

TOSHIBA Intelligent Power Device High Voltage Monolithic Silicon Power IC

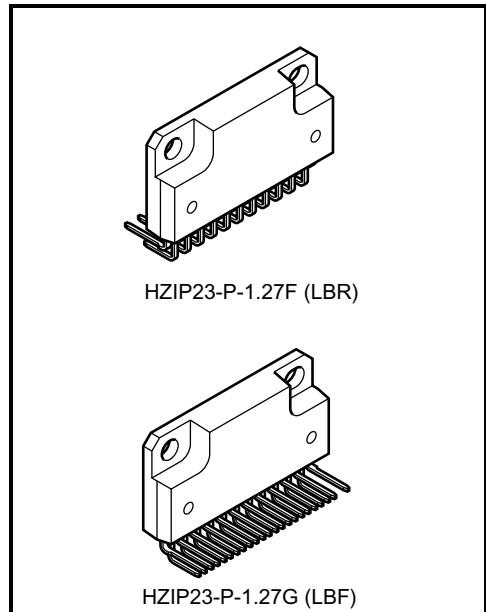
# TPD4011K

The TPD4011K 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 TPD4011K.

## 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.



### Weight

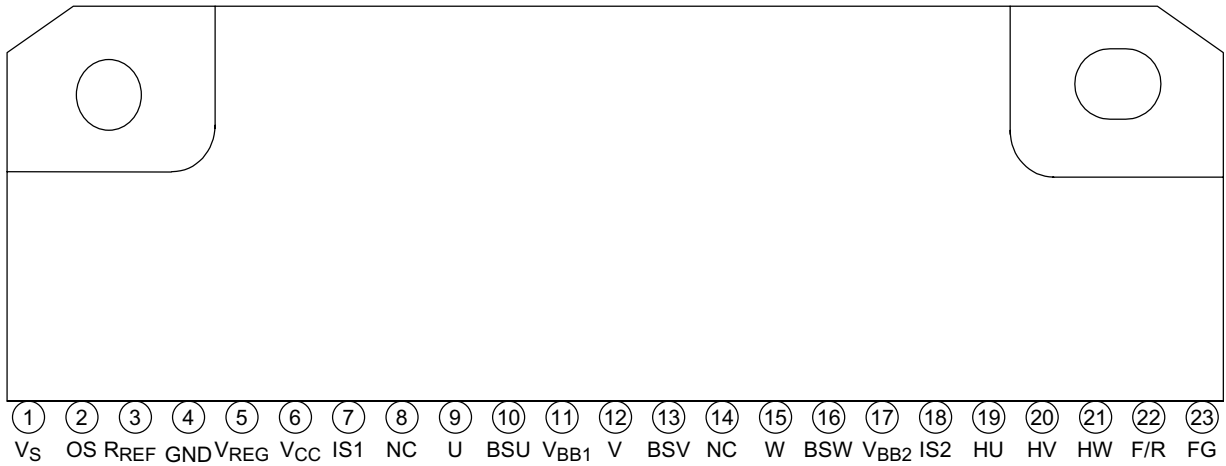
HZIP23-P-1.27F : 6.1 g (typ.)

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

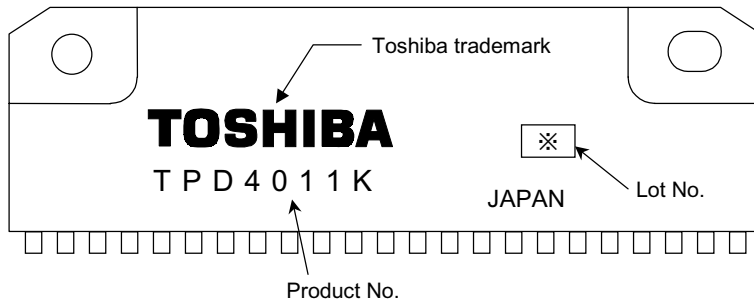
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## Pin Assignment



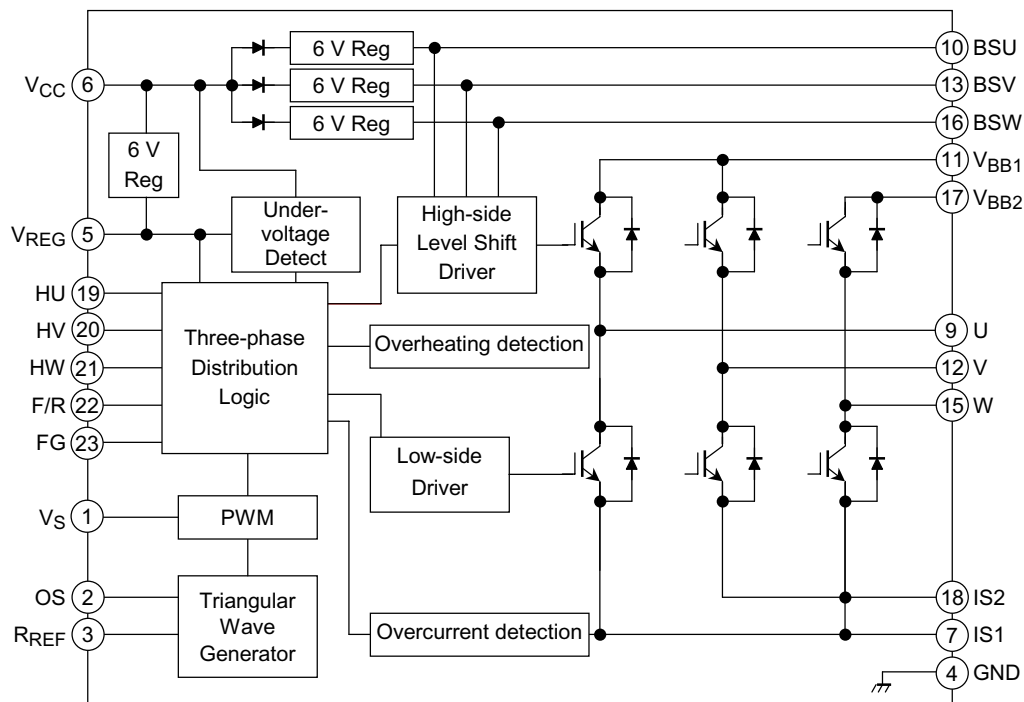
## Marking



※ Lot No.

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

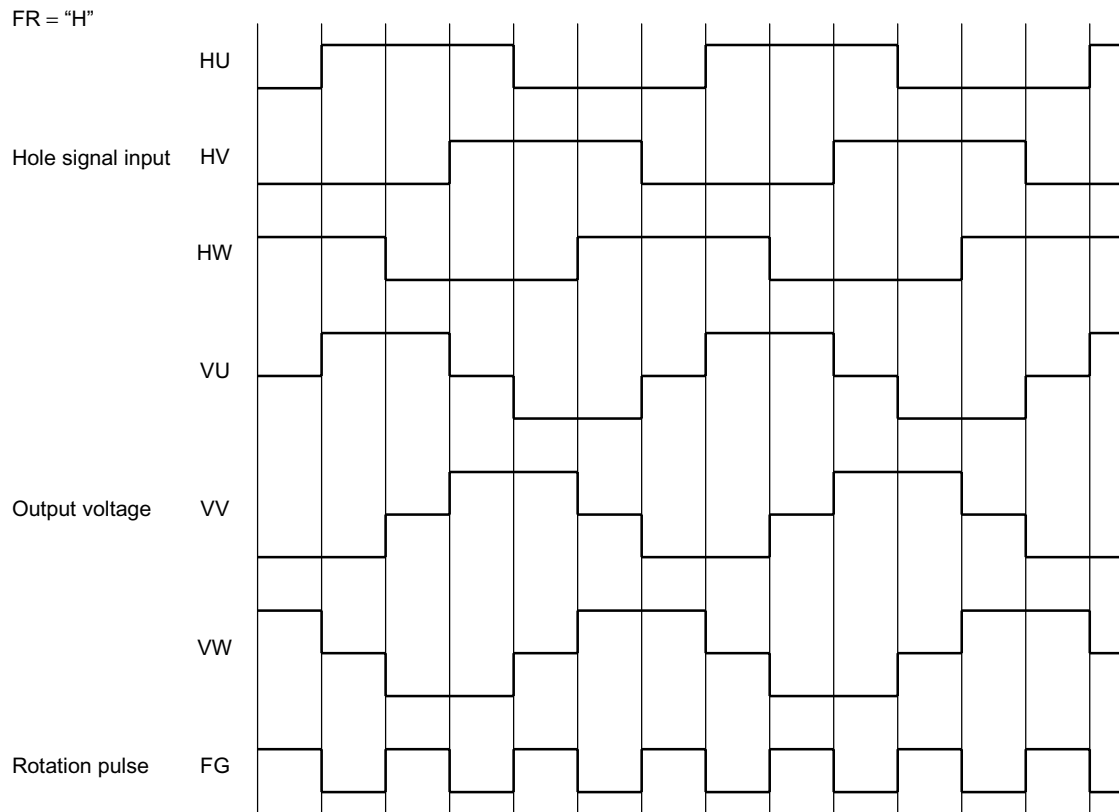
## Block Diagram



## Pin Description

Pin No.	Symbol	Pin Description
1	V <sub>S</sub>	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	RREF	PWM triangular wave oscillation frequency setup pin. (Connect a resistor to this pin.)
4	GND	Ground pin.
5	V <sub>REG</sub>	6 V regulator output pin.
6	V <sub>CC</sub>	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 <sub>BB1</sub>	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 <sub>BB2</sub>	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.

## Timing Chart



## Truth Table

FR	Hole Signal Input			U Phase		V Phase		W Phase		FG
	HU	HV	HW	Upper Arm	Lower Arm	Upper Arm	Lower Arm	Upper Arm	Lower Arm	
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

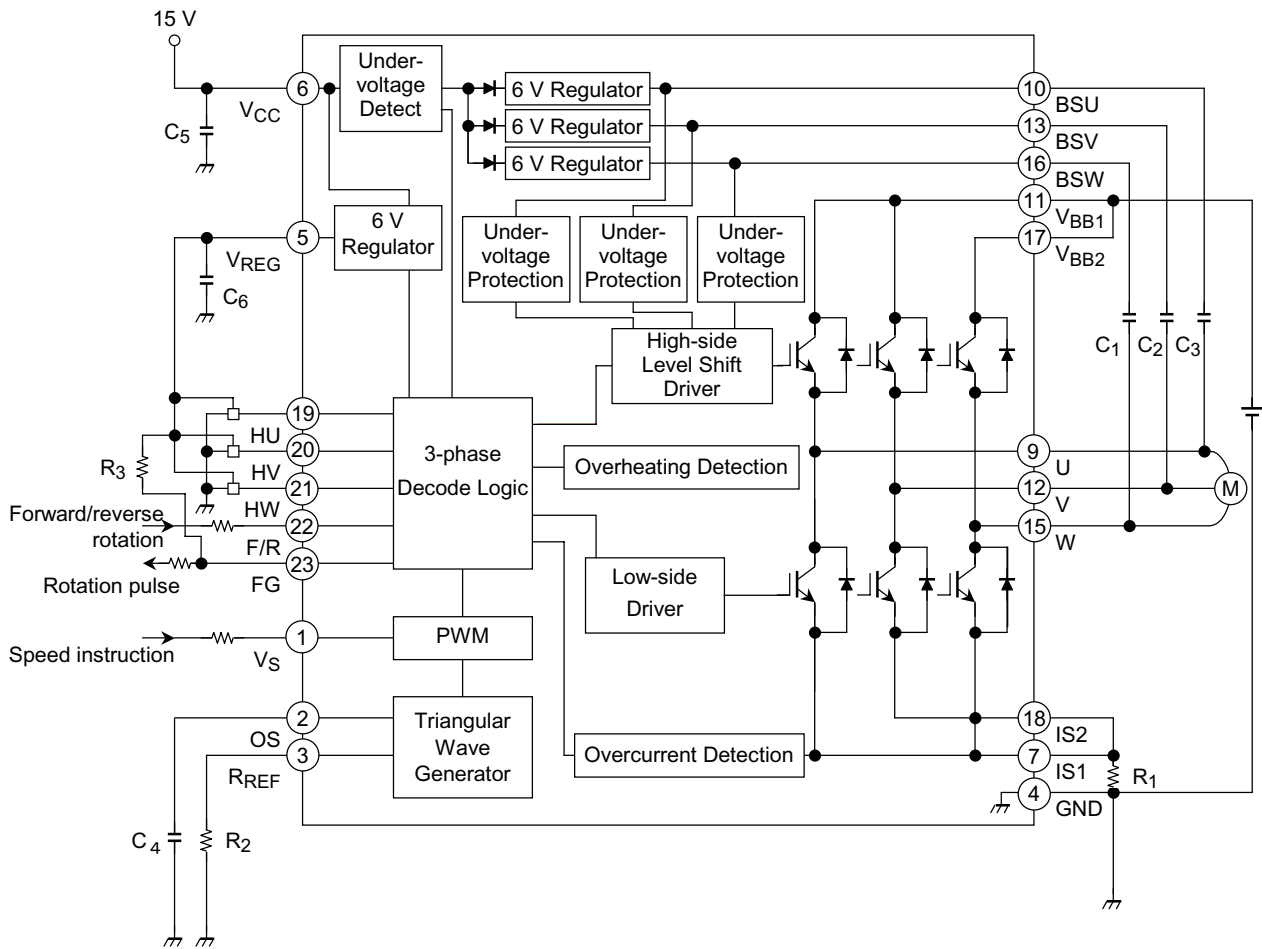
## Absolute Maximum Ratings (Ta = 25°C)

Characteristics	Symbol	Rating	Unit
Power supply voltage	V <sub>BB</sub>	330	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 (except VS)	V <sub>IN</sub>	-0.5~V <sub>REG</sub> + 0.5	V
Input voltage (only VS)	V <sub>VS</sub>	6.5	V
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>OPe</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 (per 1 m)	V

## Electrical Characteristics (Ta = 25°C)

Characteristics	Symbol	Test Condition	Min	Typ.	Max	Unit
Operating power supply voltage	V <sub>BB</sub>	—	50	—	165	V
	V <sub>CC</sub>	—	9	12	16.5	
Current dissipation	I <sub>BB</sub>	V <sub>BB</sub> = 165 V, duty = 0%	—	—	1	mA
	I <sub>CC</sub>	V <sub>CC</sub> = 12 V, duty = 0%	—	—	10	
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> = V <sub>REG</sub>	—	—	100	μA
	I <sub>IL</sub>	V <sub>IN</sub> = 0 V	—	—	100	
Output saturation voltage	V <sub>satU</sub>	V <sub>CC</sub> = 12 V, I <sub>C</sub> = 0.5 A	—	2.0	3.0	V
	V <sub>satL</sub>	V <sub>CC</sub> = 12V, I <sub>C</sub> = 0.5 A	—	2.0	3.0	
FRD forward voltage	V <sub>FU</sub>	I <sub>F</sub> = 0.5 A, high side	—	1.4	2.1	V
	V <sub>FL</sub>	I <sub>F</sub> = 0.5 A, low side	—	1.2	1.8	
PWM ON-duty ratio	PWMMIN	—	0	—	—	%
	PWMMAX	—	—	—	100	
PWM ON-duty ratio, 0%	V <sub>Vs0%</sub>	PWM = 0%	1.7	2.1	2.5	V
PWM ON-duty ratio, 100%	V <sub>Vs100%</sub>	PWM = 100%	4.9	5.4	6.1	V
PWM ON-duty voltage range	V <sub>VsW</sub>	V <sub>Vs100%</sub> – V <sub>Vs0%</sub>	2.8	3.3	3.8	V
Output all-OFF voltage	V <sub>VsOFF</sub>	Output all-OFF	1.1	1.3	1.5	V
Regulator voltage	V <sub>REG</sub>	V <sub>CC</sub> = 12 V, I <sub>O</sub> = 30 mA	5	6	7	V
Speed control voltage range	V <sub>S</sub>	—	0	—	6.5	V
FG output saturation voltage	V <sub>FGsat</sub>	I <sub>FG</sub> = 20 mA	—	—	0.5	V
Current limiting voltage	V <sub>R</sub>	—	0.45	0.5	0.55	V
Overheat protection temperature	TSD	—	150	165	200	°C
Overheat protection hysteresis	ΔTSD	—	—	10	—	°C
Under voltage protection	V <sub>CCUVD</sub>	—	6.5	7.5	8.5	V
Under voltage protection recovery	V <sub>CCUVR</sub>	—	7.0	8.0	9.0	V
Output on delay time	t <sub>on</sub>	V <sub>BB</sub> = 141 V, I <sub>C</sub> = 0.5 A	—	2.5	3	μs
Output off delay time	t <sub>off</sub>	V <sub>BB</sub> = 141 V, I <sub>C</sub> = 0.5 A	—	1.5	3	μs
FRD reverse recovery time	t <sub>rr</sub>	V <sub>BB</sub> = 141 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	Other
C <sub>1</sub> , C <sub>2</sub> , C <sub>3</sub>	2.2 μF	Bootstrap capacitor	(Note1)
R <sub>1</sub>	0.62 Ω ± 1% (1 W)	Current detection	(Note2)
C <sub>4</sub>	1000 pF ± 5%	PWM frequency setup	(Note3)
R <sub>2</sub>	27 kΩ ± 5%	PWM frequency setup	(Note3)
C <sub>5</sub>	10 μF	Control power supply stability	(Note4)
C <sub>6</sub>	0.1 μF	V <sub>REG</sub> power supply stability	(Note4)
R <sub>3</sub>	5.1 kΩ	FG pin pull-up resistor	(Note5)

Note1: Although the required bootstrap capacitance value with the motor drive conditions, care must be taken to keep the capacitor voltage above 5 V at startup and during drive. The capacitor is biased by 6 V (typ.) and must be sufficiently derated for it.

Note2: The following formula shows the detection current:  $I_O = V_R \div R_{IS}$  ( $V_R = 0.5$  V typ.)  
Do not exceed a detection current of 900 mA when using the IC.

Note3: With the combination of C<sub>os</sub> and R<sub>REF</sub> 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.)

$$f_{PWM} = 0.65 \div (C_{os} \times R_{REF}) \text{ [Hz]}$$

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

Note4: 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.

Note5: 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<sub>CC</sub>, a protector circuit is triggered so that the current flows continuously. If not using the FG pin, connect to the GND.

Note6: If noise is detected on the Hall signal pin, add a CR filter.  
(recommended 0.1 μF capacitor and 1 kΩ resistor)

**Handling precautions**

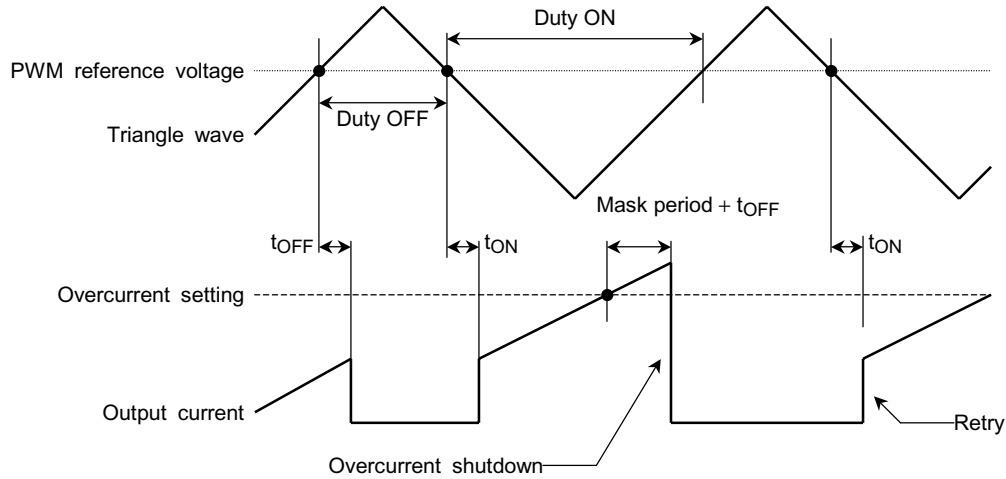
- (1) When switching the power supply to the circuit on/off, ensure that  $V_S < V_{VSOFF}$  (all IGBT outputs off). At that time, either the V<sub>CC</sub> or the V<sub>BB</sub> can be turned on/off first. Note that if the power supply is switched off as described above, the IC may be destroyed if the current regeneration route to the V<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 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<sub>OS</sub> and R<sub>REF</sub>, 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  $V_R = 0.5\text{ V}$  (typ.), the high-side IGBT output, which is on, temporarily shuts down after a mask period (approx.  $1\ \mu\text{s}$ ), preventing any additional current from flowing to the IC. The next PWM ON signal releases the shutdown state.



(2) Undervoltage

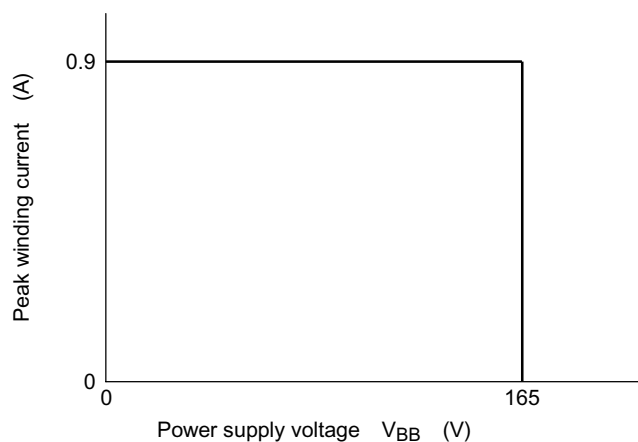
When the  $V_{CC}$  power supply falls to the IC internal setting ( $V_{CCUVD} = 7.5\text{ V}$  typ.), all IGBT outputs shut down regardless of the input. This protection function has hysteresis. When the  $V_{CCUVR}$  ( $= 8.0\text{ V}$  typ.) reaches  $0.5\text{ V}$  higher than the shutdown voltage,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

(3) Overheating

When the the temperature of this chip rises due to external causes or internal heat generation and the internal setting TSD reaches  $165^\circ\text{C}$ , all IGBT outputs shut down regardless of the input. This protection function has hysteresis ( $\Delta TSD = 10^\circ\text{C}$  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.

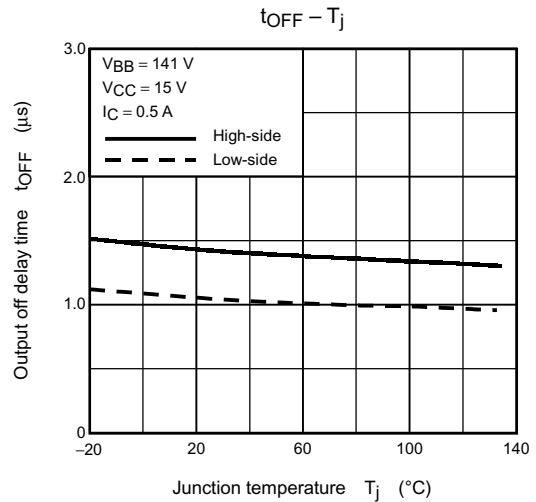
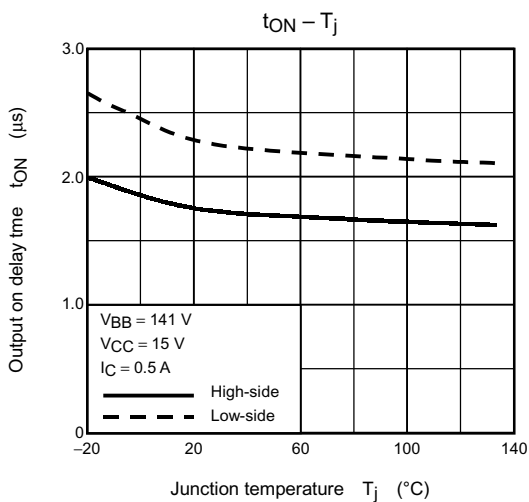
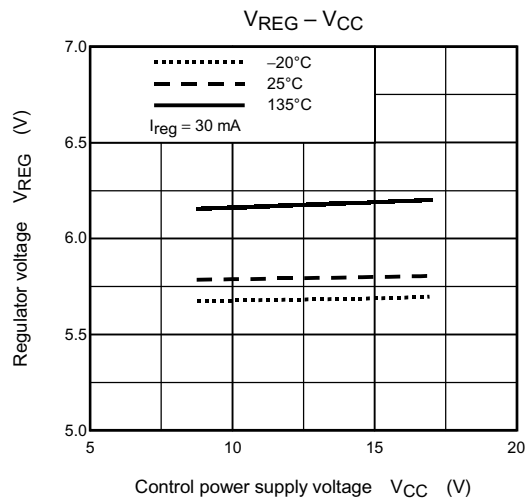
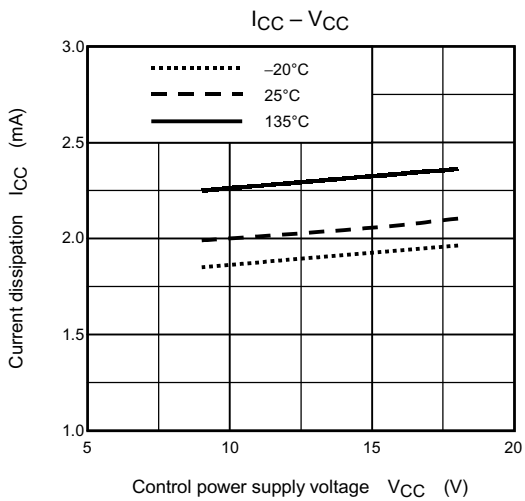
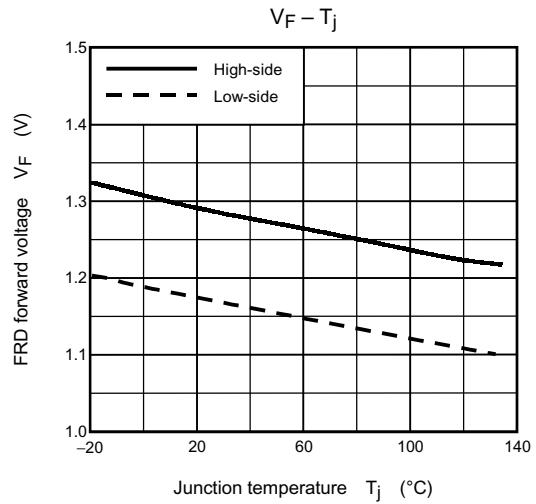
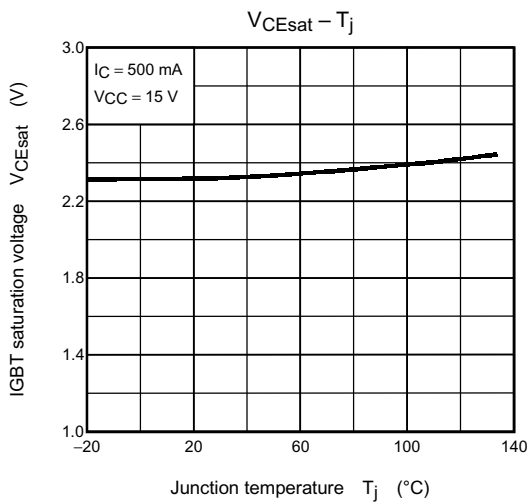
Because the chip contains just one temperature detection location, when the chip heats up due to the IGBT, for example, the differences in distance from the detection location in the IGBT (the source of the heat) cause differences in the time taken for shutdown to occur.

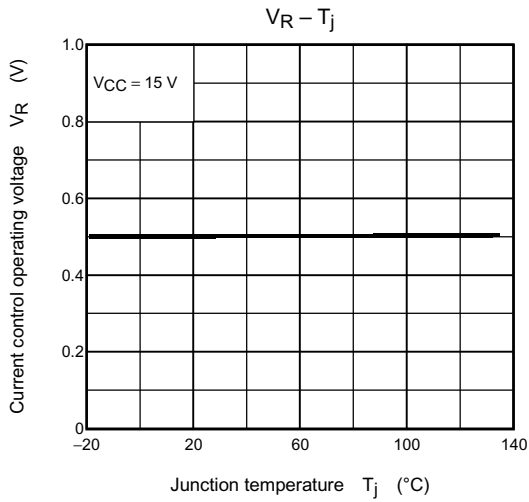
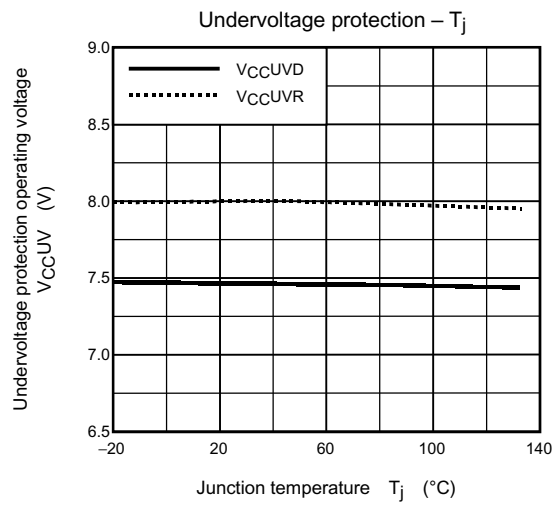
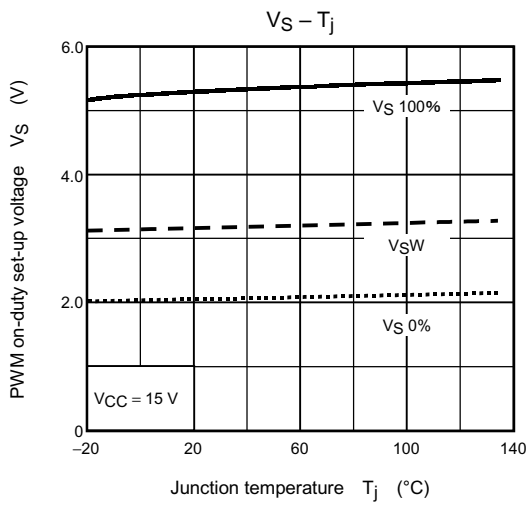
**Safe Operating Area**



\*: The above safe operating area is  $T_c = 95^\circ\text{C}$ . If the temperature exceeds this, the safe operation area reduces.

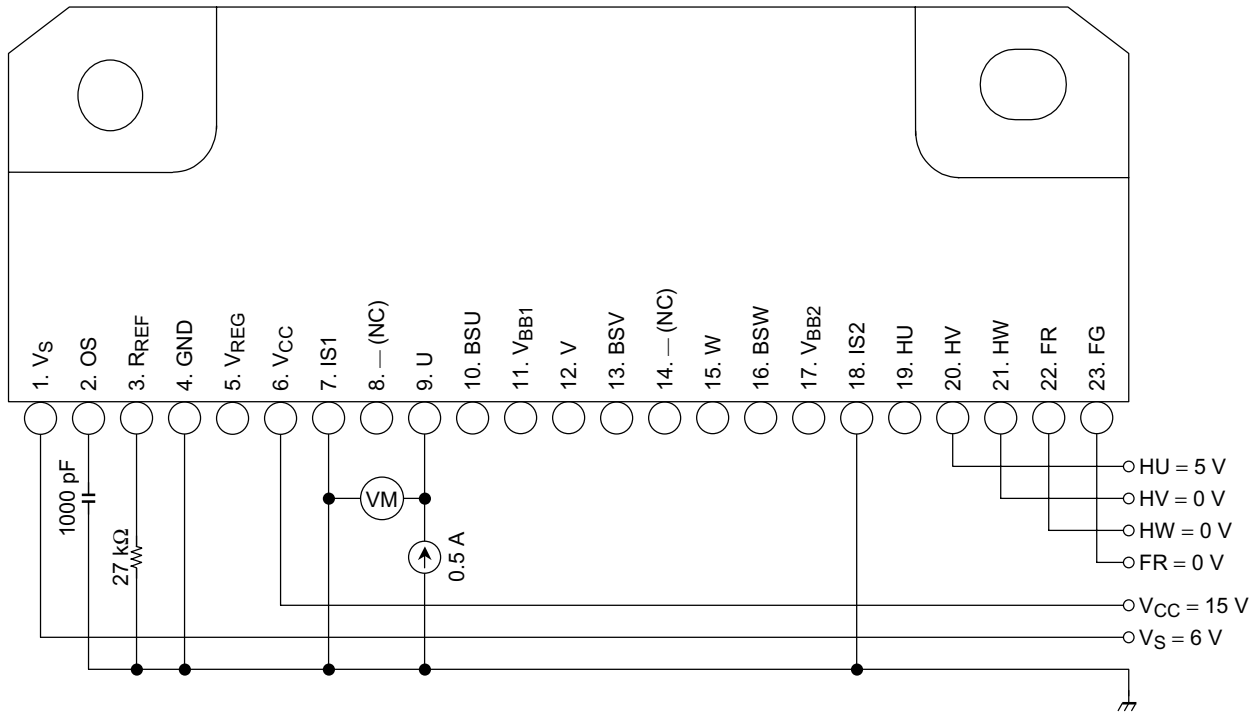
\*: The above safe operating area includes the overcurrent protection operation area. If the overcurrent protection operation continues, depending on the heat discharge conditions, an overheating protection operation may result.



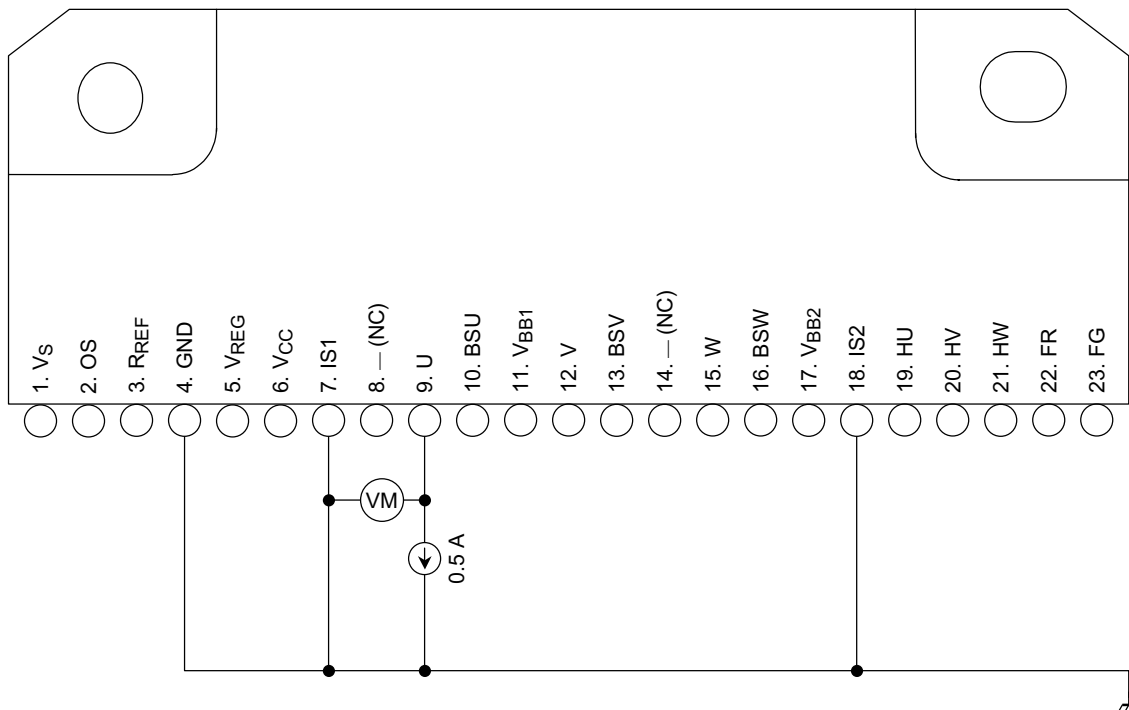


## Test Circuits

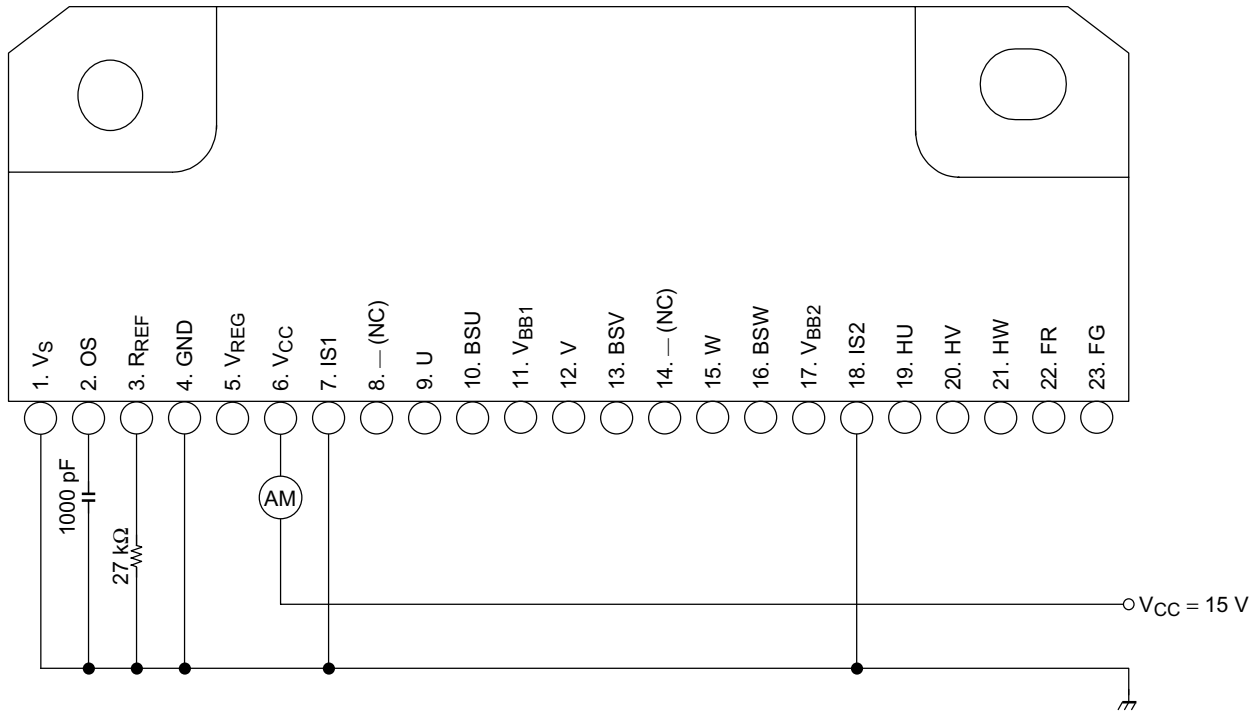
### IGBT Saturation Voltage (U-phase low side)



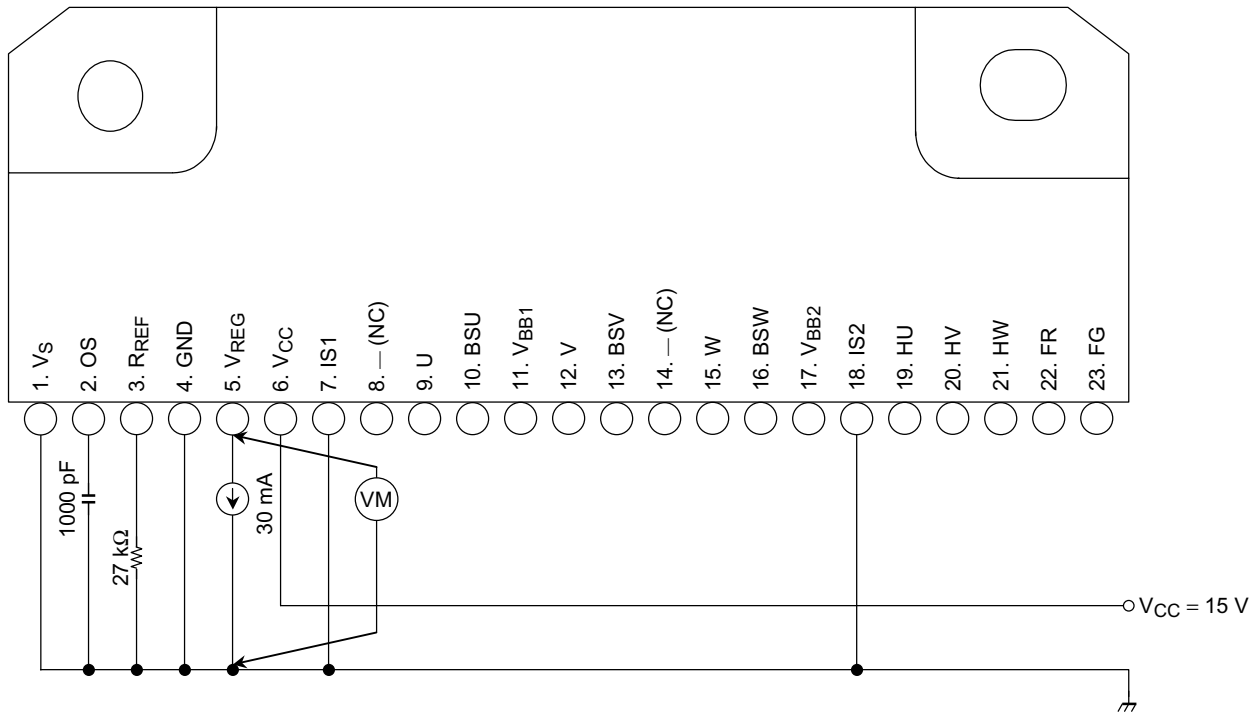
### FRD Forward Voltage (U-phase low side)



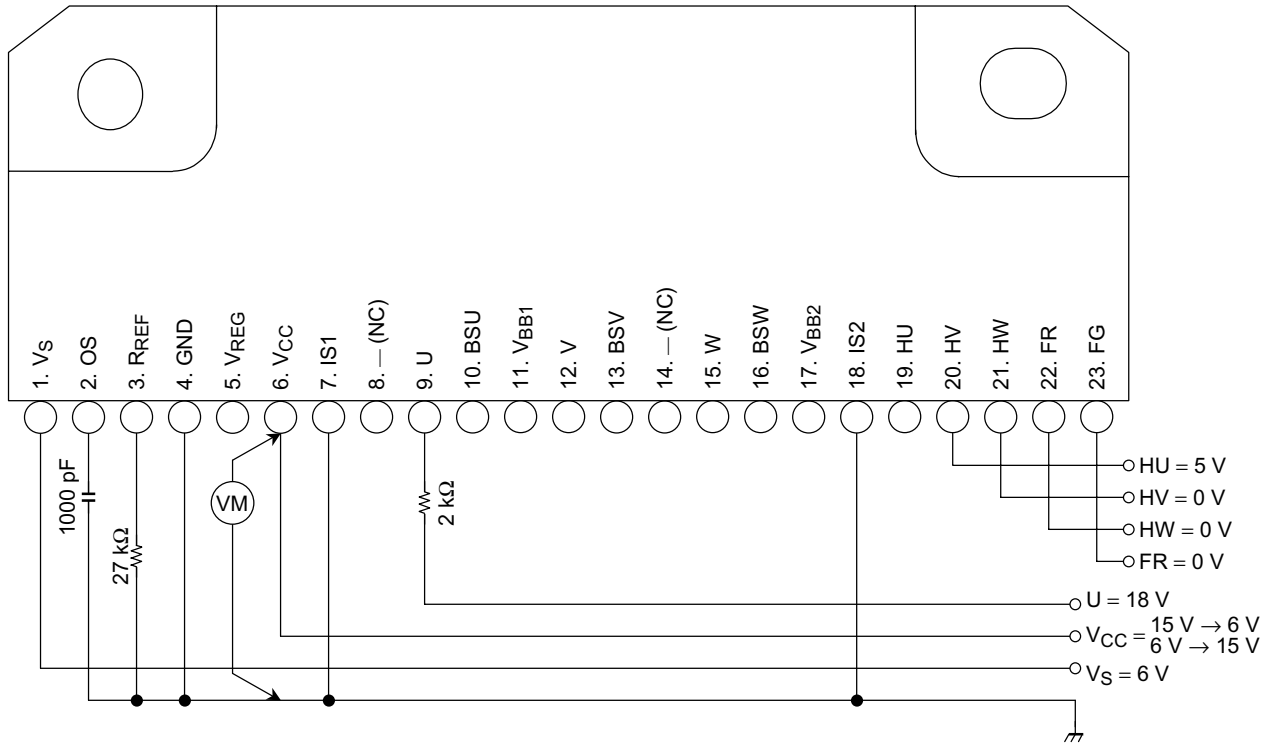
## Current Dissipation (I<sub>CC</sub>)



## Regulator Voltage

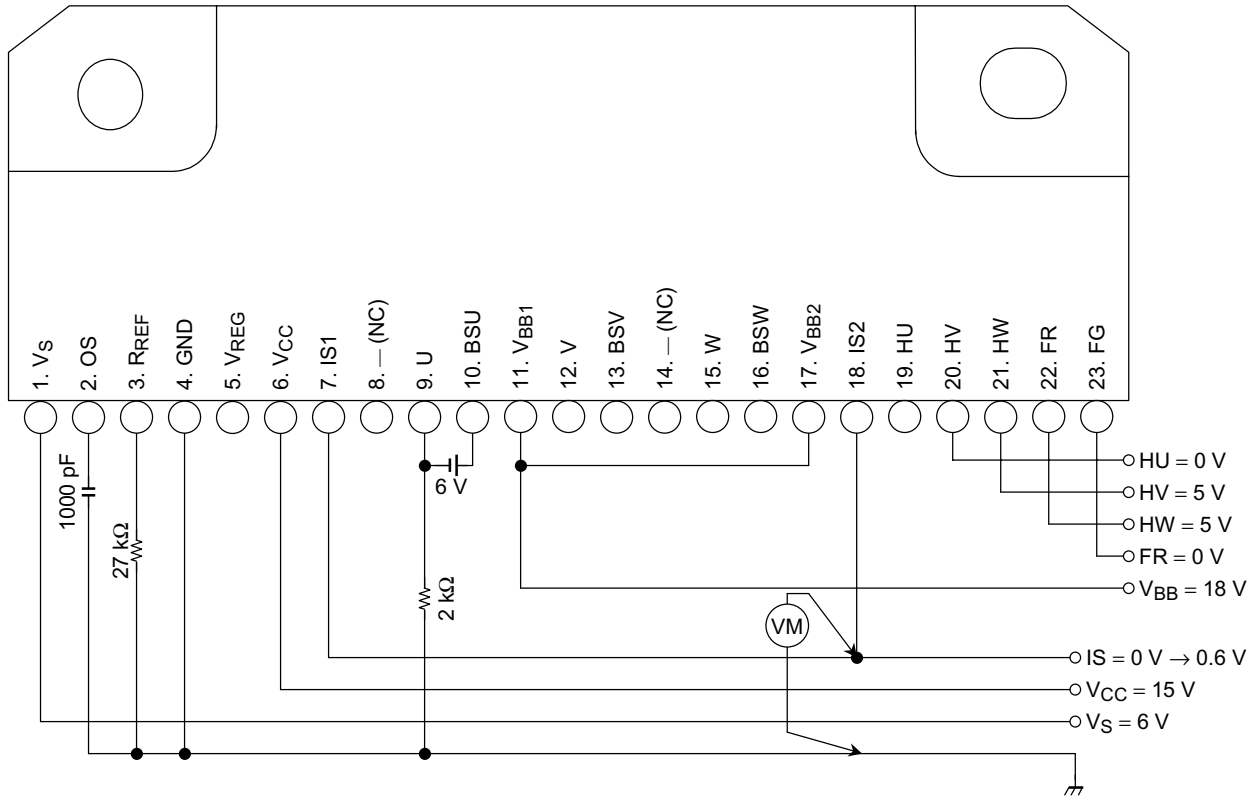


**Undervoltage Protection Operation/Recovery Voltage (U-phase low side)**



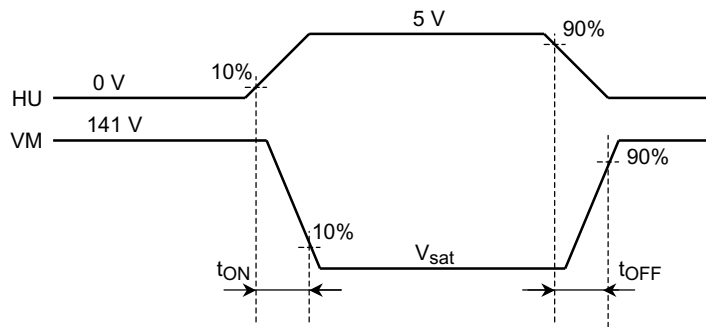
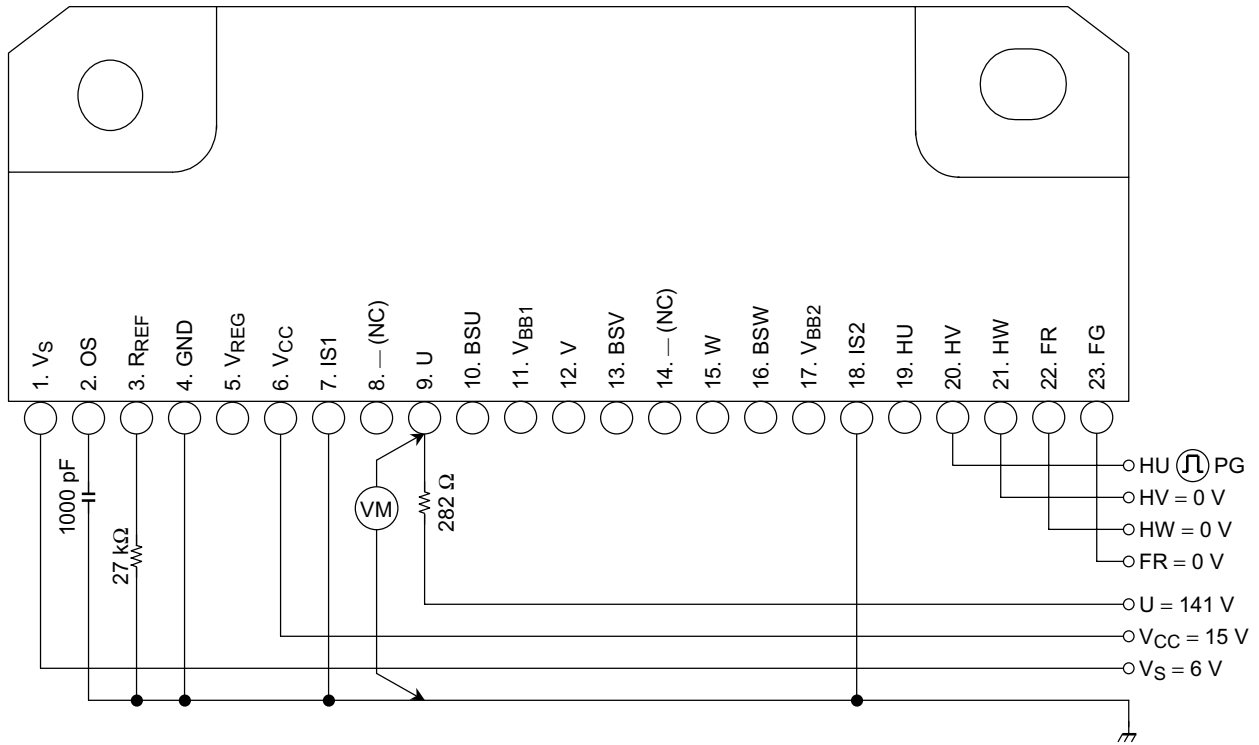
\*: Sweeps the V<sub>CC</sub> pin voltage from 15 V to decrease and monitors the U pin voltage. The V<sub>CC</sub> pin voltage when output is off defines the undervoltage protection operating voltage. Also sweeps from 6 V to increase. The V<sub>CC</sub> pin voltage when output is on defines the undervoltage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

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

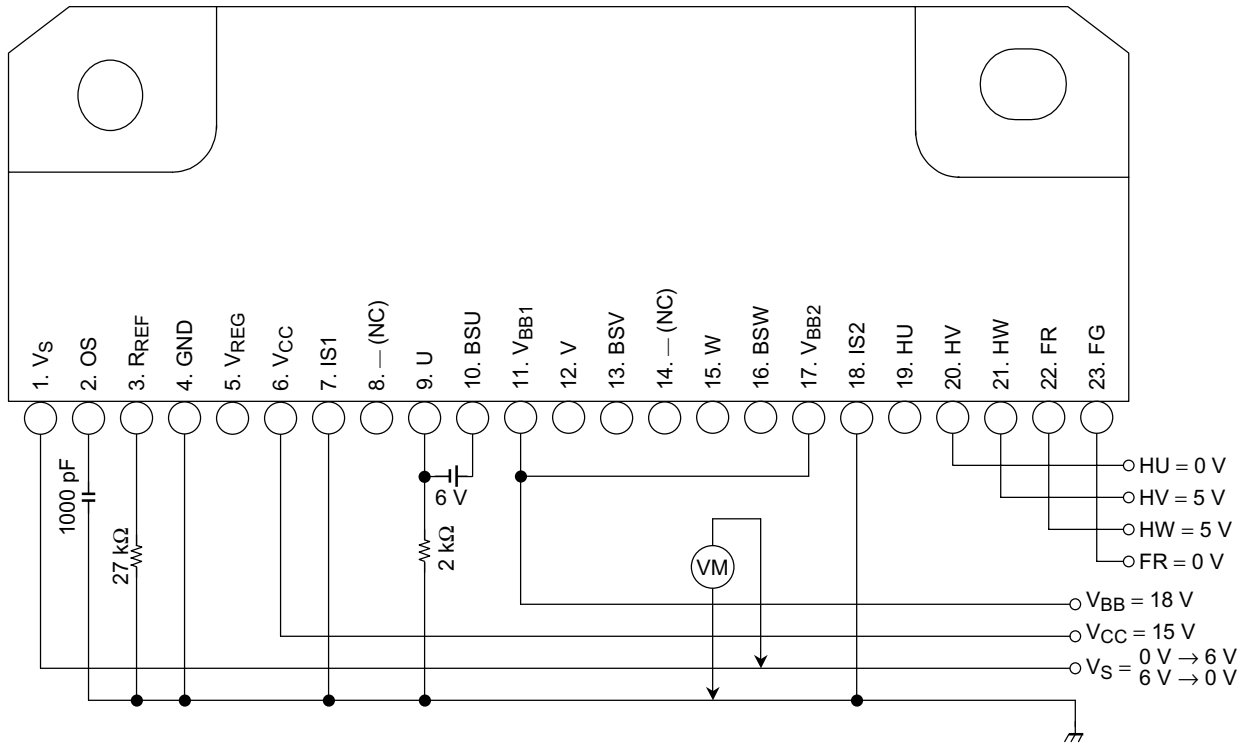


\*: Sweeps the IS pin voltage to increase and monitors the U pin voltage. The IS pin voltage when output is off defines the current-limit operating voltage.

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



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



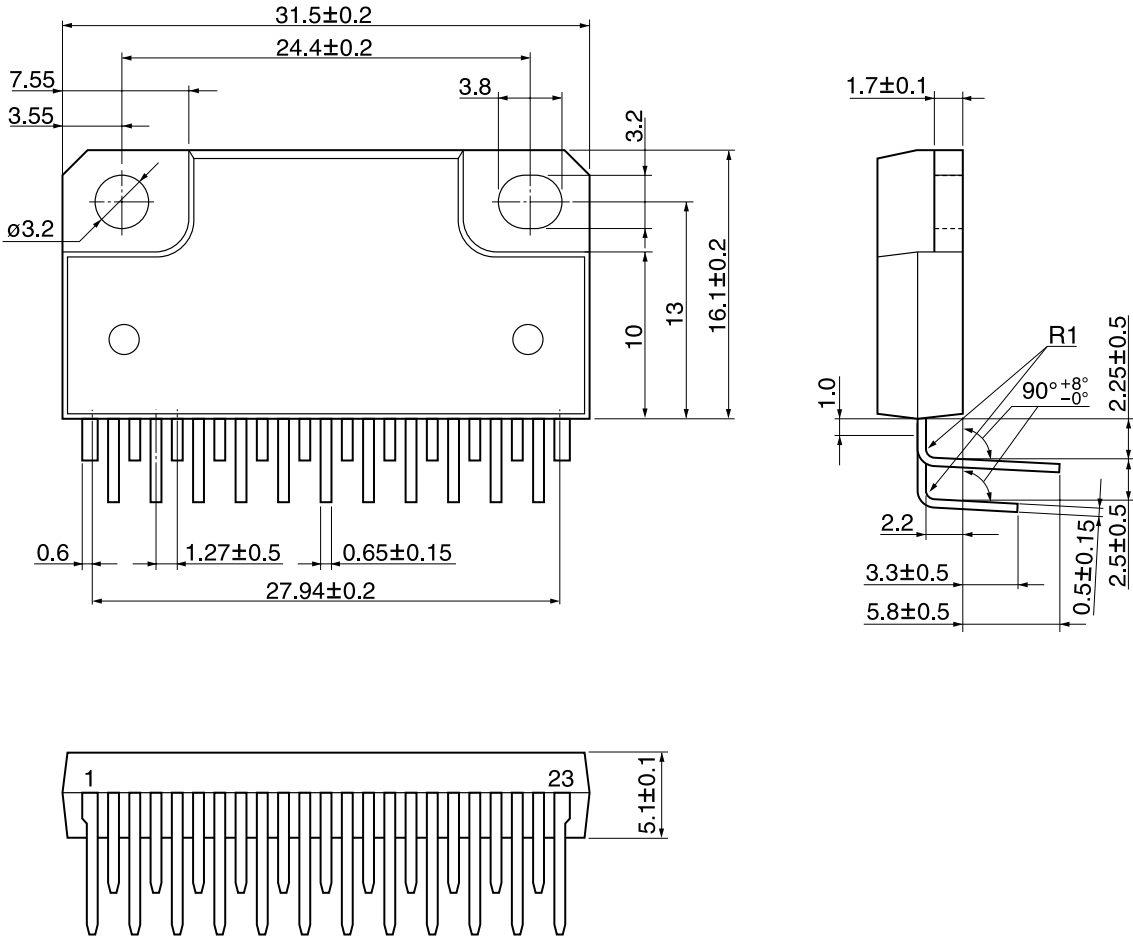
\*: Sweeps the VS pin voltage to increase and monitors the U pin.  
 When output is turned off from on, the PWM = 0%. When output is full on, the PWM = 100%.



Package Dimensions

HZIP23-P-1.27F

Unit: mm

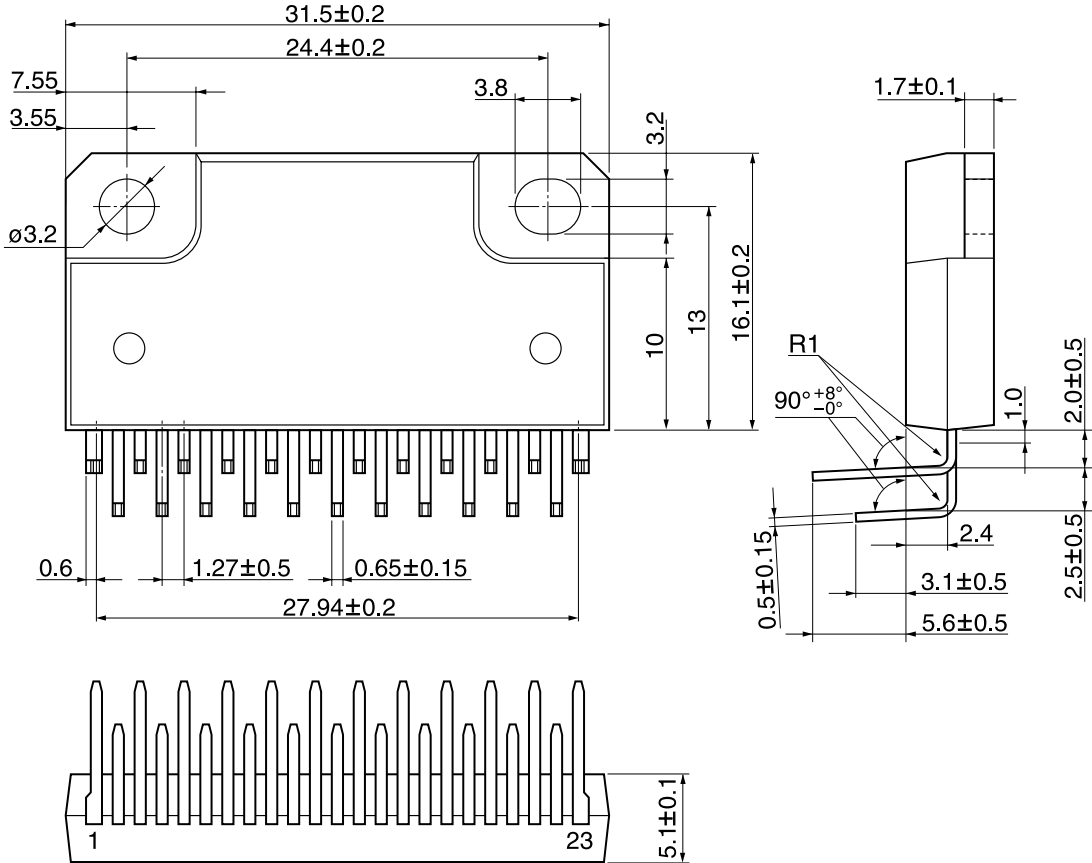


Weight: 6.1 g (typ.)

Package Dimensions

HZIP23-P-1.27G

Unit: mm



Weight: 6.1 g (typ.)