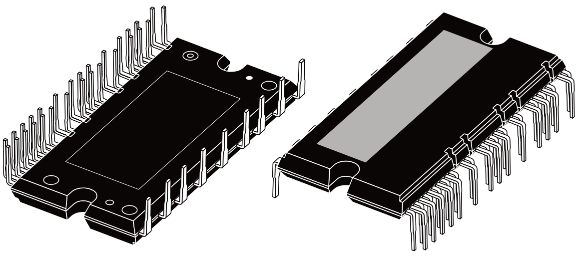
STGIPL14K60, STGIPL14K60-S

SLLIMM™ (small low-loss intelligent molded module) IPM, 3-phase inverter, 15 A, 600 V short-circuit rugged IGBT

Datasheet - production data



SDIP-38L option A

AM01193v1

Features

- IPM 15 A, 600 V 3-phase IGBT inverter bridge including control ICs for gate driving and free-wheeling diodes
- Short-circuit rugged IGBTs
- $V_{CE(sat)}$ negative temperature coefficient
- 3.3 V, 5 V, 15 V CMOS/TTL inputs comparators with hysteresis and pull down/pull up resistors
- Undervoltage lockout
- Internal bootstrap diode
- Interlocking function
- Smart shut down function
- Comparators for fault protection against overtemperature and overcurrent
- Op amps for advanced current sensing
- DBC substrate leading to low thermal resistance
- Isolation rating of 2500 V_{rms}/min
- 5 kΩ NTC for temperature control
- UL Recognized: UL1557 file E81734

Applications

- 3-phase inverters for motor drives
- Home appliances, such as washing machines, refrigerators, air conditioners and sewing machines

Description

These intelligent power modules provides a compact, high performance AC motor drive in a simple, rugged design. Combining ST proprietary control ICs with the most advanced short-circuit-rugged IGBT system technology, this device is ideal for 3-phase inverters in applications such as home appliances and air conditioners. SLLIMM™ is a trademark of STMicroelectronics.

Table 1. Device summary

Order code	Marking	Package	Packaging
STGIPL14K60	GIPL14K60	SDIP-38L option A	Tube
STGIPL14K60-S	GIPL14K60-S	SDIP-38L option B	Tube

Contents

1 Internal block diagram and pin configuration

Figure 1. Internal block diagram

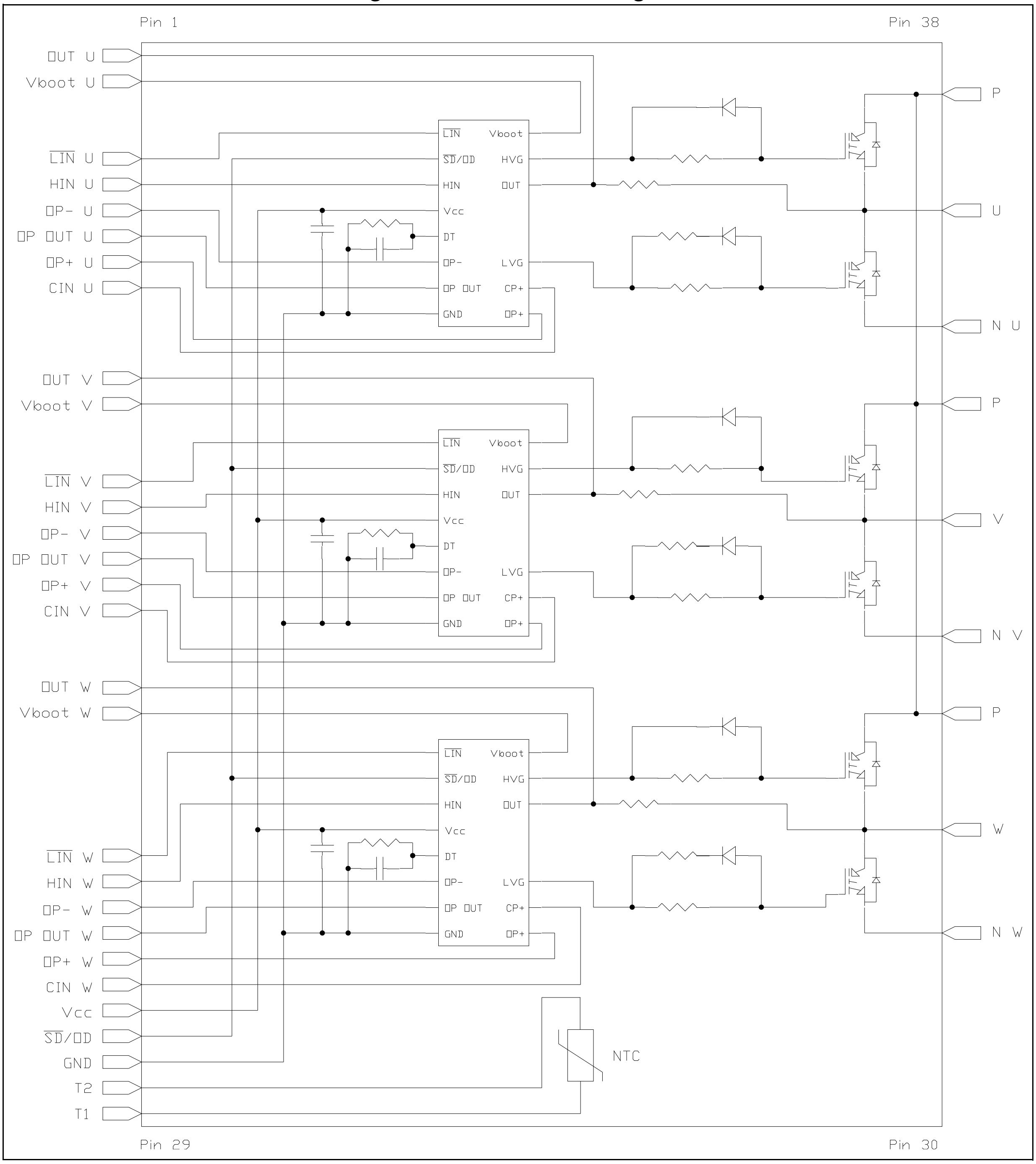


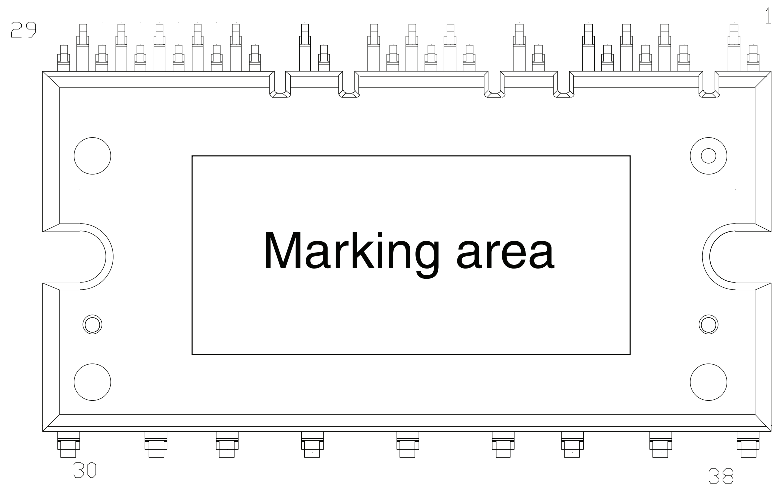
Table 2. Pin description

Pin	Symbol	Description
1	OUT_U	High side reference output for U phase
2	$V_{boot\ U}$	Bootstrap voltage for U phase
3	$\overline{LIN}_U$	Low side logic input for U phase
4	HIN_U	High side logic input for U phase
5	$OP-_U$	Op amp inverting input for U phase
6	$OP_{OUT\ U}$	Op amp output for U phase
7	$OP+_U$	Op amp non inverting input for U phase
8	CIN_U	Comparator input for U phase
9	OUT_V	High side reference output for V phase
10	$V_{boot\ V}$	Bootstrap voltage for V phase
11	$\overline{LIN}_V$	Low side logic input for V phase
12	HIN_V	High side logic input for V phase
13	$OP-_V$	Op amp inverting input for V phase
14	$OP_{OUT\ V}$	Op amp output for V phase
15	$OP+_V$	Op amp non inverting input for V phase
16	CIN_V	Comparator input for V phase
17	OUT_W	High side reference output for W phase
18	$V_{boot\ W}$	Bootstrap voltage for W phase
19	$\overline{LIN}_W$	Low side logic input for W phase
20	HIN_W	High side logic input for W phase
21	$OP-_W$	Op amp inverting input for W phase
22	$OP_{OUT\ W}$	Op amp output for W phase
23	$OP+_W$	Op amp non inverting input for W phase
24	CIN_W	Comparator input for W phase
25	V_{CC}	Low voltage power supply
26	$\overline{SD}$ / OD	Shut down logic input (active low) / open drain (comparator output)
27	GND	Ground
28	T_2	NTC thermistor terminal 2
29	T_1	NTC thermistor terminal 1
30	N_W	Negative DC input for W phase
31	W	W phase output
32	P	Positive DC input
33	N_V	Negative DC input for V phase
34	V	V phase output

Table 2. Pin description (continued)

Pin	Symbol	Description
35	P	Positive DC input
36	N_U	Negative DC input for U phase
37	U	U phase output
38	P	Positive DC input

Figure 2. Pin layout (bottom view)



2 Electrical ratings

2.1 Absolute maximum ratings

Table 3. Inverter part

Symbol	Parameter	Value	Unit
V_{PN}	Supply voltage applied between P-N_U, N_V, N_W	450	V
$V_{PN(surge)}$	Supply voltage (surge) applied between P-N_U, N_V, N_W	500	V
V_{CES}	Each IGBT collector emitter voltage (V_{IN} (1) = 0)	600	V
$\pm I_C$ (2)	Each IGBT continuous collector current at T_C = 25°C	15	A
$\pm I_{CP}$ (3)	Each IGBT pulsed collector current	30	A
P_{TOT}	Each IGBT total dissipation at T_C = 25°C	44	W
t_{scw}	Short circuit withstand time, V_{CE} = 0.5 $V_{(BR)CES}$ T_j = 125 °C, V_{CC} = V_{boot}= 15 V, $V_{IN\ (1)}$= 0÷5 V	5	µs

1. Applied between HIN_i, $\overline{LIN_i}$ and GND for i = U, V, W
2. Calculated according to the iterative formula:

$$I_C(T_C) = \frac{T_{j(max)} - T_C}{R_{thj-c} \times V_{CE(sat)(max)}(T_{j(max)}, I_C(T_C))}$$

3. Pulse width limited by max junction temperature

Table 4. Control part

Symbol	Parameter	Min.	Max.	Unit
V_{OUT}	Output voltage applied between OUT_U, OUT_V, OUT_W - GND	V_{boot} - 21	V_{boot} + 0.3	V
V_{CC}	Low voltage power supply	- 0.3	21	V
V_{CIN}	Comparator input voltage	- 0.3	V_{CC} + 0.3	V
V_{op+}	OPAMP non-inverting input	- 0.3	V_{CC} + 0.3	V
V_{op-}	OPAMP inverting input	- 0.3	V_{CC} + 0.3	V
V_{boot}	Bootstrap voltage	- 0.3	620	V
V_{IN}	Logic input voltage applied between HIN, $\overline{LIN}$ and GND	- 0.3	15	V
$V_{\overline{SD}/OD}$	Open drain voltage	- 0.3	15	V
dV_{OUT}/dt	Allowed output slew rate		50	V/ns

Table 5. Total system

Symbol	Parameter	Value	Unit
V_{ISO}	Isolation withstand voltage applied between each pin and heatsink plate (AC voltage, t = 60sec.)	2500	V
T_j	Power chips operating junction temperature	-40 to 150	°C
T_C	Module case operation temperature	-40 to 125	°C

2.2 Thermal data

Table 6. Thermal data

Symbol	Parameter	Value	Unit
$R_{th(j-c)}$	Thermal resistance junction-case single IGBT	2.8	°C/W
	Thermal resistance junction-case single diode	5	°C/W

3 Electrical characteristics

T_j = 25 °C unless otherwise specified.

Table 7. Inverter part

Symbol	Parameter	Test condition	Value			Unit
			Min.	Typ.	Max.	
$V_{CE(sat)}$	Collector-emitter saturation voltage	$V_{CC} = V_{Boot}$ = 15 V, V_{IN}(1)= 0 ÷ 5 V, I_C = 7 A	-	2.1	2.5	V
		$V_{CC} = V_{Boot}$ = 15 V, V_{IN}(1)= 0 ÷ 5 V, I_C = 7 A, T_j= 125 °C	-	1.8		
I_{CES}	Collector-cut off current (V_{IN}(1)=0 "logic state")	V_{CE} = 550 V $V_{CC} = V_{boot}$ = 15 V	-		150	µA
V_F	Diode forward voltage	V_{IN}(1) = 0 "logic state", I_C = 7 A	-		2.1	V
Inductive load switching time and energy						
t_{on}	Turn-on time	V_{DD} = 300 V, $V_{CC} = V_{boot}$ = 15 V, V_{IN}(1)= 0 ÷ 5 V, I_C = 7 A (see *Figure 3*)	-	270		ns
$t_{c(on)}$	Crossover time (on)		-	130		
t_{off}	Turn-off time		-	320		
$t_{c(off)}$	Crossover time (off)		-	110		
t_{rr}	Reverse recovery time		-	130		
E_{on}	Turn-on switching losses		-	150		µJ
E_{off}	Turn-off switching losses		-	90		

1. Applied between HINi $\overline{\text{LIN}}$i and GND for i = U, V, W ($\overline{\text{LIN}}$ inputs are active-low).

Note: *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 condition.*

Figure 3. Switching time test circuit

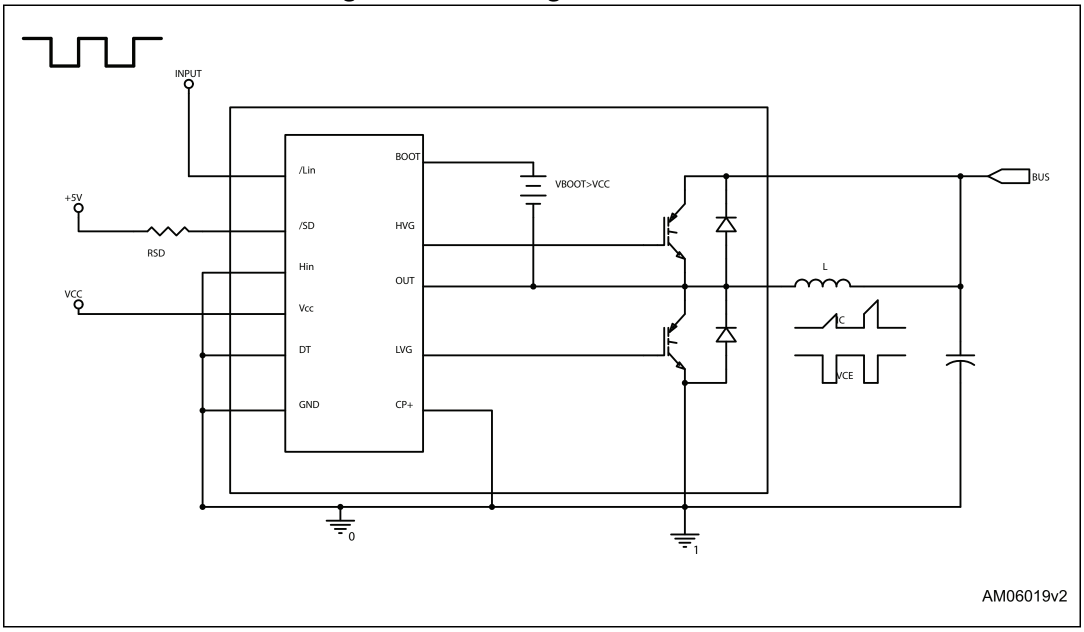


Figure 4. Switching time definition

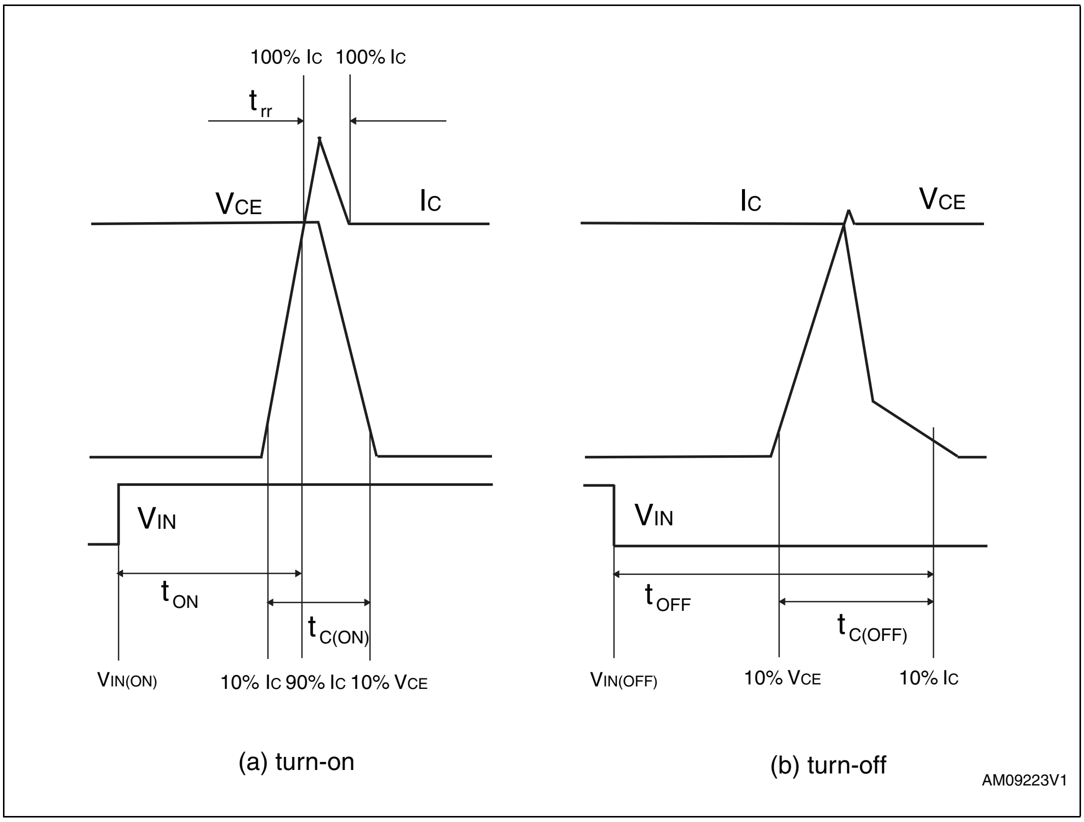


Figure 4 "Switching time definition" refers to HIN inputs (active high). For $\overline{\text{LIN}}$ inputs (active low), V_{IN} polarity must be inverted for turn-on and turn-off.

3.1 Control part

Table 8. Low voltage power supply (V_{CC} = 15 V unless otherwise specified)

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 V $\overline{SD}$/OD = 5 V; $\overline{LIN}$ = 5 V; H_{IN} = 0, C_{IN} = 0			450	µA
I_{qcc}	Quiescent current	V_{CC} = 15 V $\overline{SD}$/OD = 5 V; $\overline{LIN}$ = 5 V H_{IN} = 0, C_{IN} = 0			3.5	mA
V_{ref}	Internal comparator (CIN) reference voltage		0.5	0.54	0.58	V

Table 9. Bootstrapped voltage (V_{CC} = 15 V unless otherwise specified)

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 V $\overline{SD}$/OD = 5 V; $\overline{LIN}$ and HIN = 5 V; C_{IN} = 0		70	110	µA
I_{QBS}	V_{BS} quiescent current	V_{BS} = 15 V $\overline{SD}$/OD = 5 V; $\overline{LIN}$ and HIN = 5 V; C_{IN} = 0		200	300	µA
$R_{DS(on)}$	Bootstrap driver on resistance	LVG ON		120		W

Table 10. Logic inputs (V_{CC} = 15 V unless otherwise specified)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_{il}	Low logic level voltage		0.8		1.1	V
V_{ih}	High logic level voltage		1.9		2.25	V
I_{HINh}	HIN logic “1” input bias current	HIN = 15 V	110	175	260	µA
I_{HINl}	HIN logic “0” input bias current	HIN = 0 V			1	µA
I_{LINl}	$\overline{LIN}$ logic “1” input bias current	$\overline{LIN}$ = 0 V	3	6	20	µA
I_{LINh}	$\overline{LIN}$ logic “0” input bias current	$\overline{LIN}$ = 15 V			1	µA
I_{SDh}	$\overline{SD}$ logic “0” input bias current	$\overline{SD}$ = 15 V	30	120	300	µA

Table 10. Logic inputs (V_{CC} = 15 V unless otherwise specified) (continued)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
I_{SDI}	$\overline{SD}$ logic “1” input bias current	$\overline{SD}$ = 0 V			3	µA
Dt	Dead time	see *Figure 9*		600		ns

Table 11. OPAMP characteristics (V_{CC} = 15 V unless otherwise specified)

Symbol	Parameter	Test condition	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 (1)			100	200	nA
$ς_{icm}$	Input common mode voltage range		0			V
$ς_{OL}$	Low level output voltage	R_L = 10 kΩ to V_{CC}		75	150	mV
$ς_{OH}$	High level output voltage	R_L = 10 kΩ to GND	14	14.7		V
I_o	Output short circuit current	Σουρχε, $ς_{ιδ}$ = +1; $ς_ο$ = 0 ς	16	30		mA
		Sink, $ς_{ιδ}$ = -1; $ς_ο$ = $ς_{XX}$	50	80		mA
SR	Slew rate	V_i = 1 ÷ 4 V; C_L = 100 pF; unity gain	2.5	3.8		V/µs
GBWP	Gain bandwidth product	V_o = 7.5 V	8	12		MHz
A_{vd}	Large signal voltage gain	R_L = 2 kΩ	70	85		dB
SVR	Supply voltage rejection ratio	vs. V_{CC}	60	75		dB
CMRR	Common mode rejection ratio		55	70		dB

1. The direction of input current is out of the IC.

Table 12. Sense comparator characteristics (V_{CC} = 15 V unless otherwise specified)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$I_{ib(i)}$	Input bias current	$V_{CIN(i)}$ =1 V, i= U, V o W	-		3	µA
V_{ol}	Open-drain low-level output voltage	I_{od} = 3 mA	-		0.5	V
t_{d_comp}	Comparator delay	$\overline{SD}$/OD pulled to 5 V through 100 kΩ resistor	-	90	130	ns
SR	Slew rate	C_L = 180 pF; R_{pu} = 5 kΩ	-	60		V/µsec
t_{sd}	Shut down to high / low side driver propagation delay	V_{OUT} = 0, V_{boot} = V_{CC}, V_{IN} = 0 to 3.3 V	50	125	200	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_i	50	200	250	

Table 13. Truth table

Condition	Logic input (V_I)			Output	
	$\overline{SD}$/OD	LIN	HIN	LVG	HVG
Shutdown enable half-bridge 3-state	L	X	X	L	L
Interlocking half-bridge 3-state	H	L	H	L	L
0 ''logic state" half-bridge 3-state	H	H	L	L	L
1 "logic state" low side direct driving	H	L	L	H	L
1 "logic state" high side direct driving	H	H	H	L	H

Note: X: don't care

.

Figure 5. Maximum $I_{C(RMS)}$ current vs. switching frequency (1)

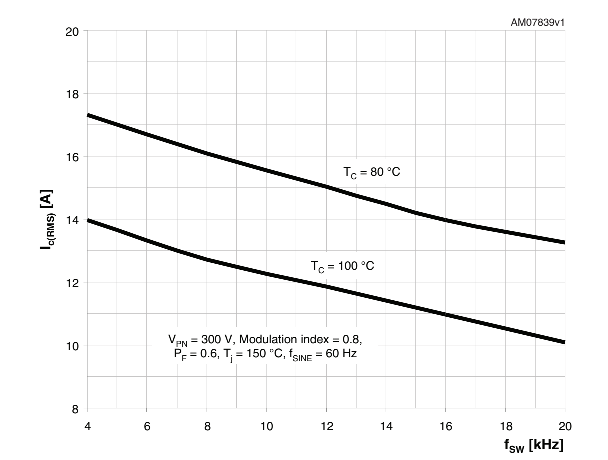
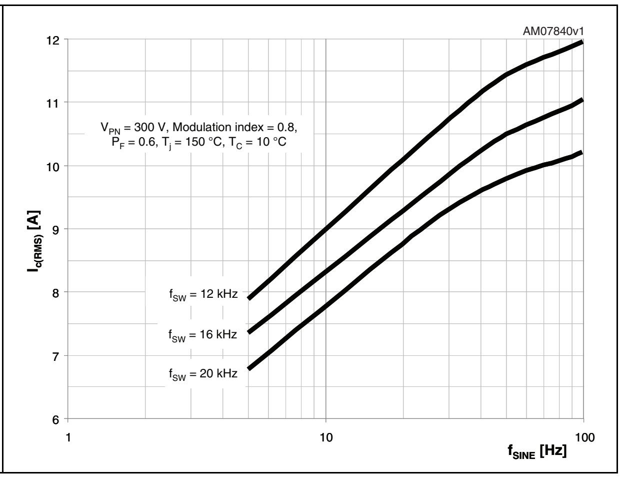


Figure 6. Maximum $I_{C(RMS)}$ current vs. f_{sine}(1)



1. Simulated curves refer to typical IGBT parameters and maximum R_{thj-c}.

3.1.1 NTC thermistor

Table 14. NTC thermistor

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit.
R_{25}	Resistance	T = 25°C		5		kΩ
R_{125}	Resistance	T = 125°C		300		Ω
B	B-constant	T = 25°C to 85°C		3340		K
T	Operating temperature		-40		125	°C

Equation 1: resistance variation vs. temperature

$$R(T) = R_{25} \cdot e^{B\left(\frac{1}{T} - \frac{1}{298}\right)}$$

Where T are temperatures in Kelvin.

Figure 7. NTC resistance vs. temperature

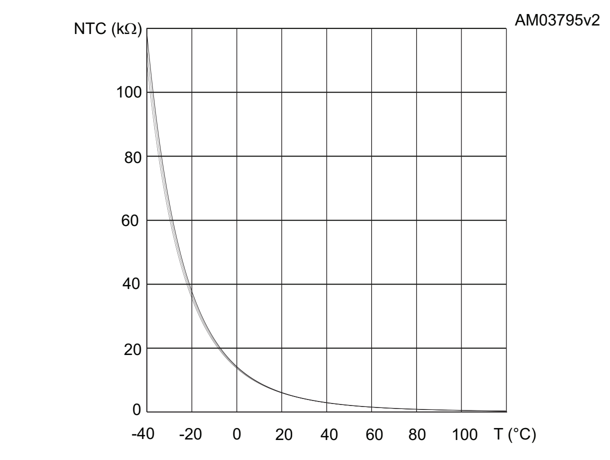
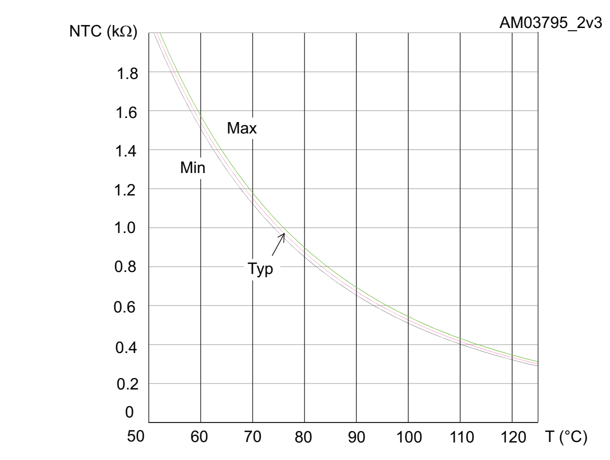
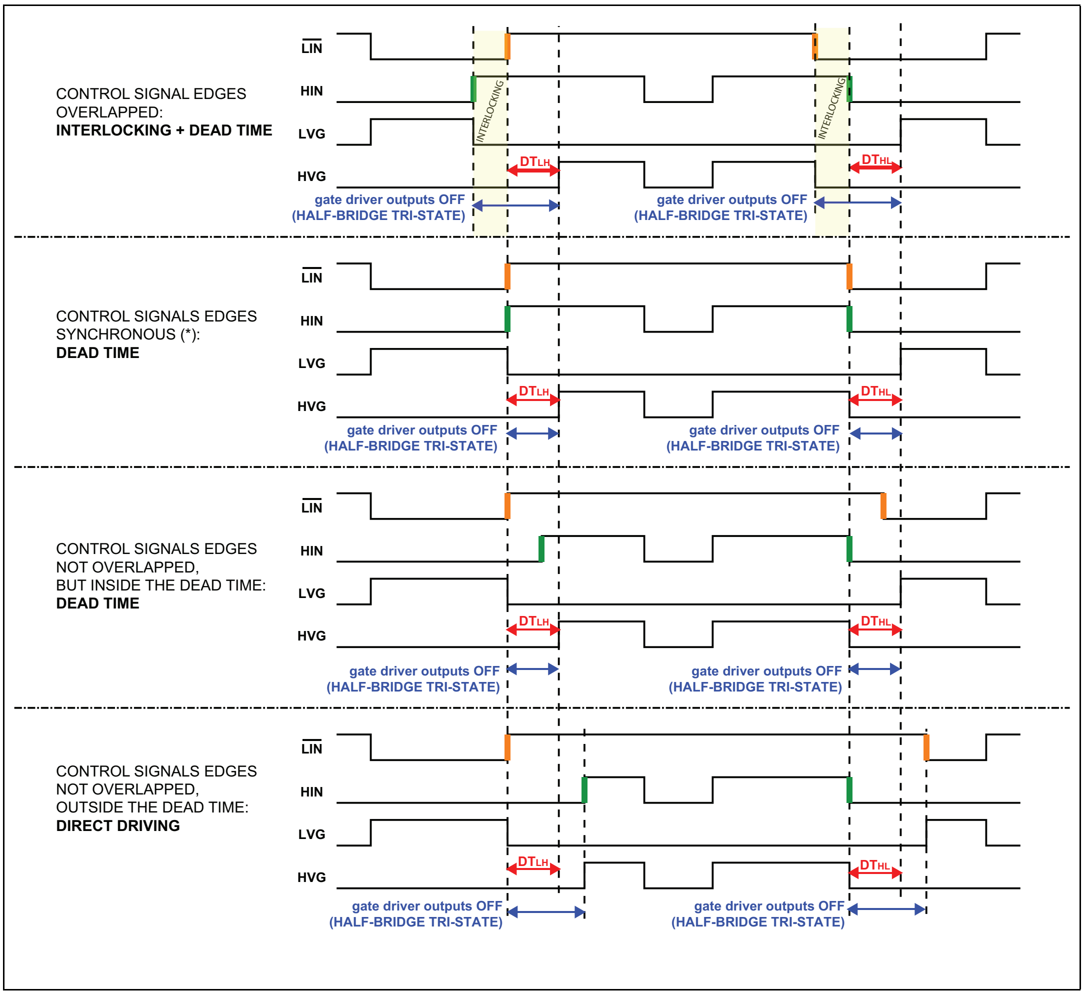


Figure 8. NTC resistance vs. temperature zoom



3.2 Waveforms definitions

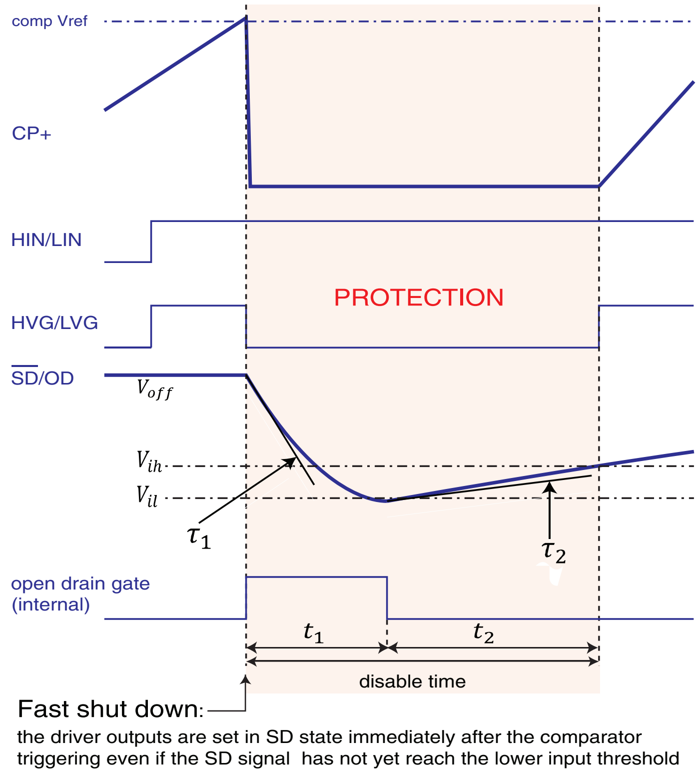
Figure 9. Dead time and interlocking waveforms definitions



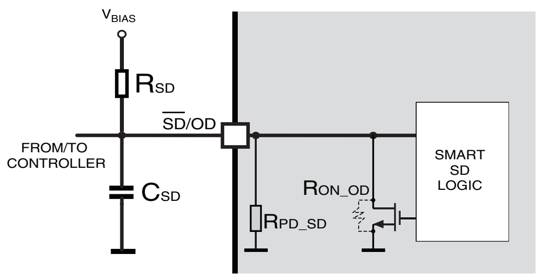
4 Smart shutdown function

The devices integrate 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, available on pin (CIN), can be connected to an external shunt resistor in order to implement a simple over-current protection function. When the comparator triggers, the device is set in shutdown state and both its outputs are set to low-level leading the halfbridge in tri-state. In the common overcurrent protection architectures the comparator output is usually connected to the shutdown input through a RC network, in order to provide a mono-stable circuit, which implements a protection time that follows the fault condition. Our smart shutdown architecture allows to immediately turn-off the output gate driver in case of overcurrent, the fault signal has a preferential path which directly switches off the outputs. The time delay between the fault and the outputs turn-off is no more dependent 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 SD/OD) is turned on by the internal logic which holds it on until the shutdown voltage is lower than the logic input lower threshold (Vil). Finally, the smart shutdown function provides the possibility to increase the real disable time without increasing the constant time of the external RC network.

Figure 10. Smart shutdown timing waveforms



SHUT DOWN CIRCUIT



An approximation of the disable time is given by:

$$t_1 \cong \tau_1 \cdot ln\left(\frac{V_{off} - V_{on}}{V_{il} - V_{on}}\right)$$

$$t_2 \cong \tau_2 \cdot ln\left(\frac{V_{il} - V_{off}}{V_{ih} - V_{off}}\right)$$

where:

$$\tau_1 = \left(R_{ON\_OD} // R_{SD}\right) \cdot C_{SD}$$

$$\tau_2 = \left(R_{PD\_SD} // R_{SD}\right) \cdot C_{SD}$$

$$V_{on} = \frac{R_{ON\_OD}}{R_{ON\_OD} + R_{SD}} \cdot V_{BIAS}$$

$$V_{off} = \frac{R_{PD\_SD}}{R_{PD\_SD} + R_{SD}} \cdot V_{BIAS}$$

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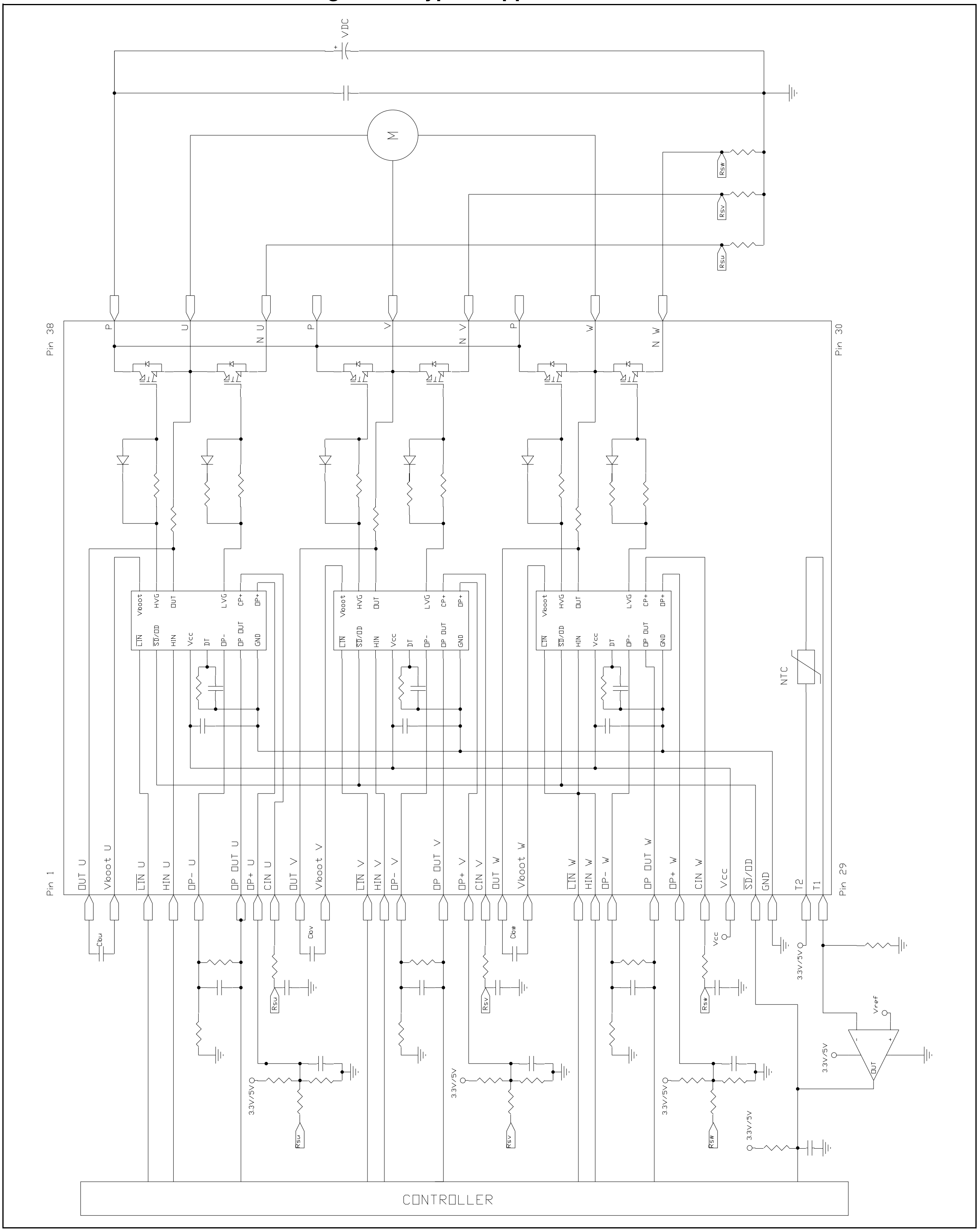
Please refer to *Table 12* for internal propagation delay time details.

5 Applications information

Figure 11. Typical application circuit



5.1 Recommendations

- Input signal HIN is active high logic. A 85kΩ (typ.) pull down resistor is built-in for each high side input. If an external RC filter is used, for noise immunity, pay attention to the variation of the input signal level.
- Input signal $\overline{\text{LIN}}$ is active low logic. A 720 kΩ (typ.) pull-up resistor, connected to an internal 5 V regulator through a diode, is built-in for each low side input.
- To prevent the input signals oscillation, the wiring of each input should be as short as possible.
- By integrating an application specific type HVIC inside the module, direct coupling to MCU terminals without any opto-coupler is possible.
- Each capacitor should be located as nearby the pins of IPM as possible.
- Low inductance shunt resistors should be used for phase leg current sensing.
- Electrolytic bus capacitors should be mounted as close to the module bus terminals as possible. Additional high frequency ceramic capacitor mounted close to the module pins will further improve performance.
- The $\overline{\text{SD}}$/OD signal should be pulled up to 5 V / 3.3 V with an external resistor (see *Section 4: Smart shutdown function* for detailed info).

Table 15. Recommended operating conditions

Symbol	Parameter	Conditions	Value			Unit
			Min.	Typ.	Max.	
V_{PN}	Supply Voltage	Applied between P-Nu, Nv, Nw		300	400	V
V_{CC}	Control supply voltage	Applied between V_{CC}-GND	13.5	15	18	V
V_{BS}	High side bias voltage	Applied between V_{BOOTi}-OUT_i for i = U, V, W	13		18	V
t_{dead}	Blanking time to prevent Arm-short	For each input signal	1			µs
f_{PWM}	PWM input signal	-40°C < T_c < 100°C -40°C < T_j < 125°C			20	kHz
T_C	Case operation temperature				100	°C

Note: For further details refer to AN3338.

6 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*. ECOPACK® is an ST trademark.

Please refer to dedicated technical note TN0107 for mounting instructions.

Table 16. SDIP-38L option A mechanical data

Dimensions	mm.		
	Min.	Typ.	Max.
A	49.10	49.60	50.10
A1	1.10	1.30	1.50
A2	1.40	1.60	1.80
A3	44.10	44.60	45.10
B	24.00	24.50	25.00
B1	11.25	11.85	12.45
B2	27.10	27.60	28.10
B3	28.60	29.10	29.60
C	5.00	5.40	6.00
C1	6.50	7.00	7.50
C2	10.35	10.85	11.35
e	1.10	1.30	1.50
e1	3.20	3.40	3.60
e2	5.80	6.00	6.20
e3	4.60	4.80	5.00
e4	5.60	5.80	6.00
e5	6.30	6.50	6.70
e6	4.50	4.70	4.90
D		38.10	
D1		5.75	
E		11.80	
E1		2.15	
F	0.85	1.00	1.15
F1	0.35	0.50	0.65
R	1.55	1.75	1.95
T	0.45	0.55	0.65
V	0°		6°

Figure 12. SDIP-38L option A drawing dimensions

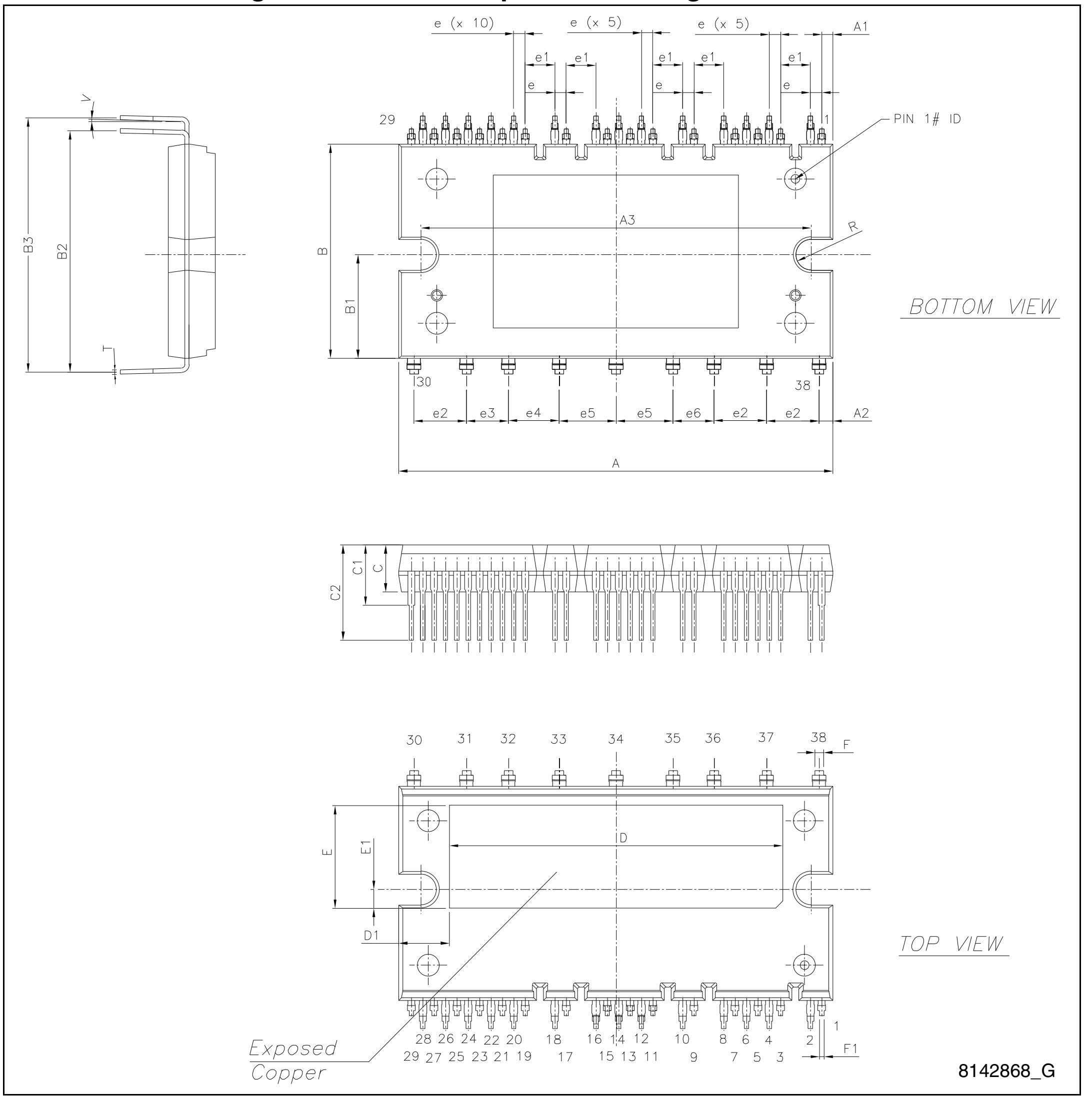


Table 17. SDIP-38L option B mechanical data

Dimensions	mm.		
	Min.	Typ.	Max.
A	49.10	49.60	50.10
A1	1.10	1.30	1.50
A2	1.40	1.60	1.80
A3	44.10	44.60	45.10
B	24.00	24.50	25.00
B1	11.25	11.85	12.45
B2	27.10	27.60	28.10
B3	29.65	30.15	30.65
C	5.00	5.40	6.00
C2	8.15	8.35	8.55
e	1.10	1.30	1.50
e1	3.20	3.40	3.60
e2	5.80	6.00	6.20
e3	4.60	4.80	5.00
e4	5.60	5.80	6.00
e5	6.30	6.50	6.70
e6	4.50	4.70	4.90
D		38.10	
D1		5.75	
E		11.80	
E1		2.15	
F	0.85	1.00	1.15
F1	0.35	0.50	0.65
R	1.55	1.75	1.95
T	0.45	0.55	0.65
V	0°		6°

Figure 13. SDIP-38L option B drawing dimensions

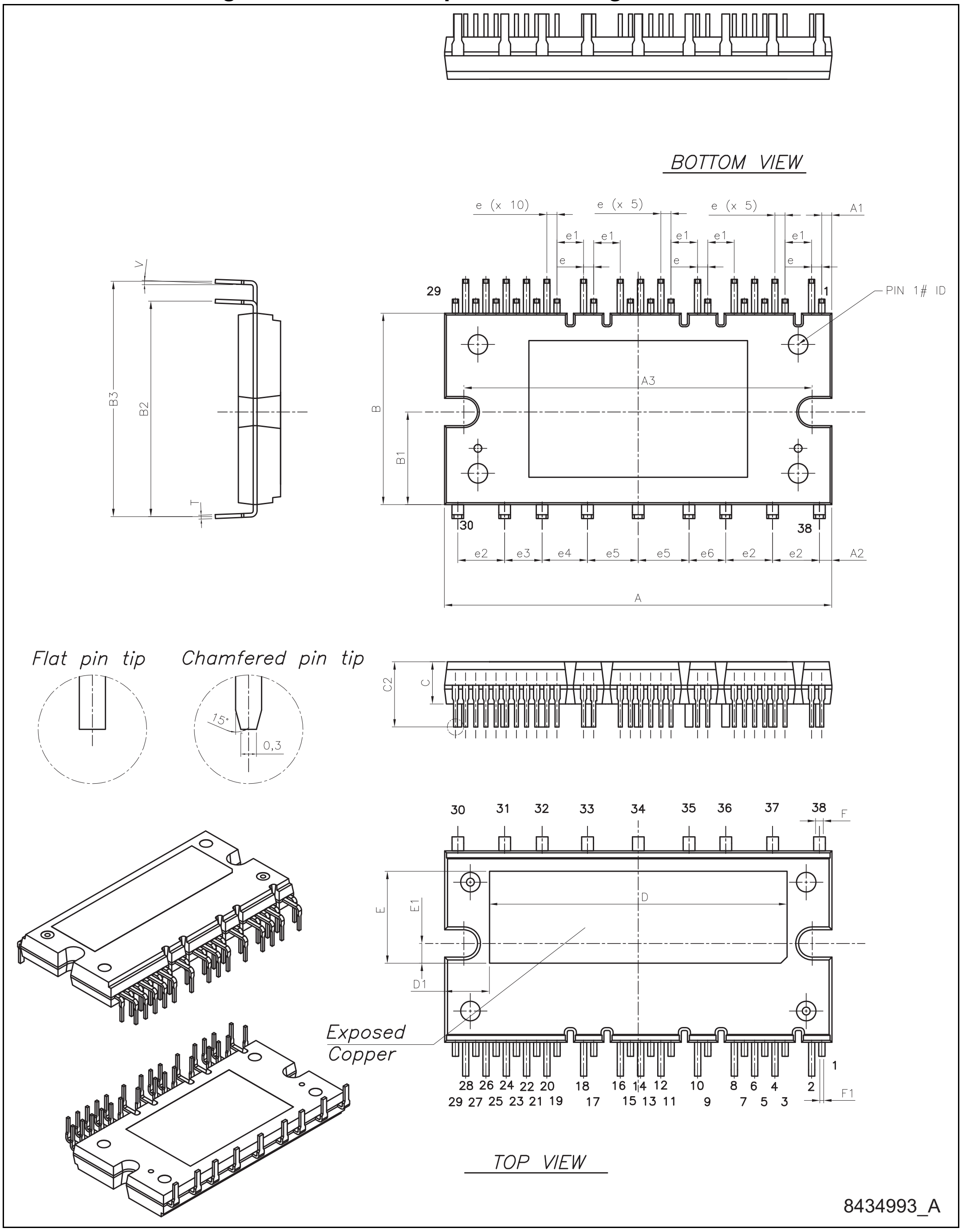


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Figure 14. SDIP-38L shipping tube type A (dimensions are in mm.)

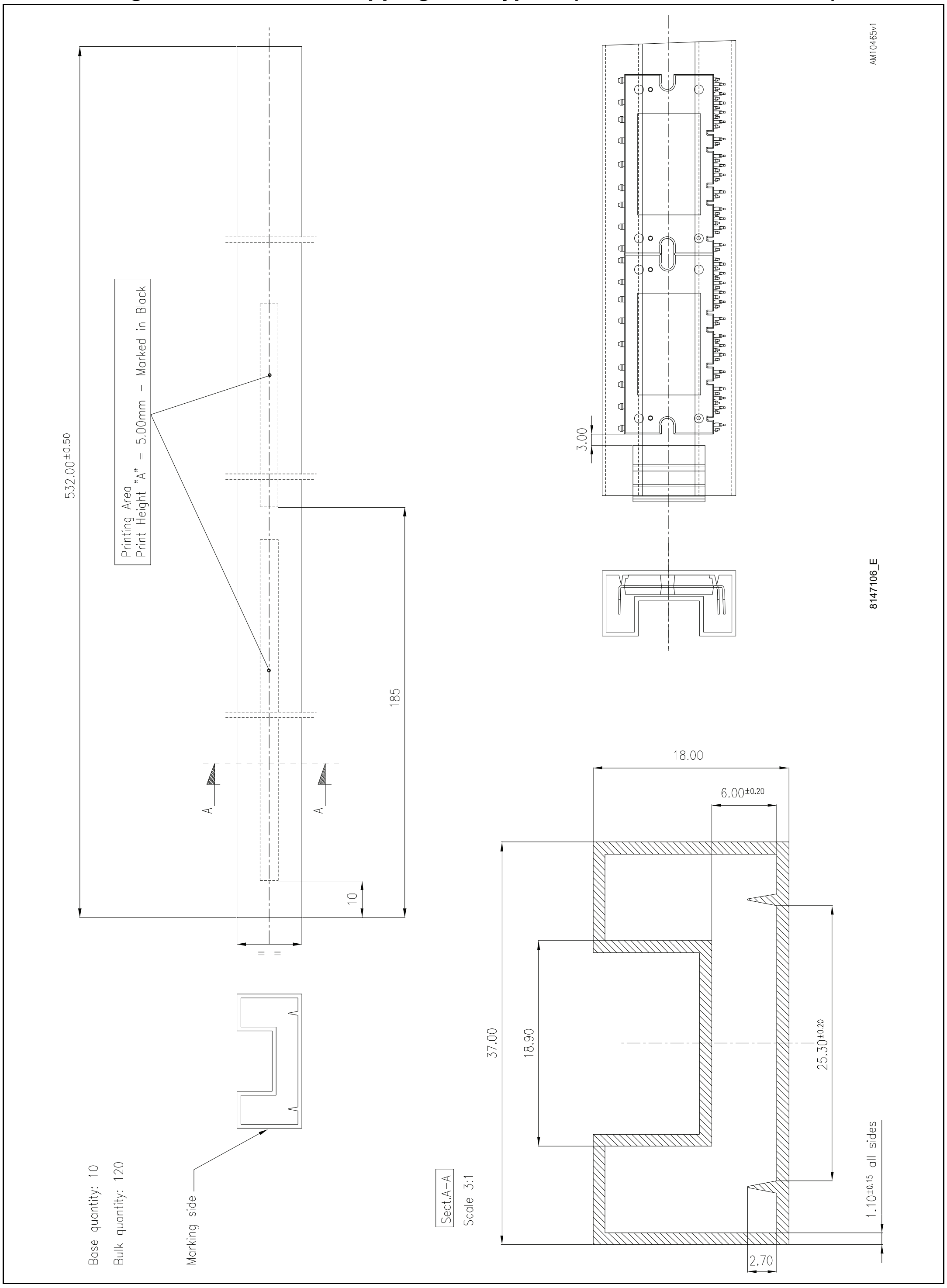
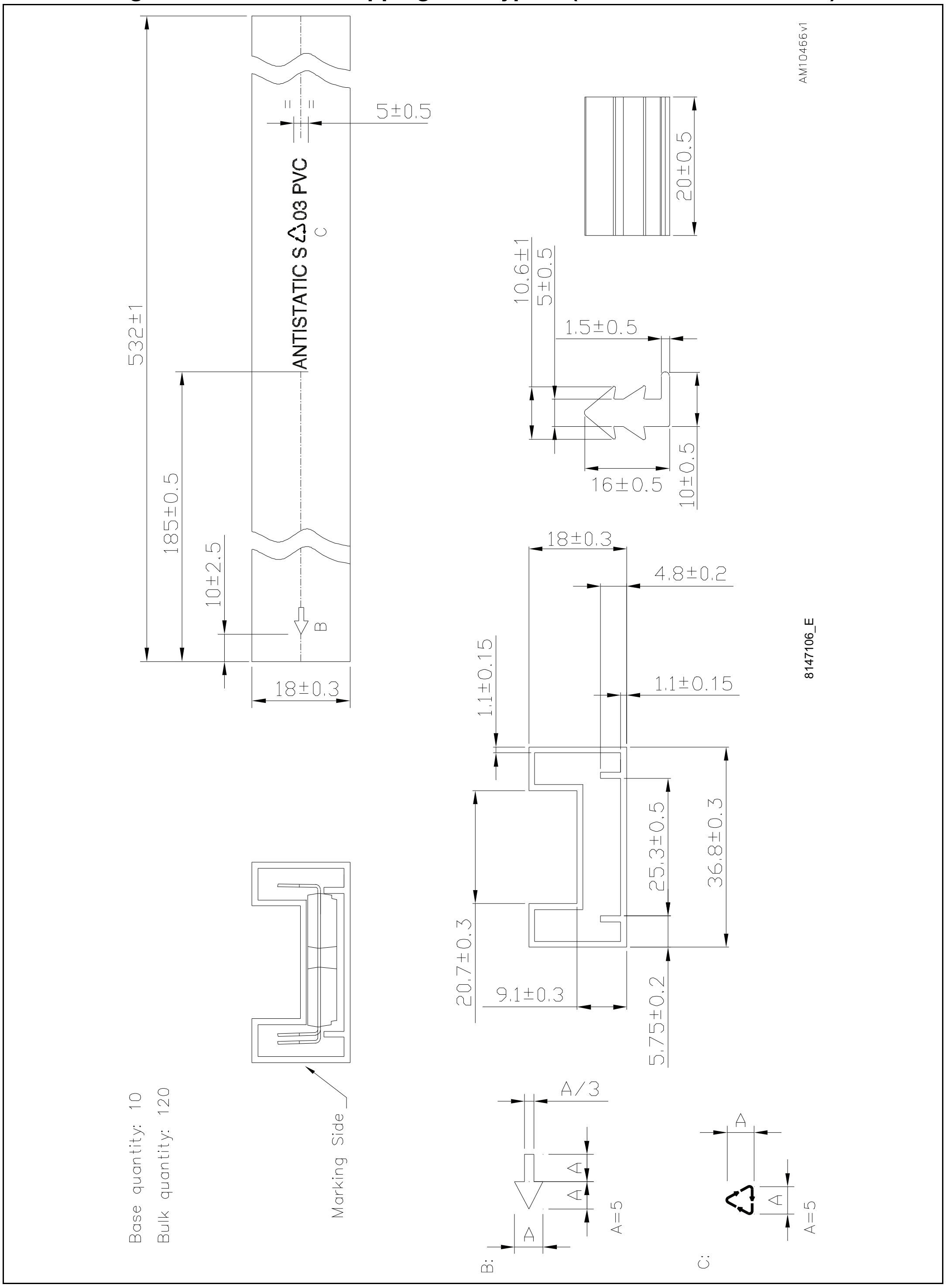


Figure 15. SDIP-38L shipping tube type B (dimensions are in mm.)



8 Revision history

Table 18. Document revision history

Date	Revision	Changes
16-Apr-2009	1	Initial release
29-Mar-2010	2	Inserted *Figure 5*, *Figure 6* and *Section 4: Smart shutdown function*. Updated *Section 3.1: Control part* and package mechanical data, *Section 6*. Minor text changes to improve readability.
14-Jun-2010	3	Document status promoted from preliminary data to datasheet. Updated *Table 7: Inverter part*, *Figure 5: Maximum IC(RMS) current vs. switching frequency* and *Figure 6: Maximum IC(RMS) current vs. fsine(1)*.
21-Sep-2010	4	Updated: *Table 3*, *5*, *8*, *9*, *10* and *12*. Modified: *Figure 5* and *Figure 6*.
09-Mar-2011	5	Updated title with SLLIMM™ in cover page, added SDIP-38L tube dimensions *Figure 14*.
04-Nov-2011	6	Updated title with SLLIMM™ (small low-loss intelligent molded module) IPM, 3-phase inverter - 15 A, 600 V short-circuit rugged IGBT in cover page and SDIP-38L mechanical data *Table 16 on page 19*, *Figure 12*.
28-Aug-2012	7	Modified: Min. and Max. value *Table 4 on page 6*. Updated: *Figure 14*. Added: *Figure 15*.
04-Mar-2013	8	Added: *Figure 7* and *Figure 8*
13-Mar-2013	9	Modified: *Figure 8 on page 13*
17-Jun-2013	10	Updated: *Figure 9: Dead time and interlocking waveforms definitions*.
17-Oct-2013	11	Added device STGIPL14K60-S and modified *Table 1: Device summary* accordingly. Updated *Section 6: Package information* and *Section 7: Packaging mechanical data*. Minor text changes.