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# BTS441RG

Smart Power High-Side-Switch
One Channel 20 mΩ

# Data sheet

Rev. 1.21, 2012-12-06

# Automotive Power

# Smart Power High-Side-Switch
## One Channel: 20 mΩ

**BTS441RG**

# 1 Overview

**General Description**

- N channel vertical power FET with charge pump, ground referenced CMOS compatible input, monolithically integrated in Smart SIPMOS technology
- Providing embedded protective functions
- Green Product (RoHS compliant)
- AEC Qualified

**Application**

- µC compatible power switch 5 V, 12 V and 24 V DC applications
- All types of resistive, inductive and capatitive 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
- Optimized static electromagnetic compatibility (EMC)
- µC and CMOS compatible
- Fast demagnetization of inductive loads
- Stable behavior at undervoltage

**Protection Functions**

- Short circuit protection
- Current limitation
- Overload protection
- Thermal Shutdown
- Overvoltage protection (including load dump) with external GND resistor
- Reverse battery protection with external GND-resistor
- Loss of ground and loss of $V_{bb}$ protection
- Electrostatic discharge (ESD) protection
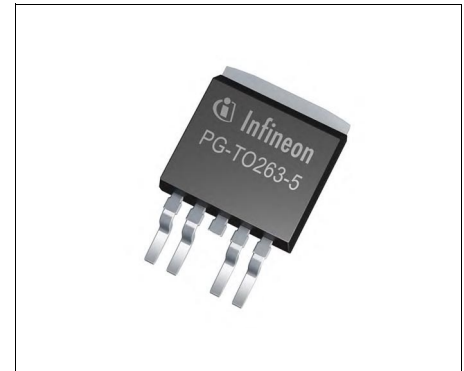


**PG-TO263-5**
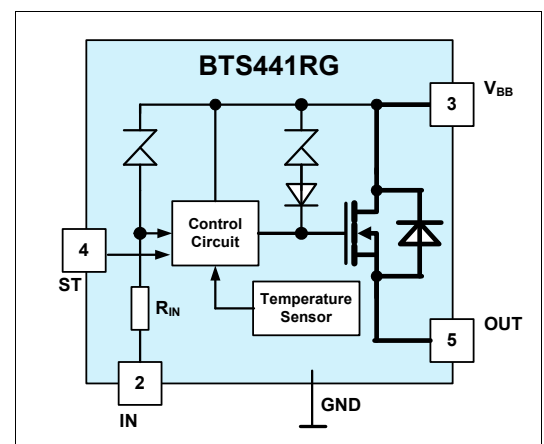


| Type | Package | Marking |
|---|---|---|
| BTS441RG | PG-TO263-5 | BTS441R |

**Diagnostic Function**

- Diagnostic feedback with open drain output
- Open load detection in OFF-state
- Feedback of thermal shutdown in ON-state

**Product Summary**

| | | |
|---|---|---|
| Maximum on-state resistance at $T_j$ = 150 °C | $R_{DS(ON)}$ | 20 mΩ |
| Operating voltage | $V_{SOP}$ | 4.75 V … 41 V |
| Nominal load current | $I_{L\,(nom)}$ | 21 A |
| Current limitation | $I_{L(lim)}$ | 65 A |

**Product Information**

| Device Name | Status | Package | Pins | ECO status |
|---|---|---|---|---|
| BTS441RG | Active | PG-TO263-5 | 5 | Green |
| BTS441RG | Discontinued | P-TO263-5 | 5 | Gray |
| BTS441RS | Discontinued | P-TO220-5 | 5 | Gray |
| BTS441RS | Discontinued | PG-TO220-5 | 5 | Green |

**Functional diagram**
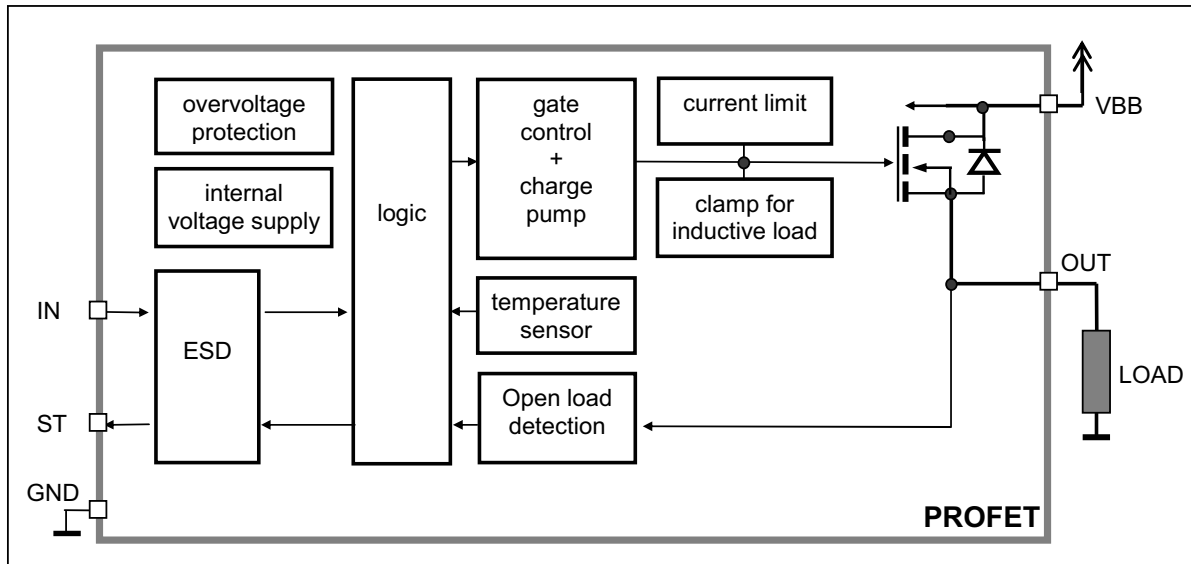


**Pin Definitions and Functions**

| Pin | Symbol | Function |
|-----|--------|----------|
| 1 | GND | **Logic ground** |
| 2 | IN | **Input**, activates the power switch in case of logical high signal |
| 3 | $V_{bb}$ | **Positive power supply voltage** The tab is shorted to pin 3 |
| 4 | ST | **Diagnostic feedback**, low on failure |
| 5 | OUT | **Output** to the load |
| Tab | $V_{bb}$ | **Positive power supply voltage** The tab is shorted to pin 3 |

**Pin configuration**

(top view)



Tab = $V_{BB}$

| 1 | 2 | (3) | 4 | 5 |
| GND | IN | | ST | OUT |
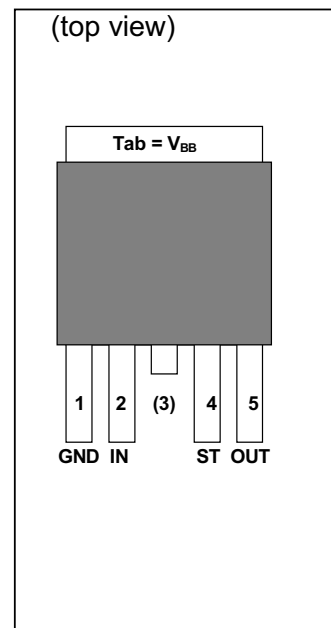
**Maximum Ratings**  at $T_j$ = 25 °C unless otherwise specified

| Parameter | Symbol | Values | Unit |
|---|---|---|---|
| Supply voltage (overvoltage protection see page 4) | $V_{bb}$ | 43 | V |
| Supply voltage for full short circuit protection $T_{j\,Start}$=-40 ...+150°C | $V_{bb}$ | 34 | V |
| Load dump protection[1] $V_{LoadDump} = V_A + V_s$, $V_A$ = 13.5 V   $R_I$[2]= 2 $\Omega$, $R_L$= 0,5 $\Omega$, $t_d$= 200 ms, IN= low or high | $V_{Load\,dump}$[3] | 60 | V |
| Load current (Short-circuit current, see page 5) | $I_L$ | self-limited | A |
| Operating temperature range | $T_j$ | -40 ...+150 | °C |
| Storage temperature range | $T_{stg}$ | -55 ...+150 | |
| Power dissipation (DC) ; TC≤25°C | $P_{tot}$ | 125 | W |
| Maximal switchable inductance, single pulse $V_{bb}$ = 12V, $T_{j,start}$ = 150°C, $T_C$ = 150°C const. (see diagram, p.7)  $I_{L(ISO)}$ = 21 A, RL= 0 $\Omega$: $E$[4]$_{AS}$=0.7J: | $Z_L$ | 2.1 | mH |
| Electrostatic discharge capability (ESD)                    IN:  (Human Body Model)                                        ST:                     Out to all other pins shorted: acc. MIL-STD883D, method 3015.7 and ESD assn. std. S5.1-1993;  R=1.5k$\Omega$; C=100pF | $V_{ESD}$ | 1.0 4.0 8.0 | kV |
| Input voltage (DC) | $V_{IN}$ | -10 ... +16 | V |
| Current through input pin (DC) | $I_{IN}$ | ±2.0 | mA |
| Current through status pin (DC) see internal circuit diagrams page 7 | $I_{ST}$ | ±5.0 | |
| Thermal resistance                                     chip - case: | $R_{thJC}$ | ≤ 1 | K/W |
| junction - ambient (free air): | $R_{thJA}$ | ≤ 75 | |
| SMD version, device on pcb[5]: | | ≤ 33 | |

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[1]  Supply voltages higher than $V_{bb(AZ)}$ require an external current limit for the GND pin, e.g. with a 150 $\Omega$ resistor in the GND connection. A resistor for the protection of the input is integrated.

[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]  $E_{AS}$ is the maximum inductive switch off energy

[5]  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.

## Electrical Characteristics

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

**Load Switching Capabilities and Characteristics**

| Parameter and Conditions | Symbol | min | typ | max | Unit |
|---|---|---|---|---|---|
| On-state resistance ($V_{bb}$ (pin3) to OUT (pin5)); $I_L$ = 2 A $V_{bb} \geq 7V$: $T_j$=25 °C: $T_j$=150 °C: see diagram page 9 | $R_{ON}$ | -- | 15 / 28 | 20 / 37 | mΩ |
| Nominal load current (pin 3 to 5) 'ISO 10483-1, 6.7:$V_{ON}$=0.5V, $T_c$=85°C | $I_{L(ISO)}$ | 17 | 21 | -- | A |
| Output current (pin 5) while GND disconnected or GND pulled up[6], $V_{bb}$=30 V, $V_{IN}$= 0, see diagram page 7 | $I_{L(GNDhigh)}$ | -- | -- | 2 | mA |
| Turn-on time IN ⌐ to 90% $V_{OUT}$: Turn-off time IN ⌐ to 10% $V_{OUT}$: $R_L$ = 12 Ω, | $t_{on}$ / $t_{off}$ | 40 / 40 | 90 / 110 | 200 / 250 | µs |
| Slew rate on 10 to 30% $V_{OUT}$, $R_L$ = 12 Ω, | d$V$/dt$_{on}$ | 0.1 | -- | 1 | V/µs |
| Slew rate off 70 to 40% $V_{OUT}$, $R_L$ = 12 Ω, | -d$V$/dt$_{off}$ | 0.1 | -- | 1 | V/µs |

**Operating Parameters**

| Parameter and Conditions | Symbol | min | typ | max | Unit |
|---|---|---|---|---|---|
| Operating voltage $T_j$ =-40°C $T_j$ =+25°C $T_j$ =+105°C[6] $T_j$ =+150°C | $V_{bb(on)}$ | 4.75 4.75 4.75 5.0 | -- -- -- -- | 41 43 43 43 | V |
| Overvoltage protection[7] $T_j$ =-40°C: $I_{bb}$ = 40 mA $T_j$ =+25...+150°C: | $V_{bb(AZ)}$ | 41 43 | -- 47 | -- 52 | V |
| Standby current (pin 3) [8] $T_j$=-40...+25°C: $T_j$=+105°C[6]: $V_{IN}$=0 see diagram page 9 $T_j$=+150°C: | $I_{bb(off)}$ | -- -- -- | 5 -- -- | 10 10 25 | µA |
| Off-State output current (included in $I_{bb(off)}$) $V_{IN}$=0 | $I_{L(off)}$ | -- | 1.5 | 10 | µA |
| Operating current (Pin 1)[9], $V_{IN}$=5 V, | $I_{GND}$ | -- | 2 | 4 | mA |

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6) not subject to production test, specified by design

7) see also $V_{ON(CL)}$ in table of protection functions and circuit diagram page 7

8) Measured with load, typ. 40 µA when no load in off

9) Add $I_{ST}$, if $I_{ST}$ > 0, add $I_{IN}$, if $V_{IN}$>5.5 V

| Parameter and Conditions | | Symbol | Values | | | Unit |
|---|---|---|---|---|---|---|
| at $T_j$ =-40...+150°C, $V_{bb}$ = 12 V unless otherwise specified | | | min | typ | max | |
| **Protection Functions[10)]** | | | | | | |
| Current limit (pin 3 to 5) | $T_j$ =-40°C: | $I_{L(lim)}$ | -- | -- | 85 | A |
| (see timing diagrams, page 9) | $T_j$ =25°C: | | -- | 65 | -- | |
| | $T_j$ =+150°C: | | 40 | -- | -- | |
| Repetitive short circuit current limit | | $I_{L(SCr)}$ | -- | 55 | -- | A |
| $T_j = T_{jt}$ (see timing diagrams, page 10) | | | | | | |
| Thermal shutdown time[11)12)] | $T_{j,start}$ =25°C: | $T_{off(SC)}$ | -- | 14 | -- | ms |
| (see timing diagram on page 10) | | | | | | |
| Output clamp (inductive load switch off) | ;$T_j$ =-40°C: | | 41 | -- | -- | V |
| at $V_{OUT}$ = $V_{bb}$ - $V_{ON(CL)}$, $I_L$= 40 mA | $T_j$=25..150°C: | $V_{ON(CL)}$ | 43 | 47 | 52 | |
| Thermal overload trip temperature | | $T_{jt}$ | 150 | -- | -- | °C |
| Thermal hysteresis | | $\Delta T_{jt}$ | -- | 10 | -- | K |
| Reverse battery (pin 3 to 1) [13)] | | $-V_{bb}$ | -- | -- | 32 | V |
| Reverse battery voltage drop ($V_{OUT} > V_{bb}$) $I_L$ = -2A | $T_j$ =+150°C: | $-V_{ON(rev)}$ | -- | 540 | -- | mV |

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[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)] not subject to production test, specified by design

[12)] 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.

[13)] Requires 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 1 and circuit page 7).

| Parameter and Conditions | Symbol | Values | | | Unit |
|---|---|---|---|---|---|
| at $T_j$ =-40...+150°C, $V_{bb}$ = 12 V unless otherwise specified | | min | typ | max | |
| **Diagnostic Characteristics** | | | | | |
| Open load detection voltage [14] | $V_{OUT(OL)}$ | 2 | 3 | 4 | V |
| **Input and Status Feedback [15]** | | | | | |
| Input resistance                                   see circuit page 7 | $R_I$ | 2.5 | 3.8 | 6.5 | kΩ |
| Input turn-on threshold voltage ⟋ | $V_{IN(T+)}$ | 1.2 | -- | 2.2 | V |
| Input turn-off threshold voltage ⟍ | $V_{IN(T-)}$ | 0.8 | -- | -- | V |
| Input threshold hysteresis | $\Delta V_{IN(T)}$ | -- | 0.3 | -- | V |
| Off state input current (pin 2)         $V_{IN}$ = 0.4 V: | $I_{IN(off)}$ | 1 | -- | 15 | μA |
| On state input current (pin 2)          $V_{IN}$ = 5 V: | $I_{IN(on)}$ | 4.5 | 12 | 24 | μA |
| Delay time for status with open load after switch off     (see timing diagrams, page 11), | $t_{ST\ delay}$ | -- | -- | 500 | μs |
| Status output (open drain) | | | | | |
| Zener limit voltage                  $I_{ST}$ = +1.6 mA: | $V_{ST(high)}$ | 5.4 | 6.1 | -- | V |
| ST low voltage                        $I_{ST}$ = +1.6 mA:: | $V_{ST(low)}$ | -- | -- | 0.4 | |

## Truth Table

| | IN | OUT | ST |
|---|---|---|---|
| **Normal operation** | L | L | H |
| | H | H | H |
| **Open load** | L | Z | L[16] |
| | H | H | H |
| **Short circuit to $V_{bb}$** | L | H | L |
| | H | H | H |
| **Overtemperature** | L | L | H |
| | H | L | L |

L = "Low" Level                    Z = high impedance, potential depends on external circuit
H = "High" Level                   Status signal valid after the time delay shown in the timing diagrams

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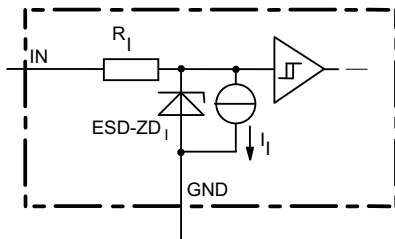[14] External pull up resistor required for open load detection in off state

[15] If a ground resistor $R_{GND}$ is used, add the voltage drop across this resistor.

[16] L, if potential at the Output exceeds the OpenLoad detection voltage
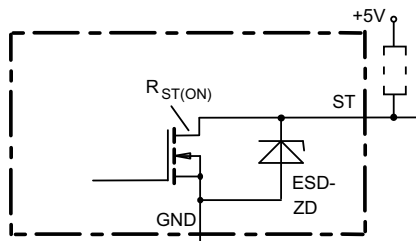
## Terms
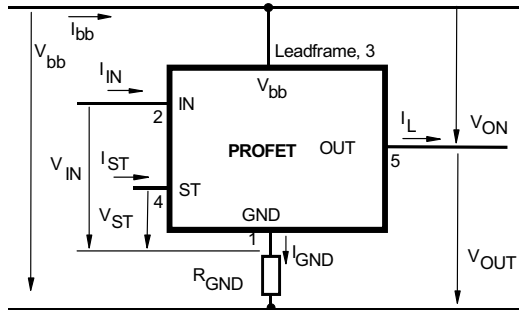


## Input circuit (ESD protection)



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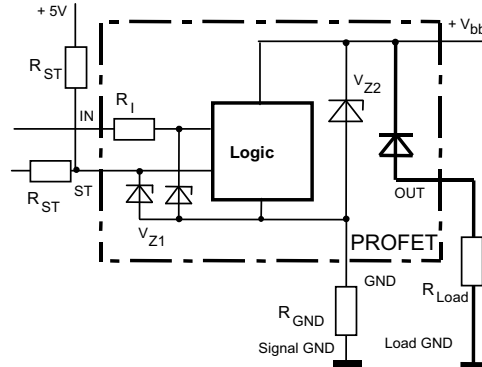
## Status output



ESD-Zener diode: 6.1 V typ., max 5.0 mA; $R_{ST(ON)}$ < 375 $\Omega$ 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).

## Inductive and overvoltage output clamp
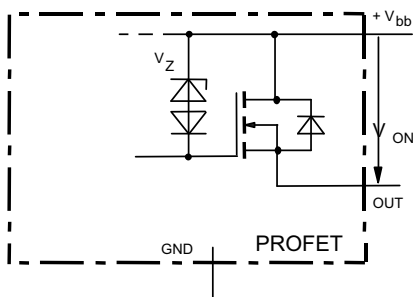


$V_{ON}$ clamped to 47 V typ.

## Overvolt. and reverse batt. protection



$V_{Z1}$ = 6.1 V typ., $V_{Z2}$ = 47 V typ., $R_{GND}$ = 150 $\Omega$, $R_{ST}$= 15 k$\Omega$, $R_I$= 3.5 k$\Omega$ typ.
In case of reverse battery the load current has to be limited by the load. Temperature protection is not active

## Open-load detection

OFF-state diagnostic condition:
Open Load, if $V_{OUT}$ > 3 V typ.; IN low
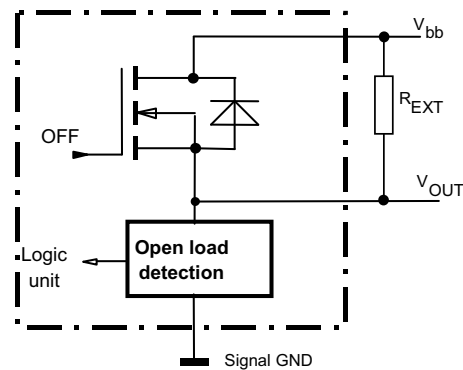


## GND disconnect
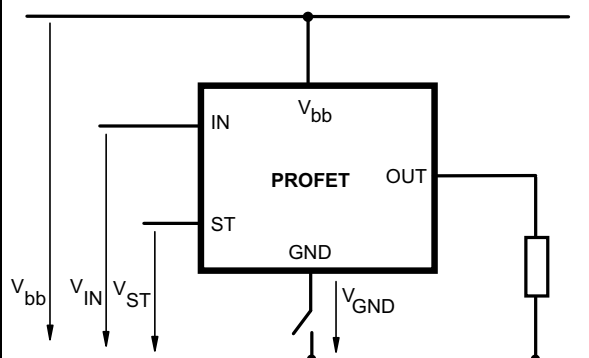


Any kind of load. In case of Input=high is $V_{OUT} \approx V_{IN} - V_{IN(T+)}$.

## GND disconnect with GND pull up
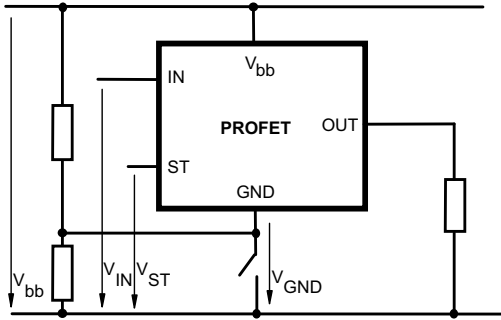


Any kind of load. If $V_{GND} > V_{IN} - V_{IN(T+)}$ device stays off
Due to $V_{GND} > 0$, no $V_{ST}$ = low signal available.

## $V_{bb}$ disconnect with charged inductive load
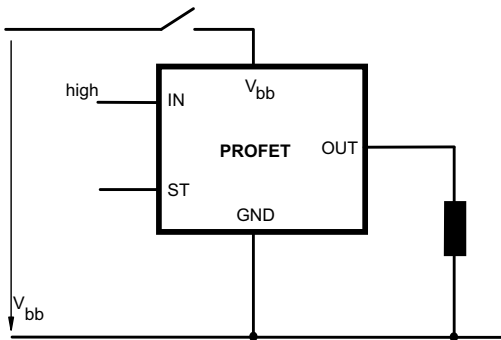


For inductive load currents up to the limits defined by $Z_L$ (max. ratings and diagram on page 8) each switch is protected against loss of $V_{bb}$.

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
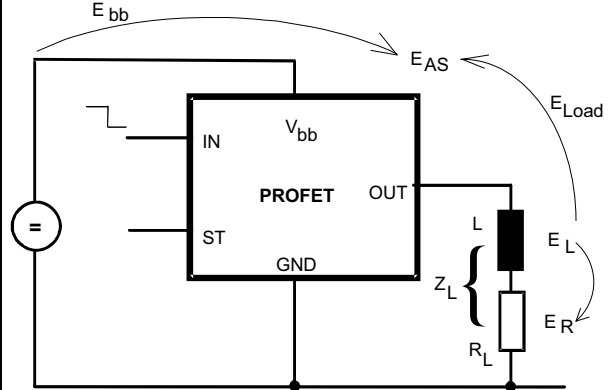


Energy stored in load inductance:

$$E_L = {}^1\!/_2 \cdot L \cdot I_L^2$$

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 $R_L > 0\,\Omega$:

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

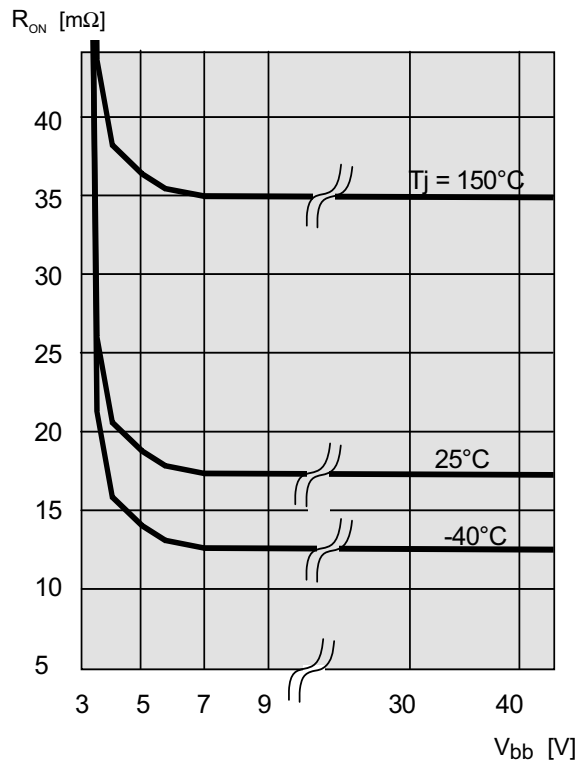## Maximum allowable load inductance for a single switch off

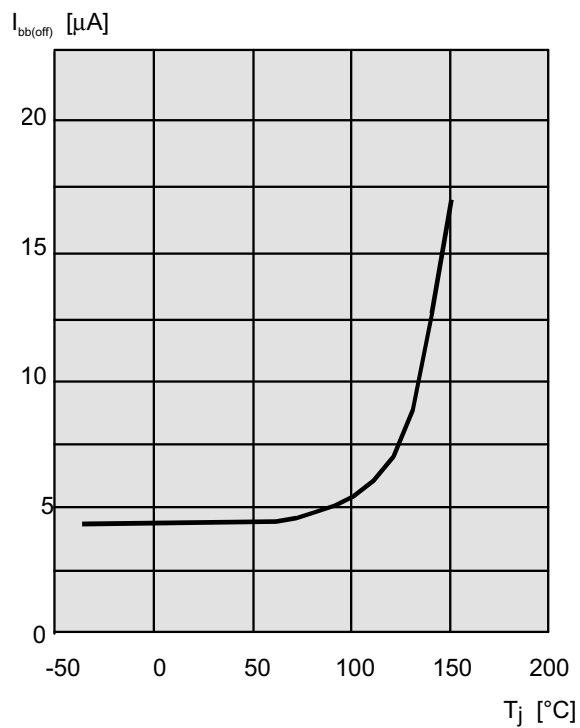$L = f(I_L)$; $T_{j,start} = 150°C$, $V_{bb} = 12\,V$, $R_L = 0\,\Omega$
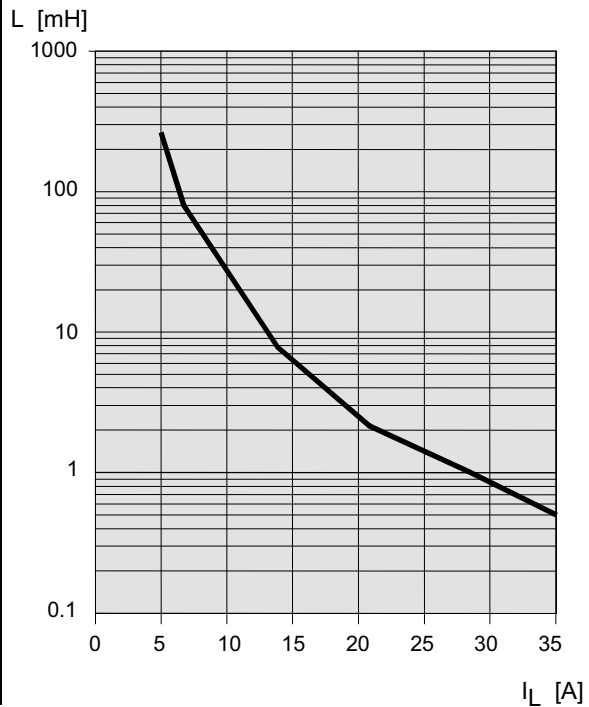
**Typ. on-state resistance**
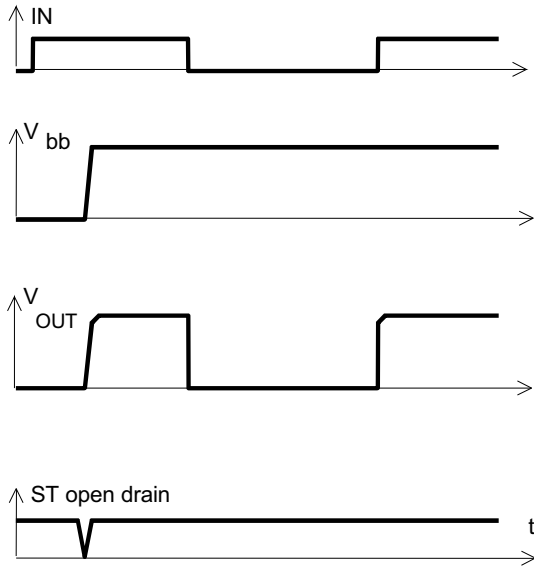
$R_{ON} = f(V_{bb}, T_j)$; $I_L = 2\,A$, IN = high

R$_{ON}$ [mΩ]



Tj = 150°C

25°C

-40°C

V$_{bb}$ [V]

**Typ. standby current**

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

I$_{bb(off)}$ [µA]



T$_j$ [°C]

## Timing diagrams

**Figure 1a:** $V_{bb}$ turn on:



IN

$V_{bb}$

$V_{OUT}$

ST open drain

t
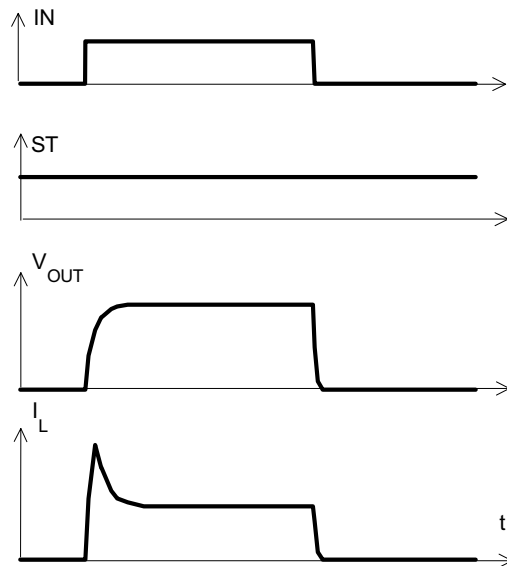
proper turn on under all conditions

**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
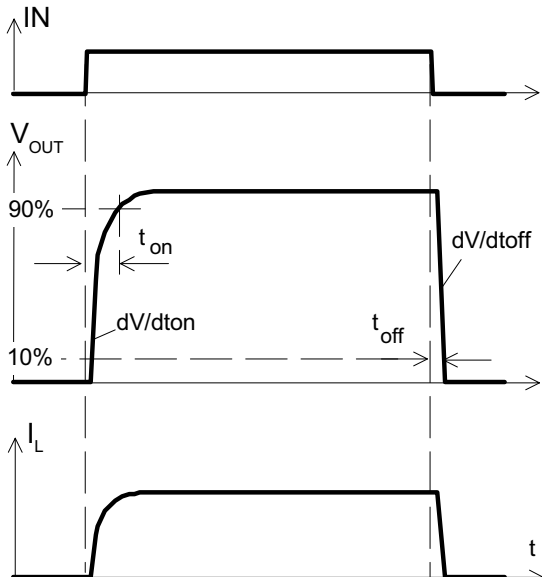
**Figure 2b:** Switching a lamp,



IN

ST

$V_{OUT}$

$I_L$

t

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



IN    other channel: normal operation

$I_L$

$I_{L(lim)}$
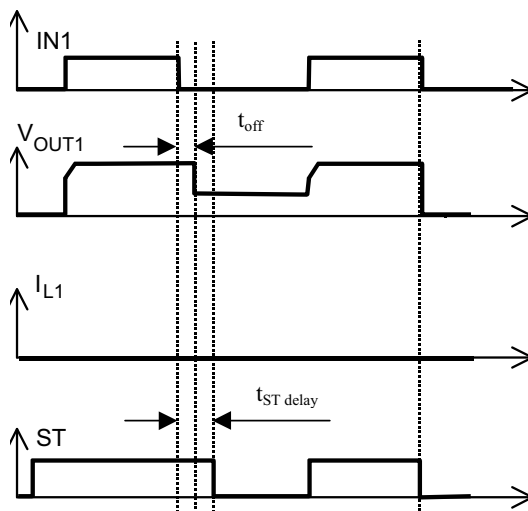
$I_{L(SCr)}$

$t_{off(SC)}$

ST

t
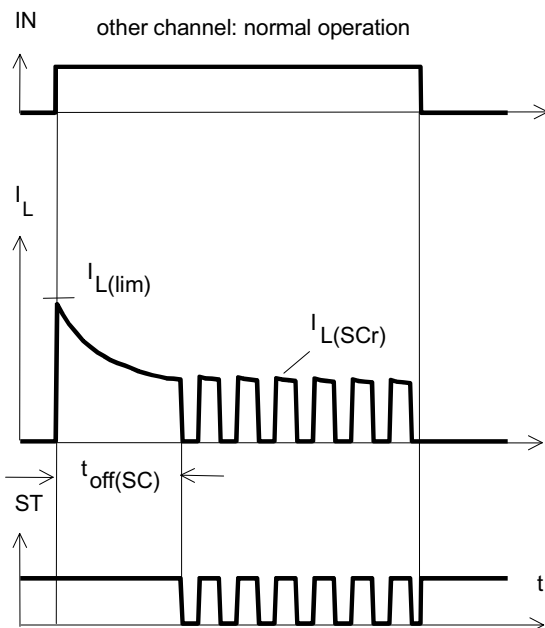
Heating up may require several milliseconds, depending on
external conditions

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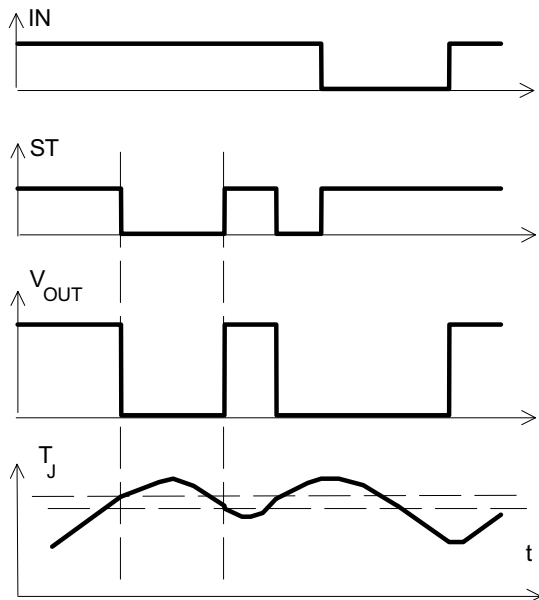


**Figure 5a:** Open load: detection in OFF-state, turn on/off to open load



$t_{ST\ delay}$ = 500µs
Open load detection requires an external pull up resistor between OUT and $V_{BB}$
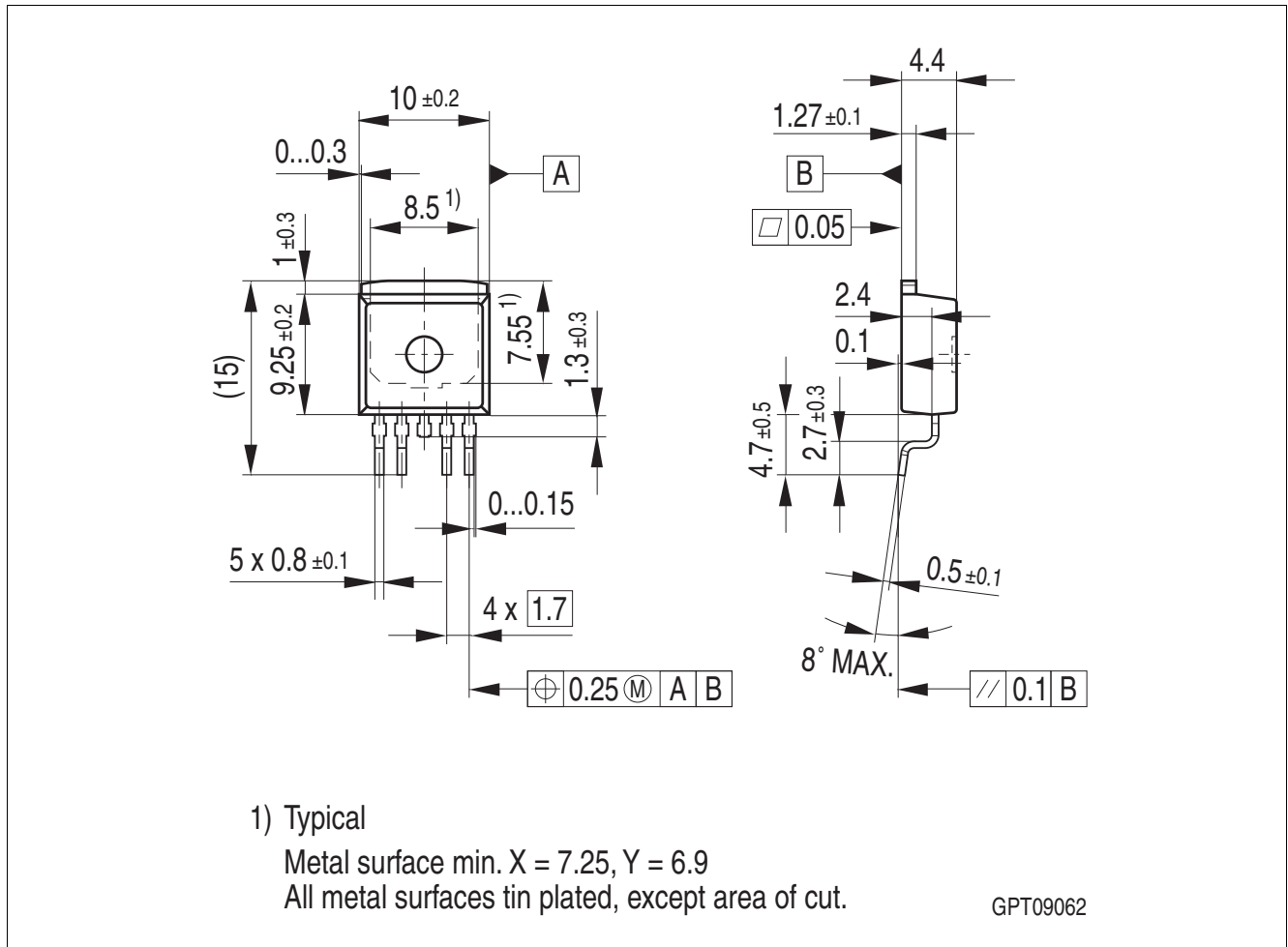
## Package Outlines



Figure 6: PG-TO263-5-2

1) Typical
   Metal surface min. X = 7.25, Y = 6.9
   All metal surfaces tin plated, except area of cut.

GPT09062

**Green Product (RoHS compliant)**

To meet the world-wide customer requirements for environmentally friendly products and to be compliant with government regulations the device is available as a green product. Green products are RoHS-Compliant (i.e Pb-free finish on leads and suitable for Pb-free soldering according to IPC/JEDEC J-STD-020).

For further information on alternative packages, please visit our website:
**http://www.infineon.com/packages**.

Dimensions in mm

# Revision History

| Revision | Date | Changes |
|---|---|---|
| 1.21 | 2012-12-06 | Device marking correction on page overview. |
| 1.20 | 2012-06-27 | Remove PG-TO-220-5-12 package on page overview and in package outlines. Added coverpage. |
| 1.1 | 2009-01-30 | RoHS-compliant PG-TO220 and PG-TO263 packages version of the BTS441R<br>All pages: Infineon logo updated<br>Page 1:<br>Added "AEC Qualified" and "RoHS" logo, added "Green Product (RoHS compliant)" and "AEC Qualified" statement to feature list, package names changed to RoHS compliant versions, updated package drawing.<br>Page 12-13:<br>Package names changed to RoHS compliant versions ( PG-TO220-12 and PG-TO263-5-2),  added "Green Product" description<br>added Revision History<br>added Legal Disclaimer |

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