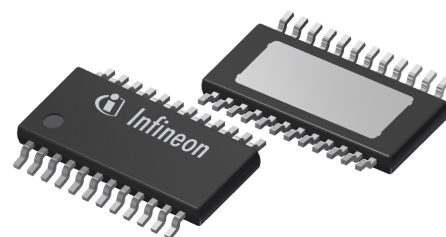


# PROFET™ + 24V

# BTT6200-4ESA

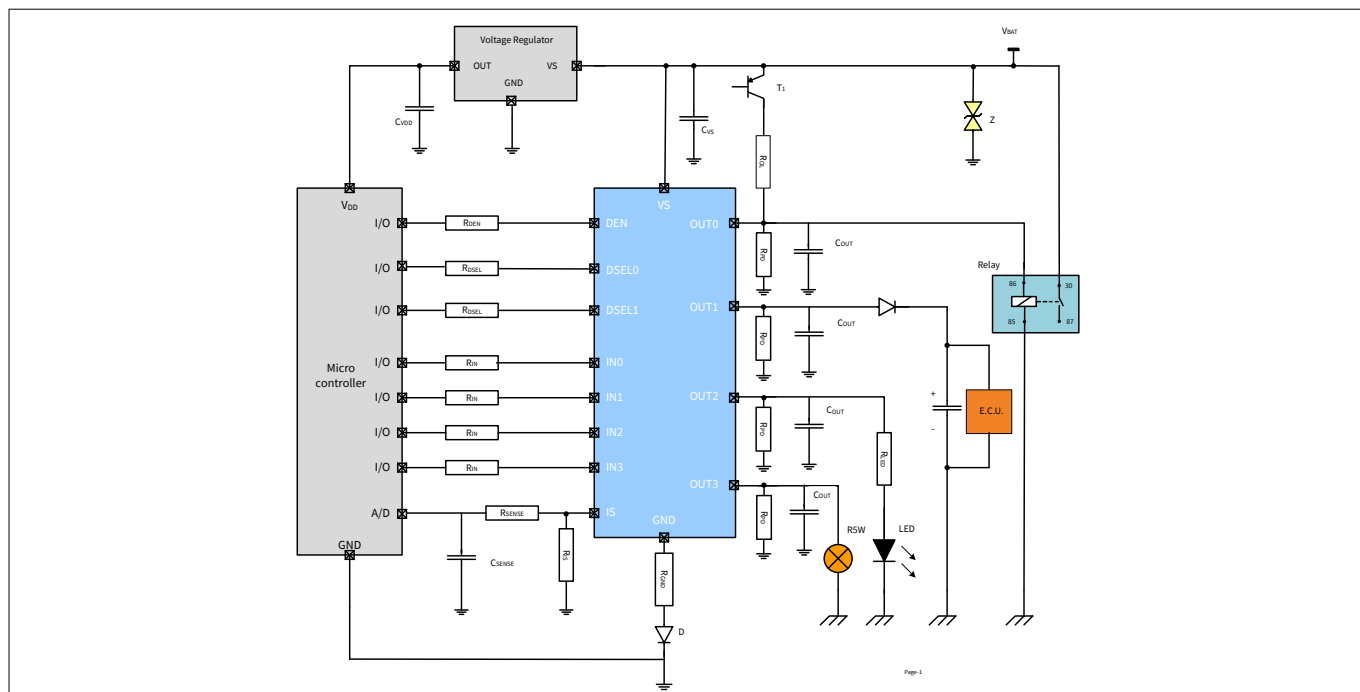
## Feature list

- Quad channel device
- Very low stand-by current
- 3.3 V and 5 V compatible logic inputs
- Electrostatic discharge protection (ESD)
- Optimized electromagnetic compatibility
- Logic ground independent from load ground
- Very low power DMOS leakage current in OFF state
- Green product (RoHS compliant)



## Potential applications

- Suitable for resistive, inductive and capacitive loads
- Replaces electromechanical relays, fuses and discrete circuits
- Most suitable for loads with high inrush current, such as lamps
- Suitable for 12 V and 24 V trucks and transportation systems



### Figure 1 Application Diagram with BTT6200-4ESA

| Product Type | Package     | Marking     |
|--------------|-------------|-------------|
| BTT6200-4ESA | PG-TSDSO-24 | BTT62004ESA |

---

**Product summary**

## Product summary

The BTT6200-4ESA is a 200 mΩ quad channel Smart High-Side Power Switch, embedded in a PG-TSDSO-24 package, providing protective functions and diagnosis.

The power transistor is built by an N-channel vertical power MOSFET with charge pump. The device is integrated in Smart6 HV technology. It is specially designed to drive lamps up to R10 W 24 V or R5 W 12 V, as well as LEDs in the harsh automotive environment.

**Table 1**                      **Product summary**

| Parameter                                                              | Symbol        | Value       |
|------------------------------------------------------------------------|---------------|-------------|
| Operating voltage range                                                | $V_{S(OP)}$   | 5 V to 36 V |
| Maximum supply voltage                                                 | $V_{S(LD)}$   | 65 V        |
| Maximum ON state resistance at $T_J = 150^{\circ}\text{C}$ per channel | $R_{DS(ON)}$  | 400 mΩ      |
| Nominal load current (one channel active)                              | $I_{L(NOM)1}$ | 1.5 A       |
| Nominal load current (all channels active)                             | $I_{L(NOM)2}$ | 1 A         |
| Typical current sense ratio                                            | $k_{ILIS}$    | 300         |
| Minimum current limitation                                             | $I_{L5(SC)}$  | 9 A         |
| Maximum standby current with load at $T_J = 25^{\circ}\text{C}$        | $I_{S(OFF)}$  | 500 nA      |

### Diagnostic functions

- Proportional load current sense multiplexed for the 4 channels
- Open load detection in ON and OFF
- Short circuit to battery and ground indication
- Overtemperature switch off detection
- Stable diagnostic signal during short circuit
- Enhanced  $k_{ILIS}$  dependency with temperature and load current

### Protection functions

- Stable behavior during undervoltage
- Reverse polarity protection with external components
- Secure load turn-off during logic ground disconnection with external components
- Overtemperature protection with latch
- Overvoltage protection with external components
- Enhanced short circuit operation

## Product validation

Qualified for Automotive Applications.

Product validation according to AEC-Q100/101.

## Table of contents

|          |                                                               |    |
|----------|---------------------------------------------------------------|----|
|          | <b>Feature list</b> .....                                     | 1  |
|          | <b>Potential applications</b> .....                           | 1  |
|          | <b>Product summary</b> .....                                  | 2  |
|          | <b>Product validation</b> .....                               | 2  |
|          | <b>Table of contents</b> .....                                | 3  |
| <b>1</b> | <b>Description</b> .....                                      | 5  |
| <b>2</b> | <b>Block diagram reference</b> .....                          | 6  |
| <b>3</b> | <b>Pin configuration</b> .....                                | 7  |
| 3.1      | Pin assignment .....                                          | 7  |
| 3.2      | Pin definitions and functions .....                           | 7  |
| 3.3      | Voltage and current definition .....                          | 8  |
| <b>4</b> | <b>Electrical characteristics and parameters</b> .....        | 9  |
| 4.1      | Absolute maximum ratings .....                                | 9  |
| 4.2      | Functional range .....                                        | 11 |
| 4.3      | Thermal resistance .....                                      | 12 |
| 4.3.1    | PCB set-up .....                                              | 13 |
| 4.3.2    | Thermal impedance .....                                       | 14 |
| <b>5</b> | <b>Power stage</b> .....                                      | 15 |
| 5.1      | Output ON-state resistance .....                              | 15 |
| 5.2      | Turn ON/OFF characteristics with resistive load .....         | 15 |
| 5.3      | Inductive load .....                                          | 16 |
| 5.3.1    | Output clamping .....                                         | 16 |
| 5.3.2    | Maximum load inductance .....                                 | 17 |
| 5.4      | Inverse current capability .....                              | 17 |
| 5.5      | Electrical characteristics - power stage .....                | 18 |
| <b>6</b> | <b>Protection functions</b> .....                             | 20 |
| 6.1      | Loss of ground protection .....                               | 20 |
| 6.2      | Undervoltage protection .....                                 | 20 |
| 6.3      | Overvoltage protection .....                                  | 21 |
| 6.4      | Reverse polarity protection .....                             | 22 |
| 6.5      | Overload protection .....                                     | 23 |
| 6.5.1    | Current limitation .....                                      | 23 |
| 6.5.2    | Temperature limitation in the power DMOS .....                | 23 |
| 6.6      | Electrical characteristics for the protection functions ..... | 25 |
| <b>7</b> | <b>Diagnostic functions</b> .....                             | 26 |
| 7.1      | IS pin .....                                                  | 26 |

## Table of contents

---

|           |                                                                            |    |
|-----------|----------------------------------------------------------------------------|----|
| 7.2       | SENSE signal in different operating modes .....                            | 27 |
| 7.3       | SENSE signal in nominal current range .....                                | 28 |
| 7.3.1     | SENSE signal variation as a function of temperature and load current ..... | 28 |
| 7.3.2     | SENSE signal timing .....                                                  | 30 |
| 7.3.3     | SENSE signal in open load .....                                            | 30 |
| 7.3.3.1   | Open load in ON diagnostic .....                                           | 30 |
| 7.3.3.2   | Open load in OFF diagnostic .....                                          | 31 |
| 7.3.3.3   | Open load diagnostic timing .....                                          | 32 |
| 7.3.4     | SENSE signal in short circuit to $V_S$ .....                               | 33 |
| 7.3.5     | SENSE signal in case of overload .....                                     | 34 |
| 7.3.6     | SENSE signal in case of inverse current .....                              | 34 |
| 7.4       | Electrical characteristics diagnostic function .....                       | 35 |
| <b>8</b>  | <b>Input pins</b> .....                                                    | 39 |
| 8.1       | Input circuitry .....                                                      | 39 |
| 8.2       | DEN / DSEL0, 1 pin .....                                                   | 39 |
| 8.3       | Input pin voltage .....                                                    | 39 |
| 8.4       | Electrical characteristics .....                                           | 39 |
| <b>9</b>  | <b>Characterization results</b> .....                                      | 41 |
| 9.1       | General product characteristics .....                                      | 41 |
| 9.2       | Power stage .....                                                          | 42 |
| 9.3       | Protection functions .....                                                 | 44 |
| 9.4       | Diagnostic mechanism .....                                                 | 45 |
| 9.5       | Input pins .....                                                           | 46 |
| <b>10</b> | <b>Application information</b> .....                                       | 47 |
| 10.1      | Further application information .....                                      | 48 |
| <b>11</b> | <b>Package outlines</b> .....                                              | 49 |
|           | <b>Revision history</b> .....                                              | 50 |
|           | <b>Disclaimer</b> .....                                                    | 51 |

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## Description

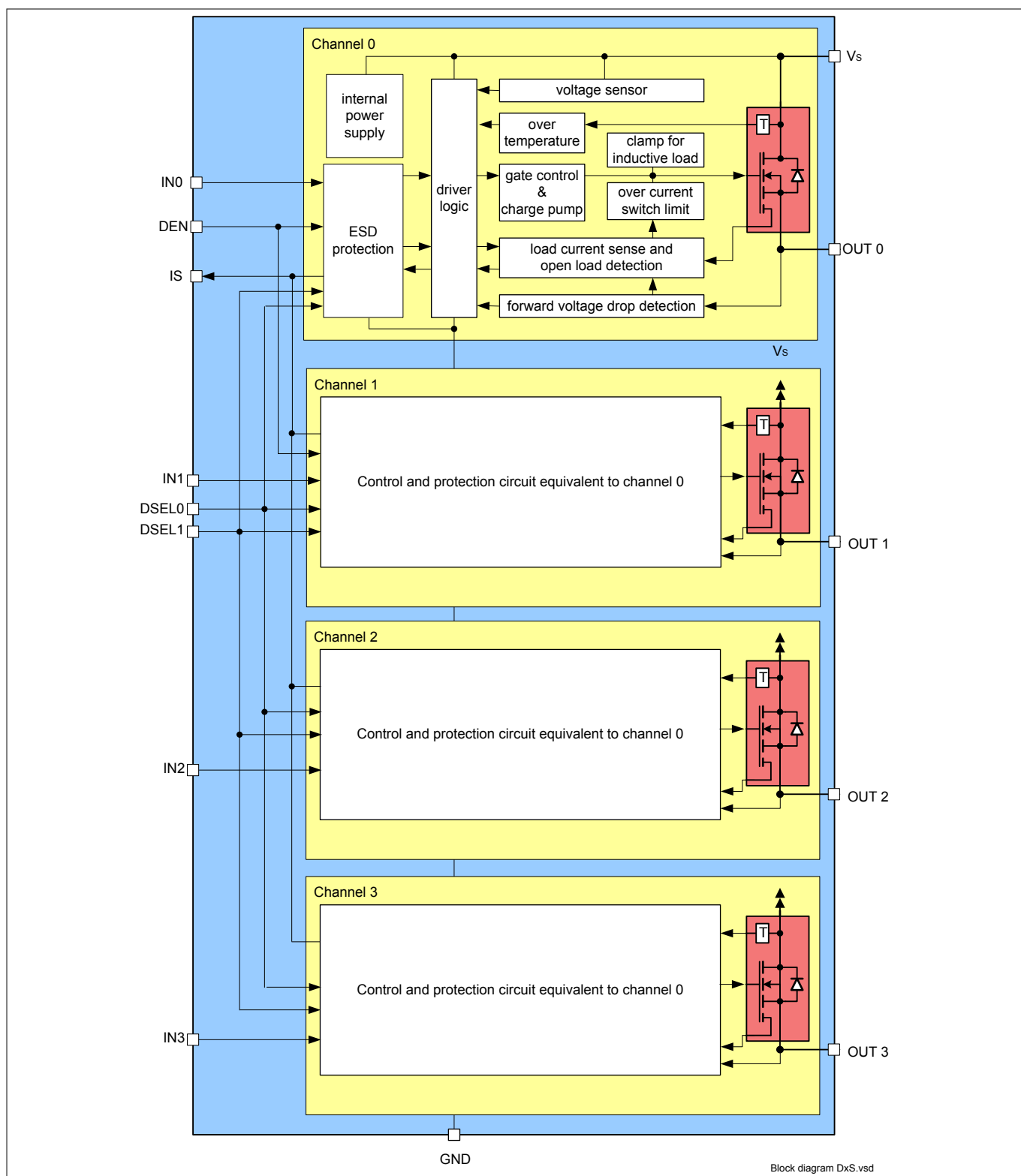
### **1 Description**

The BTT6200-4ESA is a 200 mΩ quad channel Smart High-Side Power Switch, embedded in a PG-TSDSO-24 package, providing protective functions and diagnosis.

The power transistor is built by an N-channel vertical power MOSFET with charge pump. The device is integrated in Smart6 HV technology. It is specially designed to drive lamps up to R10 W 24 V or R5 W 12 V, as well as LEDs in the harsh automotive environment.

**Block diagram reference**

## 2 Block diagram reference

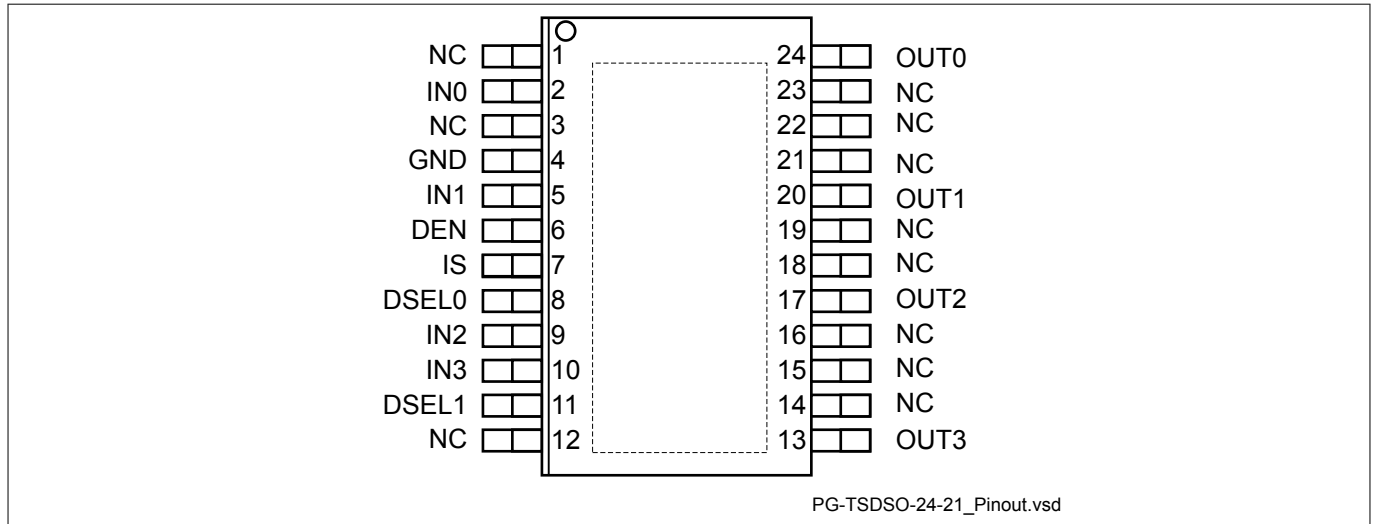


**Figure 2** **Block diagram for BTT6200-4ESA**

## Pin configuration

### 3 Pin configuration

#### 3.1 Pin assignment



**Figure 3** Pin configuration

#### 3.2 Pin definitions and functions

**Table 2** Pin definitions and functions

| Pin                                      | Symbol | Function                                                                        |
|------------------------------------------|--------|---------------------------------------------------------------------------------|
| 1, 3, 12, 14, 15, 16, 18, 19, 21, 22, 23 | NC     | Not Connected; No internal connection to the chip                               |
| 2                                        | IN0    | INput channel 0; Input signal for channel 0 activation                          |
| 4                                        | GND    | GrouND; Ground connection                                                       |
| 5                                        | IN1    | INput channel 1; Input signal for channel 1 activation                          |
| 6                                        | DEN    | Diagnostic ENable; Digital signal to enable/disable the diagnosis of the device |
| 7                                        | IS     | Sense; Sense current of the selected channel                                    |
| 8                                        | DSEL0  | Diagnostic SElection; Digital signal to select the channel to be diagnosed      |
| 9                                        | IN2    | INput channel 2; Input signal for channel 2 activation                          |
| 10                                       | IN3    | INput channel 3; Input signal for channel 3 activation                          |
| 11                                       | DSEL1  | Diagnostic SElection; Digital signal to select the channel to be diagnosed      |
| 13                                       | OUT3   | OUTput 3; Protected high side power output channel 3                            |
| 17                                       | OUT2   | OUTput 2; Protected high side power output channel 2                            |
| 20                                       | OUT1   | OUTput 1; Protected high side power output channel 1                            |

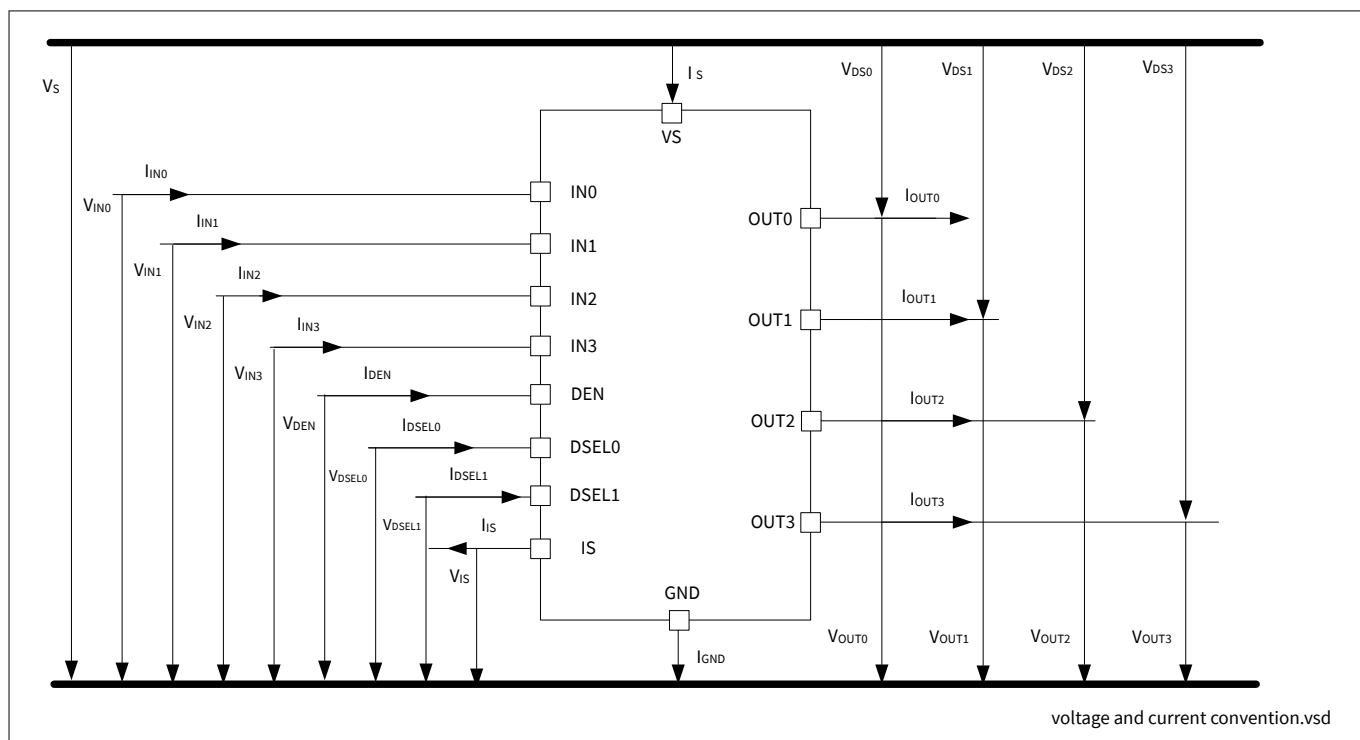
## Pin configuration

**Table 2** Pin definitions and functions (continued)

| Pin         | Symbol | Function                                             |
|-------------|--------|------------------------------------------------------|
| 24          | OUT0   | OUTput 0; Protected high side power output channel 0 |
| Cooling tab | VS     | Voltage Supply; Battery voltage                      |

## 3.3 Voltage and current definition

**Figure 4** shows all terms used in this data sheet, with associated convention for positive values.



**Figure 4** Voltage and current definition



## Electrical characteristics and parameters

### 4 Electrical characteristics and parameters

#### 4.1 Absolute maximum ratings

**Table 3** Absolute maximum ratings<sup>1)</sup>

$T_J = -40^{\circ}\text{C}$  to  $150^{\circ}\text{C}$ ; (unless otherwise specified)

| Parameter                                   | Symbol               | Values    |      |        | Unit     | Note or Test Condition                                                                                                                                                                                                                                                                                        | Number   |
|---------------------------------------------|----------------------|-----------|------|--------|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
|                                             |                      | Min.      | Typ. | Max.   |          |                                                                                                                                                                                                                                                                                                               |          |
| Supply voltages                             |                      |           |      |        |          |                                                                                                                                                                                                                                                                                                               |          |
| Supply voltage                              | $V_S$                | -0.3      | –    | 48     | V        | –                                                                                                                                                                                                                                                                                                             | P_4.1.1  |
| Reverse polarity voltage                    | $-V_{S(\text{REV})}$ | 0         | –    | 28     | V        | $t < 2 \text{ min}$<br>$T_A = 25^{\circ}\text{C}$<br>$R_L \geq 47 \Omega$<br>$Z_{\text{GND}} = \text{Diode} + 27 \Omega$                                                                                                                                                                                      | P_4.1.2  |
| Supply voltage for short circuit protection | $V_{\text{BAT(SC)}}$ | 0         | –    | 36     | V        | $R_{\text{Supply}} = 10 \text{ m}\Omega$<br>$L_{\text{Supply}} = 5 \mu\text{H}$<br>$R_{\text{ECU}} = 20 \text{ m}\Omega$<br>$R_{\text{Cable}} = 16 \text{ m}\Omega/\text{m}$<br>$L_{\text{Cable}} = 1 \mu\text{H}/\text{m}$ ,<br>$l = 0 \text{ or } 5 \text{ m}$<br>See <b>Chapter 6</b> and <b>Figure 29</b> | P_4.1.3  |
| Supply voltage for Load dump protection     | $V_{S(\text{LD})}$   | –         | –    | 65     | V        | <sup>2)</sup> $R_I = 2 \Omega$<br>$R_L = 47 \Omega$                                                                                                                                                                                                                                                           | P_4.1.12 |
| Short circuit capability                    |                      |           |      |        |          |                                                                                                                                                                                                                                                                                                               |          |
| Permanent short circuit IN pin toggles      | $n_{\text{RSC1}}$    | –         | –    | 100    | k cycles | <sup>3)</sup> –                                                                                                                                                                                                                                                                                               | P_4.1.4  |
| Input pins                                  |                      |           |      |        |          |                                                                                                                                                                                                                                                                                                               |          |
| Voltage at INPUT pins                       | $V_{\text{IN}}$      | -0.3<br>– | –    | 6<br>7 | V        | –<br>$t < 2 \text{ min}$                                                                                                                                                                                                                                                                                      | P_4.1.13 |
| Current through INPUT pins                  | $I_{\text{IN}}$      | -2        | –    | 2      | mA       | –                                                                                                                                                                                                                                                                                                             | P_4.1.14 |
| Voltage at DEN pin                          | $V_{\text{DEN}}$     | -0.3<br>– | –    | 6<br>7 | V        | –<br>$t < 2 \text{ min}$                                                                                                                                                                                                                                                                                      | P_4.1.15 |
| Current through DEN pin                     | $I_{\text{DEN}}$     | -2        | –    | 2      | mA       | –                                                                                                                                                                                                                                                                                                             | P_4.1.16 |

<sup>1)</sup> Not subject to production test. Specified by design.

<sup>2)</sup>  $V_{S(\text{LD})}$  is setup without the DUT connected to the generator per ISO 7637-1.

<sup>3)</sup> Threshold limit for short circuit failures: 100 ppm. Please refer to the legal disclaimer for short-circuit capability at the end of this document.

## Electrical characteristics and parameters

**Table 3** Absolute maximum ratings<sup>1)</sup> (continued)

$T_J = -40^{\circ}\text{C}$  to  $150^{\circ}\text{C}$ ; (unless otherwise specified)

| Parameter                | Symbol            | Values    |      |        | Unit | Note or Test Condition   | Number   |
|--------------------------|-------------------|-----------|------|--------|------|--------------------------|----------|
|                          |                   | Min.      | Typ. | Max.   |      |                          |          |
| Voltage at DSEL pin      | $V_{\text{DSEL}}$ | -0.3<br>– | –    | 6<br>7 | V    | –<br>$t < 2 \text{ min}$ | P_4.1.17 |
| Current through DSEL pin | $I_{\text{DSEL}}$ | -2        | –    | 2      | mA   | –                        | P_4.1.18 |

### Sense pin

|                        |                 |      |   |       |    |   |          |
|------------------------|-----------------|------|---|-------|----|---|----------|
| Voltage at IS pin      | $V_{\text{IS}}$ | -0.3 | – | $V_S$ | V  | – | P_4.1.19 |
| Current through IS pin | $I_{\text{IS}}$ | -25  | – | 50    | mA | – | P_4.1.20 |

### Power stage

|                                                          |                  |   |   |                     |    |                                                                                                    |          |
|----------------------------------------------------------|------------------|---|---|---------------------|----|----------------------------------------------------------------------------------------------------|----------|
| Load current                                             | $ I_L $          | – | – | $I_{\text{L(LIM)}}$ | A  | –                                                                                                  | P_4.1.21 |
| Power dissipation (DC)                                   | $P_{\text{TOT}}$ | – | – | 1.8                 | W  | $T_A = 85^{\circ}\text{C}$<br>$T_J < 150^{\circ}\text{C}$                                          | P_4.1.22 |
| Maximum energy dissipation<br>Single pulse (one channel) | $E_{\text{AS}}$  | – | – | 20                  | mJ | $I_{\text{L(0)}} = 1 \text{ A}$<br>$T_{\text{J(0)}} = 150^{\circ}\text{C}$<br>$V_S = 28 \text{ V}$ | P_4.1.23 |
| Voltage at power transistor                              | $V_{\text{DS}}$  | – | – | 65                  | V  | –                                                                                                  | P_4.1.26 |

### Currents

|                            |                  |             |   |          |    |                          |          |
|----------------------------|------------------|-------------|---|----------|----|--------------------------|----------|
| Current through ground pin | $I_{\text{GND}}$ | -20<br>-150 | – | 20<br>20 | mA | –<br>$t < 2 \text{ min}$ | P_4.1.27 |
|----------------------------|------------------|-------------|---|----------|----|--------------------------|----------|

### Temperatures

|                      |                  |     |   |     |                    |   |          |
|----------------------|------------------|-----|---|-----|--------------------|---|----------|
| Junction temperature | $T_J$            | -40 | – | 150 | $^{\circ}\text{C}$ | – | P_4.1.28 |
| Storage temperature  | $T_{\text{STG}}$ | -55 | – | 150 | $^{\circ}\text{C}$ | – | P_4.1.30 |

### ESD susceptibility

|                                                           |                  |      |   |     |    |                   |          |
|-----------------------------------------------------------|------------------|------|---|-----|----|-------------------|----------|
| ESD susceptibility (all pins)                             | $V_{\text{ESD}}$ | -2   | – | 2   | kV | <sup>4)</sup> HBM | P_4.1.31 |
| ESD susceptibility OUT pin vs.<br>GND and $V_S$ connected | $V_{\text{ESD}}$ | -4   | – | 4   | kV | <sup>4)</sup> HBM | P_4.1.32 |
| ESD susceptibility                                        | $V_{\text{ESD}}$ | -500 | – | 500 | V  | <sup>5)</sup> CDM | P_4.1.33 |
| ESD susceptibility pin<br>(corner pins)                   | $V_{\text{ESD}}$ | -750 | – | 750 | V  | <sup>5)</sup> CDM | P_4.1.34 |

### Notes:

1. 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.

<sup>1</sup> Not subject to production test. Specified by design.

<sup>4</sup> ESD susceptibility Human Body Model "HBM" according to AEC Q100-002

<sup>5</sup> ESD susceptibility Charged Device Model "CDM" according to AEC Q100-011

## Electrical characteristics and parameters

2. 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 Functional range

**Table 4 Functional range**

$T_J = -40^{\circ}\text{C}$  to  $150^{\circ}\text{C}$ ; (unless otherwise specified)

| Parameter                               | Symbol                 | Values |      |      | Unit | Note or Test Condition                                                                                                                                                                                                                                | Number   |
|-----------------------------------------|------------------------|--------|------|------|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
|                                         |                        | Min.   | Typ. | Max. |      |                                                                                                                                                                                                                                                       |          |
| Nominal operating voltage               | $V_{\text{NOM}}$       | 8      | 28   | 36   | V    | –                                                                                                                                                                                                                                                     | P_4.2.1  |
| Extended operating voltage              | $V_{\text{S(OP)}}$     | 5      | –    | 48   | V    | <sup>7)</sup> $V_{\text{IN}} = 4.5 \text{ V}$<br>$R_L = 47 \Omega$<br>$V_{\text{DS}} < 0.5 \text{ V}$                                                                                                                                                 | P_4.2.2  |
| Minimum functional supply voltage       | $V_{\text{S(OP)_MIN}}$ | 3.8    | 4.3  | 5    | V    | <sup>6)</sup> $V_{\text{IN}} = 4.5 \text{ V}$<br>$R_L = 47 \Omega$<br>From $I_{\text{OUT}} = 0 \text{ A}$ to<br>$V_{\text{DS}} < 0.5 \text{ V}$ ; see<br><a href="#">Figure 16</a>                                                                    | P_4.2.3  |
| Undervoltage shutdown                   | $V_{\text{S(UV)}}$     | 3      | 3.5  | 4.1  | V    | <sup>6)</sup> $V_{\text{IN}} = 4.5 \text{ V}$<br>$V_{\text{DEN}} = 0 \text{ V}$<br>$R_L = 47 \Omega$<br>From $V_{\text{DS}} < 1 \text{ V}$ ;<br>to $I_{\text{OUT}} = 0 \text{ A}$<br>See <a href="#">Chapter 9.1</a><br>and <a href="#">Figure 16</a> | P_4.2.4  |
| Undervoltage shutdown hysteresis        | $V_{\text{S(UV)_HYS}}$ | –      | 850  | –    | mV   | <sup>7)</sup> –                                                                                                                                                                                                                                       | P_4.2.13 |
| Operating current<br>One channel active | $I_{\text{GND}_1}$     | –      | 2    | 4    | mA   | $V_{\text{IN}} = 5.5 \text{ V}$<br>$V_{\text{DEN}} = 5.5 \text{ V}$<br>Device in $R_{\text{DS(ON)}}$<br>$V_S = 36 \text{ V}$<br>See <a href="#">Chapter 9.1</a>                                                                                       | P_4.2.5  |

<sup>7</sup> Not subject to production test. Specified by design.

<sup>6</sup> Test at  $T_J = -40^{\circ}\text{C}$  only.

## Electrical characteristics and parameters

**Table 4**      **Functional range (continued)**

$T_J = -40^\circ\text{C}$  to  $150^\circ\text{C}$ ; (unless otherwise specified)

| Parameter                                                     | Symbol                    | Values |      |      | Unit          | Note or Test Condition                                                                                                                                       | Number   |
|---------------------------------------------------------------|---------------------------|--------|------|------|---------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
|                                                               |                           | Min.   | Typ. | Max. |               |                                                                                                                                                              |          |
| Operating current<br>All channels active                      | $I_{\text{GND}_4}$        | –      | 6    | 9    | mA            | $V_{\text{IN}} = 5.5\text{ V}$<br>$V_{\text{DEN}} = 5.5\text{ V}$<br>Device in $R_{\text{DS(ON)}}$<br>$V_S = 36\text{ V}$<br>See <a href="#">Chapter 9.1</a> | P_4.2.6  |
| Standby current for whole device with load (ambient)          | $I_{\text{S(OFF)}}$       | –      | 0.1  | 0.5  | $\mu\text{A}$ | <sup>6)</sup> $V_S = 36\text{ V}$<br>$V_{\text{OUT}} = 0\text{ V}$<br>$V_{\text{IN}}$ floating<br>$V_{\text{DEN}}$ floating<br>$T_J \leq 85^\circ\text{C}$   | P_4.2.7  |
| Maximum standby current for whole device with load            | $I_{\text{S(OFF)}_{150}}$ | –      | –    | 20   | $\mu\text{A}$ | $V_S = 36\text{ V}$<br>$V_{\text{OUT}} = 0\text{ V}$<br>$V_{\text{IN}}$ floating<br>$V_{\text{DEN}}$ floating<br>$T_J = 150^\circ\text{C}$                   | P_4.2.10 |
| Standby current for whole device with load, diagnostic active | $I_{\text{S(OFF\_DEN)}}$  | –      | 0.6  | –    | mA            | <sup>7)</sup> $V_S = 36\text{ V}$<br>$V_{\text{OUT}} = 0\text{ V}$<br>$V_{\text{IN}}$ floating<br>$V_{\text{DEN}} = 5.5\text{ V}$                            | P_4.2.8  |

*Note:*      Within the functional range the IC operates as described in the circuit description. The electrical characteristics are specified within the conditions given in the related electrical characteristics table.

## 4.3 Thermal resistance

**Table 5**      **Thermal resistance**

| Parameter                                  | Symbol            | Values |      |      | Unit | Note or Test Condition | Number  |
|--------------------------------------------|-------------------|--------|------|------|------|------------------------|---------|
|                                            |                   | Min.   | Typ. | Max. |      |                        |         |
| Junction to case                           | $R_{\text{thJC}}$ | –      | 3    | –    | K/W  | <sup>8)</sup>          | P_4.3.1 |
| Junction to ambient<br>All channels active | $R_{\text{thJA}}$ | –      | 28   | –    | K/W  | <sup>8)9)</sup>        | P_4.3.2 |

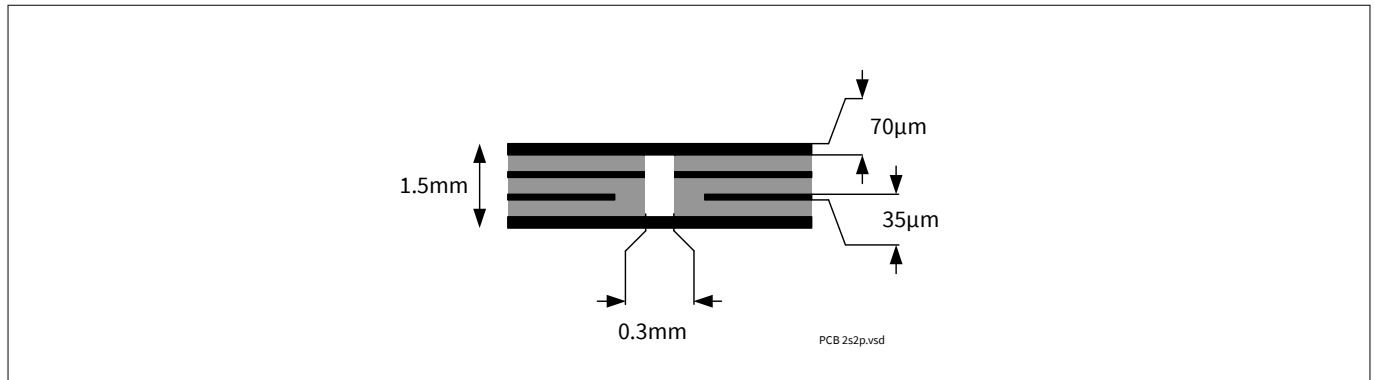
<sup>6</sup> Test at  $T_J = -40^\circ\text{C}$  only.

<sup>7</sup> Not subject to production test. Specified by design.

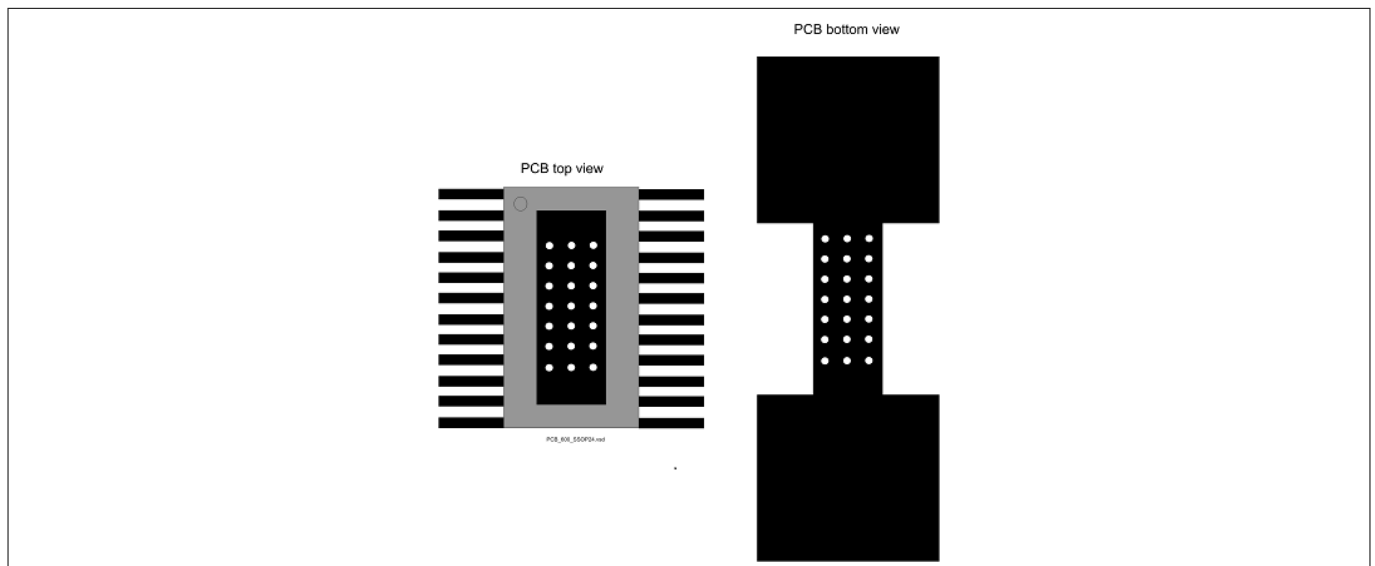
<sup>8</sup> Not subject to production test. Specified by design.

## Electrical characteristics and parameters

### 4.3.1 PCB set-up



**Figure 5** 2s2p PCB cross section



**Figure 6** PC board top and bottom view for thermal simulation with 600 mm<sup>2</sup> cooling area

<sup>9</sup> Specified  $R_{thja}$  value is according to JEDEC JESD51-2,-5,-7 at natural convection on FR4 2s2p board with 1 W power dissipation equally dissipated for all channel at  $T_A = 105^\circ\text{C}$ ; The product (chip + package) was simulated on a 76.4 mm x 114.3 mm x 1.5 mm board with 2 inner copper layers (2 x 70 µm Cu, 2 x 35 µm Cu). Where applicable, a thermal via array under the exposed pad contacts the first inner copper layer. Please refer to [Figure 5](#).

## Electrical characteristics and parameters

### 4.3.2 Thermal impedance

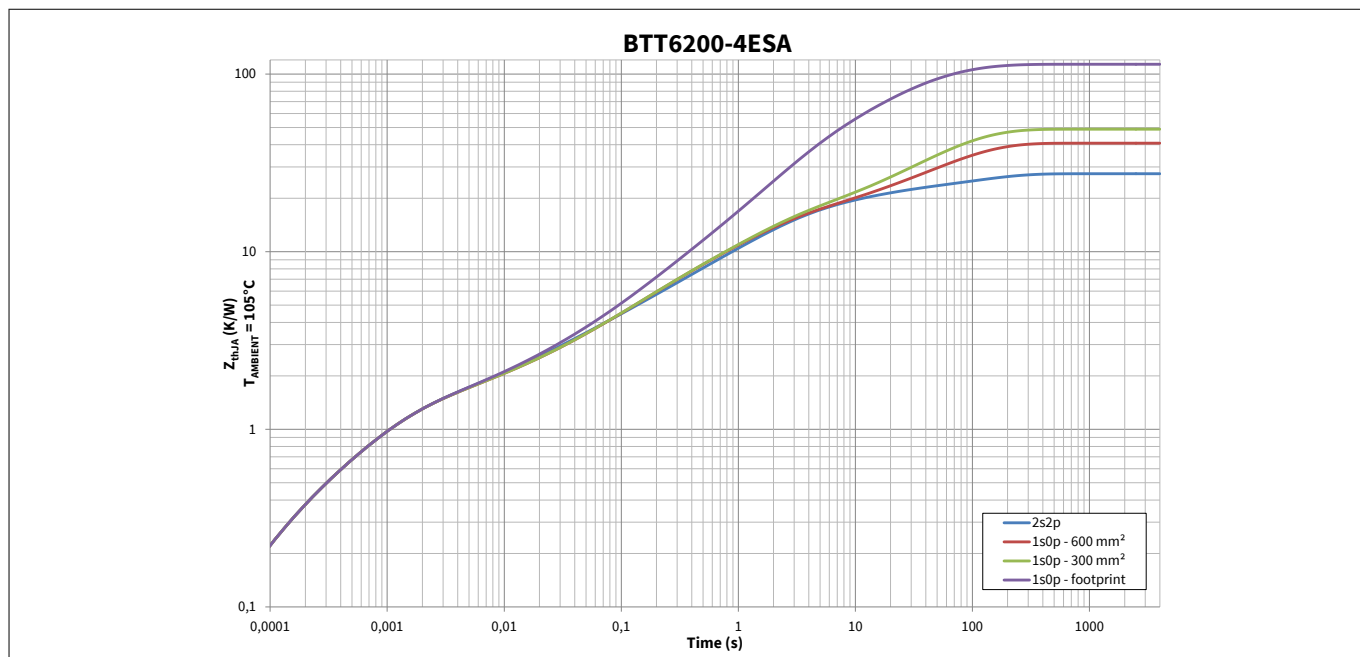


Figure 7 Typical thermal impedance. 2s2p PCB set-up according to Figure 5

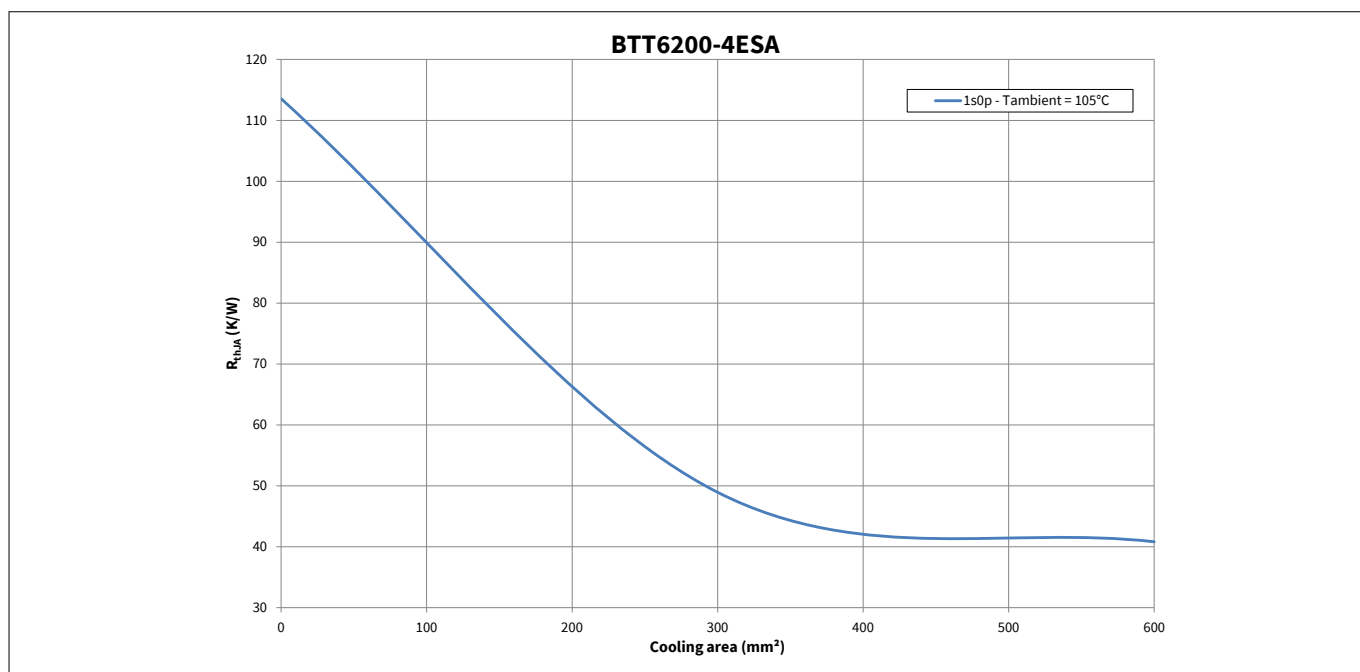


Figure 8 Typical thermal resistance. PCB set-up 1s0p

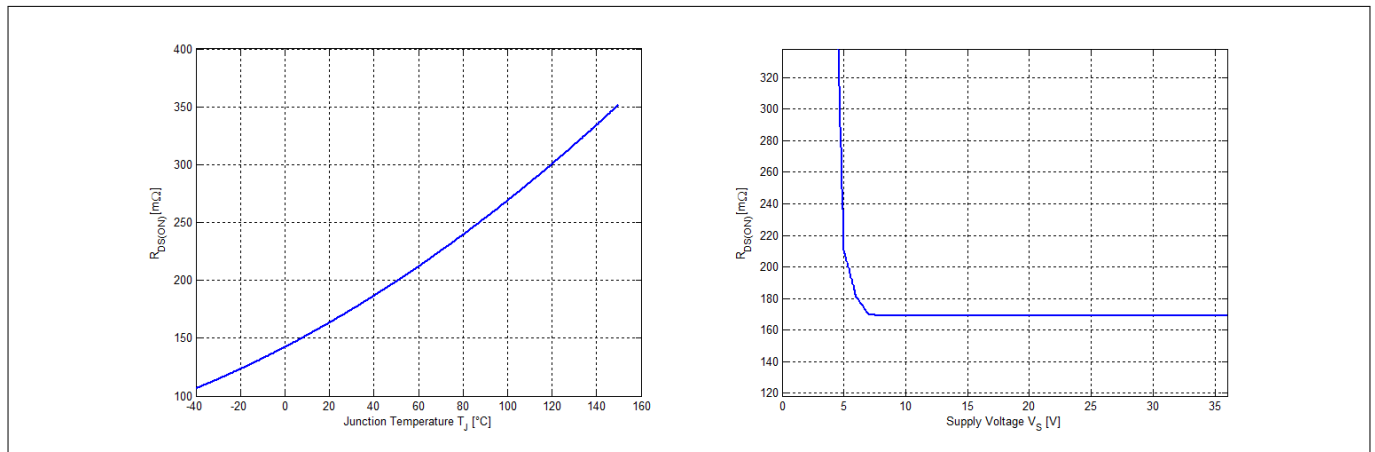
## Power stage

## 5 Power stage

The power stages are built using an N-channel vertical power MOSFET (DMOS) with charge pump.

### 5.1 Output ON-state resistance

The ON-state resistance  $R_{DS(ON)}$  depends on the supply voltage as well as the junction temperature  $T_J$ . **Figure 9** shows the dependencies in terms of temperature and supply voltage for the typical ON-state resistance. The behavior in reverse polarity is described in **Chapter 6.4**.

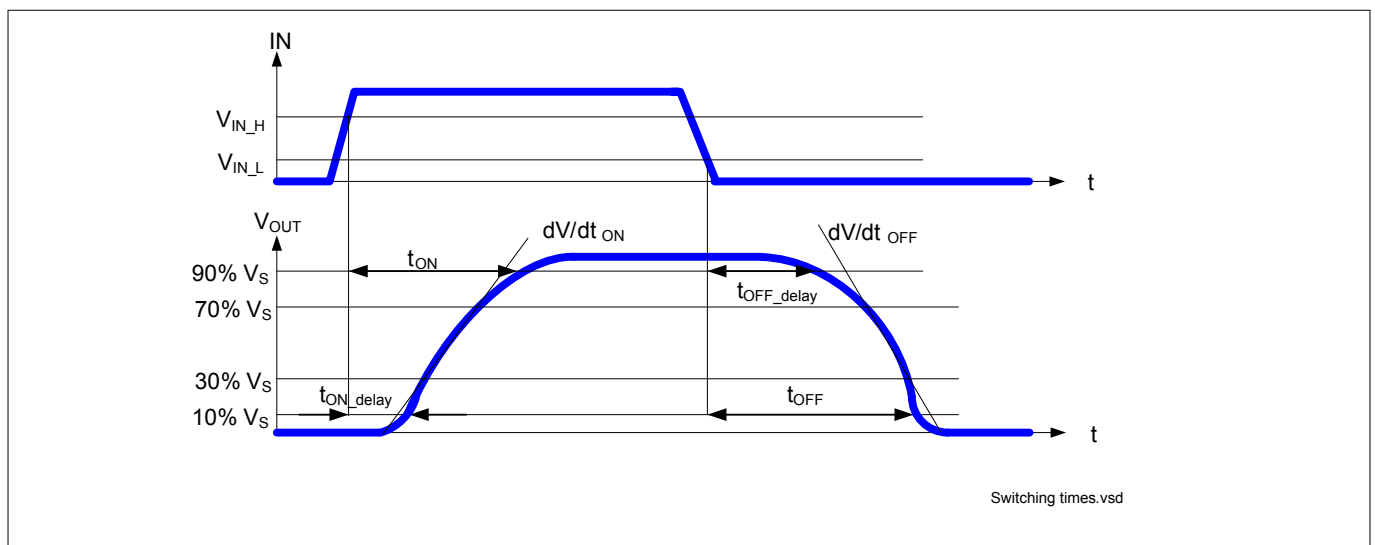


**Figure 9** Typical ON-state resistance

A high signal at the input pin (see **Chapter 8**) causes the power DMOS to switch ON with a dedicated slope, which is optimized in terms of EMC emission.

### 5.2 Turn ON/OFF characteristics with resistive load

**Figure 10** shows the typical timing when switching a resistive load.



**Figure 10** Switching a resistive load timing

Power stage

## 5.3 Inductive load

### 5.3.1 Output clamping

When switching OFF inductive loads with high side switches, the voltage  $V_{OUT}$  drops below ground potential, because the inductance intends to continue driving the current. To prevent the destruction of the device by avalanche due to high voltages, there is a voltage clamp mechanism  $Z_{DS(AZ)}$  implemented that limits negative output voltage to a certain level ( $V_S - V_{DS(AZ)}$ ). Please refer to [Figure 11](#) and [Figure 12](#) for details. Nevertheless, the maximum allowed load inductance is limited.

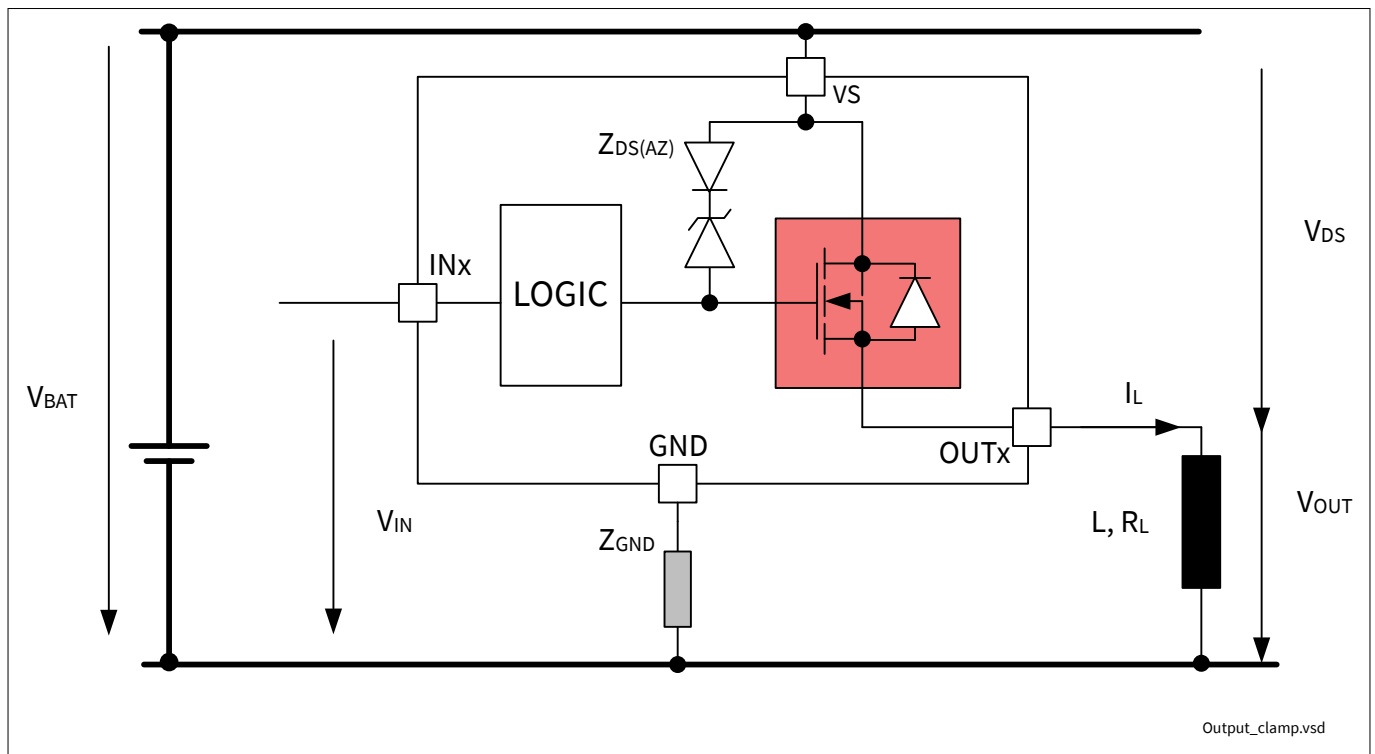


Figure 11 Output clamp

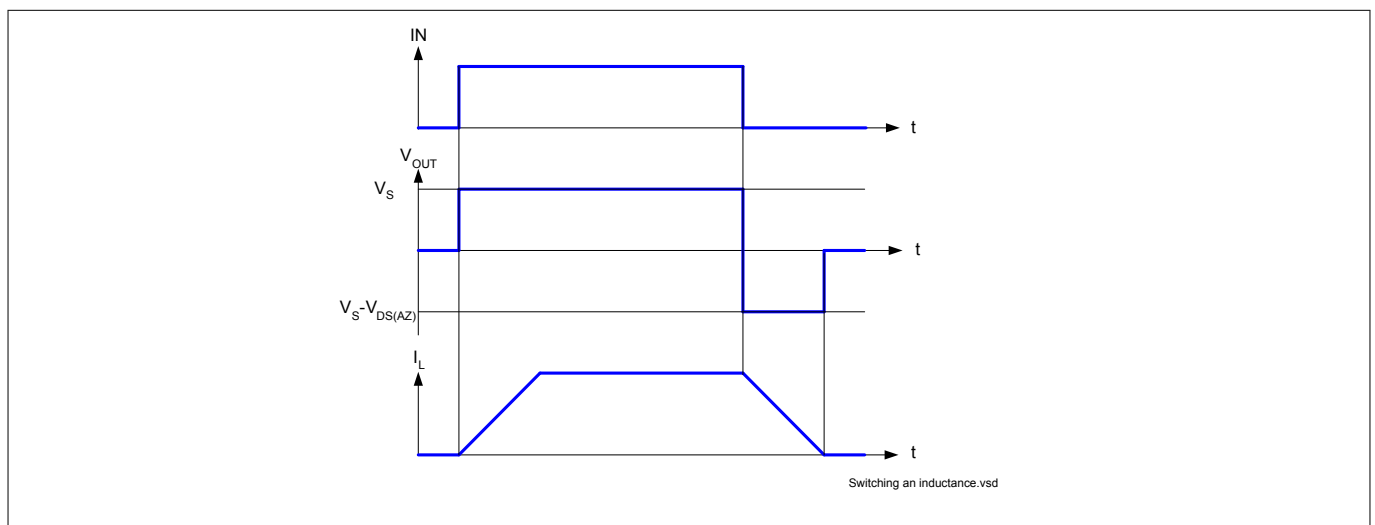


Figure 12 Switching an inductive load timing



## Power stage

### 5.3.2 Maximum load inductance

During demagnetization of inductive loads, energy has to be dissipated in the BTT6200-4ESA. This energy can be calculated with following equation:

$$E = V_{DS(AZ)} \cdot \frac{L}{R_L} \cdot \left[ \frac{V_S - V_{DS(AZ)}}{R_L} \cdot \ln \left( 1 - \frac{R_L \cdot I_L}{V_S - V_{DS(AZ)}} \right) + I_L \right]$$

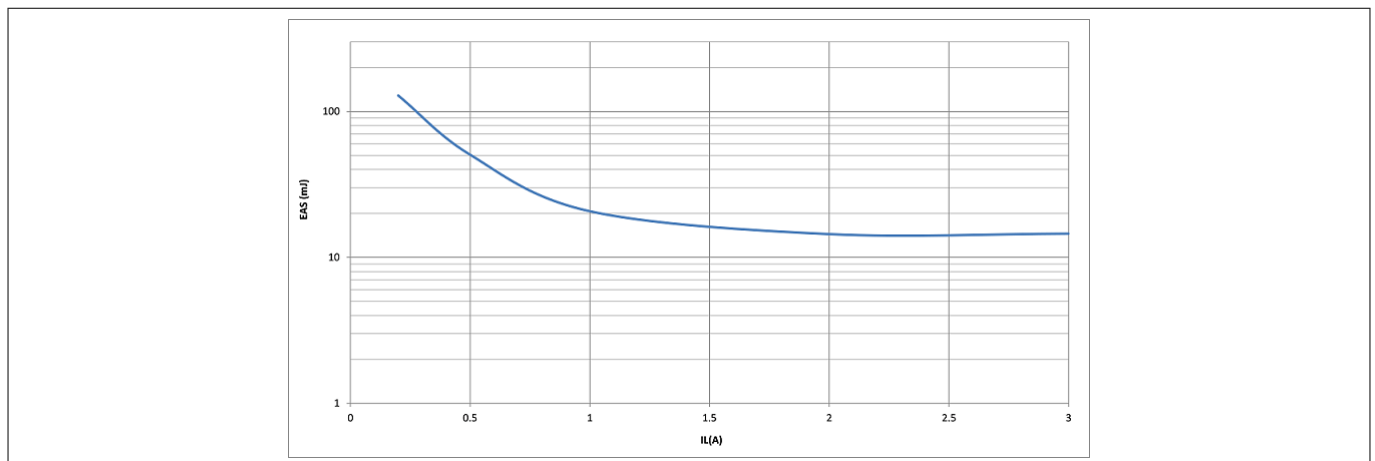
#### Equation 1

The following equation simplifies under the assumption of  $R_L = 0 \Omega$ .

$$E = \frac{1}{2} \cdot L \cdot I^2 \cdot \left( 1 - \frac{V_S}{V_S - V_{DS(AZ)}} \right)$$

#### Equation 2

The energy, which is converted into heat, is limited by the thermal design of the component. See [Figure 13](#) for the maximum allowed energy dissipation as a function of the load current.

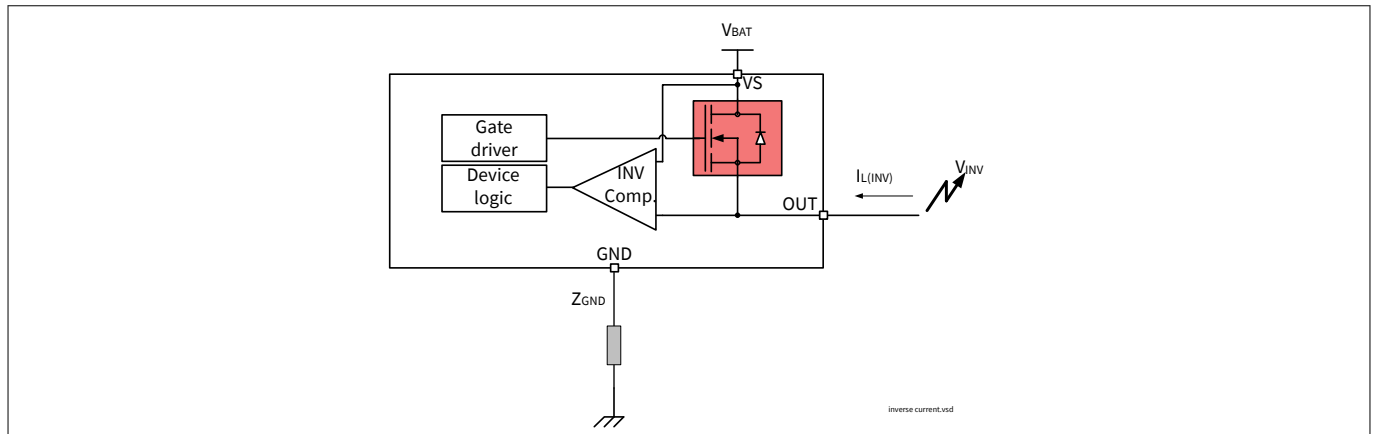


**Figure 13** Maximum energy dissipation single pulse,  $T_{J\_START} = 150^\circ\text{C}$ ;  $V_S = 28 \text{ V}$

### 5.4 Inverse current capability

In case of inverse current, meaning a voltage  $V_{INV}$  at the OUTput higher than the supply voltage  $V_S$ , a current  $I_{INV}$  will flow from output to  $V_S$  pin via the body diode of the power transistor (please refer to [Figure 14](#)). The output stage follows the state of the IN pin, except if the IN pin goes from OFF to ON during inverse. In that particular case, the output stage is kept OFF until the inverse current disappears. Nevertheless, the current  $I_{INV}$  should not be higher than  $I_{L(INV)}$ . If the channel is OFF, the diagnostic will detect an open load at OFF. If the affected channel is ON, the diagnostic will detect open load at ON (the overtemperature signal is inhibited). At the appearance of  $V_{INV}$ , a parasitic diagnostic can be observed. After, the diagnosis is valid and reflects the output state. At  $V_{INV}$  vanishing, the diagnosis is valid and reflects the output state. During inverse current, no protection functions are available.

**Power stage**



**Figure 14** Inverse current circuitry

## 5.5 Electrical characteristics - power stage

**Table 6** Electrical characteristics: Power stage

$V_S = 8\text{ V to }36\text{ V}$ ,  $T_J = -40^\circ\text{C to }150^\circ\text{C}$  (unless otherwise specified).

Typical values are given at  $V_S = 28\text{ V}$ ,  $T_J = 25^\circ\text{C}$

| Parameter                                                          | Symbol             | Values |      |      | Unit | Note or Test Condition                                                                                              | Number   |
|--------------------------------------------------------------------|--------------------|--------|------|------|------|---------------------------------------------------------------------------------------------------------------------|----------|
|                                                                    |                    | Min.   | Typ. | Max. |      |                                                                                                                     |          |
| ON-state resistance per channel                                    | $R_{DS(ON)_{150}}$ | 300    | 360  | 400  | mΩ   | $I_L = I_{L4} = 1\text{ A}$<br>$V_{IN} = 4.5\text{ V}$<br>$T_J = 150^\circ\text{C}$<br>See <a href="#">Figure 9</a> | P_5.5.1  |
| ON-state resistance per channel                                    | $R_{DS(ON)_{25}}$  | –      | 200  | –    | mΩ   | <sup>10)</sup> $T_J = 25^\circ\text{C}$                                                                             | P_5.5.21 |
| Nominal load current One channel active                            | $I_{L(NOM)1}$      | –      | 1.5  | –    | A    | <sup>10)</sup> $T_A = 85^\circ\text{C}$<br>$T_J < 150^\circ\text{C}$                                                | P_5.5.2  |
| Nominal load current All channels active                           | $I_{L(NOM)2}$      | –      | 1    | –    | A    |                                                                                                                     | P_5.5.3  |
| Output voltage drop limitation at small load currents              | $V_{DS(NL)}$       | –      | 10   | 22   | mV   | $I_L = I_{L0} = 25\text{ mA}$<br>See <a href="#">Chapter 9.3</a>                                                    | P_5.5.4  |
| Drain to source clamping voltage<br>$V_{DS(AZ)} = [V_S - V_{OUT}]$ | $V_{DS(AZ)}$       | 65     | 70   | 75   | V    | $I_{DS} = 5\text{ mA}$<br>See <a href="#">Figure 12</a><br>See <a href="#">Chapter 9.1</a>                          | P_5.5.5  |
| Output leakage current per channel $T_J \leq 85^\circ\text{C}$     | $I_{L(OFF)}$       | –      | 0.1  | 0.5  | μA   | <sup>11)</sup> $V_{IN}$ floating<br>$V_{OUT} = 0\text{ V}$<br>$T_J \leq 85^\circ\text{C}$                           | P_5.5.6  |

<sup>10)</sup> Not subject to production test, specified by design.

<sup>11)</sup> Test at  $T_J = -40^\circ\text{C}$  only

**Power stage**

**Table 6 Electrical characteristics: Power stage (continued)**

$V_S = 8\text{ V to }36\text{ V}$ ,  $T_J = -40^\circ\text{C to }150^\circ\text{C}$  (unless otherwise specified).

Typical values are given at  $V_S = 28\text{ V}$ ,  $T_J = 25^\circ\text{C}$

| Parameter                                                      | Symbol                   | Values |      |      | Unit                   | Note or Test Condition                                                                                                     | Number   |
|----------------------------------------------------------------|--------------------------|--------|------|------|------------------------|----------------------------------------------------------------------------------------------------------------------------|----------|
|                                                                |                          | Min.   | Typ. | Max. |                        |                                                                                                                            |          |
| Output leakage current per channel $T_J = 150^\circ\text{C}$   | $I_{L(\text{OFF})\_150}$ | –      | 1    | 5    | $\mu\text{A}$          | $V_{\text{IN}}$ floating<br>$V_{\text{OUT}} = 0\text{ V}$<br>$T_J = 150^\circ\text{C}$                                     | P_5.5.8  |
| Inverse current capability                                     | $I_{L(\text{INV})}$      | –      | 1    | –    | A                      | <sup>10)</sup> $V_S < V_{\text{OUTX}}$ See <a href="#">Figure 14</a>                                                       | P_5.5.9  |
| Slew rate<br>30% to 70% $V_S$                                  | $dV/dt_{\text{ON}}$      | 0.3    | 0.8  | 1.3  | $\text{V}/\mu\text{s}$ | $R_L = 47\ \Omega$<br>$V_S = 28\text{ V}$                                                                                  | P_5.5.11 |
| Slew rate<br>70% to 30% $V_S$                                  | $-dV/dt_{\text{OFF}}$    | 0.3    | 0.8  | 1.3  | $\text{V}/\mu\text{s}$ | See <a href="#">Figure 10</a><br>See <a href="#">Chapter 9.1</a>                                                           | P_5.5.12 |
| Slew rate matching<br>$dV/dt_{\text{ON}} - dV/dt_{\text{OFF}}$ | $\Delta dV/dt$           | -0.15  | 0    | 0.15 | $\text{V}/\mu\text{s}$ |                                                                                                                            | P_5.5.13 |
| Turn-ON time to $V_{\text{OUT}} = 90\% V_S$                    | $t_{\text{ON}}$          | 20     | 70   | 150  | $\mu\text{s}$          |                                                                                                                            | P_5.5.14 |
| Turn-OFF time to $V_{\text{OUT}} = 10\% V_S$                   | $t_{\text{OFF}}$         | 20     | 70   | 150  | $\mu\text{s}$          |                                                                                                                            | P_5.5.15 |
| Turn-ON / OFF matching<br>$t_{\text{OFF}} - t_{\text{ON}}$     | $\Delta t_{\text{SW}}$   | -50    | 0    | 50   | $\mu\text{s}$          |                                                                                                                            | P_5.5.16 |
| Turn-ON time to $V_{\text{OUT}} = 10\% V_S$                    | $t_{\text{ON\_delay}}$   | –      | 35   | 70   | $\mu\text{s}$          |                                                                                                                            | P_5.5.17 |
| Turn-OFF time to $V_{\text{OUT}} = 90\% V_S$                   | $t_{\text{OFF\_delay}}$  | –      | 35   | 70   | $\mu\text{s}$          |                                                                                                                            | P_5.5.18 |
| Switch ON energy                                               | $E_{\text{ON}}$          | –      | 190  | –    | $\mu\text{J}$          | <sup>10)</sup> $R_L = 47\ \Omega$<br>$V_{\text{OUT}} = 90\% V_S$<br>$V_S = 36\text{ V}$<br>See <a href="#">Chapter 9.1</a> | P_5.5.19 |
| Switch OFF energy                                              | $E_{\text{OFF}}$         | –      | 210  | –    | $\mu\text{J}$          | <sup>10)</sup> $R_L = 47\ \Omega$<br>$V_{\text{OUT}} = 10\% V_S$<br>$V_S = 36\text{ V}$<br>See <a href="#">Chapter 9.1</a> | P_5.5.20 |

<sup>10)</sup> Not subject to production test, specified by design.

## Protection functions

### 6 Protection functions

The device provides integrated protection functions. These functions are designed to prevent the destruction of the IC from fault conditions described in the data sheet. Fault conditions are considered as “outside” normal operating range. Protection functions are designed for neither continuous nor repetitive operation.

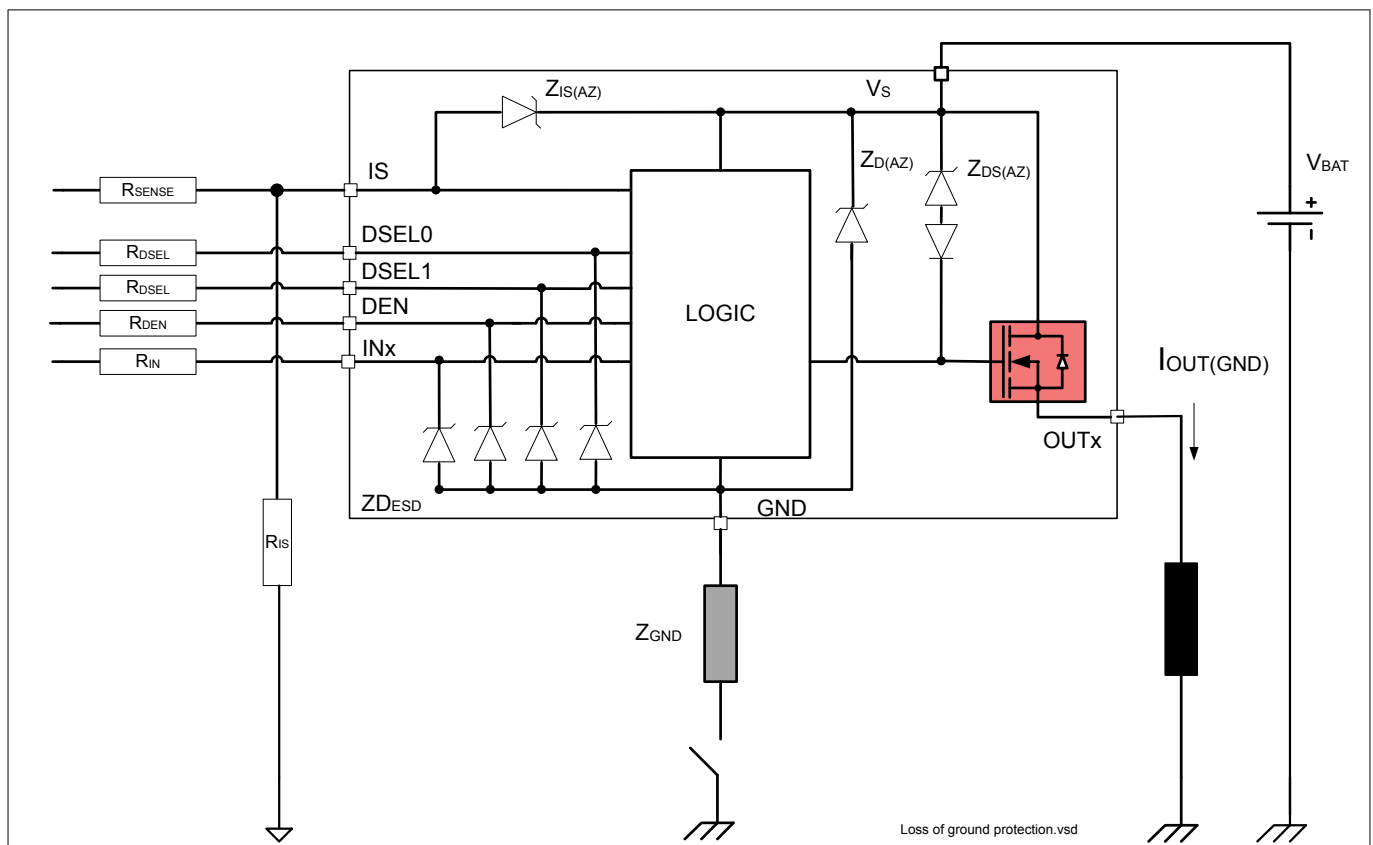
#### 6.1 Loss of ground protection

In case of loss of the module ground and the load remains connected to ground, the device protects itself by automatically turning OFF (when it was previously ON) or remains OFF, regardless of the voltage applied on IN pins.

In case of loss of device ground, it's recommended to use input resistors between the microcontroller and the BTT6200-4ESA to ensure switching OFF of channels.

In case of loss of module or device ground, a current ( $I_{OUT(GND)}$ ) can flow out of the DMOS. **Figure 15** sketches the situation.

$Z_{GND}$  is recommended to be a resistor in series to a diode.

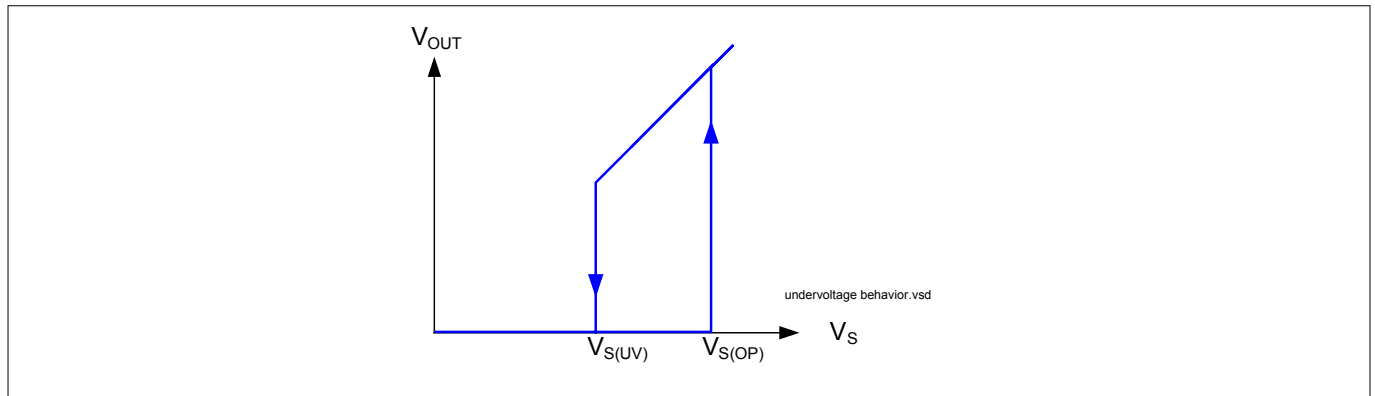


**Figure 15** Loss of ground protection with external components

#### 6.2 Undervoltage protection

Between  $V_{S(UV)}$  and  $V_{S(OP)}$ , the undervoltage mechanism is triggered.  $V_{S(OP)}$  represents the minimum voltage where the switching ON and OFF can take place.  $V_{S(UV)}$  represents the minimum voltage the switch can hold ON. If the supply voltage is below the undervoltage mechanism  $V_{S(UV)}$ , the device is OFF (turns OFF). As soon as the supply voltage is above the undervoltage mechanism  $V_{S(OP)}$ , then the device can be switched ON. When the switch is ON, protection functions are operational. Nevertheless, the diagnosis is not guaranteed until  $V_S$  is in the  $V_{NOM}$  range. **Figure 16** illustrates the undervoltage mechanism.

## Protection functions

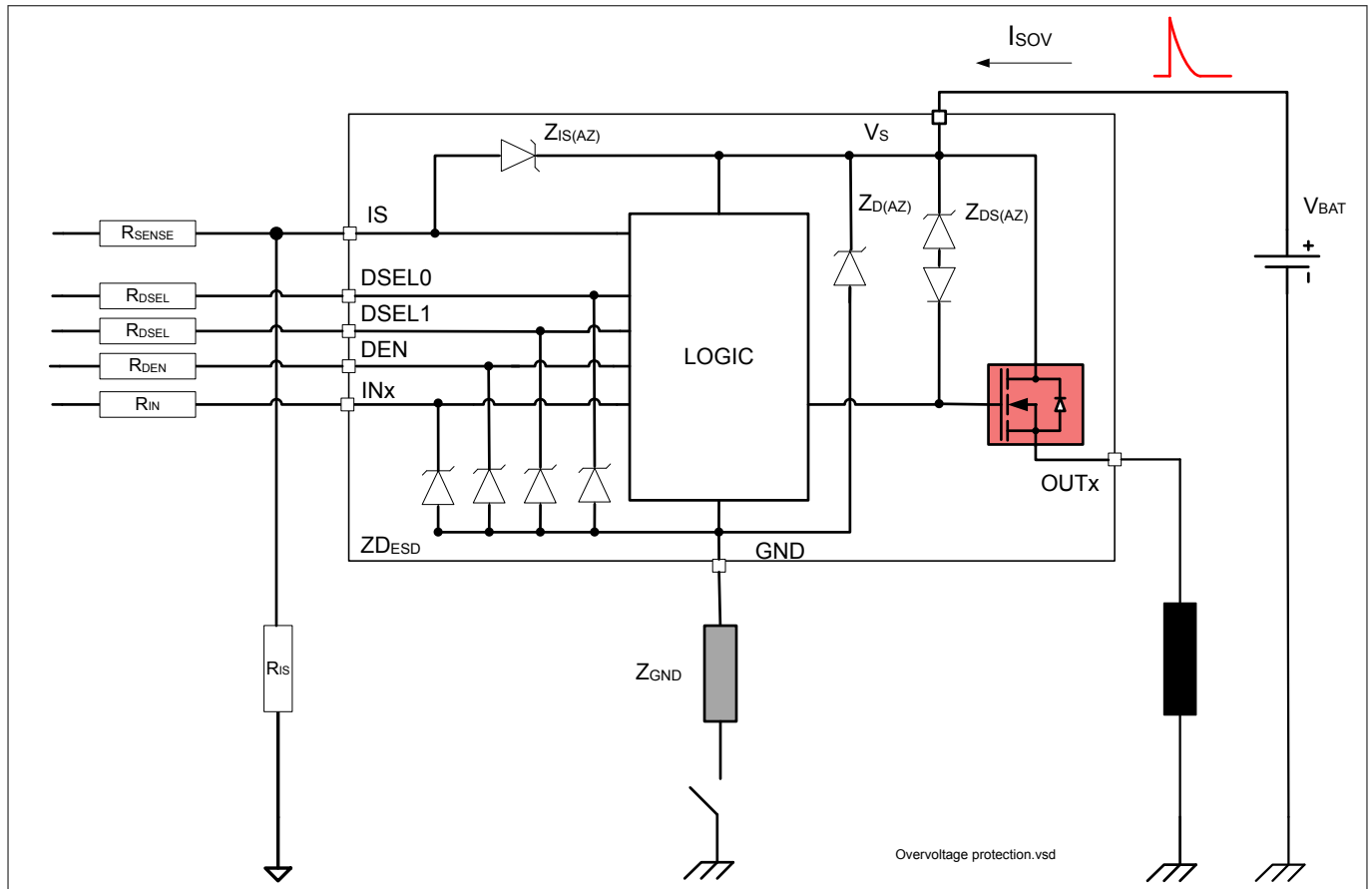


**Figure 16** Undervoltage behavior

### 6.3 Overvoltage protection

There is an integrated clamp mechanism for overvoltage protection ( $Z_{D(AZ)}$ ). To guarantee this mechanism operates properly in the application, the current in the Zener diode has to be limited by a ground resistor. **Figure 17** shows a typical application to withstand overvoltage issues. In case of supply voltage higher than  $V_{S(AZ)}$ , the power transistor switches ON and in addition the voltage across the logic section is clamped. As a result, the internal ground potential rises to  $V_S - V_{S(AZ)}$ . Due to the ESD Zener diodes, the potential at pin INx, DSELx, and DEN rises almost to that potential, depending on the impedance of the connected circuitry. In the case the device was ON, prior to overvoltage, the BTT6200-4ESA remains ON. In the case the BTT6200-4ESA was OFF, prior to overvoltage, the power transistor can be activated. In the case the supply voltage is in above  $V_{BAT(SC)}$  and below  $V_{DS(AZ)}$ , the output transistor is still operational and follows the input. If at least one channel is in the ON state, parameters are no longer guaranteed and lifetime is reduced compared to the nominal supply voltage range. This especially impacts the short circuit robustness, as well as the maximum energy  $E_{AS}$  capability.  $Z_{GND}$  is recommended to be a resistor in series to a diode.

## Protection functions



**Figure 17** Overvoltage protection with external components

## 6.4 Reverse polarity protection

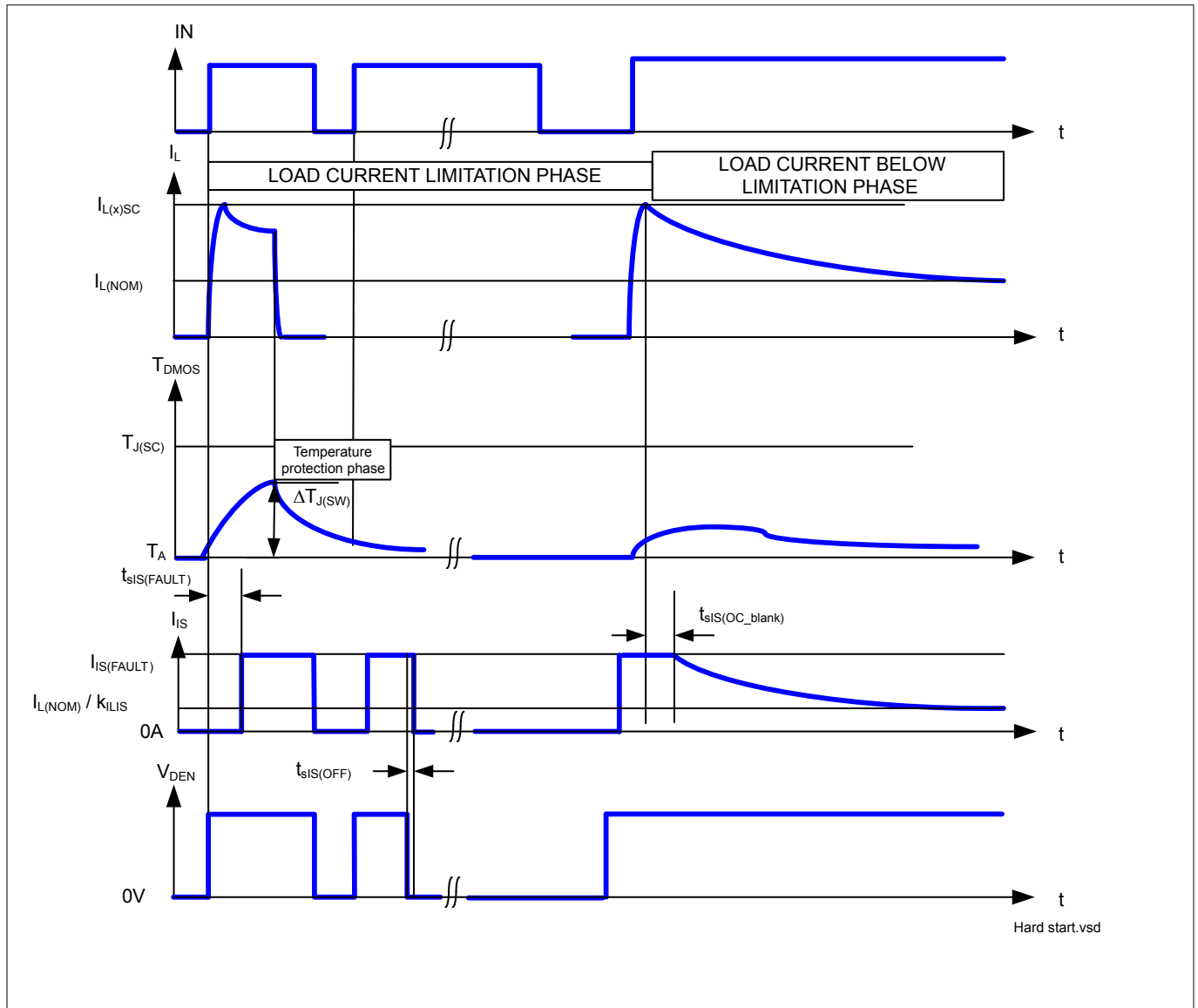
In case of reverse polarity, the intrinsic body diodes of the power DMOS causes power dissipation. The current in this intrinsic body diode is limited by the load itself. Additionally, the current into the ground path and the logic pins has to be limited to the maximum current described in [Chapter 4.1](#) with an external resistor. [Figure 18](#) shows a typical application.  $R_{GND}$  resistor is used to limit the current in the Zener protection of the device. Resistors  $R_{DSEL}$ ,  $R_{DEN}$ , and  $R_{IN}$  are used to limit the current in the logic of the device and in the ESD protection stage.  $R_{SENSE}$  is used to limit the current in the sense transistor which behaves as a diode. The recommended value for  $R_{DEN} = R_{DSEL} = R_{IN} = R_{SENSE} = 10\text{ k}\Omega$ . It is recommended to use a resistor in series to a diode in the ground path.

During reverse polarity, no protection functions are available.

The diagram illustrates a reverse polarity protection circuit for a microcontroller. The microcontroller is shown with several pins:  $R_{SENSE}$ ,  $R_{SELO}$ ,  $R_{SELL}$ ,  $R_{DEN}$ ,  $R_{IN}$ ,  $I_S$ ,  $DSEL0$ ,  $DSEL1$ ,  $DEN$ , and  $IN_x$ . These pins are connected to a network of resistors and diodes. A MOSFET, labeled  $OUT_x$ , is used to switch the load. The circuit is powered by a battery with voltage  $-V_S(REV)$ . The MOSFET is controlled by a logic block. The circuit is labeled "Reverse Polarity.vsd".

Rev. 1.00  
2019-03-09

**Protection functions**



**Figure 19**      **Overload protection**

*Note: For better understanding, the time scale is not linear. The real timing of this drawing is application dependant and cannot be described.*



## Protection functions

### 6.6 Electrical characteristics for the protection functions

**Table 7 Electrical Characteristics: Protection**

$V_S = 8\text{ V to }36\text{ V}$ ,  $T_J = -40^\circ\text{C to }150^\circ\text{C}$ , (unless otherwise specified).

Typical values are given at  $V_S = 28\text{ V}$ ,  $T_J = 25^\circ\text{C}$

| Parameter                                          | Symbol                    | Values |      |      | Unit | Note or Test Condition                                                                  | Number   |
|----------------------------------------------------|---------------------------|--------|------|------|------|-----------------------------------------------------------------------------------------|----------|
|                                                    |                           | Min.   | Typ. | Max. |      |                                                                                         |          |
| Loss of ground                                     |                           |        |      |      |      |                                                                                         |          |
| Output leakage current while GND disconnected      | $I_{\text{OUT(GND)}}$     | –      | 0.1  | –    | mA   | <sup>12)13)</sup> $V_{\text{S}} = 28\text{ V}$<br>See <b>Figure 15</b>                  | P_6.6.1  |
| Reverse polarity                                   |                           |        |      |      |      |                                                                                         |          |
| Drain source diode voltage during reverse polarity | $V_{\text{DS(REV)}}$      | 200    | 650  | 700  | mV   | <sup>14)</sup> $I_{\text{L}} = -1\text{ A}$<br>See <b>Figure 18</b>                     | P_6.6.2  |
| Overvoltage                                        |                           |        |      |      |      |                                                                                         |          |
| Overvoltage protection                             | $V_{\text{S(AZ)}}$        | 65     | 70   | 75   | V    | $I_{\text{SOV}} = 5\text{ mA}$<br>See <b>Figure 17</b>                                  | P_6.6.3  |
| Overload condition                                 |                           |        |      |      |      |                                                                                         |          |
| Load current limitation                            | $I_{\text{L5(SC)}}$       | 9      | 11   | 14   | A    | <sup>15)</sup> $V_{\text{DS}} = 5\text{ V}$ See <b>Figure 19</b> and <b>Chapter 9.3</b> | P_6.6.4  |
| Dynamic temperature increase while switching       | $\Delta T_{\text{J(SW)}}$ | –      | 80   | –    | K    | <sup>16)</sup> See <b>Figure 19</b>                                                     | P_6.6.8  |
| Thermal shutdown temperature                       | $T_{\text{J(SC)}}$        | 150    | 170  | 200  | °C   | <sup>14)</sup> See <b>Figure 19</b>                                                     | P_6.6.10 |
| Thermal shutdown hysteresis                        | $\Delta T_{\text{J(SC)}}$ | –      | 30   | –    | K    | <sup>13)</sup>                                                                          | P_6.6.11 |

<sup>12)</sup> All pins are disconnected except  $V_S$  and OUT.

<sup>13)</sup> Not Subject to production test, specified by design.

<sup>14)</sup> Test at  $T_J = +150^\circ\text{C}$  only.

<sup>15)</sup> Test at  $T_J = -40^\circ\text{C}$  only.

<sup>16)</sup> Functional test only

## Diagnostic functions

### 7 Diagnostic functions

For diagnosis purposes, the BTT6200-4ESA provides a combination of digital and analog signals at pin IS. These signals are called SENSE. In case the diagnostic is disabled via DEN, pin IS becomes high impedance. In case DEN is activated, the sense current of the channel X is enabled/disabled via associated pins DSEL0 and DSEL1.

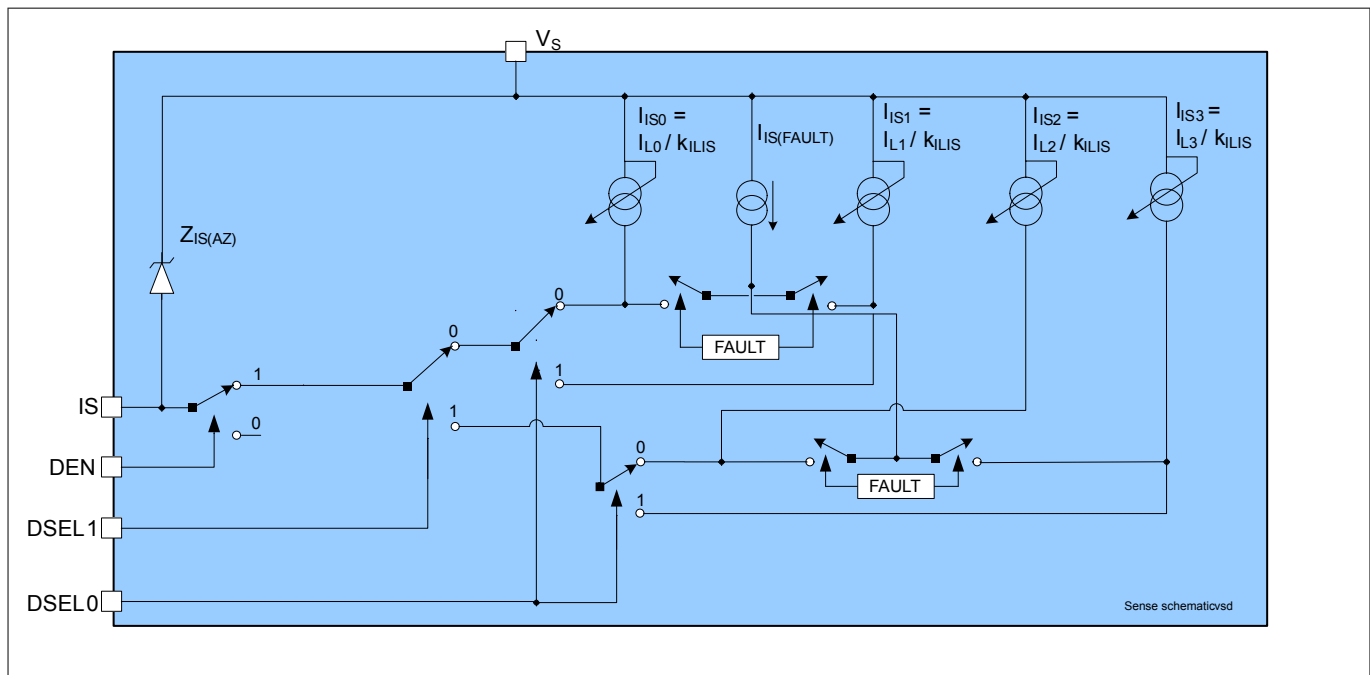
**Table 8** gives the truth table.

**Table 8** Diagnostic truth table

| DEN | DSEL1      | DSEL0      | IS          |             |             |             |
|-----|------------|------------|-------------|-------------|-------------|-------------|
| 0   | don't care | don't care | Z           | Z           | Z           | Z           |
| 1   | 0          | 0          | $I_{IS(0)}$ | 0           | 0           | 0           |
| 1   | 0          | 1          | 0           | $I_{IS(1)}$ | 0           | 0           |
| 1   | 1          | 0          | 0           | 0           | $I_{IS(2)}$ | 0           |
| 1   | 1          | 1          | 0           | 0           | 0           | $I_{IS(3)}$ |

#### 7.1 IS pin

The BTT6200-4ESA provides a sense signal called  $I_{IS}$  at pin IS. As long as no “hard” failure mode occurs (short circuit to GND / current limitation / overtemperature / excessive dynamic temperature increase or open load at OFF) a proportional signal to the load current (ratio  $k_{ILIS} = I_L / I_{IS}$ ) is provided. The complete IS pin and diagnostic mechanism is described in **Figure 20**. The accuracy of the sense current depends on temperature and load current. The sense pin multiplexes the currents  $I_{IS(0)}$ ,  $I_{IS(1)}$ ,  $I_{IS(2)}$  and  $I_{IS(3)}$  via the pins DSEL0 and DSEL1. Thanks to this multiplexing, the matching between  $k_{ILISCHANNEL0}$ ,  $k_{ILISCHANNEL1}$ ,  $k_{ILISCHANNEL2}$  and  $k_{ILISCHANNEL3}$  is optimized. Due to the ESD protection, in connection to  $V_S$ , it is not recommended to share the IS pin with other devices if these devices are using another battery feed. The consequence is that the unsupplied device would be fed via the IS pin of the supplied device.



**Figure 20** Diagnostic block diagram

## Diagnostic functions

### 7.2 SENSE signal in different operating modes

Table 9 gives a quick reference for the state of the IS pin during device operation.

**Table 9** Sense signal, function of operation mode

| Operation mode                           | Input level channel x | DEN <sup>17)</sup>             | Output level                                                                | Diagnostic output                                     |
|------------------------------------------|-----------------------|--------------------------------|-----------------------------------------------------------------------------|-------------------------------------------------------|
| Normal operation                         | OFF                   | H                              | Z                                                                           | Z                                                     |
| Short circuit to GND                     |                       |                                | ~GND                                                                        | Z                                                     |
| Overtemperature                          |                       |                                | Z                                                                           | Z                                                     |
| Short circuit to V <sub>S</sub>          |                       |                                | V <sub>S</sub>                                                              | I <sub>IS</sub> (FAULT)                               |
| Open load                                |                       |                                | < V <sub>OL(OFF)</sub> <sup>18)</sup>                                       | Z                                                     |
|                                          |                       |                                | > V <sub>OL(OFF)</sub> <sup>18)</sup>                                       | I <sub>IS</sub> (FAULT)                               |
| Inverse current                          |                       |                                | ~V <sub>INV</sub>                                                           | I <sub>IS</sub> (FAULT)                               |
| Normal operation                         | ON                    |                                | ~V <sub>S</sub>                                                             | I <sub>IS</sub> = I <sub>L</sub> / k <sub>ILIS</sub>  |
| Current limitation                       |                       |                                | <V <sub>S</sub>                                                             | I <sub>IS</sub> (FAULT)                               |
| Short circuit to GND                     |                       |                                | ~GND                                                                        | I <sub>IS</sub> (FAULT)                               |
| Overtemperature T <sub>J(SW)</sub> event |                       |                                | Z                                                                           | I <sub>IS</sub> (FAULT)                               |
| Short circuit to VS                      |                       |                                | V <sub>S</sub>                                                              | I <sub>IS</sub> < I <sub>L</sub> / k <sub>ILIS</sub>  |
| Open load                                |                       |                                | ~V <sub>S</sub> <sup>19)</sup>                                              | I <sub>IS</sub> < I <sub>IS</sub> (OL)                |
| Inverse current                          |                       |                                | ~V <sub>INV</sub>                                                           | I <sub>IS</sub> < I <sub>IS</sub> (OL) <sup>20)</sup> |
| Underload                                |                       | ~V <sub>S</sub> <sup>21)</sup> | I <sub>IS</sub> (OL) < I <sub>IS</sub> < I <sub>L</sub> / k <sub>ILIS</sub> |                                                       |
| Don't care                               | Don't care            | L                              | Don't care                                                                  | Z                                                     |

<sup>17</sup> The table doesn't indicate but it is assumed that the appropriate channel is selected via the DSEL pins.

<sup>18</sup> Stable with additional pull-up resistor.

<sup>19</sup> The output current has to be smaller than  $I_{L(OL)}$ .

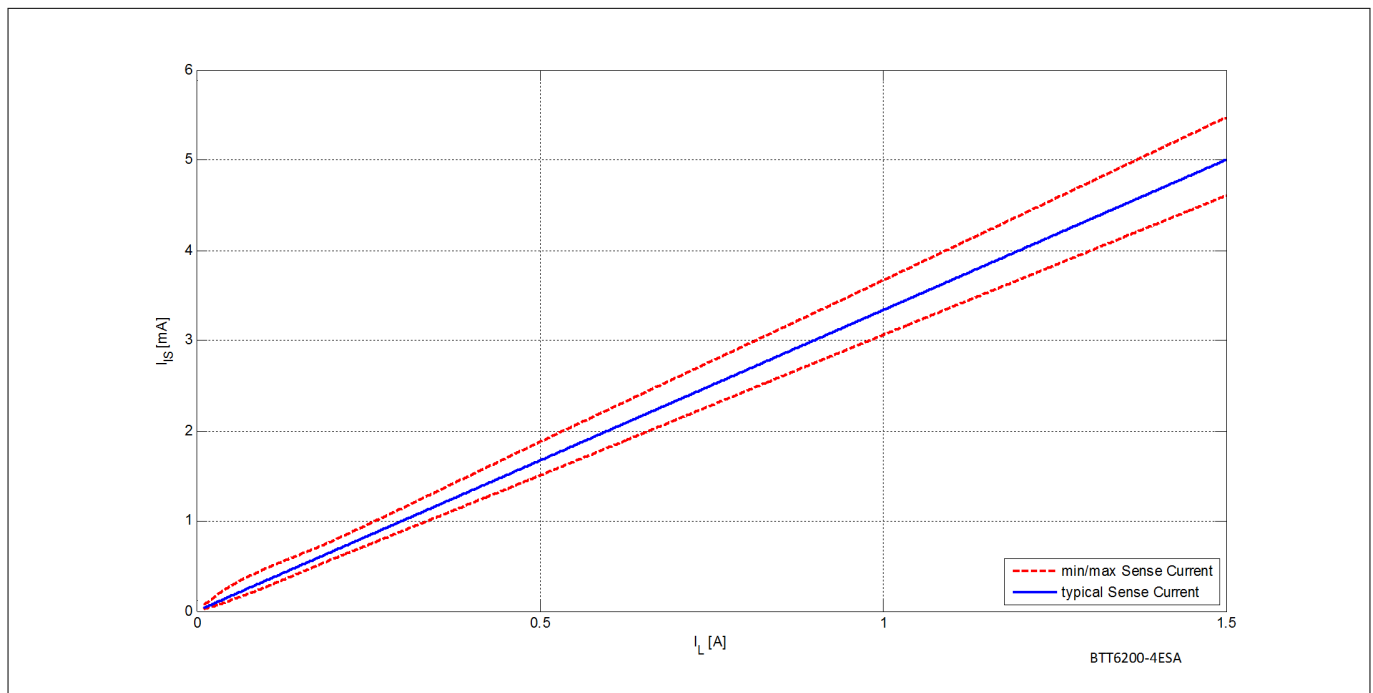
<sup>20</sup> After maximum  $t_{INV}$ .

<sup>21</sup> The output current has to be higher than  $I_{L(OL)}$ .

## Diagnostic functions

### 7.3 SENSE signal in nominal current range

**Figure 21** shows the current sense as a function of the load current in the power DMOS. Usually, a pull-down resistor  $R_{IS}$  is connected to the current sense IS pin. This resistor has to be higher than  $560\ \Omega$  to limit the power losses in the sense circuitry. A typical value is  $1.2\ \text{k}\Omega$ . The blue curve represents the ideal sense current, assuming an ideal  $k_{ILIS}$  factor value. The red curves show the accuracy the device provides across full temperature range at a defined current.



**Figure 21** Current sense for nominal load

#### 7.3.1 SENSE signal variation as a function of temperature and load current

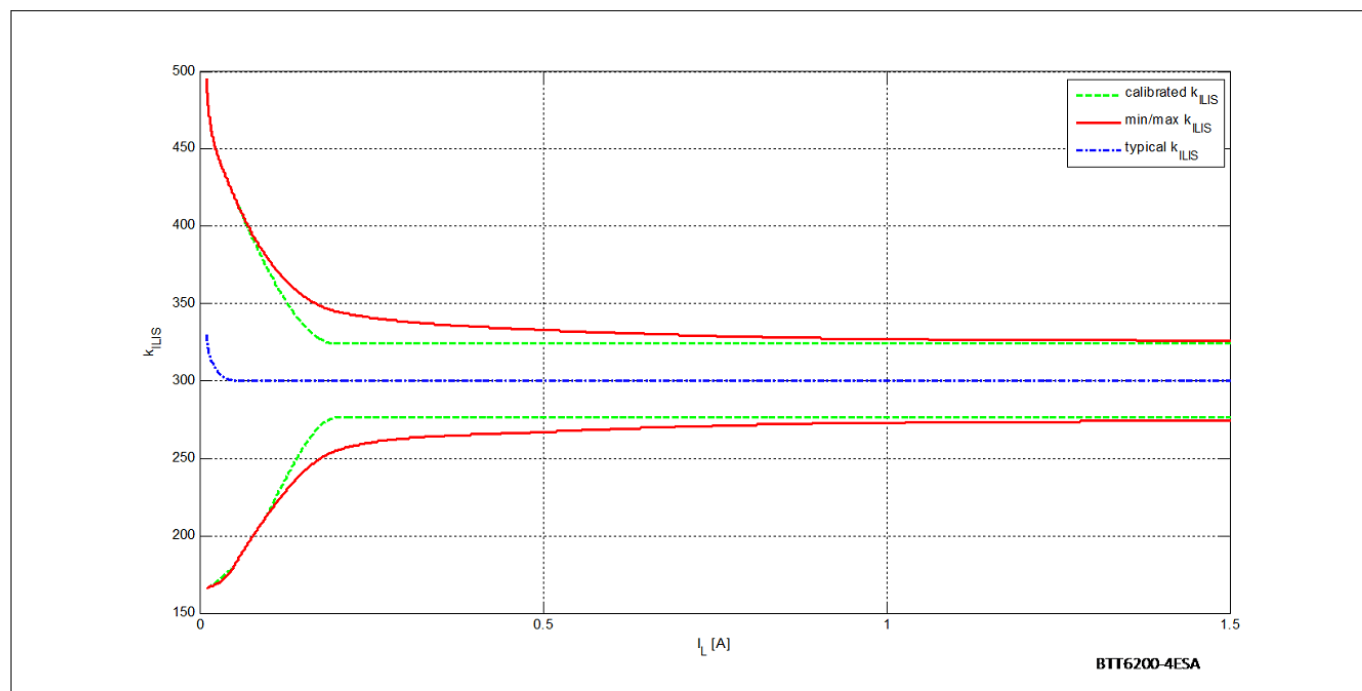
In some applications a better accuracy is required at smaller currents. To achieve this accuracy requirement, a calibration on the application is possible. To avoid multiple calibration points at different load and temperature conditions, the BTT6200-4ESA allows limited derating of the  $k_{ILIS}$  value, at a given point ( $I_{L3}$ ;  $T_J = +25^\circ\text{C}$ ). This derating is described by the parameter  $\Delta k_{ILIS}$ . **Figure 22** shows the behavior of the sense current, assuming one calibration point at nominal load at  $+25^\circ\text{C}$ .

The blue line indicates the ideal  $k_{ILIS}$  ratio.

The green lines indicate the derating on the parameter across temperature and voltage, assuming one calibration point at nominal temperature and nominal battery voltage.

The red lines indicate the  $k_{ILIS}$  accuracy without calibration.

## Diagnostic functions



**Figure 22** Improved current sense accuracy with one calibration point at 0.2 A

## Diagnostic functions

### 7.3.2 SENSE signal timing

Figure 23 shows the timing during settling and disabling of the SENSE.

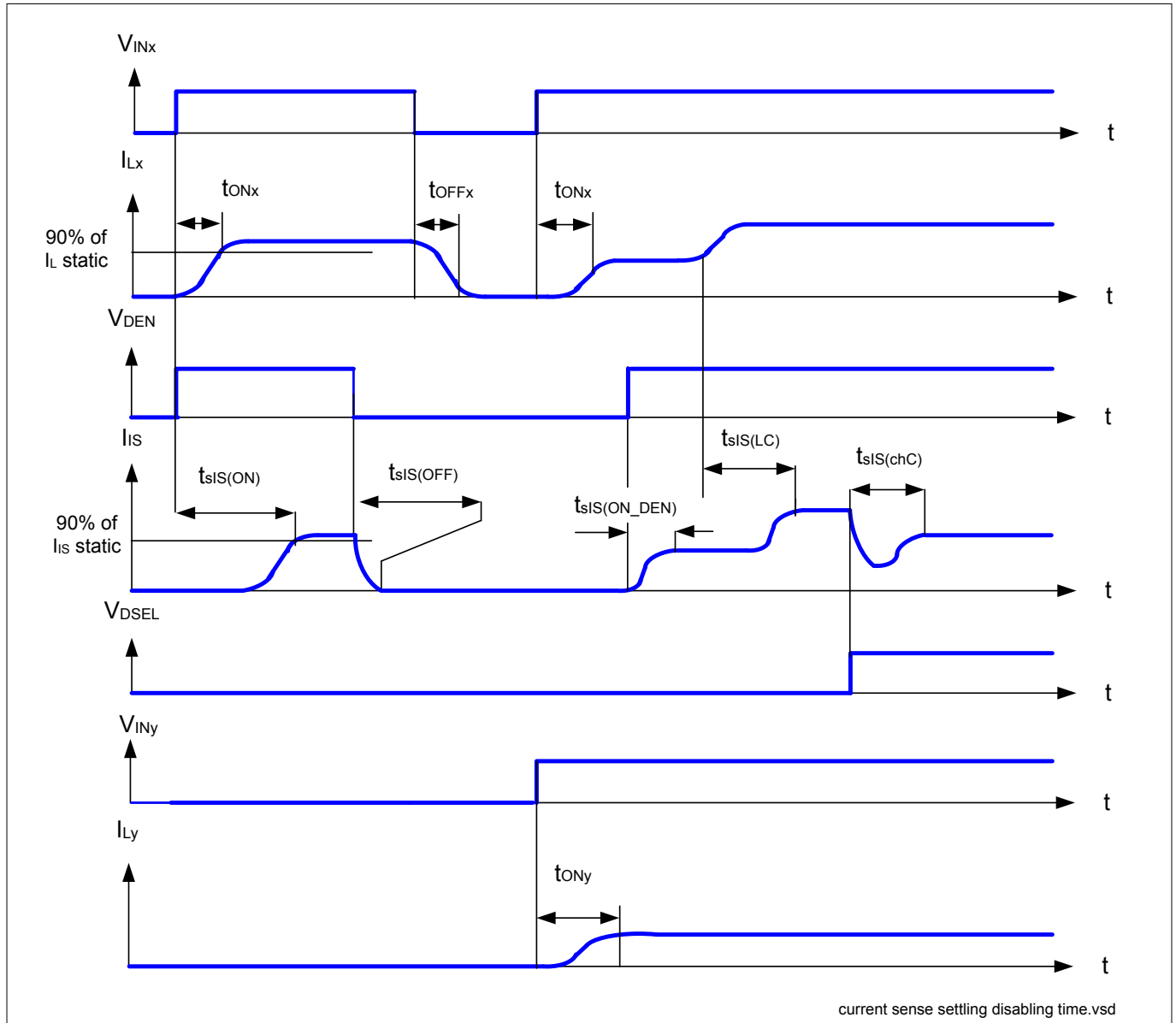


Figure 23 Current sense settling / disabling timing

### 7.3.3 SENSE signal in open load

#### 7.3.3.1 Open load in ON diagnostic

If the channel is ON, a leakage current can still flow through an open load, for example due to humidity. The parameter  $I_{L(OL)}$  gives the threshold of recognition for this leakage current. If the current  $I_L$  flowing out the power DMOS is below this value, the device recognizes a failure, if the DEN (and DSEL) is selected. In that case, the SENSE current is below  $I_{IS(OL)}$ . Otherwise, the minimum SENSE current is given above parameter  $I_{IS(OL)}$ .

Figure 24 shows the SENSE current behavior in this area. The red curve shows a typical product curve. The blue curve shows the ideal current sense.

## Diagnostic functions

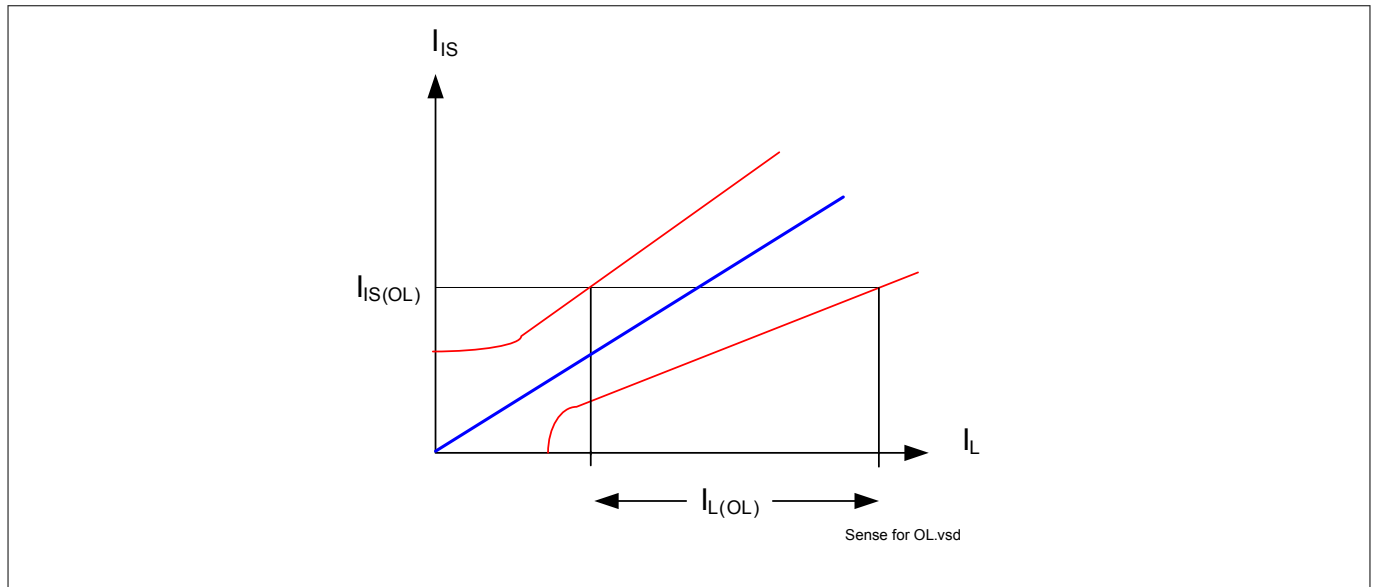


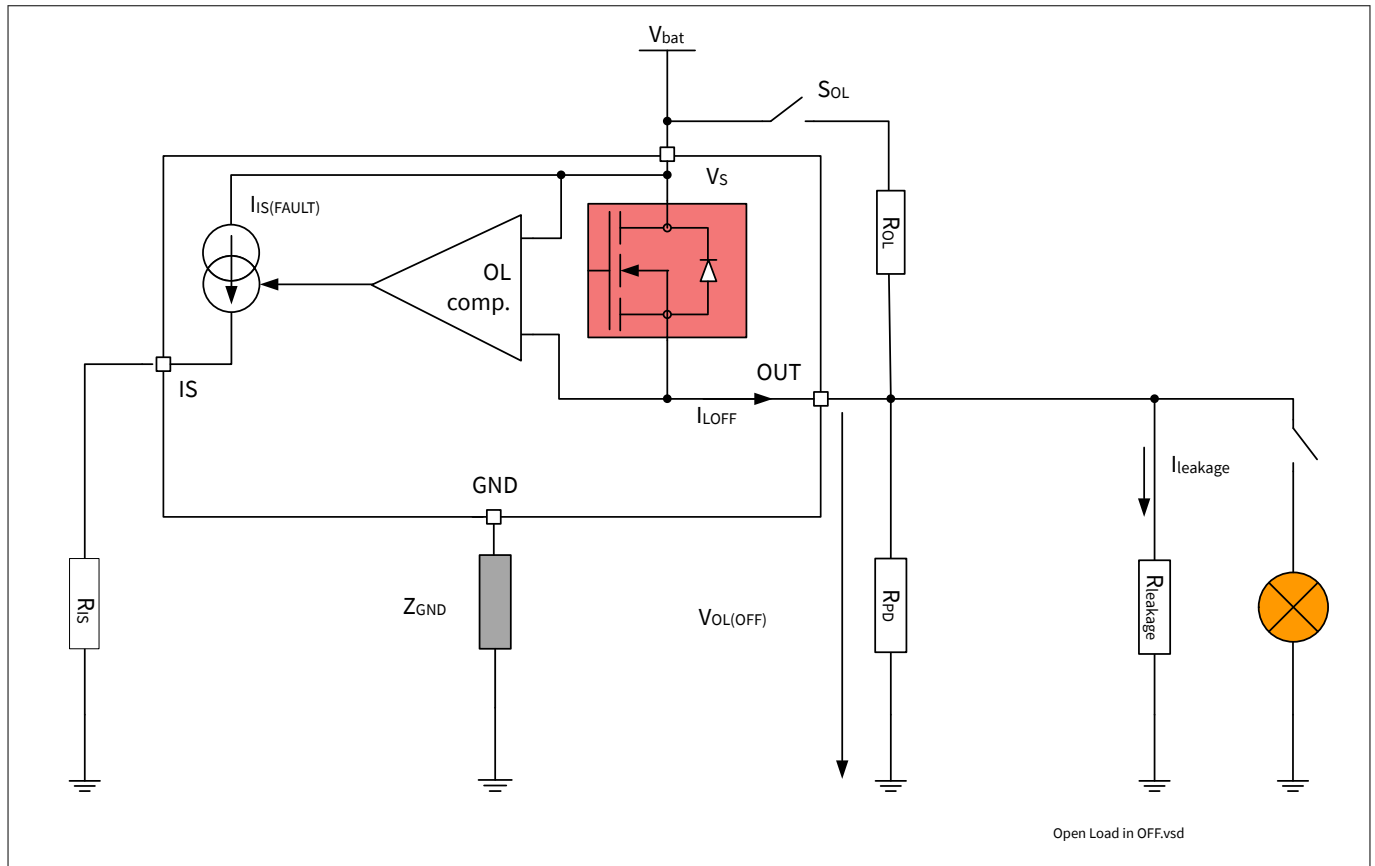
Figure 24 Current sense ratio for low currents

### 7.3.3.2 Open load in OFF diagnostic

For open load diagnosis in OFF-state, an external output pull-up resistor ( $R_{OL}$ ) is recommended. For the calculation of pull-up resistor value, the leakage currents and the open load threshold voltage  $V_{OL(OFF)}$  have to be taken into account. [Figure 25](#) gives a sketch of the situation.  $I_{leakage}$  defines the leakage current in the complete system, including  $I_{L(OFF)}$  (see [Chapter 5.5](#)) and external leakages, e.g. due to humidity, corrosion, etc... in the application.

To reduce the stand-by current of the system, an open load resistor switch  $S_{OL}$  is recommended. If the channel x is OFF, the output is no longer pulled down by the load and  $V_{OUT}$  voltage rises to nearly  $V_S$ . This is recognized by the device as an open load. The voltage threshold is given by  $V_{OL(OFF)}$ . In that case, the SENSE signal is switched to the  $I_{IS(FAULT)}$ .

An additional RPD resistor can be used to pull  $V_{OUT}$  to 0 V. Otherwise, the OUT pin is floating. This resistor can be used as well for short circuit to battery detection, see [Chapter 7.3.4](#)



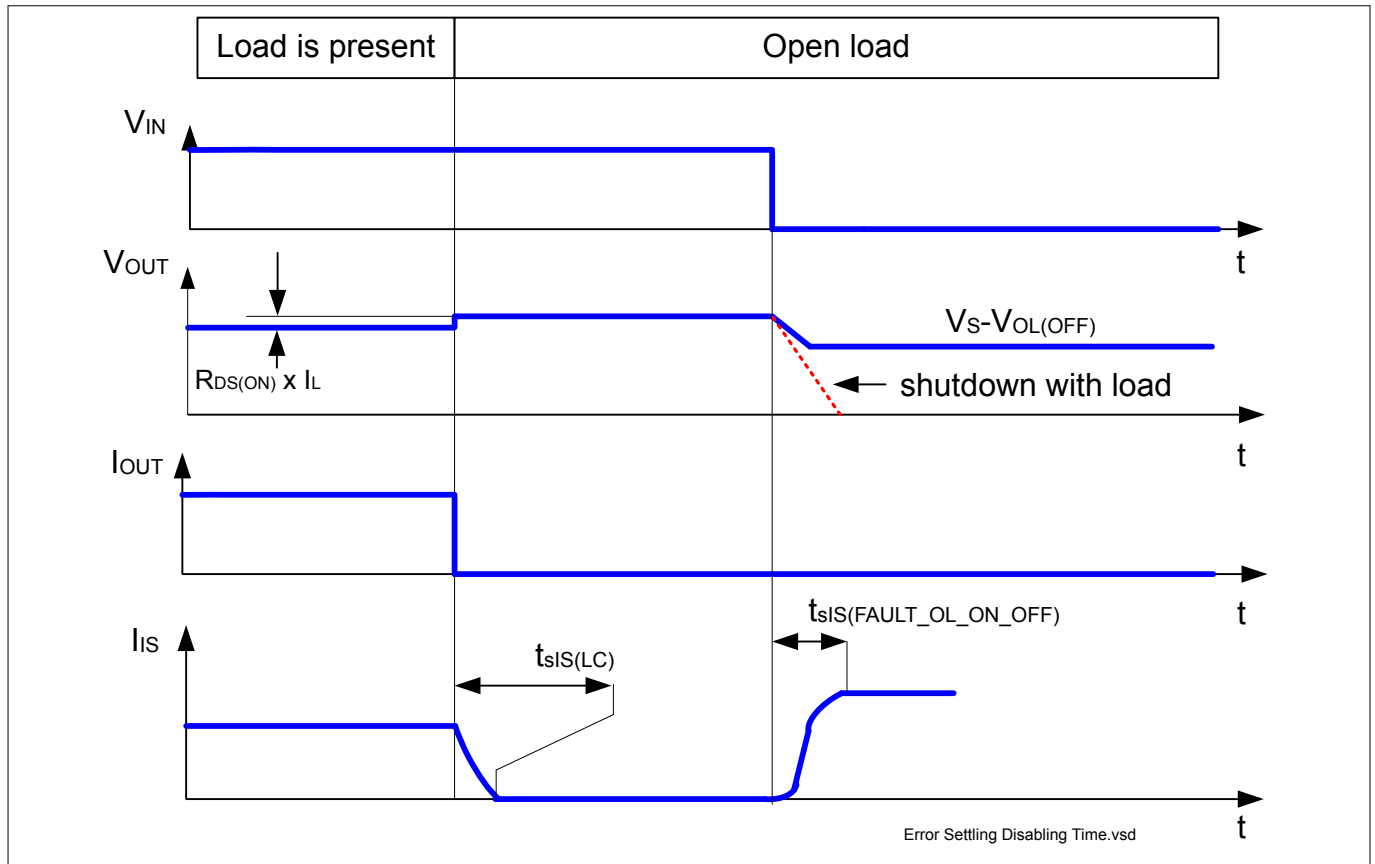
**Figure 25**      **Open load detection in OFF electrical equivalent circuit**

### 7.3.3.3 Open load diagnostic timing

**Figure 26** shows the timing during either Open Load in ON or OFF condition when the DEN pin is HIGH. Please note that a delay  $t_{SIS(FAULT\_OL\_OFF)}$  has to be respected after the falling edge of the input, when applying an open load in OFF diagnosis request, otherwise the diagnosis can be wrong.



## Diagnostic functions

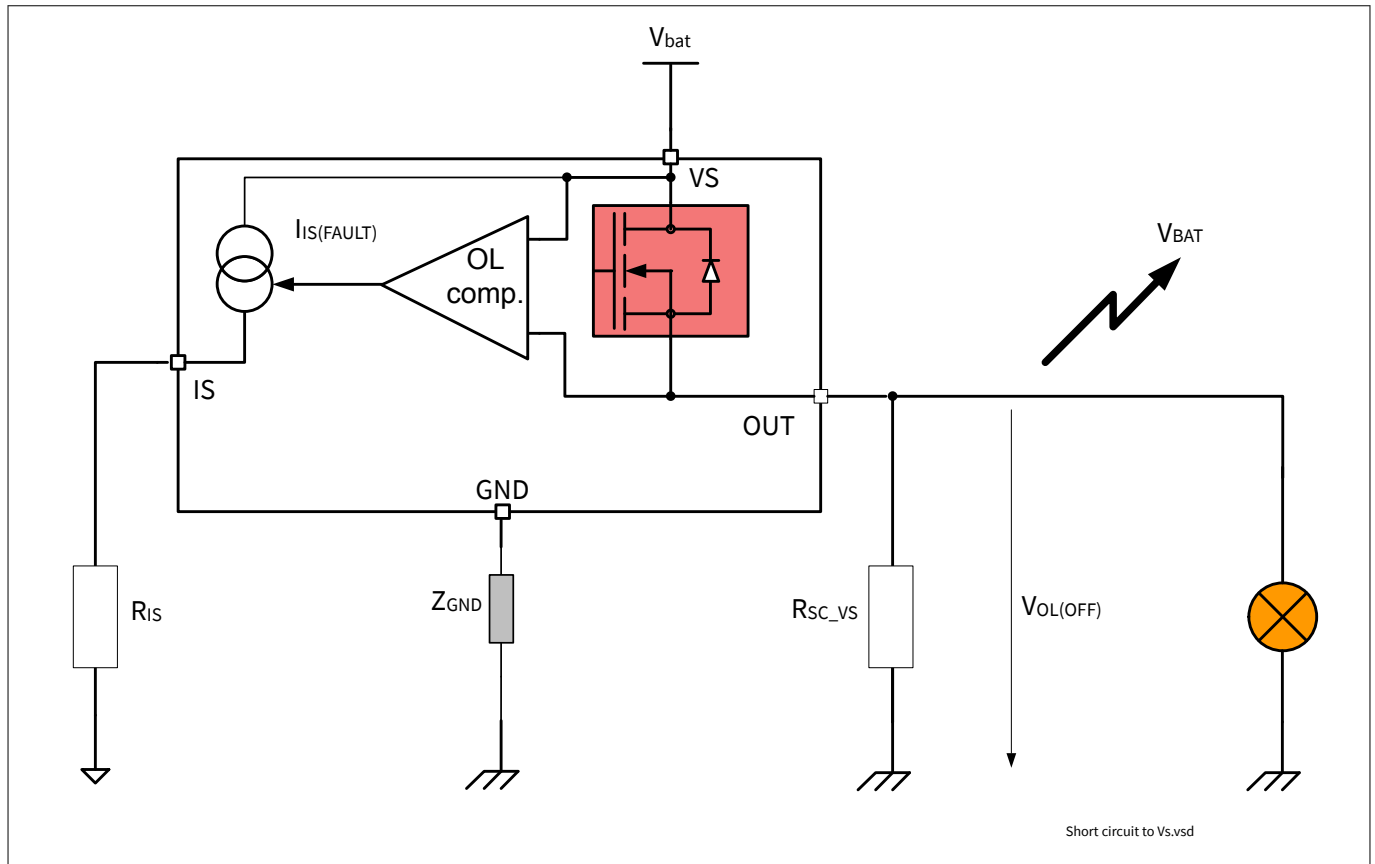


**Figure 26** Sense signal in open load timing

### 7.3.4 SENSE signal in short circuit to $V_S$

In case of a short circuit between the OUTput-pin and the  $V_S$  pin, all or portion (depending on the short circuit impedance) of the load current will flow through the short circuit. As a result, a lower current compared to the normal operation will flow through the DMOS of the BTT6200-4ESA, which can be recognized at the current sense signal. The open load at OFF detection circuitry can also be used to distinguish a short circuit to  $V_S$ . In that case, an external resistor to ground  $R_{SC\_VS}$  is required. [Figure 27](#) gives a sketch of the situation.

## Diagnostic functions



**Figure 27** Short circuit to battery detection in OFF electrical equivalent circuit

### 7.3.5 SENSE signal in case of overload

An overload condition is defined by a current flowing out of the DMOS reaching the current limitation and / or the absolute dynamic temperature swing  $T_{J(SW)}$  is reached, and / or the junction temperature reaches the thermal shutdown temperature  $T_{J(SC)}$ . Please refer to [Chapter 6.5](#) for details.

In that case, the SENSE signal given is by  $I_{IS(FAULT)}$  when the diagnostic is selected.

The device has a thermal latch behavior, such that when the overtemperature or the exceed dynamic temperature condition has disappeared, the DMOS is reactivated only when the IN is toggled LOW to HIGH. If the DEN pin is activated, and DSEL pin is selected to the correct channel, the SENSE follows the output stage. If no reset of the latch occurs, the device remains in the latching phase and  $I_{IS(FAULT)}$  at the IS pin, even though the DMOS is OFF.

### 7.3.6 SENSE signal in case of inverse current

In the case of inverse current, the sense signal of the affected channel will indicate open load in OFF state and indicate open load in ON state. The unaffected channels indicate normal behavior as long as the  $I_{INV}$  current does not exceed the maximum value specified in [Chapter 5.4](#).

## Diagnostic functions

### 7.4 Electrical characteristics diagnostic function

**Table 10** Electrical characteristics: Diagnostics

$V_S = 8\text{ V}$  to  $36\text{ V}$ ,  $T_J = -40^\circ\text{C}$  to  $150^\circ\text{C}$  (unless otherwise specified).

Typical values are given at  $V_S = 28\text{ V}$ ,  $T_J = 25^\circ\text{C}$

| Parameter                                       | Symbol                    | Values |      |      | Unit          | Note or Test Condition                                                                                                                                   | Number  |
|-------------------------------------------------|---------------------------|--------|------|------|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|---------|
|                                                 |                           | Min.   | Typ. | Max. |               |                                                                                                                                                          |         |
| Load condition threshold for diagnostic         |                           |        |      |      |               |                                                                                                                                                          |         |
| Open load detection threshold in OFF state      | $V_S - V_{OL(OFF)}$       | 4      | –    | 6    | V             | <sup>22)</sup> $V_{IN} = 0\text{ V}$<br>$V_{DEN} = 4.5\text{ V}$<br>See <b>Figure 26</b>                                                                 | P_7.5.1 |
| Open load detection threshold in ON state       | $I_{L(OL)}$               | 5      | –    | 15   | mA            | $V_{IN} = V_{DEN} = 4.5\text{ V}$<br>$I_{IS(OL)} = 33\text{ }\mu\text{A}$<br>See <b>Figure 24</b><br>See <b>Chapter 9.4</b>                              | P_7.5.2 |
| Sense pin                                       |                           |        |      |      |               |                                                                                                                                                          |         |
| IS pin leakage current when sense is disabled   | $I_{IS\_DIS}$             | –      | 0.02 | 1    | $\mu\text{A}$ | <sup>22)</sup> $V_{IN} = 4.5\text{ V}$<br>$V_{DEN} = 0\text{ V}$<br>$I_L = I_{L4} = \text{A}$                                                            | P_7.5.4 |
| Sense signal saturation voltage                 | $V_S - V_{IS}$<br>(RANGE) | 1      | –    | 3.5  | V             | $V_{IN} = 0\text{ V}$<br>$V_{OUT} = V_S > 10\text{ V}$<br>$V_{DEN} = 4.5\text{ V}$<br>$I_{IS} = 6\text{ mA}$<br>See <b>Chapter 9.4</b>                   | P_7.5.6 |
| Sense signal maximum current in fault condition | $I_{IS(FAULT)}$           | 6      | 15   | 35   | mA            | $V_{IS} = V_{IN} = V_{DSEL} = 0\text{ V}$<br>$V_{OUT} = V_S > 10\text{ V}$<br>$V_{DEN} = 4.5\text{ V}$<br>See <b>Figure 20</b><br>See <b>Chapter 9.4</b> | P_7.5.7 |
| Sense pin maximum voltage VS to IS              | $V_{IS(AZ)}$              | 65     | 70   | 75   | V             | $I_{IS} = 5\text{ mA}$<br>See <b>Figure 20</b>                                                                                                           | P_7.5.3 |

#### Current sense ratio signal in the nominal area, stable load current condition

<sup>22)</sup> DSEL pin select channel 0 only.

## Diagnostic functions

**Table 10 Electrical characteristics: Diagnostics (continued)**

$V_S = 8\text{ V}$  to  $36\text{ V}$ ,  $T_J = -40^\circ\text{C}$  to  $150^\circ\text{C}$  (unless otherwise specified).

Typical values are given at  $V_S = 28\text{ V}$ ,  $T_J = 25^\circ\text{C}$

| Parameter                                        | Symbol            | Values |      |      | Unit | Note or Test Condition                                                         | Number   |
|--------------------------------------------------|-------------------|--------|------|------|------|--------------------------------------------------------------------------------|----------|
|                                                  |                   | Min.   | Typ. | Max. |      |                                                                                |          |
| Current sense ratio<br>$I_{L0} = 10\text{ mA}$   | $k_{ILIS0}$       | -50%   | 330  | +50% |      | $V_{IN} = 4.5\text{ V}$<br>$V_{DEN} = 4.5\text{ V}$                            | P_7.5.8  |
| Current sense ratio<br>$I_{L1} = 0.05\text{ A}$  | $k_{ILIS1}$       | -40%   | 300  | +40% |      | See <a href="#">Figure 21</a><br>$T_J = -40^\circ\text{C}; 150^\circ\text{C}$  | P_7.5.9  |
| Current sense ratio<br>$I_{L2} = 0.2\text{ A}$   | $k_{ILIS2}$       | -15%   | 300  | +15% |      |                                                                                | P_7.5.10 |
| Current sense ratio<br>$I_{L3} = 0.5\text{ A}$   | $k_{ILIS3}$       | -11%   | 300  | +11% |      |                                                                                | P_7.5.11 |
| Current sense ratio<br>$I_{L4} = 1\text{ A}$     | $k_{ILIS4}$       | -9%    | 300  | +9%  |      |                                                                                | P_7.5.12 |
| $k_{ILIS}$ derating with current and temperature | $\Delta k_{ILIS}$ | -8     | 0    | +8   | %    | <sup>23)</sup> $k_{ILIS3}$ versus $k_{ILIS2}$<br>See <a href="#">Figure 22</a> | P_7.5.17 |

### Diagnostic timing in normal condition

|                                                                                                            |                    |   |   |     |               |                                                                                                                                                                                                                  |          |
|------------------------------------------------------------------------------------------------------------|--------------------|---|---|-----|---------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| Current sense settling time to $k_{ILIS}$ function stable after positive input slope on both INput and DEN | $t_{SIS(ON)}$      | – | – | 150 | $\mu\text{s}$ | <sup>23)</sup> $V_{DEN} = V_{IN} = 0$ to $4.5\text{ V}$<br>$V_S = 28\text{ V}$<br>$R_{IS} = 1.2\text{ k}\Omega$<br>$C_{SENSE} < 100\text{ pF}$<br>$I_L = I_{L3} = 0.5\text{ A}$<br>See <a href="#">Figure 23</a> | P_7.5.18 |
| Current sense settling time with load current stable and transition of the DEN                             | $t_{SIS(ON\_DEN)}$ | – | – | 10  | $\mu\text{s}$ | <sup>22)</sup> $V_{DEN} = 0$ to $4.5\text{ V}$<br>$R_{IS} = 1.2\text{ k}\Omega$<br>$C_{SENSE} < 100\text{ pF}$<br>$I_L = I_{L3} = 0.5\text{ A}$<br>See <a href="#">Figure 23</a>                                 | P_7.5.19 |
| Current sense settling time to $I_{IS}$ stable after positive input slope on current load                  | $t_{SIS(LC)}$      | – | – | 15  | $\mu\text{s}$ | <sup>22)</sup> $V_{DEN} = 4.5\text{ V}$<br>$R_{IS} = 1.2\text{ k}\Omega$<br>$C_{SENSE} < 100\text{ pF}$<br>$I_L = I_{L2} = 0.2\text{ A}$ to $I_{L3} = 0.5\text{ A}$<br>See <a href="#">Figure 23</a>             | P_7.5.20 |

### Diagnostic timing in open load condition

<sup>23)</sup> Not subject to production test, specified by design. Current sense settling time to

<sup>22)</sup> DSEL pin select channel 0 only.

## Diagnostic functions

**Table 10**      **Electrical characteristics: Diagnostics (continued)**

$V_S = 8\text{ V to }36\text{ V}$ ,  $T_J = -40^\circ\text{C to }150^\circ\text{C}$  (unless otherwise specified).

Typical values are given at  $V_S = 28\text{ V}$ ,  $T_J = 25^\circ\text{C}$

| Parameter                                                                                   | Symbol                        | Values |      |      | Unit          | Note or Test Condition                                                                                                                                                                                        | Number   |
|---------------------------------------------------------------------------------------------|-------------------------------|--------|------|------|---------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
|                                                                                             |                               | Min.   | Typ. | Max. |               |                                                                                                                                                                                                               |          |
| Current sense settling time to $I_{IS}$ stable for open load detection in OFF state         | $t_{SIS(FAULT\_OL\_OFF)}$     | –      | –    | 50   | $\mu\text{s}$ | <sup>22)</sup> $V_{DEN} = 0\text{ to }4.5\text{ V}$<br>$R_{IS} = 1.2\text{ k}\Omega$<br>$C_{SENSE} < 100\text{ pF}$<br>$V_{OUT} = V_S = 28\text{ V}$                                                          | P_7.5.22 |
| Current sense settling time to $I_{IS}$ stable for open load detection in ON-OFF transition | $t_{SIS(FAULT\_OL\_ON\_OFF)}$ | –      | 150  | –    | $\mu\text{s}$ | <sup>23)</sup> $V_{IN} = 4.5\text{ to }0\text{ V}$<br>$V_{DEN} = 4.5\text{ V}$<br>$R_{IS} = 1.2\text{ k}\Omega$<br>$C_{SENSE} < 100\text{ pF}$<br>$V_{OUT} = V_S = 28\text{ V}$ See <a href="#">Figure 26</a> | P_7.5.23 |

### Diagnostic timing in overload condition

|                                                                                |                      |   |     |     |               |                                                                                                                                                                                                                      |          |
|--------------------------------------------------------------------------------|----------------------|---|-----|-----|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
| Current sense settling time to $I_{IS}$ stable for overload detection          | $t_{SIS(FAULT)}$     | – | –   | 150 | $\mu\text{s}$ | <sup>24)</sup> <sup>25)</sup> <sup>26)</sup> $V_{IN} = V_{DEN} = 0\text{ to }4.5\text{ V}$<br>$R_{IS} = 1.2\text{ k}\Omega$<br>$C_{SENSE} < 100\text{ pF}$<br>$V_{DS} = 5\text{ V}$<br>See <a href="#">Figure 19</a> | P_7.5.24 |
| Current sense over current blanking time                                       | $t_{SIS(OC\_blank)}$ | – | 350 | –   | $\mu\text{s}$ | $V_{IN} = V_{DEN} = 4.5\text{ V}$<br>$R_{IS} = 1.2\text{ k}\Omega$<br>$C_{SENSE} < 100\text{ pF}$<br>$V_{DS} = 5\text{ V to }0\text{ V}$<br>See <a href="#">Figure 19</a>                                            | P_7.5.32 |
| Diagnostic disable time<br>DEN transition to<br>$I_{IS} < 50\% I_L / k_{ILIS}$ | $t_{SIS(OFF)}$       | – | –   | 20  | $\mu\text{s}$ | $V_{IN} = 4.5\text{ V}$<br>$V_{DEN} = 4.5\text{ V to }0\text{ V}$<br>$R_{IS} = 1.2\text{ k}\Omega$<br>$C_{SENSE} < 100\text{ pF}$<br>$I_L = I_{L3} = 0.5\text{ A}$<br>See <a href="#">Figure 23</a>                  | P_7.5.25 |

<sup>22)</sup> DSEL pin select channel 0 only.

<sup>23)</sup> Not subject to production test, specified by design. Current sense settling time to

<sup>24)</sup> DSEL pin select channel 0 only.

<sup>25)</sup> Test at  $T_J = -40^\circ\text{C}$  only.

<sup>26)</sup> Functional Test only.

## Diagnostic functions

**Table 10**      **Electrical characteristics: Diagnostics (continued)**

$V_S = 8\text{ V}$  to  $36\text{ V}$ ,  $T_J = -40^\circ\text{C}$  to  $150^\circ\text{C}$  (unless otherwise specified).

Typical values are given at  $V_S = 28\text{ V}$ ,  $T_J = 25^\circ\text{C}$

| Parameter                                               | Symbol                | Values |      |      | Unit          | Note or Test Condition                                                                                                                                                                                                                                                                                                                                      | Number   |
|---------------------------------------------------------|-----------------------|--------|------|------|---------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|
|                                                         |                       | Min.   | Typ. | Max. |               |                                                                                                                                                                                                                                                                                                                                                             |          |
| Current sense settling time from one channel to another | $t_{\text{SIS(ChC)}}$ | –      | –    | 20   | $\mu\text{s}$ | $V_{\text{IN0}} = V_{\text{IN1}} = 4.5\text{ V}$<br>$V_{\text{DEN}} = 4.5\text{ V}$<br>$V_{\text{DSEL}} = 0$ to $4.5\text{ V}$<br>$R_{\text{IS}} = 1.2\text{ k}\Omega$<br>$C_{\text{SENSE}} < 100\text{ pF}$<br>$I_{\text{L(OUT0)}} = I_{\text{L3}} = 0.5\text{ A}$<br>$I_{\text{L(OUT1)}} = I_{\text{L2}} = 0.2\text{ A}$<br>See <a href="#">Figure 23</a> | P_7.5.26 |



## Input pins

**Table 11**      **Electrical characteristics: Input pins (continued)**

$V_S = 8\text{ V}$  to  $36\text{ V}$ ,  $T_J = -40^\circ\text{C}$  to  $150^\circ\text{C}$  (unless otherwise specified).

Typical values are given at  $V_S = 28\text{ V}$ ,  $T_J = 25^\circ\text{C}$

| Parameter                | Symbol        | Values |      |      | Unit          | Note or Test Condition                                     | Number  |
|--------------------------|---------------|--------|------|------|---------------|------------------------------------------------------------|---------|
|                          |               | Min.   | Typ. | Max. |               |                                                            |         |
| Input voltage hysteresis | $V_{IN(HYS)}$ | –      | 250  | –    | mV            | <sup>27)</sup> See <a href="#">Chapter 9.5</a>             | P_8.4.3 |
| Low level input current  | $I_{IN(L)}$   | 1      | 10   | 25   | $\mu\text{A}$ | $V_{IN} = 0.8\text{ V}$                                    | P_8.4.4 |
| High level input current | $I_{IN(H)}$   | 2      | 10   | 25   | $\mu\text{A}$ | $V_{IN} = 5.5\text{ V}$<br>See <a href="#">Chapter 9.5</a> | P_8.4.5 |

### DEN Pin

|                                |                |      |     |     |               |                          |          |
|--------------------------------|----------------|------|-----|-----|---------------|--------------------------|----------|
| Low level input voltage range  | $V_{DEN(L)}$   | -0.3 | –   | 0.8 | V             | –                        | P_8.4.6  |
| High level input voltage range | $V_{DEN(H)}$   | 2    | –   | 6   | V             | –                        | P_8.4.7  |
| Input voltage hysteresis       | $V_{DEN(HYS)}$ | –    | 250 | –   | mV            | <sup>27)</sup>           | P_8.4.8  |
| Low level input current        | $I_{DEN(L)}$   | 1    | 10  | 25  | $\mu\text{A}$ | $V_{DEN} = 0.8\text{ V}$ | P_8.4.9  |
| High level input current       | $I_{DEN(H)}$   | 2    | 10  | 25  | $\mu\text{A}$ | $V_{DEN} = 5.5\text{ V}$ | P_8.4.10 |

### DSEL Pins

|                                |                 |      |     |     |               |                           |          |
|--------------------------------|-----------------|------|-----|-----|---------------|---------------------------|----------|
| Low level input voltage range  | $V_{DSEL(L)}$   | -0.3 | –   | 0.8 | V             | –                         | P_8.4.11 |
| High level input voltage range | $V_{DSEL(H)}$   | 2    | –   | 6   | V             | –                         | P_8.4.12 |
| Input voltage hysteresis       | $V_{DSEL(HYS)}$ | –    | 250 | –   | mV            | <sup>27)</sup>            | P_8.4.13 |
| Low level input current        | $I_{DSEL(L)}$   | 1    | 10  | 25  | $\mu\text{A}$ | $V_{DSEL} = 0.8\text{ V}$ | P_8.4.14 |
| High level input current       | $I_{DSEL(H)}$   | 2    | 10  | 25  | $\mu\text{A}$ | $V_{DSEL} = 5.5\text{ V}$ | P_8.4.15 |

<sup>27)</sup> Not subject to production test, specified by design.



## Characterization results

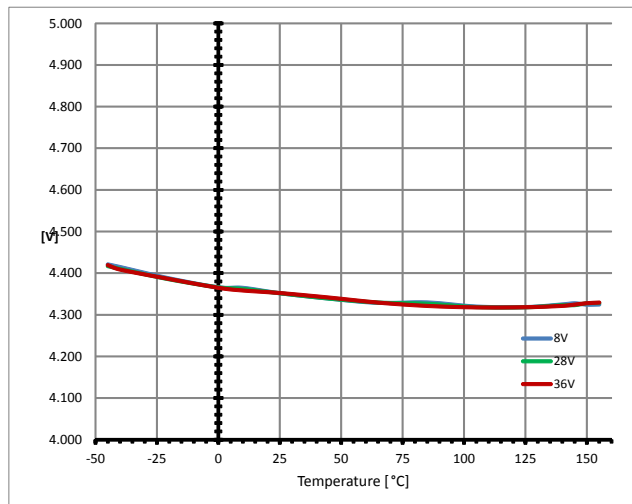
# 9 Characterization results

The characterization has been performed on 3 lots, with 3 devices each. Characterization has been performed at 8 V, 28 V and 36 V overtemperature range.

## 9.1 General product characteristics

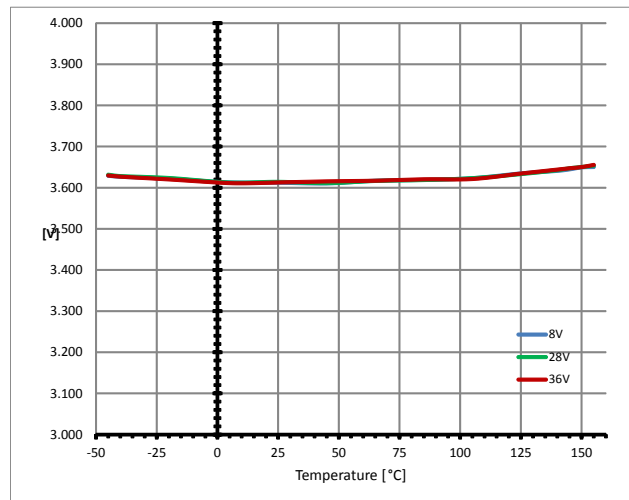
### P\_4.2.3

Minimum functional supply voltage  $V_{S(OP\_MIN)} = f(T_J)$



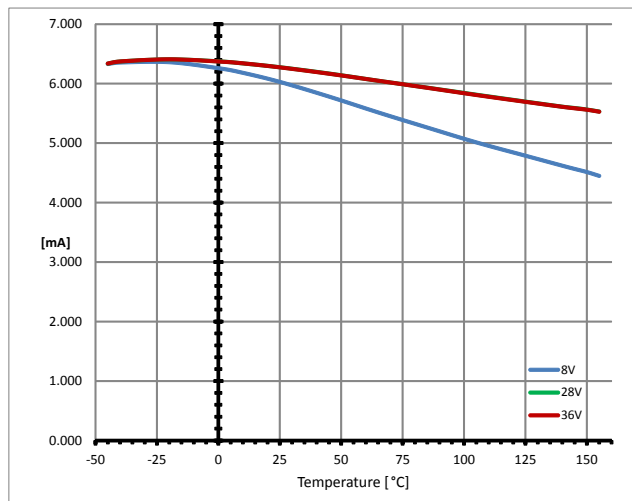
### P\_4.2.4

Undervoltage threshold  $V_{S(UV)} = f(T_J)$



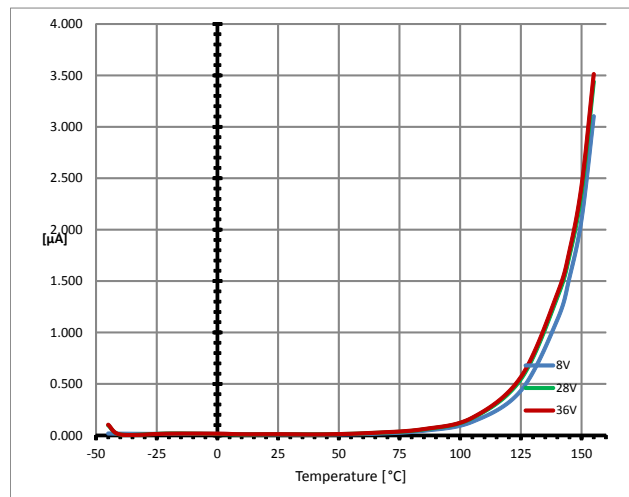
### P\_4.2.6

Current consumption for whole device with load - all channels active  $I_{GND\_2} = f(T_J; V_S)$



### P\_4.2.7, P\_4.2.10

Standby current for whole device with load  $I_{S(OFF)} = f(T_J; V_S)$

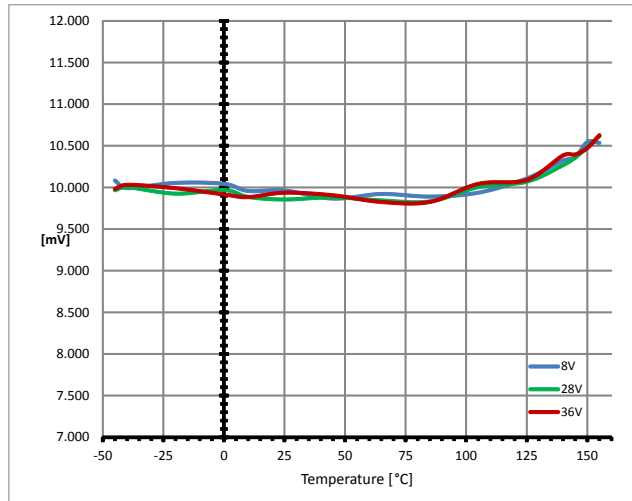


## Characterization results

### 9.2 Power stage

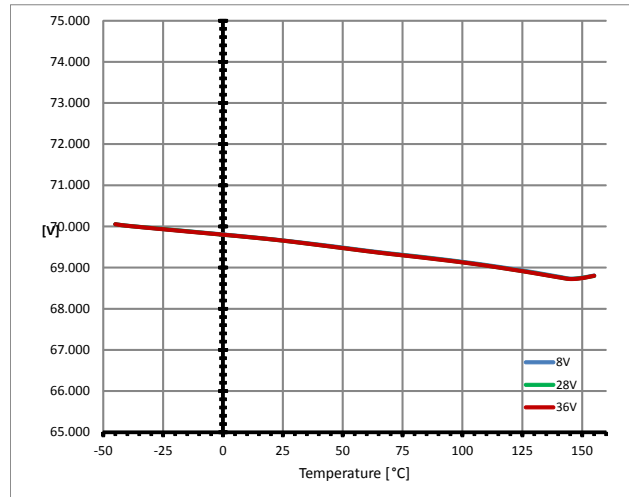
#### P\_5.5.4

Output voltage drop limitation at low load current:  
 $V_{DS(NL)} = f(T_J)$  and  $V_{DS(NL)} = f(V_S)$



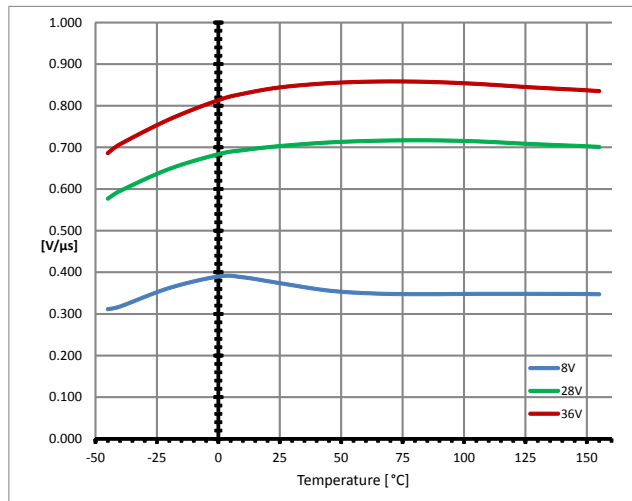
#### P\_5.5.5

Drain to source clamp voltage  $V_{DS(AZ)} = f(T_J)$



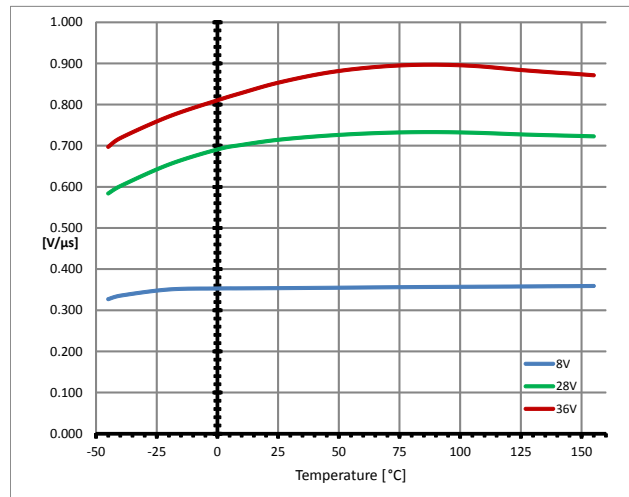
#### P\_5.5.11

Slew rate at turn ON  $dV / dt_{ON} = f(T_J; V_S) = R_L = 47 \Omega$



#### P\_5.5.12

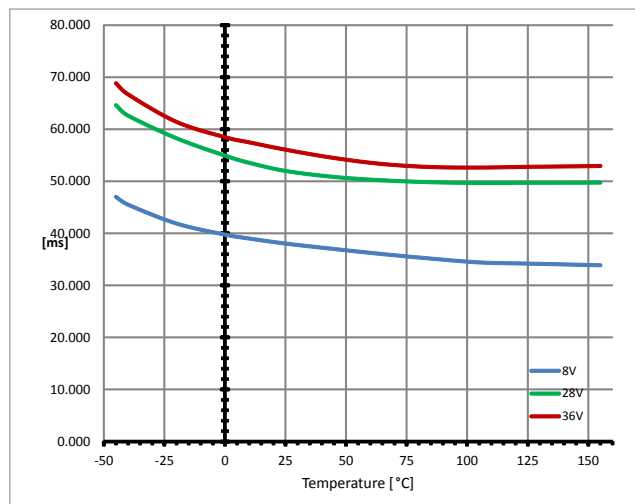
Slew rate at turn OFF  $-dV / dt_{OFF} = f(T_J; V_S) = R_L = 47 \Omega$



## Characterization results

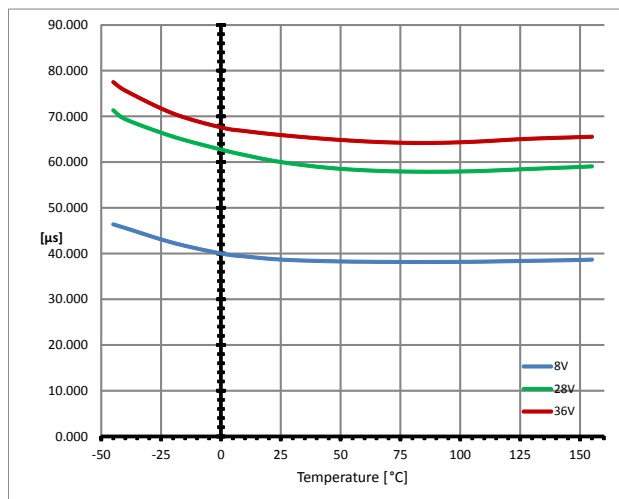
### P\_5.5.14

Turn ON  $t_{ON} = f(T_J; V_S) = R_L = 47 \Omega$



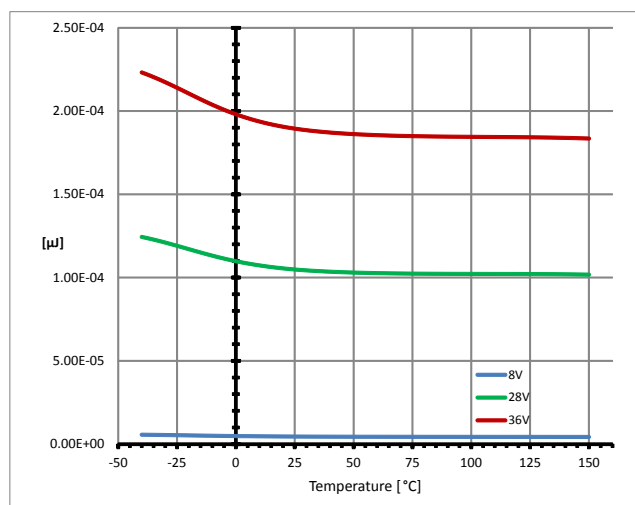
### P\_5.5.15

Turn OFF  $t_{OFF} = f(T_J; V_S) = R_L = 47 \Omega$



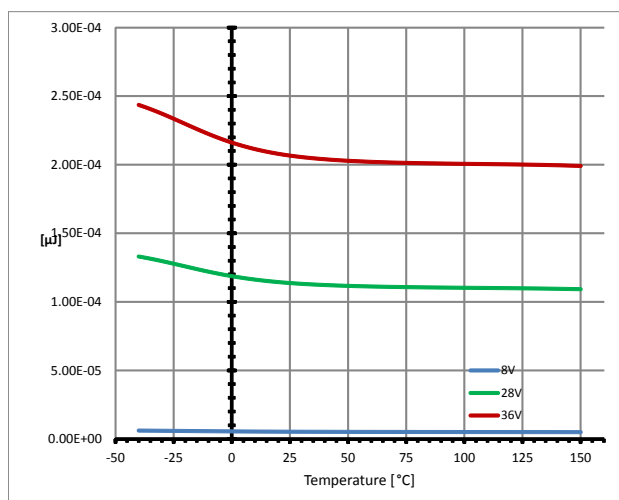
### P\_5.5.19

Switch ON energy  $E_{ON} = f(T_J; V_S) = R_L = 47 \Omega$



### P\_5.5.20

Switch OFF energy  $E_{OFF} = f(T_J; V_S) = R_L = 47 \Omega$

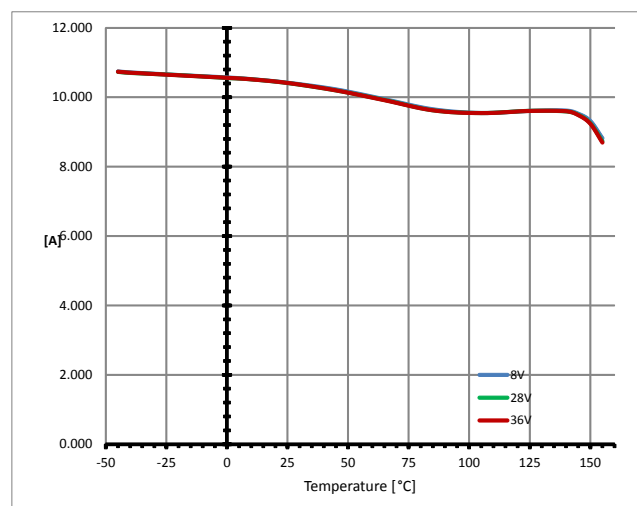


## Characterization results

### 9.3 Protection functions

#### P\_6.6.4

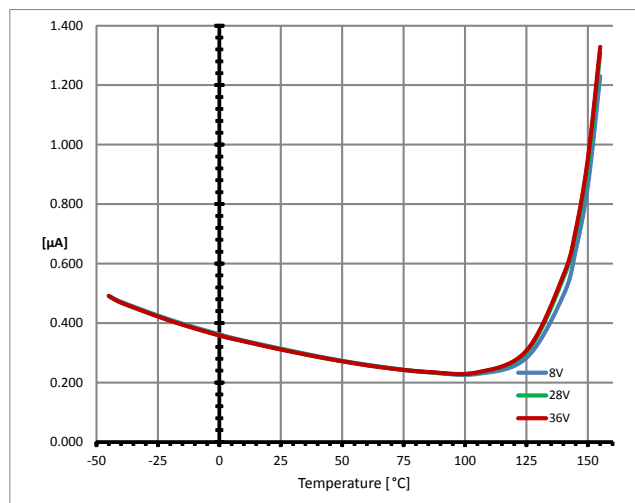
Overload condition in the low voltage area  $I_{L5(SC)} = f(T_J; V_S)$



## Characterization results

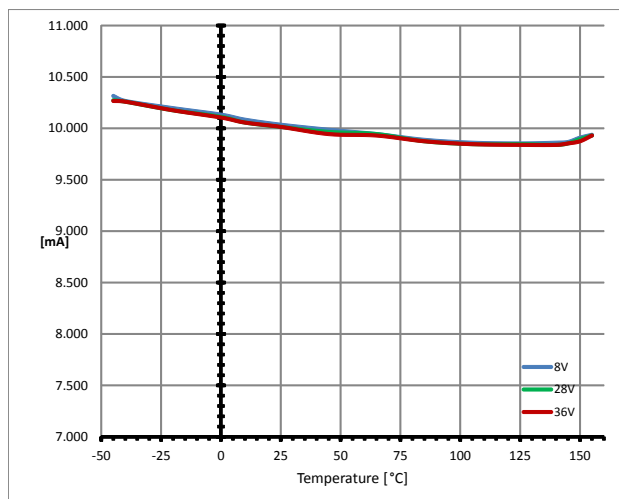
### 9.4 Diagnostic mechanism

Current sense at no load  $I_{IS} = f(T_J; V_S)/I_L = 0$



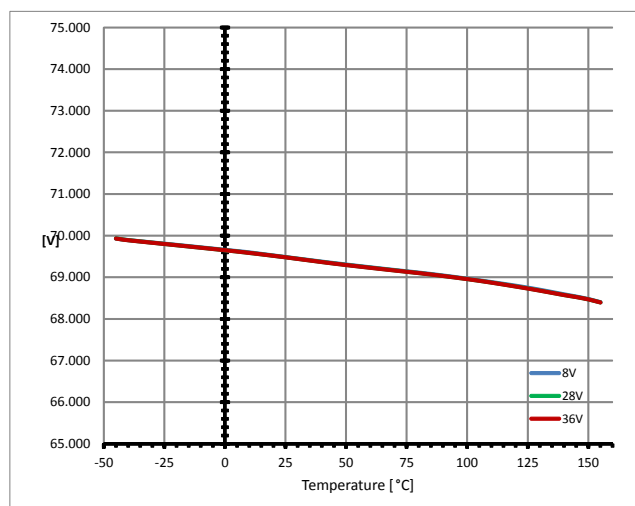
P\_7.5.2

Open load detection ON state threshold  $I_{L(OL)} = f(T_J)$



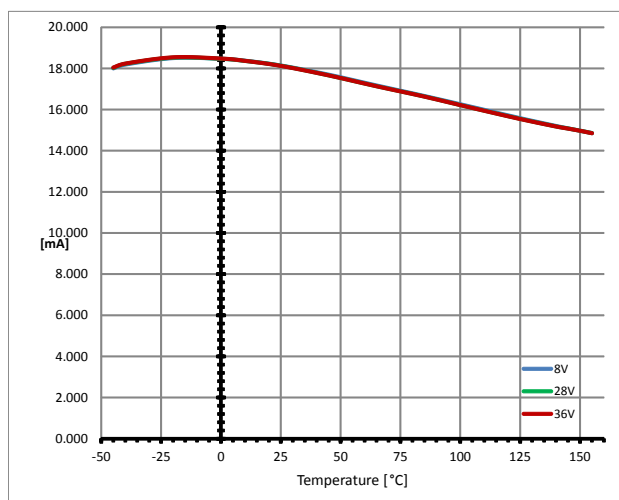
P\_7.5.3

Sense signal at maximum voltage  $V_{IS(AZ)} = f(T_J; V_S)$



P\_7.5.7

Sense signal maximum current in fault condition  $I_{IS(FAULT)} = f(T_J; V_S)$

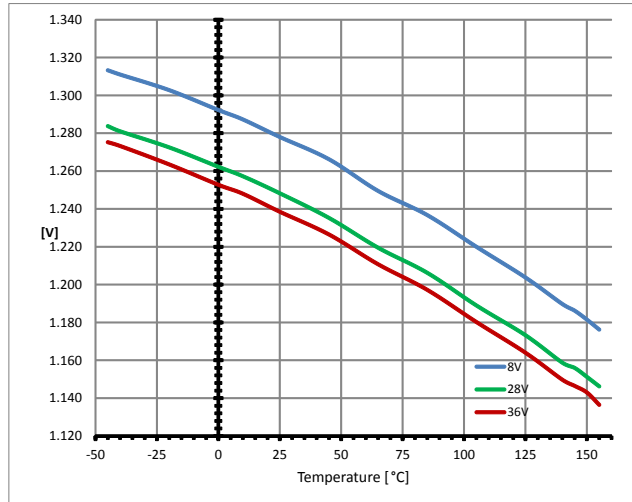


## Characterization results

### 9.5 Input pins

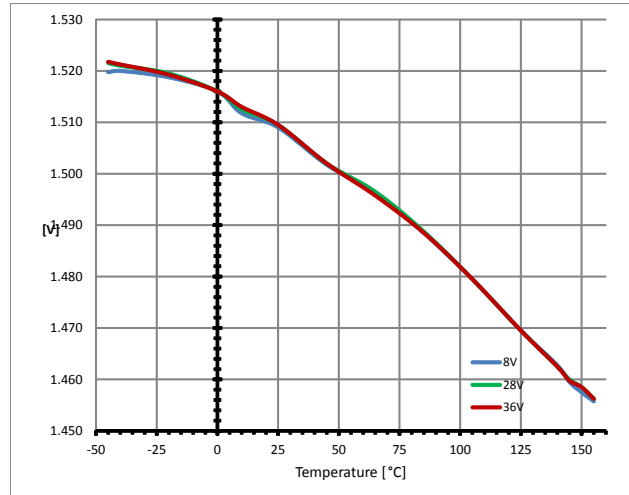
#### P\_8.4.1

Input voltage threshold  $V_{IN(L)} = f(T_J; V_S)$



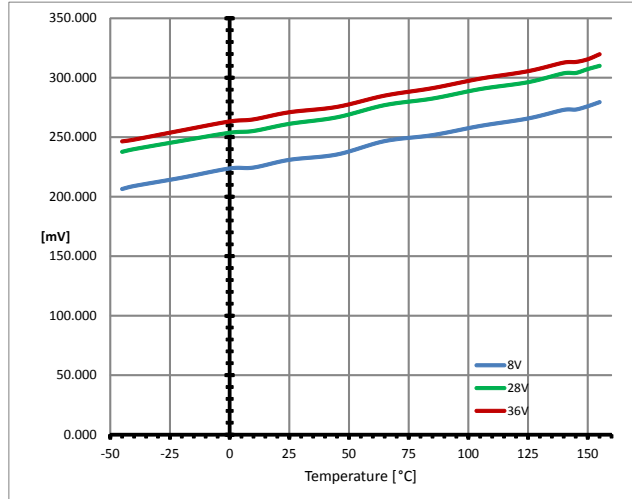
#### P\_8.4.2

Input voltage threshold  $V_{IN(H)} = f(T_J; V_S)$



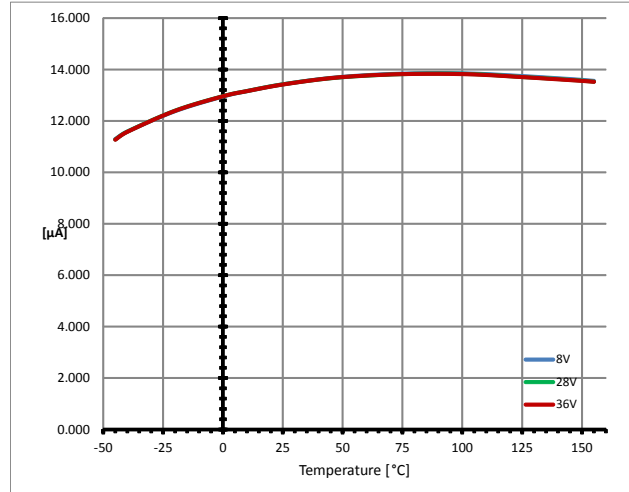
#### P\_8.4.3

Input voltage hysteresis  $V_{IN(HYS)} = f(T_J; V_S)$



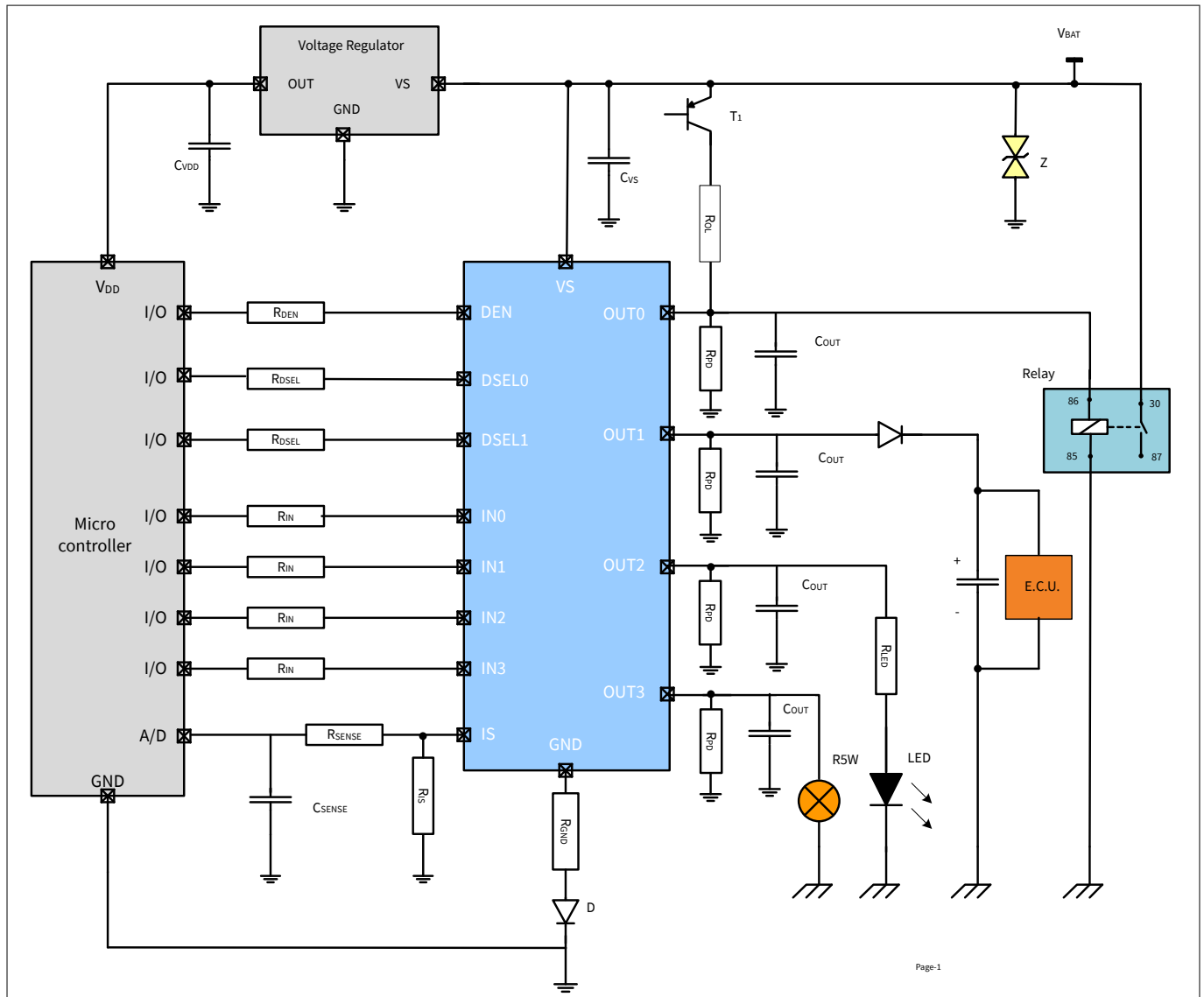
#### P\_8.4.5

Input current high level  $I_{IN(H)} = f(T_J; V_S)$



## 10 Application information

*Note: The following information is given as a hint for the implementation of the device only and shall not be regarded as a description or warranty of a certain functionality, condition or quality of the device.*



**Figure 29**      **Application diagram with BTT6200-4ESA**

*Note: This is a very simplified example of an application circuit. The function must be verified in the real application.*

**Table 12**                      **Bill of material**

| Reference  | Value         | Purpose                                                                                                                             |
|------------|---------------|-------------------------------------------------------------------------------------------------------------------------------------|
| $R_{IN}$   | 10 k $\Omega$ | Protection of the microcontroller during overvoltage, reverse polarity<br>Guarantee BTT6200-4ESA channels OFF during loss of ground |
| $R_{DSEL}$ | 10 k $\Omega$ | Protection of the microcontroller during overvoltage, reverse polarity                                                              |
| $R_{DEN}$  | 10 k $\Omega$ | Protection of the microcontroller during overvoltage, reverse polarity                                                              |

## Application information

**Table 12**                      **Bill of material (continued)**

| Reference   | Value            | Purpose                                                                                                              |
|-------------|------------------|----------------------------------------------------------------------------------------------------------------------|
| $R_{PD}$    | 47 k $\Omega$    | Polarization of the output for short circuit to VS detection. Improve BTT6200-4ESA immunity to electromagnetic noise |
| $R_{OL}$    | 1.5 k $\Omega$   | Polarization of the output during open load in OFF detection                                                         |
| $R_{IS}$    | 1.2 k $\Omega$   | Sense resistor                                                                                                       |
| $R_{SENSE}$ | 10 k $\Omega$    | Overvoltage, reverse polarity, loss of ground. Value to be tuned with microcontroller specification.                 |
| $C_{SENSE}$ | 100 pF           | Sense signal filtering                                                                                               |
| $C_{OUT}$   | 10 nF            | Protection of the device during ESD and BCI                                                                          |
| $R_{LED}$   | 680 $\Omega$     | Overvoltage protection of the LED. Value to be tuned with LED specification                                          |
| $R_{GND}$   | 27 $\Omega$      | Protection of the BTT6200-4ESA during overvoltage                                                                    |
| $D$         | BAS21            | Protection of the BTT6200-4ESA during reverse polarity                                                               |
| $Z$         | 58 V Zener diode | Protection of the device during overvoltage                                                                          |
| $CVS$       | 100 nF           | Filtering of voltage spikes at the battery line                                                                      |
| $T1$        | Dual NPN/PNP     | Switch the battery voltage for open load in OFF diagnostic                                                           |

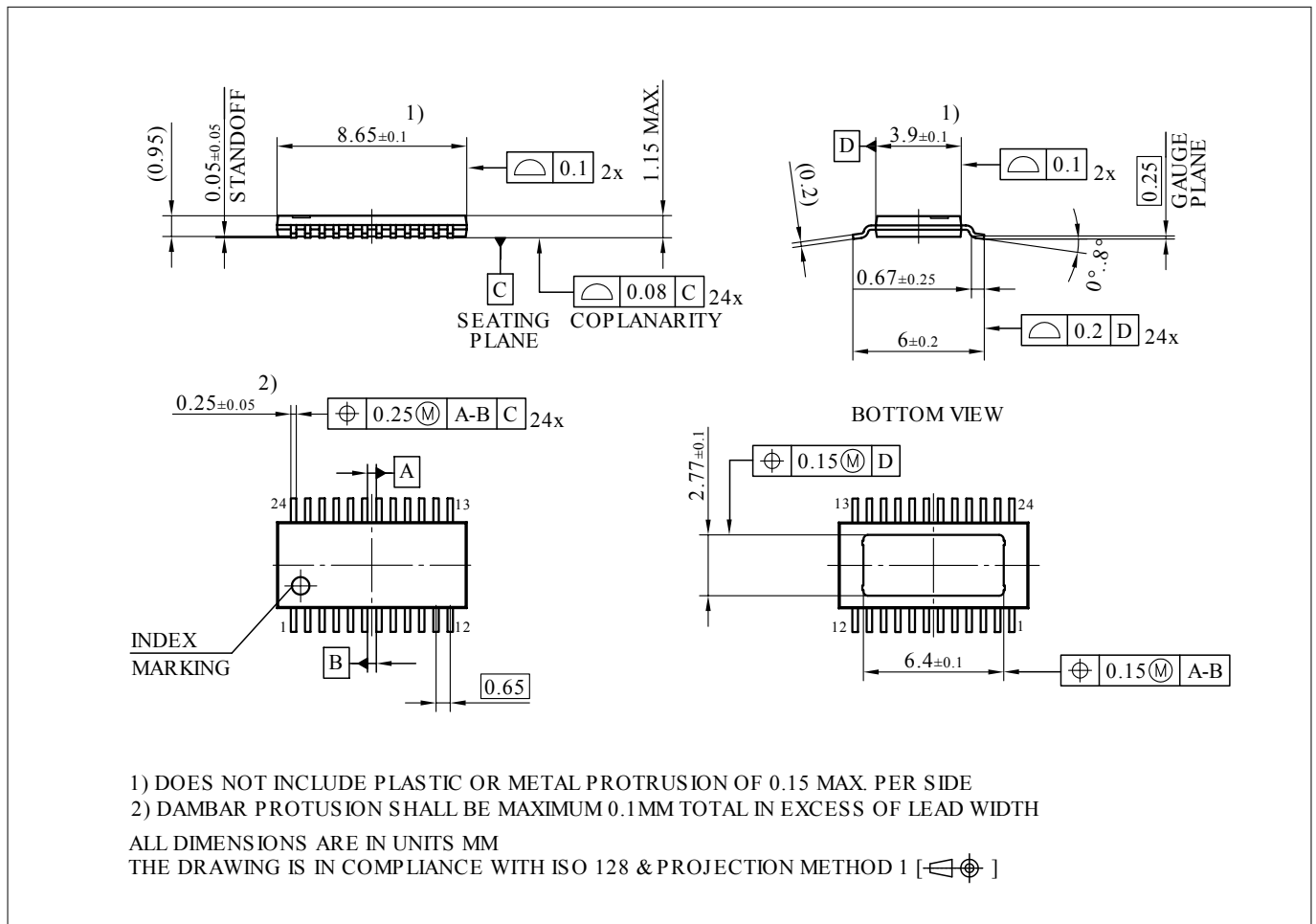
## 10.1 Further application information

- Please contact us to get the pin FMEA
- Existing App. Notes
- For further information you may visit [www.infineon.com](http://www.infineon.com)



**Package outlines**

# **11 Package outlines**



**Figure 30 PG-TSDSO-24 (Plastic dual small outline package)(RoHS-compliant)**

## **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).

## **Legal disclaimer for short-circuit capability**

Infineon disclaims any warranties and liabilities, whether expressed or implied, for any short-circuit failures below the threshold limit.

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**Revision history**

**Revision history**

| <b>Document version</b> | <b>Date of release</b> | <b>Description of changes</b> |
|-------------------------|------------------------|-------------------------------|
| 1.00                    | 2019-03-09             | Datasheet created             |

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