Smart Two Channel Highside Power Switch

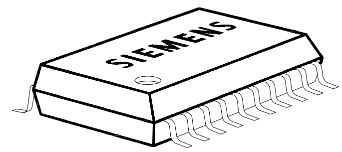
Features

- Overload protection
- Current limitation
- Short-circuit protection
- Thermal shutdown
- Overvoltage protection
- Fast demagnetization of inductive loads
- Reverse battery protection[1)]

- Open drain diagnostic output
- Open load detection in OFF-state
- CMOS compatible input
- Loss of ground and loss of V_{bb} protection
- **E**lectro**s**tatic **d**ischarge (**ESD**) protection

Product Summary

Overvoltage Protection	$V_{bb(AZ)}$		65	V
Operating voltage	$V_{bb(on)}$		5.8 ... 58	V
active channels:		one	two parallel	
On-state resistance	R_{ON}	250	125	mΩ
Nominal load current	$I_{L(NOM)}$	1.9	2.8	A



Application

- µC compatible power switch with diagnostic feedback for 12 V and 24 V DC grounded loads
- Most suitable for inductive loads
- Replaces electromechanical relays, fuses and discrete circuits

General Description

N channel vertical power FET with charge pump, ground referenced CMOS compatible input and diagnostic feedback, monolithically integrated in Smart SIPMOS® technology.
Providing embedded protective functions.

Pin Definitions and Functions

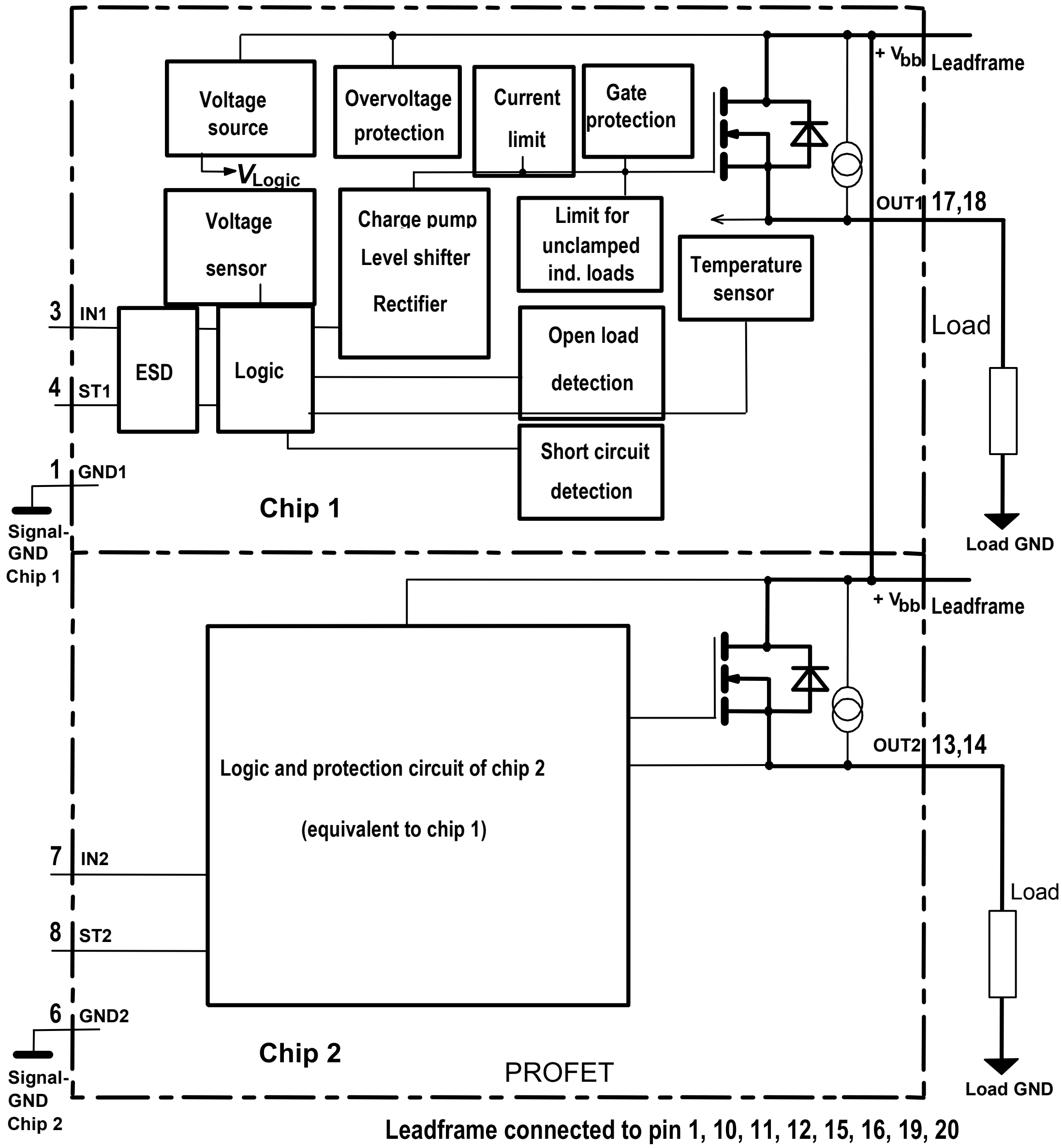
Pin	Symbol	Function
1,10, 11,12, 15,16, 19,20	V_{bb}	**Positive power supply voltage**. Design the wiring for the simultaneous max. short circuit currents from channel 1 to 2 and also for low thermal resistance
3	IN1	**Input 1,2**, activates channel 1,2 in case of logic high signal
7	IN2	
17,18	OUT1	**Output 1,2**, protected high-side power output of channel 1,2. Design the wiring for the max. short circuit current
13,14	OUT2	
4	ST1	**Diagnostic feedback 1,2** of channel 1,2, open drain**,** low in on state on failure or high in off state on failure
8	ST2	
2	GND1	**Ground 1** of chip 1 (channel 1)
6	GND2	**Ground 2** of chip 2 (channel 2)
5,9	N.C.	**Not Connected**

Pin configuration (top view)

V_{bb}	1	20	V_{bb}
GND1	2	19	V_{bb}
IN1	3	18	OUT1
ST1	4	17	OUT1
N.C.	5	16	V_{bb}
GND2	6	15	V_{bb}
IN2	7	14	OUT2
ST2	8	13	OUT2
N.C.	9	12	V_{bb}
V_{bb}	10	11	V_{bb}

1) With external current limit (e.g. resistor R_{GND}=150 Ω) in GND connection, resistor in series with ST connection, reverse load current limited by connected load.

Block diagram



Leadframe connected to pin 1, 10, 11, 12, 15, 16, 19, 20

Maximum Ratings at T_j = 25°C unless otherwise specified

Parameter	Symbol	Values	Unit
Supply voltage (overvoltage protection see page 4)	V_{bb}	65	V
Supply voltage for full short circuit protection $T_{j,start}$ = -40 ...+150°C	V_{bb}	40	V
Load current (Short-circuit current, see page 5)	I_L	self-limited	A
Operating temperature range Storage temperature range	T_j T_{stg}	-40 ...+150 -55 ...+150	°C

Maximum Ratings at T_j = 25°C unless otherwise specified

Parameter		Symbol	Values	Unit
Power dissipation (DC)[2] (all channels active)	T_a = 25°C:	P_{tot}	3	W
	T_a = 85°C:		1.6	
Electrostatic discharge capability (ESD)	IN, ST:	V_{ESD}	1.0	kV
(Human Body Model)	all other pins:		1.0	
Input voltage (DC)		V_{IN}	-0.5 ... +36	V
Current through input pin (DC)		I_{IN}	±2.0	mA
Current through status pin (DC) see internal circuit diagram page 7		I_{ST}	±5.0	

Thermal Characteristics

Parameter and Conditions		Symbol	Values			Unit
			min	typ	max	
Thermal resistance junction - soldering point[2),3)]	each channel:	R_{thjs}	--	--	18	K/W
junction - ambient[2)]	one channel active:	R_{thja}	--	45	--	
	all channels active:		--	37	--	

Electrical Characteristics

Parameter and Conditions, each of the two channels at T_j = 25 °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	each channel, T_j = 25°C:	R_{ON}	--	225	250	mΩ
V_{bb} = 24 V	T_j = 150°C:			400	500	
	two parallel channels, T_j = 25°C:			113	125	
Nominal load current	one channel active:	$I_{L(NOM)}$	1.60	1.9	--	A
	two parallel channels active:		2.4	2.8		
Device on PCB[2)], T_a = 85°C, $T_j \le$ 150°C						
Output current while GND disconnected or pulled up; V_{bb} = 32 V, V_{IN} = 0, see diagram page 8		$I_{L(GNDhigh)}$	--	--	1.1	mA

2) 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. See page 12

3) Soldering point: upper side of solder edge of device pin 15. See page 12

Parameter and Conditions, each of the two channels at T_j = 25 °C, V_{bb} = 12 V unless otherwise specified	**Symbol**	**Values**			**Unit**
		min	typ	max	
Turn-on time to 90% V_{OUT}:	t_{on}	15	--	80	µs
Turn-off time to 10% V_{OUT}: $R_L = 12\ \Omega$, V_{bb} = 20 V, T_j =-40...+150°C	t_{off}	20	--	70	
Slew rate on 10 to 30% V_{OUT}, $R_L = 12\ \Omega$, V_{bb} = 20 V, T_j =-40...+150°C:	dV/dt_{on}	--	--	6	V/µs
Slew rate off 70 to 40% V_{OUT}, $R_L = 12\ \Omega$, V_{bb} = 20 V, T_j =-40...+150°C:	$-dV/dt_{off}$	--	--	7	V/µs
Operating Parameters					
Operating voltage[4] T_j =-40...+150°C:	$V_{bb(on)}$	5.8	--	58	V
Undervoltage shutdown T_j =-40...+150°C:	$V_{bb(under)}$	2.7	--	4.7	V
Undervoltage restart T_j =-40...+150°C:	$V_{bb(u\ rst)}$	--	--	4.9	V
Undervoltage restart of charge pump see diagram page 10 T_j =-40...+150°C:	$V_{bb(ucp)}$	--	5.6	7.5	V
Undervoltage hysteresis $\Delta V_{bb(under)} = V_{bb(u\ rst)} - V_{bb(under)}$	$\Delta V_{bb(under)}$	--	0.4	--	V
Overvoltage protection[5] T_j =-40...+150°C: I_{bb} = 40 mA	$V_{bb(AZ)}$	65	70	--	V
Standby current, all channels off V_{IN} = 0 T_j =150°C:	$I_{bb(off)}$	-- --	20	70	µA
Operating current[6], V_{IN} = 5V, T_j =-40...+150°C $I_{GND} = I_{GND1} + I_{GND2}$, one channel on: two channels on:	I_{GND}	-- --	2.2 4.4	-- --	mA
Protection Functions[7]					
Initial peak short circuit current limit, (see timing diagrams, page 9) each channel, T_j =-40°C:	$I_{L(SCp)}$	--	--	19	A
T_j =25°C:		--	10	--	
T_j =+150°C:		4.0	--	--	
two parallel channels	twice the current of one channel				
Output clamp (inductive load switch off)[8] at $V_{ON(CL)} = V_{bb} - V_{OUT}$	$V_{ON(CL)}$	59	--	75	V
Thermal overload trip temperature	T_{jt}	150	--	--	°C
Thermal hysteresis	ΔT_{jt}	--	10	--	K

4) At supply voltage increase up to V_{bb} = 5.6 V typ without charge pump, $V_{OUT} \approx V_{bb}$ - 2 V

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

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

7) 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.

8) 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 two channels at T_j = 25 °C, V_{bb} = 12 V unless otherwise specified	**Symbol**	**Values**			**Unit**
		min	typ	max	
Reverse Battery					
Reverse battery voltage [9]	$-V_{bb}$	--	--	32	V
Diagnostic Characteristics					
Open load detection current	$I_{L(off)}$	--	6	--	µA
Open load detection voltage T_j =-40..+150°C:	$V_{OUT(OL)}$	2.4	3	4	V
Short circuit detection voltage (pin 3 to 5)	$V_{ON(SC)}$	--	2.5	--	V
Input and Status Feedback [10]					
Input resistance (see circuit page 7)	R_I	--	20	--	kΩ
Input turn-on threshold voltage	$V_{IN(T+)}$	1	--	2.5	V
Input turn-off threshold voltage	$V_{IN(T-)}$	0.8	--	--	V
Input threshold hysteresis	$\Delta V_{IN(T)}$	--	0.5	--	V
Off state input current V_{IN} = 0.4 V:	$I_{IN(off)}$	1	--	30	µA
On state input current V_{IN} = 2.5 V:	$I_{IN(on)}$	10	25	70	µA
Delay time for status with open load (see timing diagrams, page 10)	$t_{d(ST\ OL3)}$	--	200	--	µs
Status output (open drain)					
Zener limit voltage T_j =-40...+150°C, I_{ST} = +1.6 mA:	$V_{ST(high)}$	5.4	6.1	--	V
ST low voltage T_j =-40...+150°C, I_{ST} = +1.6 mA:	$V_{ST(low)}$	--	--	0.4	

9) 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. Note that the power dissipation is higher compared to normal operating conditions due to the voltage drop across the intrinsic 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 3 and circuit page 7).

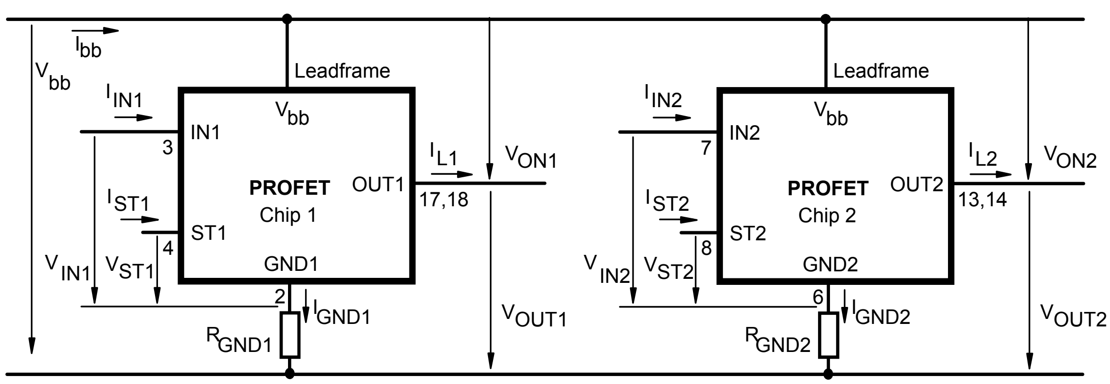
10) If ground resistors R_{GND} are used, add the voltage drop across these resistors.

Truth Table

Channel 1	Input 1	Output 1	Status 1
Channel 2	Input 2	Output 2	Status 2
	level	level	BTS 707
Normal operation	**L** **H**	**L** **H**	**L** **H**
Open load	**L** **H**	**Z** **H**	**H** **H**
Short circuit to GND	**L** **H**	**L** **L**	**L** **L**
Short circuit to V_{bb}	**L** **H**	**H** **H**	**H** **H**
Overtem-perature	**L** **H**	**L** **L**	**L** **L**
Under-voltage	**L** **H**	**L** **L**	**L** **L**
Overvoltage	**no overvoltage shutdown, see normal operation**		

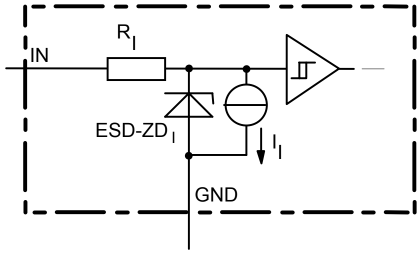
Parallel switching of channel 1 and 2 is easily possible by connecting the inputs and outputs in parallel. The status outputs ST1 and ST2 have to be configured as a 'Wired OR' function with a single pull-up resistor.

Terms



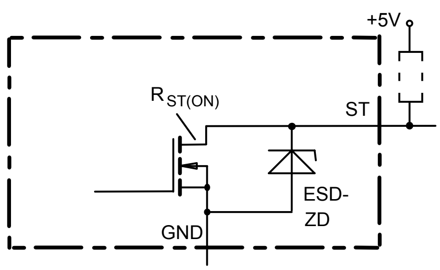
Leadframe (V_{bb}) is connected to pin 1,10,11,12,15,16,19,20
External R_{GND} optional; two resistors R_{GND1}, $R_{GND2} = 150\ \Omega$ or a single resistor $R_{GND} = 75\ \Omega$ for reverse battery protection up to the max. operating voltage.

Input circuit (ESD protection), IN1 or IN2



ESD zener diodes are not to be used as voltage clamp at DC conditions. Operation in this mode may result in a drift of the zener voltage (increase of up to 1 V).

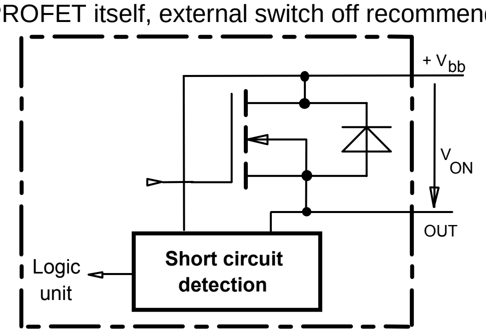
Status output, ST1 or ST2



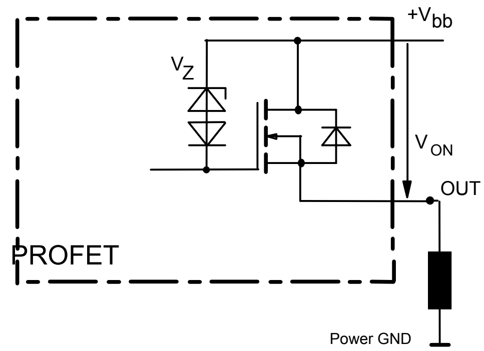
ESD-Zener diode: 6.1 V typ., max 5.0 mA; $R_{ST(ON)}$ < 0 Ω at 1.6 mA, ESD zener diodes are not to be used as voltage clamp at DC conditions. Operation in this mode may result in a drift of the zener voltage (increase of up to 1 V).

Short Circuit detection

Fault Signal at ST-Pin: V_{ON} > 2.5 V typ, no switch off by the PROFET itself, external switch off recommended!



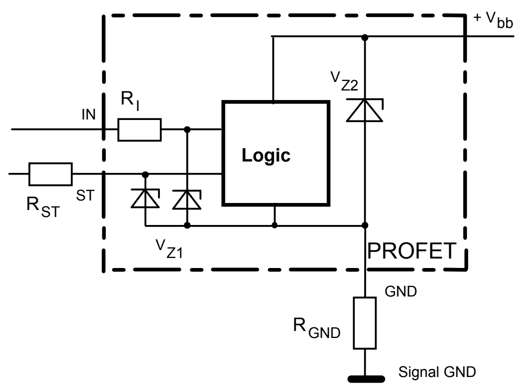
Inductive and overvoltage output clamp, OUT1 or OUT2



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

Overvoltage protection of logic part

GND1 or GND2

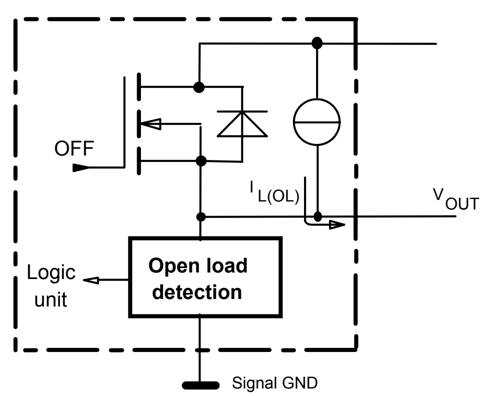


V_{Z1} = 6.1 V typ., V_{Z2} = 70 V typ., R_I = 20 kΩ typ., R_{GND} = 150 Ω, R_{ST} = 15 kΩ nominal.

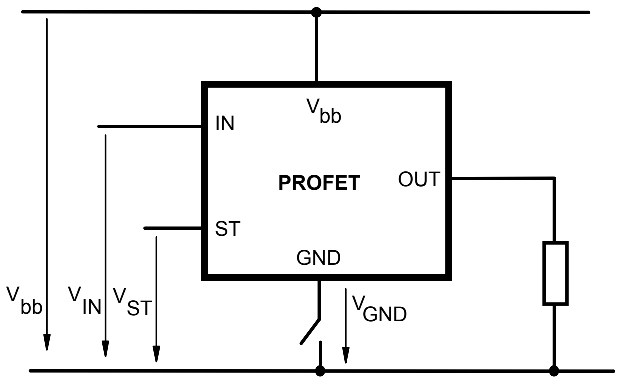
Open-load detection, OUT1 or OUT2

OFF-state diagnostic condition:

V_{OUT} > 3 V typ.; IN low

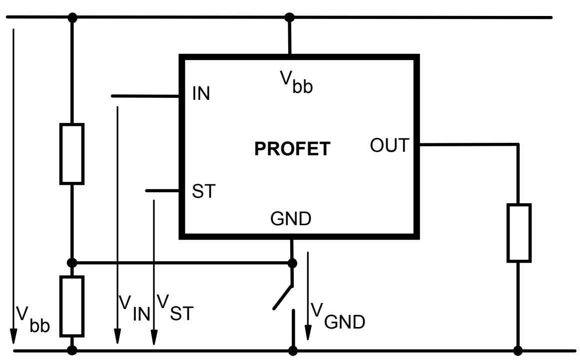


GND disconnect



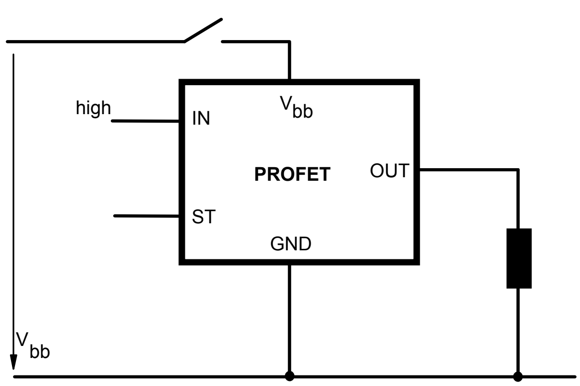
Any kind of load. In case of IN = high is $V_{OUT} \approx V_{IN} - V_{IN(T+)}$.
Due to $V_{GND} > 0$, no V_{ST} = low signal available.

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.

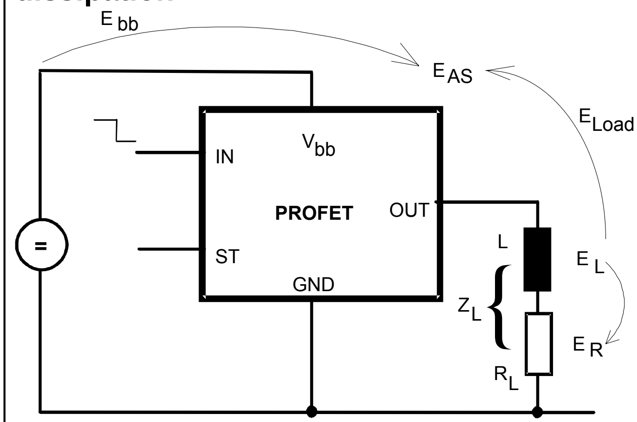
V_{bb} disconnect with energized inductive load



For an inductive load current up to the limit defined by E_{AS} (max. ratings) each switch is protected against loss of V_{bb}.

Consider at your PCB layout that in the case of Vbb dis-connection with energized inductive load the whole 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

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

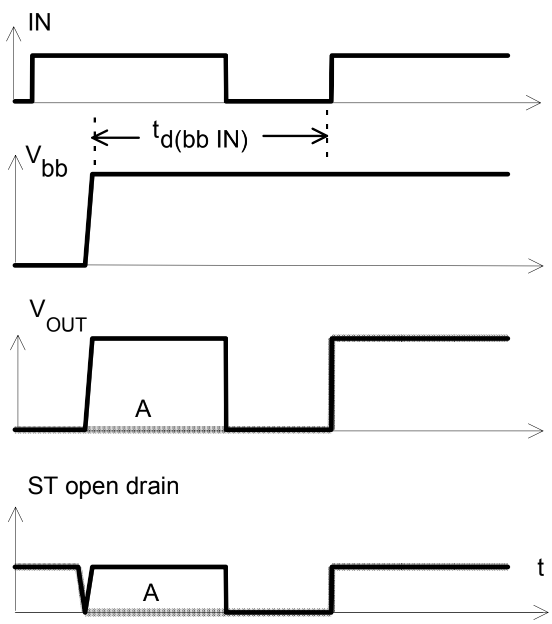
with an approximate solution for $R_L > 0\,\Omega$:

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

Timing diagrams

Both channels are symmetric and consequently the diagrams are valid for channel 1 and channel 2

Figure 1a: V_{bb} turn on, :



in case of too early V_{IN}=high the device may not turn on (curve A)
$t_{d(bb\ IN)}$ approx. 150 µs

Figure 2a: Switching an inductive load

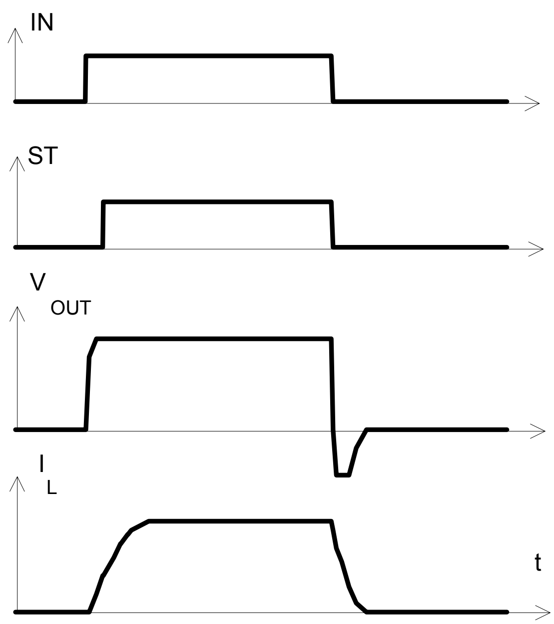
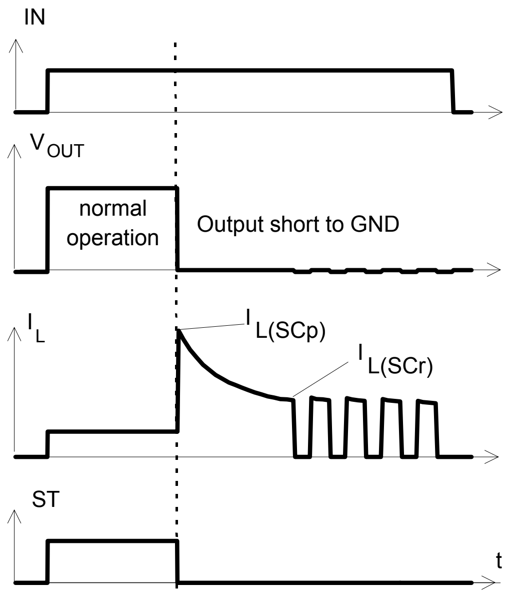


Figure 3a: Short circuit:
shut down by overtempertature, reset by cooling



Heating up requires several milliseconds, depending on external conditions. External shutdown in response to status fault signal recommended.

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

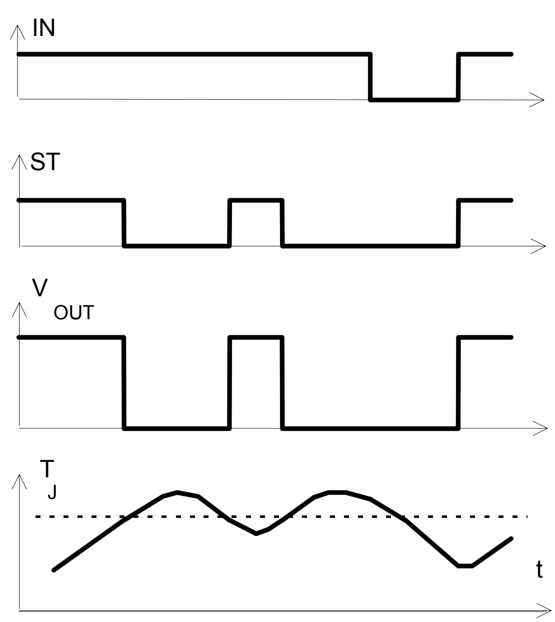
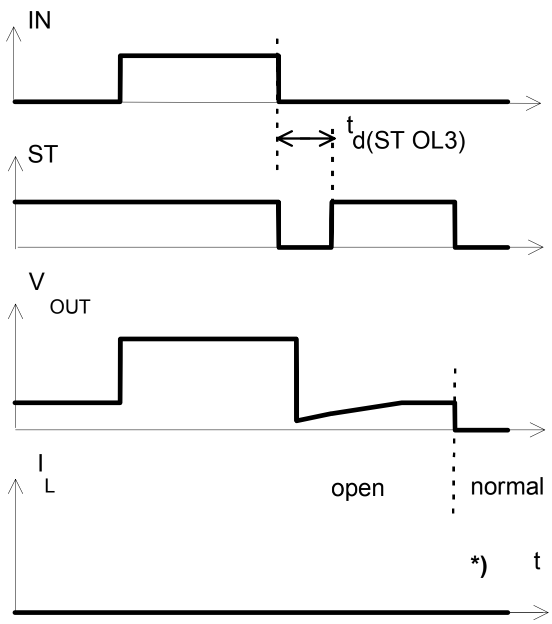


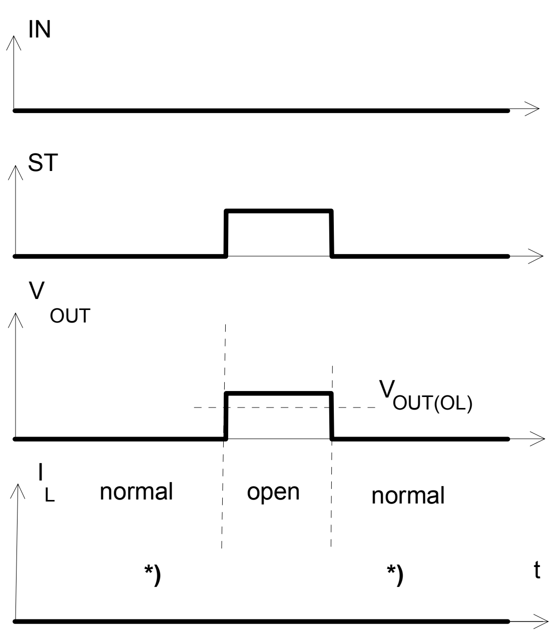
Figure 5a: Open load, : detection in OFF-state, turn on/off to open load



$t_{d(ST,OL3)}$ depends on external circuitry because of high impedance

*) I_L = 6 µA typ

Figure 5b: Open load, : detection in OFF-state, open load occurs in off-state



*) I_L = 6 µA typ

Figure 6a: Undervoltage:

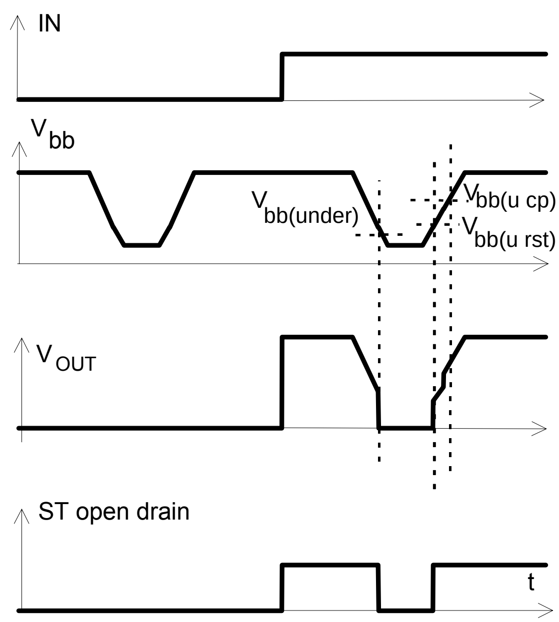
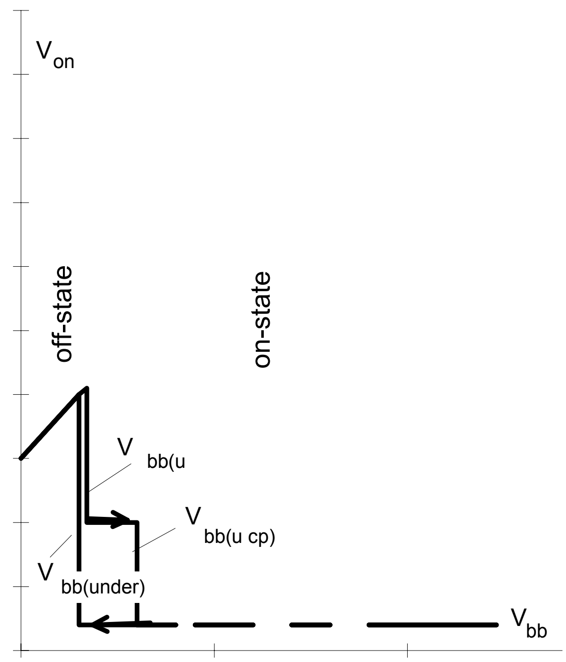
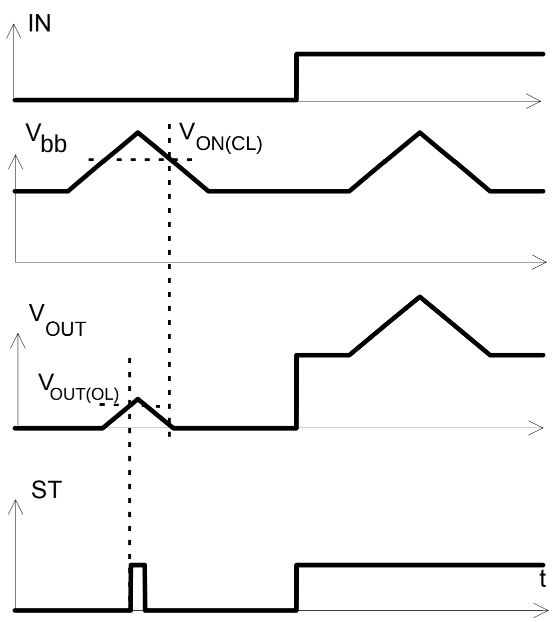


Figure 6b: Undervoltage restart of charge pump



charge pump starts at $V_{bb(ucp)}$ =5.6 V typ.

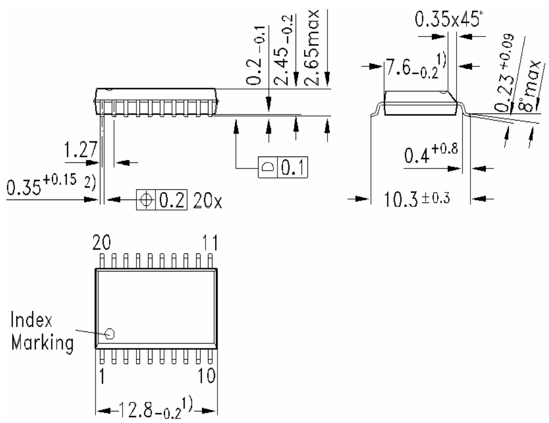
Figure 7a: Overvoltage, no shutdown:



Package and Ordering Code

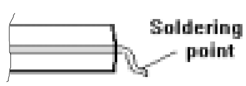
Standard P-DSO-20-9 Ordering Code

BTS 707	Q67060-S7010-A2



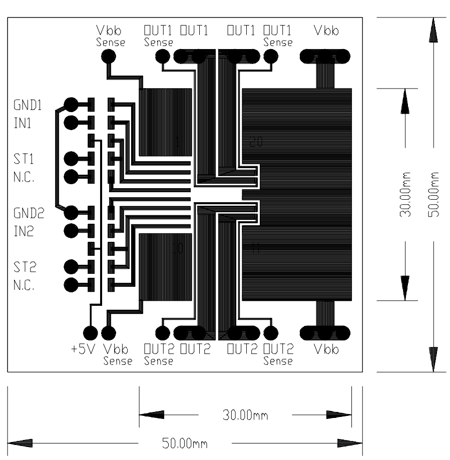
All dimensions in millimetres
1) Does not include plastic or metal protrusions of 0.15 max per side
2) Does not include dambar protrusion of 0.05 max per side

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, $6cm^2$ active heatsink area) as a reference for max. power dissipation P_{tot}, nominal load current $I_{L(NOM)}$ and thermal resistance R_{thja}



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