# Smart Power High-Side-Switch

Features

- Overload protection

- Current limitation

- Short circuit protection

- Thermal shutdown with restart

- Overvoltage protection (including load dump)

- Fast demagnetization of inductive loads

- Reverse battery protection with external resistor

- CMOS compatible input

- Loss of GND and loss of V_{bb} protection

- ESD - Protection

- Very low standby current

Product Summary

Overvoltage protection	$V_{bb(AZ)}$	41	V
Operating voltage	$V_{bb(on)}$	5...34	V
On-state resistance	R_{ON}	100	mΩ
Nominal load current	$I_{L(nom)}$	2	A

P-DSO-8
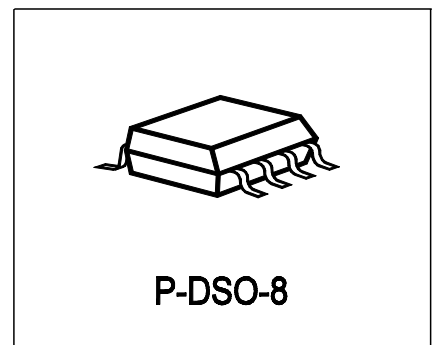
## Application

- All types of resistive, inductive and capacitive loads
- µC compatible power switch for 12 V and 24 V DC applications
- Replaces electromechanical relays and discrete circuits

General Description

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

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Block Diagram
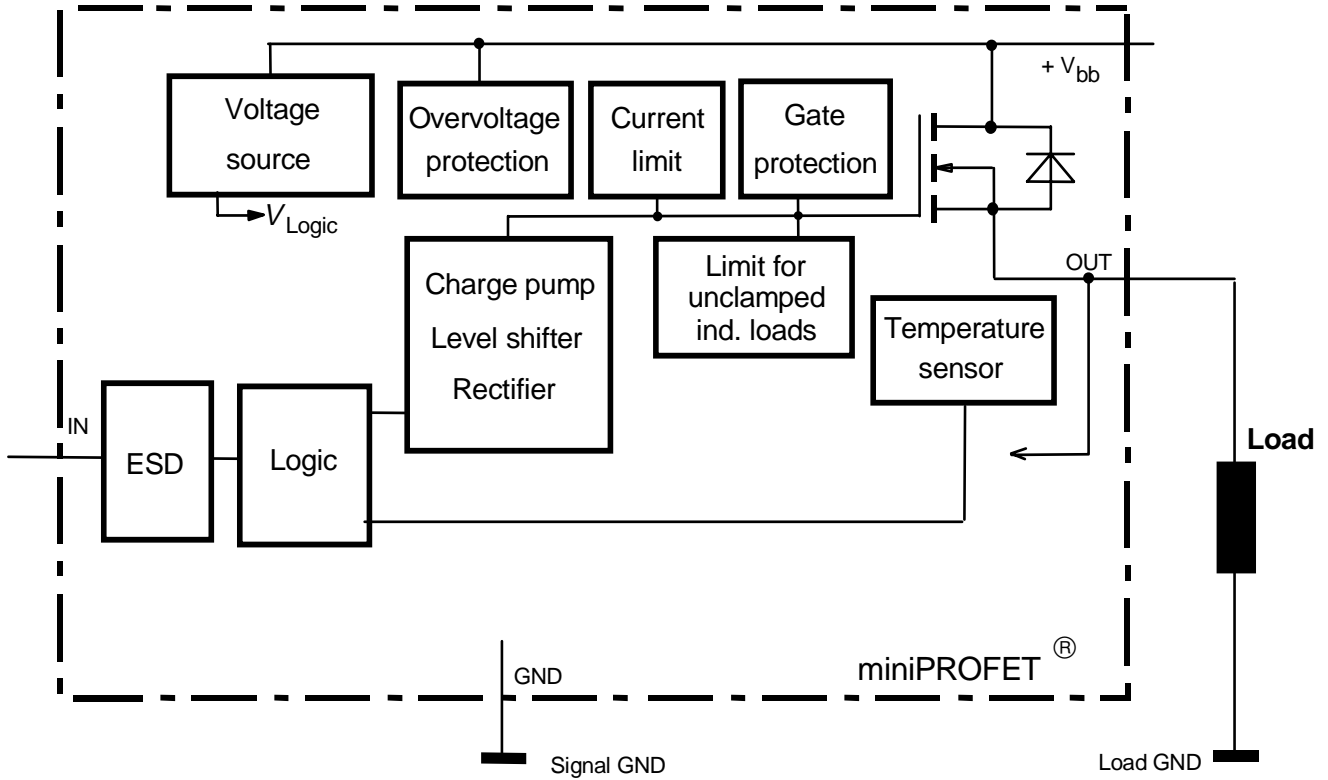
Pin	Symbol	Function
1	GND	Logic ground
2	IN	Input, activates the power switch in case of logic high signal
3	OUT	Output to the load
4	NC	not connected
5	Vbb	Positive power supply voltage
6	Vbb	Positive power supply voltage
7	Vbb	Positive power supply voltage
8	Vbb	Positive power supply voltage

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Maximum Ratings at $T_j = 25°C$, unless otherwise specified

Parameter	Symbol	Value	Unit
Supply voltage	V_{bb}	40	V
Supply voltage for full short circuit protection T_j = -40...+150°C	$V_{bb(SC)}$	V_{bb}	
Continuous input voltage	V_{IN}	-10 ... +16	
Load current (Short - circuit current, see page 5)	I_L	self limited	A
Current through input pin (DC)	I_{IN}	± 5	mA
Operating temperature	T_j	-40 ...+150	°C
Storage temperature	T_{stg}	-55 ... +150	
Power dissipation [1]	P_{tot}	1.5	W
Inductive load switch-off energy dissipation[1][2] single pulse, (see page 8) Tj =150 °C, V_{bb} = 13.5 V, I_L = 1 A	E_{AS}	870	mJ
Load dump protection[2] $V_{LoadDump}$[3]$= V_A + V_S$ R_I=2Ω, t_d=400ms, V_{IN}= low or high, V_A=13,5V R_L = 13.5 Ω	$V_{Loaddump}$	60	V
Electro**s**tatic **d**ischarge voltage (Human Body Model) according to ANSI EOS/ESD - S5.1 - 1993 ESD STM5.1 - 1998 Input pin all other pins	V_{ESD}	± 1 ± 5	kV

Thermal Characteristics

	Symbol				Unit
Thermal resistance @ min. footprint	$R_{th(JA)}$	-	95	-	K/W
Thermal resistance @ 6 cm^2 cooling area [1]	$R_{th(JA)}$	-	70	83	

[1] Device on 50mm*50mm*1.5mm epoxy PCB FR4 with 6 cm2 (one layer, 70µm thick) copper area for drain connection. PCB is vertical without blown air. (see page 16)

[2]not tested, specified by design

[3]$V_{Loaddump}$ is setup without the DUT connected to the generator per ISO 7637-1 and DIN 40839 . Supply voltages higher than $V_{bb(AZ)}$ require an external current limit for the GND pin, e.g. with a 150Ω resistor in GND connection. A resistor for the protection of the input is integrated.

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Electrical Characteristics

Parameter and Conditions	Symbol	Values			Unit
at T_j = -40...+150°C, V_{bb} = 13,5V, unless otherwise specified		min.	typ.	max.	
Load Switching Capabilities and Characteristics					
On-state resistance	R_{ON}				mΩ
T_j = 25 °C, I_L = 2 A, V_{bb} = 9...40 V		-	70	100	
T_j = 150 °C		-	140	200	
Nominal load current; Device on PCB [1] T_C = 85 °C, $T_j \le$ 150 °C	$I_{L(nom)}$	2	2.4	-	A
Turn-on time to 90% V_{OUT} R_L = 47 Ω	t_{on}	-	90	170	µs
Turn-off time to 10% V_{OUT} R_L = 47 Ω	t_{off}	-	90	230	
Slew rate on 10 to 30% V_{OUT}, R_L = 47 Ω	dV/dt_{on}	-	0.8	1.7	V/µs
Slew rate off 70 to 40% V_{OUT}, R_L = 47 Ω	$-dV/dt_{off}$	-	0.8	1.7	

Operating Parameters

Parameter and Conditions	Symbol	Values			Unit
Operating voltage	$V_{bb(on)}$	5	-	34	V
Undervoltage shutdown of charge pump	$V_{bb(under)}$				
T_j = -40...+85 °C		-	-	4	
T_j = 150 °C		-	-	5.5	
Undervoltage restart of charge pump	$V_{bb(u\,cp)}$	-	4	5.5	
Standby current	$I_{bb(off)}$				µA
T_j = -40...+85 °C, V_{IN} = 0 V		-	-	10	
T_j = 150°C[2] , V_{IN} = 0 V		-	-	15	
Leakage output current (included in $I_{bb(off)}$) V_{IN} = 0 V	$I_{L(off)}$	-	-	5	
Operating current V_{IN} = 5 V	I_{GND}	-	0.5	1.3	mA

[1] Device on 50mm*50mm*1.5mm epoxy PCB FR4 with 6 cm2 (one layer, 70µm thick) copper area for drain connection. PCB is vertical without blown air. (see page 16)

[2] higher current due temperature sensor

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Electrical Characteristics

Parameter and Conditions	Symbol	Values			Unit
at T_j = -40...+150°C, V_{bb} = 13,5V, unless otherwise specified		min.	typ.	max.	
Protection Functions					
Initial peak short circuit current limit (pin 5 to 3)	$I_{L(SCp)}$				A
T_j = -40 °C, V_{bb} = 20 V, t_m = 150 µs		-	-	18	
T_j = 25 °C		-	10	-	
T_j = 150 °C		4	-	-	
Repetitive short circuit current limit	$I_{L(SCr)}$				
T_j = T_{jt} (see timing diagrams)		-	7	-	
Output clamp (inductive load switch off) at V_{OUT} = V_{bb} - $V_{ON(CL)}$, I_{bb} = 4 mA	$V_{ON(CL)}$	41	47	-	V
Overvoltage protection [1] I_{bb} = 4 mA	$V_{bb(AZ)}$	41	-	-	
Thermal overload trip temperature	T_{jt}	150	-	-	°C
Thermal hysteresis	ΔT_{jt}	-	10	-	K

Reverse Battery

Parameter and Conditions	Symbol	Values			Unit
Reverse battery[2]	$-V_{bb}$	-	-	32	V
Drain-source diode voltage (V_{OUT} > V_{bb}) T_j = 150 °C	$-V_{ON}$	-	600	-	mV

[1] see also $V_{ON(CL)}$ in circuit diagram on page 7

[2] 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 current has to be limited (see max. ratings page 3).

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Electrical Characteristics

Parameter and Conditions	Symbol	Values			Unit
at T_j = -40...+150°C, V_{bb} = 13,5V, unless otherwise specified		**min.**	**typ.**	**max.**	
Input					
Input turn-on threshold voltage (see page 12)	$V_{IN(T+)}$	-	-	2.2	V
Input turn-off threshold voltage (see page 12)	$V_{IN(T-)}$	0.8	-	-	
Input threshold hysteresis	$\Delta V_{IN(T)}$	-	0.3	-	
Off state input current (see page 12) V_{IN} = 0.7 V	$I_{IN(off)}$	1	-	25	µA
On state input current (see page 12) V_{IN} = 5 V	$I_{IN(on)}$	3	-	25	
Input resistance (see page 7)	R_I	1.5	3.5	5	kΩ

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Terms
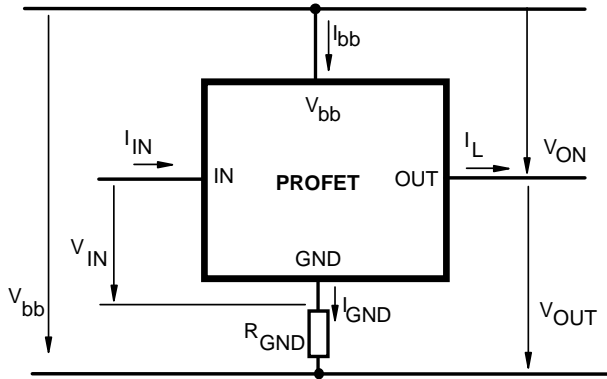
Inductive and overvoltage output clamp
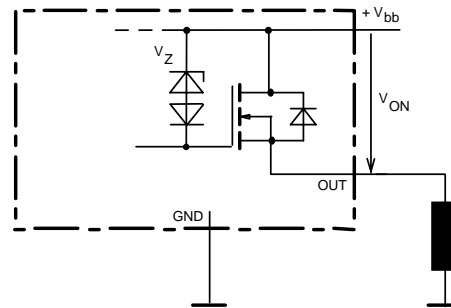
V_{ON} clamped to 47V typ.

Input circuit (ESD protection)
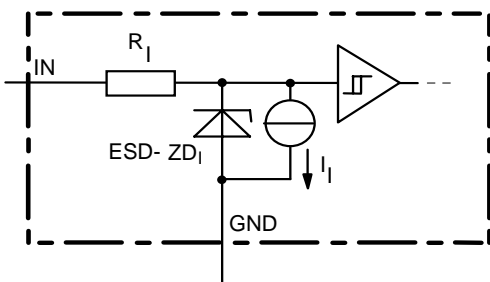
The use of ESD zener diodes as voltage clamp at DC conditions is not recommended

Overvoltage protection of logic part
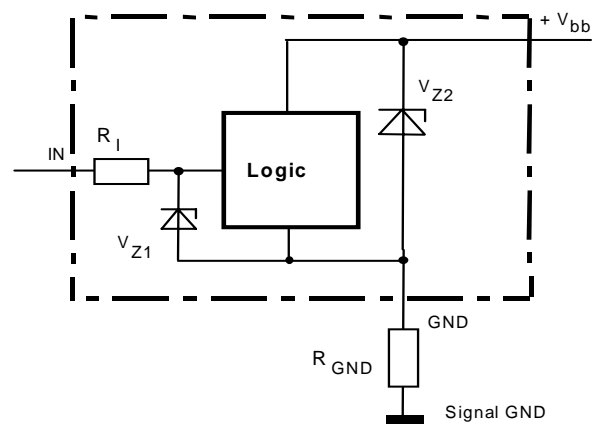
V_{Z1}=6.1V typ., V_{Z2}=$V_{bb(AZ)}$=47V typ.,
R_I=3.5 kΩ typ., R_{GND}=150Ω

Reverse battery protection
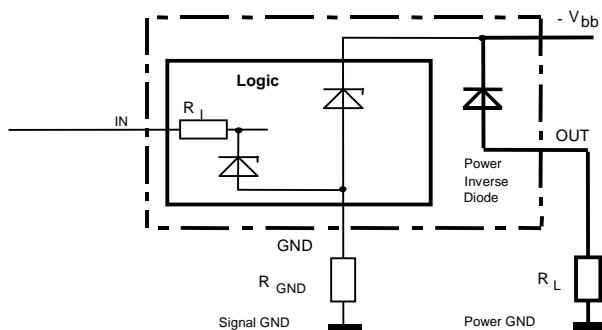
R_{GND}=150Ω, R_I=3.5kΩ typ.,

Temperature protection is not active during inverse current

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GND disconnect

GND disconnect with GND pull up

V$_{bb}$ disconnect with charged inductive load
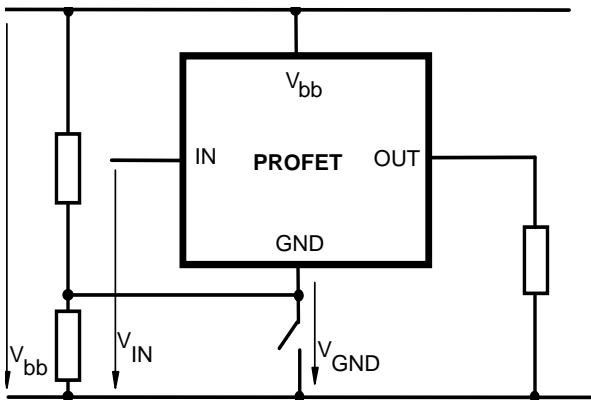
Inductive Load switch-off energy dissipation
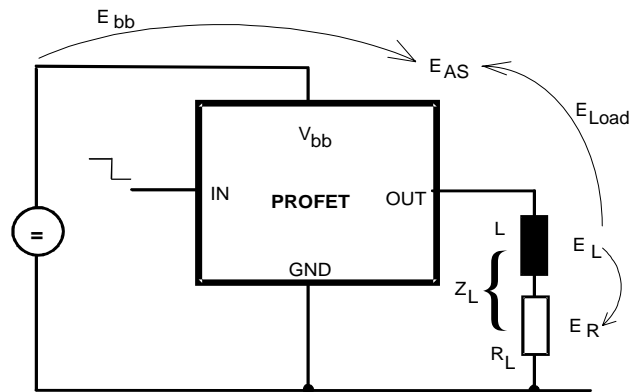
Energy stored in load inductance: $E_L = \frac{1}{2} * L * I_L^2$

While demagnetizing load inductance,
the enérgy dissipated in PROFET is
$E_{AS} = E_{bb} + E_L - E_R = \int V_{ON(CL)} * i_L(t)\, dt$,
with an approximate solution for $R_L > 0\Omega$:

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

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Typ. transient thermal impedance

Z_{thJA}=f(t_p) @ 6cm^2 heatsink area

Parameter: $D=t_p/T$
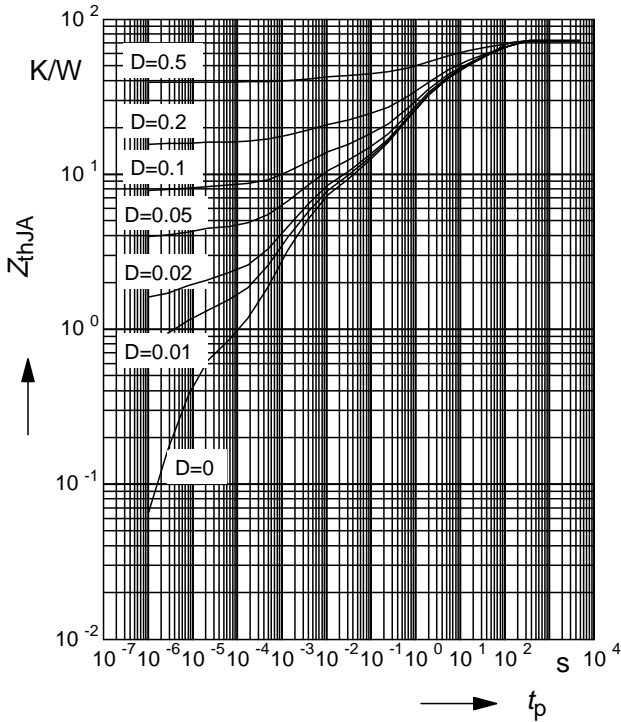
Typ. transient thermal impedance

Z_{thJA}=f(t_p) @ min. footprint

Parameter: $D=t_p/T$
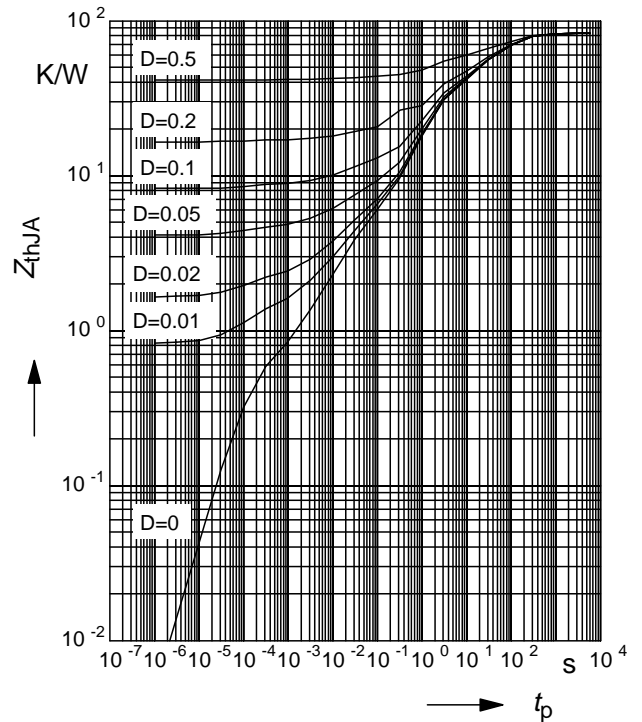
Typ. on-state resistance

R_{ON} = f(T_j) ; V_{bb} = 13,5V ; V_{in} = high
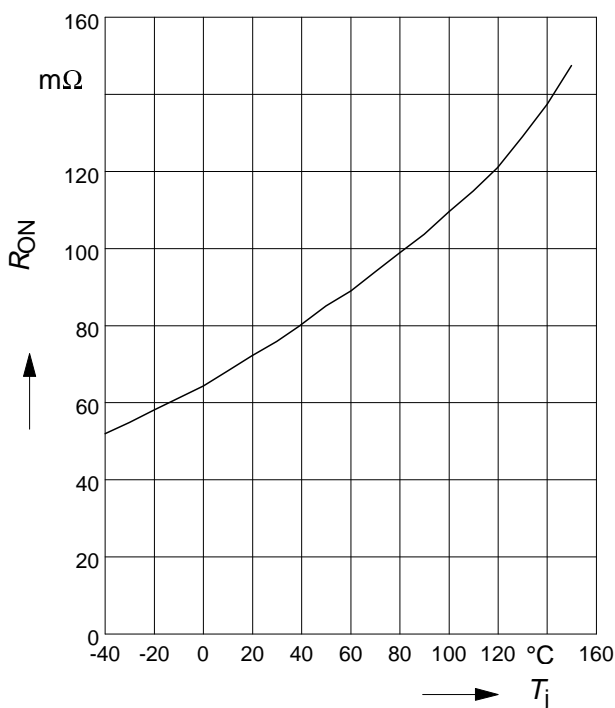
Typ. on-state resistance

R_{ON} = f(V_{bb}); I_L = 0.5A ; V_{in} = high

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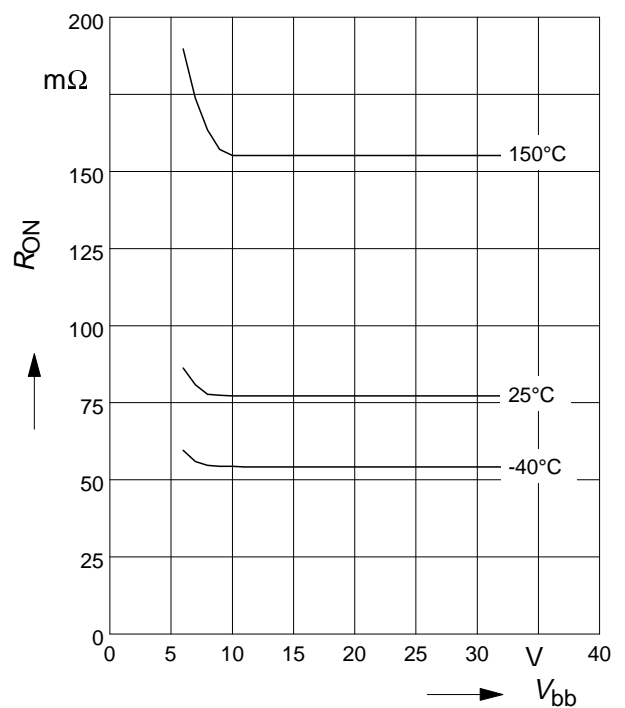
Typ. turn on time

t_{on} = f(T_j); R_L = 47Ω
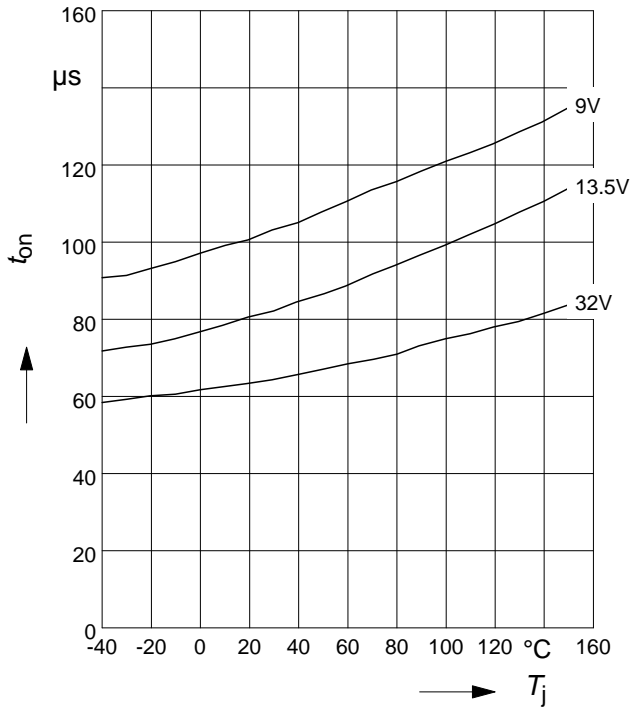
Typ. turn off time

t_{off} = f(T_j); R_L = 47Ω
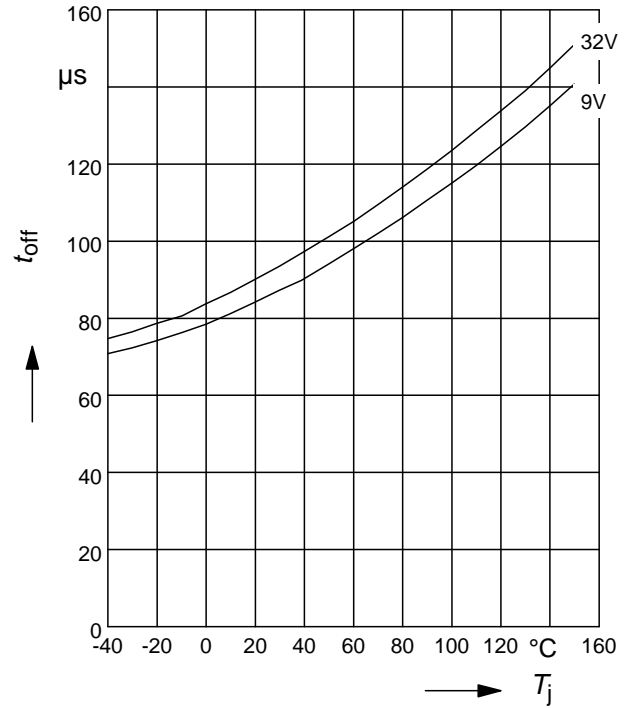
Typ. slew rate on

dV/dt_{on} = f(T_j) ; R_L = 47 Ω
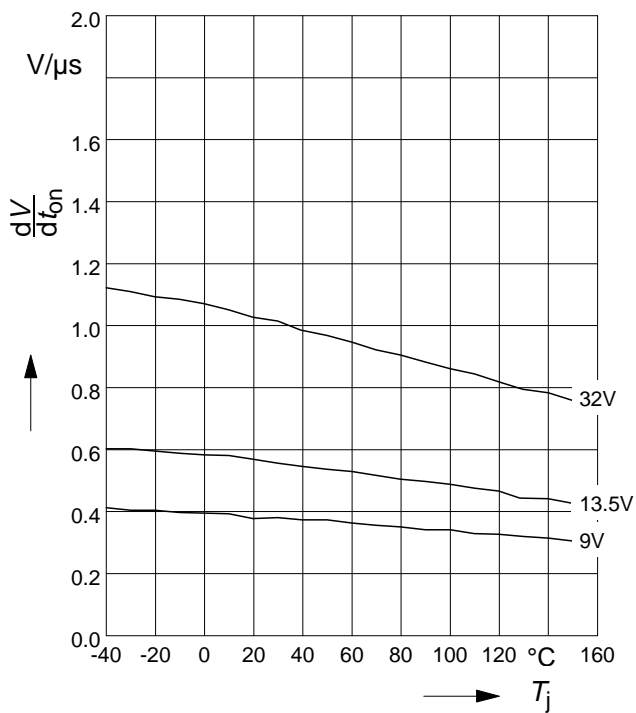
Typ. slew rate off

dV/dt_{off} = f(T_j); R_L = 47 Ω

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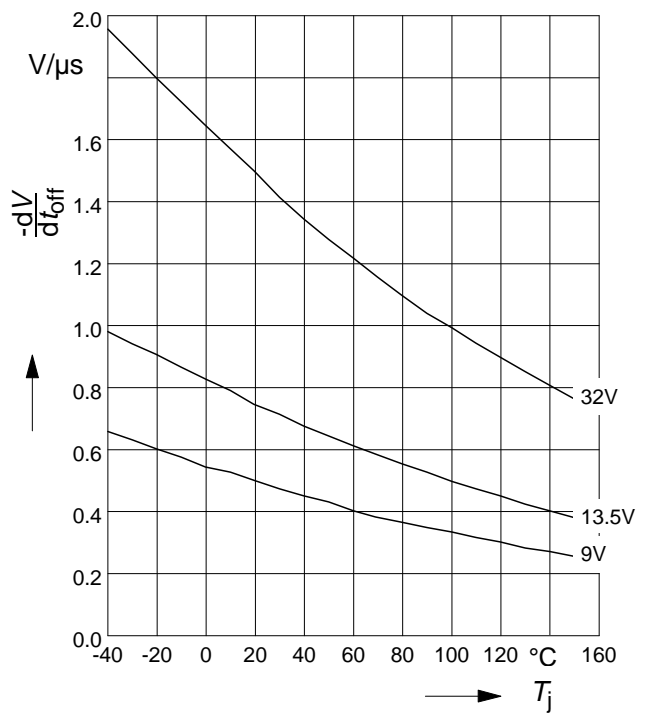
Typ. standby current

$I_{bb(off)} = f(T_j)$; $V_{bb} = 32V$; $V_{IN} = low$
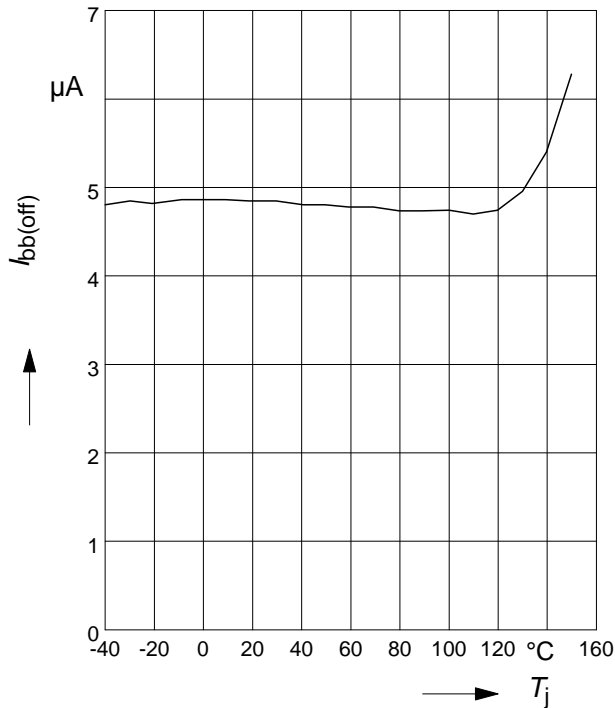
Typ. leakage current

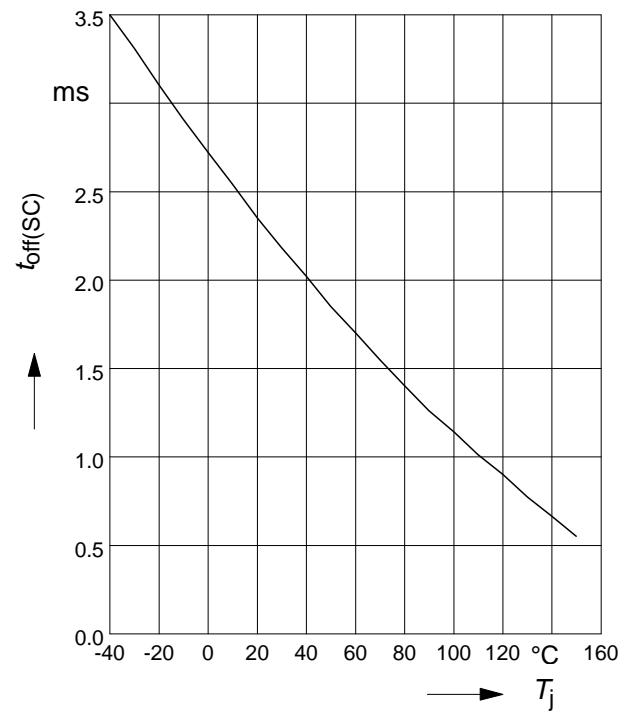$I_{L(off)} = f(T_j)$; $V_{bb} = 32V$; $V_{IN} = low$
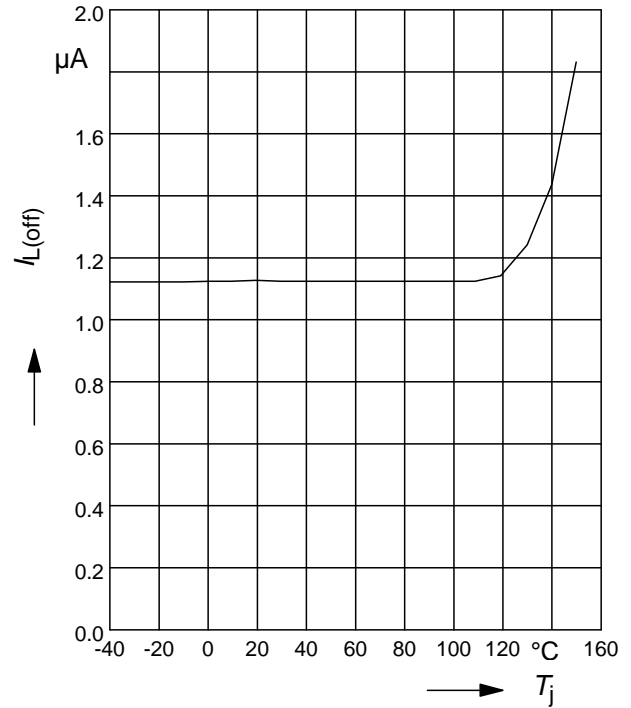
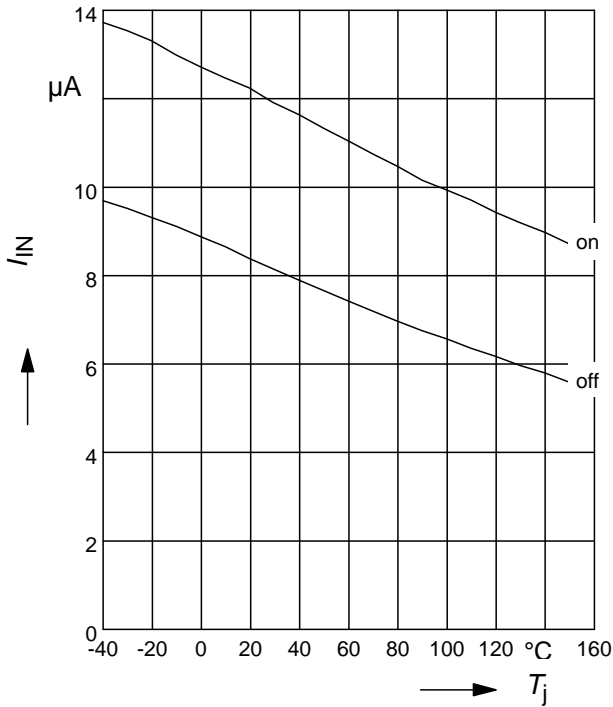**Typ. initial peak short circuit current limit**

$I_{L(SCp)} = f(T_j)$; $V_{bb} = 20V$
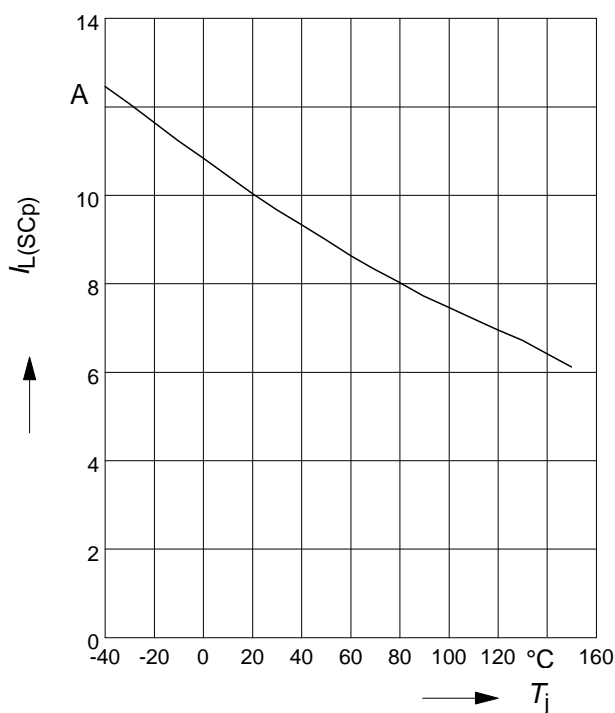
Typ. initial short circuit shutdown time

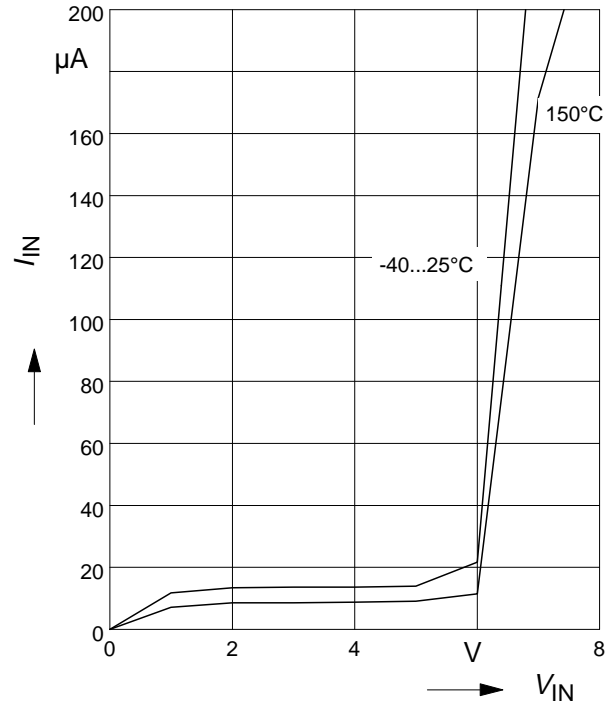$t_{off(SC)} = f(T_{j,start})$; $V_{bb} = 20V$

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Typ. input current

$I_{IN(on/off)}$ **= f(T_j)**; V_{bb} = 13,5V; V_{IN} = low/high
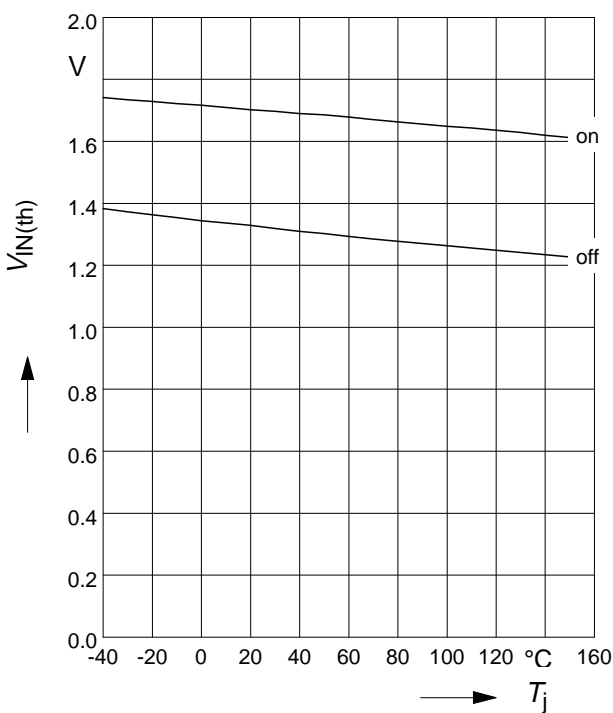
$V_{INlow} \leq 0,7V$; V_{INhigh} = 5V

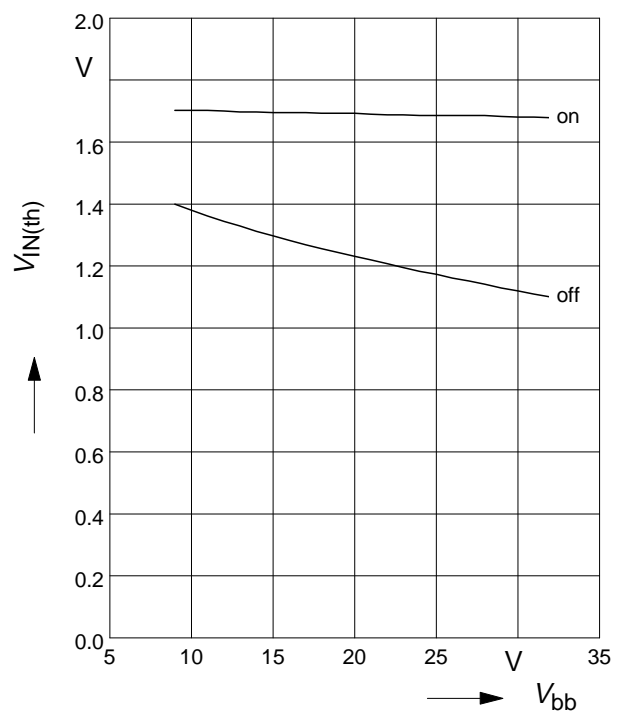**Typ. input current**

I_{IN} **= f(V_{IN})**; V_{bb} = 13.5V

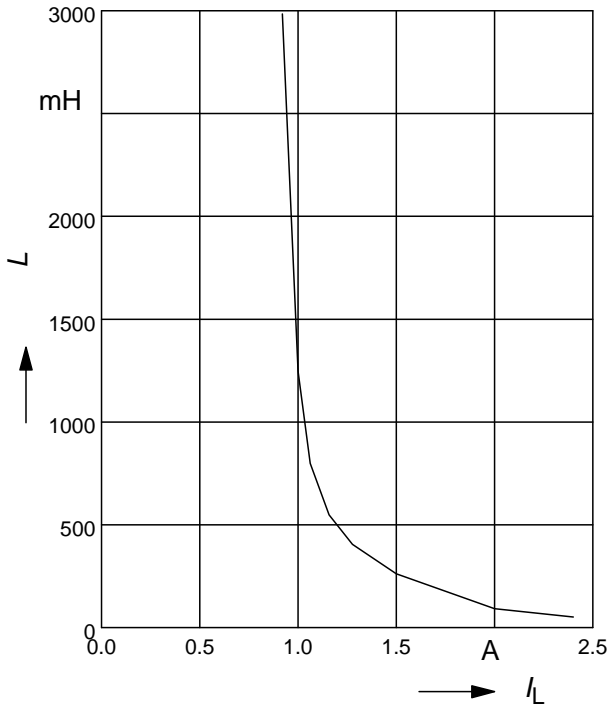
Typ. input threshold voltage

$V_{IN(th)}$ **= f(T_j)** ; V_{bb} = 13,5V

Typ. input threshold voltage

$V_{IN(th)}$ **= f(V_{bb})** ; T_j = 25°C

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Maximum allowable load inductance for a single switch off

L = f(I_L); T_{jstart}=150°C, V_{bb}=13.5V, R_L=0Ω

Maximum allowable inductive switch-off energy, single pulse

E_{AS} = f(I_L); T_{jstart} = 150°C, V_{bb} = 13,5V

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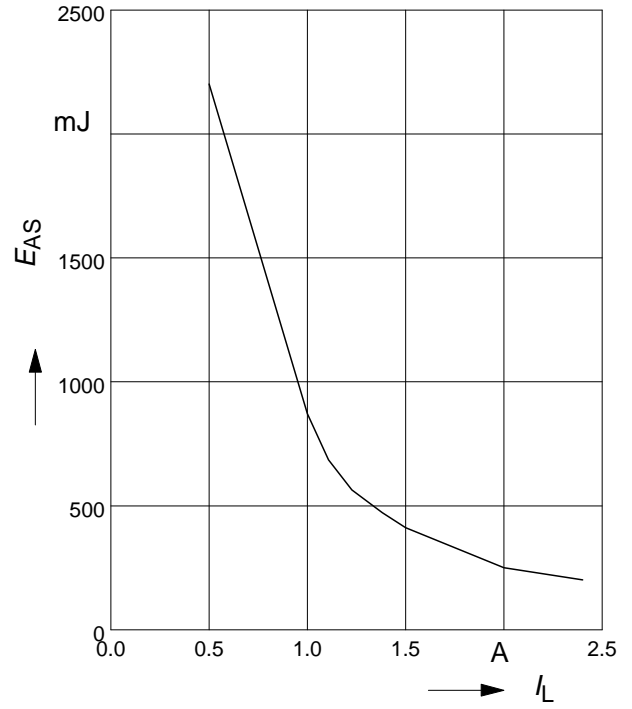
Timing diagrams

Figure 1a: Vbb turn on:

IN

V_{bb}

V_{OUT}

t
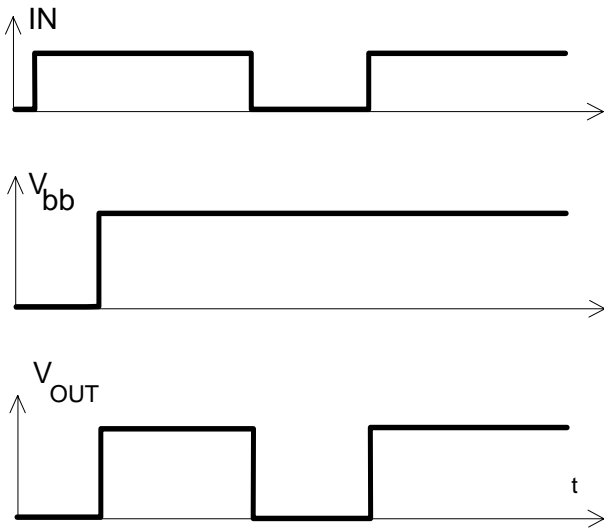
Figure 2b: Switching a lamp,

IN

OUT

I_L

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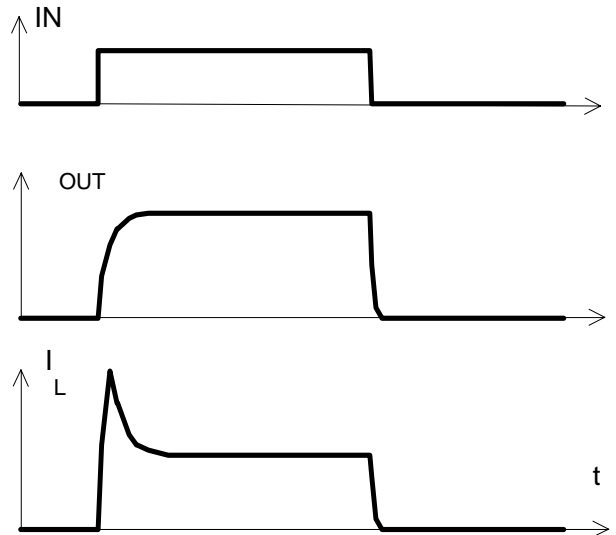
Figure 2a: Switching a resistive load,
turn-on/off time and slew rate definition

IN

V_{OUT}

90%

t_{on}

dV/dtoff

dV/dton

t_{off}

10%

I_L

t
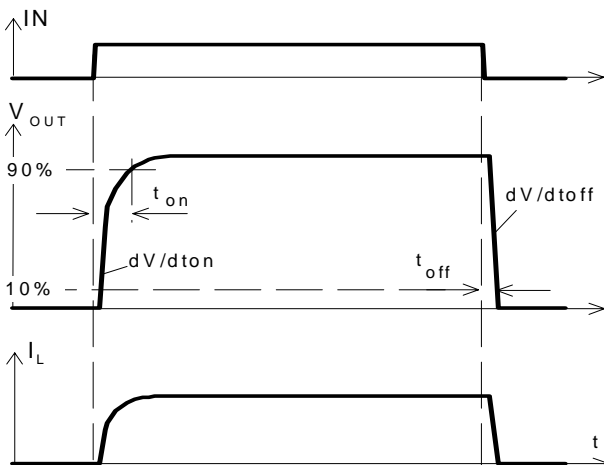
Figure 2c: Switching an inductive load

IN

V_{OUT}

I_L

t

2000-02-21

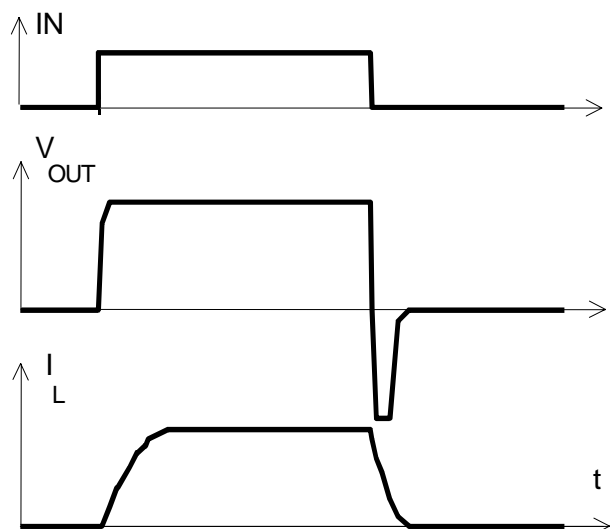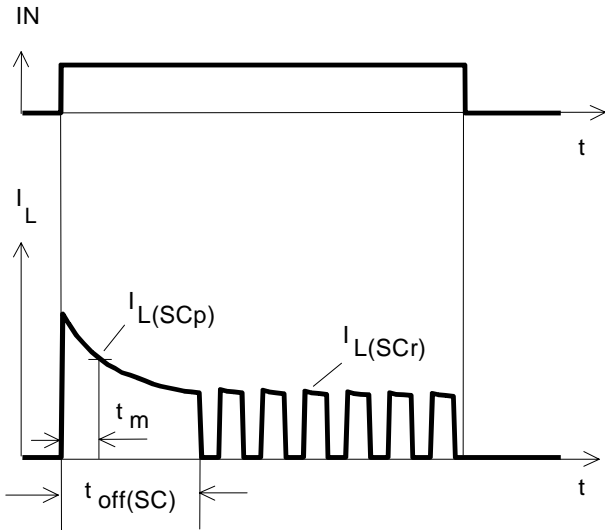**Figure 3a:** Turn on into short circuit,
shut down by overtemperature, restart by cooling

Heating up of the chip may require several milliseconds, depending
on external conditions.
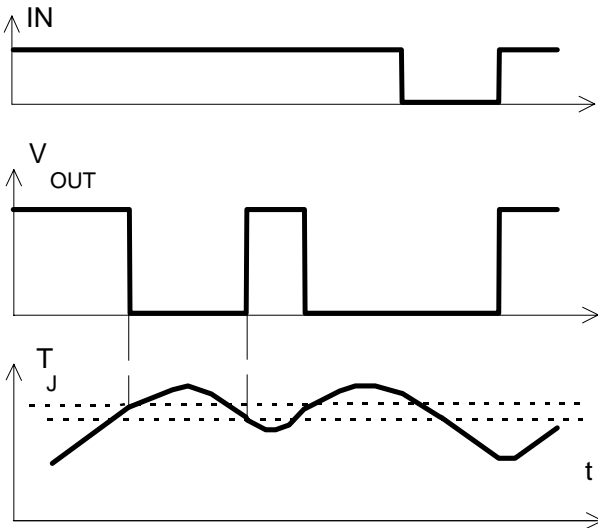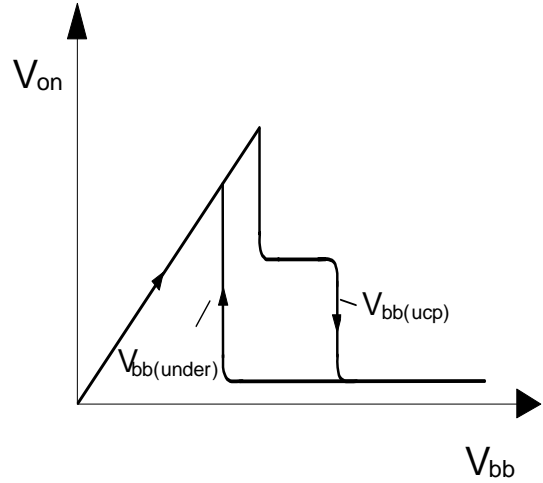
Figure 4: Overtemperature:
Reset if $T_j < T_{jt}$
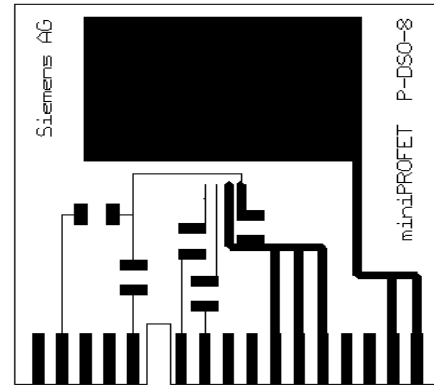

Figure 5: Undervoltage restart of charge pump

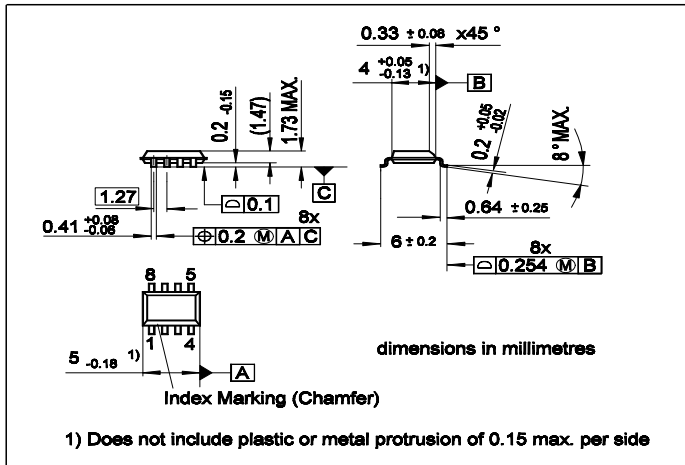2000-02-21

Package and ordering code

all dimensions in mm

Ordering code:

	Q67060-S7301-A2

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

Printed circuit board (FR4, 1.5mm thick, one layer 70µm, 6cm^2 active heatsink area) as a reference for max. power dissipation P_{tot} nominal load current $I_{L(nom)}$ and thermal resistance R_{thja}

Attention please!
The information herein is given to describe certain components and shall not be considered as warranted characteristics.

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