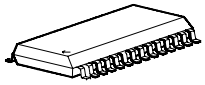
Smart High-Side Power Switch with ReverSave™
Four Channels: 4 x 35mΩ
Advanced Current Sense

Product Summary

Operating Voltage	$V_{bb(on)}$	4.5 ...40V	
Active channels		one	four parallel
On-state Resistance	R_{ON}	35mΩ	9mΩ
Nominal load current	$I_{L(NOM)}$	5.4A	11.1A
Current limitation	$I_{L(SCr)}$	21A	21A

Package

P-DSO-28



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 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
- Improved electromagnetic compatibility (EMC)
- CMOS compatible input
- Stable behaviour at undervoltage
- Wide operating voltage range

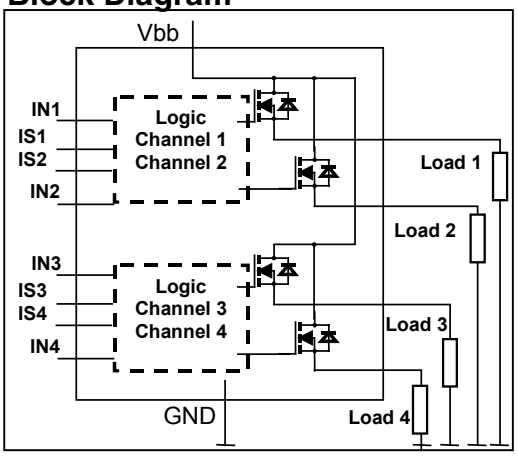
Protection Functions

- Reverse battery protection ***without*** external components (**ReverSave™**)
- Short circuit protection
- Overload protection
- Current limitation
- Thermal shutdown
- Overvoltage protection (not load dump) without external resistor
- Loss of ground protection
- Electrostatic discharge protection (ESD)

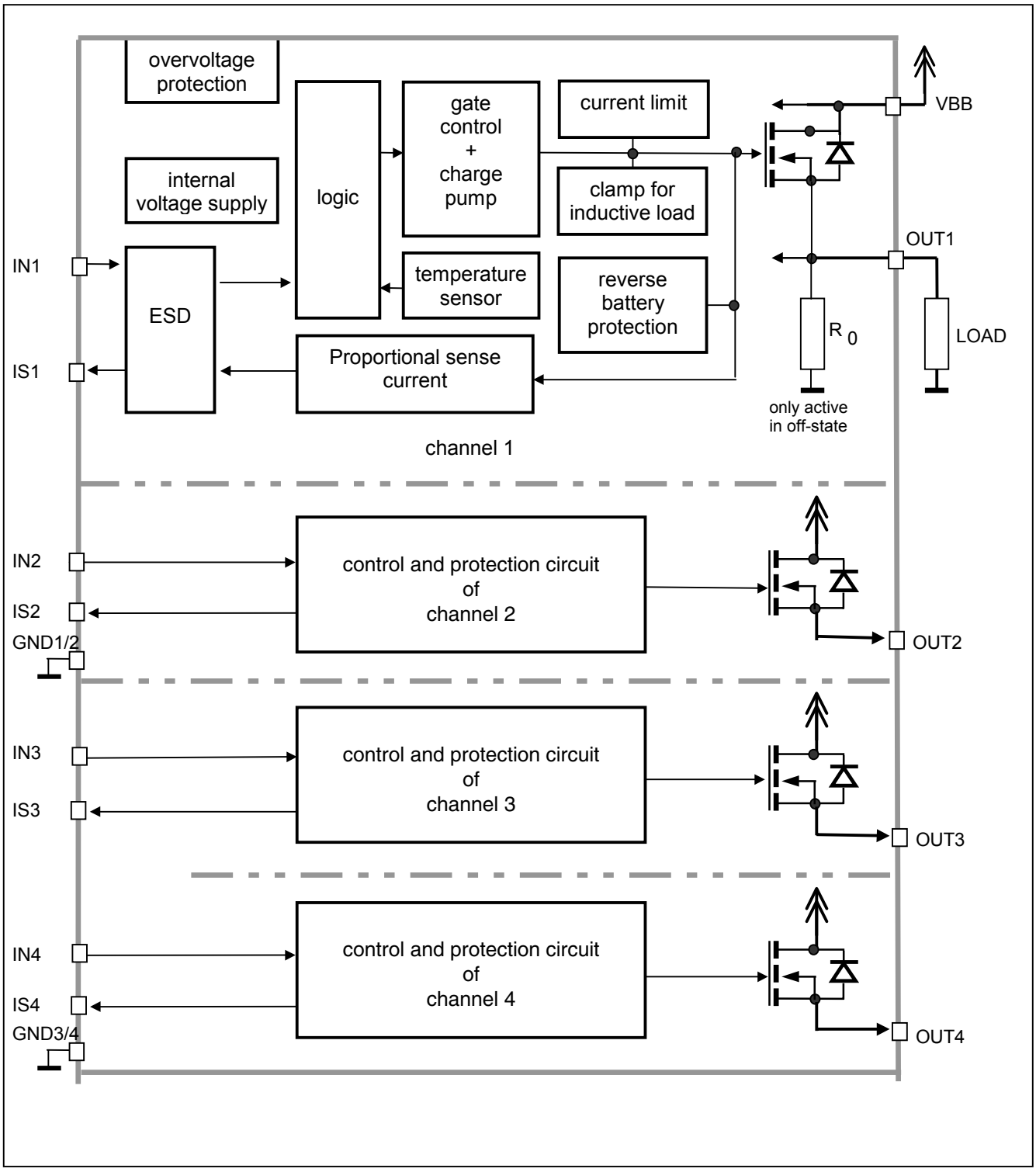
Diagnostic Function

- Proportional load current sense (with defined fault signal during thermal shutdown)

Block Diagram



Functional diagram

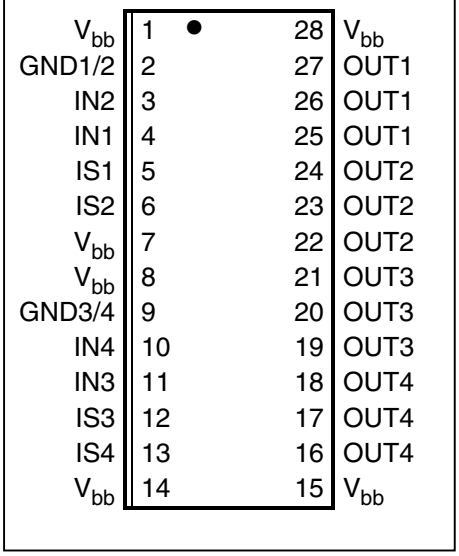


Pin Definitions and Functions

Pin	Symbol	Function
1, 7, 8, 14, 15, 28	V_{bb}	**Positive power supply voltage**. Design the wiring for the simultaneous max. short circuit currents from channel 1 to 4 and also for low thermal resistance
4	IN1	**Input 1,2, 3,4** activates channel 1,2,3,4 in case of logic high signal
3	IN2	
11	IN3	
10	IN4	
25,26,27	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
22,23,24	OUT2	
19,20,21	OUT3	
16,17,18	OUT4	
5	IS1	**Diagnostic feedback 1 .. 4** of channel 1 to 4 Providing a sense current, proportional to the load current
6	IS2	
12	IS3	
13	IS4	
2	GND1/2	**Ground** of chip 1 (channel 1,2)
9	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 6)	V_{bb}	43	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 = 400 ms; IN = low or high, each channel loaded with R_L = 4.7 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}	3.7	W
(all channels active) T_a = 85°C:		1.9	
Maximal switchable inductance, single pulse V_{bb} = 12V, $T_{j,start}$ = 150°C[4],			
I_L = 4.0 A, E_{AS} = 0.8J, 0 Ω one channel:	Z_L	33	mH
I_L = 6.0 A, E_{AS} = 1.0J, 0 Ω two parallel channels:		37	
I_L = 9.5 A, E_{AS} = 1.5J, 0 Ω four parallel channels:		64	
see diagrams on page 11			
Electrostatic discharge capability (ESD) IN:	V_{ESD}	1.0	kV
(Human Body Model) IS:		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}	±0.3	mA
Current through sense pin (DC)	I_{IS}	±0.3	
see internal circuit diagram page 10			

1) Supply voltages higher than $V_{bb(AZ)}$ require an external current limit for the GND and status pins (a 75Ω 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 16

Thermal Characteristics

Parameter and Conditions	Symbol	Values			Unit
		min	typ	Max	
Thermal resistance					
junction - soldering point[5)6)], each channel:	R_{thjs}	--	--	11	K/W
junction – ambient[6)]	R_{thja}				
@ 6 cm² cooling area, one channel active:		--	40	--	
all channels active:		--	33	--	

Electrical Characteristics

Parameter and Conditions, each of the four 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 = 5 A, $V_{bb} \geq$ 7V					
each channel, T_j = 25°C:	R_{ON}	--	30	35	mΩ
T_j = 150°C:		--	55	64	
two parallel channels, T_j = 25°C:		--	15	18	
four parallel channels, T_j = 25°C:		--	8	9	
see diagram, page 12					
Nominal load current, one channel active:	$I_{L(NOM)}$	5.0	5.4	--	A
two parallel channels active:		6.7	7.4	--	
four parallel channels active:		10.5	11.1	--	
Device on PCB[6)], T_a = 85°C, $T_j \leq$ 150°C					
Output current while GND disconnected, V_{IN} = 0, see diagram page 11; (not tested specified by design)	$I_{L(GNDhigh)}$	--	--	1	mA
Turn-on time[7)] IN ⌋‾ to 90% V_{OUT}:	t_{on}	--	50	150	µs
Turn-off time IN ⌉_ to 10% V_{OUT}:	t_{off}	--	120	220	
R_L = 12 Ω					
Slew rate on[7)] 10 to 30% V_{OUT}, R_L = 12 Ω:	dV/dt_{on}	0.3	--	1	V/µs
Slew rate off[7)] 70 to 40% V_{OUT}, R_L = 12 Ω:	$-dV/dt_{off}$	0.15	--	1	V/µs

5) Soldering point: upper side of solder edge of device pin 7,8. See page 16.

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 16

7) See timing diagram on page 13.

Parameter and Conditions, each of the four channels at T_j = -40...+150°C, V_{bb} = 12 V unless otherwise specified	**Symbol**	**Values**			**Unit**
		min	typ	Max	
Operating Parameters					
Operating voltage	$V_{bb(on)}$	4.5	--	40	V
Overvoltage protection[8] I_{bb} = 40 mA	$V_{bb(AZ)}$	41	47	52	V
Standby current[9] T_j =-40...25°C:	$I_{bb(off)}$	--	10	25	µA
V_{IN} = 0; see diagram page 12 T_j =150°C:		--	40	80	
not tested, specified by design: T_j =125°C:			--	25	
Off-State output current T_j =-40...25°C:	$I_{L(off)}$	--	1	4	µA
(included in $I_{bb(off)}$) V_{IN} = 0; each channel; T_j=150°C:		--	--	15	
Operating current, V_{IN} = 5V,					
I_{GND} = $I_{GND1/2}$ + $I_{GND3/4}$, one channel on:	I_{GND}	--	1.6	--	mA
four channels on:		--	6.0	--	
Protection Functions[10]					
Current limit, (see timing diagrams, page 14)	$I_{L(lim)}$	36	45	58	A
Repetitive short circuit current limit,					
T_j = T_{jt} each channel	$I_{L(SCr)}$	--	40	--	A
two,three or four parallel channels		--	40		
(see timing diagrams, page 14)				--	
Initial short circuit shutdown time $T_{j,start}$ =25°C: (see timing diagrams on page 14)	$t_{off(SC)}$	--	4	--	ms
Output clamp (inductive load switch off)[11]					
at $V_{ON(CL)}$ = V_{bb} - V_{OUT}, I_L= 40 mA T_j =-40°C..25°C:	$V_{ON(CL)}$	18	21	30	V
T_j =150°C:		14	17	20	
Thermal overload trip temperature	T_{jt}	150	--	--	°C
Thermal hysteresis	ΔT_{jt}	--	10	--	K

8) 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 10.

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

10) 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.

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

Parameter and Conditions, each of the four channels at T_j = -40...+150°C, V_{bb} = 12 V unless otherwise specified	**Symbol**	**Values**			**Unit**
		min	typ	Max	
Reverse Battery					
Reverse battery voltage [12]	$-V_{bb}$	--	--	28	V
On-state resistance with reverse battery I_L = 2A; V_{bb} = 12V Tj =25°C: Tj =150°C:	R_{on}	-- --	45 80	60 120	mΩ
Input[13]					
Input resistance (see circuit page 10)	R_I	2.5	3.5	6.0	kΩ
Input turn-on threshold voltage	$V_{IN(T+)}$	1.7	--	3.2	V
Input turn-off threshold voltage	$V_{IN(T-)}$	1.5	--	--	V
Input threshold hysteresis	$\Delta V_{IN(T)}$	--	0.3	--	V
Off state input current V_{IN} = 0.4 V:	$I_{IN(off)}$	1	--	35	µA
On state input current V_{IN} = 5 V:	$I_{IN(on)}$	20	50	90	µA

12) Power dissipation is higher compared to normal operating conditions due to the elevated on-state reistance. The temperature protection and sense functionality is not active during reverse current operation! Input and Status currents have to be limited (see max. ratings page 4 and circuit page 10).

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

Parameter and Conditions, each of the four channels at T_j = -40...+150°C, V_{bb} = 12 V unless otherwise specified	**Symbol**	**Values**			**Unit**
		min	typ	Max	
Diagnostic Characteristics					
Current sense ratio, static on-condition, $k_{ILIS} = I_L : I_{IS}$	k_{ILIS}	--	5 000	--	
-40°C I_L = 10 A:		4575	5000	5425	
I_L = 2 A:		4100	5000	5900	
I_L = 1 A:		4200	5200	6200	
I_L = 0.5 A:		3580	5800	8080	
+25°C I_L = 10 A:		4600	4900	5200	
I_L = 2 A:		4250	4900	5550	
I_L = 1 A:		4310	5100	6010	
I_L = 0.5 A:		3820	5600	7320	
+150°C I_L = 10 A:		4675	4900	5125	
I_L = 2 A:		4475	4900	5325	
I_L = 1 A:		4350	5000	5650	
I_L = 0.5 A:		4200	5200	6200	
Sense signal in case of fault-conditions[14]	V_{fault}	5.8	6.3	6.9	V
Sense signal delay after thermal shutdown[15]	$t_{delay(fault)}$	--	--	1	ms
Sense current saturation	$I_{IS,lim}$	4	--	--	mA
Current sense output voltage limitation I_{IS} = 0, I_L = 5 A:	$V_{IS(lim)}$	5.8	6.3	6.9	V
Current sense leakage/offset current					
V_{IN}=0, V_{IS} = 0, I_L = 0:	$I_{IS(LL)}$	--	--	1	µA
V_{IN}=5 V, V_{IS} = 0, I_L = 0:	$I_{IS(LH)}$	--	2.5	--	
Current sense settling time to $I_{IS\ static}$±10% after positive input slope, I_L = 0 ⎍ 5 A, (not tested, specified by design)	$t_{son(IS)}$	--	--	300	µs
Internal output pull down only active in off-state	R_0	--	7	--	kΩ

14) In the case of current limitation or thermal shutdown the sense signal is no longer a current proportional to the load current, but a fixed voltage of typ. 5 V.

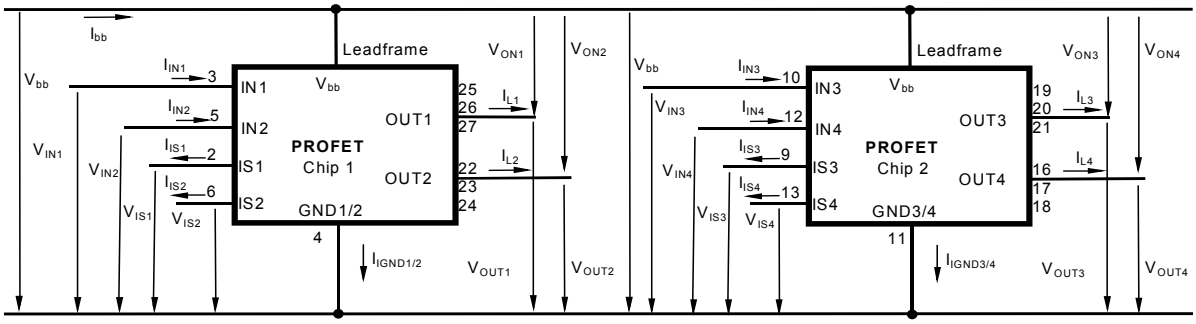
15) In the case of thermal shutdown the V_{fault} signal remains for $t_{delay(fault)}$ longer than the restart of the switch (see diagram on page 15).

Truth Table

	Input level	Output level	Current Sense I_{IS}
Normal Operation	**L** **H**	**L** **H**	**0** **nominal**
Current-Limitation[16]	**H**	**H**	V_{fault}
Short circuit to GND	**L** **H**	**L** **L**	**0** V_{fault}
Overtemperature	**L** **H**	**L** **L**	**0** V_{fault}
Short circuit to Vbb	**L** **H**	**H** **H**	**0** **<nominal**[17]
Open load	**L** **H**	**Z** **H**	**0** **0**
Negative output Voltage clamp	**L**	**L**	**0**

L = "Low" Level X = don't care Z = high impedance, potential depends on external circuit
H = "High" Level V_{fault} = 5V typ, constant voltage independent of external used sense resistor.
Parallel switching of channels is possible by connecting the inputs and outputs in parallel. The current sense outputs have to be connected with a single sense resistor.

Terms



Leadframe (V_{bb}) is connected to pin 1, 7, 8, 14, 15, 28

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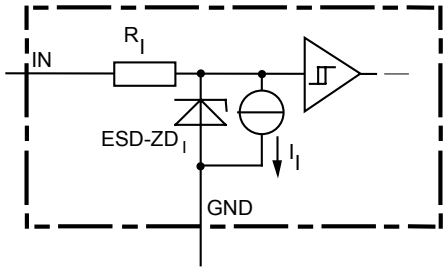
16) Current limitation is only possible while the device is switched on.

17) Low ohmic short to V_{bb} may reduce the output current I_L and therefore also the sense current I_{IS}.

Input circuit (ESD protection), IN1 to IN4



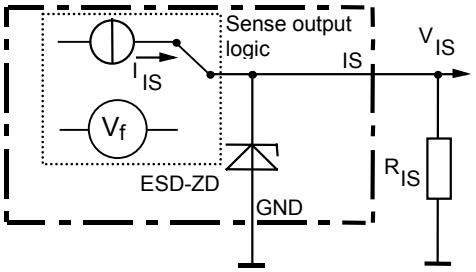
The use of ESD zener diodes as voltage clamp at DC conditions is not recommended.

Sense output

Normal operation: $I_S = I_L / k_{ILIS}$

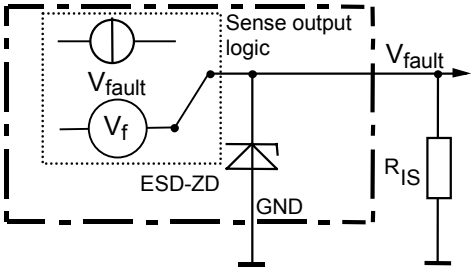
$V_{IS} = I_S * R_{IS}$; R_{IS} = 1 kΩ nominal

$R_{IS} > 500\Omega$



ESD-Zener diode: V_{ESD} = 6.1 V typ., max 14 mA;

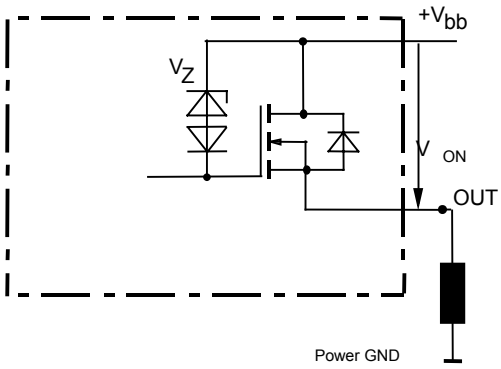
Operation under fault condition
so as thermal shut down or current limitation



V_{fault} = 6V typ

$V_{fault} < V_{ESD}$ under all conditions

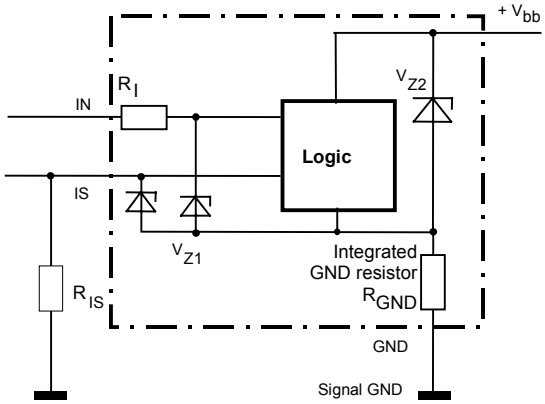
Overvoltage output clamp, OUT1 or OUT2



V_{ON} clamped to $V_{ON(CL)}$ = 21 V typ.

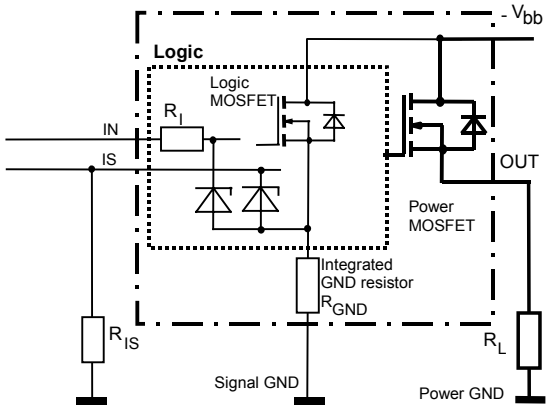
Overvoltage protection of logic part

GND1/2 or GND3/4



V_{Z1} = 6.1 V typ., V_{Z2} = 47 V typ., R_I = 3.5 kΩ typ.,
R_{GND} = 75 Ω

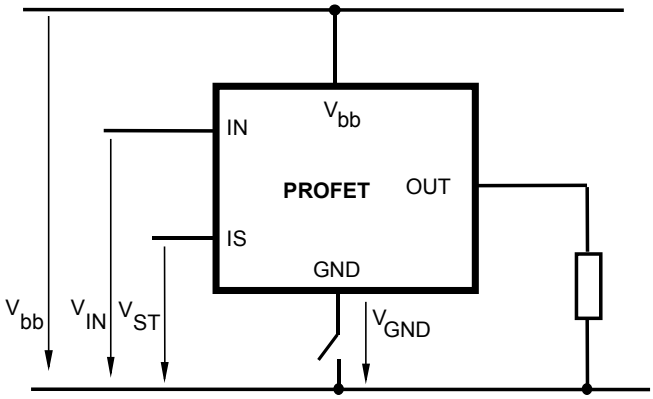
Reverse battery protection



R_{GND} = 75 Ω, R_I = 3.5 kΩ typ,

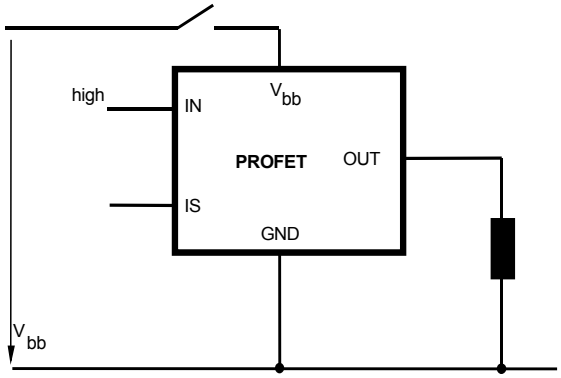
In case of reverse battery the channel of the MOSFET is turned on.
Temperature protection and sense functionality is not active during inverse current operation.

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.

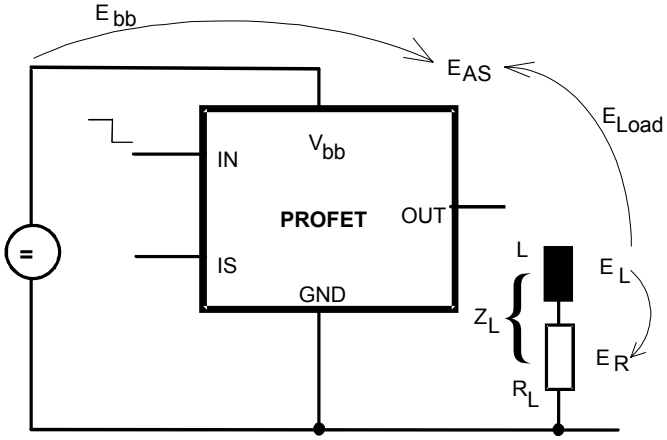
V_{bb} disconnect with energized inductive load



For inductive load currents up to the limits defined by Z_L (max. ratings and diagram on page 11) 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

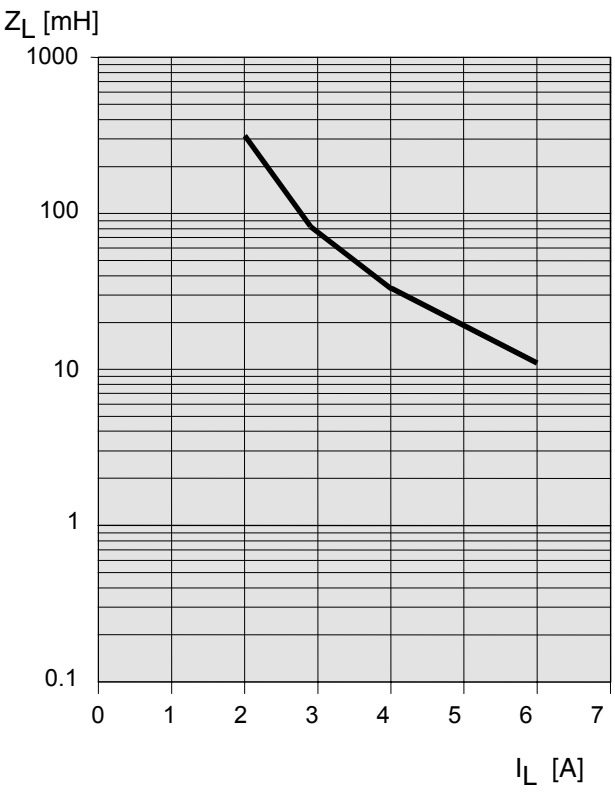
$$E_{AS} = E_{bb} + E_L - E_R = \int V_{ON(CL)} \cdot i_L(t)\, dt,$$

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

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

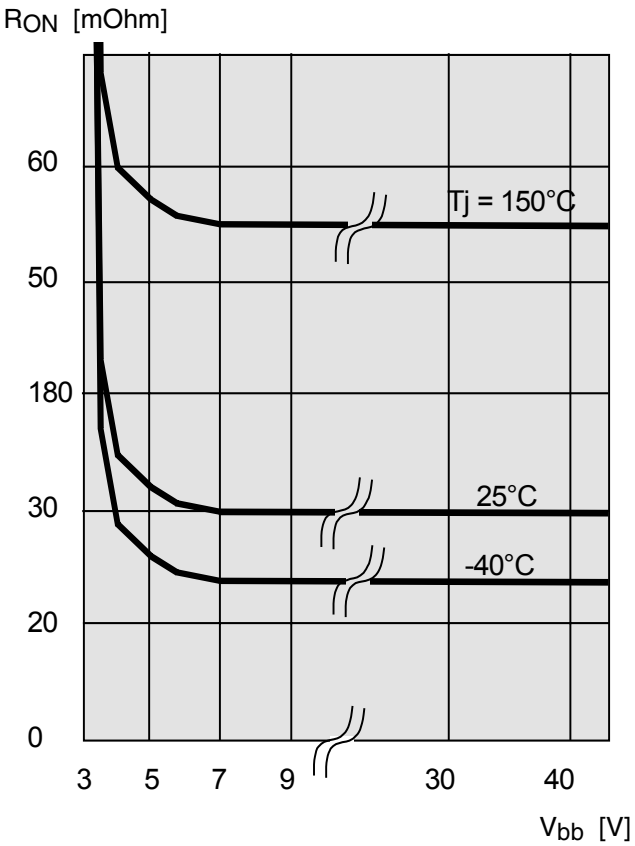
Maximum allowable load inductance for a single switch off (one channel)[4)]

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



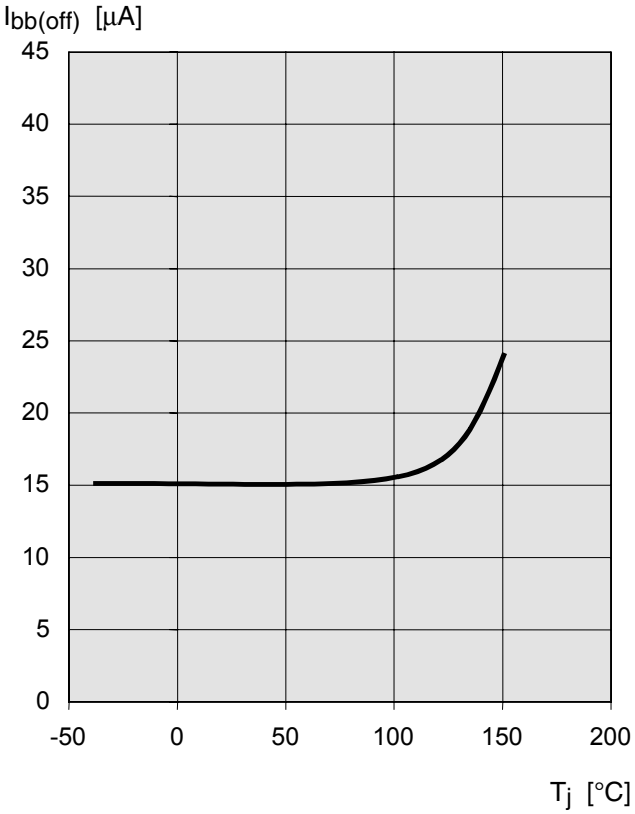
Typ. on-state resistance

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



Typ. standby current

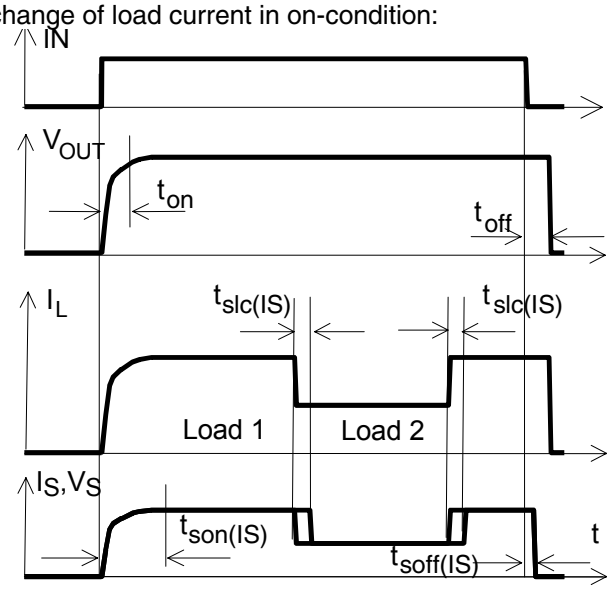
$I_{bb(off)} = f(T_j)$; V_{bb} = 9...34 V, IN1,2,3,4 = low



Functionality diagrams

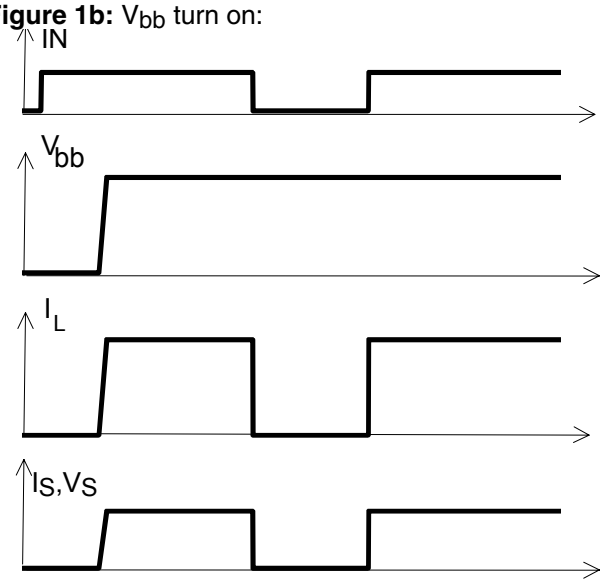
All diagrams are shown for chip 1 (channel 1/2). For chip 2 (channel 3/4) the diagrams are valid too. The channels 1 and 2, respectively 3 and 4, are symmetric and consequently the diagrams are valid for each channel as well as for permuted channels

Figure 1a: Switching a resistive load, change of load current in on-condition:



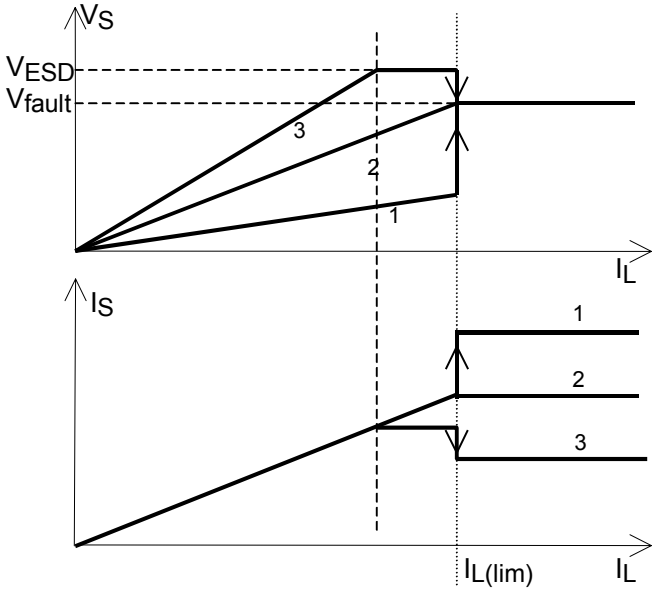
The sense signal is not valid during settling time after turn on or change of load current.

Figure 1b: V_{bb} turn on:



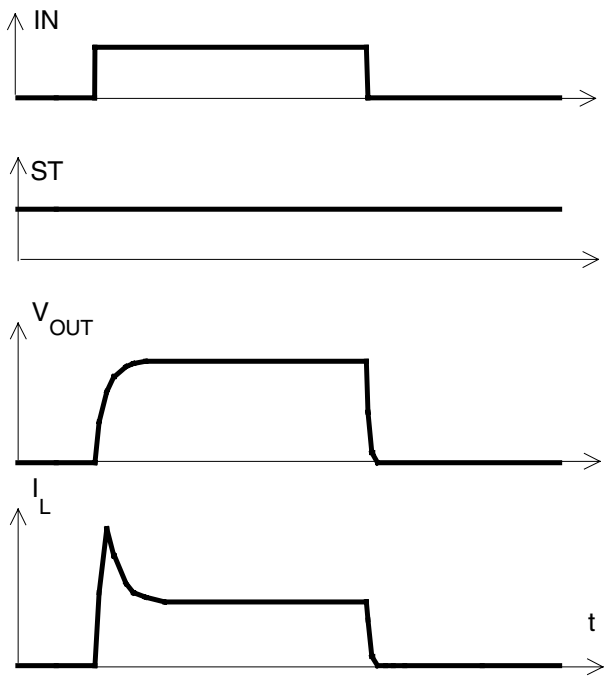
proper turn on under all conditions

Figure 1c: Behaviour of sense output:
Sense current (I_S) and sense voltage (V_S) as function of load current dependent on the sense resistor
Shown is V_S and I_S for three different sense resistors. Curve 1 refers to a low resistor, curve 2 to a medium-sized resistor and curve 3 to a big resistor. Note, that the sense resistor may not fall short of a minimum value of 500Ω.



$I_S = I_L / k_{ILIS}$
$V_{IS} = I_S * R_{IS}$; R_{IS} = 1 kΩ nominal
$R_{IS} > 500\Omega$

Figure 2a: Switching a lamp:



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

Figure 2b: Switching a lamp with current limit:
The behaviour of IS and VS is shown for a resistor, which refers to curve 1 in figure 1c

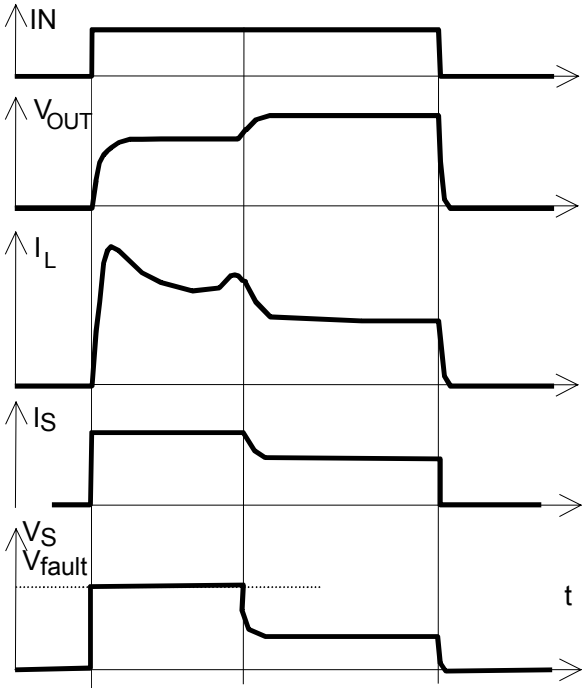
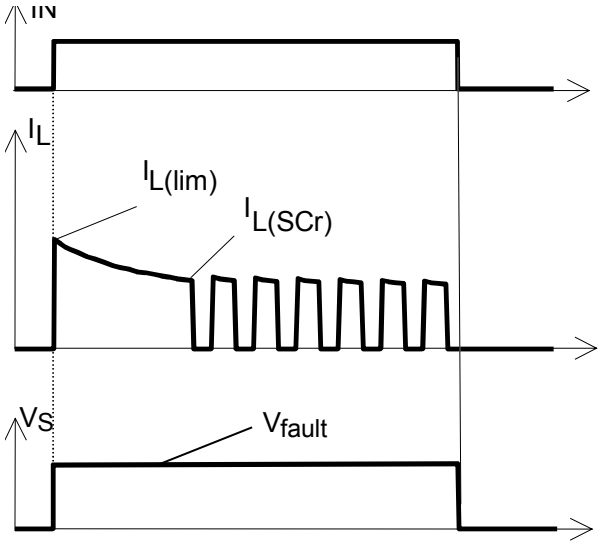


Figure 3a: Short circuit:
shut down by overtempertature, reset by cooling



Heating up may require several milliseconds, depending on external conditions
$I_{LL(lim')}$ = 50 A typ. increases with decreasing temperature.

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

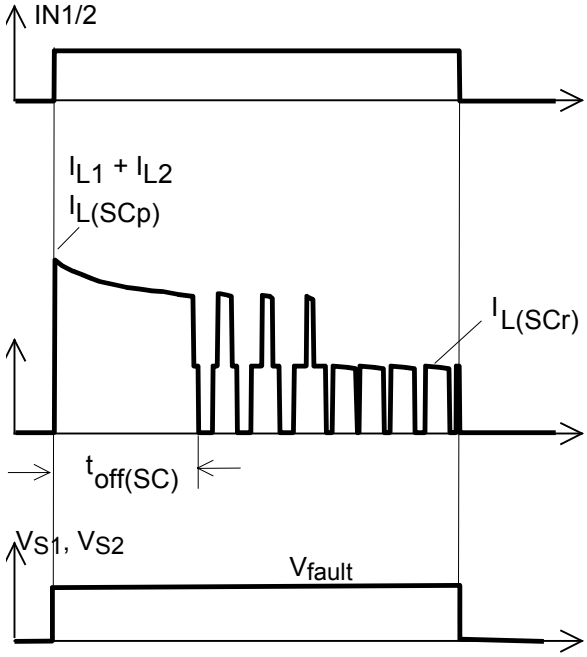


Figure 4a: Overtemperature:
Reset if $T_j < T_{jt}$
The behaviour of IS and VS is shown for a resistor, which refers to curve 1 in figure 1c

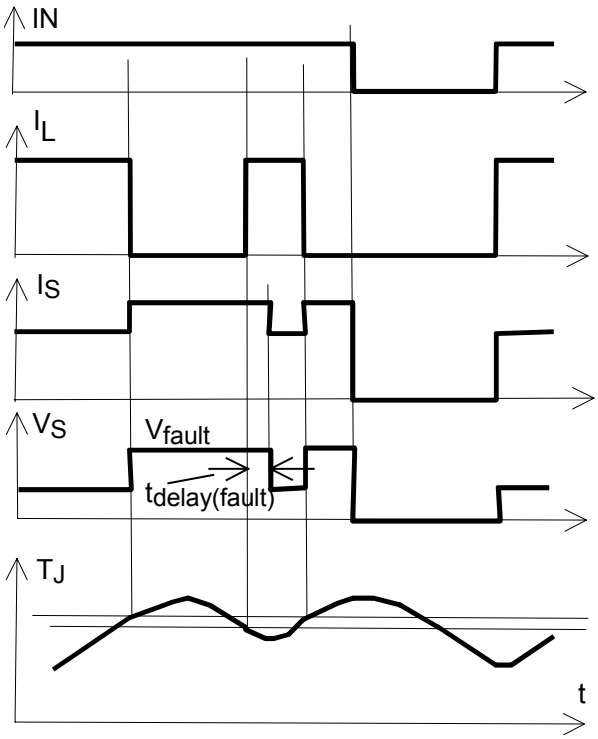


Figure 6a: Current sense versus load current:

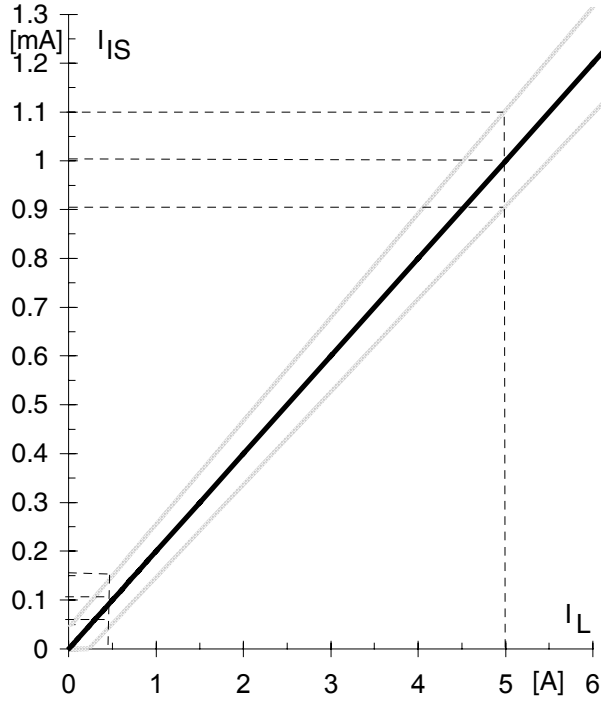
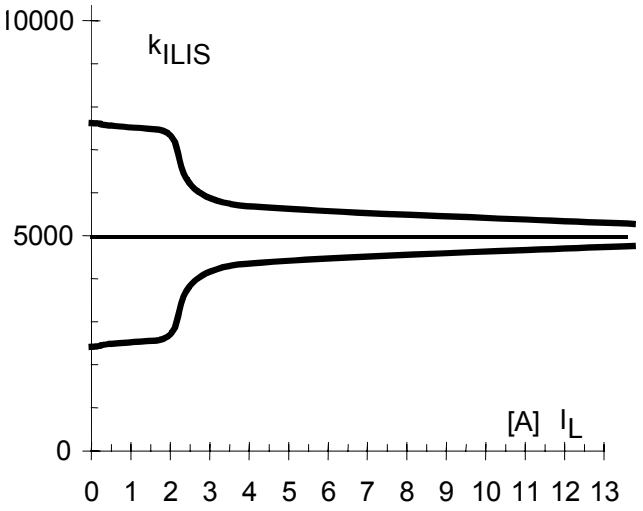


Figure 6b: Current sense ratio[18]:

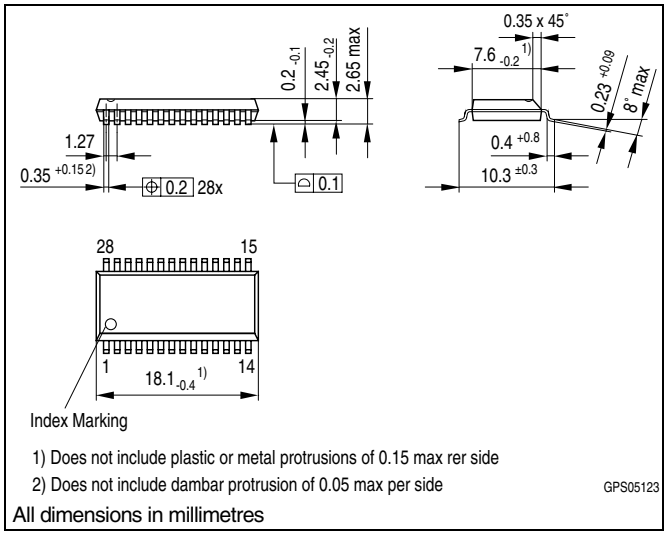


[18] This range for the current sense ratio refers to all devices. The accuracy of the k_{ILIS} can be raised at least by a factor of two by calibrating the value of k_{ILIS} for every single device.

Package and Ordering Code

Standard: P-DSO-28-16

Sales Code	BTS 737 S2
Ordering Code	Q67060-S7017



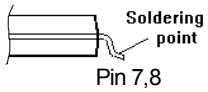
1) Does not include plastic or metal protrusions of 0.15 max rer side

2) Does not include dambar protrusion of 0.05 max per side

GPS05123

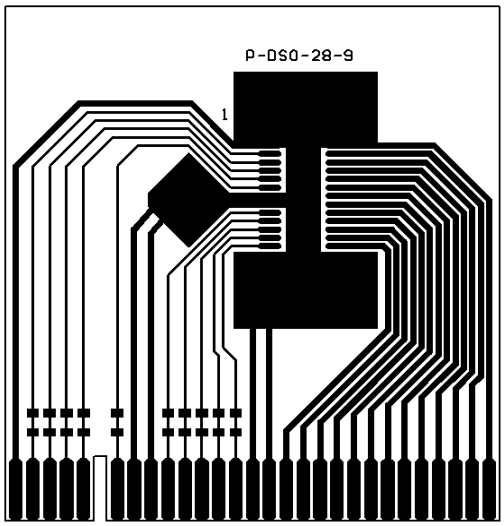
All dimensions in millimetres

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



Pin 7,8

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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19) A critical component is a component used in a life-support device or system whose failure can reasonably be expected to cause the failure of that life-support device or system, or to affect its safety or effectiveness of that device or system.

20) Life support devices or systems are intended (a) to be implanted in the human body or (b) support and/or maintain and sustain and/or protect human life. If they fail, it is reasonably to assume that the health of the user or other persons may be endangered.