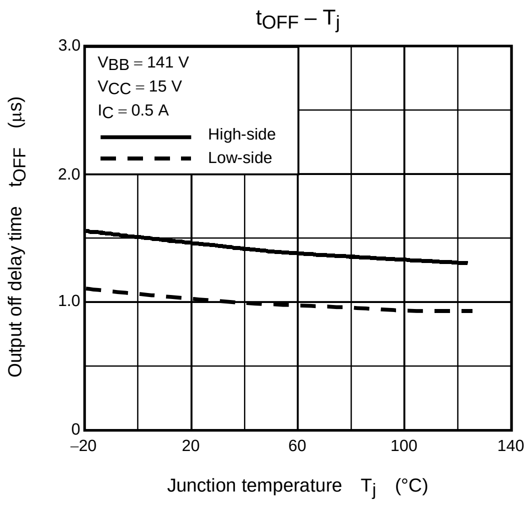


$V_{REG} – V_{CC}$

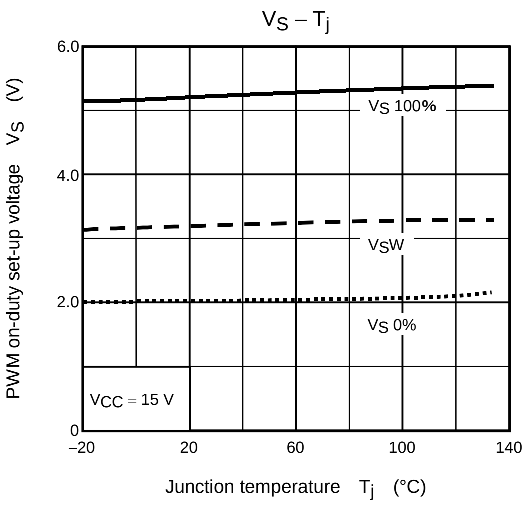




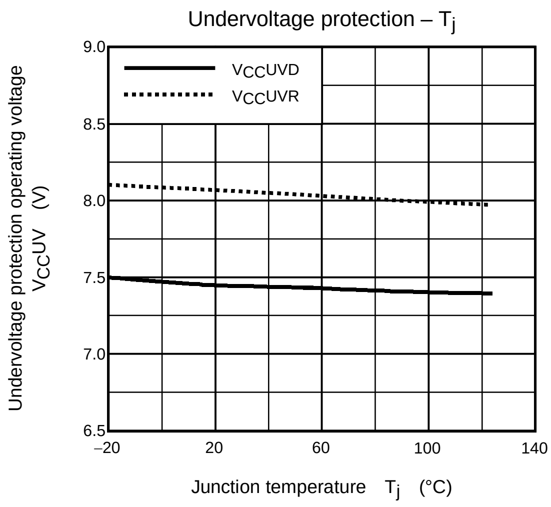
t_{ON} – T_j
Output on delay time t_{ON} (µs)
V_{BB} = 141 V
V_{CC} = 15 V
I_C = 0.5 A
High-side
Low-side
Junction temperature T_j (°C)



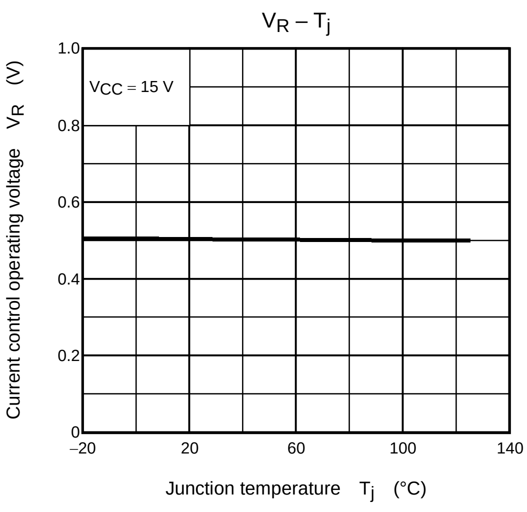
t_{OFF} – T_j
Output off delay time t_{OFF} (µs)
V_{BB} = 141 V
V_{CC} = 15 V
I_C = 0.5 A
High-side
Low-side
Junction temperature T_j (°C)



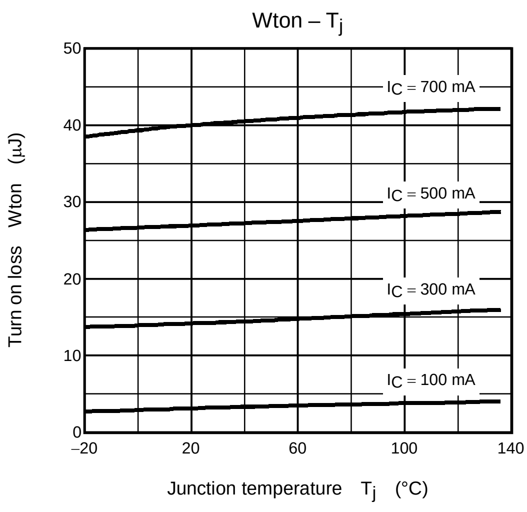
V_S – T_j
PWM on-duty set-up voltage V_S (V)
V_S 100%
V_{SW}
V_S 0%
V_{CC} = 15 V
Junction temperature T_j (°C)



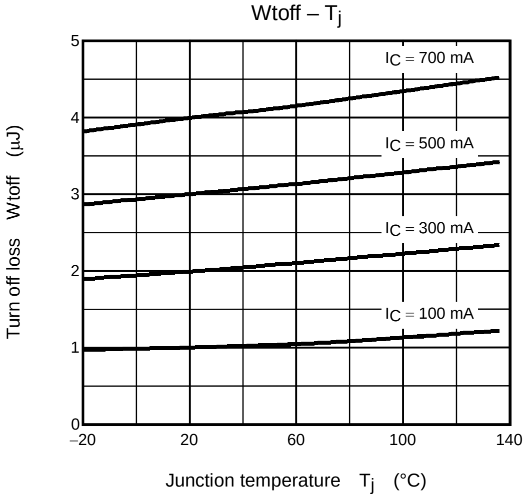
Undervoltage protection – T_j
Undervoltage protection operating voltage V_{CCUV} (V)
V_{CCUVD}
V_{CCUVR}
Junction temperature T_j (°C)



V_R – T_j
Current control operating voltage V_R (V)
V_{CC} = 15 V
Junction temperature T_j (°C)

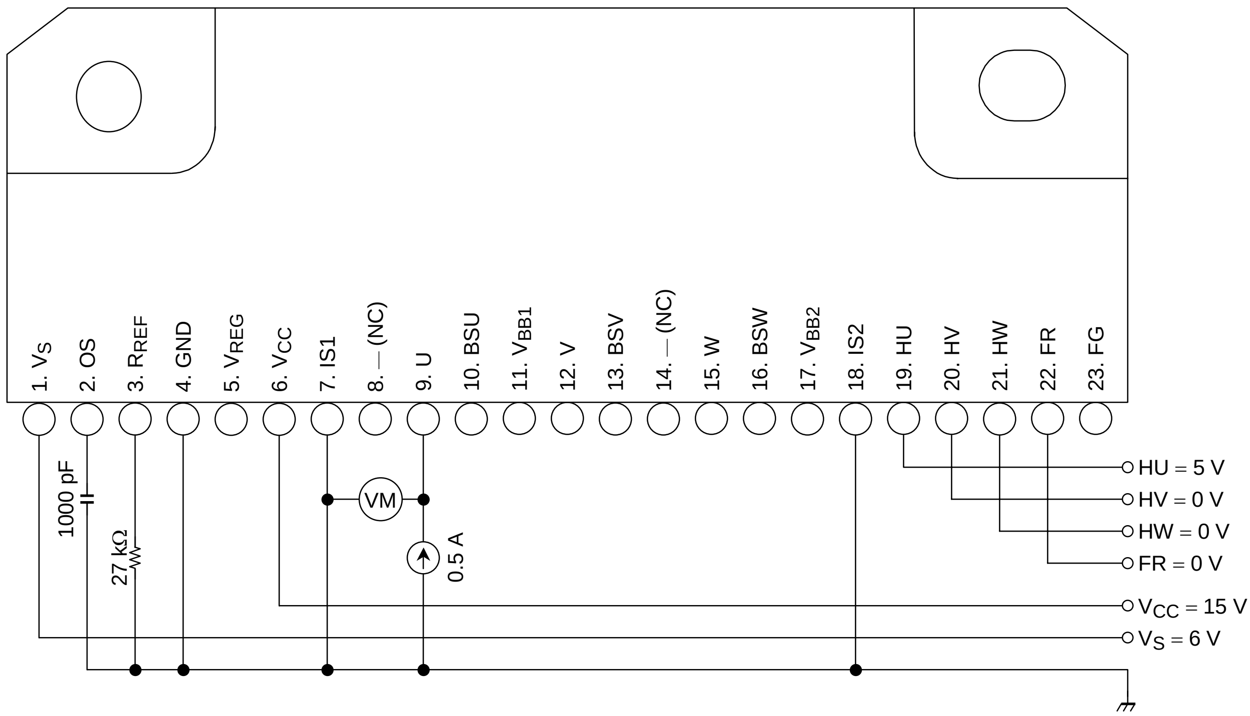


Wton – T_j
Turn on loss Wton (µJ)
I_C = 700 mA
I_C = 500 mA
I_C = 300 mA
I_C = 100 mA
Junction temperature T_j (°C)

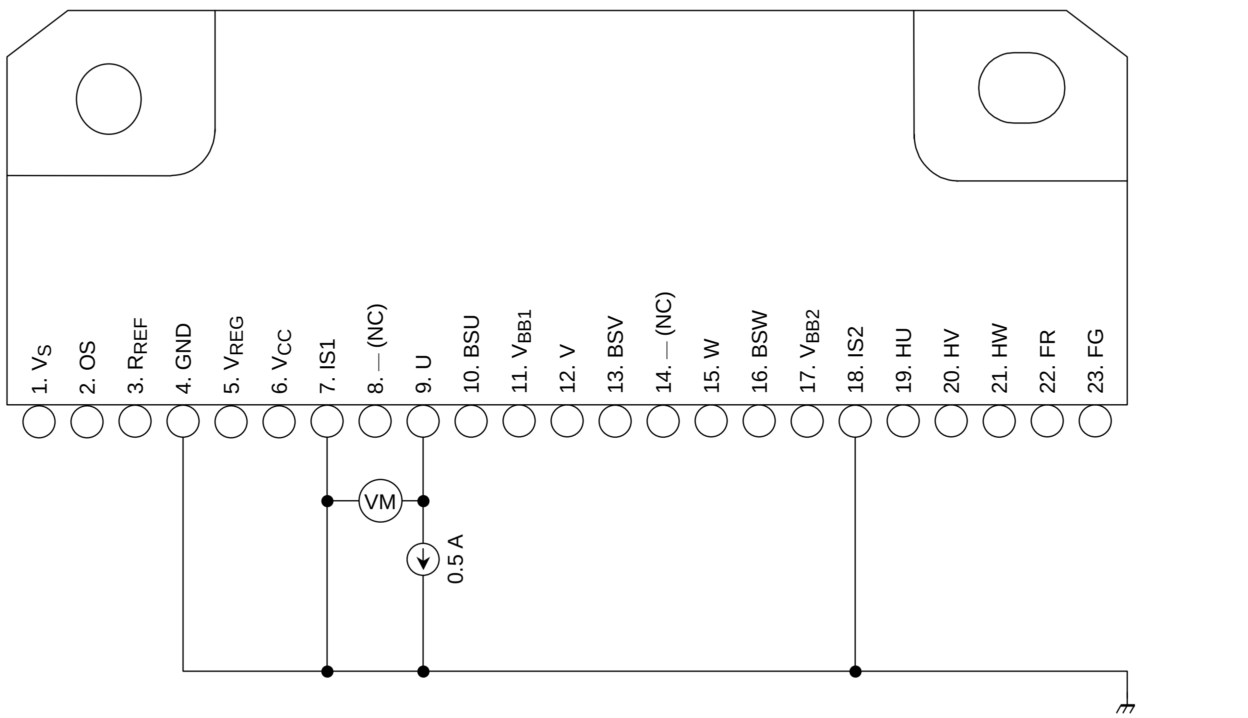

Wtoff – Tj
IC = 700 mA
IC = 500 mA
IC = 300 mA
IC = 100 mA
Turn off loss Wtoff (μJ)
Junction temperature Tj (°C)
0
1
2
3
4
5
–20
20
60
100
140

Test Circuits

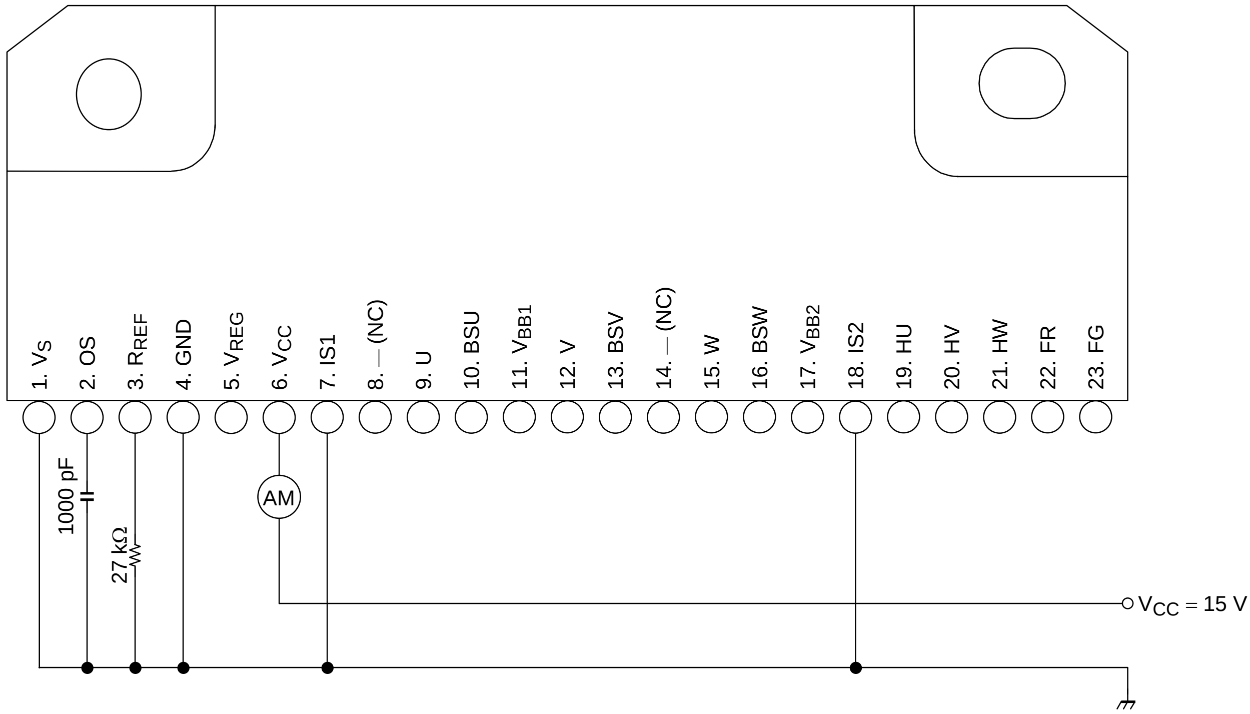
IGBT Saturation Voltage (U-phase low side)



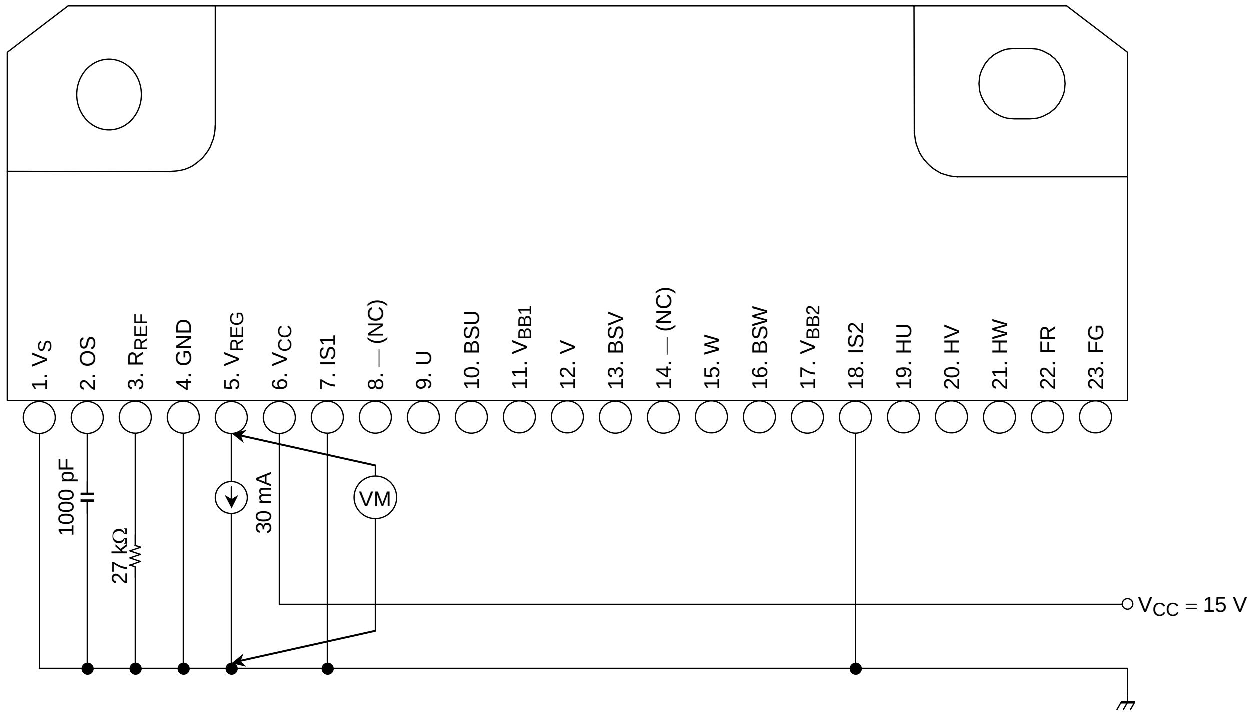
FRD Forward Voltage (U-phase low side)



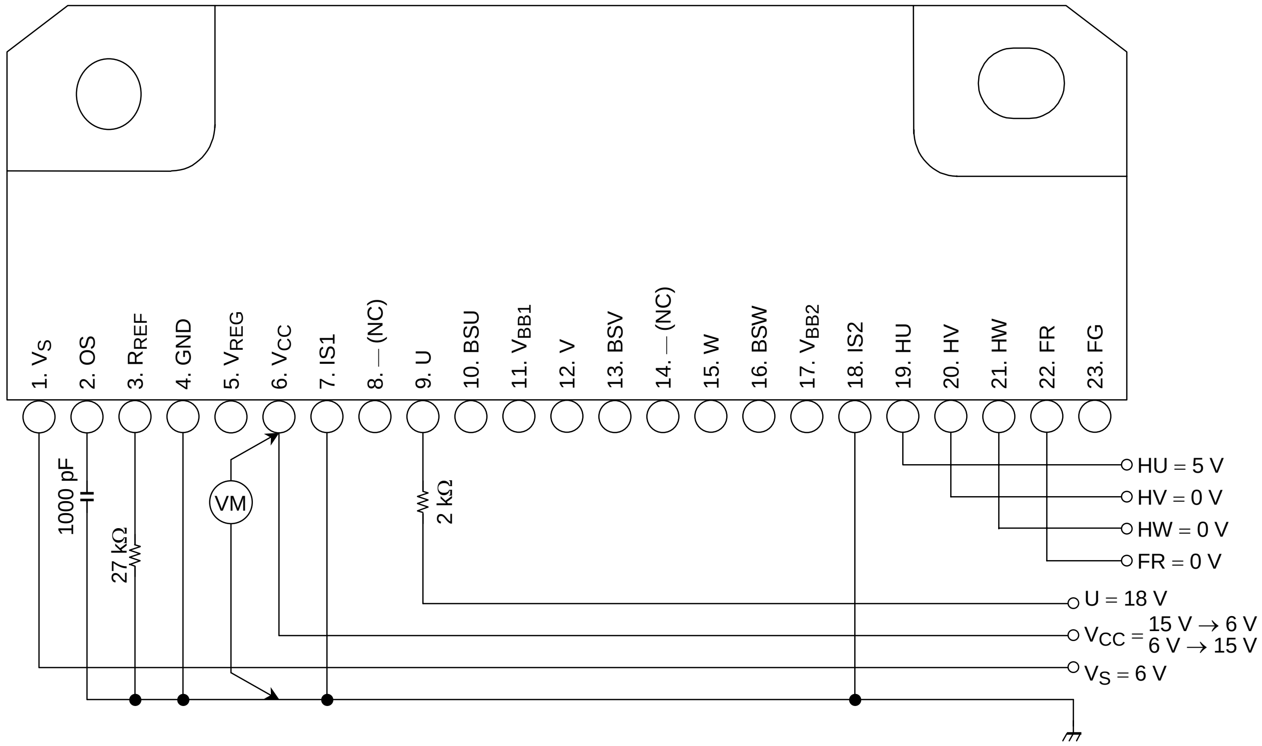
Current Dissipation (I_{CC})



Regulator Voltage

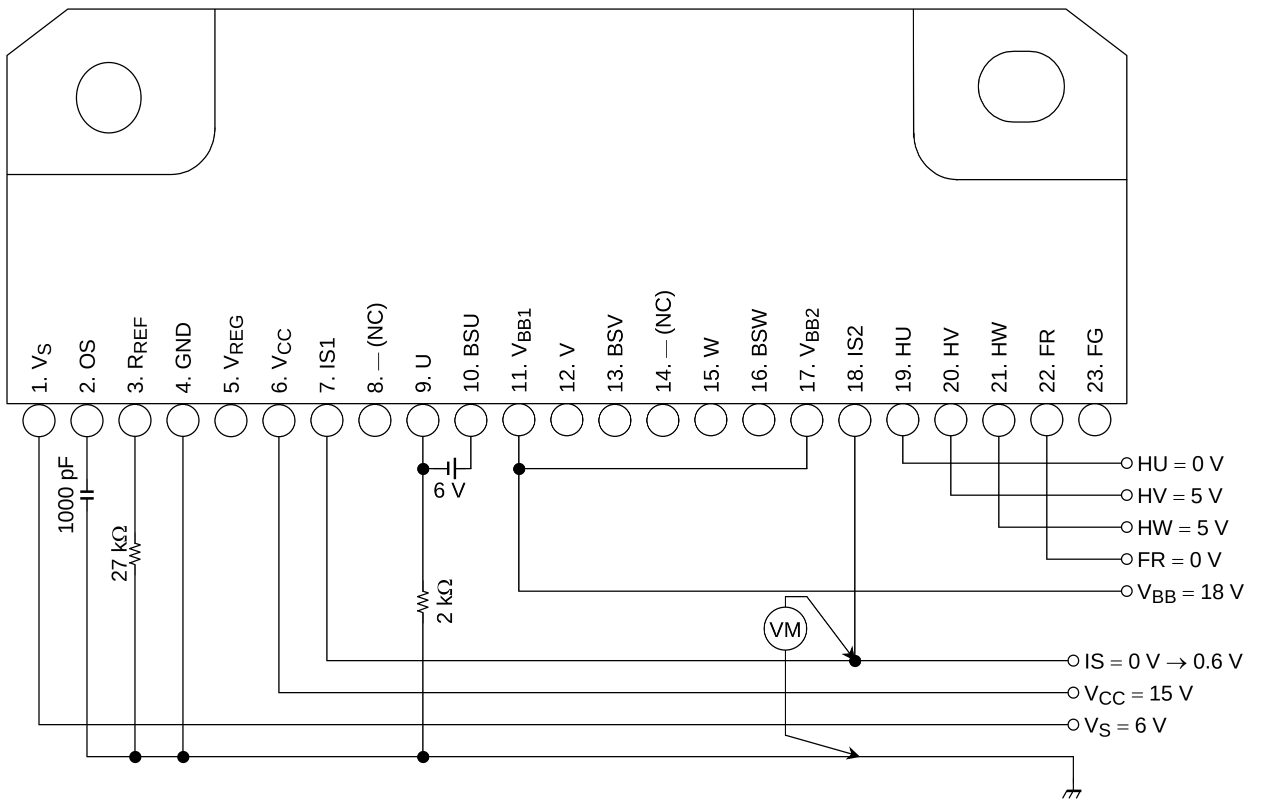


Undervoltage Protection Operation/Recovery Voltage (U-phase low side)



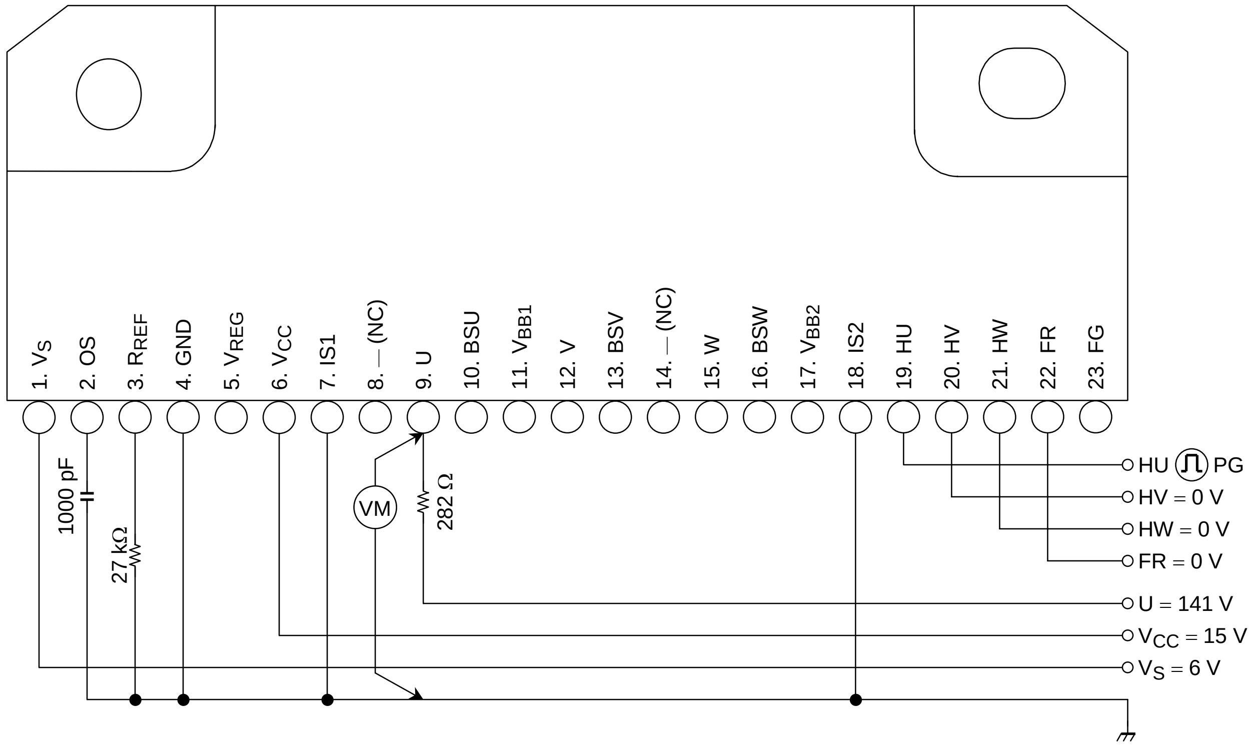
*: Sweeps the V_{CC} pin voltage from 15 V to decrease and monitors the U pin voltage.
The V_{CC} pin voltage when output is off defines the undervoltage protection operating voltage.
Also sweeps from 6 V to increase. The V_{CC} pin voltage when output is on defines the undervoltage protection recovery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

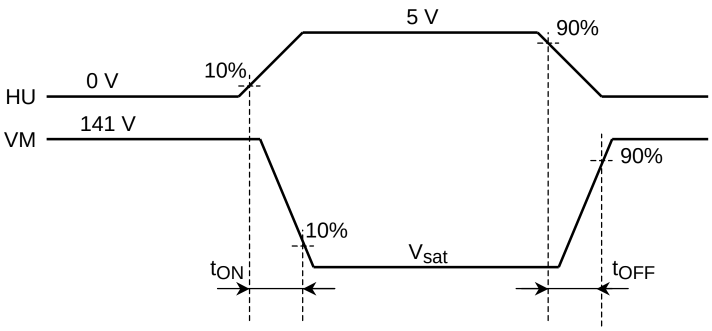
Current-limit Operating Voltage (U-phase high side)



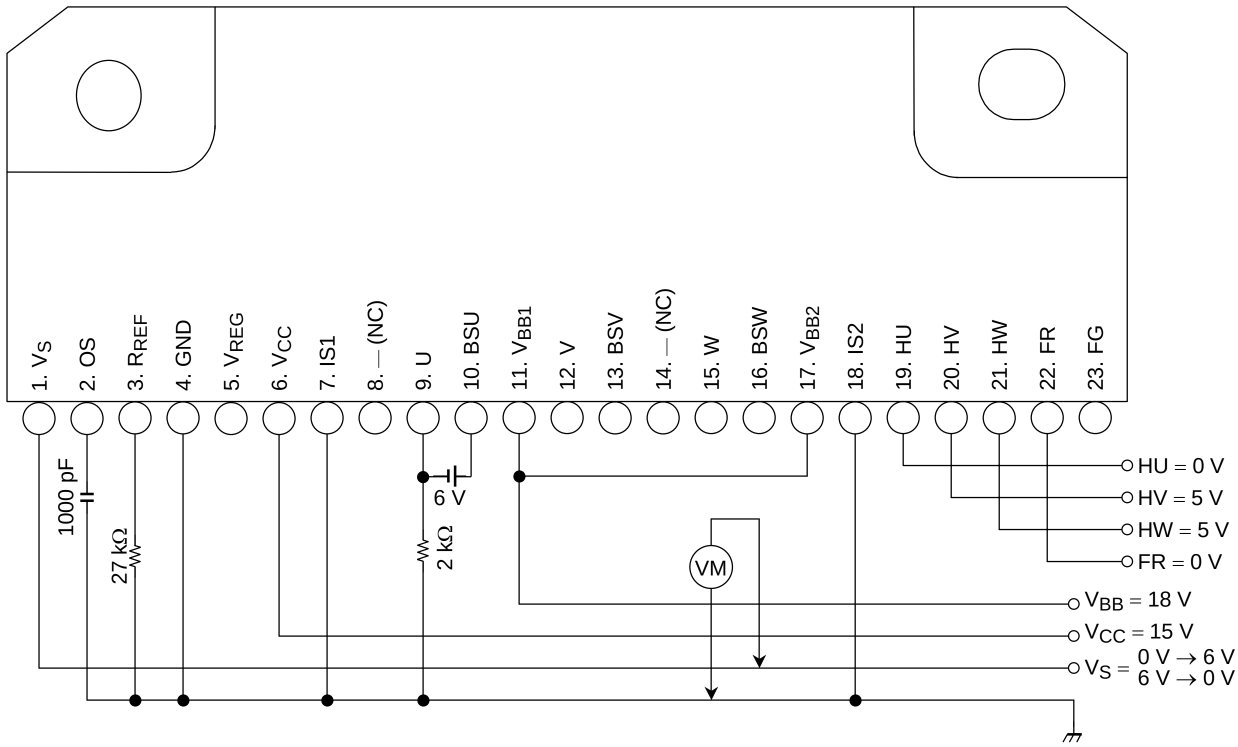
*: Sweeps the IS pin voltage to increase and monitors the U pin voltage.
The IS pin voltage when output is off defines the current-limit operating voltage.

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



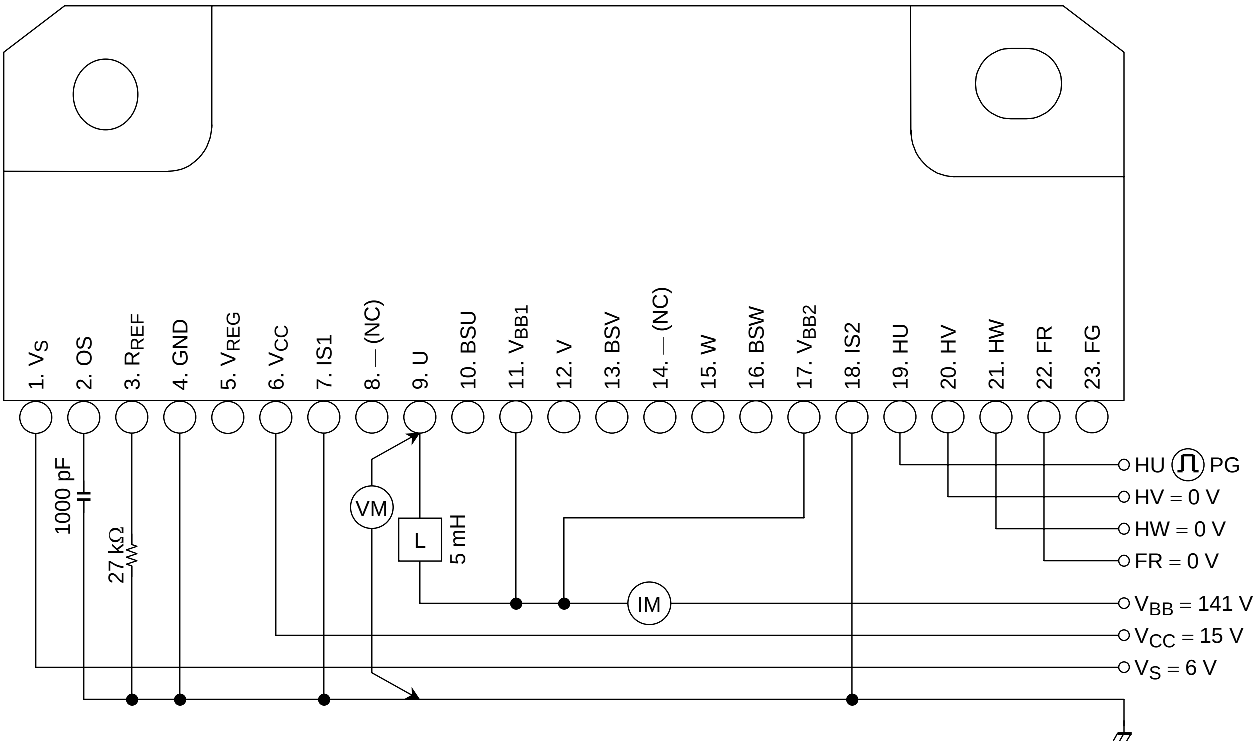


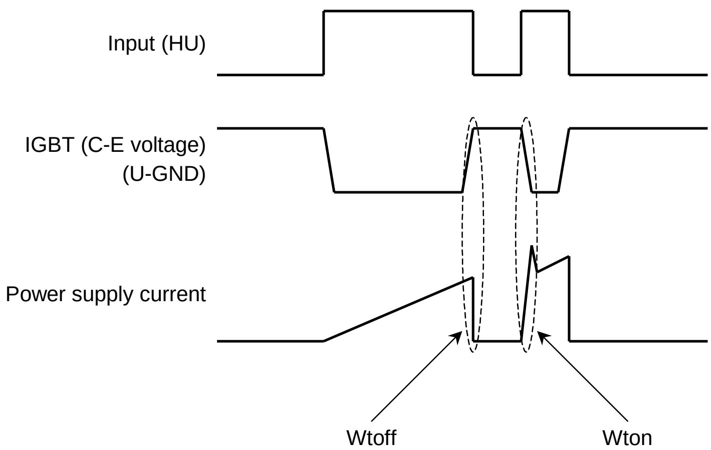
PWM ON-duty Setup Voltage (U-phase high side)



*: Sweeps the VS pin voltage to increase and monitors the U pin.
When output is turned off from on, the PWM = 0%. When output is full on, the PWM = 100%.

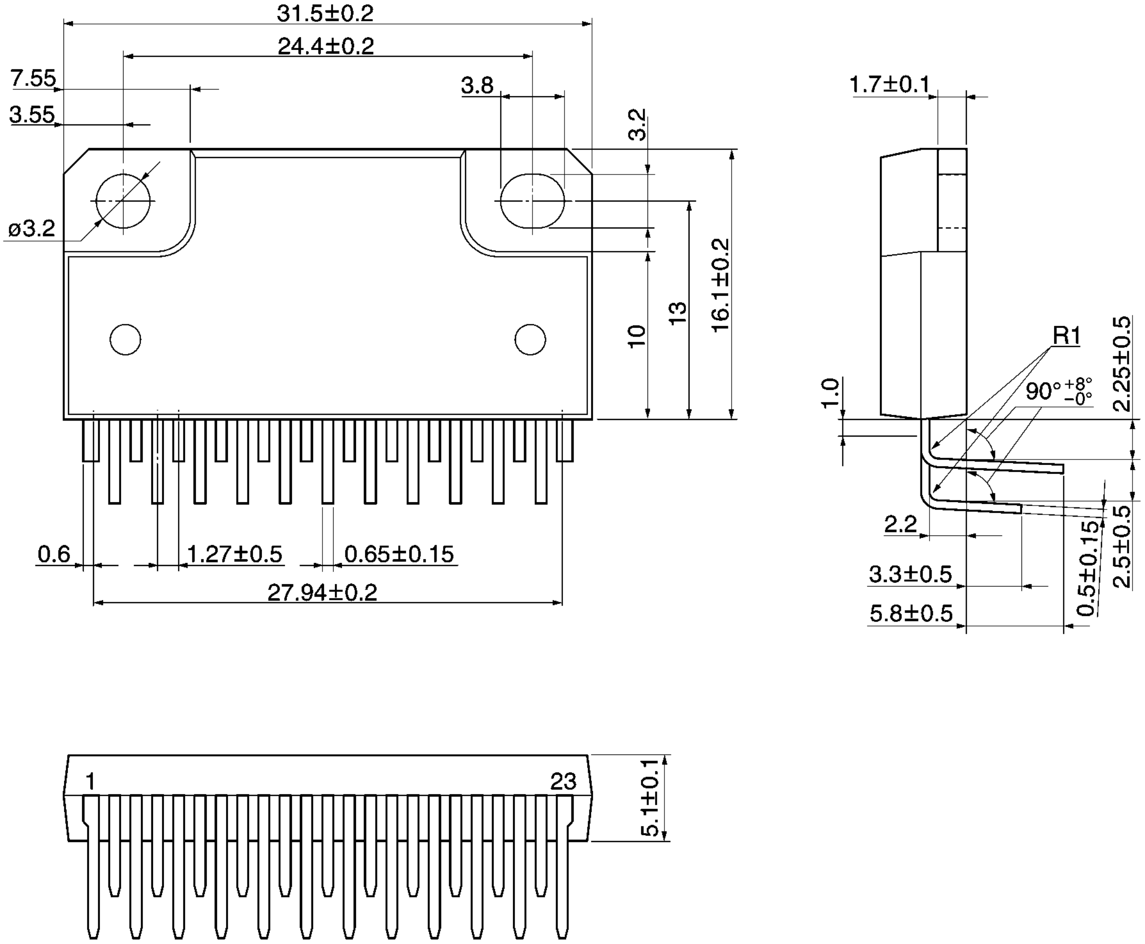
Turn-ON/OFF Loss (Low-side IGBT + High-side FRD)





Package Dimensions

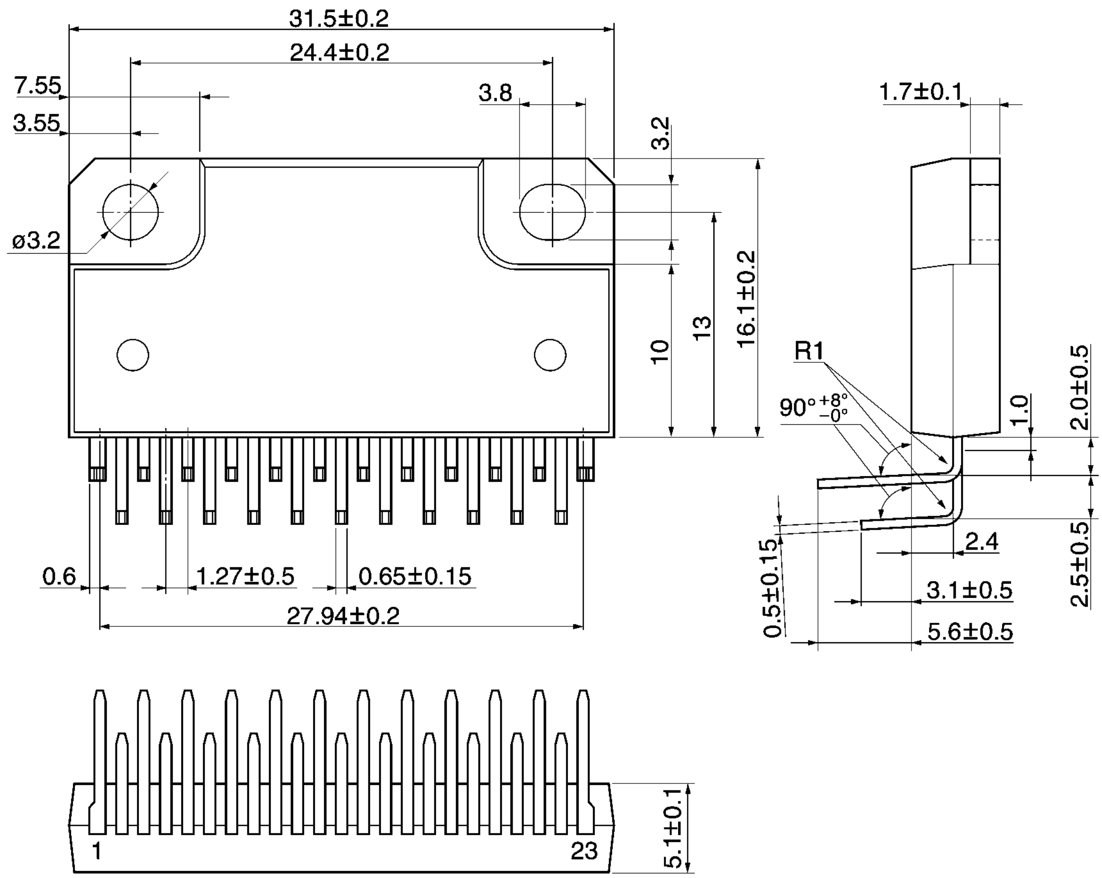
HZIP23-P-1.27F Unit: mm



Weight: 6.1 g (typ.)

Package Dimensions

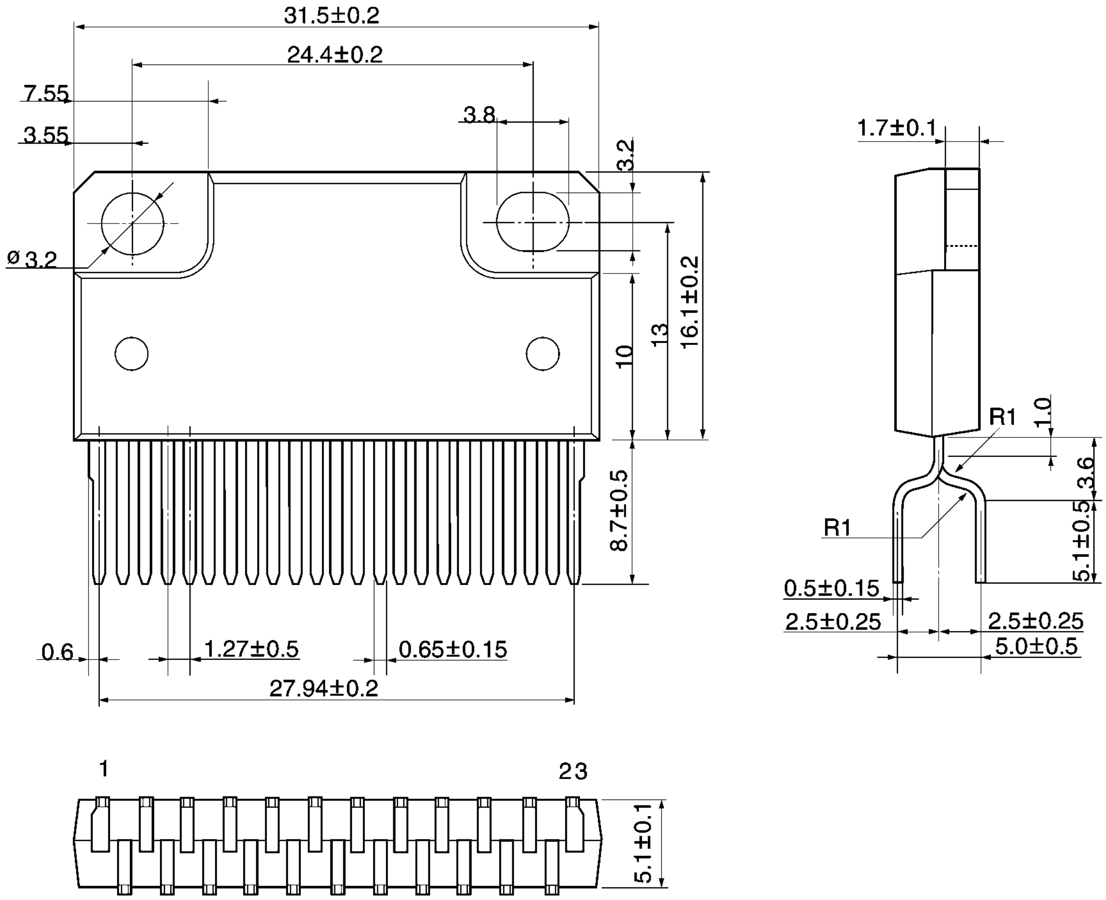
HZIP23-P-1.27G Unit: mm



Weight: 6.1 g (typ.)

Package Dimensions

HZIP23-P-1.27H Unit: mm



Weight: 6.1 g (typ.)

RESTRICTIONS ON PRODUCT USE

000707EBA

- TOSHIBA is continually working to improve the quality and reliability of its products. Nevertheless, semiconductor devices in general can malfunction or fail due to their inherent electrical sensitivity and vulnerability to physical stress. It is the responsibility of the buyer, when utilizing TOSHIBA products, to comply with the standards of safety in making a safe design for the entire system, and to avoid situations in which a malfunction or failure of such TOSHIBA products could cause loss of human life, bodily injury or damage to property.
  In developing your designs, please ensure that TOSHIBA products are used within specified operating ranges as set forth in the most recent TOSHIBA products specifications. Also, please keep in mind the precautions and conditions set forth in the “Handling Guide for Semiconductor Devices,” or “TOSHIBA Semiconductor Reliability Handbook” etc..
- The TOSHIBA products listed in this document are intended for usage in general electronics applications (computer, personal equipment, office equipment, measuring equipment, industrial robotics, domestic appliances, etc.). These TOSHIBA products are neither intended nor warranted for usage in equipment that requires extraordinarily high quality and/or reliability or a malfunction or failure of which may cause loss of human life or bodily injury (“Unintended Usage”). Unintended Usage include atomic energy control instruments, airplane or spaceship instruments, transportation instruments, traffic signal instruments, combustion control instruments, medical instruments, all types of safety devices, etc.. Unintended Usage of TOSHIBA products listed in this document shall be made at the customer’s own risk.
- The products described in this document are subject to the foreign exchange and foreign trade laws.
- The information contained herein is presented only as a guide for the applications of our products. No responsibility is assumed by TOSHIBA CORPORATION for any infringements of intellectual property or other rights of the third parties which may result from its use. No license is granted by implication or otherwise under any intellectual property or other rights of TOSHIBA CORPORATION or others.
- The information contained herein is subject to change without notice.