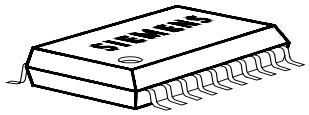
Smart High-Side Power Switch
Four Channels: 4 x 140mΩ
Status Feedback

Product Summary

Operating Voltage	$V_{bb(on)}$	5.5 ...41V	
Active channels		one	four parallel
On-state Resistance	R_{ON}	140mΩ	35mΩ
Nominal load current	$I_{L(NOM)}$	2.5A	5.5A
Current limitation	$I_{L(SCr)}$	8A	8A

Package

P-DSO-20



General Description

- N channel vertical power MOSFET with charge pump, ground referenced CMOS compatible input and diagnostic feedback, monolithically integrated in Smart SIPMOS® technology.
- Fully protected by embedded protection functions

Applications

- µC compatible high-side power switch with diagnostic feedback for 12V and 24V grounded loads
- All types of resistive, inductive and capacitve loads
- Most suitable for loads with high inrush currents, so as lamps
- Replaces electromechanical relays, fuses and discrete circuits

Basic Functions

- Very low standby current
- CMOS compatible input
- Improved electromagnetic compatibility (EMC)
- Fast demagnetization of inductive loads
- Stable behaviour at undervoltage
- Wide operating voltage range
- Logic ground independent from load ground

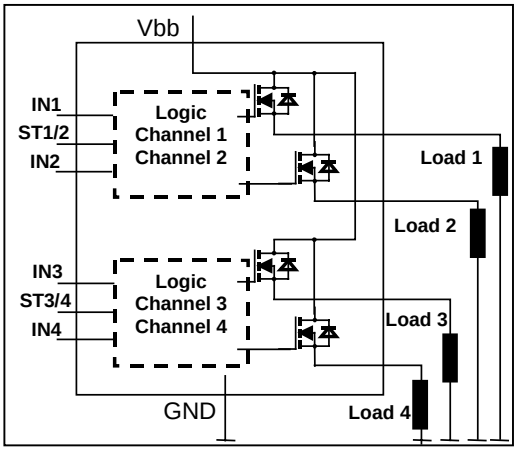
Protection Functions

- Short circuit protection
- Overload protection
- Current limitation
- Thermal shutdown
- Overvoltage protection (including load dump) with external resistor
- Reverse battery protection with external resistor
- Loss of ground and loss of V_{bb} protection
- Electrostatic discharge protection (ESD)

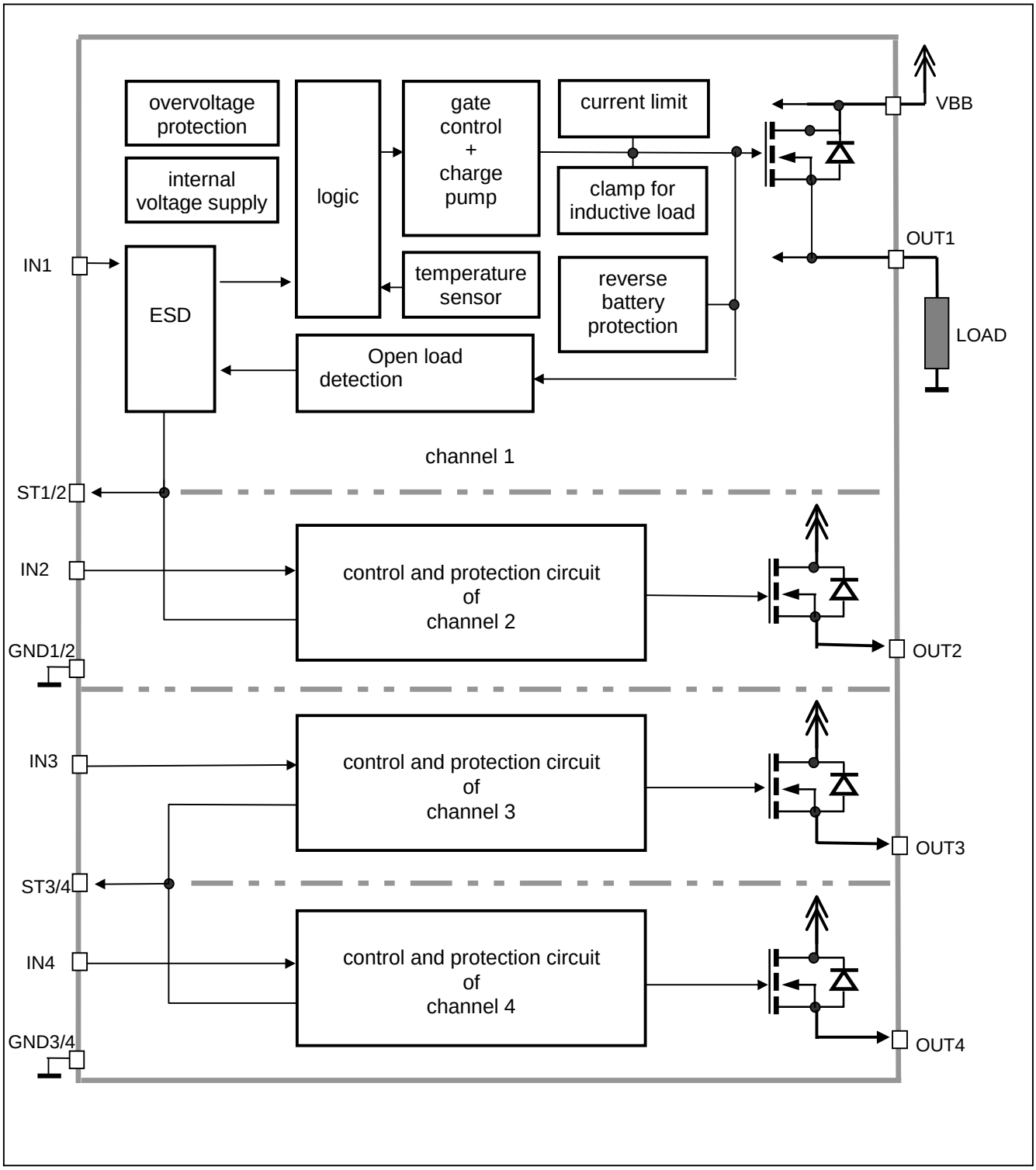
Diagnostic Function

- Diagnostic feedback with open drain output
- Open load detection in OFF-state
- Feedback of thermal shutdown in ON-state

Block Diagram



Functional diagram

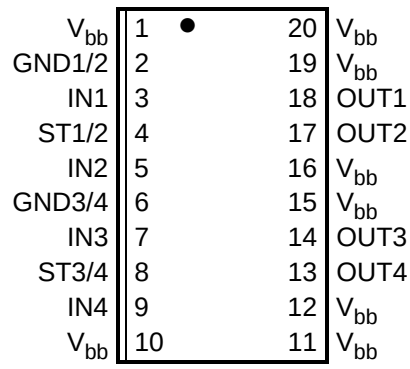


Pin Definitions and Functions

Pin	Symbol	Function
1,10, 11,12, 15,16, 19,20	V_{bb}	**Positive power supply voltage**. Design the wiring for the simultaneous max. short circuit currents from channel 1 to 2 and also for low thermal resistance
3	IN1	**Input 1,2, 3,4** activates channel 1,2,3,4 in case of logic high signal
5	IN2	
7	IN3	
9	IN4	
18	OUT1	**Output 1,2,3,4** protected high-side power output of channel 1,23,4. Design the wiring for the max. short circuit current
17	OUT2	
14	OUT3	
13	OUT4	
4	ST1/2	**Diagnostic feedback 1/2,3/4** of channel 1,2,3,4 open drain, low on failure
8	ST3/4	
2	GND1/2	**Ground** of chip 1 (channel 1,2)
6	GND3/4	**Ground** of chip 2 (channel 3,4)

Pin configuration

(top view)



Maximum Ratings at T_j = 25°C unless otherwise specified

Parameter	Symbol	Values	Unit
Supply voltage (overvoltage protection see page 5)	V_{bb}	42	V
Supply voltage for full short circuit protection $T_{j,start}$ = -40 ...+150°C	V_{bb}	36	V
Load current (Short-circuit current, see page 6)	I_L	self-limited	A
Load dump protection[1] $V_{LoadDump} = V_A + V_s$, V_A = 13.5 V R_I[2] = 2 Ω, t_d = 200 ms; IN = low or high, each channel loaded with R_L = tbd Ω,	$V_{Load\,dump}$[3]	60	V
Operating temperature range	T_j	-40 ...+150	°C
Storage temperature range	T_{stg}	-55 ...+150	
Power dissipation (DC)[4] T_a = 25°C:	P_{tot}	3.5	W
(all channels active) T_a = 85°C:		1.7	
Maximal switchable inductance, single pulse V_{bb} = 12V, $T_{j,start}$ = 150°C[4],			
I_L = 3.3 A, E_{AS} = tbd mJ, 0 Ω one channel:	Z_L	tbd	mH
I_L = 4.7 A, E_{AS} = tbd mJ, 0 Ω two parallel channels:		tbd	
I_L = 7.3 A, E_{AS} = tbd mJ, 0 Ω four parallel channels:		tbd	
see diagrams on page 10			
Electrostatic discharge capability (ESD) IN:	V_{ESD}	1.0	kV
(Human Body Model) ST:		4.0	
out to all other pins shorted:		8.0	
acc. MIL-STD883D, method 3015.7 and ESD assn. std. S5.1-1993 R=1.5kΩ; C=100pF			
Input voltage (DC)	V_{IN}	-10 ... +16	V
Current through input pin (DC)	I_{IN}	±5.0	mA
Current through status pin (DC)	I_{ST}	±5.0	
see internal circuit diagram page 9			

Thermal Characteristics

Parameter and Conditions	Symbol	Values			Unit
		min	typ	Max	
Thermal resistance					
junction - soldering point[4],[5] each channel:	R_{thjs}	--	--	tbd	K/W
junction - ambient[4] one channel active:	R_{thja}	--	44	--	
all channels active:		--	35	--	

1) Supply voltages higher than $V_{bb(AZ)}$ require an external current limit for the GND and status pins (a 150Ω resistor for the GND connection is recommended.

2) R_I = internal resistance of the load dump test pulse generator

3) $V_{Load\,dump}$ is setup without the DUT connected to the generator per ISO 7637-1 and DIN 40839

4) Device on 50mm*50mm*1.5mm epoxy PCB FR4 with 6cm² (one layer, 70µm thick) copper area for V_{bb} connection. PCB is vertical without blown air. See page 14

5) Soldering point: upper side of solder edge of device pin 15. See page 14

Electrical Characteristics

Parameter and Conditions, each of the two channels at T_j = -40...+150°C, V_{bb} = 12 V unless otherwise specified	**Symbol**	**Values**			**Unit**
		min	typ	Max	
Load Switching Capabilities and Characteristics					
On-state resistance (V_{bb} to OUT); I_L = 2 A, $V_{bb} \geq$ 7V each channel, T_j = 25°C: T_j = 150°C: two parallel channels, T_j = 25°C: four parallel channels, T_j = 25°C: see diagram, page 11	R_{ON}	-- -- -- --	120 240 60 30	140 280 70 35	mΩ
Nominal load current one channel active: two parallel channels active: four parallel channels active: Device on PCB[6], T_a = 85°C, $T_j \leq$ 150°C	$I_{L(NOM)}$	2.3 3.3 5.2	2.5 3.5 5.5	-- -- --	A
Output current while GND disconnected or pulled up; Vbb = 30 V, V_{IN} = 0, see diagram page 9; (not tested specified by design)	$I_{L(GNDhigh)}$	--	--	2	mA
Turn-on time[7] IN ⌐‾ to 90% V_{OUT}: Turn-off time IN ‾⌐ to 10% V_{OUT}: R_L = 12 Ω	t_{on} t_{off}	-- --	80 70	200 150	µs
Slew rate on[7] 10 to 30% V_{OUT}, R_L = 12 Ω:	dV/dt_{on}	tbd	--	tbd	V/µs
Slew rate off[7] 70 to 40% V_{OUT}, R_L = 12 Ω:	$-dV/dt_{off}$	tbd	--	tbd	V/µs
Operating Parameters					
Operating voltage[8]	$V_{bb(on)}$	3.2	--	40	V
Undervoltage shutdown	$V_{bb(under)}$	1.8	--	3.2	V
Undervoltage restart	$V_{bb(u\ rst)}$	--	--	5.5	V
Undervoltage hysteresis $\Delta V_{bb(under)} = V_{bb(u\ rst)} - V_{bb(under)}$	$\Delta V_{bb(under)}$	--	1	--	V
Overvoltage protection[9] T_j =-40°C: I_{bb} = 40 mA T_j =25...150°C:	$V_{bb(AZ)}$	41 43	-- 47	-- 52	V
Standby current[10] T_j =-40°C...25°C: V_{IN} = 0; see diagram page 10 T_j =150°C:	$I_{bb(off)}$	-- --	9 --	16 20	µA
Off-State output current (included in $I_{bb(off)}$) V_{IN} = 0; each channel	$I_{L(off)}$	--	1	6	µA

6) Device on 50mm*50mm*1.5mm epoxy PCB FR4 with 6cm² (one layer, 70µm thick) copper area for V_{bb} connection. PCB is vertical without blown air. See page 14

7) See timing diagram on page 12.

8) After $V_{bb(on)}$ rising above $V_{bb(u\ rst)}$

9) Supply voltages higher than $V_{bb(AZ)}$ require an external current limit for the GND and status pins (a 150Ω resistor for the GND connection is recommended). See also $V_{ON(CL)}$ in table of protection functions and circuit diagram on page 9.

10) Measured with load; for the whole device; all channels off

Parameter and Conditions, each of the two channels at T_j = -40...+150°C, V_{bb} = 12 V unless otherwise specified	**Symbol**	**Values**			**Unit**
		min	typ	Max	
Operating current [11], V_{IN} = 5V, $I_{GND} = I_{GND1} + I_{GND2}$, one channel on:	I_{GND}	--	1.2	2.4	mA
two channels on:		--	3	4.8	
Protection Functions					
Current limit, (see timing diagrams, page 12)					
T_j =-40°C:	$I_{L(lim)}$	10	12.5	15	A
T_j =25°C:		8	10	12	
T_j =+150°C:		6	8	10	
Repetitive short circuit current limit, $T_j = T_{jt}$ each channel	$I_{L(SCr)}$	--	8	--	A
two,three or four parallel channels		--	8	--	
(see timing diagrams, page 12)					
Initial short circuit shutdown time $T_{j,start}$ =25°C:	$t_{off(SC)}$	--	tbd	--	ms
(see timing diagrams on page 12)					
Output clamp (inductive load switch off)[12]					V
at $V_{ON(CL)} = V_{bb} - V_{OUT}$, I_L= 40 mA T_j =-40°C:	$V_{ON(CL)}$	41	--	--	
T_j =25°C...150°C:		43	47	52	
Thermal overload trip temperature	T_{jt}	155	--	--	°C
Thermal hysteresis	ΔT_{jt}	--	10	--	K
Reverse Battery					
Reverse battery voltage [13]	$-V_{bb}$	--	--	tbd	V
Drain-source diode voltage ($V_{out} > V_{bb}$) I_L = - 2.0 A, T_j = +150°C	$-V_{ON}$	--	750	--	mV

11) Add I_{ST}, if $I_{ST} > 0$

12) If channels are connected in parallel, output clamp is usually accomplished by the channel with the lowest $V_{ON(CL)}$

13) Requires a 150 Ω resistor in GND connection. The reverse load current through the intrinsic drain-source diode has to be limited by the connected load. Power dissipation is higher compared to normal operating conditions due to the voltage drop across the drain-source diode. The temperature protection is not active during reverse current operation! Input and Status currents have to be limited (see max. ratings page 4 and circuit page 9).

Parameter and Conditions, each of the two channels at T_j = -40...+150°C, V_{bb} = 12 V unless otherwise specified	**Symbol**	**Values**			**Unit**
		min	typ	Max	
Diagnostic Characteristics					
Open load detection voltage	$V_{OUT(OL)}$	2	3	4	V
Input and Status Feedback[14)]					
Input resistance (see circuit page 9)	R_I	2.5	3.5	6.0	kΩ
Input turn-on threshold voltage	$V_{IN(T+)}$	--	--	2.5	V
Input turn-off threshold voltage	$V_{IN(T-)}$	1.0	--	--	V
Input threshold hysteresis	$\Delta V_{IN(T)}$	--	0.3	--	V
Off state input current V_{IN} = 0.4 V:	$I_{IN(off)}$	5	--	20	µA
On state input current V_{IN} = 5 V:	$I_{IN(on)}$	15	30	60	µA
Status output (open drain)					
Zener limit voltage I_{ST} = +1.6 mA:	$V_{ST(high)}$	5.4	--	--	V
ST low voltage I_{ST} = +1.6 mA:	$V_{ST(low)}$	--	--	0.6	

14) If ground resistors R_{GND} are used, add the voltage drop across these resistors.

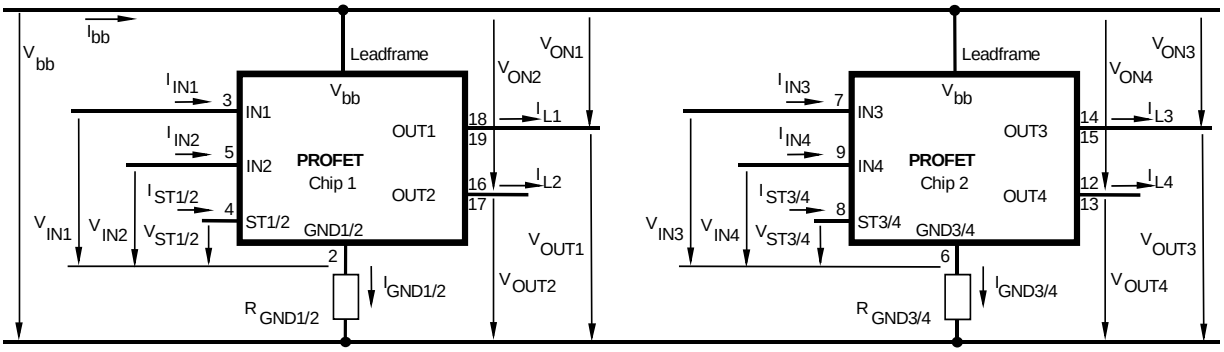
Truth Table

Channel 1 and 2 / Channel 3 and 4 (equivalent to channel 1 and 2)		Chip 1 / Chip 2	IN1 / IN3	IN2 / IN4	OUT1 / OUT3	OUT2 / OUT4	ST1/2 / ST3/4
Normal operation			**L**	**L**	**L**	**L**	**H**
			L	**H**	**L**	**H**	**H**
			H	**L**	**H**	**L**	**H**
			H	**H**	**H**	**H**	**H**
Open load	Channel 1 (3)		**L**	**X**	**Z**	**X**	**L**[15)]
			H	**X**	**H**	**X**	**H**
	Channel 2 (4)		**X**	**L**	**X**	**Z**	**L**[15)]
			X	**H**	**X**	**H**	**H**
Overtemperature	both channel		**L**	**L**	**L**	**L**	**H**
			X	**H**	**L**	**L**	**L**
			H	**X**	**L**	**L**	**L**
	Channel 1 (3)		**L**	**X**	**L**	**X**	**H**
			H	**X**	**L**	**X**	**L**
	Channel 2 (4)		**X**	**L**	**X**	**L**	**H**
			X	**H**	**X**	**L**	**L**

L = "Low" Level X = don't care Z = high impedance, potential depends on external circuit
H = "High" Level Status signal valid after the time delay shown in the timing diagrams

Parallel switching of channel 1 and 2 (also channel 3 and 4) is easily possible by connecting the inputs and outputs in parallel (see truth table). If switching channel 1 to 4 in parallel, the status outputs ST1/2 and ST3/4 have to be configured as a 'Wired OR' function with a single pull-up resistor.

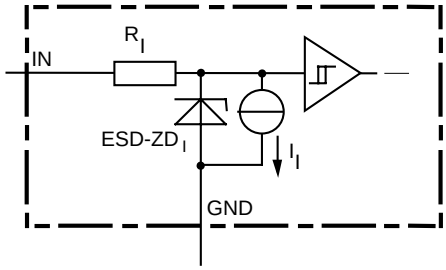
Terms



Leadframe (V_{bb}) is connected to pin 1,10,11,20
External R_{GND} optional; two resistors R_{GND1}, R_{GND2} = 150 Ω or a single resistor R_{GND} = 75 Ω for reverse battery protection up to the max. operating voltage.

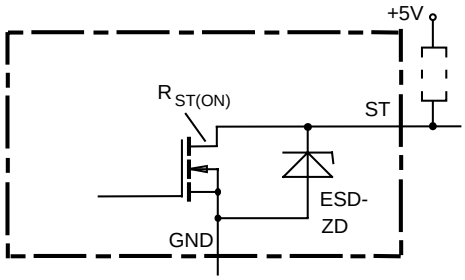
15) L, if potential at the Output exceeds the OpenLoad detection voltage

Input circuit (ESD protection), IN1 or IN2



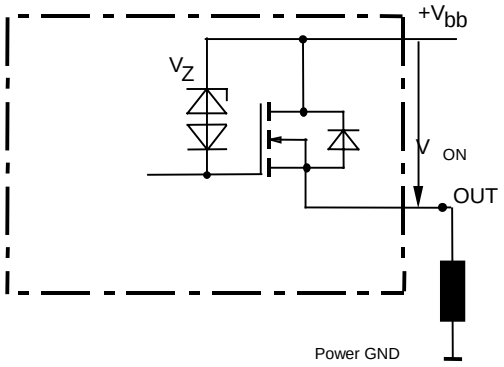
The use of ESD zener diodes as voltage clamp at DC conditions is not recommended.

Status output, ST1 or ST2



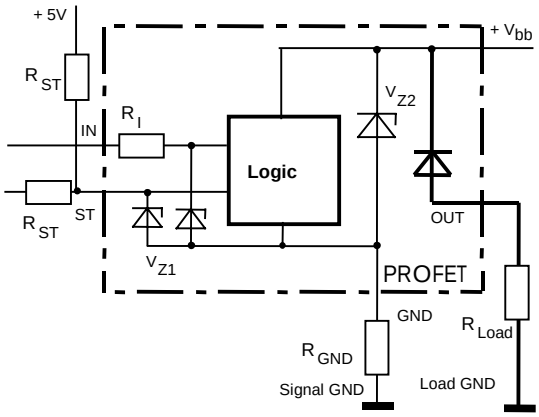
ESD-Zener diode: 6.1 V typ., max 5.0 mA; $R_{ST(ON)}$ < 375 Ω at 1.6 mA. The use of ESD zener diodes as voltage clamp at DC conditions is not recommended.

Inductive and overvoltage output clamp, OUT1 or OUT2



V_{ON} clamped to $V_{ON(CL)}$ = 47 V typ.

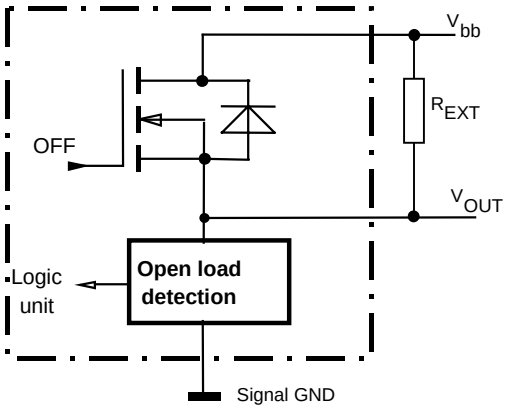
Overvolt. and reverse batt. protection



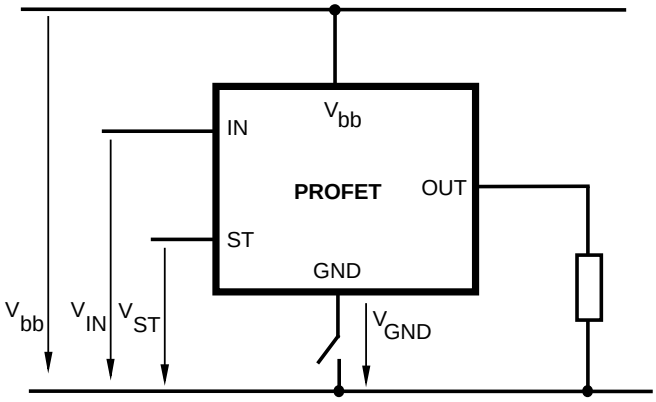
V_{Z1} = 6.1 V typ., V_{Z2} = 47 V typ., R_{GND} = 150 Ω, R_{ST}= 15 kΩ, R_I= 3.5 kΩ typ.
In case of reverse battery the load current has to be limited by the load. Temperature protection is not active

Open-load detection, OUT1...4

OFF-state diagnostic condition:
Open Load, if V_{OUT} > 3 V typ.; IN low

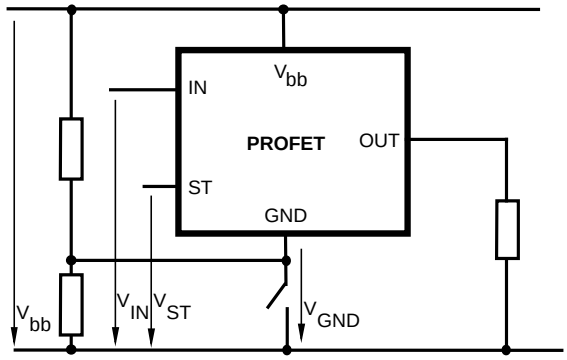


GND disconnect



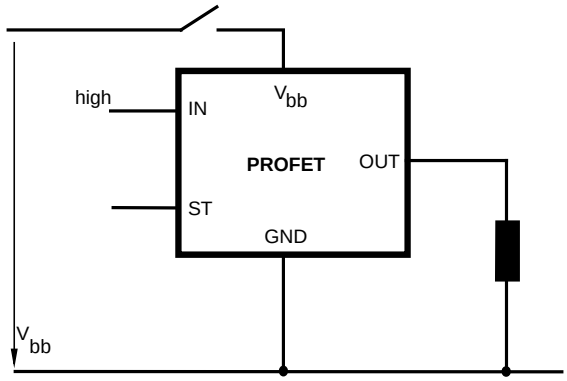
Any kind of load. In case of IN = high is $V_{OUT} \approx V_{IN} - V_{IN(T+)}$.
Due to $V_{GND} > 0$, no V_{ST} = low signal available.

GND disconnect with GND pull up



Any kind of load. If $V_{GND} > V_{IN} - V_{IN(T+)}$ device stays off
Due to $V_{GND} > 0$, no V_{ST} = low signal available.

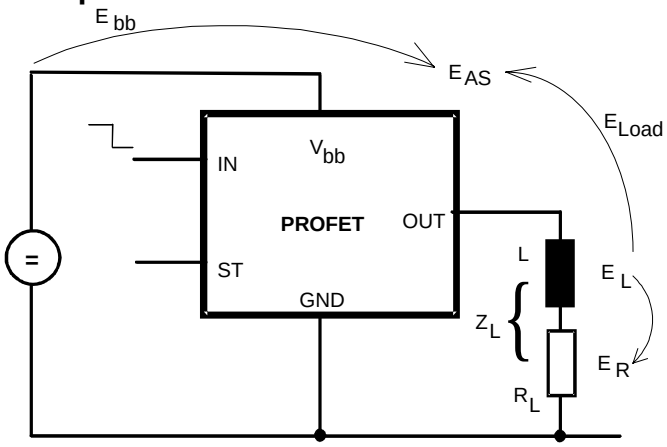
V_{bb} disconnect with energized inductive load



For inductive load currents up to the limits defined by Z_L (max. ratings and diagram on page 10) each switch is protected against loss of V_{bb}.

Consider at your PCB layout that in the case of Vbb disconnection with energized inductive load all the load current flows through the GND connection.

Inductive load switch-off energy dissipation



Energy stored in load inductance:

$$E_L = {}^1/_2 \cdot L \cdot I_L^2$$

While demagnetizing load inductance, the energy dissipated in PROFET is

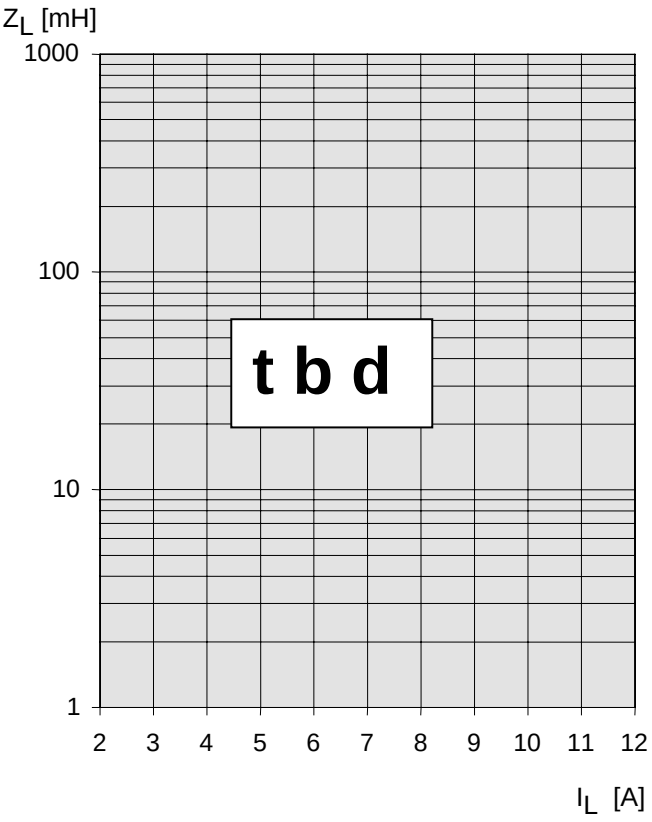
$$E_{AS} = E_{bb} + E_L - E_R = \int V_{ON(CL)} \cdot i_L(t)\, dt,$$

with an approximate solution for $R_L > 0\,\Omega$:

$$E_{AS} = \frac{I_L \cdot L}{2 \cdot R_L}\left(V_{bb} + |V_{OUT(CL)}|\right)\ ln\ \left(1 + \frac{I_L \cdot R_L}{|V_{OUT(CL)}|}\right)$$

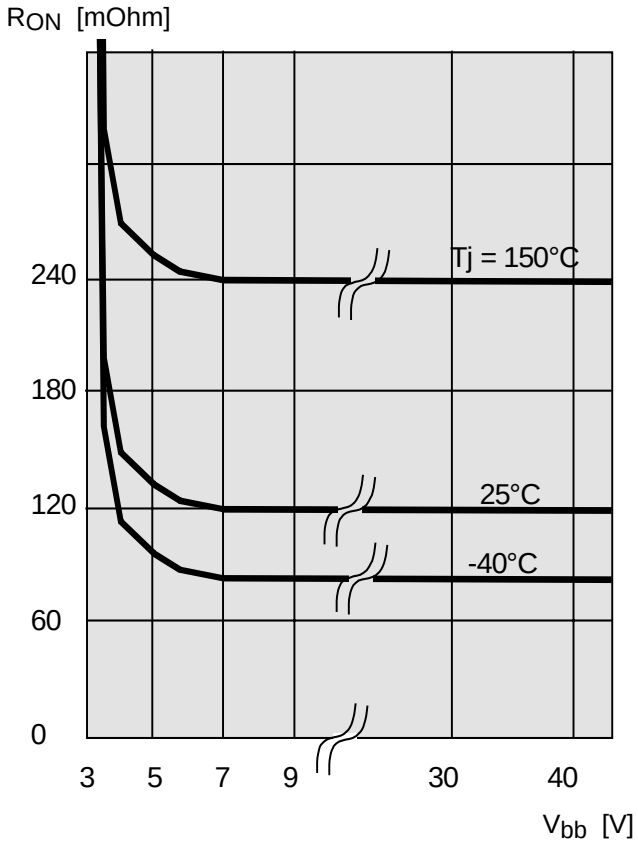
Maximum allowable load inductance for a single switch off (one channel)[4)]

$L = f(I_L)$; $T_{j,start} = 150°C$, $V_{bb} = 12\,V$, $R_L = 0\,\Omega$



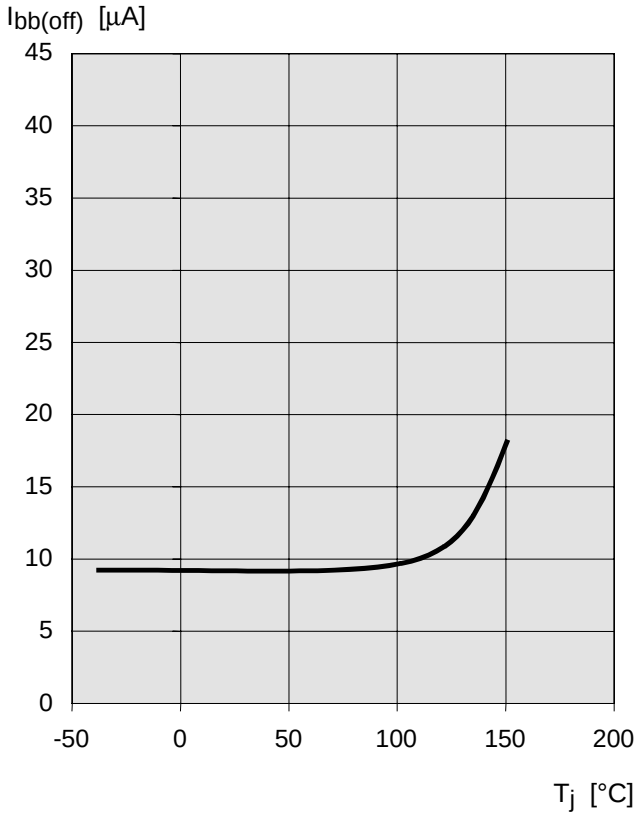
Typ. on-state resistance

$R_{ON} = f(V_{bb}, T_j)$; I_L = 2 A, IN = high



Typ. standby current

$I_{bb(off)} = f(T_j)$; V_{bb} = 9...34 V, IN1,2,3,4 = low



Timing diagrams

All channels are symmetric and consequently the diagrams are valid for channel 1 to channel 4

Figure 1a: V_{bb} turn on:

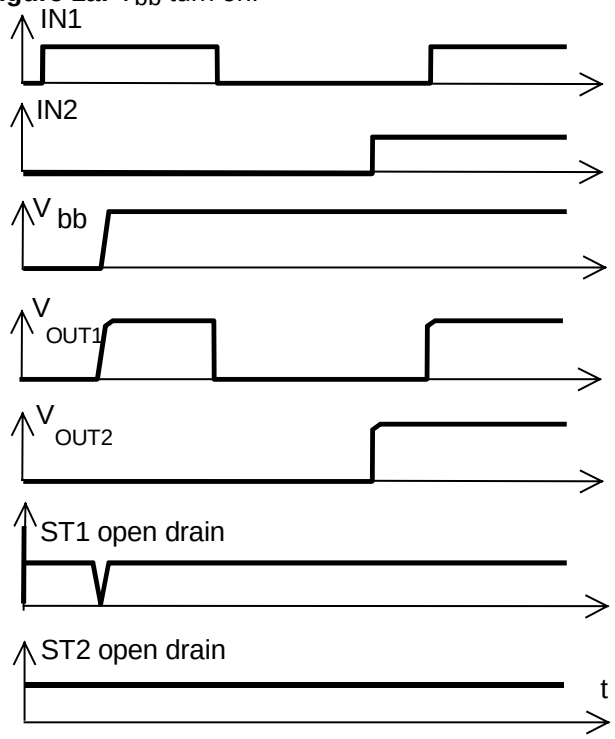


Figure 2a: Switching a resistive load, turn-on/off time and slew rate definition:

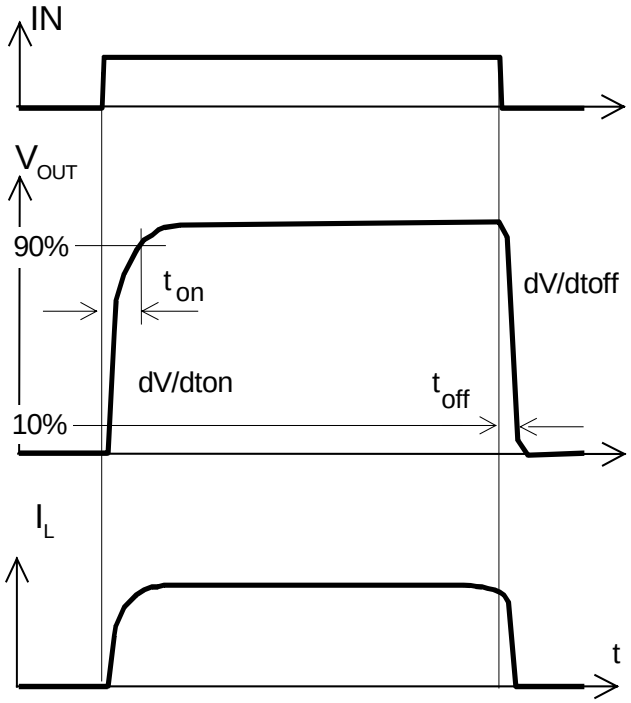
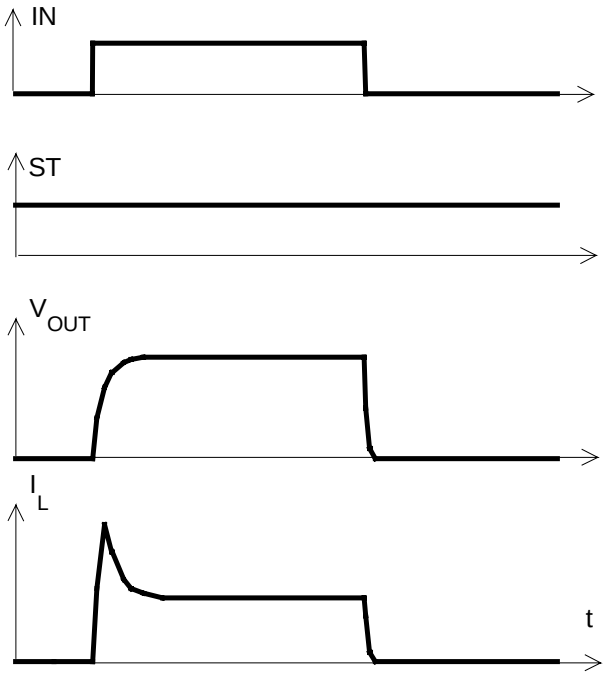
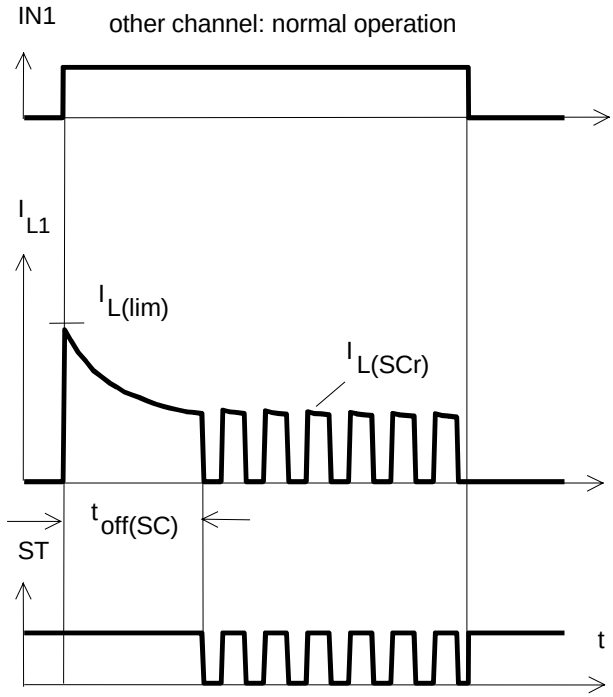


Figure 2b: Switching a lamp:



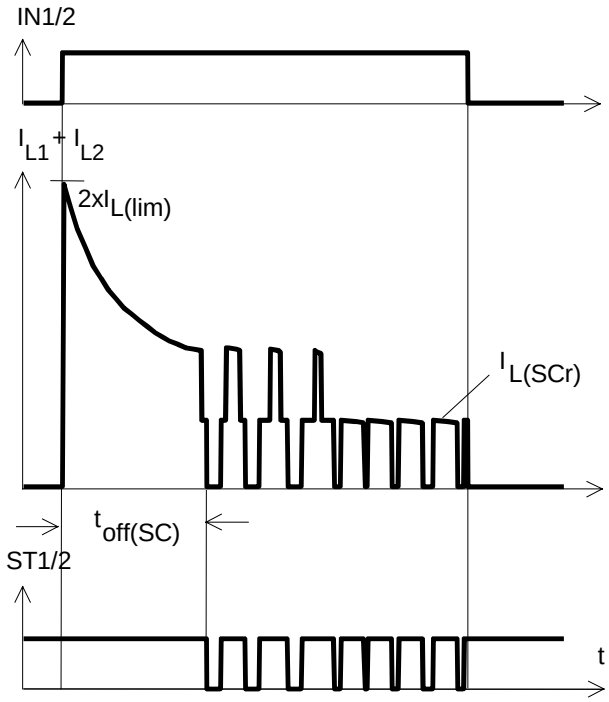
The initial peak current should be limited by the lamp and not by the current limit of the device.

Figure 3a: Turn on into short circuit: shut down by overtemperature, restart by cooling



Heating up of the chip may require several milliseconds, depending on external conditions

Figure 3b: Turn on into short circuit:
shut down by overtemperature, restart by cooling
(two parallel switched channels 1 and 2)



ST1 and ST2 have to be configured as a 'Wired OR' function ST1/2 with a single pull-up resistor.

Figure 4a: Overtemperature:
Reset if $T_j < T_{jt}$

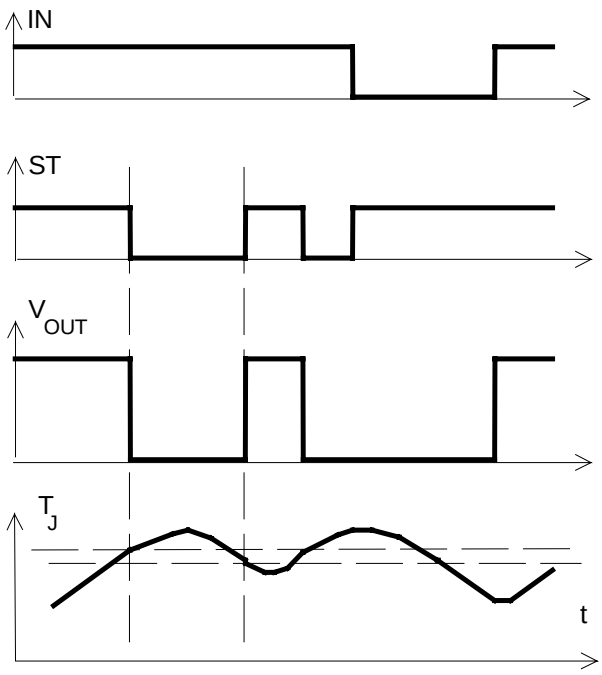
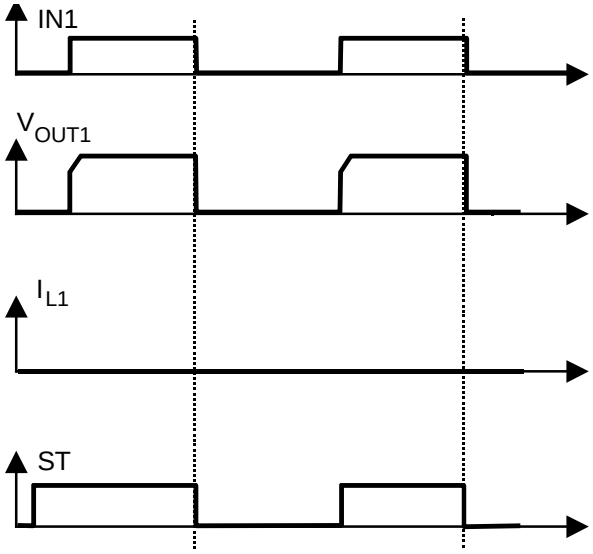


Figure 5a: Open load: detection in OFF-state, turn on/off to open load
Open load of channel 1; other channels normal operation

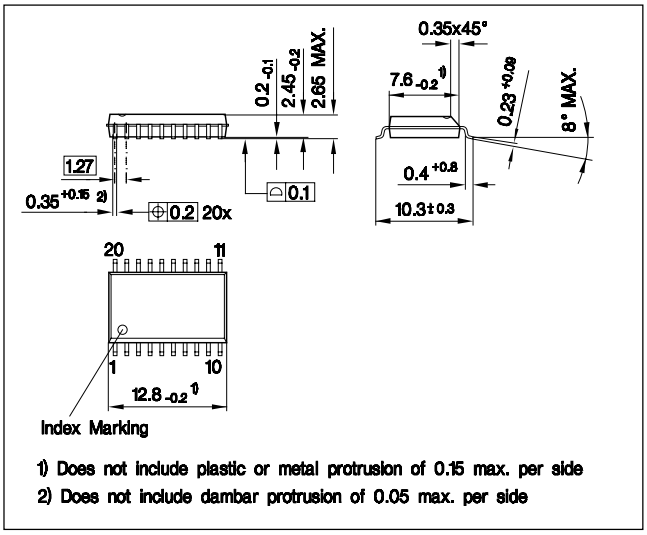


Package and Ordering Code

Standard: P-DSO-20-9

Sales Code	BTS 716
Ordering Code	tbd

All dimensions in millimetres

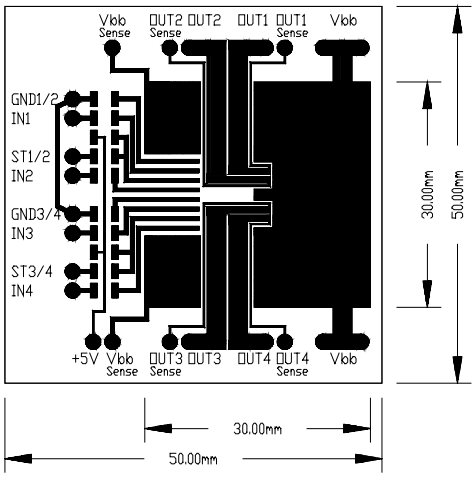


1) Does not include plastic or metal protrusion of 0.15 max. per side
2) Does not include dambar protrusion of 0.05 max. per side

Definition of soldering point with temperature T_S: upper side of solder edge of device pin 15.

Pin 15

Printed circuit board (FR4, 1.5mm thick, one layer 70µm, 6cm² active heatsink area) as a reference for max. power dissipation P_{tot}, nominal load current $I_{L(NOM)}$ and thermal resistance R_{thja}



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