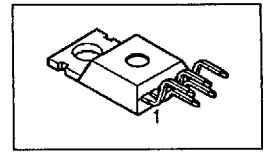
PROFET®

- High-side switch
- Short-circuit protection
- Overtemperature protection
- Overload protection
- Load dump protection[1)]
- Undervoltage and overvoltage shutdown with auto-restart and hysteresis
- Reverse battery protection [1)]
- Input and status protection
- Clamp of negative output voltage with inductive loads
- Protection against charged inductive load disconnect[2)]
- Open load detection in ON-state
- Maximum current internally limited
- Status output for load fault
- R_{ON} constant versus V_{bb}
- Electrostatic Discharge (ESD) protection

Version differences see truth table and options overview, page 20...21



Package: TO220AB/5 (mounting flange is shorted to pin 3), different package outlines (see page 28) on request

Ordering codes and packages see page 28

Pins				
1	2	3	4	5
GND	IN	V_{bb}	ST	OUT
-	I	+	S	O (Load,L)

Maximum Ratings

Parameter	Symbol	Values	Unit
Active overvoltage protection	$V_{bb(AZ)}$	> 50	V
Load current (Short-circuit current, see page 19)	I_L	self-limited	A
Operating temperature range	T_j	-40 ...+150	°C
Storage temperature range	T_{stg}	-55 ...+150	
Max. power dissipation	P_{tot}	75	W
Maximum current through input pin (DC)	I_{IN}	±2.0	mA
Maximum current through status pin (DC)	I_{ST}	±5.0	
see internal circuit diagram see chapter 2			
Thermal resistance chip - case	R_{thJC}	1.67	K/W
chip - ambient:	R_{thJA}	75	

1) with resistor R_{GND}=150 Ω in GND connection, 15 kΩ resistor in series with IN and ST connections, reverse load current limited by connected load.

2) with 150 Ω resistor in GND connection or freewheeling diode between V_{bb} and GND or freewheeling diode parallel to load. To protect agains V_{bb} loss with an inductive load, it is recommended that a freewheeling diode be added between V_{bb} and GND.

Electrical Characteristics

Parameter and Conditions at T_j = 25 °C, V_{bb} = 12V unless otherwise specified	Symbol	Values			Unit
		min	typ	max	
Load Switching Capabilities and Characteristics					
On-state resistance (pin 3 to 5) I_L = 1 A, V_{IN}=high T_j=25 °C: T_j=150 °C:	R_{ON}	--	190 390	220 440	mΩ
Nominal load current (pin 3 to 5) ISO Proposal: V_{bb} - V_{OUT} ≤ 0.5 V, T_C = 85 °C	$I_{L(ISO)}$	1.6	--	--	A
Open load detection current T_j=25..150°C: T_j=-40 °C:	$I_{L(OL)}$	2 2	-- --	150 200	mA
Turn-on time to 90% V_{OUT} Turn-off time to 10% V_{OUT} R_L = 12 Ω	t_{on} t_{off}	15 5	--	60 50	µs
Slew rate on 10 to 30% V_{OUT}, R_L = 12 Ω	dV/dt_{on}	--	--	3	V/µs
Slew rate off 70 to 40% V_{OUT}, R_L = 12 Ω	$-dV/dt_{off}$	--	--	5	
Standby current (pin 3) V_{IN}=0, I_{ST}=0 T_j=150°C:	$I_{bb(off)}$	 -- --	 12 18	 25 60	µA
Operating current (Pin 1), V_{IN}=high	I_{GND}	--	2.2[3]	--	mA
Short circuit shutdown delay after input pos. slope T_j =-40..+150°C: V_{bb}-V_{OUT}=V_{ON} > $V_{ON(SC)}$ (see page 19) min value valid only, if input "low" time exceeds 60 µs	$t_{d(SC)}$	80	--	350	µs
Input and Status Feedback[4]					
Allowable input voltage range, (pin 2 to 1)	V_{IN}	-0.5	--	5.5	V
Input turn-on threshold voltage	$V_{IN(T+)}$	1.5	--	2.4	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 (pin 2) $V_{IN(off)}$ = 0.4 V On state input current (pin 2) $V_{IN(on)}$ = 3.5 V	$I_{IN(off)}$ $I_{IN(on)}$	1 10	-- 25	30 70	µA
Delay time for status with open load (see timing diagrams, page 27)	$t_{d(ST\ OL1)}$ $t_{d(ST\ OL2)}$	-- --	700 200	-- --	µs
Status valid after input slope T_j=-40 ... +150°C: (short circuit, open load)	$t_{d(ST)}$	80	--	350	µs

[3] see diagram page 25, Add I_{ST}, if I_{ST} > 0

[4] if a ground resistor R_{GND} is used, add the voltage across this resistor. Internal Z-diode typ. 6.1 V, see maximum ratings page 17, (see chapter 3)

Parameter and Conditions at T_j = 25 °C, V_{bb} = 12V unless otherwise specified	Symbol	Values			Unit
		min	typ	max	
Status output (CMOS)					
T_j =-40...+150°C, I_{ST}= - 50 µA:	$V_{ST(high)}$ [6]	4.4	5.1	6.5	V
T_j =-40...+25°C, I_{ST} = +1.6 mA:	$V_{ST(low)}$	--	--	0.8	
T_j = +150°C, I_{ST} = +1.6 mA:		--	--	1.0	
Max. status current for current source (out):	$-I_{ST}$	--	--	0.25	mA
valid status output, current sink (in) [5]:	$+I_{ST}$	--	--	1.6	
T_j =-40...+150°C					
Operating and Clamp Voltages					
Operating voltage T_j =25°C:	$V_{bb(on)}$	4.9	--	42	V
T_j =-40...+150°C:		5.8		40	
Undervoltage shutdown T_j =25..+150°C:	$V_{bb(under)}$	2.4	--	4.9	
T_j =-40°C:		3.0	--	5.4	
Undervoltage restart T_j =25...+150°C:	$V_{bb(u\ rst)}$	--	--	4.9	
T_j =-40°C:		--	--	5.8	
Overvoltage shutdown T_j =-40...+150°C:	$V_{bb(over)}$	42	--	52	
Overvoltage restart T_j =-40...+150°C:	$V_{bb(o\ rst)}$	40	--	--	
Overvoltage protection T_j =-40...+150°C:	$V_{bb(AZ)}$	50	56	--	
Load dump protection [7]	$V_{bb(LD)}$	--	--	93.5	
Output clamp (inductive load switch off)	$-V_{OUT(CL)}$	--	10	--	
Short circuit shutdown detection voltage (pin 3 to 5)	$V_{ON(SC)}$	--	8.6	10	
Protection Functions					
Overload current limit (pin 3 to 5), after 200 ms, V_{ON} =8 V, no heatsink [8], see diagram page 23 T_j=-40...+150°C	$I_{L(lim)}$	3.1	11	21	A
Thermal overload trip temperature	T_{jt}	150	--	--	°C
Inductive load switch-off energy dissipation [9],	E_{ab}	--	--	1.4	J
$T_{j\,Start}$ = 150 °C, V_{bb}=12V V_{bb} = 12 V:	E_{Load12}			0.6	
$E_{Load} = {}^1/_2 * L * I_L^2$ V_{bb} = 24 V:	E_{Load24}			0.4	
Reverse battery (pin 1 to 3) [10]	$-V_{bb}$	--	--	32	V

5) no current sink capability during undervoltage shutdown

6) $V_{St\ high} \approx V_{bb}$ during undervoltage shutdown

7) Requires 150 Ω resistor in GND connection. Input and Status currents have to be limited. It is recommended that 15kΩ resistors be inserted in series with IN and ST.

8) this occurs, if circuit resistance is so high, that no short circuit shutdown occurs ($V_{ON} < V_{ON(SC)}$)

9) while demagnetizing load inductance, dissipated energy in PROFET is $E_{ab} = \int (V_{bb} + |V_{OUT(CL)}|) * i_L(t)\ dt$,

approx. $E_{ab} = {}^1/_2 * L * I_L^2 * (1 + \frac{V_{bb}}{|V_{OUT(CL)}|})$

10) Requires 150 Ω resistor in GND connection. Reverse load current (through intrinsic drain-source diode) is normally limited by the connected load. Reverse current I_{GND} of about 0.4 A at V_{bb}= -32 V through the logic (see chapter 3) heats up the device. Time allowed under these condition is dependent on the size of the heatsink. Input and Status currents have to be limited. It is recommended that 15kΩ resistors be inserted in series with IN and ST.

Truth Table

	Input-level	Output level	Status				
			version 412 B	version D	version E/F	version G	version H
Normal operation	**L**	**L**	H	**H**	H	H	H
	H	**H**	H	**H**	H	H	H
Open load	**L**	[11] **H**	L	**H**	H	H	L
	H		H	**L**	L	L	H
Short circuit to GND	**L**	**L**	H	**H**	H	H	H
	H	**L**	L	**L**	L	H	L
Short circuit to V_{bb}	**L**	**H**	L	**H**	H	H	L
	H	**H**	H	**H (L[12])**	H (L[12])	H (L[12])	H
Overtemperature	**L**	**L**	L	**L**	L	L	L
	H	**L**	L	**L**	L	L	L
Undervoltage	**L**	**L**	L[13]	**L[13]**	H	H	H
	H	**L**	L[13]	**L[13]**	H	H	H
Overvoltage	**L**	**L**	L	**L**	H	H	H
	H	**L**	L	**L**	H	H	H

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

[11] Power Transistor off, high impedance, versions BTS 410H, BTS 412B: internal pull up current source for open load detection.
[12] low resistance to V_{bb} may be detected by no-load-detection
[13] no current sink capability during undervoltage shutdown

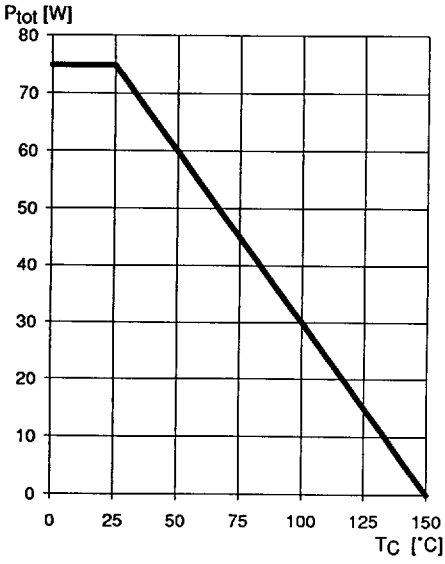
Options Overview

all versions: High-side switch, Input protection, ESD protection, load dump and reverse battery protection with 150 Ω in GND connection

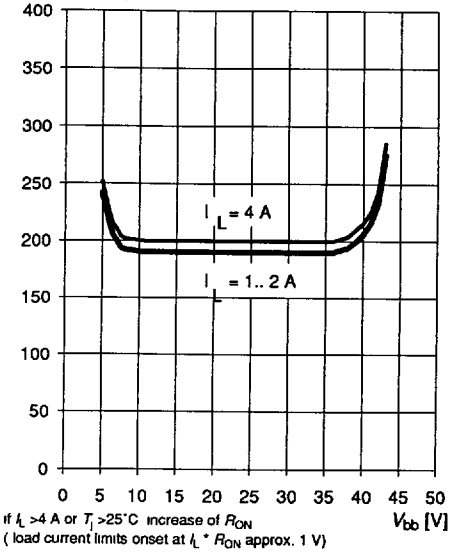
Type BTS	412 B	410D	410E	410F	410G	410H
Logic version	B	D	E	F	G	H
Overtemperature protection						
T_j >150 °C, latch function[14]	X	X		X		X
T_j >150 °C, with auto-restart on cooling			X		X	
Short-circuit to GND protection						
switches off when V_{bb}-V_{OUT}>3.5 V typ. (when first turned on after approx. 150 µs)						X
switches off when V_{bb}-V_{OUT}>8.6 V typ. (when first turned on after approx. 150 µs)	X	X	X	X		
Achieved through overtemperature protection					X	
Open load detection						
in OFF-state with sensing current 30 µA typ.	X					X
in ON-state with sensing voltage drop across power transistor		X	X	X	X	
Undervoltage shutdown with auto restart	X	X	X	X	X	X
Overvoltage shutdown with auto restart	X	X	X	X	X	X
Status feedback for						
overtemperature	X	X	X	X	X	X
short circuit to GND	X	X	X	X		X
short to V_{bb}	X					X
open load	X	X	X	X	X	X
undervoltage, overvoltage	X	X				
Status output type						
CMOS	X	X				
Open drain			X	X	X	X
Output negative voltage transient limit (fast inductive load switch off)						
to -10 V typ	X	X	X	X	X	X
Load current limit						
high level (can handle loads with high inrush currents)	X	X	X			
low level (better protection of application)				X	X	X

[14] Latch except when V_{bb} - V_{OUT} < $V_{ON(SC)}$ after shutdown. In most cases V_{OUT} =0 V after shutdown (V_{OUT} ≠ 0 V only if forced externaly). So the device remains latched unless V_{bb} < $V_{ON(SC)}$ (see page 19). No latch between turn on and $t_{d(SC)}$.

Maximum allowable power dissipation
$P_{tot} = f(T_C)$

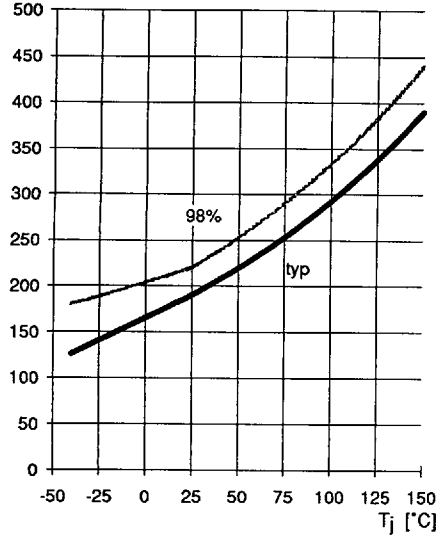


Typ. on-state resistance (V_{bb}-Pin to OUT-Pin)
$R_{ON} = f(V_{bb}, I_L)$; V_{IN}= high, T_j =25°C

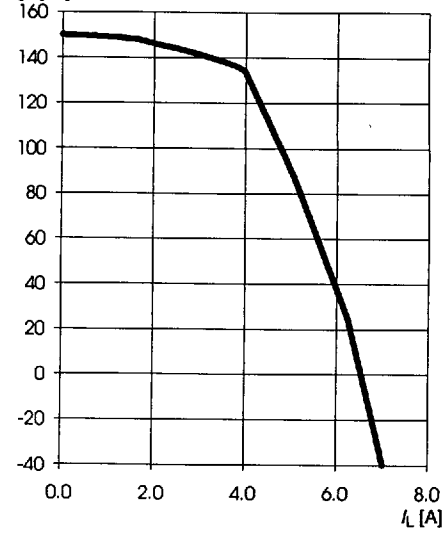


On-state resistance (V_{bb}-Pin to OUT-Pin)

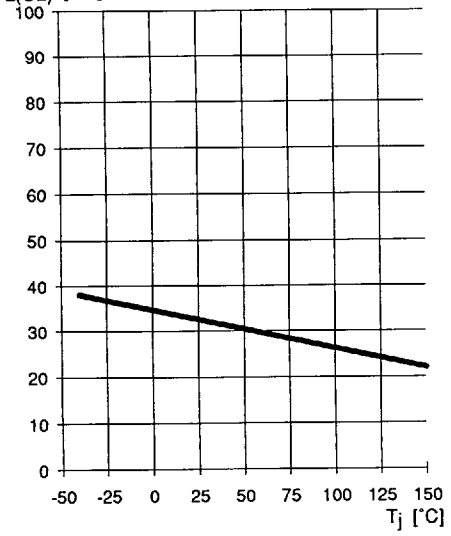
$R_{ON} = f(T_j)$; V_{bb}=9..35V; I_L= 1 A; V_{IN}= high



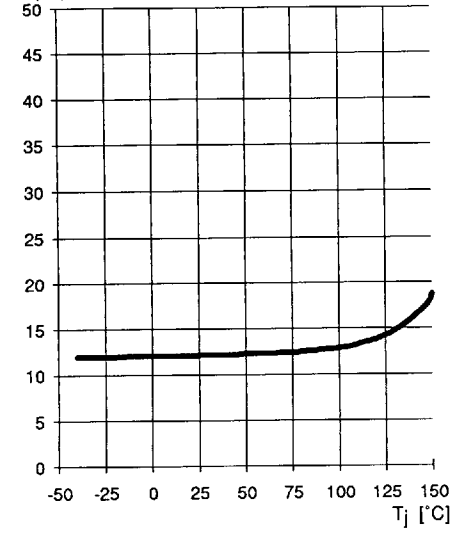
Max. case temperature vs DC load current
T_C max = f (I_L)



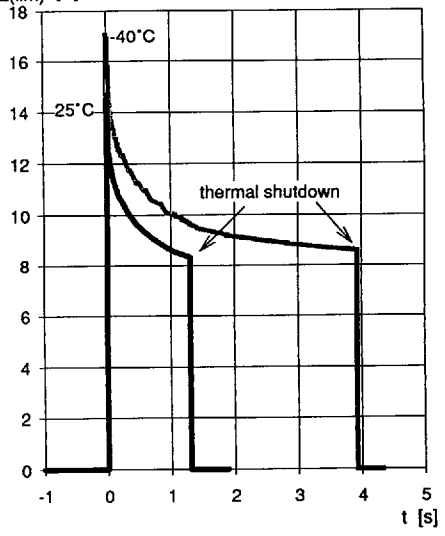
Typ. open load detect current
$I_{L(OL)} = f(T_j)$; V_{bb}=9..35 V; V_{IN}= high



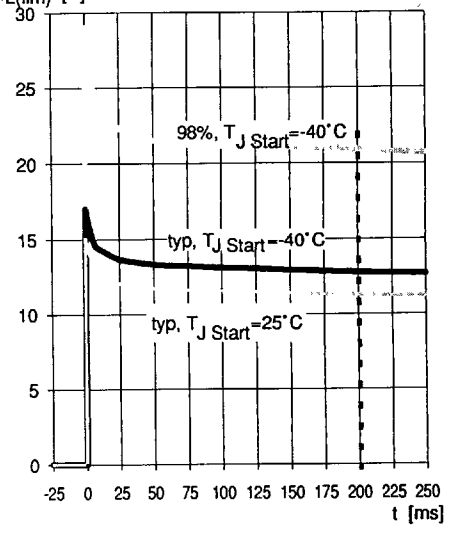
Typ. standby current
$I_{bb(off)} = f(T_j)$, V_{bb}=9...35 V, V_{IN}=low



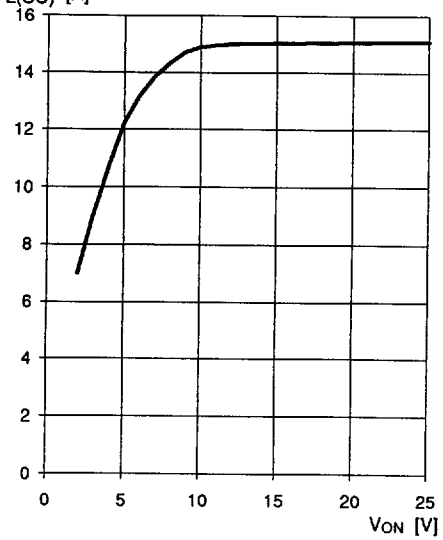
Typ. overload current
$I_{L(lim)} = f(t)$; V_{bb}= 12 V, V_{bb}-V_{OUT}=8 V, no heatsink, Parameter: $T_{j\,Start}$



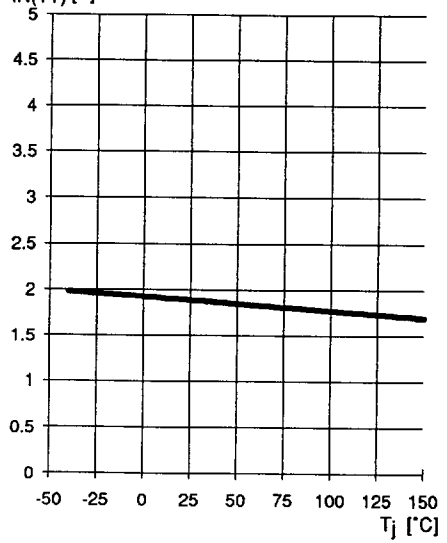
Overload Current
$I_{L(lim)} = f(t)$; V_{bb}= 12 V, V_{bb}-V_{OUT}=8 V, no heatsink



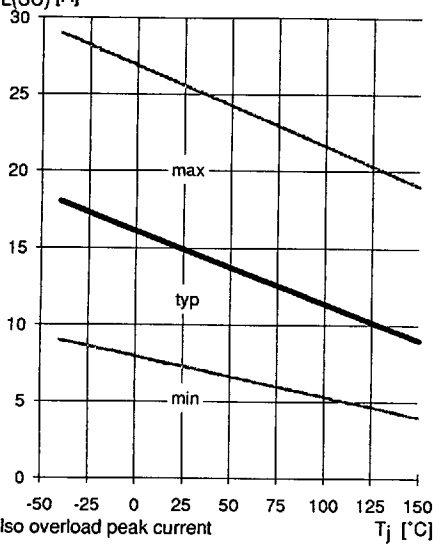
Typ. short circuit Current
$I_{L(SC)} = f(V_{ON})$; T_j= 25°C



Typ. input turn on voltage threshold
$V_{IN(T+)} = f(T_j)$; V_{bb}=9...35 V

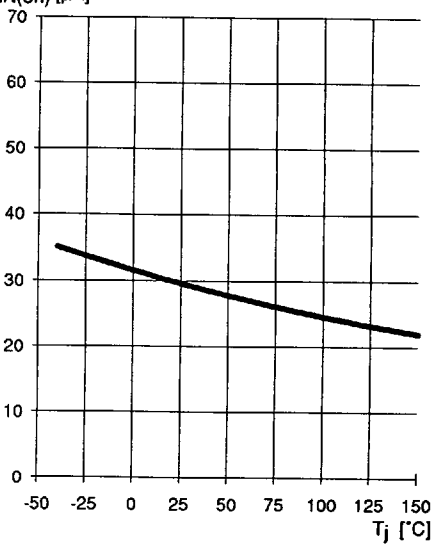


Short circuit current
max duration 350 µs prior to shutdown
$I_{L(SC)} = f(T_j)$, V_{bb}= 12...35V; V_{IN}= High

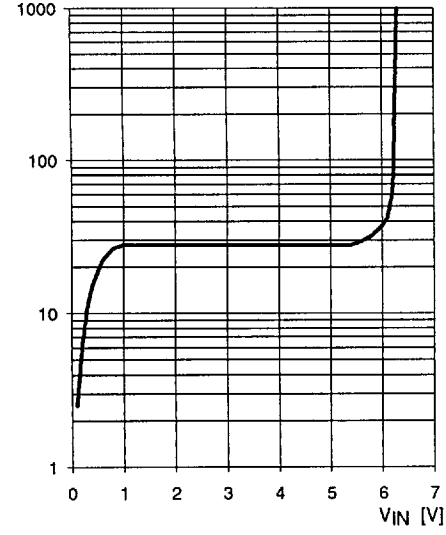


also overload peak current

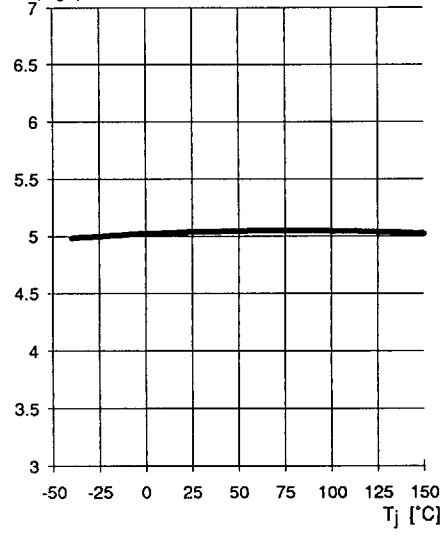
Typ. input current high
$I_{IN(on)} = f(T_j)$ V_{IN}= 3.5...5.5V



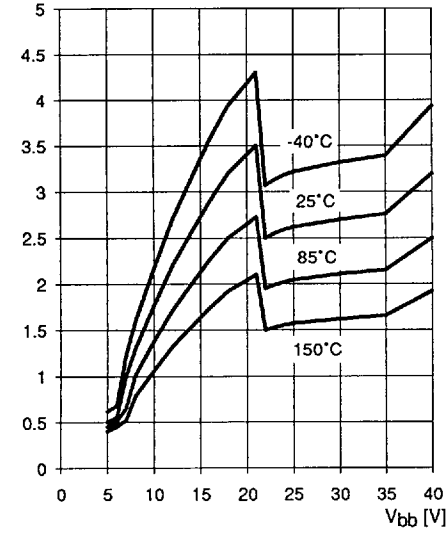
Typ. input current
$I_{IN} = f(V_{IN})$, V_{bb}= 9...35V, T_j=25°C



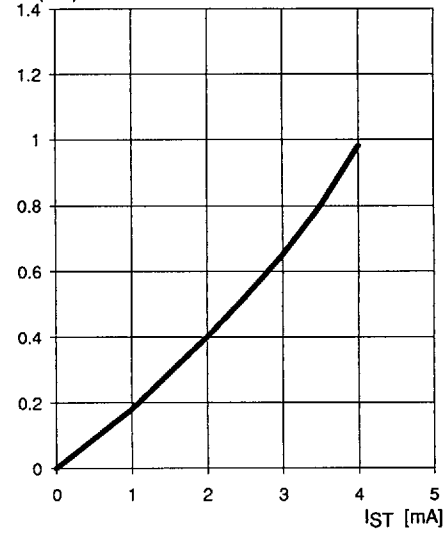
Typ. status high voltage
$V_{ST(high)} = f(T_j)$; V_{bb}=12V...35 V



Typ. ground pin operating current
$I_{GND} = f(V_{bb}, T_J)$; V_{IN}= high

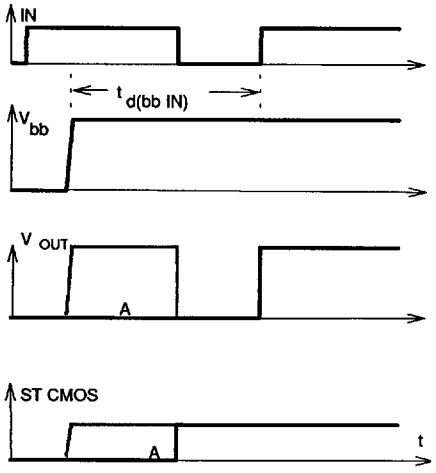


Typ. status low voltage
$V_{ST(low)} = f(I_{ST})$, V_{bb}= 9...35V, T_j=25°C



Timing diagrams

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 a lamp,

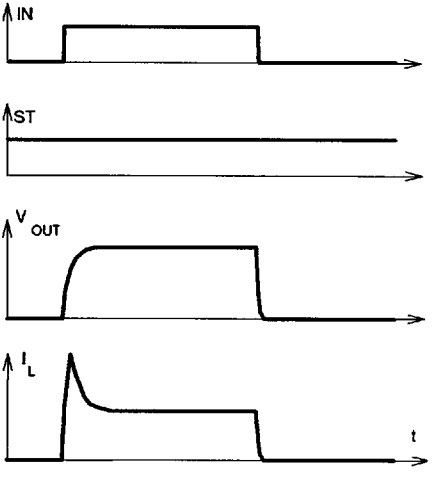
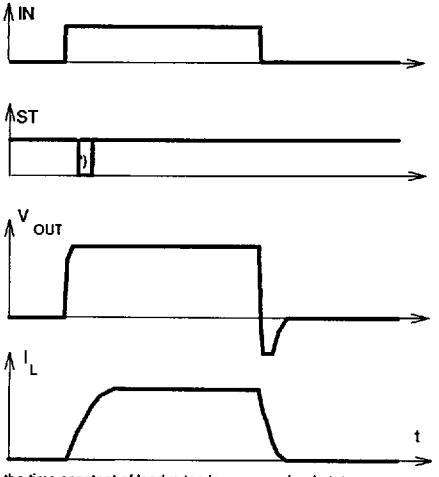


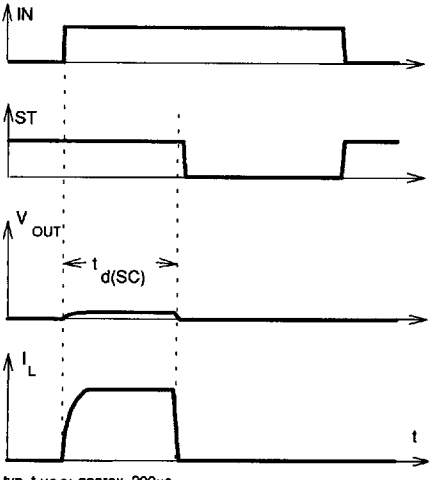
Figure 2b: Switching an inductive load,

(Better protection of application: versions BTS 410 F/G/H)



*) if the time constant of load is too large, open-load-status may occur

Figure 3a: turn on into short circuit,



typ $t_{d(SC)}$ approx 200µs

Figure 3b: short circuit while on:

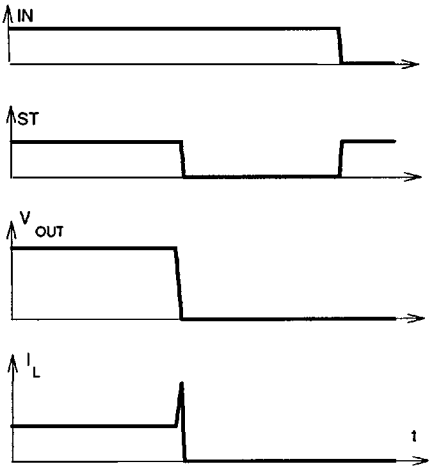
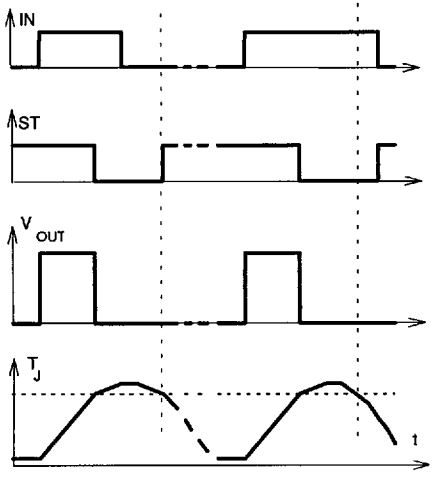


Figure 4a: overtemperature,

Reset if (IN=low) and ($T_J < T_{jt}$)



*) ST goes high , when V_{IN}=low and $T_J < T_{jt}$

Figure 5a: open load: detection in ON-state, turn on to open load

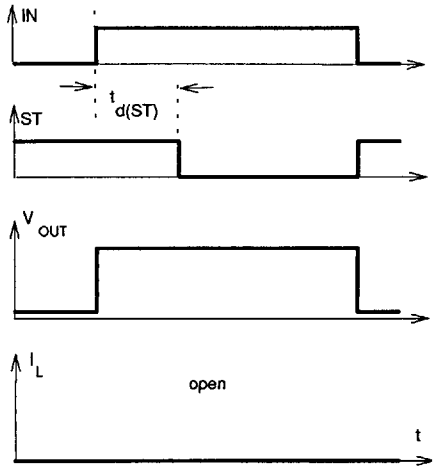
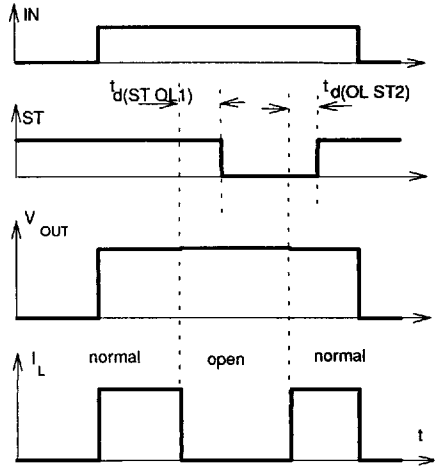


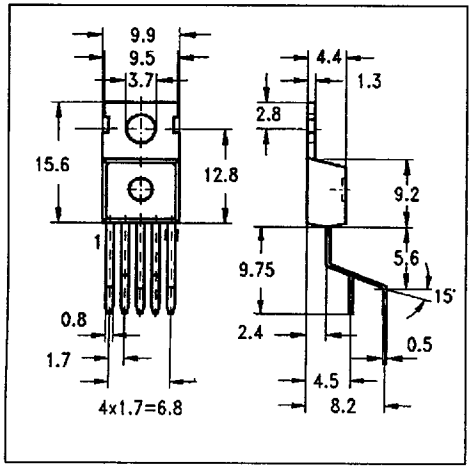
Figure 5b: open load: detection in ON-state, open load occurs in on-state



Package and ordering code

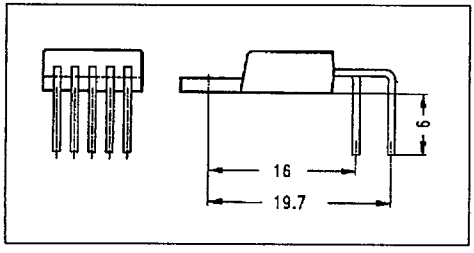
Standard

BTS 410 D	C67078-S5305-A3



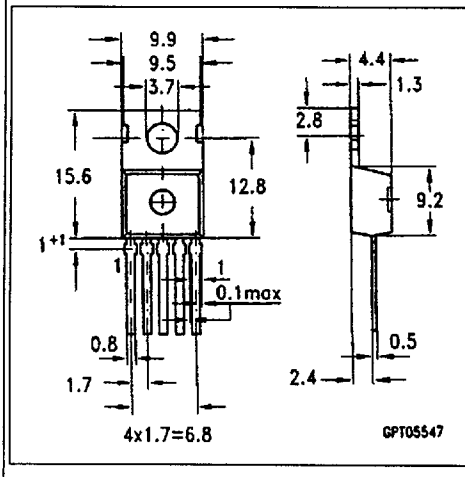
E3040

BTS 410 D	C67078-S5305-A7



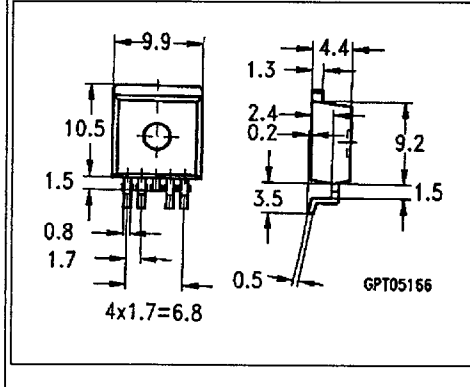
E3043

BTS 410 D	C67078-S5305-A20



SMD

BTS 410 D E3062	Tube: C67078-S5305-A11



SMD

BTS 410 D E3122	Tube: C67078-S5305-A15