Smart Highside Power Switch

Reversave™
- Reverse battery protection by self turn on of power MOSFET

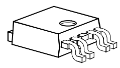
Features
- Short circuit protection
- Current limitation
- Overload protection
- Thermal shutdown
- Overvoltage protection (including load dump)
- Loss of ground protection
- Loss of V_{bb} protection (with external diode for charged inductive loads)
- Very low standby current
- Fast demagnetisation of inductive loads
- **E**lectro**s**tatic **d**ischarge (**ESD**) protection
- Optimized static **e**lectro**m**agnetic **c**ompatibility (**EMC**)

Product Summary

Operating voltage	$V_{bb(on)}$	5.0 ... 36	V
On-state resistance	R_{ON}	16	mΩ
Load current (ISO)	$I_{L(ISO)}$	25	A
Current limitation	$I_{L(SCr)}$	65	A

Package

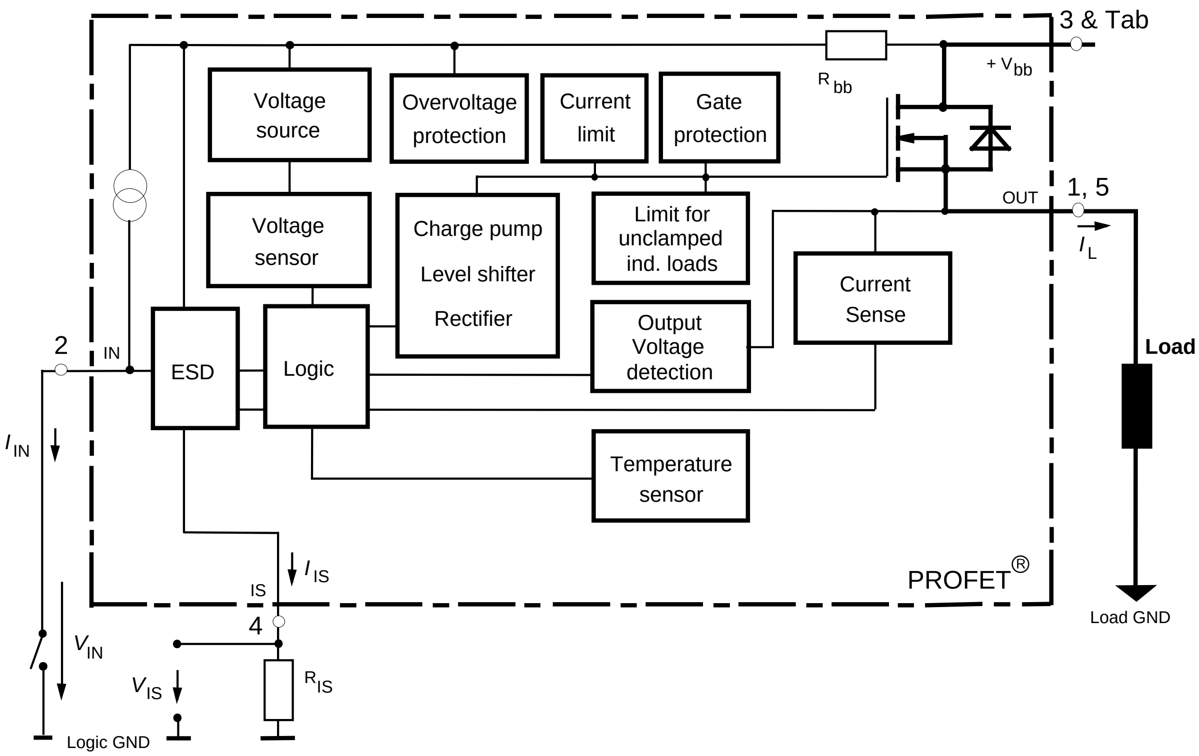
TO-252-5-1
(DPAK 5 pin; less than half the size as TO 220 SMD)



Diagnostic Function
- Proportional load current sense (with defined fault signal while thermal shutdown)

Application
- Power switch with current sense diagnostic feedback for 12V and 24 V DC grounded loads
- All types of resistive, capacitve and inductive loads (no PWM with inductive loads)
- Replaces electromechanical relays, fuses and discrete circuits

General Description
N channel vertical power FET with charge pump, current controlled input and diagnostic feedback with load current sense, integrated in Smart SIPMOS® chip on chip technology. Fully protected by embedded protection functions.



Pin	Symbol		Function
1	OUT	O	Output to the load. The pin 1 and 5 must be shorted with each other especially in high current applications!*)
2	IN	I	Input, activates the power switch in case of short to ground
Tab/(3)	Vbb	+	Positive power supply voltage, the tab is shorted to this pin.
4	IS	S	Diagnostic feedback providing a sense current proportional to the load current; high current on failure (see Truth Table)
5	OUT	O	Output to the load. The pin 1 and 5 must be shorted with each other especially in high current applications!*)

*) Not shorting all outputs will considerably increase the on-state resistance, reduce the peak current capability and decrease the current sense accuracy

Maximum Ratings at T_j = 25 °C unless otherwise specified

Parameter	Symbol	Values	Unit
Supply voltage (overvoltage protection see page 4)	V_{bb}	36	V
Supply voltage for full short circuit protection (see also diagram on page 9) T_j=-40...150 °C:	V_{bb}	24[1]	V
Load dump protection $V_{LoadDump} = U_A + V_s$, U_A = 13.5 V R_I= 2 Ω, R_L= 2.7 Ω, t_d= 200 ms, IN= low or high	$V_{Load\ dump}$[2]	60	V
Load current (Short-circuit current, see page 4)	I_L	self-limited	A
Operating temperature range Storage temperature range	T_j T_{stg}	-40 ...+150 -55 ...+150	°C
Power dissipation (DC) TC ≤ 25°C	P_{tot}	42	W
Inductive load switch-off energy dissipation, single pulse U=12V, I=10A, L=3mH T_j=150 °C:	E_{AS}	0.15	J
Electrostatic discharge capability (ESD) (Human Body Model) acc. ESD assn. std. S5.1-1993; R=1.5kΩ; C=100pF	V_{ESD}	4.0	kV
Current through input pin (DC) Current through current sense pin (DC) see internal circuit diagrams page 7	I_{IN} I_{IS}	+15, -100 +15, -100	mA

1) Short circuit is tested with 100mΩ and 20µH

2) $V_{Load\ dump}$ is set-up without the DUT connected to the generator per ISO 7637-1 and DIN 40839

Thermal Characteristics

Parameter and Conditions	Symbol	Values			Unit
		min	typ	max	
Thermal resistance chip - case:	R_{thJC} 3)	--	--	1.5	K/W
junction - ambient (free air):	R_{thJA}	--	80	--	
SMD version, device on PCB4):			45		

Electrical Characteristics

Parameter and Conditions at T_j= -40°C...150°C, V_{bb} = 12 V unless otherwise specified	Symbol	Values			Unit
		min	typ	max	

Load Switching Capabilities and Characteristics

On-state resistance (pin 3 to pin 1,5) V_{IN}= 0, I_L = 5 A T_j=25 °C:	R_{ON}	--	13	16	mΩ
T_j=150 °C:			25	31	
Output voltage drop limitation at small load currents (Tab to pin 1,5) T_j=-40...150 °C:	$V_{ON(NL)}$	--	50	--	mV
Nominal load current (Tab to pin 1,5) ISO Proposal: V_{ON} = 0.5 V, T_C = 85 °C	$I_{L(ISO)}$	21	25	--	A
Turn-on time to 90% V_{OUT}:	t_{on}	150	--	410	µs
Turn-off time to 10% V_{OUT}: R_L = 2,5Ω, T_j=-40...150 °C	t_{off}	70	--	410	
Slew rate on 10 to 30% V_{OUT}, R_L = 2.5 Ω, T_j=-40...150 °C	dV /dt$_{on}$	0.1	--	1	V/µs
Slew rate off 70 to 40% V_{OUT}, R_L = 2.5 Ω, T_j=-40...150 °C	-dV/dt$_{off}$	0.1	--	1	V/µs

3) Thermal resistance R_{thCH} case to heatsink (about 0.5 ... 0.9 K/W with silicone paste) not included!
4) Device on 50mm*50mm*1.5mm epoxy PCB FR4 with 6cm^2 (one layer, 70µm thick) copper area for V_{bb} connection. PCB is vertical without blown air.

Parameter and Conditions at T_j= -40°C...150°C, V_{bb} = 12 V unless otherwise specified	Symbol	Values			Unit
		min	typ	max	
Operating Parameters					
Operating voltage (V_{IN}=0)	$V_{bb(on)}$	5.0	--	36	V
Undervoltage shutdown[5]	$V_{bIN(u)}$	1.5	3.0	4.5	V
Undervoltage restart of charge pump	$V_{bb(ucp)}$	3.0	4.5	6.0	V
Overvoltage protection[6] I_{bb}=15 mA	$V_{Z,IN}$	61	68	--	V
Standby current T_j=-40...+25°C: I_{IN}=0 T_j=150°C:	$I_{bb(off)}$	-- --	2 4	5 8	µA
Protection Functions					
Short circuit current limit (Tab to pin 1,5) V_{ON} = 12V, time until limitation max. 300µs T_j =-40°C: T_j =25°C: T_j =+150°C:	$I_{L(SC)}$	35 35 35	75 65 65	110 110 125	A
Repetitive short circuit current limit, $T_j = T_{jt}$	$I_{L(SCr)}$	--	65	--	A
Output clamp (inductive load switch off) at $V_{OUT} = V_{bb} - V_{ON(CL)}$ (e.g. overvoltage) I_L= 40 mA [7]	$V_{ON(CL)}$	38	42	48	V
Thermal overload trip temperature	T_{jt}	150	--	--	°C
Thermal hysteresis	ΔT_{jt}	--	10	--	K
Reverse Battery					
Reverse battery voltage	$-V_{bb}$	--	--	20	V
On-state resistance (pin 1,5 to pin 3) V_{bb}= - 8V, V_{IN}= 0, I_L = -5 A, R_{IS} = 1 kΩ, T_j=25 °C: V_{bb}= -12V, V_{IN}= 0, I_L = -5 A, R_{IS} = 1 kΩ, T_j=25 °C: T_j=150 °C:	$R_{ON(rev)}$	-- --	-- 16 25	22 19 32	mΩ
Integrated resistor in V_{bb} line	R_{bb}	--	200	--	Ω

5) $V_{bIN}=V_{bb}-V_{IN}$ see diagram page 11.

6) see also $V_{ON(CL)}$ in circuit diagram page 7.

7) see also page 9

Parameter and Conditions at T_j= -40°C...150°C, V_{bb} = 12 V unless otherwise specified	Symbol	Values min	typ	max	Unit
Diagnostic Characteristics					
Current sense ratio, static on-condition $k_{ILIS} = I_L : I_{IS}$, $V_{ON} < 1.5\,V$[8], $V_{IS} < V_{OUT}$ - 5V, $V_{bIN} > 4.5\,V$	k_{ILIS}	--	8200	--	
IL = 20A, Tj = -40°C:		7400	8300	9100	
Tj = +25°C:		7500	8300	9100	
Tj = +150°C:		7500	8200	8800	
IL = 5A, Tj = -40°C:		6800	8300	9700	
Tj = +25°C:		7200	8300	9300	
Tj = +150°C:		7200	8200	9000	
IL = 2.5A, Tj = -40°C:		6800	8500	10000	
Tj = +25°C:		6800	8500	9800	
Tj = +150°C:		6800	8100	9200	
IL = 1A, Tj = -40°C:		6800	8600	10500	
Tj = +25°C:		6800	8600	10500	
Tj = +150°C:		6800	8600	10500	
I_{IN} = 0 (e.g. during deenergising of inductive loads):		--	n.a.	--	
Sense current under fault conditions; V_{DS}>1.5V, typ. T_j = -40...+150°C:	$I_{IS,fault}$	2.5	4	--	mA
Fault-Sense signal delay after negative input slope	$t_{delay(fault)}$			0.8	ms
Current sense leakage current I_{IN} = 0:	$I_{IS(LL)}$	--	--	0.5	µA
V_{IN} = 0, I_L = 0:	$I_{IS(LH)}$	--	4	12	
Current sense settling time to $I_{IS\ static}$±10% after positive input slope, I_L = 0 – 20 A, T_j= -40...+150°C (not tested, specified by design)	$t_{son(IS)}$	--	--	400	µs
Overvoltage protection I_{bb} = 15 mA T_j = -40...+150°C:	$V_{bIS(Z)}$	61	68	--	V

Parameter and Conditions	Symbol	min	typ	max	Unit
Input					
Required current capability of input switch T_j = -40..+150°C:	$I_{IN(on)}$	--	0.7	1.2	mA
Maximum input current for turn-off T_j = -40..+150°C:	$I_{IN(off)}$	--	--	50	µA

8) If V_{ON} is higher, the sense current is no longer proportional to the load current due to sense current saturation, see $I_{IS,lim}$.

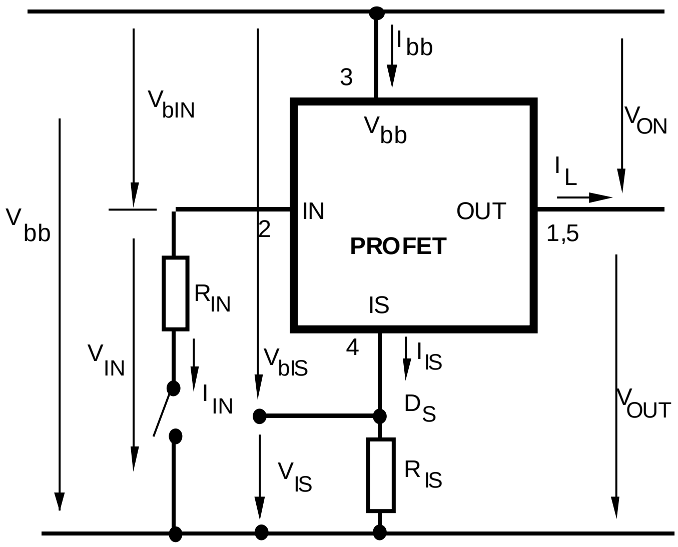
Truth Table

	Input Current level	Output level	Current Sense I_{IS}
Normal operation	L H	L H	0 nominal
Overload	L H	L H	0 $I_{ISfault}$
Short circuit to GND	L H	L L	0 $I_{ISfault}$
Overtemperature	L H	L L	0 $I_{ISfault}$
Short circuit to Vbb	L H	H H	0 <nominal[9]
Open load	L H	Z H	0 0

L = "Low" Level
H = "High" Level

Z = high impedance, potential depends on external circuit

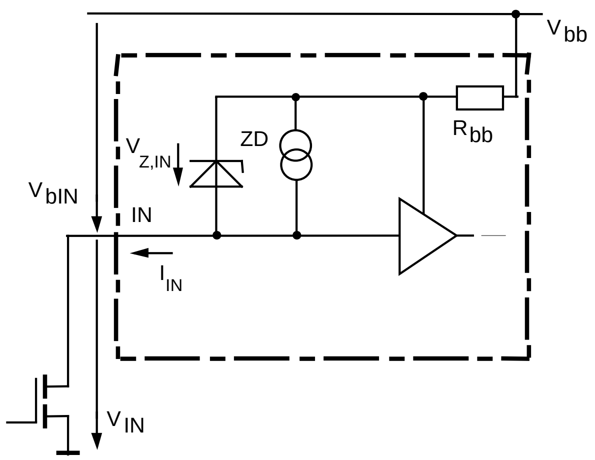
Terms



Two or more devices can easily be connected in parallel to increase load current capability.

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

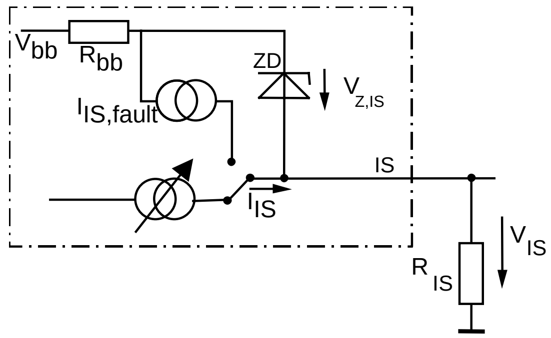
Input circuit (ESD protection)



ESD-Zener diode: 68 V typ., max 15 mA;

Current sense output

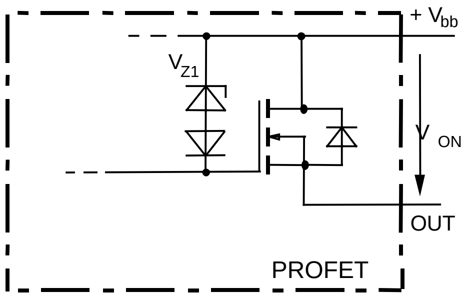
Normal operation



$V_{Z,IS}$ = 68 V (typ.), R_{IS} = 1 kΩ nominal (or 1 kΩ /n, if n devices are connected in parallel). $I_S = I_L/k_{ilis}$ can be only driven by the internal circuit as long as $V_{out} - V_{IS} > 5V$. If you want to measure load currents up to $I_{L(M)}$, R_{IS} should be less than $\frac{V_{bb} - 5V}{I_{L(M)} / K_{ilis}}$.

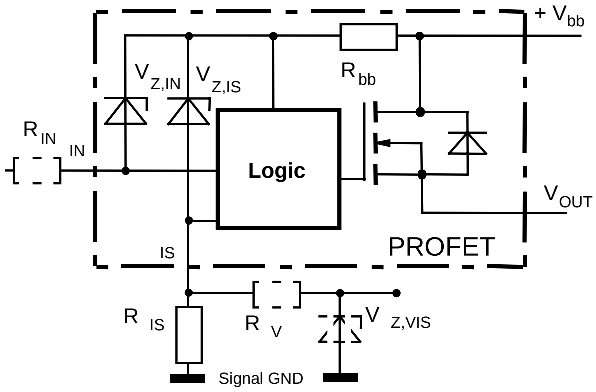
Note: For large values of R_{IS} the voltage V_{IS} can reach almost V_{bb}. See also overvoltage protection.
If you don't use the current sense output in your application, you can leave it open.

Inductive and overvoltage output clamp



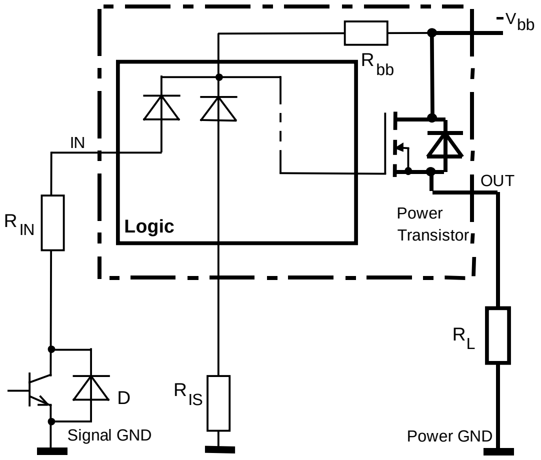
V_{ON} is clamped to $V_{ON(Cl)}$ = 42 V typ

Overvoltage protection of logic part



R_{bb} = 200 Ω typ., $V_{Z,IN} = V_{Z,IS}$ = 68 V typ., R_{IS} = 1 kΩ nominal. Note that when overvoltage exceeds 73 V typ. a voltage above 5V can occur between IS and GND, if R_V, $V_{Z,VIS}$ are not used.

Reversave™ (Reverse battery protection)



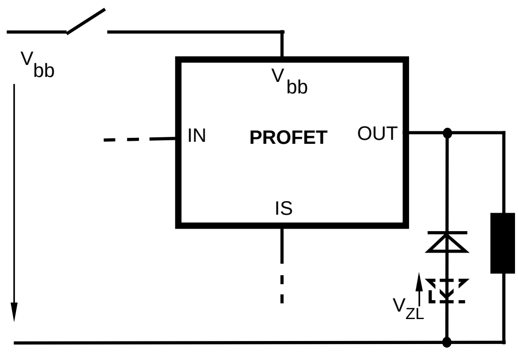
$R_V \geq 1k\Omega$, $R_{IS} = 1\,k\Omega$ nominal. Add R_{IN} for reverse battery protection in applications with V_{bb} above 16V; recommended value: $\frac{1}{R_{IN}}+\frac{1}{R_{IS}}+\frac{1}{R_V}=\frac{0.05A,}{|V_{bb}|-12V}$

To minimise power dissipation at reverse battery operation, the summarised current into the IN and IS pin should be about 50mA. The current can be provided by using a small signal diode D in parallel to the input switch, by using a MOSFET input switch or by proper adjusting the current through R_{IS} and R_V.

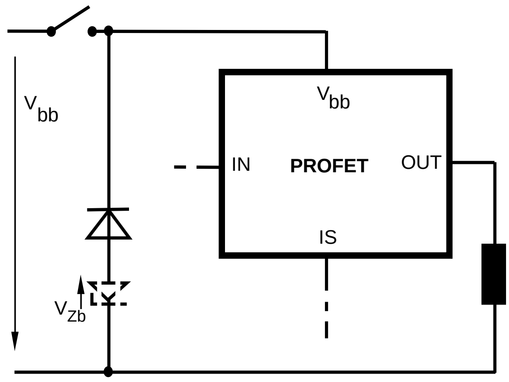
V_{bb} disconnect with energised inductive load

Provide a current path with load current capability by using a diode, a Z-diode, or a varistor. ($V_{ZL} < 73$ V or $V_{Zb} < 30$ V if R_{IN}=0). For higher clamp voltages currents at IN and IS have to be limited to 250 mA.

Version a:

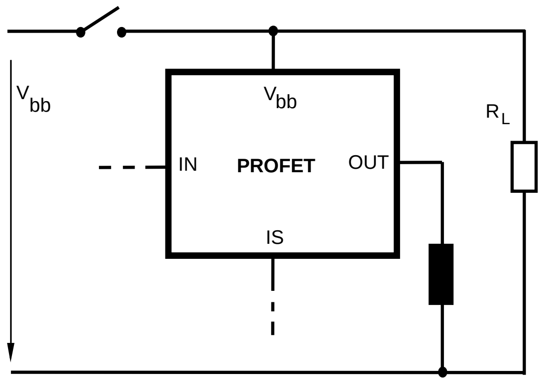


Version b:

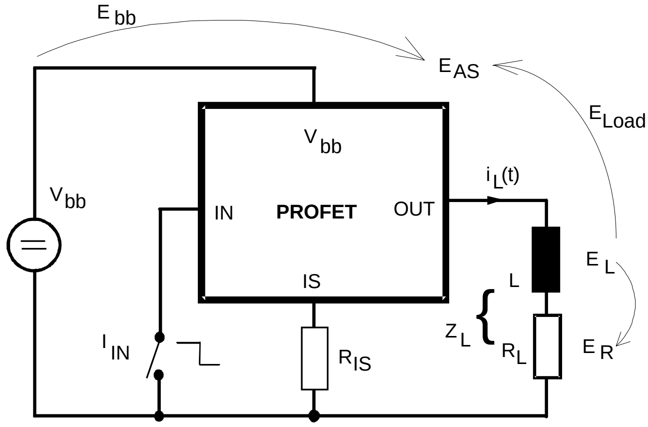


Note that there is no reverse battery protection when using a diode without additional Z-diode V_{ZL}, V_{Zb}.

Version c: Sometimes a necessary voltage clamp is given by non inductive loads R_L connected to the same switch and eliminates the need of clamping circuit:



Inductive load switch-off energy dissipation



Energy stored in load inductance:

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

While demagnetising load inductance, the energy dissipated in PROFET is

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

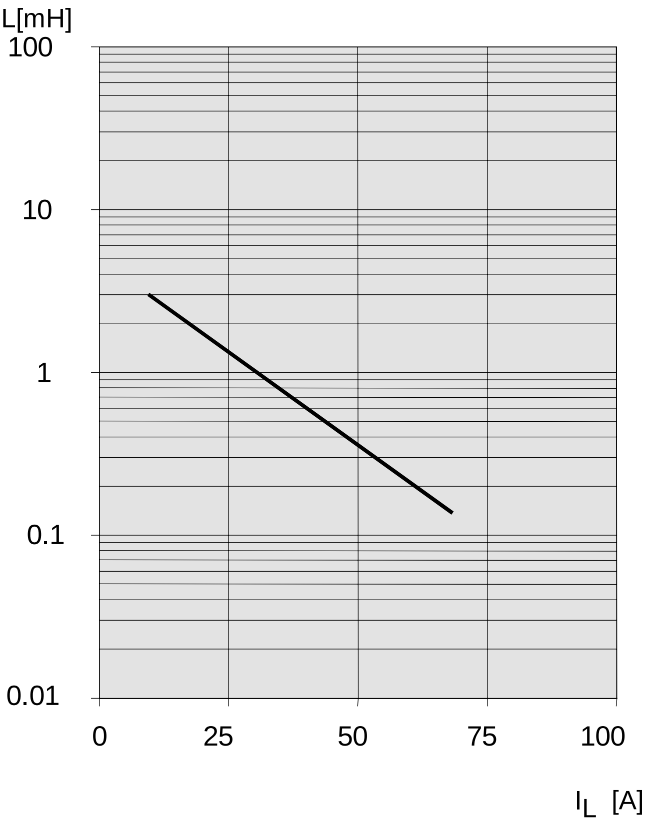
with an approximate solution for $R_L > 0\,\Omega$:

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

The device is not suitable for permanent PWM with inductive loads if active clamping occurs every cycle.

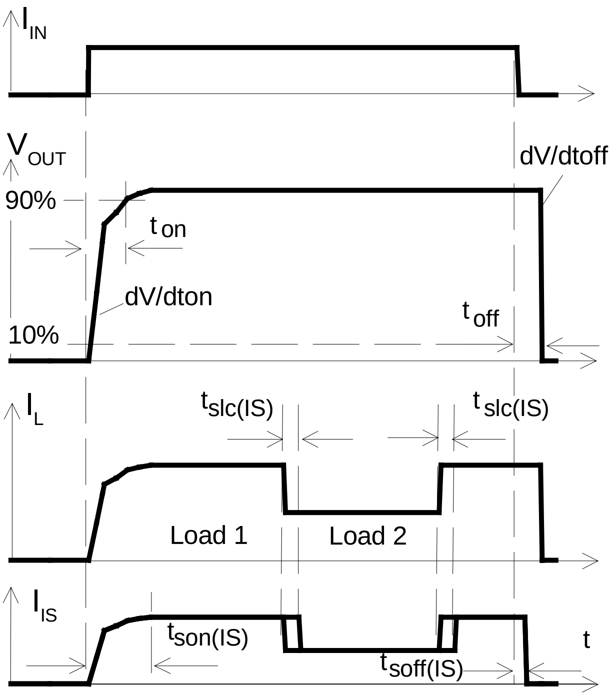
Maximum allowable load inductance for a single switch off

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



Timing diagrams

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



The sense signal is not valid during a settling time after turn-on/off and after change of load current.

Figure 1b: typical behaviour of sense output:

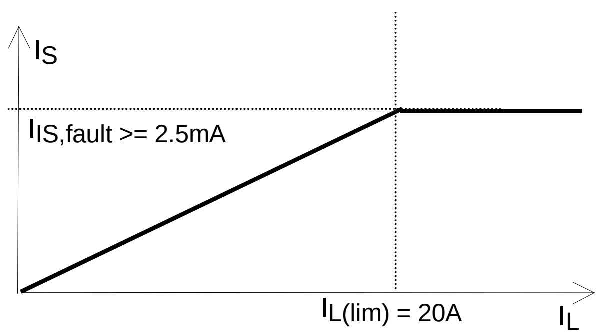
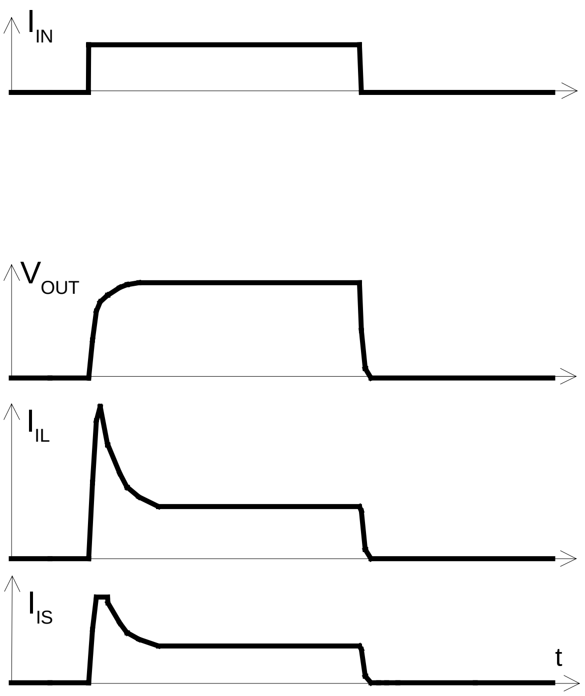


Figure 2a: Switching motors and lamps:



Sense current above $I_{IS,fault}$ can occur at very high inrush currents.

Figure 2b: Switching an inductive load:

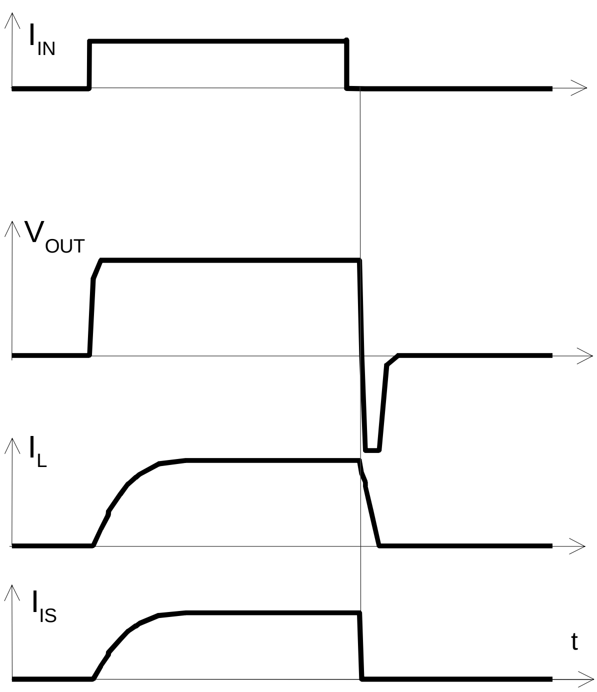


Figure 3a: Short circuit:

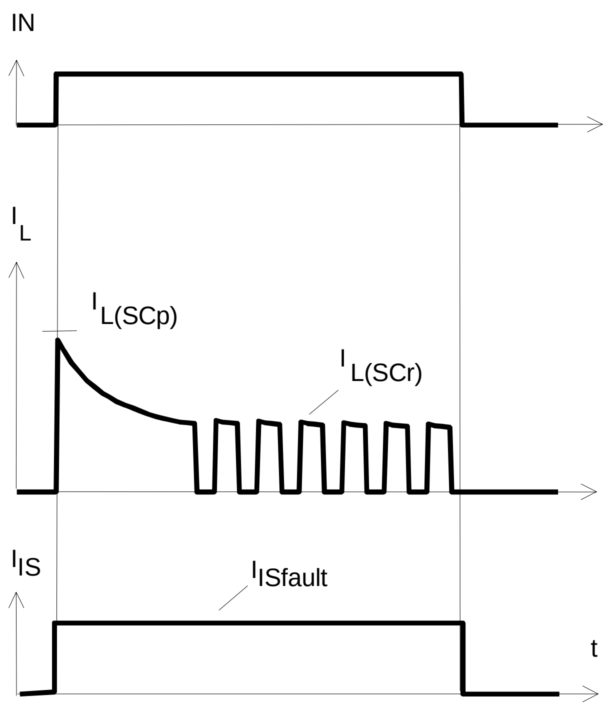


Figure 4a: Overtemperature
Reset if T_j<T_{jt}

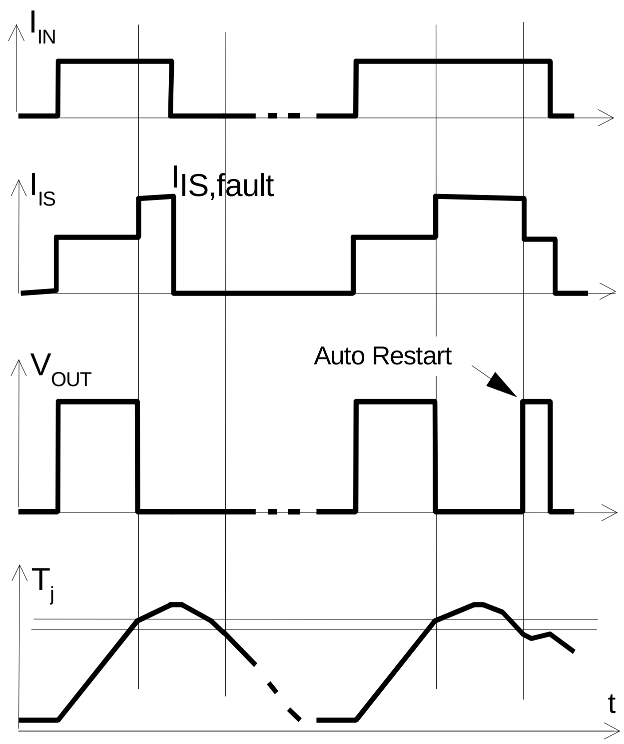


Figure 5a: Undervoltage restart of charge pump, overvoltage clamp

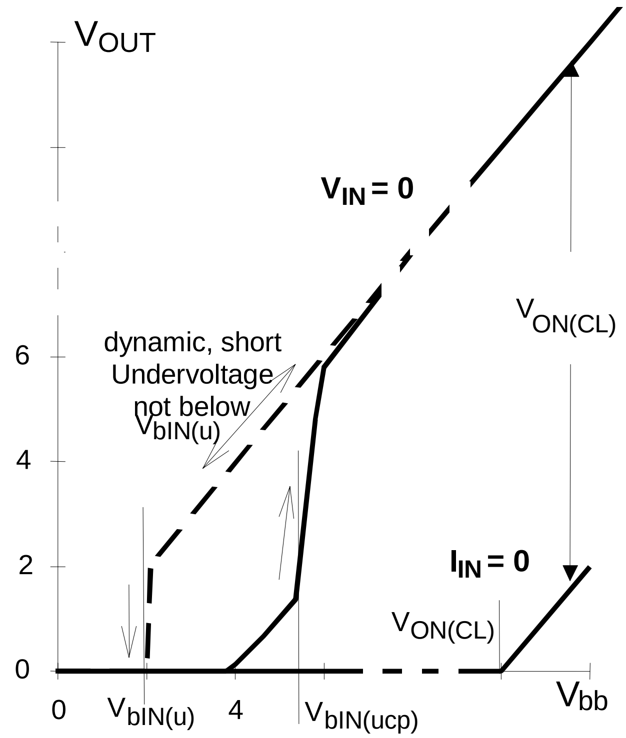


Figure 6a: Current sense versus load current:

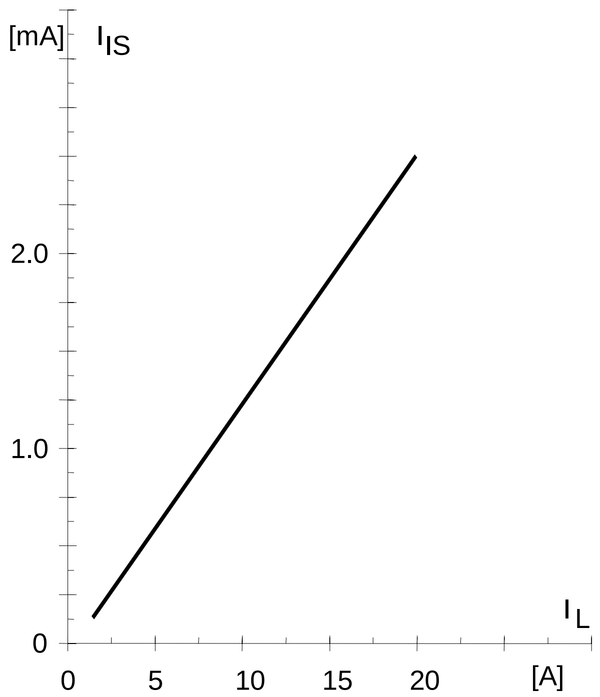


Figure 6b: Current sense ratio[10]:

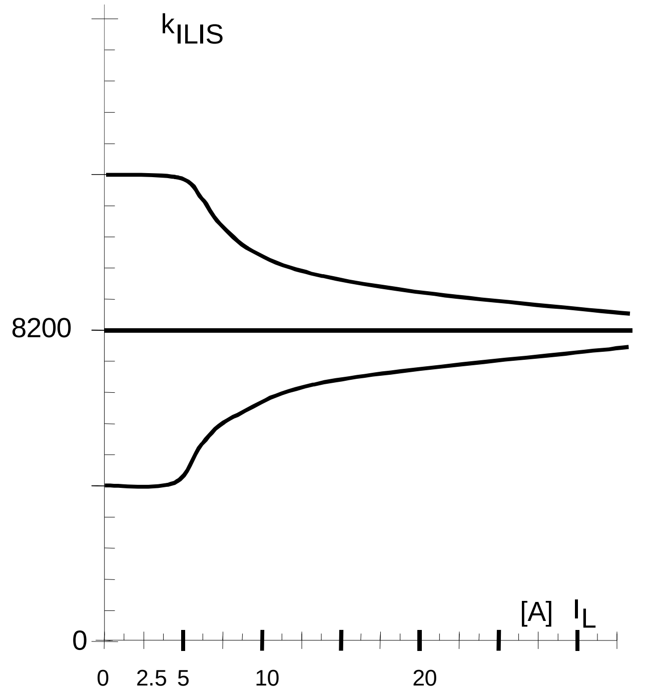
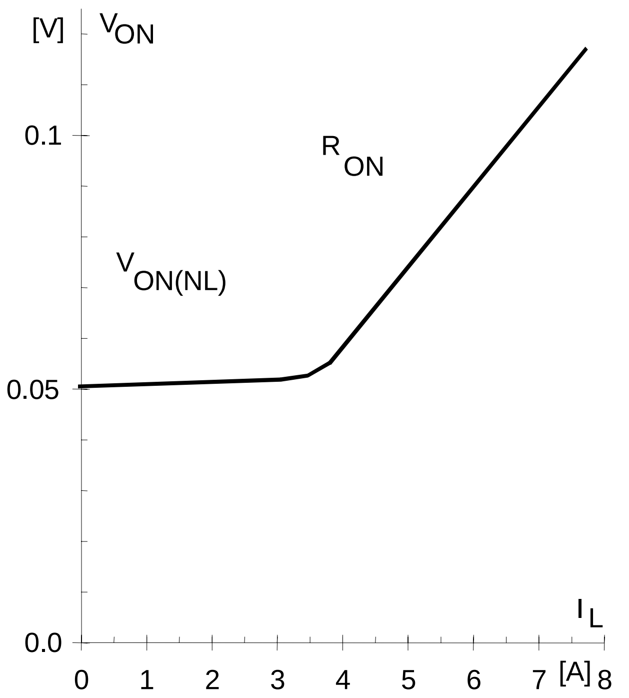


Figure 7a: Output voltage drop versus load current:



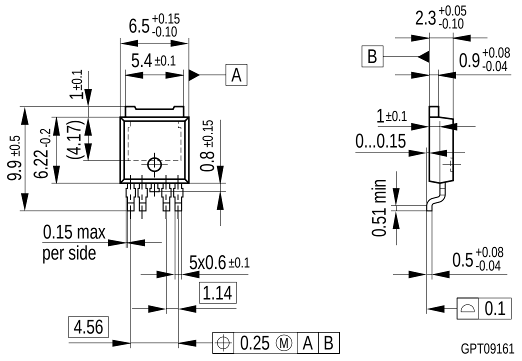
10) This range for the current sense ratio refers to all devices. The accuracy of the k_{ILIS} can be raised by means of calibration the value of k_{ILIS} for every single device.

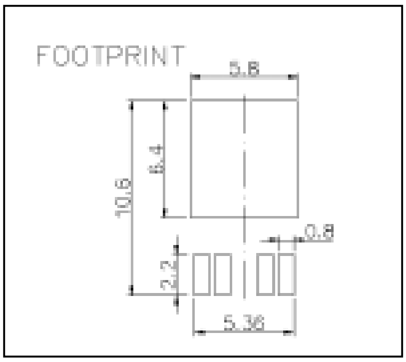
Package and Ordering Code

All dimensions in mm

D-Pak-5 Pin: TO-252-5-1

Sales Code	BTS443P
Ordering code	Q67060-S7404-A 2





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