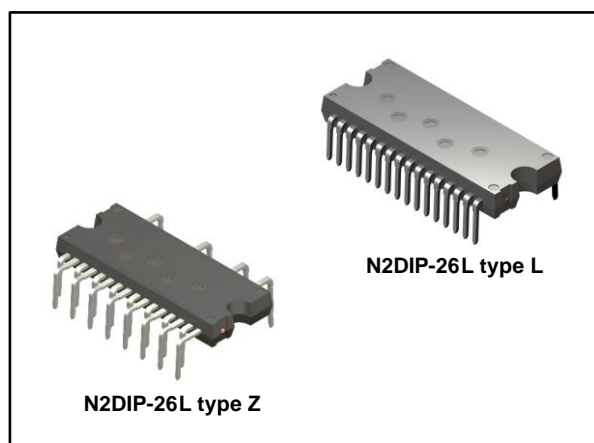


## SLLIMM™ nano - 2<sup>nd</sup> series IPM, 3-phase inverter, 5 A, 600 V short-circuit rugged IGBTs

Datasheet - production data



### Applications

- 3-phase inverters for motor drives
- Dish washers, refrigerator compressors, heating systems, air-conditioning fans, draining and recirculation pumps

### Description

This second series of SLLIMM (small low-loss intelligent molded module) nano provides a compact, high performance AC motor drive in a simple, rugged design. It is composed of six improved IGBTs with freewheeling diodes and three half-bridge HVICs for gate driving, providing low electromagnetic interference (EMI) characteristics with optimized switching speed. The package is designed to allow a better and more easily screwed-on heatsink and is optimized for thermal performance and compactness in built-in motor applications or other low power applications where assembly space is limited. This IPM includes a completely uncommitted operational amplifier and a comparator that can be used to design a fast and efficient protection circuit. SLLIMM™ is a trademark of STMicroelectronics.

### Features

- IPM 5 A, 600 V, 3-phase IGBT inverter bridge including 3 control ICs for gate driving and freewheeling diodes
- 3.3 V, 5 V, 15 V TTL/CMOS input comparators with hysteresis and pull-down/pull-up resistors
- Internal bootstrap diode
- Optimized for low electromagnetic interference
- Undervoltage lockout
- Short-circuit rugged TFS IGBTs
- Smart shutdown function
- Interlocking function
- Op-amp for advanced current sensing
- Comparator for fault protection against overcurrent
- NTC (UL 1434 CA 2 and 4)
- Isolation ratings of 1500 Vrms/min.
- Up to ±2 kV ESD protection (HBM C = 100 pF, R = 1.5 kΩ)
- UL recognition: UL 1557 file E81734

Table 1: Device summary

Order code	Marking	Package	Packing
STGIPQ5C60T-HLS	GIPQ5C60T-HLS	N2DIP-26L type L no stand-off	Tube
STGIPQ5C60T-HZS	GIPQ5C60T-HZS	N2DIP-26L type Z no stand-off	

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# 1 Internal schematic diagram and pin configuration

Figure 1: Internal schematic diagram

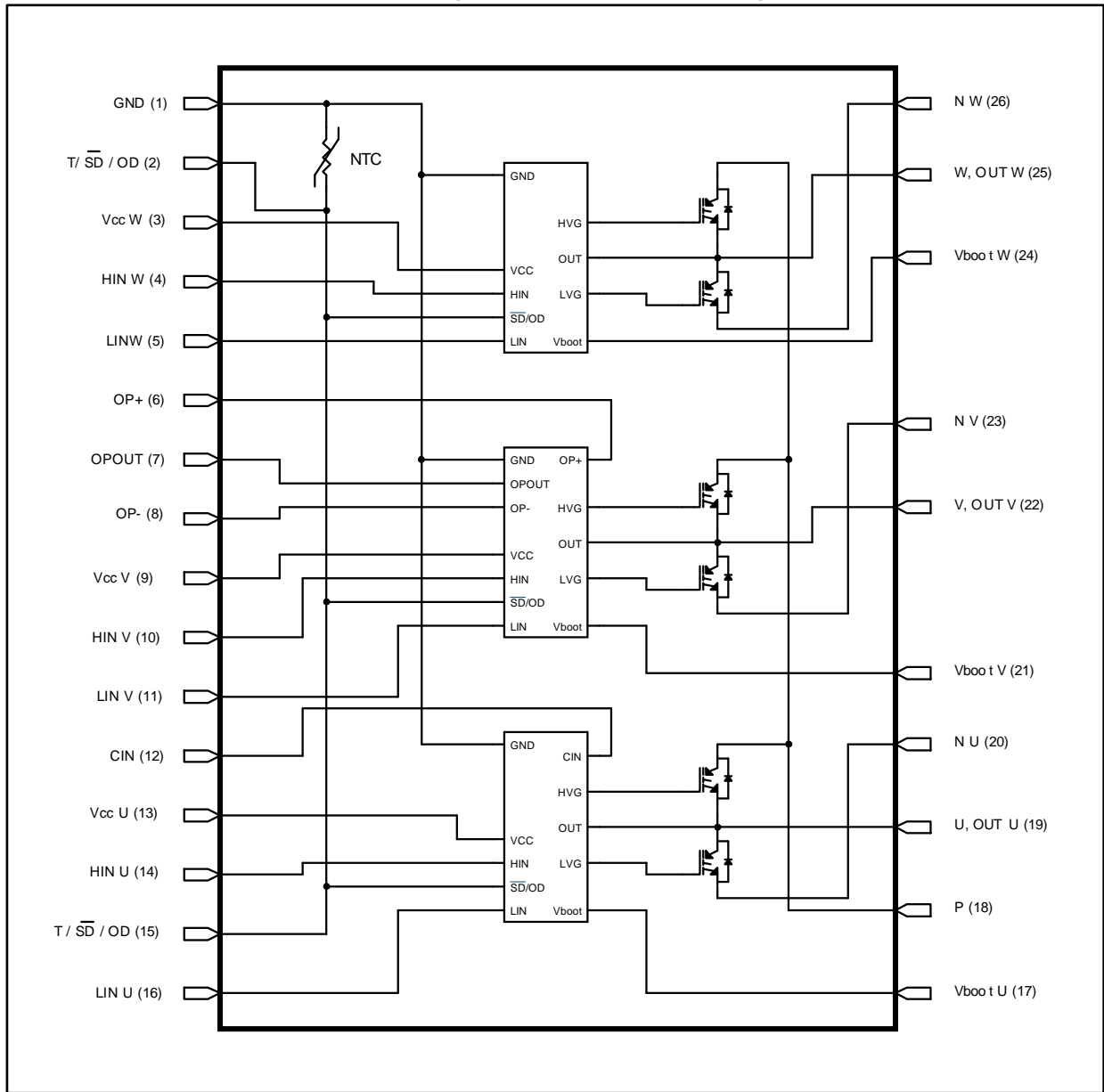


Table 2: Pin description

Pin	Symbol	Description
1	GND	Ground
2	T/ $\overline{SD}$ / OD	NTC thermistor terminal / shutdown logic input (active low) / open-drain (comparator output)
3	V <sub>CC</sub> W	Low voltage power supply W phase
4	HIN W	High-side logic input for W phase
5	LIN W	Low-side logic input for W phase
6	OP+	Op-amp non-inverting input
7	OP <sub>OUT</sub>	Op-amp output
8	OP-	Op-amp inverting input
9	V <sub>CC</sub> V	Low voltage power supply V phase
10	HIN V	High-side logic input for V phase
11	LIN V	Low-side logic input for V phase
12	CIN	Comparator input
13	V <sub>CC</sub> U	Low voltage power supply for V phase
14	HIN U	High-side logic input for V phase
15	T/ $\overline{SD}$ / OD	NTC thermistor terminal / shutdown logic input (active low) / open-drain (comparator output)
16	LIN U	Low-side logic input for U phase
17	V <sub>BOOT</sub> U	Bootstrap voltage for U phase
18	P	Positive DC input
19	U, OUT <sub>U</sub>	U phase output
20	N <sub>U</sub>	Negative DC input for U phase
21	V <sub>BOOT</sub> V	Bootstrap voltage for V phase
22	V, OUT <sub>V</sub>	V phase output
23	N <sub>V</sub>	Negative DC input for V phase
24	V <sub>BOOT</sub> W	Bootstrap voltage for W phase
25	W, OUT <sub>W</sub>	W phase output
26	N <sub>W</sub>	Negative DC input for W phase

## 2 Electrical ratings

### 2.1 Absolute maximum ratings

Table 3: Inverter part

Symbol	Parameter	Value	Unit
V <sub>CES</sub>	Collector-emitter voltage each IGBT (V <sub>IN</sub> <sup>(1)</sup> = 0)	600	V
I <sub>C</sub>	Continuous collector current each IGBT	5	A
I <sub>CP</sub> <sup>(2)</sup>	Peak collector current each IGBT (less than 1 ms)	10	A
P <sub>TOT</sub>	Total dissipation at T <sub>C</sub> = 25 °C each IGBT	13.6	W

**Notes:**

<sup>(1)</sup>Applied among HIN<sub>x</sub>, LIN<sub>x</sub> and GND for x = U, V, W.

<sup>(2)</sup>Pulse width limited by max. junction temperature.

Table 4: Control part

Symbol	Parameter	Min.	Max.	Unit
V <sub>CC</sub>	Low voltage power supply	- 0.3	21	V
V <sub>boot</sub>	Bootstrap voltage	- 0.3	620	V
V <sub>OUT</sub>	Output voltage applied among OUT <sub>u</sub> , OUT <sub>v</sub> , OUT <sub>w</sub> - GND	V <sub>boot</sub> - 21	V <sub>boot</sub> + 0.3	V
V <sub>CIN</sub>	Comparator input voltage	- 0.3	V <sub>CC</sub> + 0.3	V
V <sub>op+</sub>	Op-amp non-inverting input	- 0.3	V <sub>CC</sub> + 0.3	V
V <sub>op-</sub>	Op-amp inverting input	- 0.3	V <sub>CC</sub> + 0.3	V
V <sub>IN</sub>	Logic input voltage applied among HIN <sub>x</sub> , LIN <sub>x</sub> and GND	- 0.3	15	V
V <sub>T/SD/OD</sub>	Open-drain voltage	- 0.3	15	V
ΔV <sub>OUT/dT</sub>	Allowed output slew rate		50	V/ns

Table 5: Total system

Symbol	Parameter	Value	Unit
V <sub>ISO</sub>	Isolation withstand voltage applied between each pin and heatsink plate (AC voltage, t = 60 s)	1500	V
T <sub>j</sub>	Power chip operating junction temperature	-40 to 150	°C
T <sub>C</sub>	Module case operation temperature	-40 to 125	°C

### 2.2 Thermal data

Table 6: Thermal data

Symbol	Parameter	Value	Unit
R <sub>th(j-c)</sub>	Thermal resistance junction-case single IGBT	9.2	°C/W
	Thermal resistance junction-case single diode	15	

### 3 Electrical characteristics

$T_J = 25\text{ °C}$  unless otherwise specified

#### 3.1 Inverter part

Table 7: Static

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$I_{CES}$	Collector-cut off current ( $V_{IN} = 0$ "logic state")	$V_{CE} = 550\text{ V}$ , $V_{CC} = V_{Boot} = 15\text{ V}$	-		250	$\mu\text{A}$
$V_{CE(sat)}$	Collector-emitter saturation voltage	$V_{CC} = V_{boot} = 15\text{ V}$ , $V_{IN}^{(1)} = 0 - 5\text{ V}$ , $I_C = 5\text{ A}$	-	1.7	2.15	V
$V_F$	Diode forward voltage	$V_{IN} = 0$ "logic state", $I_C = 5\text{ A}$	-	2.1		V

**Notes:**

<sup>(1)</sup>Applied among  $HIN_x$ ,  $LIN_x$  and  $GND$  for  $x = U, V, W$ .

Table 8: Inductive load switching time and energy

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$t_{on}^{(1)}$	Turn-on time	$V_{DD} = 300\text{ V}$ , $V_{CC} = V_{boot} = 15\text{ V}$ , $V_{IN}^{(2)} = 0 - 5\text{ V}$ , $I_C = 5\text{ A}$ (see <a href="#">Figure 3: "Switching time definition"</a> )	-	280	-	ns
$t_{c(on)}^{(1)}$	Crossover time (on)		-	130	-	
$t_{off}^{(1)}$	Turn-off time		-	950	-	
$t_{c(off)}^{(1)}$	Crossover time (off)		-	115	-	
$t_{rr}$	Reverse recovery time		-	94	-	$\mu\text{J}$
$E_{on}$	Turn-on switching energy		-	110	-	
$E_{off}$	Turn-off switching energy		-	93	-	

**Notes:**

<sup>(1)</sup> $t_{ON}$  and  $t_{OFF}$  include the propagation delay time of the internal drive.  $t_{c(ON)}$  and  $t_{c(OFF)}$  are the switching time of IGBT itself under the internally given gate driving conditions.

<sup>(2)</sup>Applied among  $HIN_x$ ,  $LIN_x$  and  $GND$  for  $x = U, V, W$ .

Figure 2: Switching time test circuit

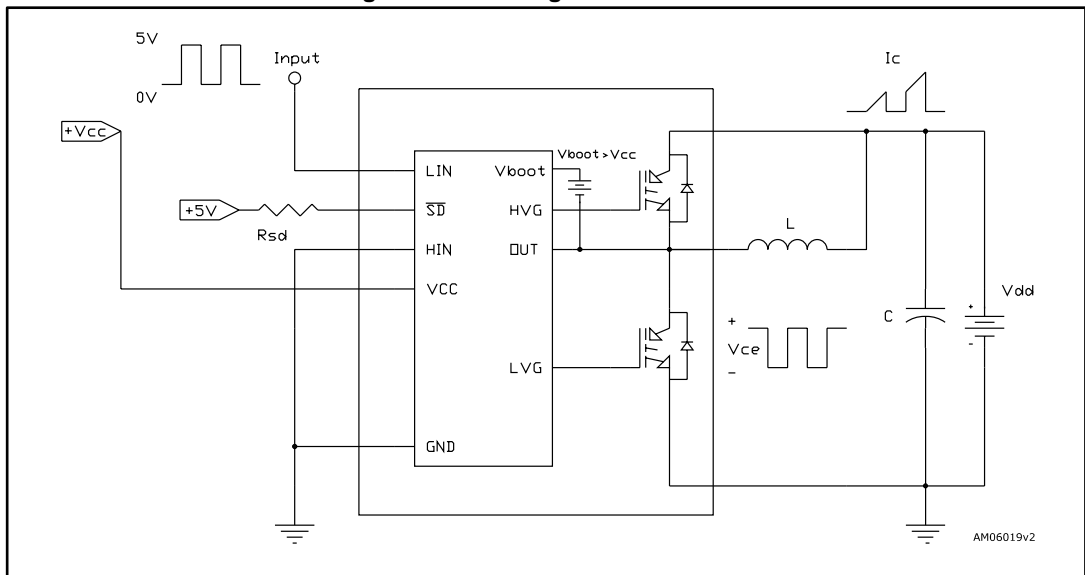


Figure 3: Switching time definition

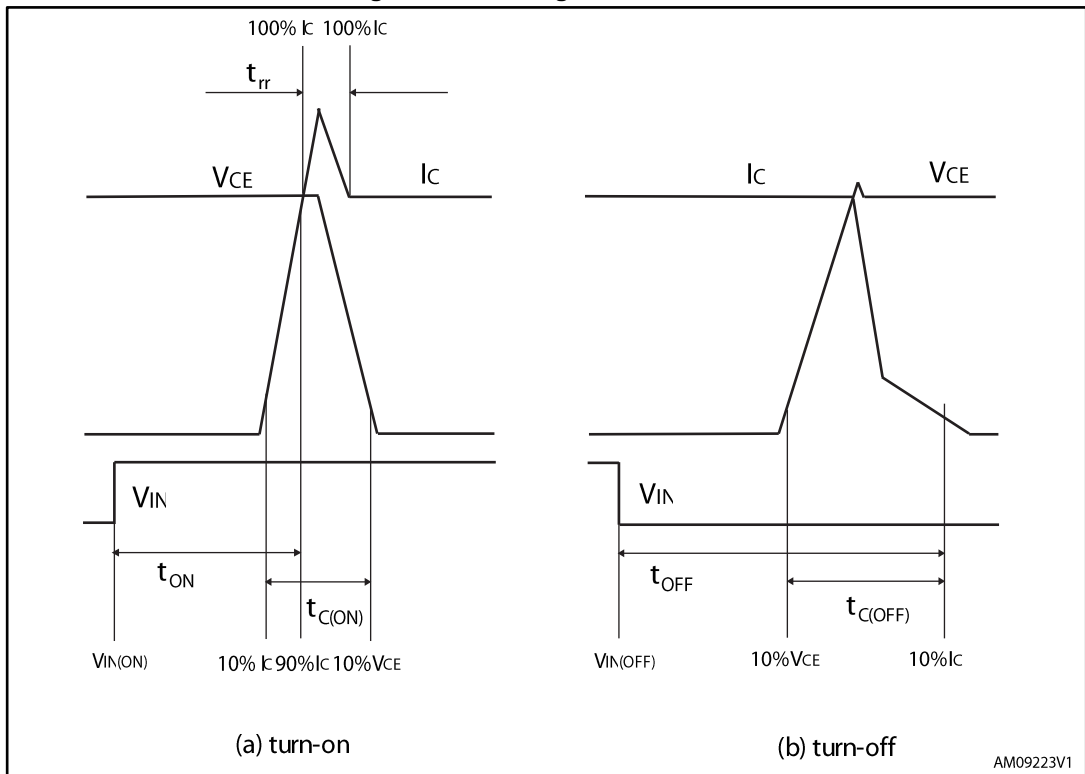


Figure 3: "Switching time definition" refers to HIN, LIN inputs (active high).

## 3.2 Control part

Table 9: Low voltage power supply

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{CC\_hys}$	$V_{CC}$ UV hysteresis		1.2	1.5	1.8	V
$V_{CC\_thON}$	$V_{CC}$ UV turn-ON threshold		11.5	12	12.5	V
$V_{CC\_thOFF}$	$V_{CC}$ UV turn-OFF threshold		10	10.5	11	V
$I_{qccu}$	Undervoltage quiescent supply current	$V_{CC} = 10\text{ V}$ , $T/\overline{SD}/OD = 5\text{ V}$ ; $L_{IN} = H_{IN} = C_{IN} = 0\text{ V}$			150	$\mu\text{A}$
$I_{qcc}$	Quiescent current	$V_{CC} = 10\text{ V}$ , $T/\overline{SD}/OD = 5\text{ V}$ ; $L_{IN} = H_{IN} = C_{IN} = 0\text{ V}$			1	mA
$V_{ref}$	Internal comparator (CIN) reference voltage		0.51	0.54	0.56	V

Table 10: Bootstrapped voltage

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{BS\_hys}$	$V_{BS}$ UV hysteresis		1.2	1.5	1.8	V
$V_{BS\_thON}$	$V_{BS}$ UV turn-ON threshold		11.1	11.5	12.1	V
$V_{BS\_thOFF}$	$V_{BS}$ UV turn-OFF threshold		9.8	10	10.6	V
$I_{qBSU}$	Undervoltage $V_{BS}$ quiescent current	$V_{BS} < 9\text{ V}$ , $T/\overline{SD}/OD = 5\text{ V}$ ; $L_{IN} = 0\text{ V}$ and $H_{IN} = 5\text{ V}$ ; $C_{IN} = 0\text{ V}$		70	110	$\mu\text{A}$
$I_{qBS}$	$V_{BS}$ quiescent current	$V_{BS} = 15\text{ V}$ , $T/\overline{SD}/OD = 5\text{ V}$ ; $L_{IN} = 0\text{ V}$ and $H_{IN} = 5\text{ V}$ ; $C_{IN} = 0$		150	210	$\mu\text{A}$
$R_{DS(on)}$	Bootstrap driver on-resistance	LVG ON		120		$\Omega$



Table 11: Logic inputs

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{il}$	Low logic level voltage				0.8	V
$V_{ih}$	High logic level voltage		2.25			V
$I_{HINh}$	HIN logic "1" input bias current	HIN = 15 V	20	40	100	$\mu$ A
$I_{HINl}$	HIN logic "0" input bias current	HIN = 0 V			1	$\mu$ A
$I_{LINl}$	LIN logic "0" input bias current	LIN = 0 V			1	$\mu$ A
$I_{LINh}$	LIN logic "1" input bias current	LIN = 15 V	20	40	100	$\mu$ A
$I_{SDh}$	$\overline{SD}$ logic "0" input bias current	$\overline{SD}$ = 15 V	220	295	370	$\mu$ A
$I_{SDl}$	$\overline{SD}$ logic "1" input bias current	$\overline{SD}$ = 0 V			3	$\mu$ A
Dt	Dead time	see <a href="#">Figure 8: "Dead time and interlocking waveform definitions"</a>		180		ns

Table 12: Op-amp characteristics

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{io}$	Input offset voltage	$V_{ic} = 0$ V, $V_o = 7.5$ V			6	mV
$I_{io}$	Input offset current	$V_{ic} = 0$ V, $V_o = 7.5$ V		4	40	nA
$I_{ib}$	Input bias current <sup>(1)</sup>			100	200	nA
$V_{OL}$	Low level output voltage	$R_L = 10$ k $\Omega$ to $V_{CC}$		75	150	mV
$V_{OH}$	High level output voltage	$R_L = 10$ k $\Omega$ to GND	14	14.7		V
$I_o$	Output short-circuit current	Source, $V_{id} = +1$ V; $V_o = 0$ V	16	30		mA
		Sink, $V_{id} = -1$ V; $V_o = V_{CC}$	50	80		mA
SR	Slew rate	$V_i = 1 - 4$ V; $C_L = 100$ pF; unity gain	2.5	3.8		V/ $\mu$ s
GBWP	Gain bandwidth product	$V_o = 7.5$ V	8	12		MHz
$A_{vd}$	Large signal voltage gain	$R_L = 2$ k $\Omega$	70	85		dB
SVR	Supply voltage rejection ratio	vs $V_{CC}$	60	75		dB
CMRR	Common mode rejection ratio		55	70		dB

**Notes:**

<sup>(1)</sup>The direction of input current is out of the IC.

Table 13: Sense comparator characteristics

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$I_{ib}$	Input bias current	$V_{CIN} = 1\text{ V}$	-		3	$\mu\text{A}$
$V_{od}$	Open-drain low level output voltage	$I_{od} = 3\text{ mA}$	-		0.5	V
$R_{ON\_OD}$	Open-drain low level output	$I_{od} = 3\text{ mA}$	-	166		$\Omega$
$R_{PD\_SD}$	$\overline{SD}$ pull-down resistor <sup>(1)</sup>		-	125		$\text{k}\Omega$
$t_{d\_comp}$	Comparator delay	T/ $\overline{SD}$ /OD pulled to 5 V through 100 $\text{k}\Omega$ resistor	-	90	130	ns
SR	Slew rate	$C_L = 180\text{ pF}$ ; $R_{pu} = 5\text{ k}\Omega$	-	60		V/ $\mu\text{s}$
$t_{sd}$	Shutdown to high / low-side driver propagation delay	$V_{OUT} = 0$ , $V_{boot} = V_{CC}$ , $V_{IN} = 0$ to 3.3 V	-	125		ns
$t_{isd}$	Comparator triggering to high / low-side driver turn-off propagation delay	Measured applying a voltage step from 0 V to 3.3 V to pin CIN	-	200		

**Notes:**

<sup>(1)</sup>Equivalent values as a result of the resistances of three drivers in parallel.

Table 14: Truth table

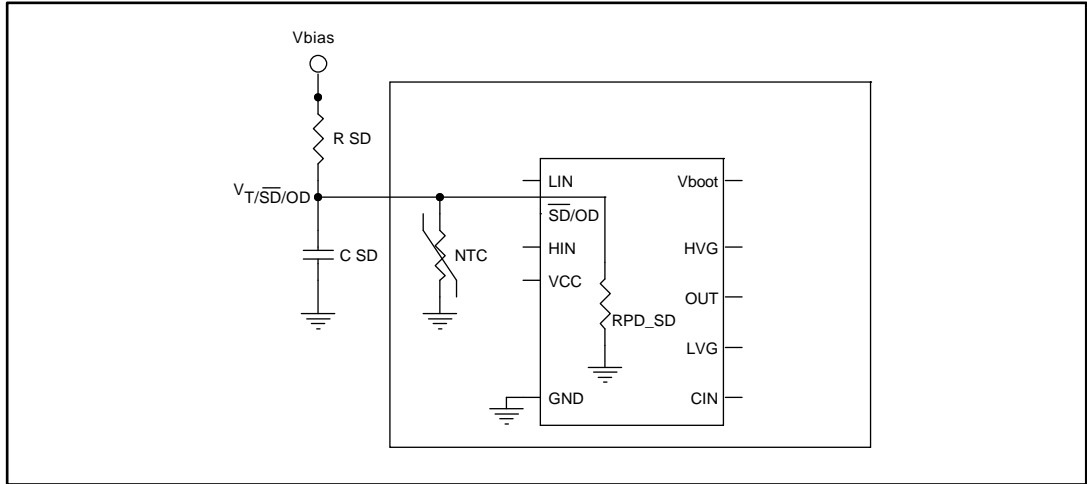
Conditions	Logic input (Vi)			Output	
	T/ $\overline{SD}$ /OD	LIN	HIN	LVG	HVG
Shutdown enable half-bridge tri-state	L	X <sup>(1)</sup>	X <sup>(1)</sup>	L	L
Interlocking half-bridge tri-state	H	H	H	L	L
0 "logic state" half-bridge tri-state	H	L	L	L	L
1 "logic state" low-side direct driving	H	H	L	H	L
1 "logic state" high-side direct driving	H	L	H	L	H

**Notes:**

<sup>(1)</sup>X: don't care.

3.2.1 NTC thermistor

Figure 4: Internal structure of  $\overline{SD}$  and NTC



RPD\_SD: equivalent value as result of resistances of three drivers in parallel.

Figure 5: Equivalent resistance (NTC//RPD\_SD)

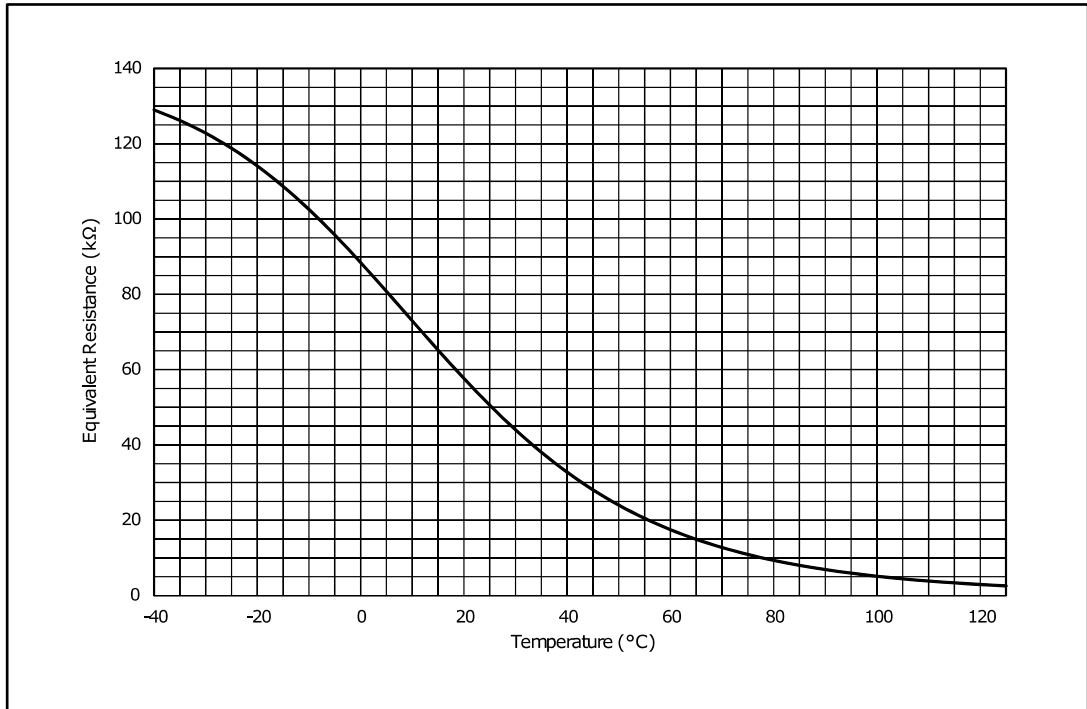


Figure 6: Equivalent resistance (NTC//RPD\_SD) zoom

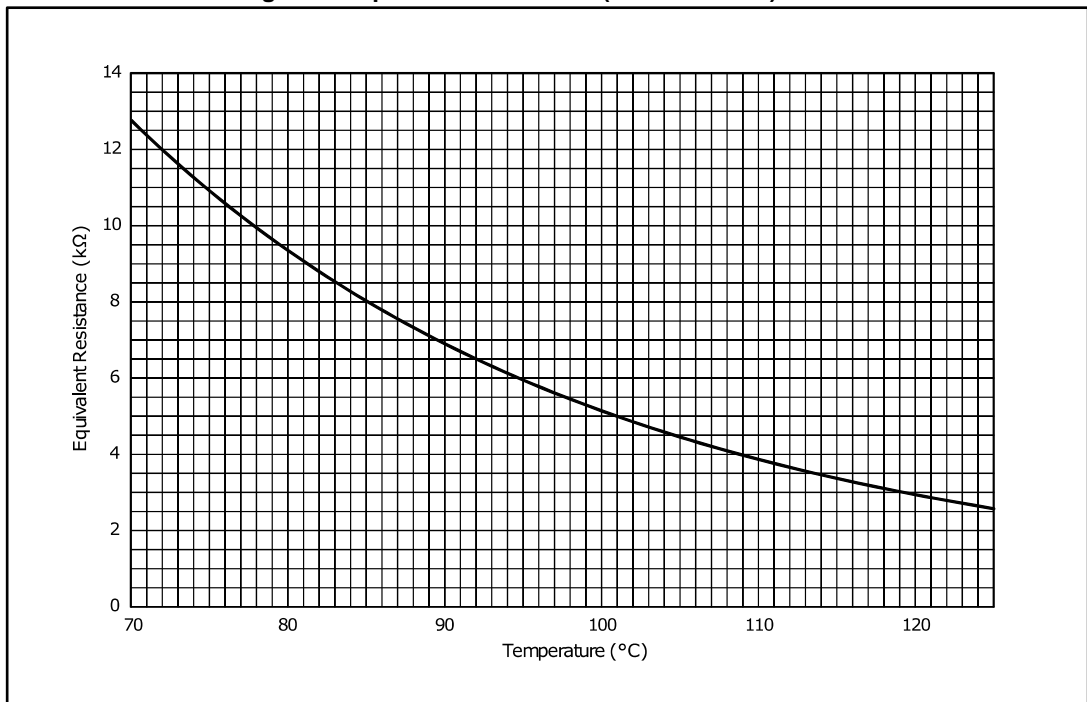
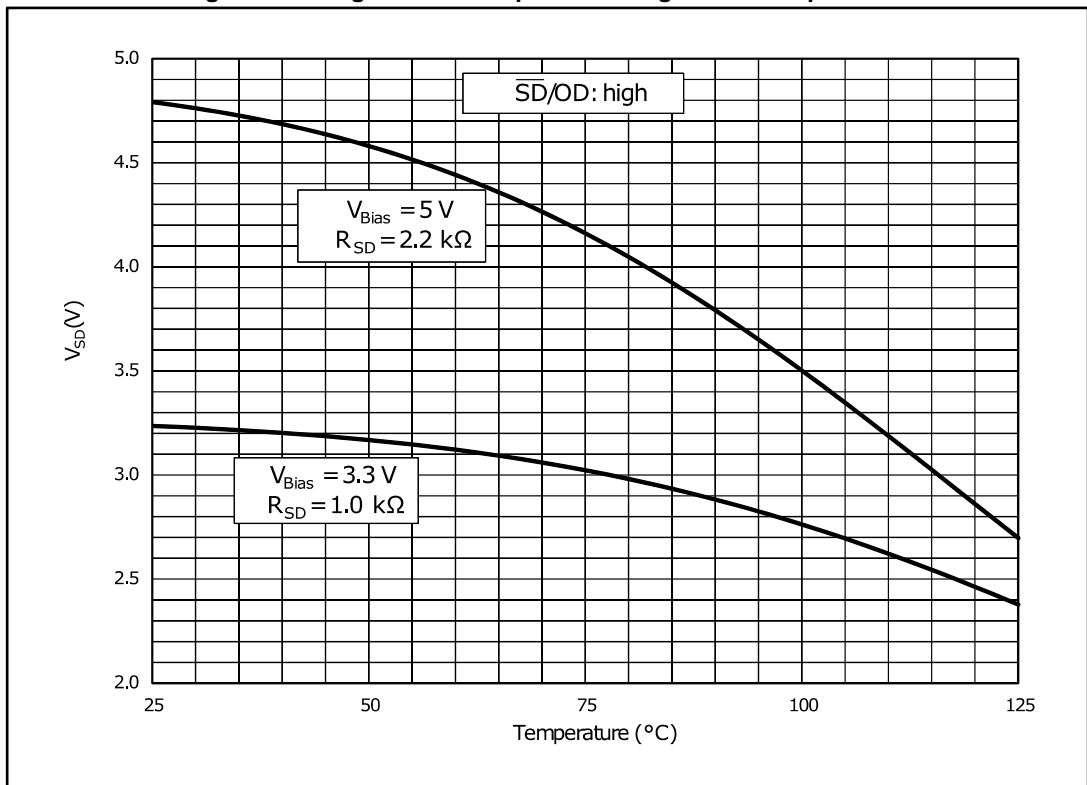
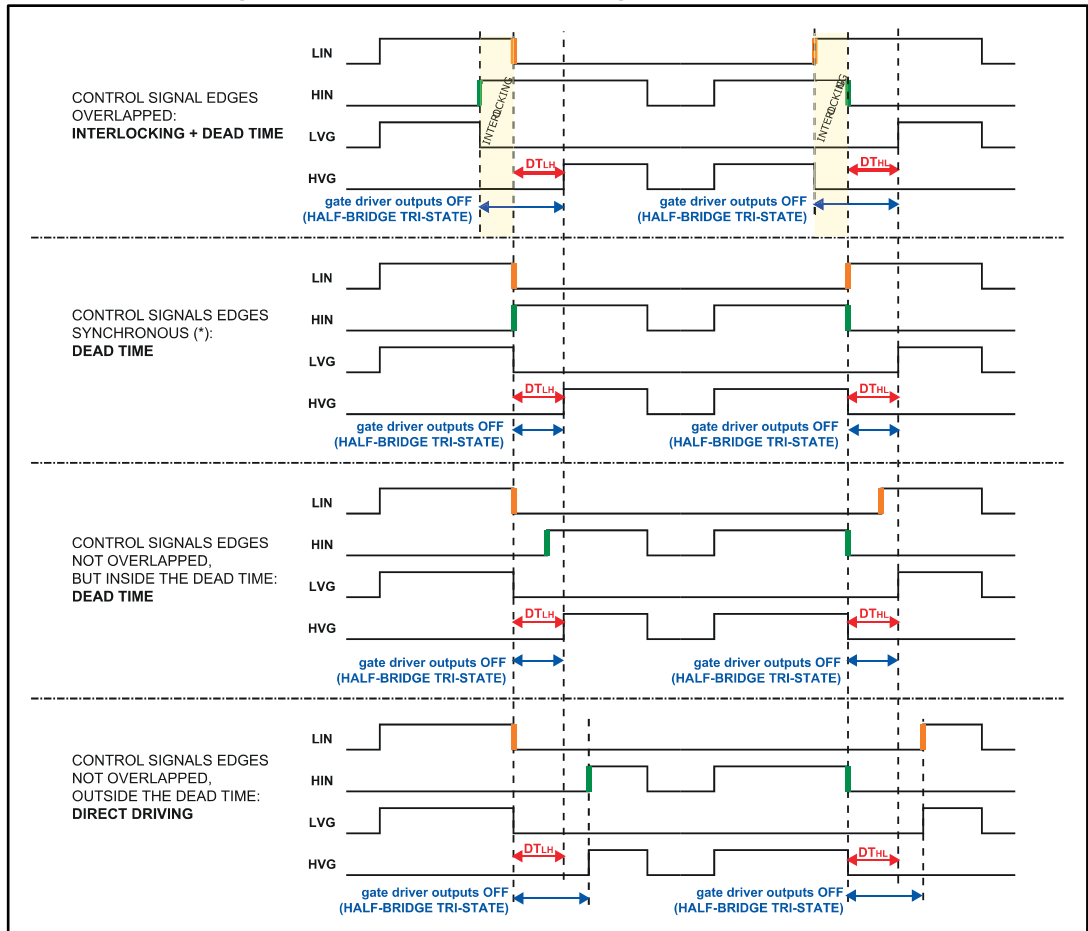


Figure 7: Voltage of T/SD/OD pin according to NTC temperature



### 3.3 Waveform definitions

Figure 8: Dead time and interlocking waveform definitions



## 4 Smart shutdown function

The device integrates a comparator for fault sensing purposes. The comparator has an internal voltage reference  $V_{REF}$  connected to the inverting input, while the non-inverting input on pin (CIN) can be connected to an external shunt resistor for overcurrent protection.

When the comparator triggers, the device is set to the shutdown state and both of its outputs are set to the low level, causing the half-bridge to enter a tri-state.

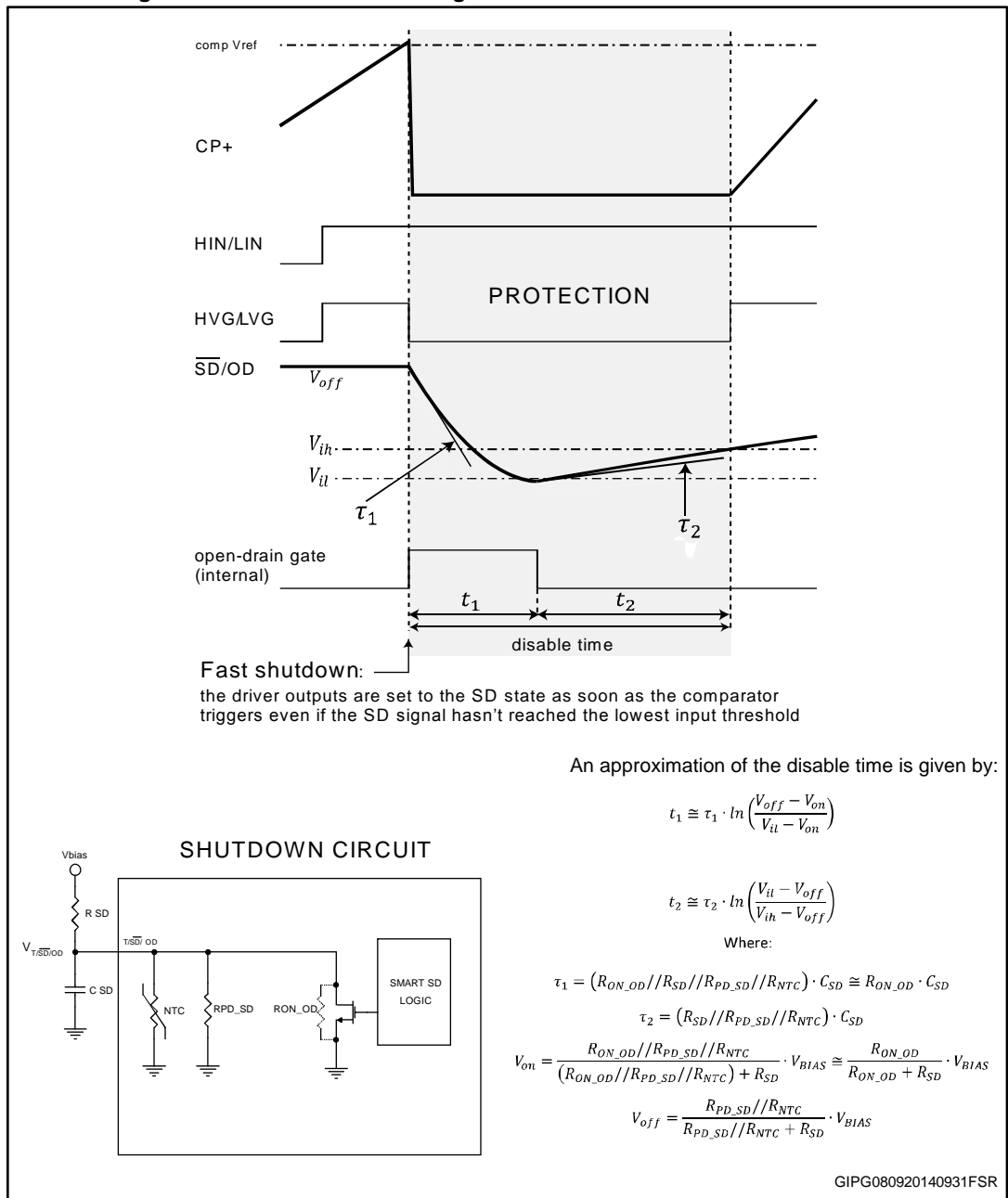
In common overcurrent protection architectures, the comparator output is usually connected to the shutdown input through an RC network so to provide a monostable circuit, which implements a protection time following to a fault condition.

Our smart shutdown architecture immediately turns off the output gate driver in case of overcurrent through a preferential path for the fault signal, which directly switches off the outputs. The time delay between the fault and output shutdown no longer depends on the RC values of the external network connected to the shutdown pin. At the same time, the DMOS connected to the open-drain output (pin T/  $\overline{SD}$  /OD) is turned on by the internal logic, which holds it on until the shutdown voltage is well below the minimum value of logic input threshold ( $V_{il}$ ).

Besides, the smart shutdown function allows the real disable time to be increased while the constant time of the external RC network remains as it is.

An NTC thermistor for temperature monitoring is internally connected in parallel to the  $\overline{SD}$  pin. To avoid an undesired shutdown, keep the voltage  $V_{T/\overline{SD}/OD}$  higher than the high level logic threshold by setting the pull-up resistor  $R_{\overline{SD}}$  to 1 k $\Omega$  or 2.2 k $\Omega$  for 3.3 V or 5 V MCU power supplies, respectively.

Figure 9: Smart shutdown timing waveforms in case of overcurrent event







## 5.2 Guidelines

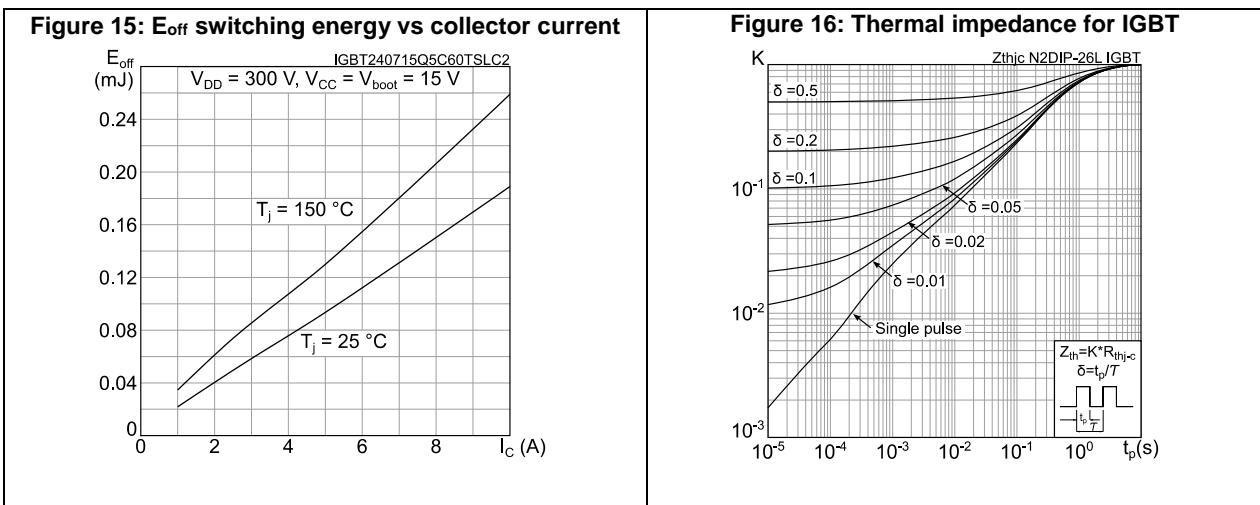
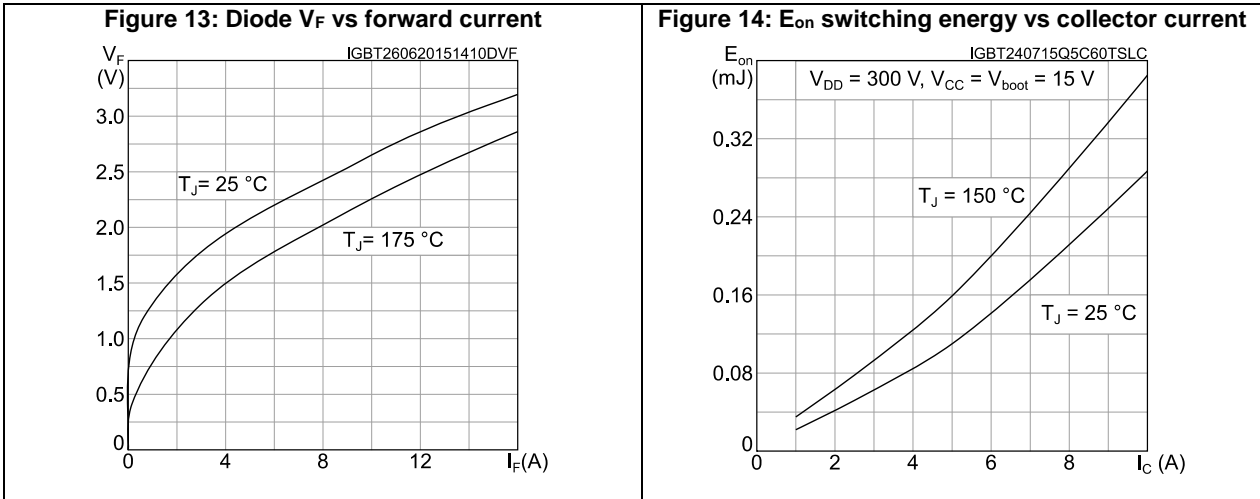
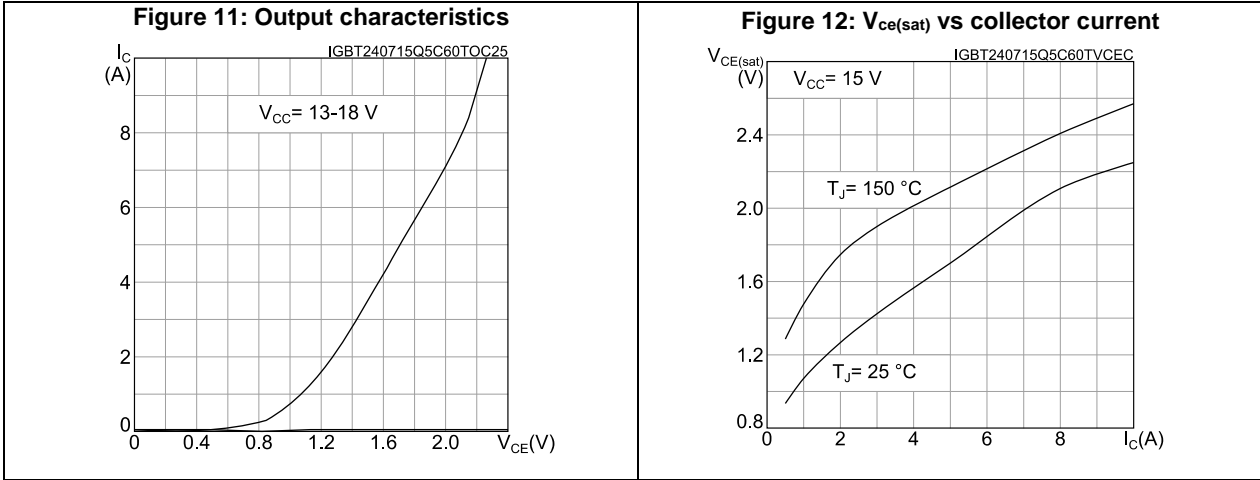
- Input signals HIN, LIN are active high logic. A 375 k $\Omega$  (typ.) pull-down resistor is built-in for each input. To avoid input signal oscillation, the wiring of each input should be as short as possible and the use of RC filters ( $R_1$ ,  $C_1$ ) on each input signal is suggested. The filters should be with a time constant of about 100 ns and placed as close as possible to the IPM input pins.
- The use of a bypass capacitor  $C_{VCC}$  (aluminum or tantalum) can reduce the transient circuit demand on the power supply. Also, to reduce high frequency switching noise distributed on the power lines, a decoupling capacitor  $C_2$  (100 to 220 nF, with low ESR and low ESL) should be placed as close as possible to Vcc pin and in parallel with the bypass capacitor.
- The use of RC filter ( $R_{SF}$ ,  $C_{SF}$ ) is recommended because it avoids protection circuit malfunction. The time constant ( $R_{SF} \times C_{SF}$ ) should be set to 1  $\mu$ s and the filter must be placed as close as possible to the  $C_{IN}$  pin.
- The  $\overline{SD}$  is an input/output pin (open-drain type if it is used as output). A built-in thermistor NTC is internally connected between the  $\overline{SD}$  pin and GND. The voltage  $V_{SD-GND}$  decreases as the temperature increases, due to the pull-up resistor  $R_{SD}$ . In order to keep the voltage always higher than the high level logic threshold, the pull-up resistor should be set to 1 k $\Omega$  or 2.2 k $\Omega$  for 3.3 V or 5 V MCU power supply, respectively. The  $C_{SD}$  capacitor of the filter on  $\overline{SD}$  should be fixed no higher than 3.3 nF in order to assure the  $\overline{SD}$  activation time  $\tau_1 \leq 500$  ns. Besides, the filter should be placed as close as possible to the  $\overline{SD}$  pin.
- The decoupling capacitor  $C_3$  (from 100 to 220 nF, ceramic with low ESR and low ESL), in parallel with each  $C_{boot}$ , filters high frequency disturbance. Both  $C_{boot}$  and  $C_3$  (if present) should be placed as close as possible to the U, V, W and  $V_{boot}$  pins. Bootstrap negative electrodes should be connected to U, V, W terminals directly and separated from the main output wires.
- To avoid the overvoltage on Vcc pin, a Zener diode ( $D_{z1}$ ) can be used. Similarly on the  $V_{boot}$  pin, a Zener diode ( $D_{z2}$ ) can be placed in parallel with each  $C_{boot}$ .
- The use of the decoupling capacitor  $C_4$  (100 to 220 nF, with low ESR and low ESL) in parallel with the electrolytic capacitor  $C_{vdc}$  avoids surge destruction. Both capacitors  $C_4$  and  $C_{vdc}$  should be placed as close as possible to the IPM ( $C_4$  has priority over  $C_{vdc}$ ).
- By integrating an application-specific type HVIC inside the module, direct coupling to the MCU terminals without an optocoupler is possible.
- Low inductance shunt resistors have to be used for phase leg current sensing.
- In order to avoid malfunctions, the wiring on N pins, the shunt resistor and  $P_{WR\_GND}$  should be as short as possible.
- The connection of  $SGN\_GND$  to  $PWR\_GND$  on one point only (close to the shunt resistor terminal) can reduce the impact of power ground fluctuation.

These guidelines ensure the specifications of the device for application designs. For further details, please refer to the relevant application note.

Table 15: Recommended operating conditions

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{PN}$	Supply voltage	Applied among P-Nu, Nv, Nw		300	500	V
$V_{CC}$	Control supply voltage	Applied to $V_{CC}$ -GND	13.5	15	18	V
$V_{BS}$	High-side bias voltage	Applied to $V_{BOOTx}$ -OUT for $x = U, V, W$	13		18	V
$t_{dead}$	Blanking time to prevent arm-short	For each input signal	1.5			$\mu$ s
$f_{PWM}$	PWM input signal	$-40\text{ }^{\circ}\text{C} < T_c < 100\text{ }^{\circ}\text{C}$ $-40\text{ }^{\circ}\text{C} < T_j < 125\text{ }^{\circ}\text{C}$			25	kHz
$T_c$	Case operation temperature				100	$^{\circ}\text{C}$

## 6 Electrical characteristics (curves)



## 7 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK® packages, depending on their level of environmental compliance. ECOPACK® specifications, grade definitions and product status are available at: [www.st.com](http://www.st.com). ECOPACK® is an ST trademark.

### 7.1 N2DIP-26L type L no stand-off package information

Figure 17: N2DIP-26L type L no stand-off package outline

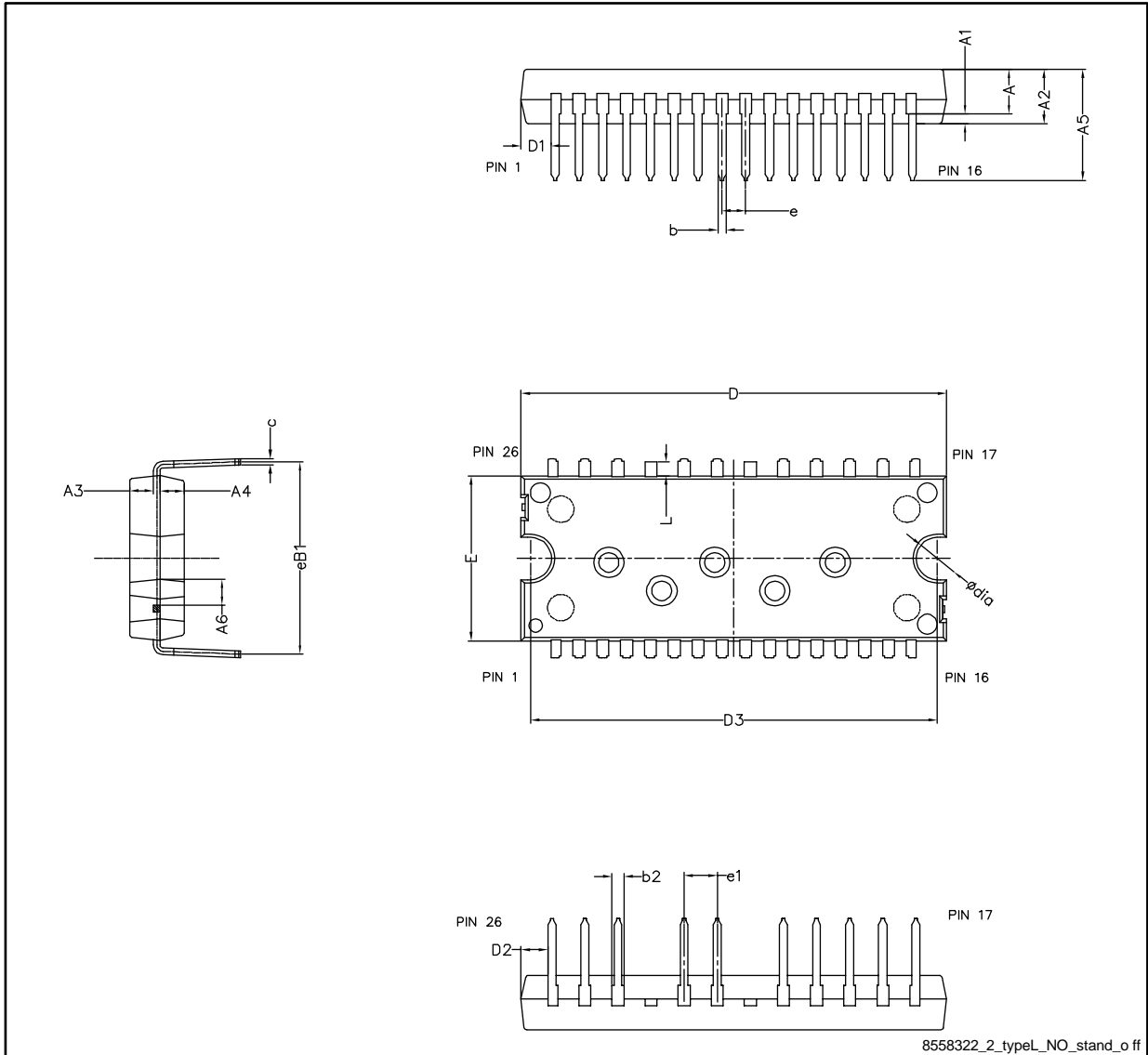


Table 16: N2DIP-26L type L no stand-off mechanical data

Dim.	mm		
	Min.	Typ.	Max.
A			3.80
A1	0.45	0.75	1.05
A2	4.00	4.10	4.20
A3	1.70	1.80	1.90
A4	1.70	1.80	1.90
A5	8.10	8.40	8.70
A6	1.75		
b	0.53		0.72
b2	0.83		1.02
c	0.46		0.59
D	32.05	32.15	32.25
D1	2.10		
D2	1.85		
D3	30.65	30.75	30.85
E	12.35	12.45	12.55
e	1.70	1.80	1.90
e1	2.40	2.50	2.60
eB1	14.25	14.55	14.85
L	0.85	1.05	1.25
Dia	3.10	3.20	3.30

### 7.2 N2DIP-26L type Z no stand-off package information

Figure 18: N2DIP-26L type Z no stand-off package outline

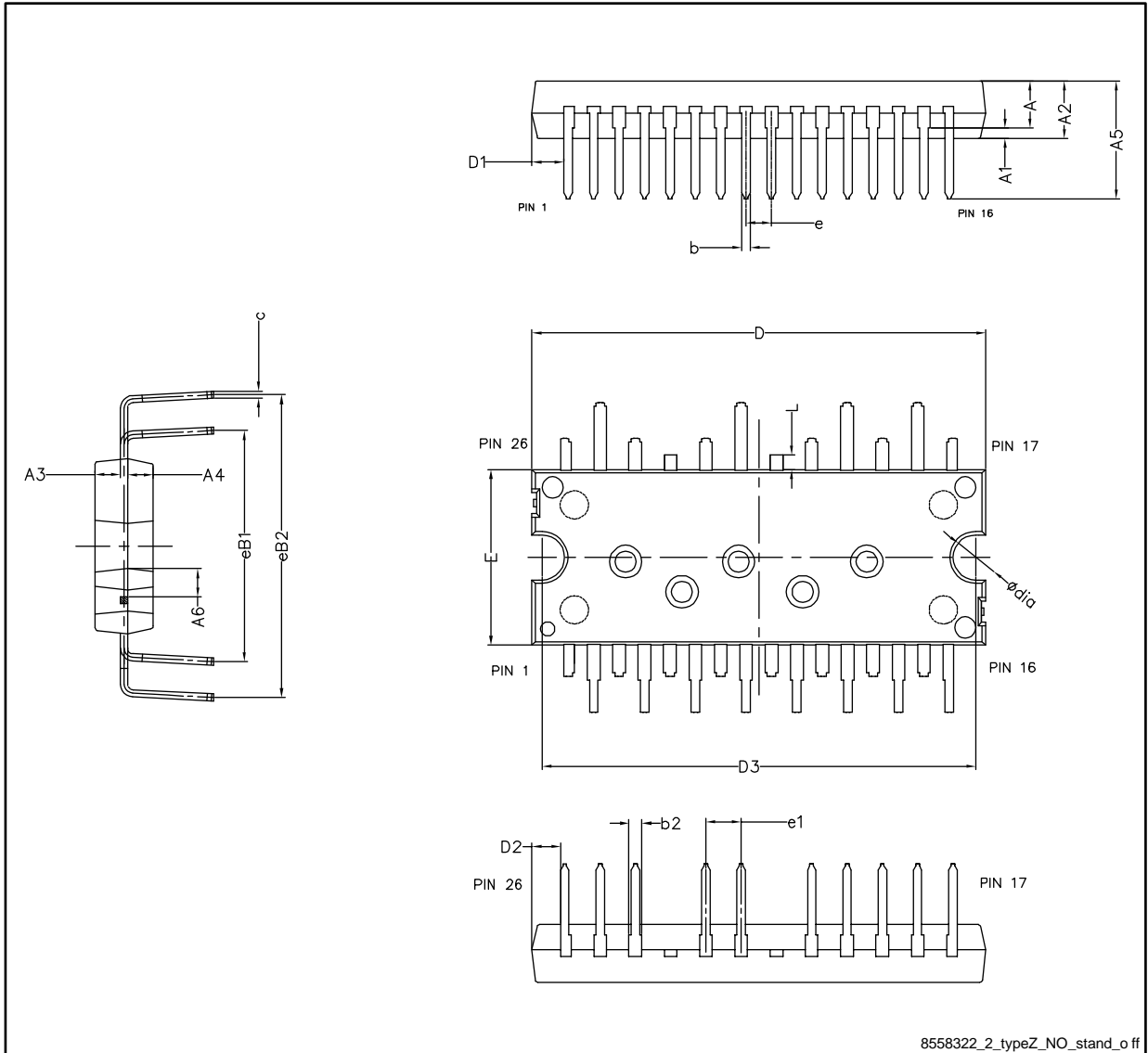
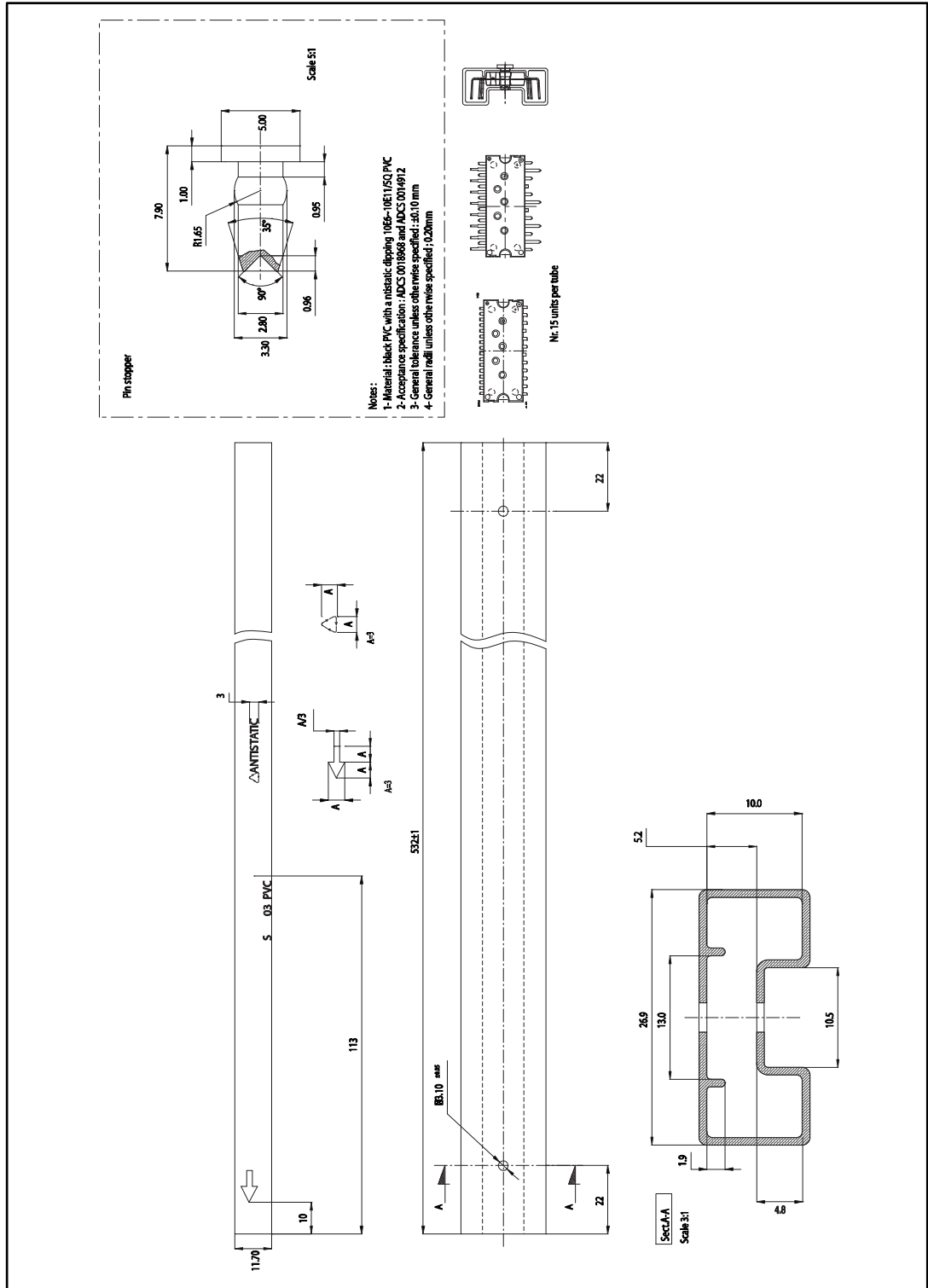


Table 17: N2DIP-26L type Z no stand-off mechanical data

Dim.	mm		
	Min.	Typ.	Max.
A			3.80
A1	0.45	0.75	1.05
A2	4.00	4.10	4.20
A3	1.70	1.80	1.90
A4	1.70	1.80	1.90
A5	8.10	8.40	8.70
A6	1.75		
b	0.53		0.72
b2	0.83		1.02
c	0.46		0.59
D	32.05	32.15	32.25
D1	2.10		
D2	1.85		
D3	30.65	30.75	30.85
E	12.35	12.45	12.55
e	1.70	1.80	1.90
e1	2.40	2.50	2.60
eB1	16.10	16.40	16.70
eB2	21.18	21.48	21.78
L	0.85	1.05	1.25
Dia	3.10	3.20	3.30

### 7.3 N2DIP-26L packing information

Figure 19: N2DIP-26L tube (dimensions are in mm)





## 8 Revision history

**Table 18: Document revision history**

Date	Revision	Changes
14-Dec-2015	1	Initial release.
09-Mar-2017	2	Modified features on cover page. Modified <i>Table 7: "Static"</i> , <i>Table 8: "Inductive load switching time and energy"</i> . Modified <i>Figure 2: "Switching time test circuit"</i> . Modified <i>Table 9: "Low voltage power supply"</i> , <i>Table 12: "Op-amp characteristics"</i> . Modified <i>Figure 4: "Internal structure of <math>\overline{SD}</math> and NTC"</i> . Modified <i>Figure 10: "Application circuit example"</i> . Minor text changes.
21-Mar-2017	3	Modified <i>Figure 14: "Eon switching energy vs collector current"</i> , <i>Figure 15: "Eoff switching energy vs collector current"</i> and <i>Figure 16: "Thermal impedance for IGBT"</i> Minor text changes.

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