

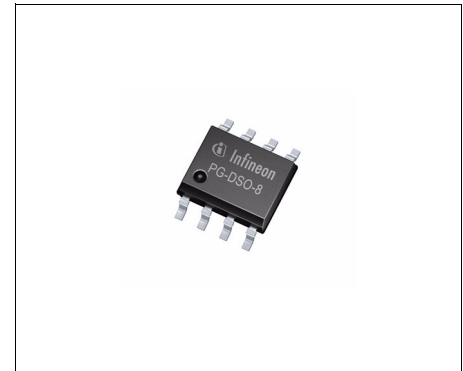
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## 1 Overview

### Features

- Low input current
- Short circuit and Overload protection
- Current limitation
- Input protection (ESD)
- Thermal protection with auto restart
- Compatible to standard Power MOSFET
- Analog driving possible
- Two channel concept saves PCB footprint
- Green Product (RoHS compliant)
- AEC Qualified



**PG-DSO-8-25**

### Description

The BTS3405G is a two channel low-side power switch in PG-DSO-8-25 package providing embedded protective functions. The device consists of two separate monolithic IC. Each with one N-channel power MOSFET transistor and additional protection circuitry.

**Table 1 Product Summary**

Drain Voltage	$V_D$	42 V <sup>1)</sup>
Input Voltage	$V_{IN(max)}$	10 V
Typical On-State Resistance at $T_j = 25^\circ\text{C}$ and $V_{in} = 10\text{V}$	$R_{DS(ON,amb typ)}$	0.7 $\Omega$
Maximum On-State Resistance at $T_j = 150^\circ\text{C}$ and $V_{in} = 10\text{V}$	$R_{DS(ON,hot max)}$	1.9 $\Omega$
Nominal Load Current	$I_{Dnom(min)}$	350 mA
Drain Current	$I_D$	600 mA <sup>2)</sup>
Single Clamping Energy	$E_{AS}$	65 mJ

1) Active clamped

2) Internally limited

Type	Package	Marking
BTS3405G	PG-DSO-8-25	BTS3405G

### Protective Functions

- Electrostatic discharge protection (ESD)
- Active clamp over voltage protection
- Thermal shutdown with auto restart
- Short circuit protection

### Fault Information

- Thermal shutdown
- Short to Battery and overload

### Applications

- Designed for driving Relays in Automotive Applications
- All types of resistive, inductive and capacitive loads
- Suitable for loads with peak currents
- Replaces discrete circuits

### Detailed Description

The device is able to switch all kind of resistive, inductive and capacitive loads, limited by  $E_{AS}$  and maximum current capabilities.

The BTS3405G offers ESD protection of each IN Pin in relation to the corresponding Source Pin.

The overtemperature protection prevents the device from overheating due to overload and/or bad cooling conditions. The temperature information is given by a temperature sensor in each of the two power MOSFET. During thermal shutdown the device tries to sink an increased input current at the corresponding IN pin to feedback the fault condition on this channel.

The BTS3405G has a thermal-auto-restart function, the regarding channel will turn on again after the measured temperature has dropped down for the thermal hysteresis.

The over voltage protection is active during load-dump or inductive turn off conditions. The power MOSFET is limiting the Drain - Source voltage to the defined clamping voltage. This function is available regardless of the input pin state, means without voltage on the IN pins.

## 2 Block Diagram

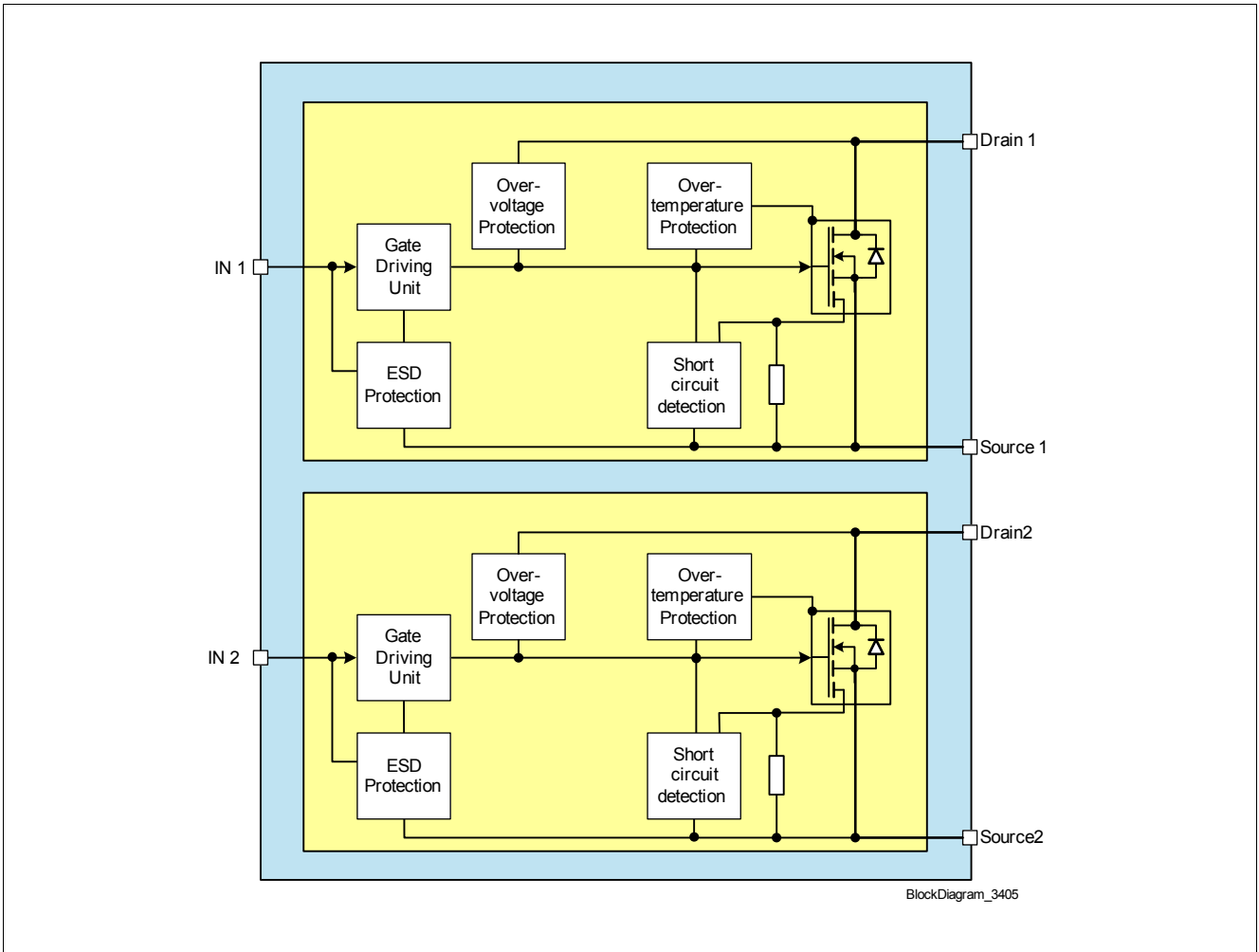


Figure 1 Block Diagram

### 2.1 Terms

Figure 2 shows all external terms used in this data sheet.

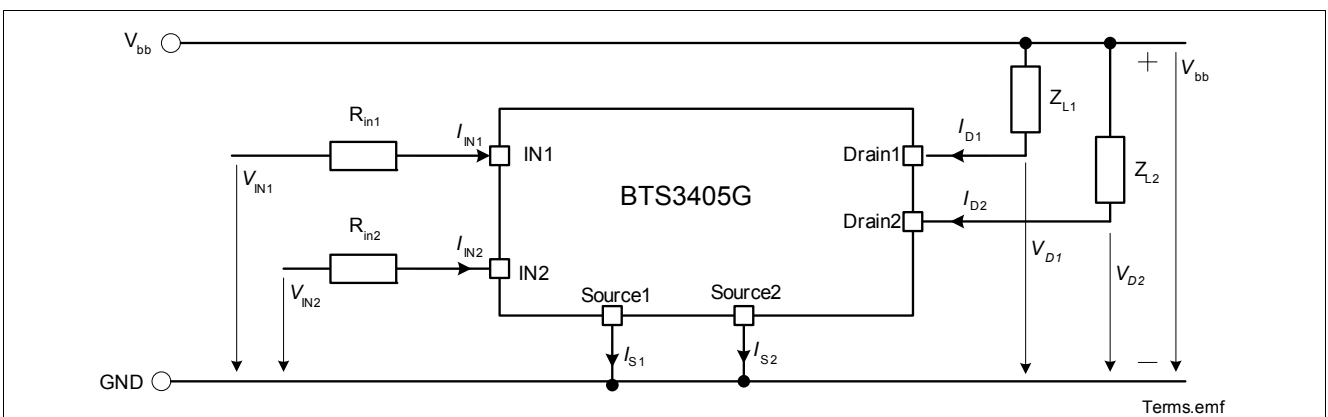


Figure 2 Terms

### 3 Pin Configuration

#### 3.1 Pin Assignment BTS3405G

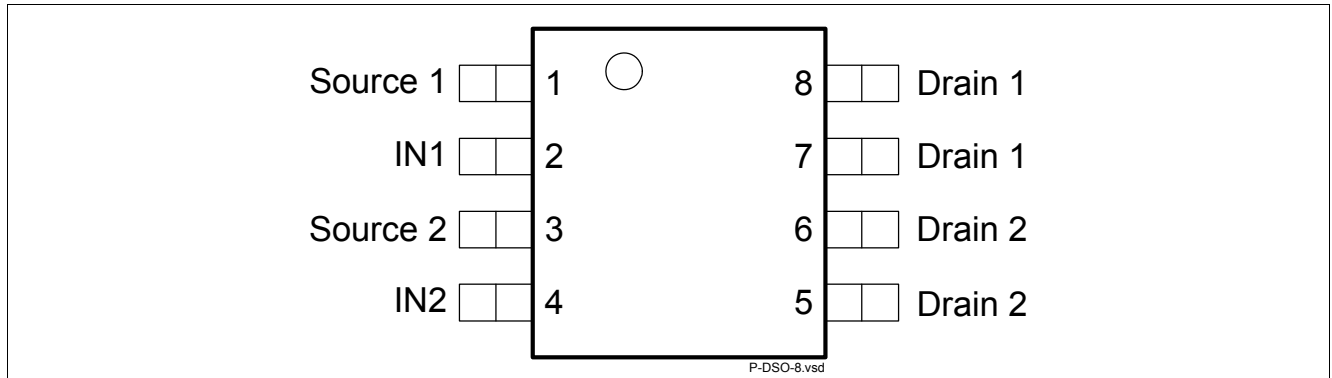


Figure 3 Pin Configuration PG-DSO-8-25

#### 3.2 Pin Definitions and Functions

Pin	Symbol	Function
1	Source1	Ground connection for channel 1
2	IN1	Input / Fault feedback for channel 1
3	Source2	Ground connection for channel 2
4	IN2	Input / Fault feedback for channel 2
5, 6	Drain2	Load connection channel 2
7, 8	Drain1	Load connection channel 1

## 4 General Product Characteristics

### 4.1 Absolute Maximum Ratings

All parameters apply for both channels accordingly.

#### Absolute Maximum Ratings <sup>1)</sup>

$T_j = -40 \text{ °C}$  to  $+150 \text{ °C}$ ; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified), all values valid for both channels

Pos.	Parameter	Symbol	Limit Values		Unit	Test Conditions
			Min.	Max.		
<b>Voltages</b>						
4.1.1	Drain voltage	$V_D$	–	42	V	<sup>2)</sup> $V_{IN} = 0 \text{ V}$ , $I_D = 10 \text{ mA}$
4.1.2	Input Voltage	$V_{IN}$	-0.2	10	V	–
4.1.3	Input Current	$I_{IN}$	self limited		mA	$-0.2 \text{ V} < V_{IN} < 10 \text{ V}$
4.1.4			-2	2	mA	$V_{IN} < -0.2 \text{ V}$ or $V_{IN} > 10 \text{ V}$
4.1.5	Drain Current	$I_D$	–	600	mA	<sup>3)</sup> $T_j = 25 \text{ °C}$
<b>Energies</b>						
4.1.6	Unclamped single pulse inductive energy single pulse	$E_{AS}$	0	65	mJ	$I_D = 350 \text{ mA}$ ; $V_{bb} = 28 \text{ V}$ ; $T_{J(\text{start})} = 85 \text{ °C}$
4.1.7	Unclamped single pulse inductive energy single pulse		–	30	mJ	$I_D = 250 \text{ mA}$ ; $V_{bb} = 28 \text{ V}$ ; $T_{J(\text{start})} = 150 \text{ °C}$
4.1.8	Unclamped repetitive pulse inductive energy $1 \times 10^4$ cycles	$E_{AR}$	0	18	mJ	$I_D = 200 \text{ mA}$ ; $V_{bb} = 13.5 \text{ V}$ ; $T_{J(\text{start})} = 105 \text{ °C}$
4.1.9	Unclamped repetitive pulse inductive energy $1 \times 10^6$ cycles		–	13	mJ	$I_D = 170 \text{ mA}$ ; $V_{bb} = 13.5 \text{ V}$ ; $T_{J(\text{start})} = 105 \text{ °C}$
4.1.10	Total Power Dissipation	$P_{tot}$	–	0.78	W	<sup>4)</sup> $T_a = 85 \text{ °C}$
<b>Temperatures</b>						
4.1.11	Operating temperature	$T_j$	-40	+150	°C	–
4.1.12	Storage temperature	$T_{stg}$	-55	+150	°C	–
<b>ESD Susceptibility</b>						
4.1.13	Electrostatic discharge voltage <sup>5)</sup>	$V_{ESD}$	-2	2	kV	IN Pin $R = 1.5 \text{ k}$ ; $C = 100 \text{ pF}$ ; $T_j = 25 \text{ °C}$

1) Not subject to production test, specified by design.

2) Active clamped.

3) Internally limited.

4) Device mounted on PCB according EIA/JEDEC standard JESD51-7 (4-layer FR4, 76.2 mm × 114.3 mm with buried planes). PCB is mounted vertical without blown air.

5) ESD susceptibility HBM according to EIA/JESD 22-A 114B, section 4.

## 4.2 Thermal Resistance

Pos.	Parameter	Symbol	Limit Values			Unit	Conditions
			Min.	Typ.	Max.		
4.2.1	Junction to Soldering Point	$R_{thJC}$	–	–	38	K/W	1) 2)
4.2.2	Junction to Ambient all channel ON	$R_{thJA}$	–	80	–	K/W	1) 2)

1) Not subject to production test, specified by design.

2) Device mounted on PCB according EIA/JEDEC standard JESD51-7 (4-layer FR4, 76.2 mm × 114.3 mm with buried planes). PCB is mounted vertical without blown air with 0.78W power dissipation generated in each channel on the DMOS.

*Note: Stresses above the ones listed here may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

*Note: 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.*

### 4.2.1 Transient Thermal Impedance

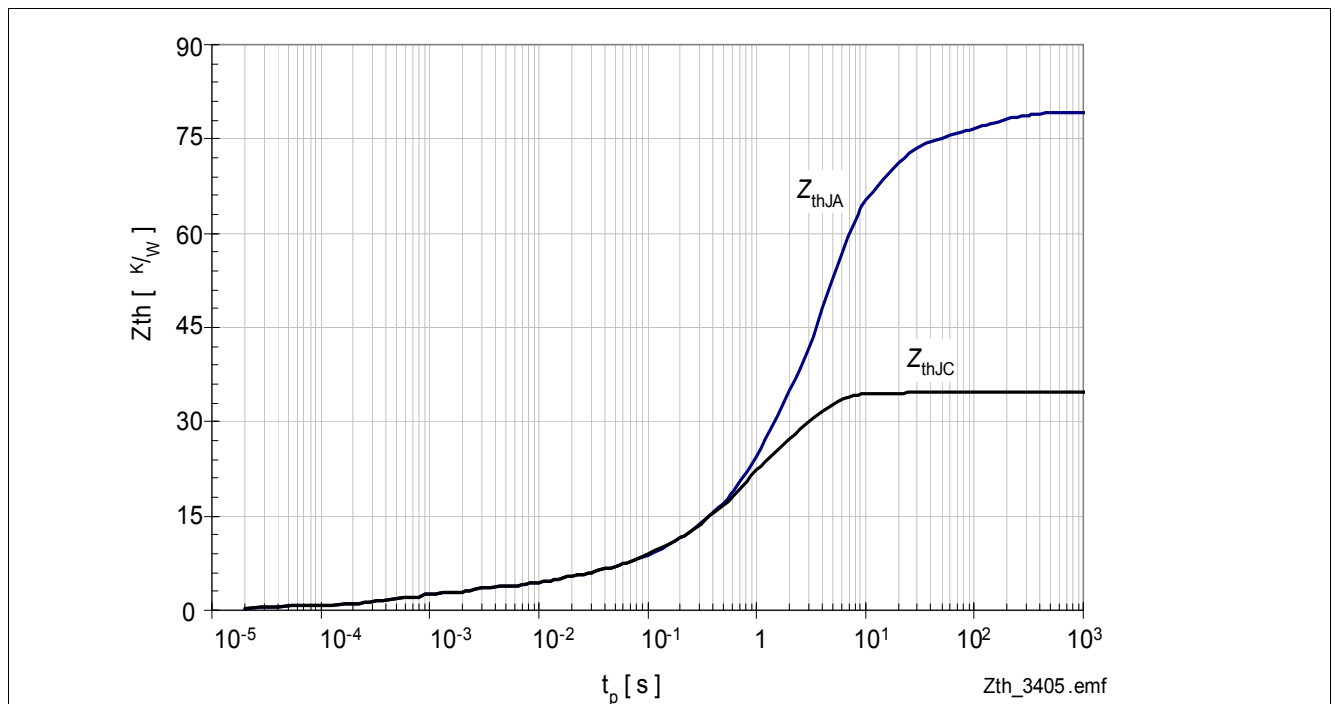
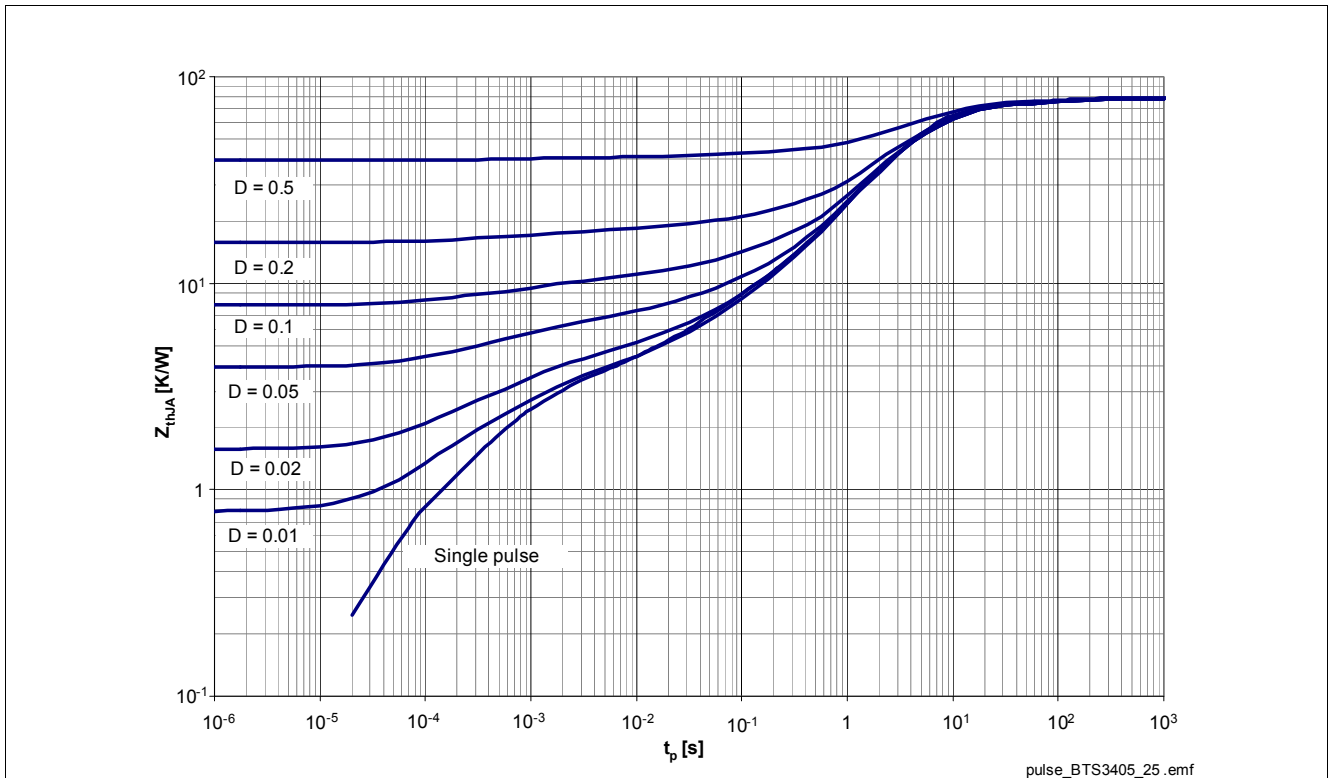


Figure 4 Typical Transient Thermal Impedance single pulse,  $Z_{thJA}$  and  $Z_{thJC}$



**Figure 5 Typical Transient Thermal Impedance  $Z_{thJA}$  with different Duty cycles**

$$Z_{thJA} = f(t_p), D = t_p/T, T_a = 25\text{ °C}$$

Device mounted on PCB according EIA/JEDEC standard JESD51-7 (4-layer FR4, 76.2 mm × 114.3 mm with buried planes). PCB is mounted vertical without blown air with 0.78W power dissipation generated in each channel for single pulse on the DMOS



## 5 Block Description and Characteristics

### 5.1 Input and Power Stage

#### 5.1.1 Input Circuit

Figure 6 shows the input circuit of the BTS3405G. The zener Diode protects the input circuit against ESD pulses. The internal circuitry is supplied by the input PIN. During normal operation the Input is connected to the Gate of the power MOSFET. During fault condition the device tries to sink the current  $I_{INlim}$  in order to give the fault information back to the driving circuit.

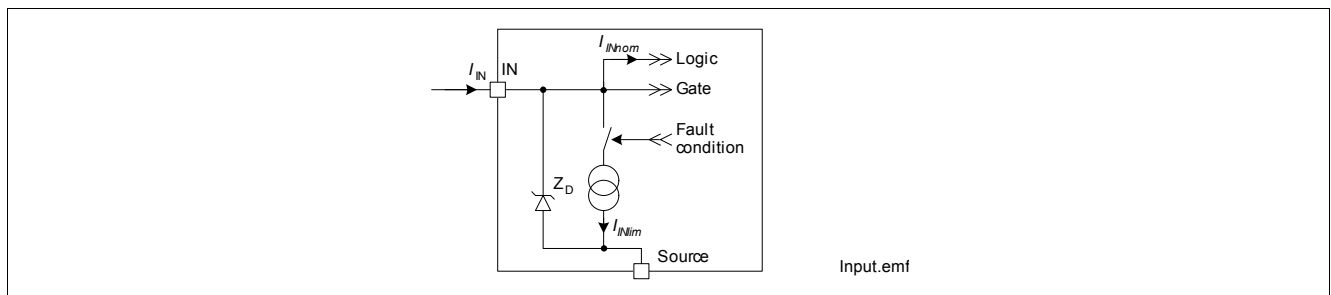


Figure 6 Input Circuit

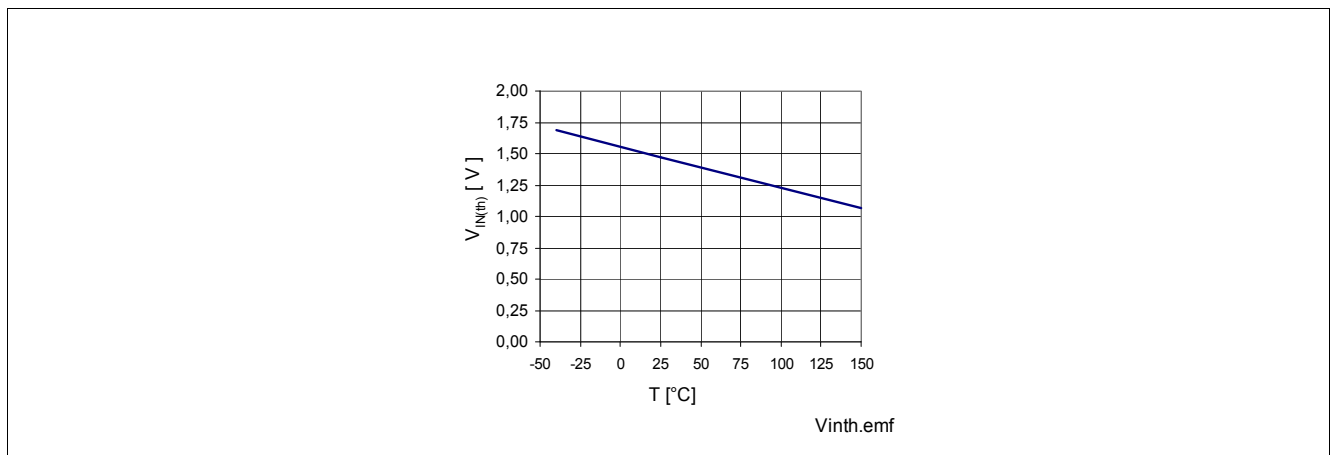


Figure 7 Typical Input Threshold Voltage  $V_{in th} = f(T_J)$ ;  $I_D = 50 \mu A$ ,  $V_D = V_{IN}$

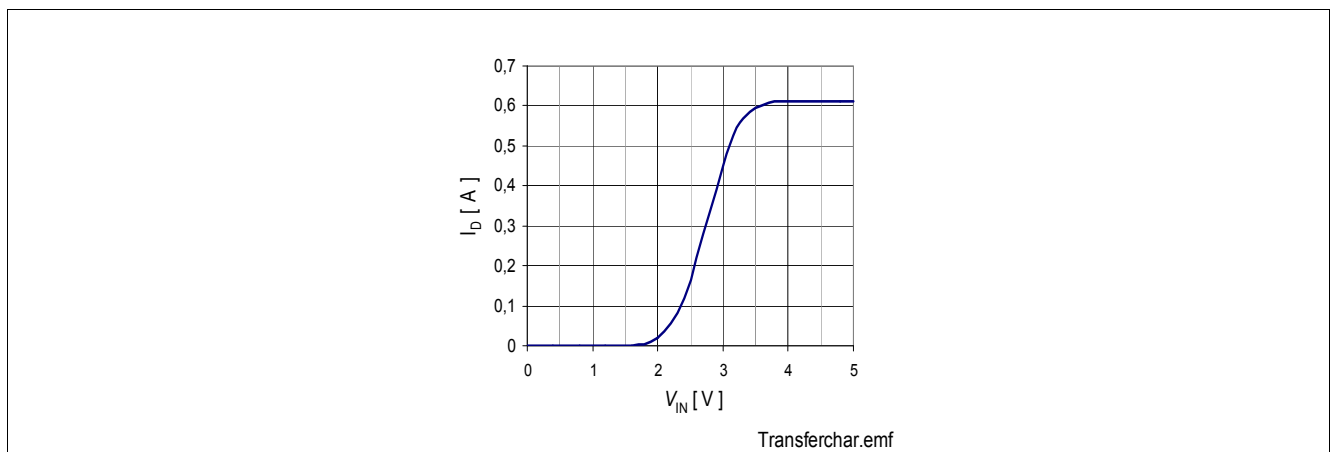


Figure 8 Typical Transfer Characteristic  $I_D = f(V_{IN})$ ;  $V_D = 12 V$ ,  $T_{Jstart} = 25 \text{ }^\circ\text{C}$

### 5.1.2 Failure Feedback

During failure condition the BTS3405G tries to sink a increased input current  $I_{Nlim}$ .

### 5.1.3 Output On-State Resistance

The on-state resistance depends on the junction temperature  $T_J$ . **Figure 9** shows this dependency for the typical on-state resistance  $R_{DS(on)}$ .

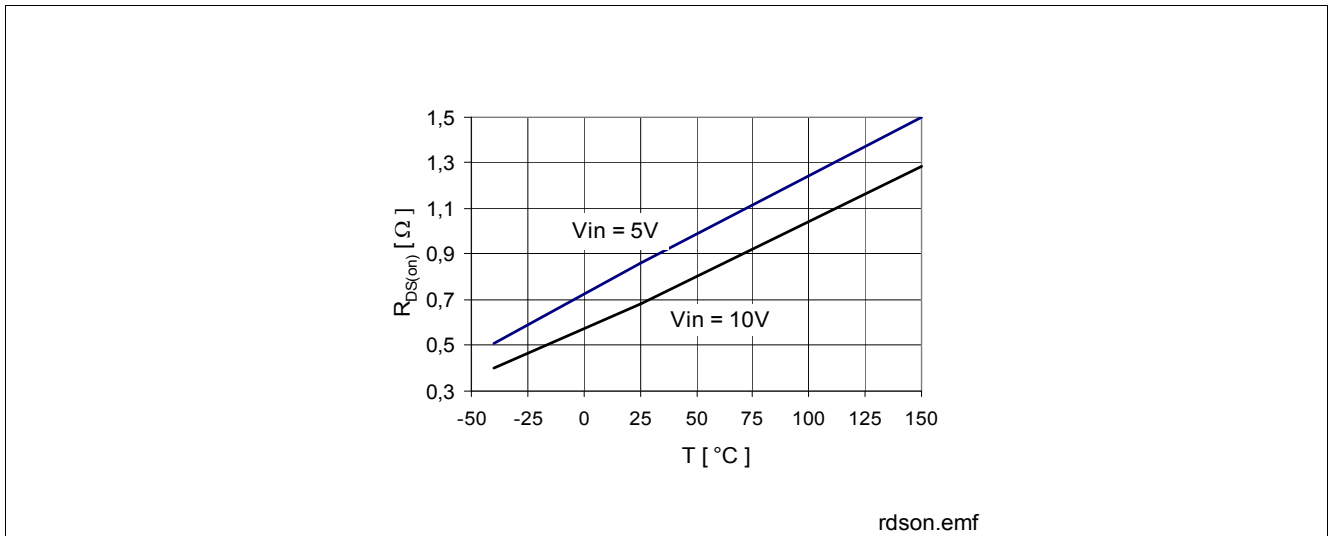


Figure 9 Typical On-State Resistance,  $R_{DS(on)} = f(T_J)$

### 5.1.4 Power Dissipation

The maximum allowed power dissipation in [Figure 10](#) is calculated by  $R_{thJC}$  and  $R_{thJA}$ .

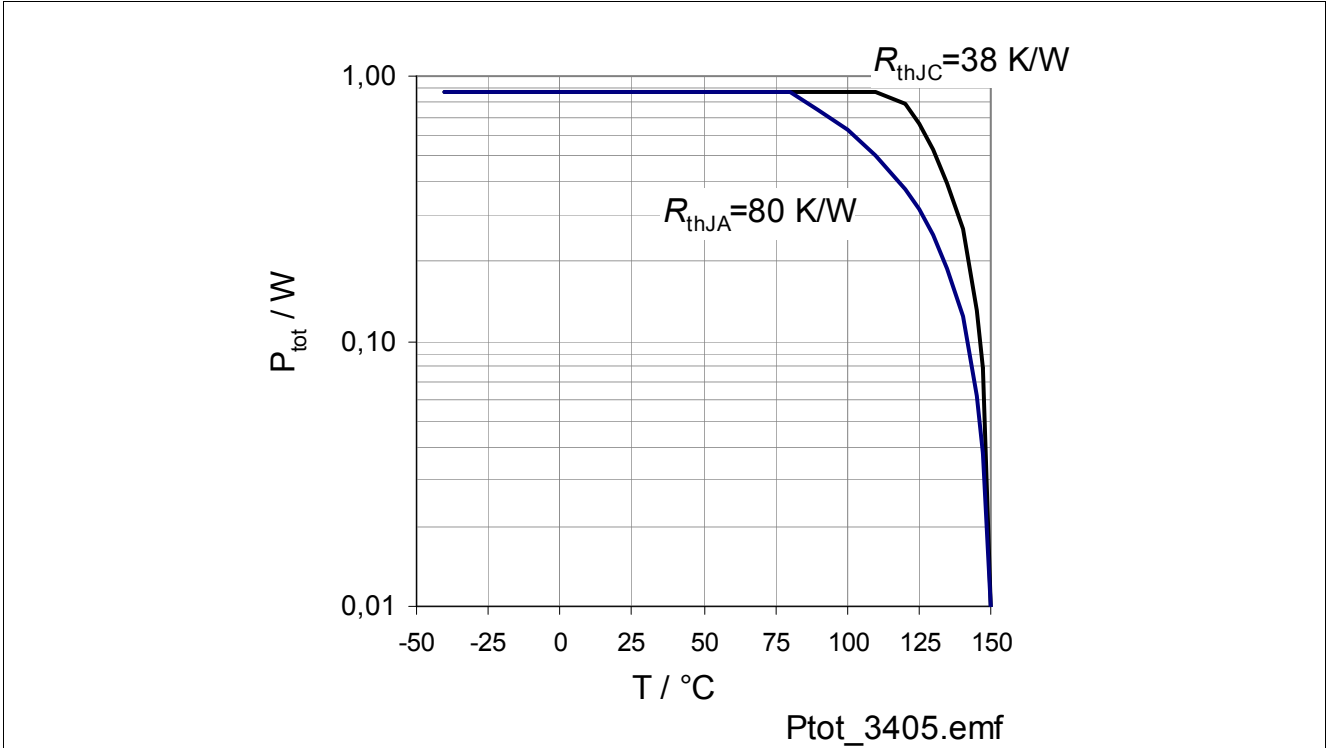


Figure 10 Maximal Allowable Power Dissipation

### 5.1.5 Output Timing

A voltage signal at the input pin above the threshold voltage causes the power MOSFET to switch on with a dedicated slope which is optimized for low EMC emission. [Figure 11](#) shows the timing definition.

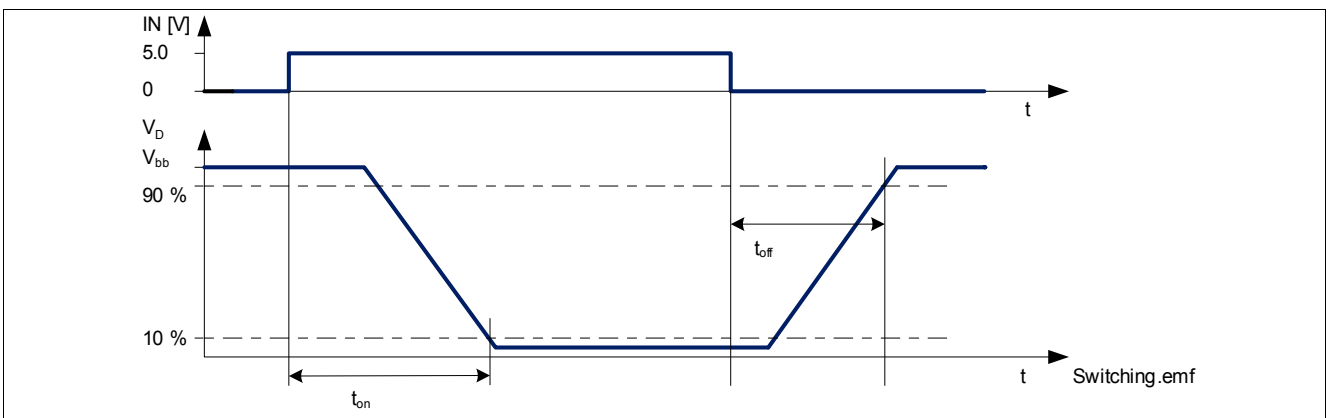


Figure 11 Definition of Power Output Timing for Resistive Load

**Block Description and Characteristics Input and Power Stage**

### 5.1.6 Characteristics

*Note: Characteristics show the deviation of parameter at given input voltage and junction temperature. Typical values show the typical parameters expected from manufacturing.*

*All voltages with respect to Source Pin unless otherwise stated.*

#### Electrical Characteristics: Input and Power Stage

$T_j = -40 \text{ °C to } +150 \text{ °C}$  , all voltages with respect to ground, positive current flowing into pin  
(unless otherwise specified)

Pos.	Parameter	Symbol	Limit Values			Unit	Test Conditions
			Min.	Typ.	Max.		
<b>Input</b>							
5.1.1	Nominal Input current	$I_{INnom}$	–	10	30	$\mu\text{A}$	$V_D = 0 \text{ V};$ $V_{IN} = 10 \text{ V}$
5.1.2	Input current protection mode	$I_{INlim}$	–	100	150	$\mu\text{A}$	$V_{IN} = 10 \text{ V};$ $T_J = 150 \text{ °C}$
5.1.3	Input threshold voltage	$V_{INTH}$	1.3	1.7	2.2	V	$V_D = V_{IN};$ $I_D = 50 \mu\text{A}$ $T_J = 25 \text{ °C}$
5.1.4			0.8	–	–	V	$V_D = V_{IN};$ $I_D = 50 \mu\text{A}, 150 \text{ °C}$
<b>Power Stage</b>							
5.1.5	On-State Resistance	$R_{DS(on)}$	–	0.9	–	$\Omega$	<sup>1)</sup> $T_J = 25 \text{ °C};$ $V_{IN} = 5 \text{ V};$ $I_D = 200\text{mA}$
5.1.6			–	1.8	2.4	$\Omega$	$T_J = 150 \text{ °C};$ $V_{IN} = 5 \text{ V};$ $I_D = 200\text{mA}$
5.1.7			–	0.7	–	$\Omega$	<sup>1)</sup> $T_J = 25 \text{ °C};$ $V_{IN} = 10 \text{ V};$ $I_D = 200\text{mA}$
5.1.8			–	1.4	1.9	$\Omega$	$T_J = 150 \text{ °C};$ $V_{IN} = 10 \text{ V};$ $I_D = 200\text{mA}$
5.1.9	Nominal load current for both channels ON	$I_{Dnom}$	350	400	–	mA	<sup>1)</sup> $T_J < 150 \text{ °C};$ $T_A = 105 \text{ °C}^{2)};$ $V_{IN} = 5 \text{ V}$
5.1.10	Zero input voltage drain current	$I_{DSS}$	–	–	5	$\mu\text{A}$	$V_{DS} = 13.5 \text{ V}; V_{IN} = 0 \text{ V};$ $T_J = 150 \text{ °C}$
			–	2.5	6	$\mu\text{A}$	$V_{DS} = 32 \text{ V}; V_{IN} = 0 \text{ V};$ $T_J = -40 \text{ °C to } 85 \text{ °C}$
			–	4	7	$\mu\text{A}$	$V_{DS} = 32 \text{ V}; V_{IN} = 0 \text{ V};$ $T_J = 150 \text{ °C}$

**Block Description and Characteristics Input and Power Stage**

**Electrical Characteristics: Input and Power Stage (cont'd)**

$T_j = -40 \text{ °C to } +150 \text{ °C}$  , all voltages with respect to ground, positive current flowing into pin  
(unless otherwise specified)

Pos.	Parameter	Symbol	Limit Values			Unit	Test Conditions
			Min.	Typ.	Max.		
<b>Switching</b> $V_{bb} = 12 \text{ V}$ , $R_L = 82 \Omega$							
5.1.11	Turn-on time	$t_{on}$	–	16	38	$\mu\text{s}$	$V_{IN} = 10 \text{ V to } 90\% I_D$
5.1.12	Turn-off time	$t_{off}$	–	15	45	$\mu\text{s}$	$V_{IN} = 0 \text{ V to } 10\% I_D$
5.1.13	Slew rate on	$dV_{ds}/dt_{on}$	–	2.5	9.3	$\text{V}/\mu\text{s}$	50% - 30% $V_{bb}$ ; $R_L = 82 \Omega$ ; $V_{IN} = 0 \text{ V to } 10 \text{ V}$ ; $V_{bb} = 12 \text{ V}$
5.1.14	Slew rate off	$dV_{ds}/dt_{off}$	–	6.0	18.2	$\text{V}/\mu\text{s}$	30% - 50% $V_{bb}$ ; $R_L = 82 \Omega$ ; $V_{IN} = 10 \text{ V to } 0 \text{ V}$ ; $V_{bb} = 12 \text{ V}$
<b>Inverse Diode</b>							
5.1.15	Inverse Diode forward voltage	$V_D$	–	-1.0	-1.5	V	$I_D = -1 \text{ A}$ ; $V_{IN} = 0 \text{ V}$

- 1) Not subject to production test, calculated by  $R_{thJA}$  and  $R_{DS(on)}$ .
- 2) Device mounted on PCB according EIA/JEDEC standard JESD51-7 (4-layer FR4, 76.2 mm × 114.3 mm with buried planes). PCB is mounted vertical without blown air.

## 6 Protection Functions

The device provides embedded protection functions. Integrated protection functions are designed to prevent IC destruction under fault conditions described in the data sheet. Fault conditions are considered as “outside” normal operation.

### 6.1 Thermal Protection

The device is protected against over temperature due to overload and / or bad cooling conditions. To ensure this a temperature sensor located in the Power MOSFET is used.

The BTS3405G has a thermal auto-restart function. After the device has cooled down it will switch on again see [Figure 12](#).

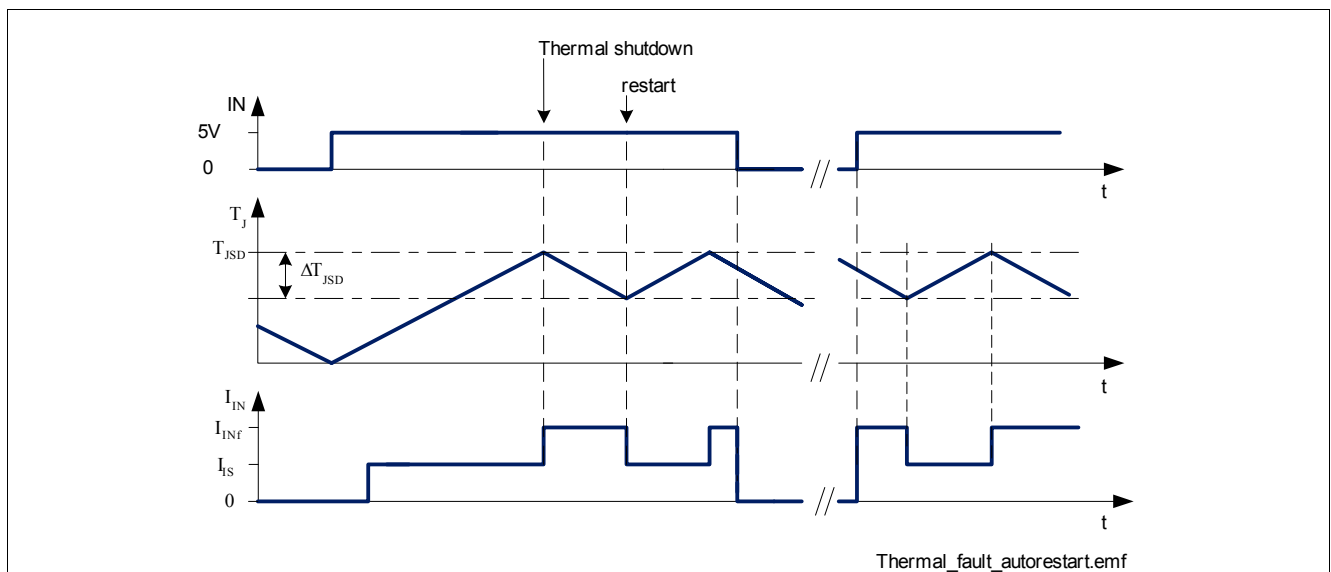


Figure 12 Error Signal via Input Current at Thermal Shutdown

### 6.2 Overvoltage Protection

When switching off inductive loads with low-side switches, the Drain-Source voltage  $V_D$  rises above battery potential, because the inductance intends to continue driving the current.

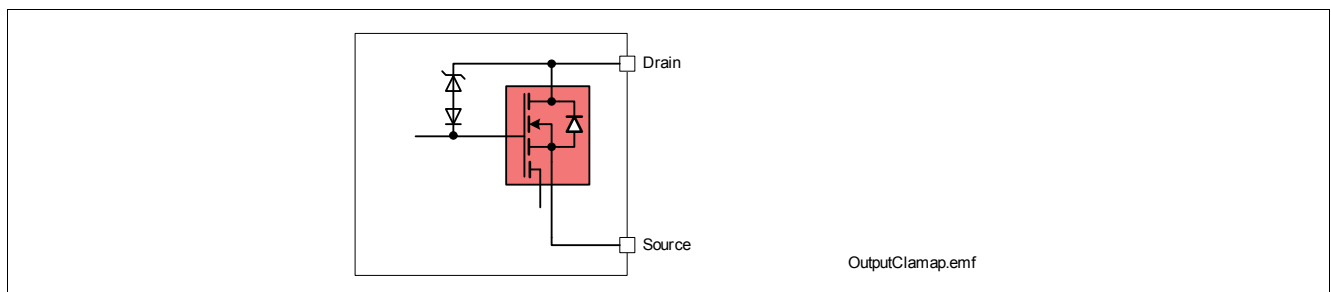
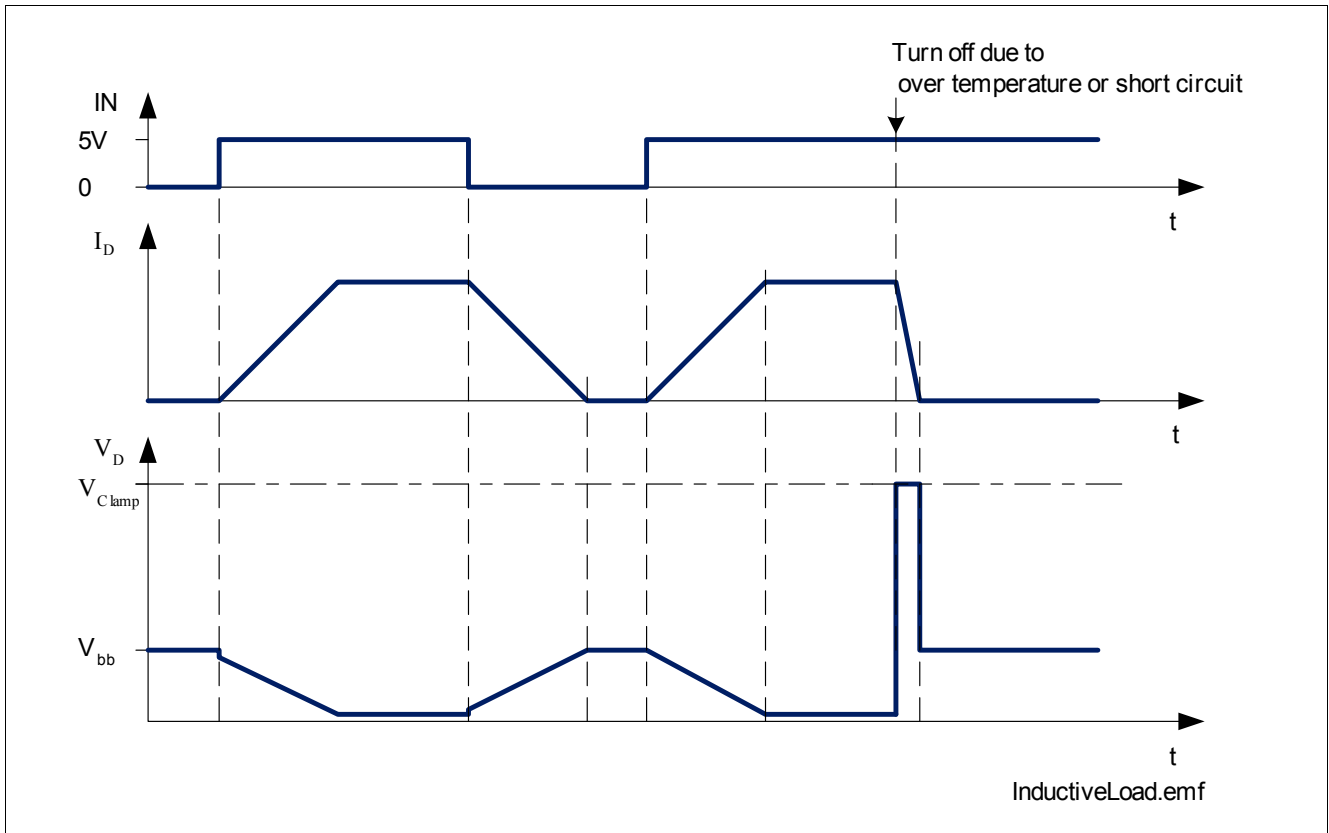


Figure 13 Output Clamp

The BTS3405G is equipped with a voltage clamp mechanism that keeps the Drain-Source voltage  $V_D$  at a certain level. See [Figure 13](#) and [Figure 14](#) for more details.



**Figure 14 Switching an Inductance**

While demagnetization of inductive loads, energy has to be dissipated in the BTS3405G. This energy can be calculated with following equation:

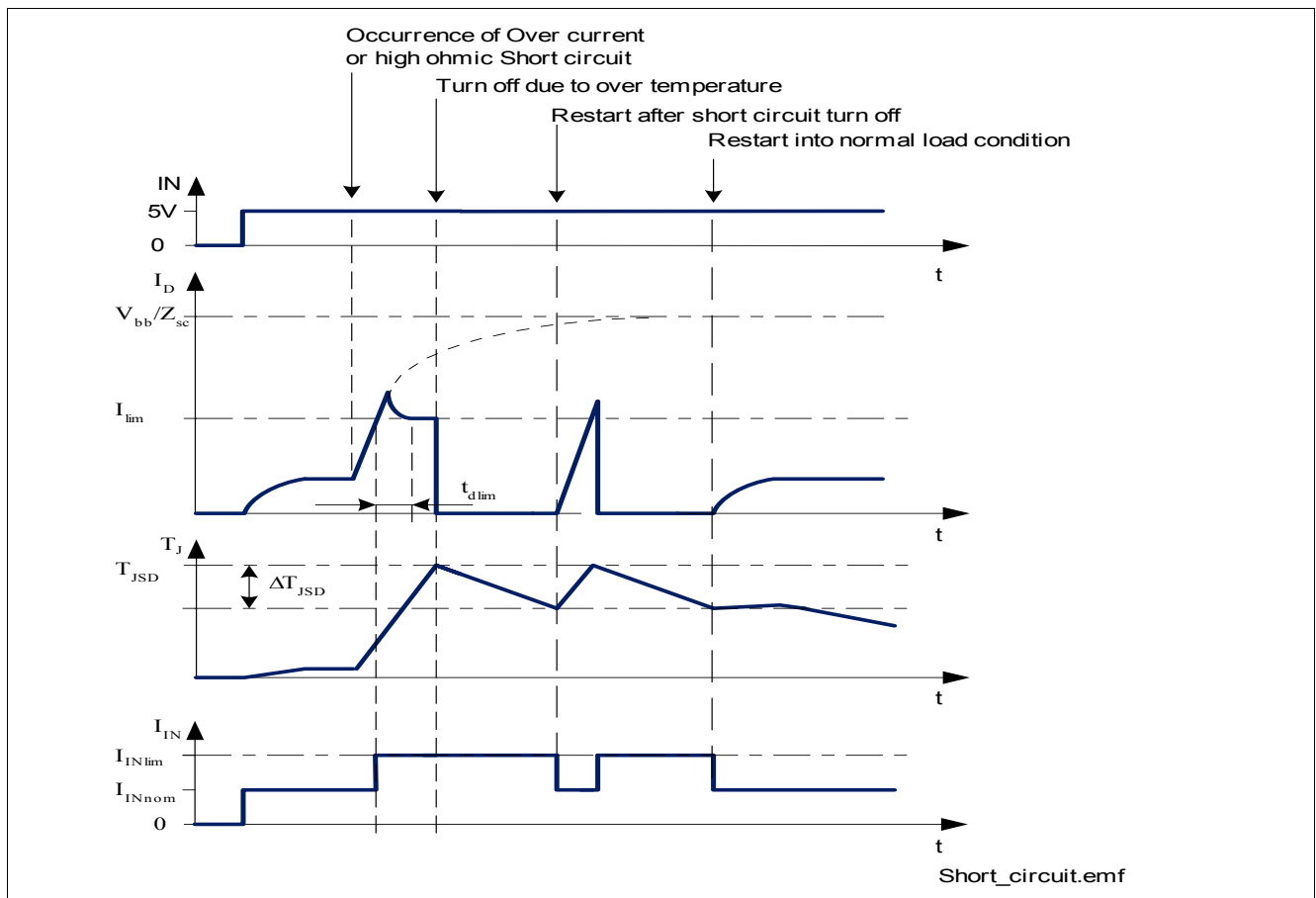
$$E = (V_{bb} + |V_{out(CL)}|) \cdot \left[ \frac{|V_{out(CL)}|}{R_L} \cdot \ln \left( 1 + \frac{R_L \cdot I_L}{|V_{out(CL)}|} \right) + I_L \right] \cdot \frac{L}{R_L} \quad (1)$$

Following equation simplifies under assumption of  $R_L = 0$

$$E = \frac{1}{2} L I_L^2 \cdot \left( 1 + \frac{V_{bb}}{|V_{out(CL)} - V_{bb}|} \right) \quad (2)$$

### 6.3 Short Circuit Protection

The condition short circuit is an overload condition of the device. If the current reaches the value of  $I_{lim}$  the device starts to limit the current. In the condition of current limitation the device heats up. If the thermal shutdown temperature is reached the device turns off. **Figure 15** shows this behavior. During the current limitation the input current is above  $I_{INnom}$ . During the time period  $t_{dlim}$ , the current can be above  $I_{lim}$ .



**Figure 15 Short Circuit Behavior of BTS3405G**

As the device is a low side switch it can be assumed that the Source to Ground path has a neglectable low impedance and resistance. Therefore all impedance and resistance in the load path during short circuit is merged into  $Z_{sc}$ .



## 6.4 Characteristics

Note: Characteristics show the deviation of parameter at given input voltage and junction temperature. Typical values show the typical parameters expected from manufacturing.

### Electrical Characteristics: Protection Functions

$T_j = -40 \text{ °C}$  to  $+150 \text{ °C}$ ; all voltages with respect to ground, positive current flowing into pin (unless otherwise specified), all values valid for both channels

Pos.	Parameter	Symbol	Limit Values			Unit	Test Conditions	
			Min.	Typ.	Max.			
<b>Thermal Protection</b>								
6.4.1	Thermal shut down junction temperature	$T_{\text{JSD}}$	150	175 <sup>1)</sup>	–	°C	–	
6.4.2	Thermal hysteresis	$\Delta T_{\text{JSD}}$	–	10	–	K	<sup>1)</sup>	
<b>Overvoltage Protection</b>								
6.4.3	Drain clamp voltage	$V_{\text{Clamp}}$	42	–	55	V	$V_{\text{IN}} = 0 \text{ V};$ $I_{\text{D}} = 10 \text{ mA};$	
<b>Current Limitation and Short Circuit Protection</b>								
6.4.4	Current limitation	$I_{\text{lim}}$	0.6	0.9	1.2	A	$V_{\text{IN}} = 10 \text{ V}; V_{\text{DS}} = 12 \text{ V};$ $t_{\text{measure}} = 4 \times t_{\text{dlim}}$ $T_{\text{J}} = 25 \text{ °C}$ <sup>1)</sup>	
			0.3	–	–			$T_{\text{J}} = 150 \text{ °C}$
			–	–	1.4			$T_{\text{J}} = -40 \text{ °C}$ <sup>1)</sup>
6.4.5	Current limitation delay time	$t_{\text{dlim}}$	–	–	50	µs	<sup>1)</sup>	

1) Not subject to production test, specified by design.

7 Package Outlines BTS3405G

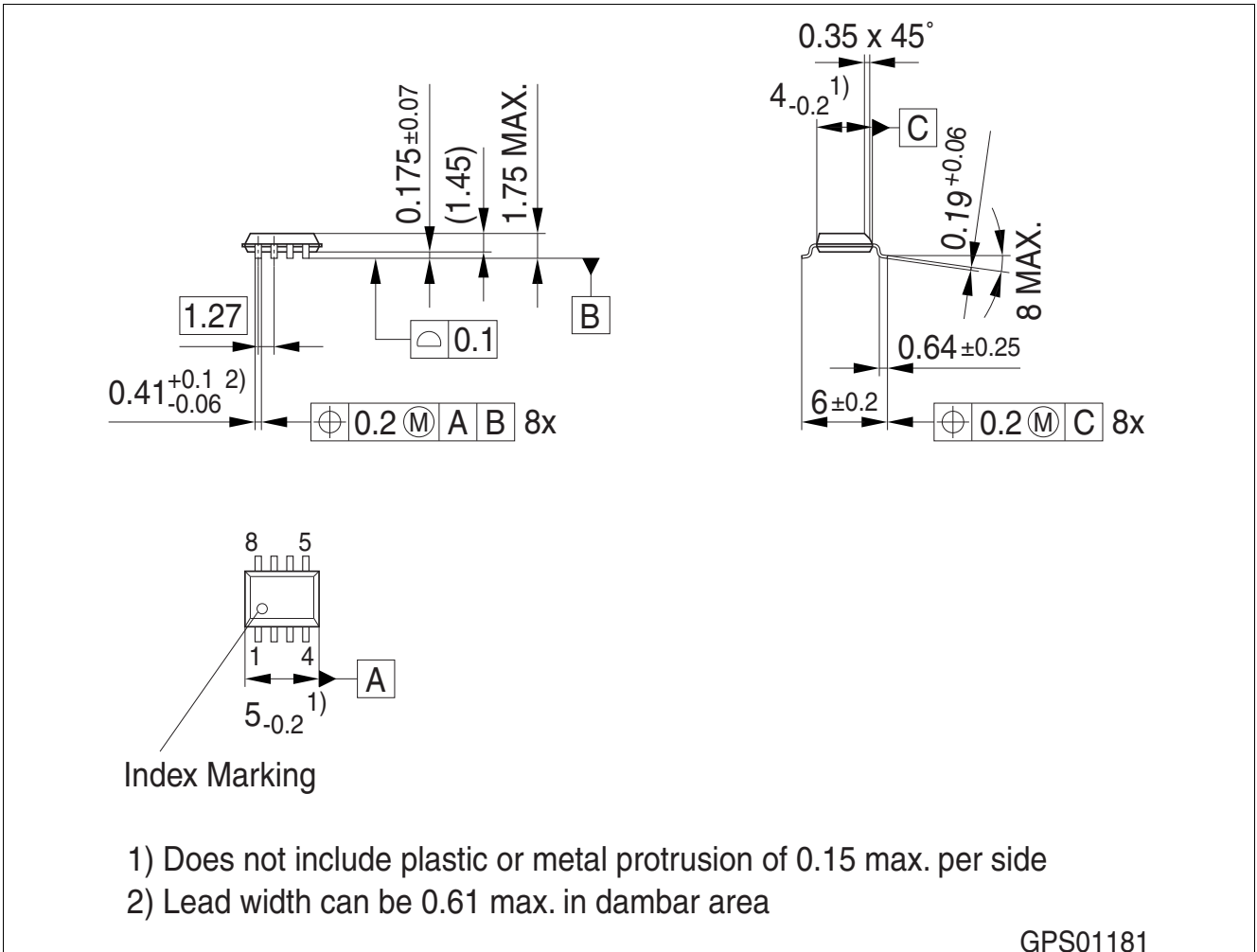


Figure 16 PG-DSO-8-25 (Plastic Dual Small Outline Package)

**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:

Dimensions in mm

## 8 Revision History

Version	Date	Changes
Rev. 1.1	2011-09-01	fixed a typo in EAR test conditions in chapter Max ratings updated Feature list and rephrased Detailed Description fixed a spelling error in 5.1.3 regarding "dependency"
Rev. 1.0	2008-09-25	released data sheet