

Smart High-Side Power Switch

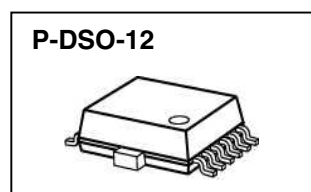
Two Channels: 2 x 140mΩ

Status Feedback

Product Summary

Operating Voltage	V_{bb}	5.5...40V	
Active channels		one	two parallel
On-state Resistance	R_{ON}	140mΩ	70mΩ
Nominal load current	$I_{L(NOM)}$	2.4A	3.9A
Current limitation	$I_{L(SCr)}$	6.5A	6.5A

Package



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 capacitive 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

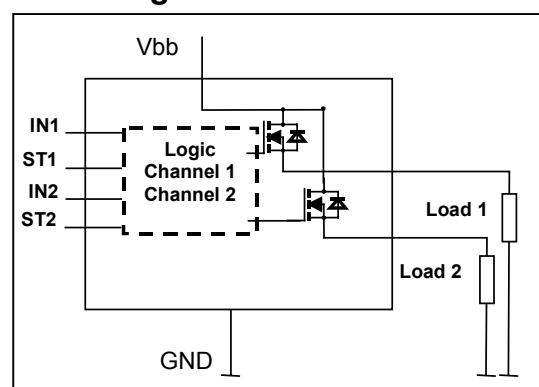
Protection Functions

- 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)

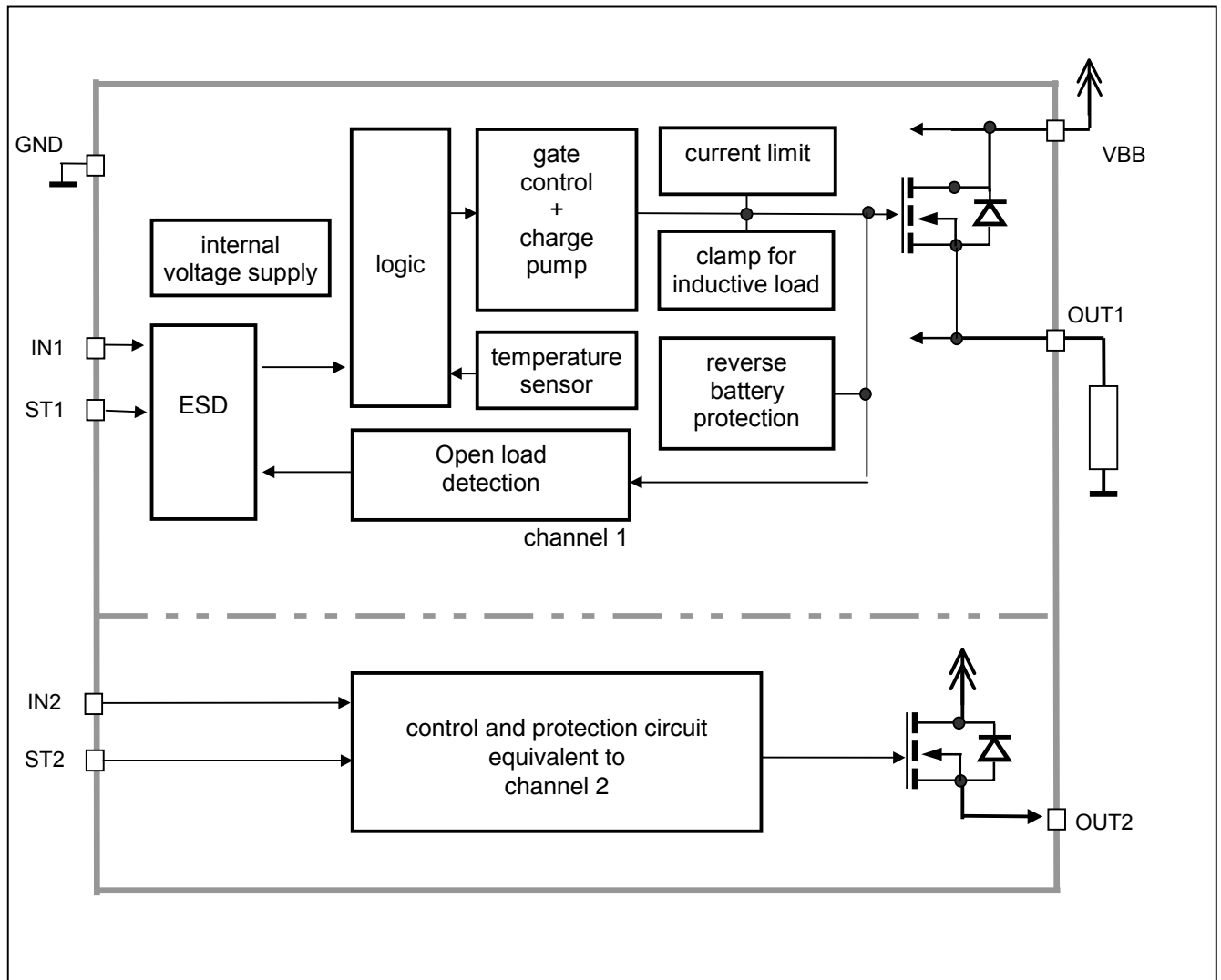
Diagnostic Function

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

Block Diagram



Functional diagram

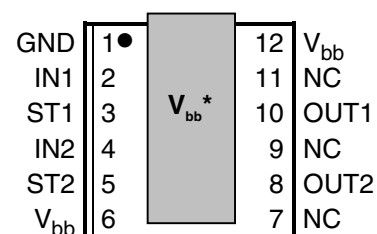


Pin Definitions and Functions

Pin	Symbol	Function
1	GND	Ground of chip
2	IN1	Input 1,2 activates channel 1,2 in case of logic high signal
4	IN2	
3	ST1	Diagnostic feedback 1 & 2 of channel 1,2 open drain, low on failure
5	ST2	
6,12, heat slug	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
7,9,11	NC	Not Connected
8	OUT2	Output 1,2 protected high-side power output of channel 1 and 2. Design the wiring for the max. short circuit current
10	OUT1	

Pin configuration

(top view)



* heat slug

Maximum Ratings at $T_j = 25^\circ\text{C}$ unless otherwise specified

Parameter	Symbol	Values	Unit
Supply voltage (overvoltage protection see page 6)	V_{bb}	43	V
Supply voltage for full short circuit protection $T_{j,start} = -40 \dots +150^\circ\text{C}$	V_{bb}	36	V
Load current (Short-circuit current, see page 6)	I_L	self-limited	A
Load dump protection ¹⁾ $V_{LoadDump} = V_A + V_S$, $V_A = 13.5 \text{ V}$ $R_l^{2)} = 2 \Omega$, $t_d = 400 \text{ ms}$; IN = low or high, each channel loaded with $R_L = 13.5 \Omega$,	$V_{Load dump}^{3)}$	60	V
Operating temperature range	T_j	-40 ... +150	$^\circ\text{C}$
Storage temperature range	T_{stg}	-55 ... +150	
Power dissipation (DC) ⁴⁾ (all channels active)	$T_a = 25^\circ\text{C}$: $T_a = 85^\circ\text{C}$: P_{tot}	3,05 1,59	W
Maximal switchable inductance, single pulse $V_{bb} = 12\text{V}$, $T_{j,start} = 150^\circ\text{C}^{4)}$, see diagrams on page 10 $I_L = 2.9 \text{ A}$, $E_{AS} = 84 \text{ mJ}$, 0Ω one channel: $I_L = 5.7 \text{ A}$, $E_{AS} = 168 \text{ mJ}$, 0Ω two parallel channels:	Z_L	14 7.6	mH
Electrostatic discharge capability (ESD) IN: (Human Body Model) ST: out to all other pins shorted: acc. MIL-STD883D, method 3015.7 and ESD assn. std. S5.1-1993 $R = 1.5\text{k}\Omega$; $C = 100\text{pF}$	V_{ESD}	1.0 4.0 8.0	kV
Input voltage (DC) see internal circuit diagram page 9	V_{IN}	-10 ... +16	V
Current through input pin (DC)	I_{IN}	± 0.3	mA
Current through status pin (DC)	I_{ST}	± 0.3	

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_l = 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 $50\text{mm} \times 50\text{mm} \times 1.5\text{mm}$ epoxy PCB FR4 with 6cm^2 (one layer, $70\mu\text{m}$ thick) copper area for V_{bb} connection. PCB is vertical without blown air. See page 14



Thermal Characteristics

Parameter and Conditions	Symbol	Values			Unit
		min	typ	max	
Thermal resistance junction - Case ⁵⁾ junction – ambient ⁵⁾ @ 6 cm ² cooling area	each channel: R_{thjC} R_{thja} one channel active: all channels active:	-- -- -- --	-- -- 45 40	5 -- -- --	K/W

Electrical Characteristics

Parameter and Conditions, each of the four channels at $T_j = -40...+150^{\circ}\text{C}$, $V_{bb} = 12\text{ V}$ unless otherwise specified	Symbol	Values			Unit
		min	typ	max	

Load Switching Capabilities and Characteristics

On-state resistance (V_{bb} to OUT); $I_L = 2\text{ A}$ each channel, $T_j = 25^{\circ}\text{C}$: $T_j = 150^{\circ}\text{C}$: two parallel channels, $T_j = 25^{\circ}\text{C}$: see diagram, page 11	R_{ON}	-- -- --	110 210 55	140 280 70	m Ω
Nominal load current one channel active: two parallel channels active: Device on PCB ⁵⁾ , $T_a = 85^{\circ}\text{C}$, $T_j \leq 150^{\circ}\text{C}$	$I_{L(NOM)}$	1.8 3.4	2.4 3.9	--	A
Output current while GND disconnected or pulled up; $V_{bb} = 32\text{ V}$, $V_{IN} = 0$, see diagram page 9; (not tested specified by design)	$I_{L(GNDhigh)}$	--	--	2	mA
Turn-on time ⁶⁾ IN  to 90% V_{OUT} : Turn-off time IN  to 10% V_{OUT} : $R_L = 12\ \Omega$	t_{on} t_{off}	-- --	100 100	250 270	μs
Slew rate on ⁶⁾ 10 to 30% V_{OUT} , $R_L = 12\ \Omega$:	dV/dt_{on}	0.2	--	1.0	V/ μs
Slew rate off ⁶⁾ 70 to 40% V_{OUT} , $R_L = 12\ \Omega$:	$-dV/dt_{off}$	0.2	--	1.1	V/ μs

⁵⁾ Device on 50mm*50mm*1.5mm epoxy PCB FR4 with 6cm² (one layer, 70 μm thick) copper area for V_{bb} connection. PCB is vertical without blown air. See page 14

⁶⁾ See timing diagram on page 12.

Parameter and Conditions, each of the four channels at $T_j = -40...+150^{\circ}\text{C}$, $V_{bb} = 12\text{ V}$ unless otherwise specified	Symbol	Values			Unit
		min	typ	max	

Operating Parameters

Operating voltage ⁷⁾	$V_{bb(\text{on})}$	5.5	--	40	V
Undervoltage switch off ⁸⁾ $T_j = -40^{\circ}\text{C}...25^{\circ}\text{C}$:	$V_{bb(\text{u so})}$	--	--	4.5	V
not tested, specified by design: $T_j = 125^{\circ}\text{C}$:		--	--	4.5	
Overvoltage protection ⁹⁾ $I_{bb} = 40\text{ mA}$	$V_{bb(\text{AZ})}$	41	47	52	V
Standby current ¹⁰⁾ $T_j = -40^{\circ}\text{C}...25^{\circ}\text{C}$:	$I_{bb(\text{off})}$	--	4.5	8	μA
$V_{IN} = 0$; see diagram page 11 $T_j = 150^{\circ}\text{C}$:		--	--	12	
not tested, specified by design: $T_j = 125^{\circ}\text{C}$:		--	--	8	
Off-State output current (included in $I_{bb(\text{off})}$) $V_{IN} = 0$; each channel	$I_{L(\text{off})}$	--	1	5	μA
Operating current ¹¹⁾ , $V_{IN} = 5\text{V}$, one channel on:	I_{GND}	--	0.5	0.9	mA
all channels on:		--	1.0	1.7	

Protection Functions¹²⁾

Current limit, $V_{\text{out}} = 0\text{V}$, (see timing diagrams, page 12) $T_j = -40^{\circ}\text{C}$:	$I_{L(\text{lim})}$	--	--	14	A
$T_j = 25^{\circ}\text{C}$:		--	9	--	
$T_j = +150^{\circ}\text{C}$:		5	--	--	
Repetitive short circuit current limit, $T_j = T_{jt}$ each channel two channels (see timing diagrams, page 12)	$I_{L(\text{SCr})}$	--	6.5	--	A
		--	6.5	--	
Initial short circuit shutdown time $T_{j,\text{start}} = 25^{\circ}\text{C}$: $V_{\text{out}} = 0\text{V}$ (see timing diagrams on page 12)	$t_{\text{off}(\text{SC})}$	--	2	--	ms
Output clamp (inductive load switch off) ¹³⁾ at $V_{\text{ON}(\text{CL})} = V_{bb} - V_{\text{OUT}}$, $I_L = 40\text{ mA}$	$V_{\text{ON}(\text{CL})}$	41	47	52	V
Thermal overload trip temperature	T_{jt}	150	--	--	$^{\circ}\text{C}$
Thermal hysteresis	ΔT_{jt}	--	10	--	K

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

8) is the voltage, where the device doesn't change its switching condition for 15ms after the supply voltage falling below $V_{bb(\text{on})}$

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

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

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

12) Integrated protection functions are designed to prevent IC destruction under fault conditions described in the data sheet. Fault conditions are considered as "outside" normal operating range. Protection functions are not designed for continuous repetitive operation.

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

Parameter and Conditions, each of the four channels at $T_j = -40...+150^{\circ}\text{C}$, $V_{bb} = 12\text{ V}$ unless otherwise specified	Symbol	Values			Unit
		min	typ	max	



Reverse Battery

Reverse battery voltage ¹⁴⁾	$-V_{bb}$	--	--	32	V
Drain-source diode voltage ($V_{out} > V_{bb}$) $I_L = -2.0\text{ A}$, $T_j = +150^{\circ}\text{C}$	$-V_{ON}$	--	600	--	mV

Diagnostic Characteristics

Open load detection voltage	$V_{OUT(OL)}$	1.7	2.8	4.0	V
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Input and Status Feedback¹⁵⁾

Input resistance (see circuit page 9)	R_I	2.5	4.0	6.0	k Ω
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	$\Delta V_{IN(T)}$	--	0.2	--	V
Status change after positive input slope ¹⁶⁾ with open load	$t_{d(STon)}$	--	10	20	μs
Status change after positive input slope ¹⁶⁾ with overload	$t_{d(STon)}$	30	--	--	μs
Status change after negative input slope ¹⁶⁾ with open load	$t_{d(SToff)}$	--	--	500	μs
Status change after negative input slope ¹⁶⁾ with overtemperature	$t_{d(SToff)}$	--	--	20	μs
Off state input current $V_{IN} = 0.4\text{ V}$:	$I_{IN(off)}$	5	--	20	μA
On state input current $V_{IN} = 5\text{ V}$:	$I_{IN(on)}$	10	35	60	μA
Status output (open drain)					
Zener limit voltage $I_{ST} = +1.6\text{ mA}$:	$V_{ST(high)}$	5.4	--	--	V
ST low voltage $I_{ST} = +1.6\text{ mA}$:	$V_{ST(low)}$	--	--	0.6	

¹⁴⁾ 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).

¹⁵⁾ If ground resistors R_{GND} are used, add the voltage drop across these resistors.

¹⁶⁾ not tested, specified by design

Truth Table

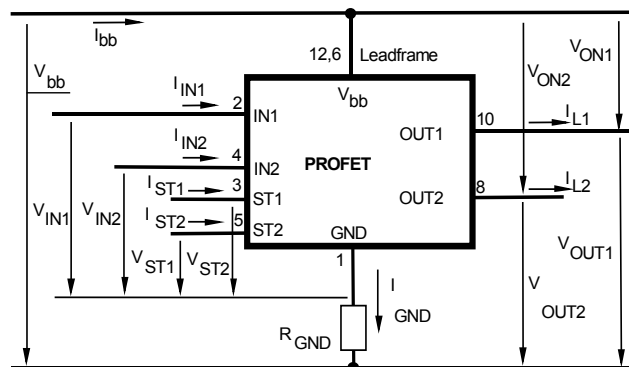
(each channel)

	IN	OUT	ST
Normal operation	L	L	H
	H	H	H
Open load	L	Z	L ¹⁷⁾
	H	H	H
Overtemperature	L	L	H
	H	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 is easily possible by connecting the inputs and outputs in parallel (see truth table). If switching channel 1 to 2 in parallel, the status outputs ST1 and ST2 have to be configured as a 'Wired OR' function with a single pull-up resistor.

Terms

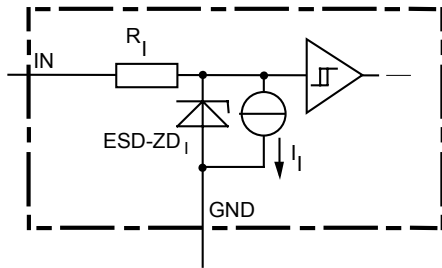


Leadframe (V_{bb}) is connected to pin 6,12

External R_{GND} optional; single resistor $R_{GND} = 150 \Omega$ for reverse battery protection up to the max. operating voltage.

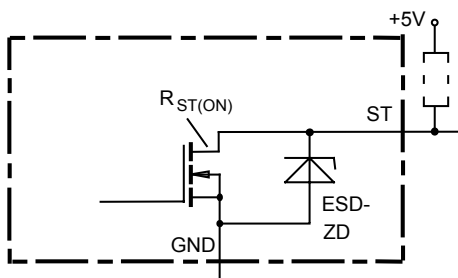
¹⁷⁾ L, if potential at the Output exceeds the OpenLoad detection voltage

Input circuit (ESD protection), IN1 or IN2



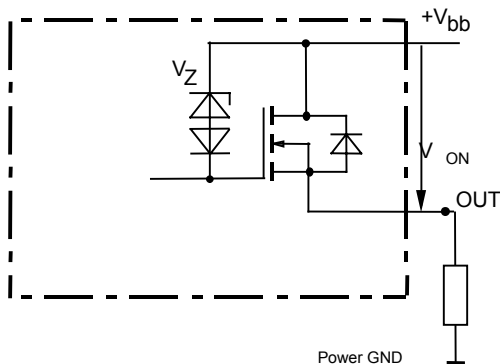
The use of ESD zener diodes as voltage clamp at DC conditions is not recommended.

Status output, ST1 or ST2



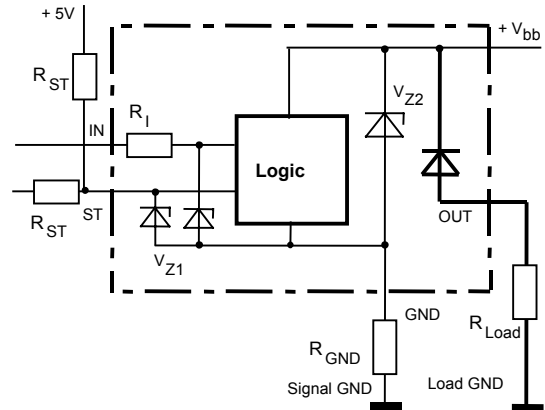
ESD-Zener diode: 6.1 V typ., max 0.3 mA; $R_{ST(ON)} < 375 \Omega$ at 1.6 mA. The use of ESD zener diodes as voltage clamp at DC conditions is not recommended.

Inductive and overvoltage output clamp, OUT1 or OUT2



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

Overvolt. and reverse batt. protection



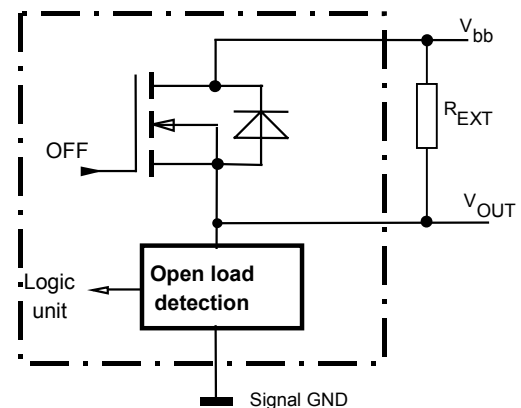
$V_{Z1} = 6.1 \text{ V typ.}$, $V_{Z2} = 47 \text{ V typ.}$, $R_{GND} = 150 \Omega$, $R_{ST} = 15 \text{ k}\Omega$, $R_I = 3.5 \text{ k}\Omega \text{ typ.}$

In case of reverse battery the load current has to be limited by the load. Temperature protection is not active

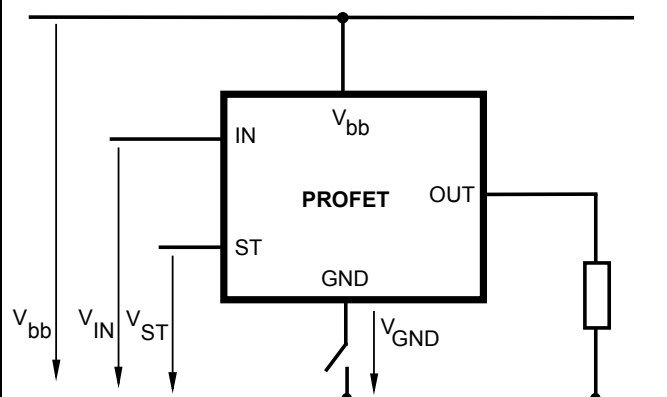
Open-load detection, OUT1 or OUT2

OFF-state diagnostic condition:

Open Load, if $V_{OUT} > 3 \text{ V typ.}$; IN low

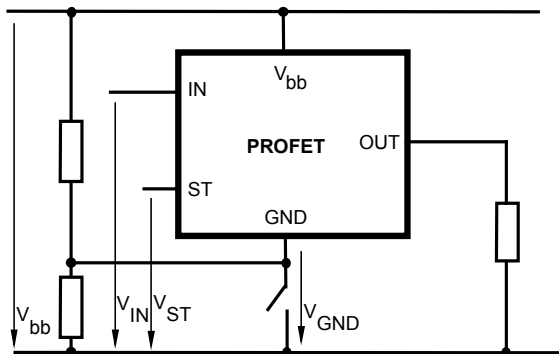


GND disconnect



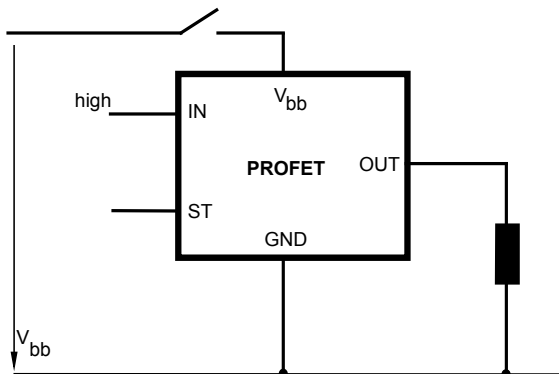
Any kind of load. In case of IN=high is $V_{OUT} \approx V_{IN} - V_{IN(T+)}$. Due to $V_{GND} > 0$, no $V_{ST} = \text{low}$ signal available.

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.

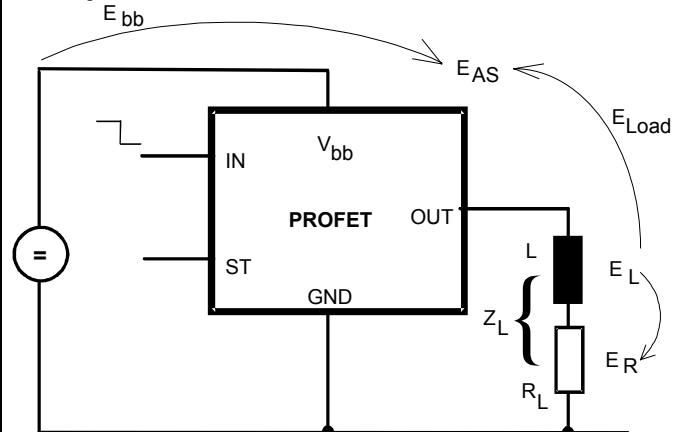
Vbb disconnect with energized inductive load



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 V_{bb} 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:

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

While demagnetizing load inductance, the energy dissipated in PROFET is

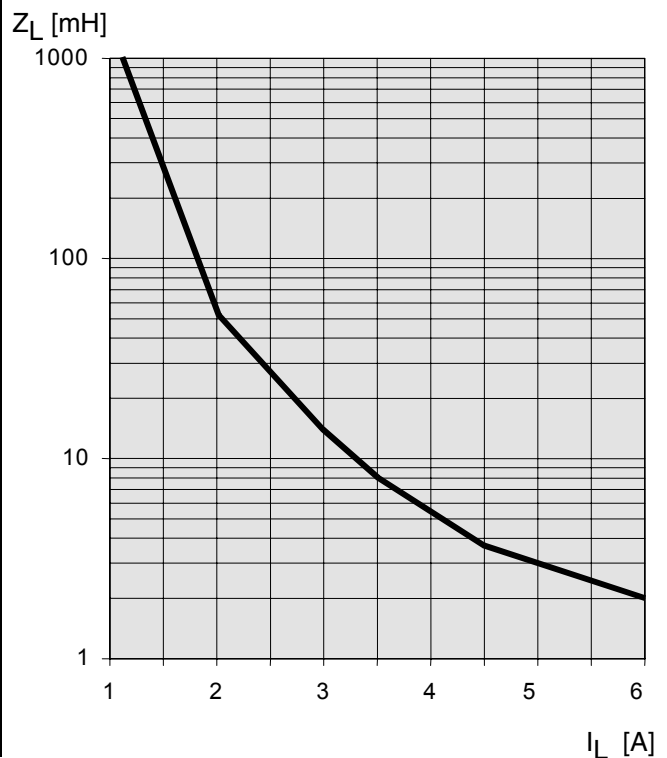
$$E_{AS} = E_{bb} + E_L - E_R = \int V_{ON(CL)} \cdot i_L(t) dt,$$

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

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

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

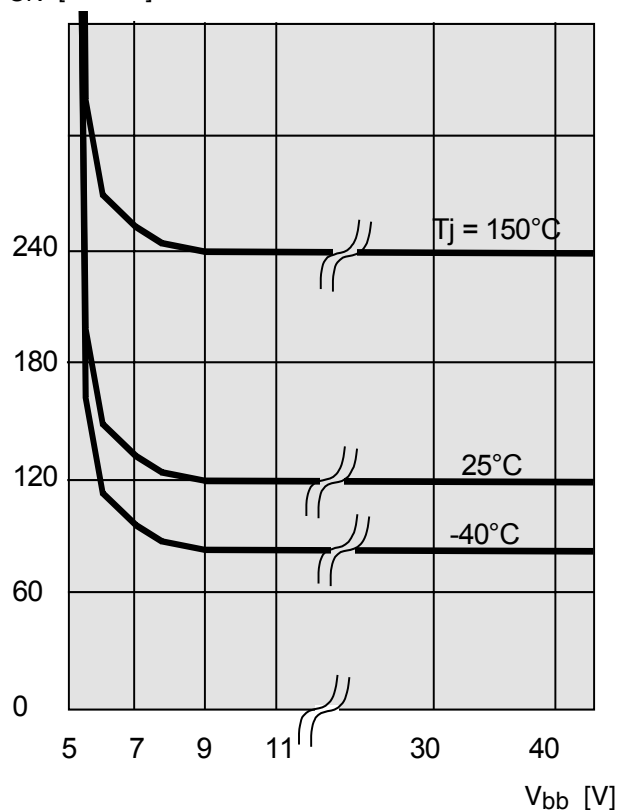
$$L = f(I_L); T_{j,start} = 150^\circ C, V_{bb} = 12 V, R_L = 0 \Omega$$



Typ. on-state resistance

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

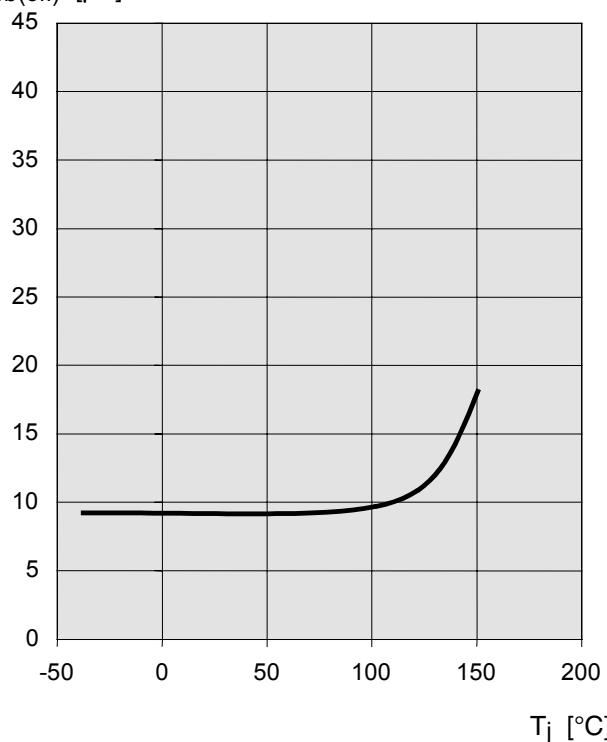
R_{ON} [mOhm]



Typ. standby current

$I_{bb(off)} = f(T_j)$; $V_{bb} = 9 \dots 34\text{ V}$, $I_{N1,2} = \text{low}$

$I_{bb(off)}$ [μA]



Timing diagrams

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

Figure 1a: V_{bb} turn on:

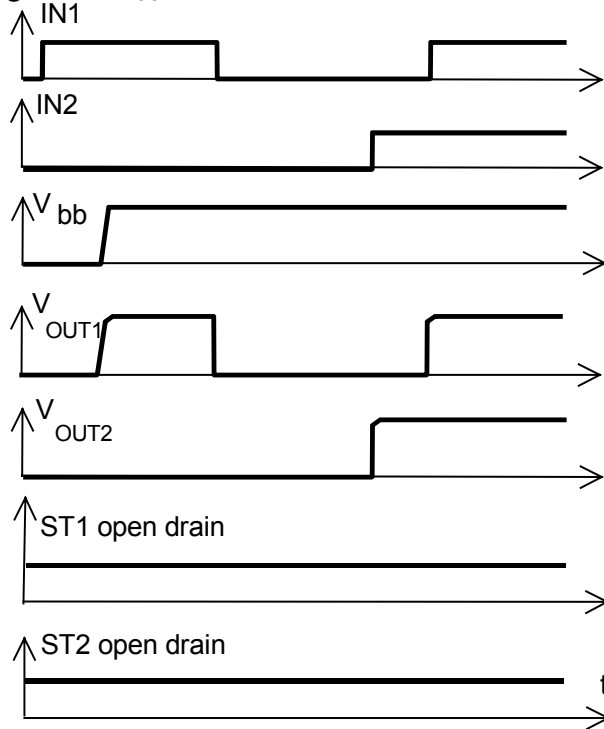


Figure 2a: Switching a resistive load, turn-on/off time and slew rate definition:

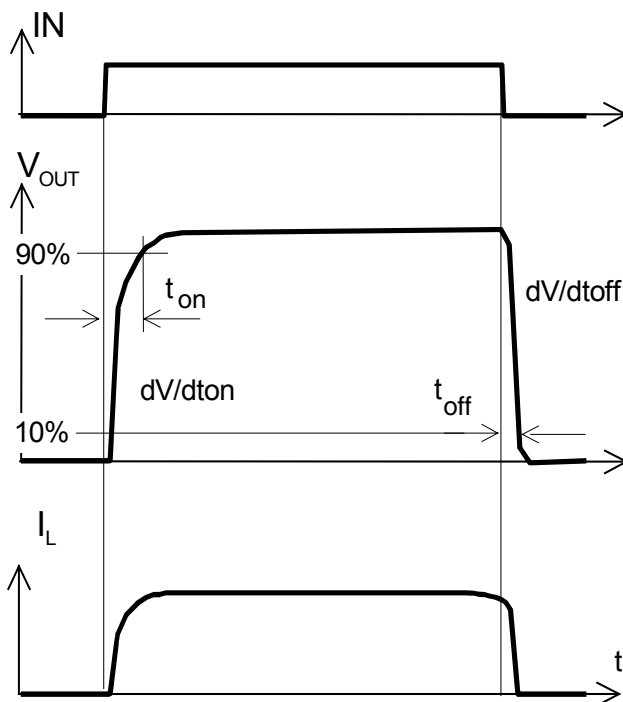
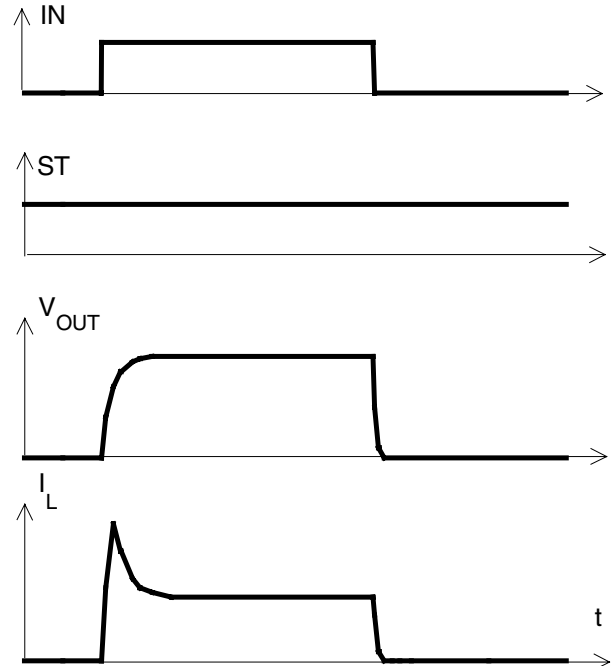
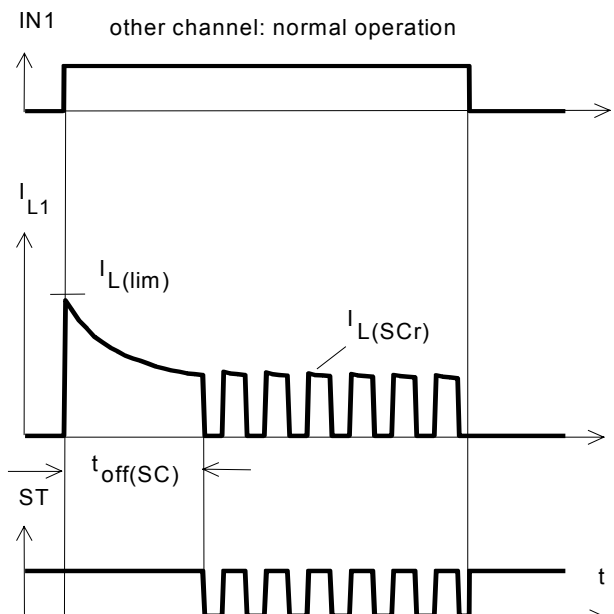


Figure 2b: Switching a lamp:



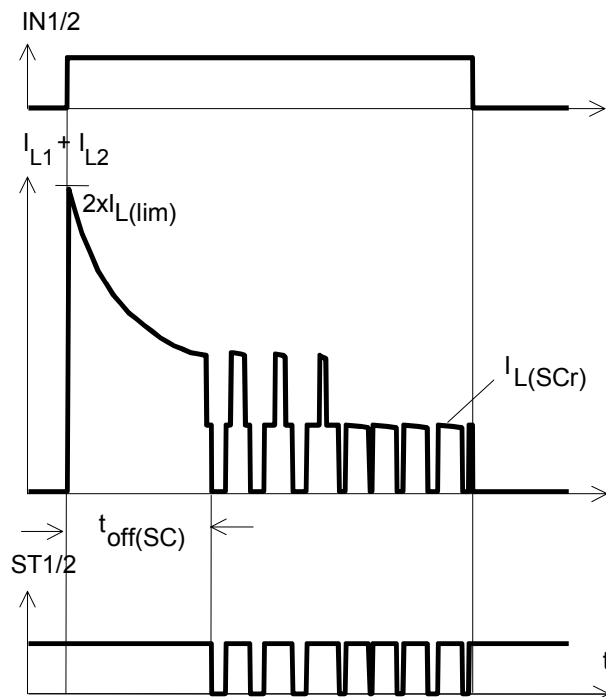
The initial peak current should be limited by the lamp and not by the current limit of the device.

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 $T_j < T_{jt}$

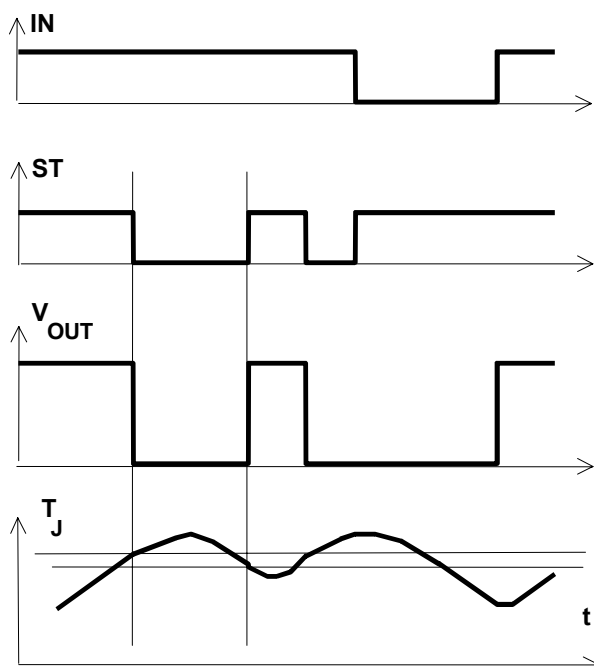


Figure 5a: Open load: detection in OFF-state, turn
on/off to open load
Open load of channel 1; other channels normal
operation

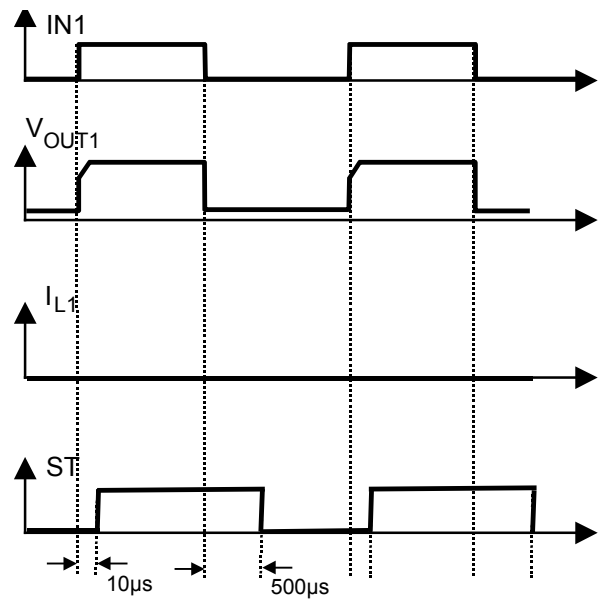
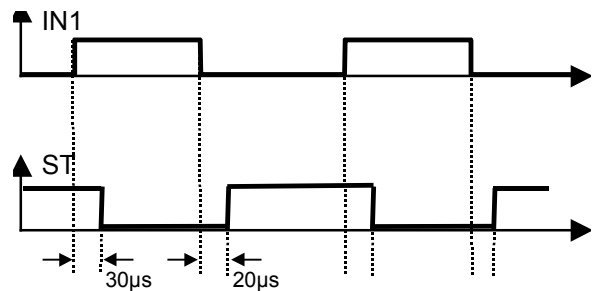


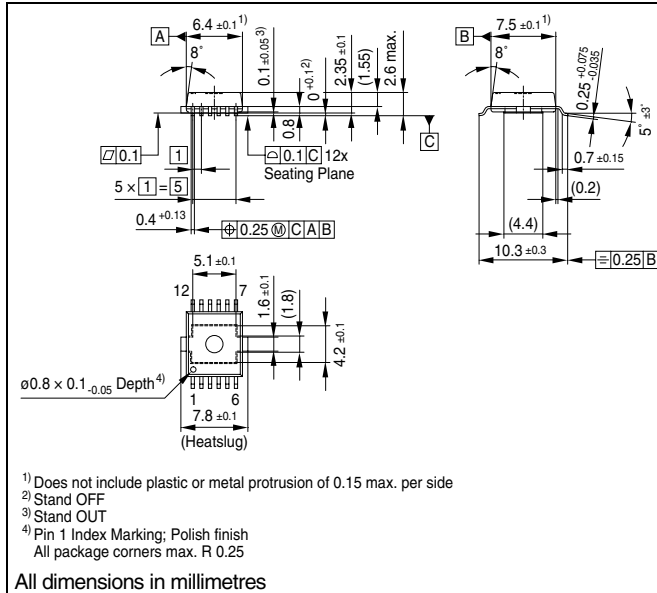
Figure 6a: Status change after, turn on/off to
overtemperature
Overtemperature of channel 1; other channels normal
operation



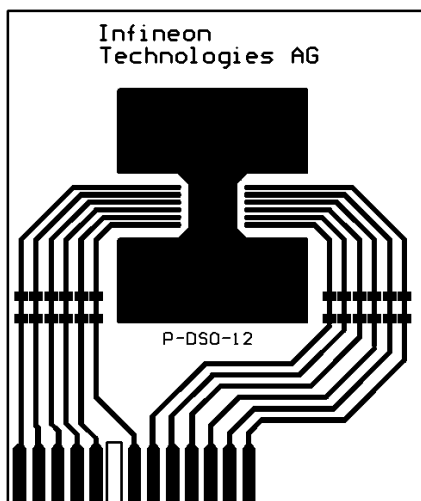
Package and Ordering Code

Standard: P-DSO-12-2

Sales Code	BTS 5210L
Ordering Code	Q67060-S7503



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



Published by
Infineon Technologies AG,
Bereich Kommunikation
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D-81541 München
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