

# CIPOS™ Mini IM535

## IM535-U6D/IM535-U6DS

### Description

The CIPOS™ IM535 product family offers the chance for integrating various power and control components to increase reliability and optimize PCB size and system cost. It is designed to control three-phase motors in variable speed drives. The package concept is specially adapted to power applications, which need good thermal conduction and electrical isolation, but also less EMI and overload protection. To deliver excellent electrical performance, Infineon's leading-edge TRENCHSTOP™ IGBTs and anti-parallel diodes are combined with an optimized SOI gate driver.

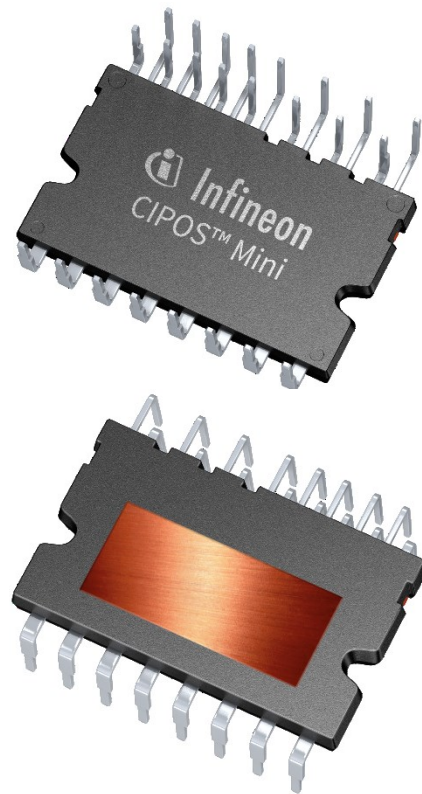
### Features

#### Package

- Fully isolated dual in-line molded module
- Very low thermal resistance due to DCB substrate
- Lead-free terminal plating; RoHS compliant

#### Inverter

- TRENCHSTOP™ IGBTs for inverter
- Rugged SOI gate driver technology with stability against transient and negative voltage
- Allowable negative  $V_S$  potential up to -11 V for signal transmission at  $V_{BS} = 15$  V
- Integrated bootstrap functionality
- Over-current shutdown
- Built-in NTC thermistor for temperature monitor
- Under-voltage lockout at all channels
- Low-side emitter pins accessible for phase current monitoring (open emitter)
- Sleep function
- Cross-conduction prevention
- All of 6 switches turn off during protection



### Potential applications

- Home appliances, low power motor drives

**Product validation**

**Product validation**

Qualified for industrial applications according to the relevant tests of JEDEC47/20/22.

**Table 1 Product Information**

Base Part Number	Package Type	Standard Pack		Remarks
		Form	MOQ	
IM535-U6D	DIP 36x21D	14 pcs / Tube	280 pcs	
IM535-U6DS	DIP 36x21D	14 pcs / Tube	280 pcs	Extended stand-off

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# 1 Internal Electrical Schematic

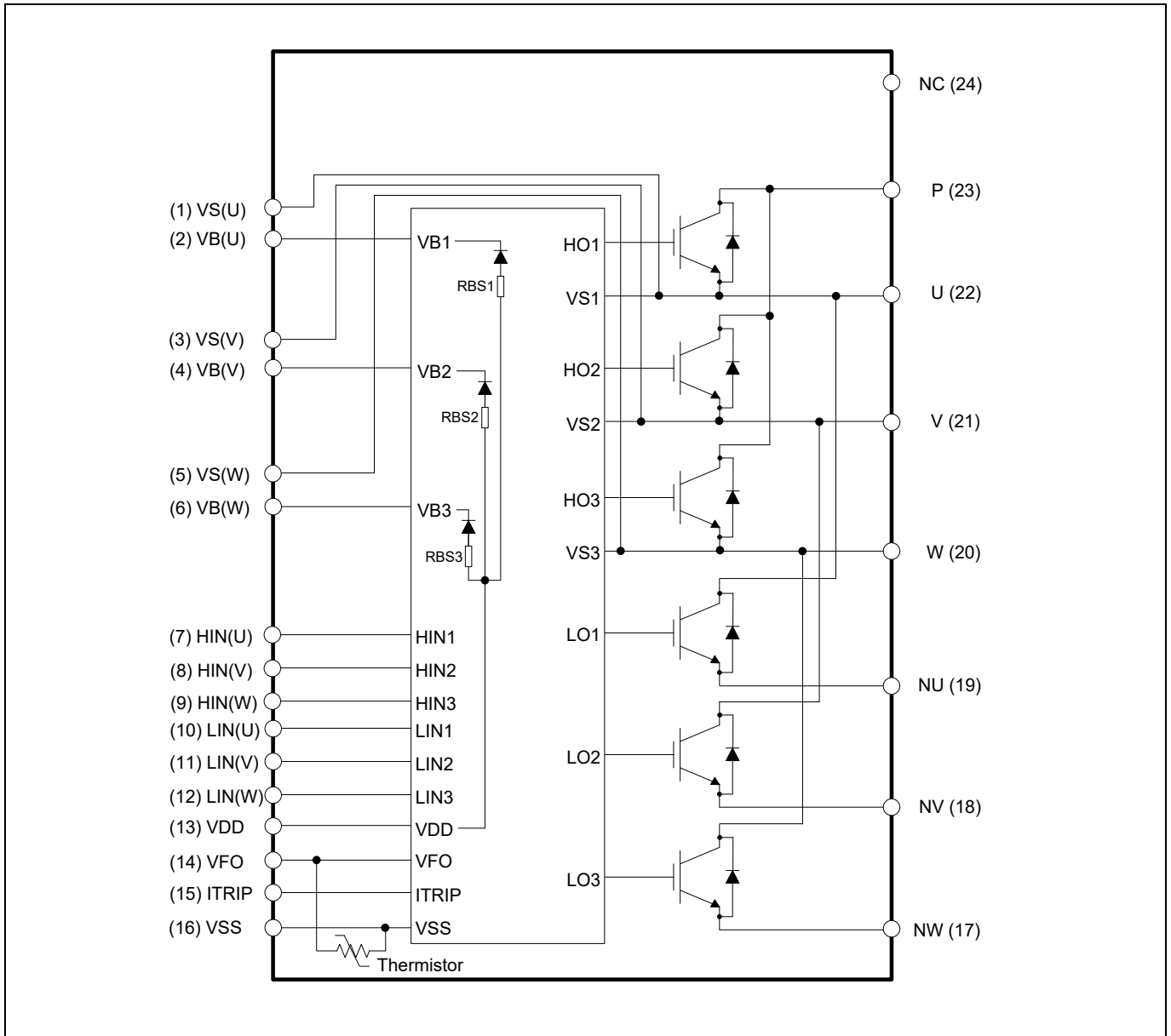


Figure 1 Internal electrical schematic

Pin Description

## 2 Pin Description

### 2.1 Pin Assignment

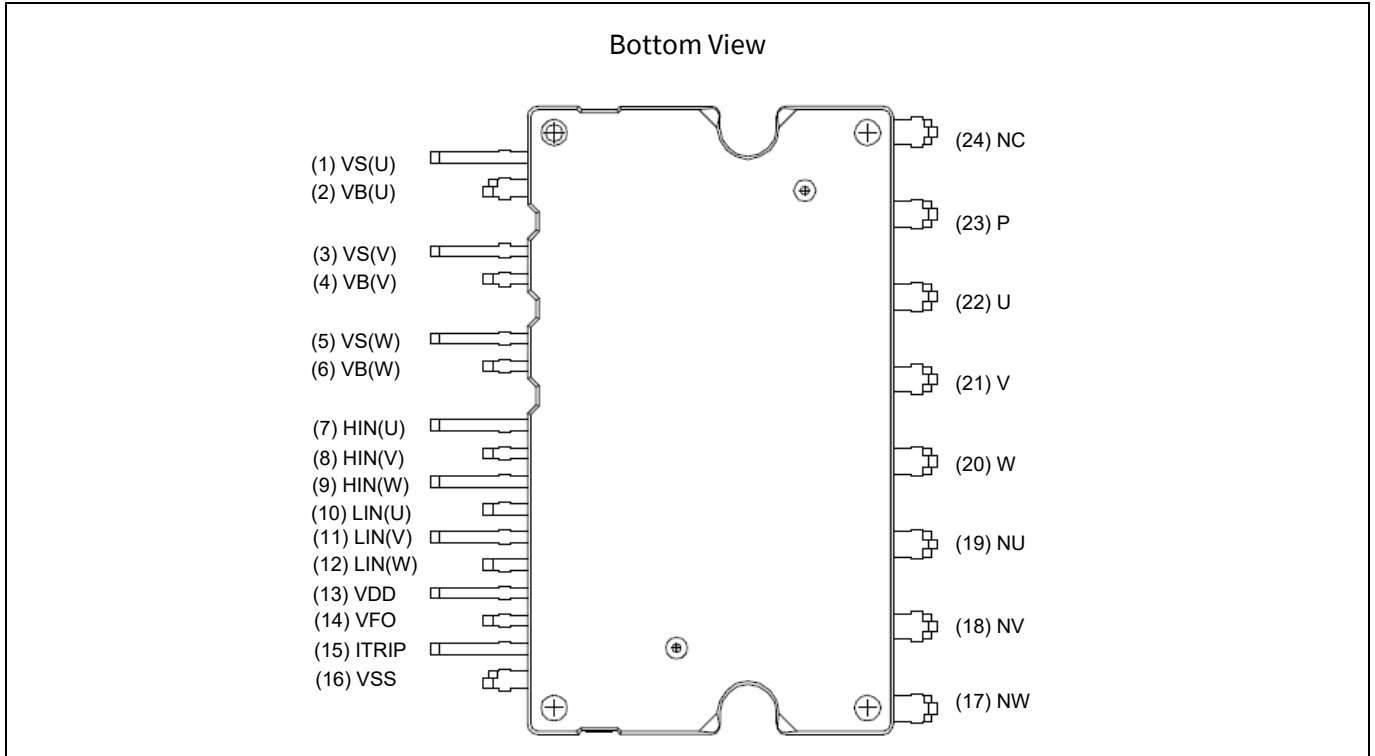


Figure 2 Pin configuration

Table 2 Pin assignment

Pin Number	Pin name	Pin Description
1	V <sub>S(U)</sub>	U-phase high-side floating IC supply offset voltage
2	V <sub>B(U)</sub>	U-phase high-side floating IC supply voltage
3	V <sub>S(V)</sub>	V-phase high-side floating IC supply offset voltage
4	V <sub>B(V)</sub>	V-phase high-side floating IC supply voltage
5	V <sub>S(W)</sub>	W-phase high-side floating IC supply offset voltage
6	V <sub>B(W)</sub>	W-phase high-side floating IC supply voltage
7	HIN(U)	U-phase high-side gate driver input
8	HIN(V)	V-phase high-side gate driver input
9	HIN(W)	W-phase high-side gate driver input
10	LIN(U)	U-phase low-side gate driver input
11	LIN(V)	V-phase low-side gate driver input
12	LIN(W)	W-phase low-side gate driver input
13	V <sub>DD</sub>	Low-side control supply
14	V <sub>FO</sub>	Fault output / temperature monitor
15	ITRIP	Over-current shutdown input
16	V <sub>SS</sub>	Low-side control negative supply
17	NW	W-phase low-side emitter

**Pin Description**

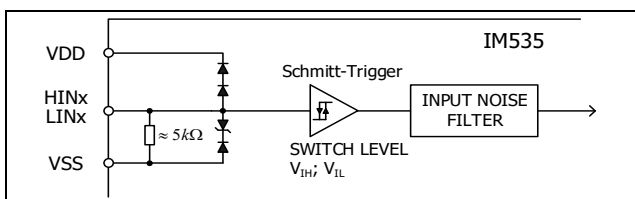
Pin Number	Pin name	Pin Description
18	NV	V-phase low-side emitter
19	NU	U-phase low-side emitter
20	W	Motor W-phase output
21	V	Motor V-phase output
22	U	Motor U-phase output
23	P	Positive bus input voltage
24	NC	No connection

**2.2 Pin Description**

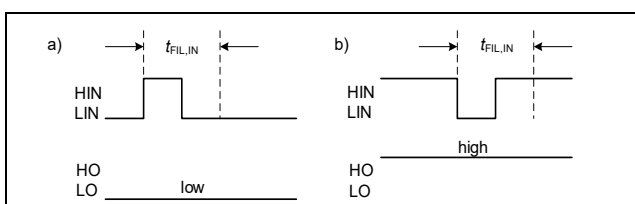
**HIN(U, V, W) and LIN(U, V, W) (Low-side and high-side control pins, Pin 7 - 12)**

These pins are positive logic and they are responsible for the control of the integrated IGBTs. The Schmitt-trigger input thresholds of them are such to guarantee LSTTL and CMOS compatibility down to 3.3 V controller outputs. A pull-down resistor of about 5 kΩ is internally provided to pre-bias input during supply start-up, and a zener clamp is provided to protect the pin. Negative pulses down to an absolute minimum of -5.5 V are allowed that offers an outstanding robustness. Input Schmitt-trigger and noise filter provide noise rejection to short input pulses.

The noise filter suppresses control pulses shorter than the filter time  $t_{FIL,IN}$ . The Figure 4 describes how the filter works. An input pulse-width shorter than 1 μs is not recommended.



**Figure 3 Input pin structure**



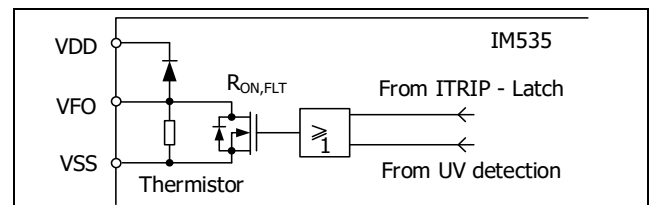
**Figure 4 Input filter timing diagram**

The integrated gate driver additionally provides a shoot-through prevention capability that avoids the simultaneous on-states of the same leg (i.e.

HO1 and LO1, HO2 and LO2, HO3 and LO3). When both inputs of the same leg are activated, only formerly activated one is remained activated so that the leg is kept steadily in a safe state. A minimum deadtime insertion of typically 360 ns is also provided by driver, in order to reduce cross-conduction of the IGBTs.

**V<sub>F0</sub> (Fault-output and NTC, Pin 14)**

The V<sub>F0</sub> pin indicates a module failure in case of under voltage at pin V<sub>DD</sub> or in case of triggered over-current detection at ITRIP. An external pull-up resistor is required.



**Figure 5 Internal circuit at pin V<sub>F0</sub>**

The sleep function is activated after each trigger of ITRIP or under-voltage lockout. A new edge input signal is mandatory to activate gate drives after fault-clear time as shown in Figure 10.

**ITRIP (Over-current detection function, Pin 15)**

The IM535 product family provides an over-current detection function by connecting the ITRIP input with the IGBT current feedback. The ITRIP comparator threshold (typ. 0.525 V) is referenced to V<sub>SS</sub>. An input noise filter ( $t_{ITRIP,MIN} = \text{typ. } 300 \text{ ns}$ ) prevents the driver to detect false over-current events.

Over-current detection generates a shutdown of outputs of the gate driver. Fast track shutdown

### Pin Description

function allows low-side outputs to be turned off faster than high side outputs about 200 ns. The fault-clear time is set to minimum 100  $\mu$ s.

#### **$V_{DD}$ , $V_{SS}$ (Low-side control supply and reference, Pin 13, 16)**

$V_{DD}$  is the control supply and it provides power both to input logic and to output stage. Input logic is referenced to  $V_{SS}$  ground.

The under-voltage circuit enables the device to operate at power on when a supply voltage of at least a typical voltage of  $V_{DDUV+} = 12.4$  V is present.

The gate driver shuts down all the outputs, when the  $V_{DD}$  supply voltage is below  $V_{DDUV-} = 11.5$  V. This prevents the IGBTs from critically low gate voltage levels during on-state and therefore from excessive power dissipation.

#### **$V_B$ (U, V, W) and $V_S$ (U, V, W) (High-side supplies, Pin 1 - 6)**

$V_B$  to  $V_S$  is the high-side supply voltage. The high-side circuit can float with respect to  $V_{SS}$  following the high-side IGBT emitter voltage.

Due to the low power consumption, the floating driver stage is supplied by integrated bootstrap circuit.

The under-voltage detection operates with a rising supply threshold of typical  $V_{BSUV+} = 11.5$  V and a falling threshold of  $V_{BSUV-} = 10.7$  V.

$V_S$ (U, V, W) provide a high robustness against negative voltage in respect of  $V_{SS}$  of -50 V transiently. This ensures very stable designs even under harsh conditions.

#### **NW, NV, NU (Low-side emitter, Pin 17 - 19)**

The low-side emitters are available for current measurement of each phase leg. It is recommended to keep the connection to pin  $V_{SS}$  as short as possible to avoid unnecessary inductive voltage drops.

#### **W, V, U (High-side emitter and low-side collector, Pin 20 - 22)**

These pins are connected to motor U, V, W input pins

#### **P (Positive bus input voltage, Pin 23)**

The high-side IGBTs are connected to the bus voltage. It is noted that the bus voltage does not exceed 450 V.

**Absolute Maximum Ratings**

### 3 Absolute Maximum Ratings

( $V_{DD} = 15\text{ V}$  and  $T_J = 25^\circ\text{C}$ , if not stated otherwise)

#### 3.1 Module Section

Description	Symbol	Condition	Value	Unit
Storage temperature range	$T_{STG}$		-40 ~ 125	$^\circ\text{C}$
Operating case temperature	$T_C$	Refer to Figure 7	-40 ~ 125	$^\circ\text{C}$
Operating junction temperature	$T_J$		-40 ~ 150	$^\circ\text{C}$
Isolation test voltage	$V_{ISO}$	1 min, RMS, $f = 60\text{ Hz}$	2000	V

#### 3.2 Inverter Section

Description	Symbol	Condition	Value	Unit
Max. blocking voltage	$V_{CES}$	$I_C = 250\ \mu\text{A}$	600	V
DC link supply voltage of P-N	$V_{PN}$	Applied between P-N	450	V
DC link supply voltage (surge) of P-N	$V_{PN(surge)}$	Applied between P-N	500	V
Continuous collector current	$I_C$	$T_C = 25^\circ\text{C}, T_J < 150^\circ\text{C}$	$\pm 30$	A
		$T_C = 80^\circ\text{C}, T_J < 150^\circ\text{C}$	$\pm 22$	
Maximum peak collector current	$I_{C(peak)}$	$T_C = 25^\circ\text{C}, T_J < 150^\circ\text{C}$ less than 1 ms	$\pm 60$	A
Power dissipation per IGBT	$P_{tot}$		83.3	W
Short circuit withstand time <sup>1</sup>	$t_{SC}$	$V_{DC} \leq 400\text{V}, T_J = 150^\circ\text{C}$	5	$\mu\text{s}$

#### 3.3 Control Section

Description	Symbol	Condition	Value	Unit
High-side offset voltage	$V_S$		600	V
Repetitive peak reverse voltage of bootstrap diode	$V_{RRM}$		600	V
Module supply voltage	$V_{DD}$		-1 ~ 20	V
High-side floating supply voltage ( $V_B$ reference to $V_S$ )	$V_{BS}$		-1 ~ 20	V
Input voltage(LIN, HIN, ITRIP)	$V_{IN}$		-1 ~ $V_{DD} + 0.3$	V

<sup>1</sup> Allowed number of short circuits: < 1000; time between short circuits: > 1 s.



## 4 Thermal Characteristics

Description	Symbol	Condition	Value			Unit
			Min.	Typ.	Max.	
Single IGBT thermal resistance, junction to case	$R_{thJC}$	Low-side U-phase (See Figure 7 for $T_c$ measurement point)			1.49	K/W
Single diode thermal resistance, junction to case	$R_{thJC,D}$	Low-side U-phase			2.18	K/W

Recommended Operation Conditions

## 5 Recommended Operation Conditions

All voltages are absolute voltages referenced to  $V_{SS}$  -potential unless otherwise specified.

Description	Symbol	Value			Unit
		Min.	Typ.	Max.	
DC link supply voltage of P-N	$V_{PN}$	0	300	450	V
Low-side supply voltage	$V_{DD}$	13	15	17.5	V
High-side floating supply voltage ( $V_B$ vs. $V_S$ )	$V_{BS}$	13	-	17.5	V
Logic input voltages LIN, HIN, ITRIP	$V_{IN}$ $V_{ITRIP}$	0	-	5	V
Inverter PWM carrier frequency	$f_{PWM}$	-	-	20	kHz
External deadtime between HIN and LIN	DT	2	-	-	$\mu s$
Voltage between $V_{SS}$ – N (including surge)	$V_{COMP}$	-5	-	5	V
Minimum input pulse width	$PW_{IN(ON)}$ $PW_{IN(OFF)}$	1	-	-	$\mu s$
Control supply variation	$\Delta V_{BS}$ , $\Delta V_{DD}$	-1 -1	- -	1 1	V/ $\mu s$

Static Parameters

## 6 Static Parameters

( $V_{DD} = 15\text{ V}$  and  $T_J = 25^\circ\text{C}$ , if not stated otherwise)

### 6.1 Inverter Section

Description	Symbol	Condition	Value			Unit
			Min.	Typ.	Max.	
Collector-emitter voltage	$V_{CE(Sat)}$	$I_C = 30\text{ A}, T_J = 25^\circ\text{C}$ $I_C = 30\text{ A}, T_J = 150^\circ\text{C}$	-	1.8 2.05	2.1 -	V
Collector-emitter leakage current	$I_{CES}$	$V_{CE} = 600\text{ V}$	-	-	1	mA
Diode forward voltage	$V_F$	$I_F = 30\text{ A}, T_J = 25^\circ\text{C}$ $I_F = 30\text{ A}, T_J = 150^\circ\text{C}$	-	1.95 1.9	2.35 -	V

### 6.2 Control Section

Description	Symbol	Condition	Value			Unit
			Min.	Typ.	Max.	
Logic "1" input voltage (LIN, HIN)	$V_{IH}$		1.7	2.0	2.3	V
Logic "0" input voltage (LIN, HIN)	$V_{IL}$		0.7	0.9	1.1	V
ITRIP positive going threshold	$V_{IT,TH+}$		475	525	570	mV
ITRIP input hysteresis	$V_{IT,HYS}$		45	70	-	mV
$V_{DD}$ and $V_{BS}$ supply under-voltage positive going threshold	$V_{DDUV+}$		11.5	12.4	13.1	V
	$V_{BSUV+}$		10.6	11.5	12.2	
$V_{DD}$ and $V_{BS}$ supply under-voltage negative going threshold	$V_{DDUV-}$		10.6	11.5	12.3	V
	$V_{BSUV-}$		9.7	10.7	11.7	
$V_{DD}$ and $V_{BS}$ supply under-voltage lockout hysteresis	$V_{DDUVH}$ $V_{BSUVH}$		0.5	0.9	-	V
Quiescent $V_{Bx}$ supply current ( $V_{Bx}$ only)	$I_{QBS}$	$H_{IN} = 0\text{ V}$	-	-	300	$\mu\text{A}$
Quiescent $V_{DD}$ supply current ( $V_{DD}$ only)	$I_{QDD}$	$L_{IN} = 0\text{ V}, H_{INX} = 5\text{ V}$	-	-	1.1	mA
Input bias current for LIN, HIN	$I_{IN+}$	$V_{IN} = 5\text{ V}$	-	1.1	1.7	mA
Input bias current for ITRIP	$I_{ITRIP+}$	$V_{ITRIP} = 5\text{ V}$	-	68	185	$\mu\text{A}$
Input bias current for $V_{FO}$	$I_{FO}$	$V_{FO} = 5\text{ V}, V_{ITRIP} = 0\text{ V}$	-	60	-	$\mu\text{A}$
$V_{FO}$ output voltage	$V_{FO}$	$I_{FO} = 10\text{ mA}, V_{ITRIP} = 1\text{ V}$	-	0.35	-	V
Bootstrap diode forward voltage	$V_{F\_BSD}$	$I_F = 0.3\text{ mA}$	-	1.0	-	V
Bootstrap diode resistance	$R_{BSD}$	Between $V_{F1} = 4\text{ V}$ and $V_{F2} = 5\text{ V}$	-	37	-	$\Omega$

Dynamic Parameters

## 7 Dynamic Parameters

( $V_{DD} = 15\text{ V}$  and  $T_J = 25^\circ\text{C}$ , if not stated otherwise)

### 7.1 Inverter Section

Description	Symbol	Condition	Value			Unit
			Min.	Typ.	Max.	
Turn-on propagation delay time	$t_{on}$	$V_{LIN, HIN} = 5\text{ V}$ , $I_C = 30\text{ A}$ , $V_{DC} = 300\text{ V}$	-	725	-	ns
Turn-on rise time	$t_r$		-	85	-	ns
Turn-on switching time	$t_{c(on)}$		-	295	-	ns
Reverse recovery time	$t_{rr}$		-	320	-	ns
Turn-off propagation delay time	$t_{off}$	$V_{LIN, HIN} = 0\text{ V}$ , $I_C = 30\text{ A}$ , $V_{DC} = 300\text{ V}$	-	900	-	ns
Turn-off fall time	$t_f$		-	25	-	ns
Turn-off switching time	$t_{c(off)}$		-	90	-	ns
Short circuit propagation delay time	$t_{SCP}$	From $V_{IT, TH+}$ to 10% $I_{SC}$	-	1550	-	ns
IGBT turn-on energy (includes reverse recovery of diode)	$E_{on}$	$V_{DC} = 300\text{ V}$ , $I_C = 30\text{ A}$ $T_J = 25^\circ\text{C}$ $T_J = 150^\circ\text{C}$	-	1430	-	$\mu\text{J}$
			-	1820	-	
IGBT turn-off energy	$E_{off}$	$V_{DC} = 300\text{ V}$ , $I_C = 30\text{ A}$ $T_J = 25^\circ\text{C}$ $T_J = 150^\circ\text{C}$	-	495	-	$\mu\text{J}$
			-	730	-	
Diode recovery energy	$E_{rec}$	$V_{DC} = 300\text{ V}$ , $I_C = 30\text{ A}$ $T_J = 25^\circ\text{C}$ $T_J = 150^\circ\text{C}$	-	105	-	$\mu\text{J}$
			-	245	-	

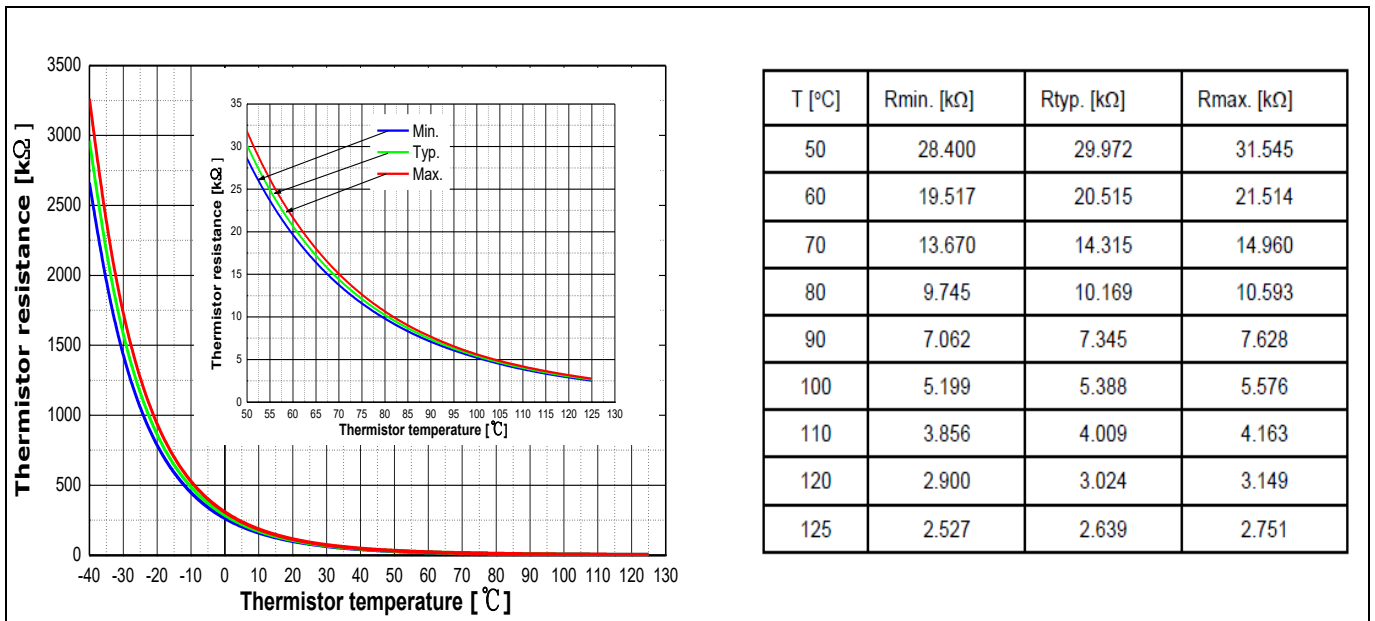
### 7.2 Control Section

Description	Symbol	Condition	Value			Unit
			Min.	Typ.	Max.	
Input filter time ITRIP	$t_{ITRIP}$	$V_{ITRIP} = 1\text{ V}$	-	530	-	ns
Input filter time at LIN, HIN for turn on and off	$t_{FIL, IN}$	$V_{LIN, HIN} = 0\text{ V}$ or $5\text{ V}$	-	290	-	ns
Fault clear time after ITRIP-fault	$t_{FLTCLR}$		100	280	-	$\mu\text{s}$
ITRIP to fault propagation delay	$t_{FLT}$	$V_{LIN, HIN} = 0$ or $V_{LIN, HIN} = 5\text{ V}$ , $V_{ITRIP} = 1\text{ V}$	-	680	1000	ns
Internal deadtime	$DT_{IC}$		-	360	-	ns
Matching propagation delay time (on and off) all channels	$M_T$	External dead time > 500 ns	-	20	-	ns

Thermistor

## 8 Thermistor

Description	Condition	Symbol	Value			Unit
			Min.	Typ.	Max.	
Resistance	$T_{NTC} = 25^{\circ}\text{C}$	$R_{NTC}$	-	85	-	$\text{k}\Omega$
B-constant of NTC (negative temperature coefficient) thermistor		B(25/100)	-	4092	-	K



**Figure 6 Thermistor resistance – temperature curve and table**  
(For more information, please refer to the application note)

## 9 Mechanical Characteristics and Ratings

Description	Condition	Value			Unit
		Min.	Typ.	Max.	
Comparative tracking index (CTI)		600	-	-	V
Mounting torque	M3 screw and washer	0.49		0.78	Nm
Backside curvature	Refer to Figure 8	-50	-	100	μm
Weight		-	6.58	-	g

## 10 Qualification Information

<b>UL certification</b>	File number: E314539	
<b>Moisture sensitivity level (SOP23 only)</b>	-	
<b>RoHS compliant</b>	Yes (Lead-free terminal plating)	
<b>ESD</b>	HBM(human body model) class	2
	CDM(charged device model) class	C3

## 11 Diagrams and Tables

### 11.1 $T_c$ Measurement Point

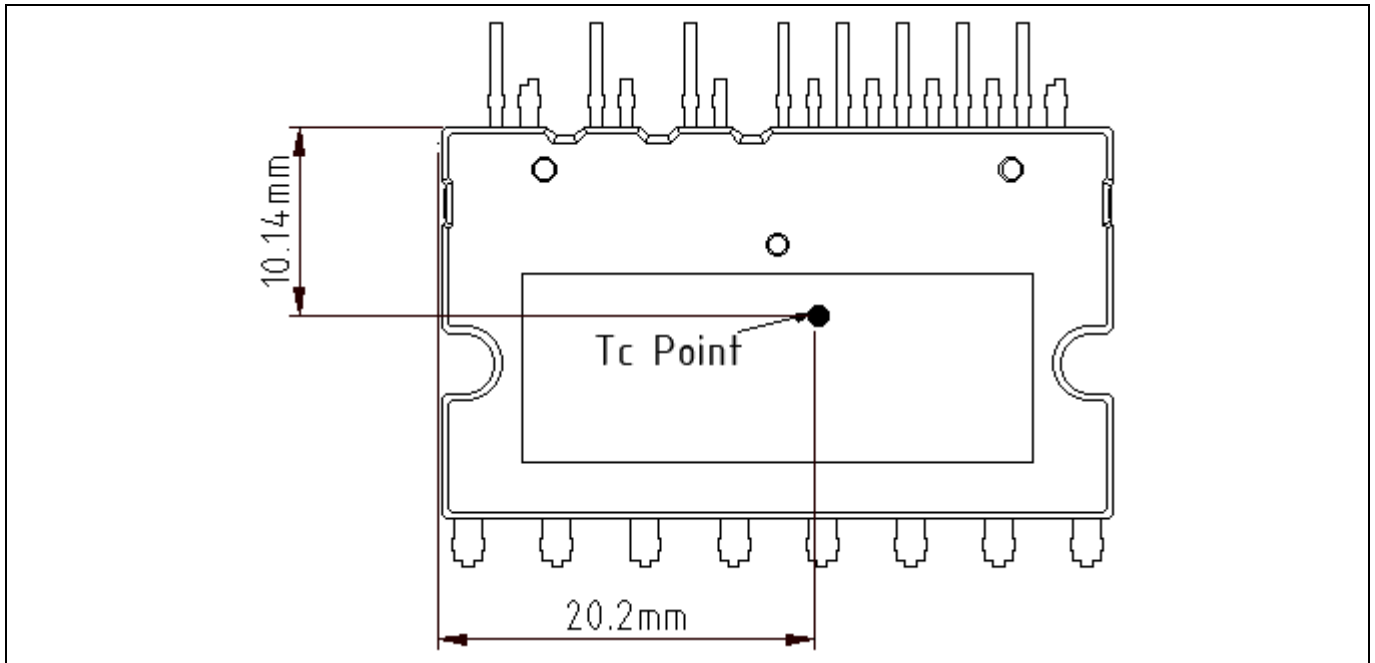


Figure 7  $T_c$  measurement point<sup>1</sup>

### 11.2 Backside Curvature Measurement Point

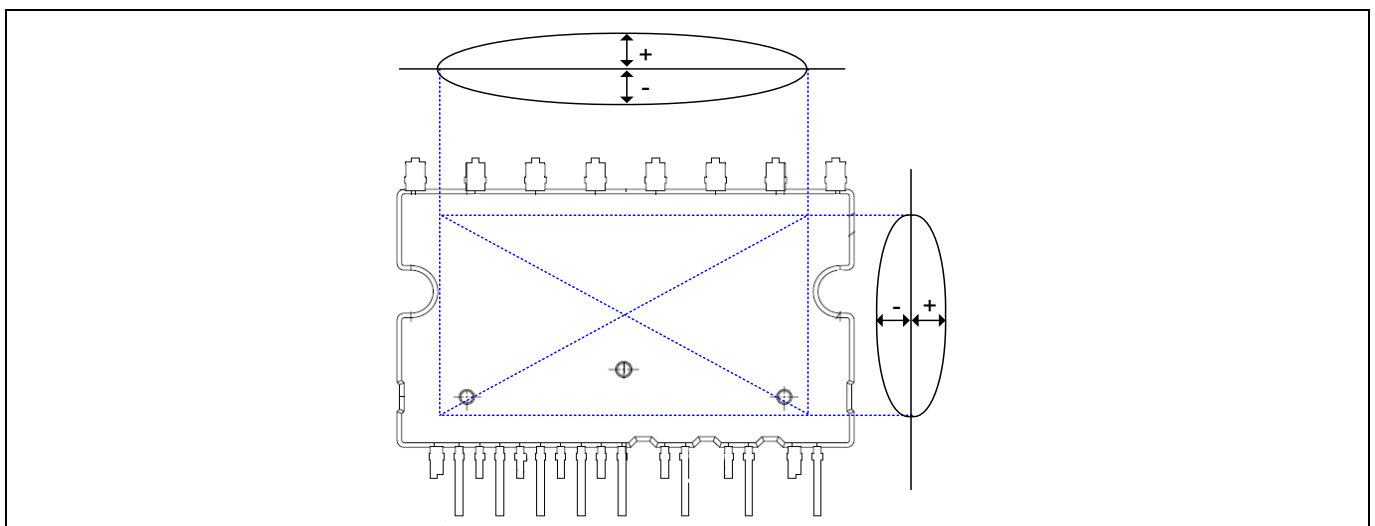


Figure 8 Backside curvature measurement position

<sup>1</sup>Any measurement except for the specified point in Figure 7 is not relevant for the temperature verification and brings wrong or different information.



### 11.3 Switching Time Definition

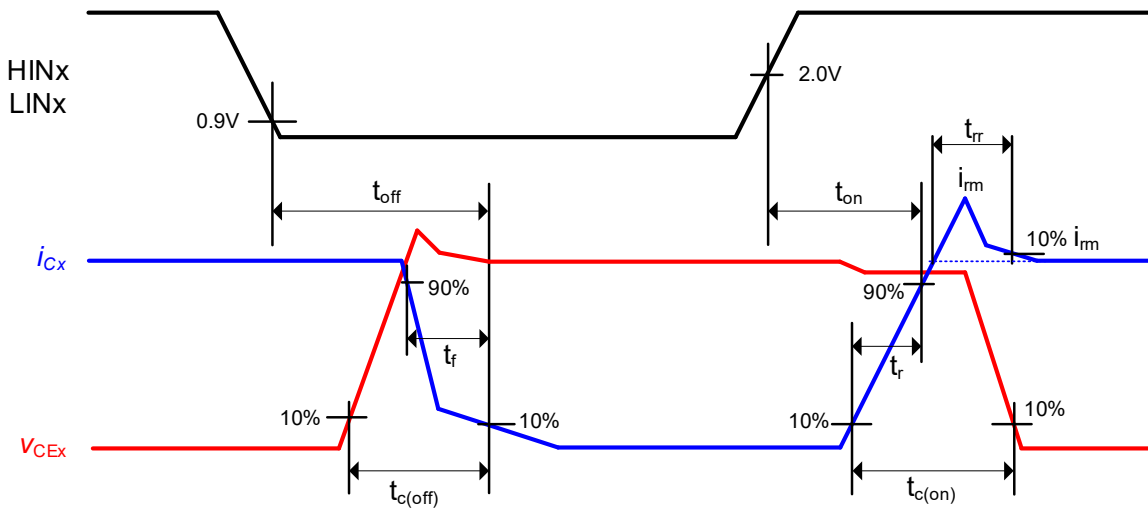


Figure 9 Switching time definition

### 11.4 Sleep function timing diagram

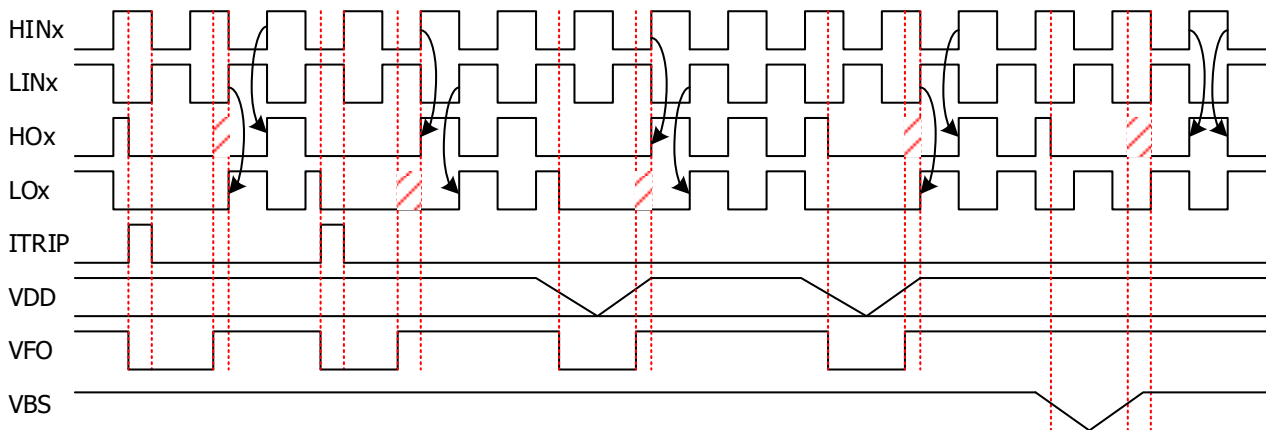
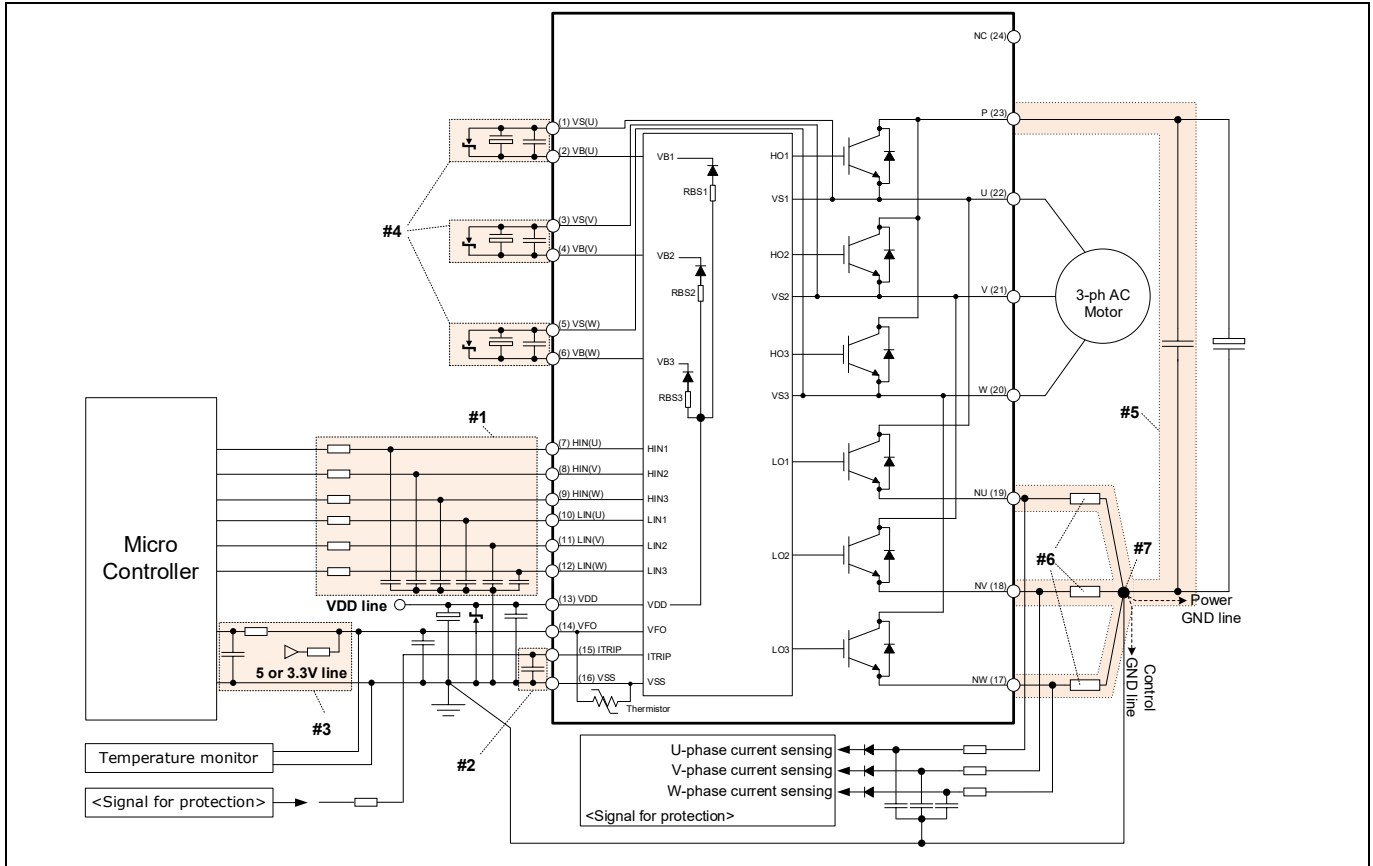


Figure 10 Sleep function timing diagram

## 12 Application Guide

### 12.1 Typical Application Schematic



**Figure 11 Typical application circuit**

- #1 Input circuit
  - RC filter can be used to reduce input signal noise. (100 Ω, 1 nF)
  - The capacitors should be located close to the IPM (to V<sub>SS</sub> terminal especially).
- #2 ITRIP circuit
  - To prevent a mis operation of protection function, RC filter is recommended.
  - The capacitor should be located close to ITRIP and V<sub>SS</sub> terminals.
- #3 V<sub>F0</sub> circuit
  - V<sub>F0</sub> pin is open drain configuration. This terminal should be pulled up to the bias voltage of the 5 V/3.3 V through a proper resistor.
  - It is recommended that RC filter is placed close to the controller.
- #4 V<sub>B</sub>-V<sub>S</sub> circuit
  - Capacitors for high-side floating supply voltage should be placed close to V<sub>B</sub> and V<sub>S</sub> terminals.
- #5 Snubber capacitor
  - The wiring among the IPM, snubber capacitor and shunt resistors should be short as possible.
- #6 Shunt resistor
  - SMD type shunt resistors are strongly recommended to minimize its internal stray inductance.
- #7 Ground pattern
  - Pattern overlap of power ground and signal ground should be minimized. The patterns should be connected at one end of shunt resistor only for the same potential.

## 12.2 Performance Chart

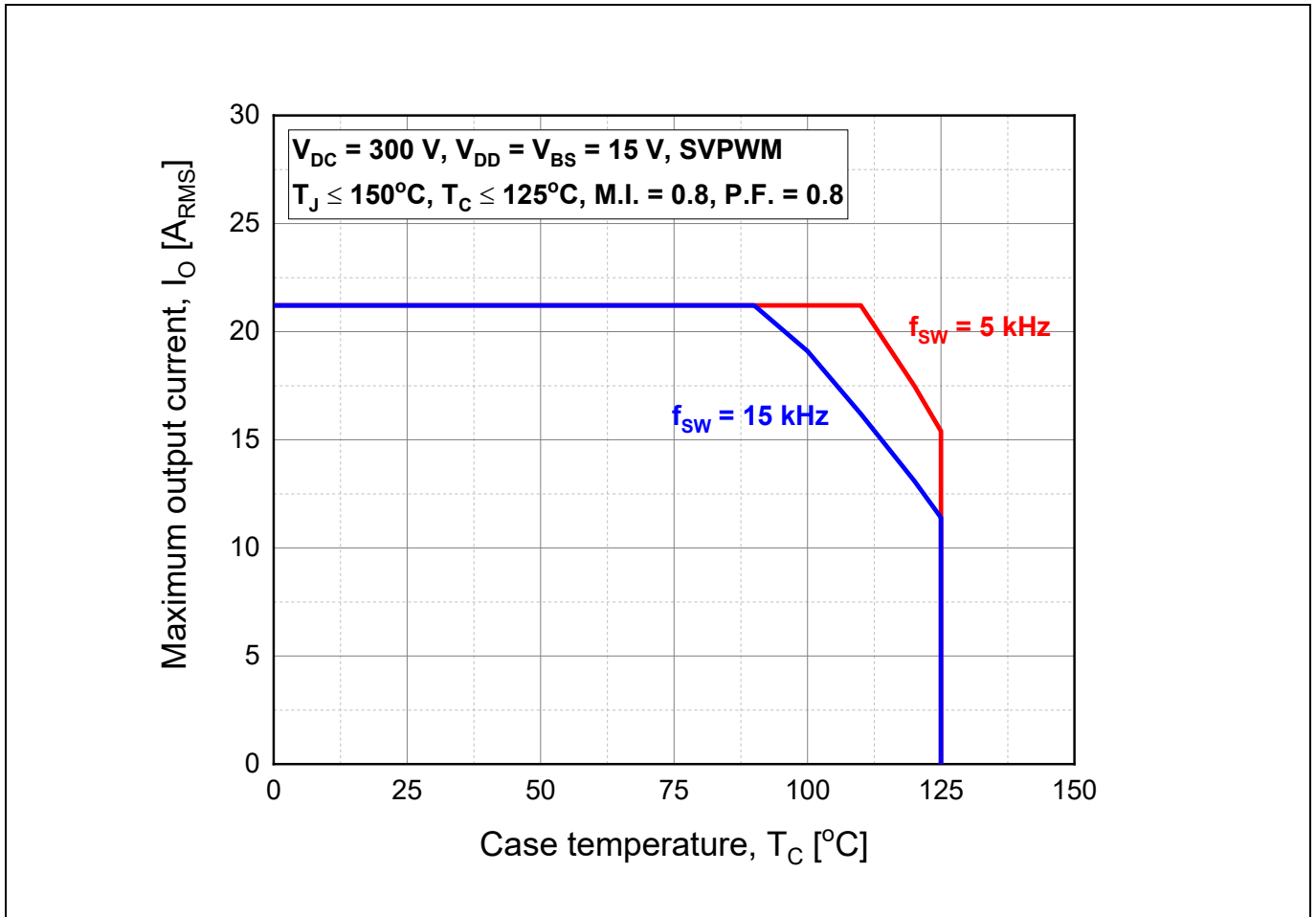


Figure 12 Maximum operating current SOA<sup>1</sup>

<sup>1</sup>This maximum operating current SOA is just one of example based on typical characteristics for this product. It can be changed by each user's actual operating conditions.

Package Outline

### 13 Package Outline

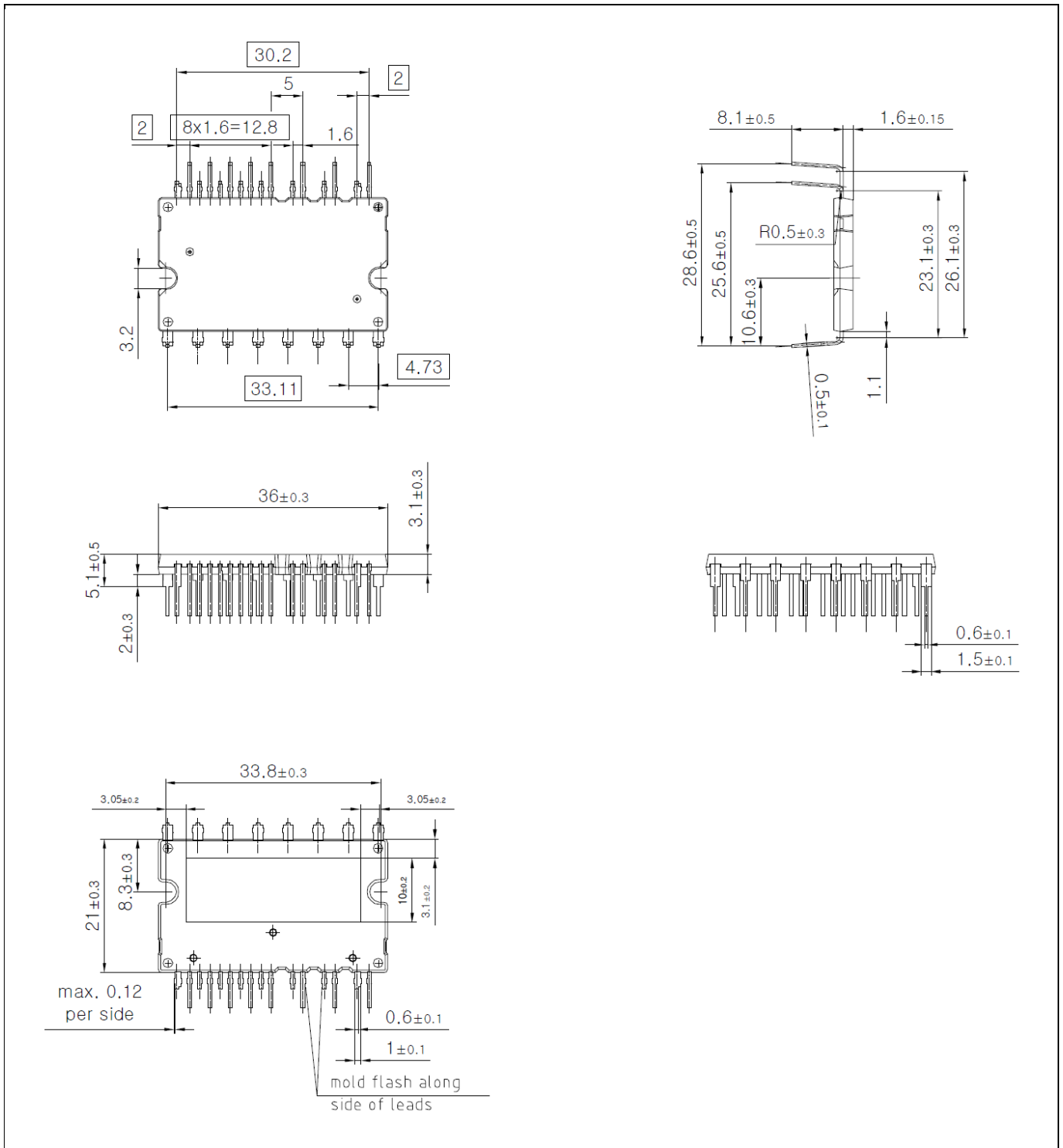


Figure 13 IM535-U6D

Package Outline

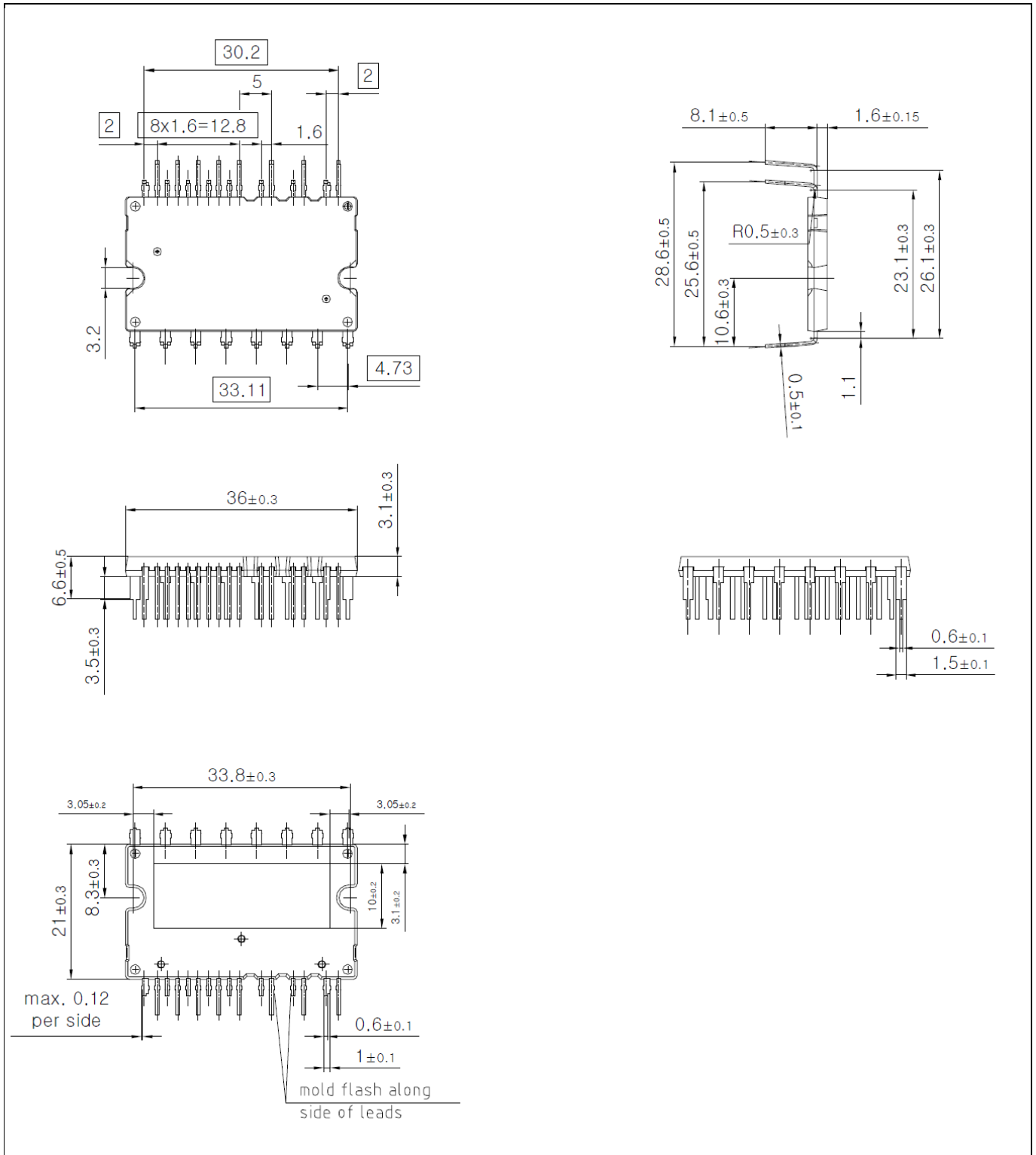


Figure 14 IM535-U6DS

Revision history

**Revision history**

<b>Document version</b>	<b>Date of release</b>	<b>Description of changes</b>
Version 2.0	2020-05-07	Initial release
Version 2.1	2021-04-09	Corrected typo in page 8 Corrected error in Figure 9 Updated Figure 11

## Trademarks

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