

TLE9201SG

6 A H-Bridge with SPI

Data Sheet

Rev. 1.0, 2014-02-25

Automotive Power

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1 Overview

Features

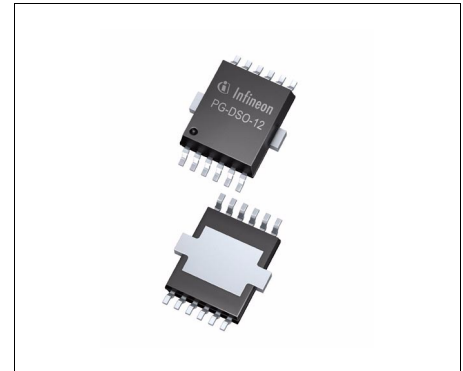
- R_{DSon} of 100 mΩ per switch typ. at $T_j=25\text{ °C}$
- Logic inputs 3.3 V and 5.0 V TTL/CMOS-compatible
- Low standby current
- Chopper current limitation
- Short circuit shut down with latch behavior
- Overtemperature shut down with latch behavior
- VS undervoltage shutdown
- Open load detection in ON and OFF state
- Detailed SPI diagnosis or simple error flag
- Green product (RoHS compliant)
- AEC qualified

Description

The TLE9201SG is a general purpose 6 A H-Bridge, designed for (but not limited to) the control of DC motors or other inductive loads in automotive applications. The outputs can be pulse width modulated at frequencies up to 20kHz. PWM/DIR control reduces the number of PWM capable pins needed on the microcontroller side.

For load currents above the current limitation threshold (8A typ.) the H-Bridge goes into chopper current limitation mode. It is protected against short circuits and overtemperature and provides extensive diagnosis via SPI or basic error feedback via error flag. Open load can be detected when the bridge is disabled or during PWM operation of inductive loads.

The robust PG-DSO-12-17 package provides excellent thermal capabilities due to the thick copper heat slug. Thanks to the protruding edges of the heatslug the package is well suited for automatic optical solder inspection.



PG-DSO-12-17

| Type | Package | Marking |
|-----------|--------------|-----------|
| TLE9201SG | PG-DSO-12-17 | TLE9201SG |

2 Pin Configuration

2.1 Pin Assignment

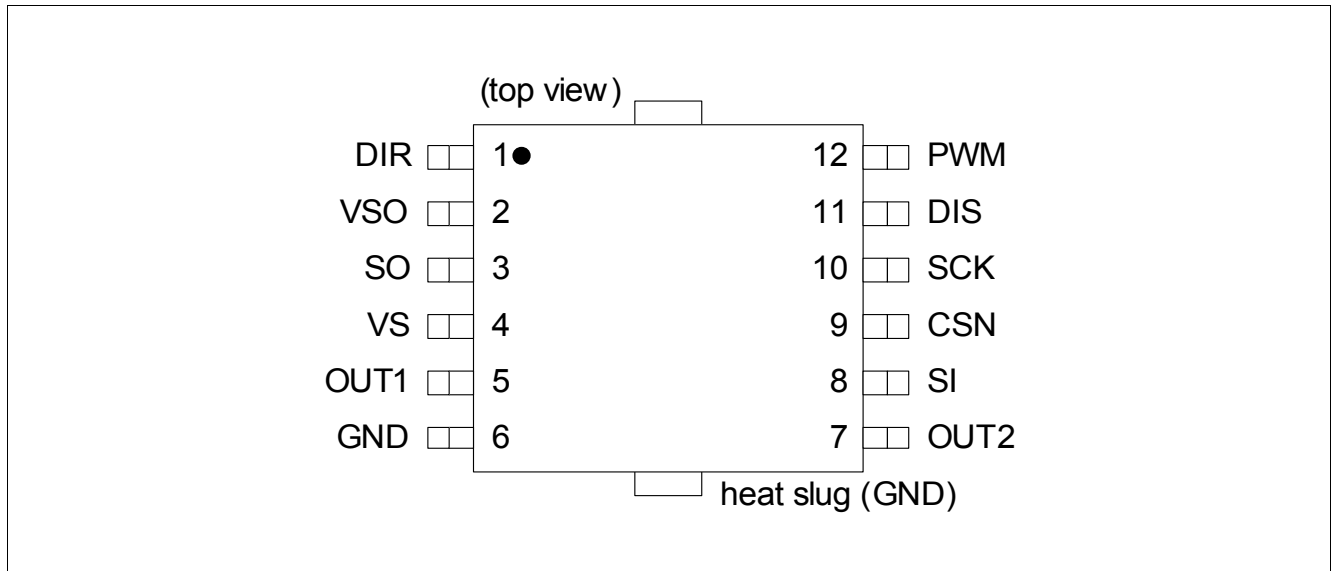


Figure 1 Pin Assignment TLE9201SG

2.2 Pin Definitions and Functions

| Pin | Symbol | Function |
|-----|--------|--|
| 1 | DIR | Direction input to define direction of the motor current |
| 2 | VSO | Supply pin for SO output. Connect to 5V or 3.3V depending on desired logic level |
| 3 | SO | SPI serial output |
| 4 | VS | Supply voltage |
| 5 | OUT1 | Output 1 |
| 6 | GND | Ground |
| 7 | OUT2 | Output 2 |
| 8 | SI | SPI serial input |
| 9 | CSN | SPI chip select (low active) |
| 10 | SCK | SPI clock input |
| 11 | DIS | Disable. Disables the outputs (all MOSFETS off) |
| 12 | PWM | Pulse width modulation input |

2.3 Terms

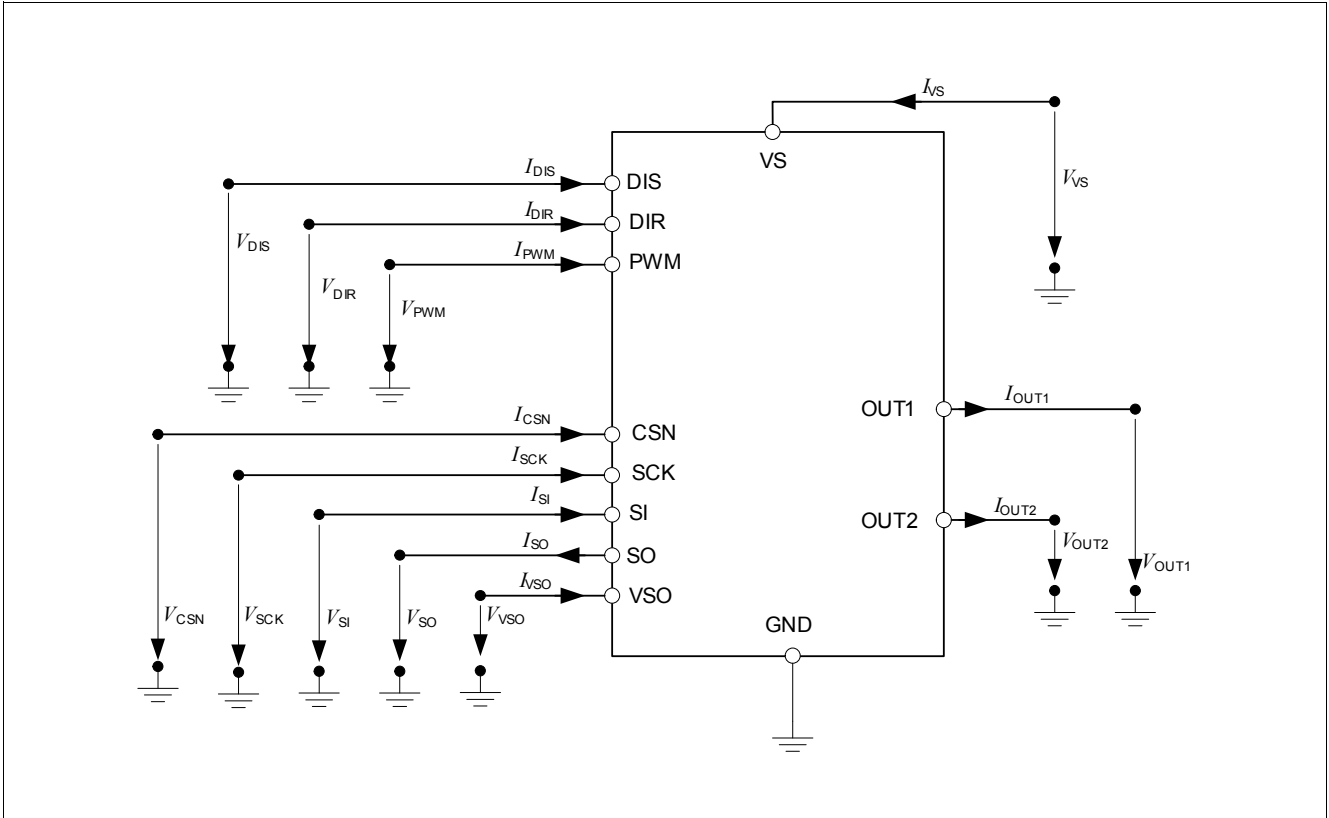


Figure 2 Terms TLE9201SG

3 Block Diagram

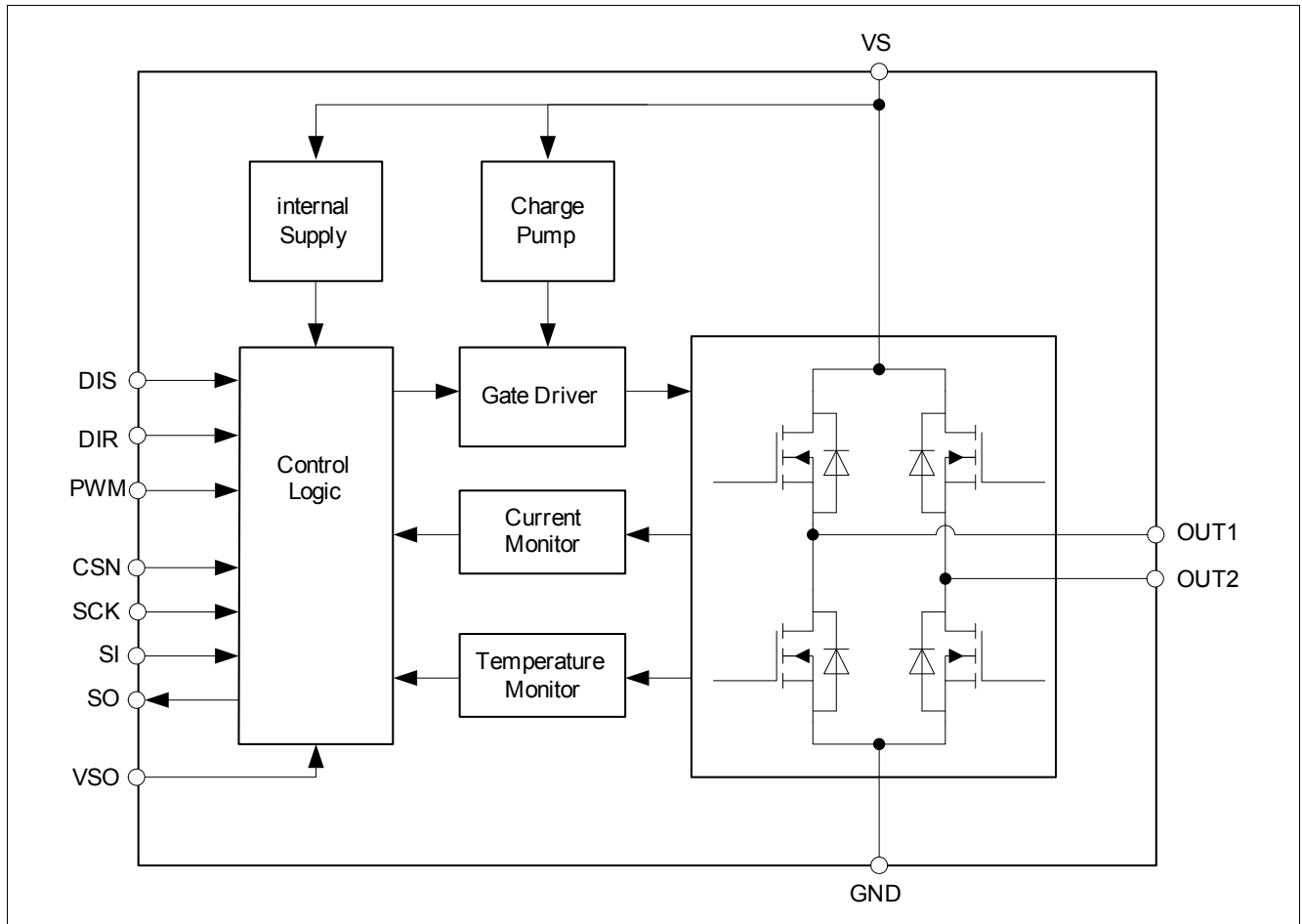


Figure 3 Block Diagram

4 Block Description

4.1 Power Supply

All internal supply voltages are derived from the pin VS. A charge pump provides the gate voltage for the high side switches. The charge pump does not require an external capacitor.

The output buffer of the digital output SO is supplied by the pin VSO. Therefore the output level at SO can be easily configured for 3.3 V or 5 V logic by connecting VSO to the respective voltage.

4.2 Sleep Mode

In order to minimize current consumption during inactive phases the device can be put into sleep mode by pulling the VSO pin to GND. This functionality can also be used to provide a second switch off path for the outputs similar to an enable pin, simply by driving VSO directly from a microcontroller output.

Since VSO is supplying also the output buffer of the SO signal it has to be ensured that the microcontroller output can provide sufficient current. Alternatively an external mosfet or a driver stage could be used to switch the VSO supply voltage. To account for dynamic switching currents it might be advisable to buffer VSO with a small capacitor (see [Figure 7 “Application Example VSO as Enable Input” on Page 24](#)).

Please note that the push pull stage of the SO output provides a current return path to VSO via the bulk diode of the highside mosfet. Therefore it has to be ensured that the voltage at SO never exceeds the voltage at VSO by more than 0.3V.

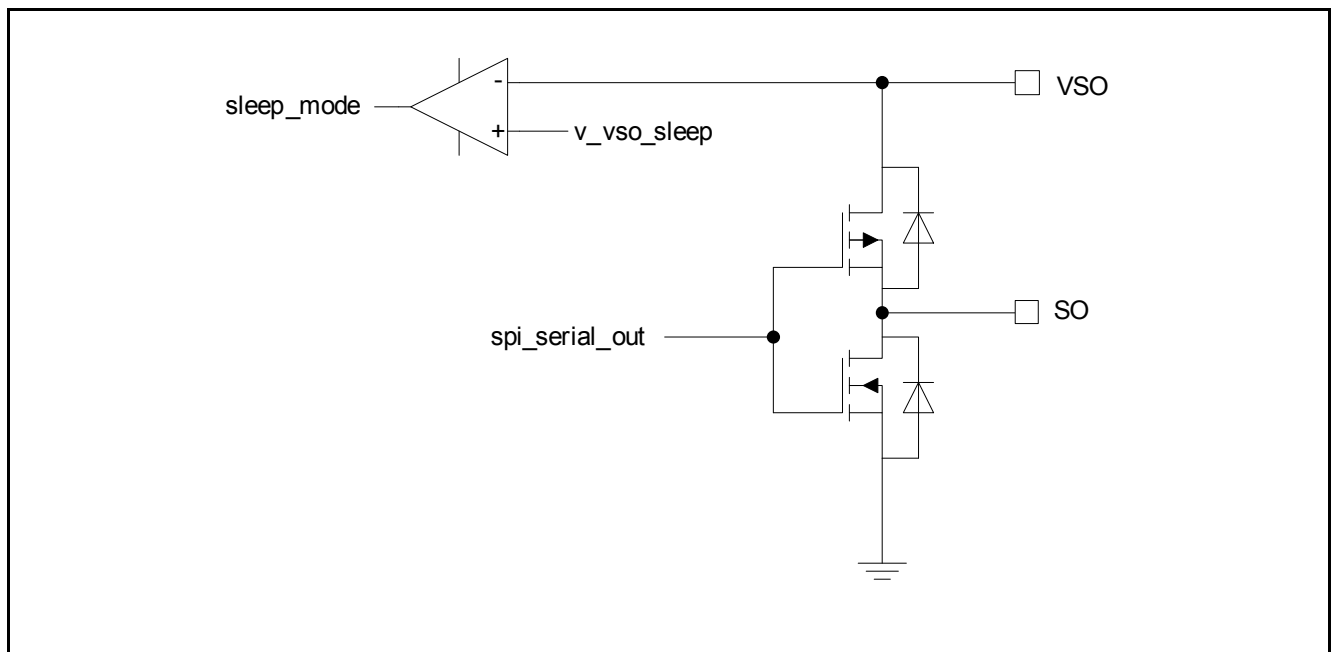


Figure 4-1 SO output buffer

4.3 Output Stages

The output stages consist of four n-channel mosfets in H-bridge configuration. The outputs are protected against short circuits and over temperature.

The bridge is controlled using the inputs PWM and DIR. The signal at DIR is defining the direction of the driven DC motor whereas the PWM signal sets the duty cycle.

The outputs can be set tristate (i.e. high side and low side switches are turned off) by setting DIS to high level.

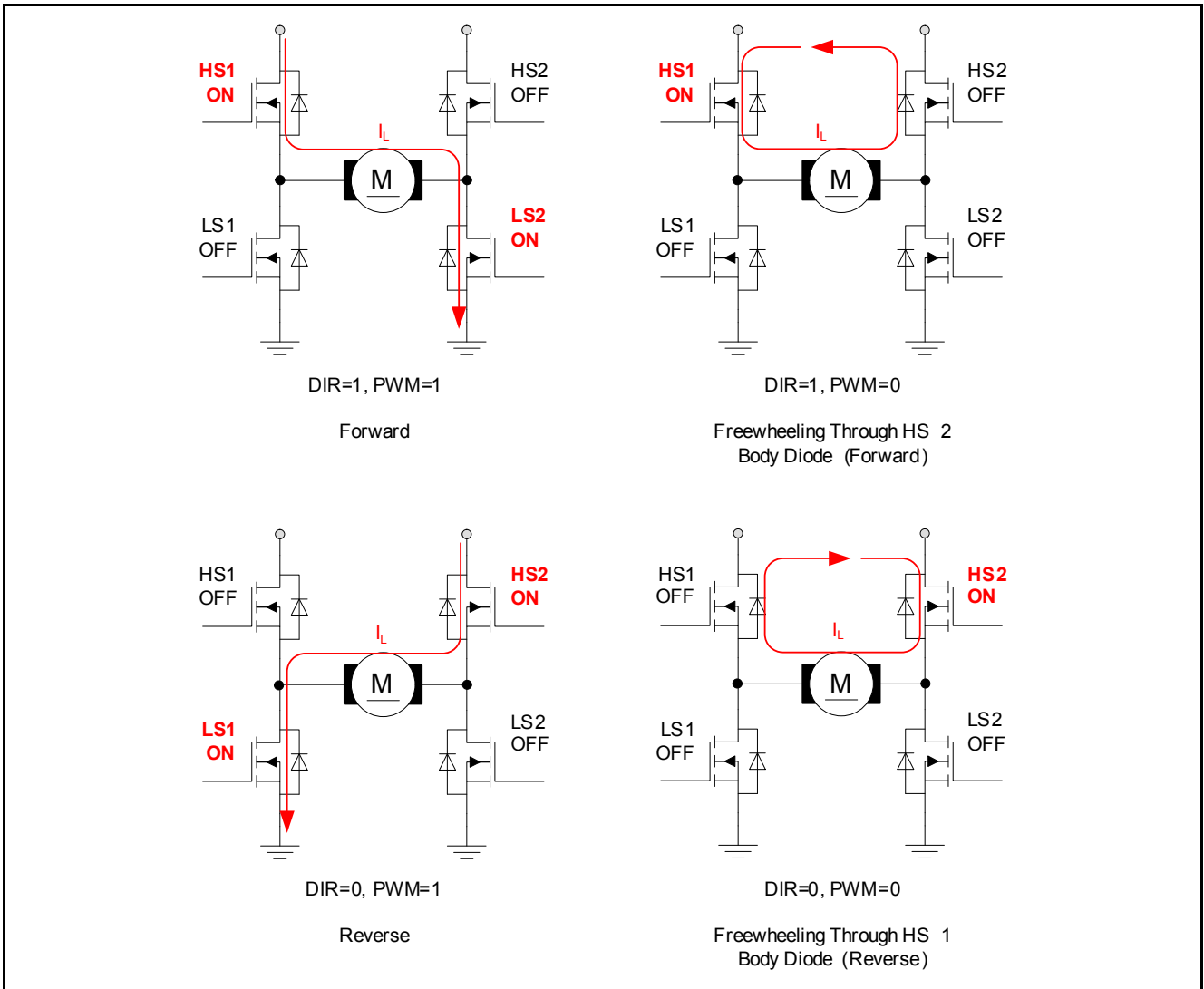


Figure 4-2 Operation Modes

Table 4-1 Output Truth Table

| DIS | PWM | DIR | OUT1 | OUT2 | Comment |
|-----|-----|-----|------|------|------------------------------|
| 1 | X | X | Z | Z | disabled, outputs tristate |
| 0 | 1 | 1 | H | L | forward / clockwise |
| 0 | 1 | 0 | L | H | reverse / counterclockwise |
| 0 | 0 | 1 | H | Z | freewheeling in HS (forward) |
| 0 | 0 | 0 | Z | H | freewheeling in HS (reverse) |

4.4 Protection and Diagnostics

Both output stages of the TLE9201SG are equipped with fault diagnostic functions:

- Short to battery voltage (SCB)
- Short to ground (SCG)
- Open load (OL)
- Over-temperature (OT)

4.5 Current Limitation

To limit the output current a chopper current limitation is integrated. Current measurement for current limitation is done in the high side path.

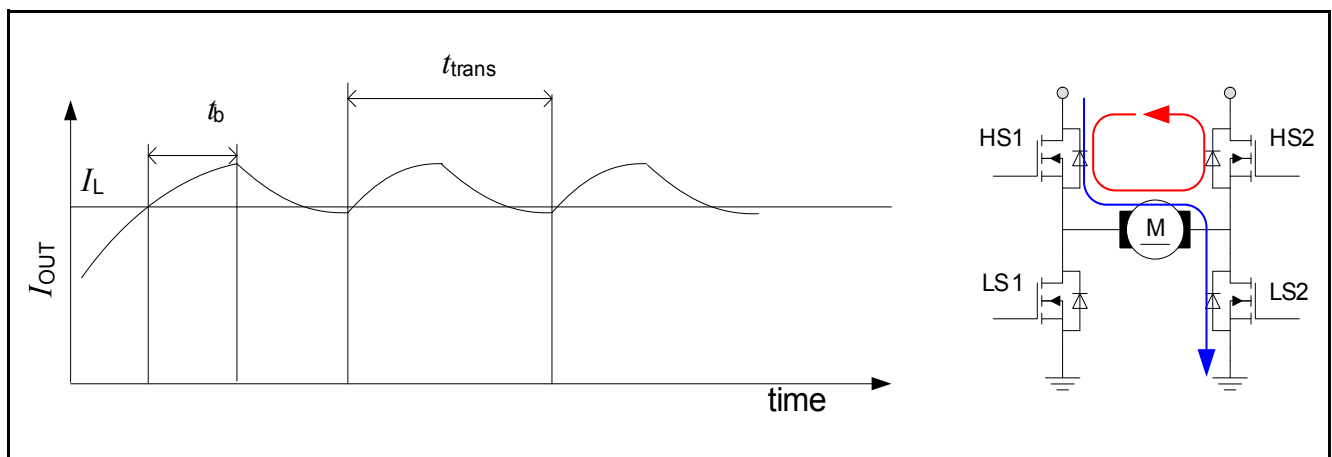


Figure 4-3 Chopper Current Limitation

Figure 4-3 shows the behavior of the current limitation for over current detection in HS1. It applies accordingly also for HS2.

When the current in high-side switch of OUT1 (HS1) exceeds the limit I_L longer than the blanking time t_b , the low side switch of OUT2 (LS2) is switched off, independent of the input signal at PWM. This leads to freewheeling through the bulk diode of HS2 and therefore to a decrease of the load current. As soon as the current falls below I_L , OUT2 is switched back to normal operation, i.e. the outputs follow the inputs according to the truth table. To avoid high switching frequencies in case of low inductive loads the minimum time between two transitions is limited to t_{trans} .

4.6 Short Circuit Detection

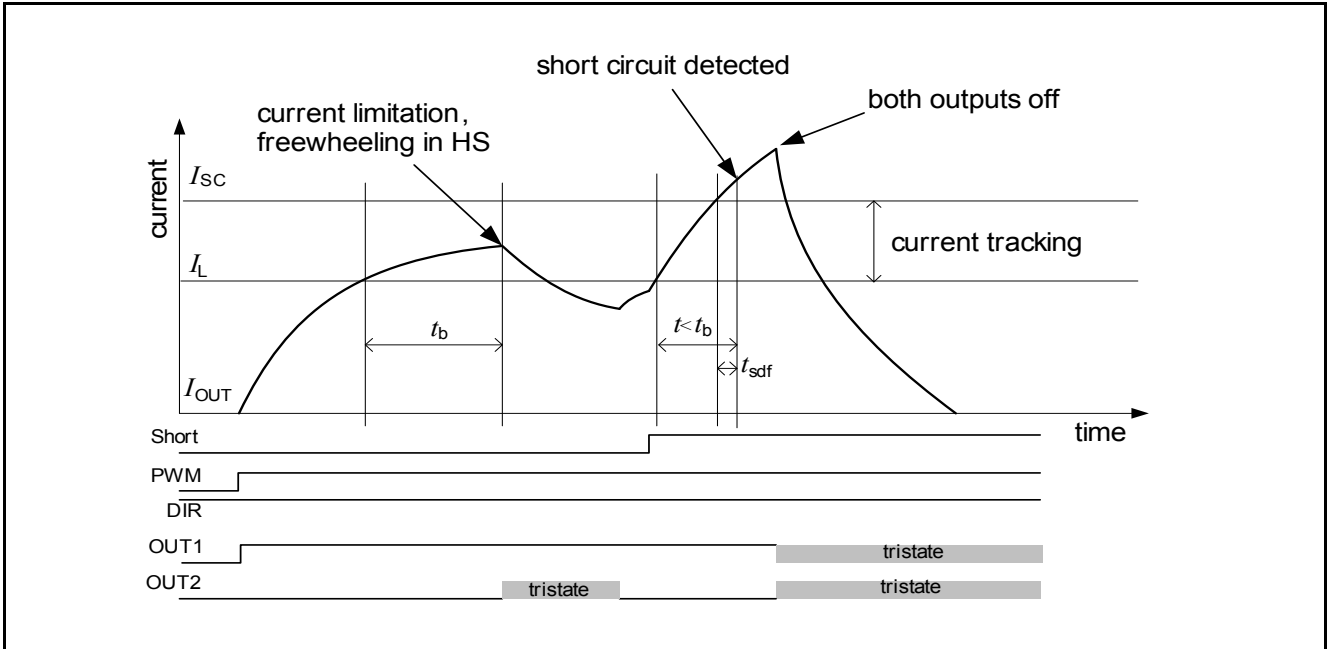


Figure 4-4 Short to Ground Detection

The short circuit to ground detection is activated when the current through one of the high side switches rises over the threshold I_{SC} and remains higher than I_{SC} for at least the filter time t_{sdf} within the blanking time t_b . Both outputs will be switched off and the failure will be reported in the SPI diagnosis register. The outputs can be re-activated by disabling and enabling the bridge via the disable signal DIS, pulling VSO to GND or by a reset command via SPI.

4.7 Short Circuit to Battery

A short circuit to battery is detected in the same way as a short circuit to ground, only in the low side switch instead of the high side switch.

4.8 Short Circuit over Load

Short circuit over load will trigger the short circuit detection either of the high side or the low side switch (whichever is faster).

4.9 Overtemperature

In case of high DC-currents, insufficient cooling or high ambient temperature, the chip temperature may rise above the thermal shut-down temperature T_{jSD} . In that case, all output transistors are turned off. Overtemperature shutdown is latching.

The outputs can be re-activated as soon as the junction temperature has fallen below the switch-on temperature T_{jSO} .

4.10 Undervoltage Shut-Down

If the supply voltage at the VS pins falls below the undervoltage detection threshold V_{UV_OFF} , the outputs are turned off. The undervoltage detection is not latching. That means that as soon as V_S rises above V_{UV_ON} again, the device is returning to normal operation.

4.11 Open Load Detection

4.11.1 Open Load Detection in OFF state

When the bridge is disabled (DIS=high) the open load in OFF detection becomes active. Two diagnostic current sources will then be connected to the outputs, a pull up current source at OUT1 and a pull down current source at OUT2. The pull down current source is stronger than the pull up current source and therefore will pull down OUT1 if a load is present. If no load is present OUT1 will be pulled high by the pull up current source. This is detected by a comparator and reported in the SPI diagnosis register.

Please note that capacitors that might be placed at the outputs for EMC reasons first have to be discharged by the pull down current source at OUT2 for the open load detection to work properly.

Also, if current is flowing through the load at the time of disabling the freewheeling current will force the outputs towards supply voltage V_S . This may lead to an erroneous reporting of open load.

Therefore the first diagnostic reading after disabling should be discarded and a second reading should be taken after the load is deenergized and the output capacitors are discharged completely.

The open load detection can be disabled by setting the OLDIS bit in the CTRL_REG register. This will disconnect the diagnostic current sources and suppress the reporting of open load in the DIA_REG register.

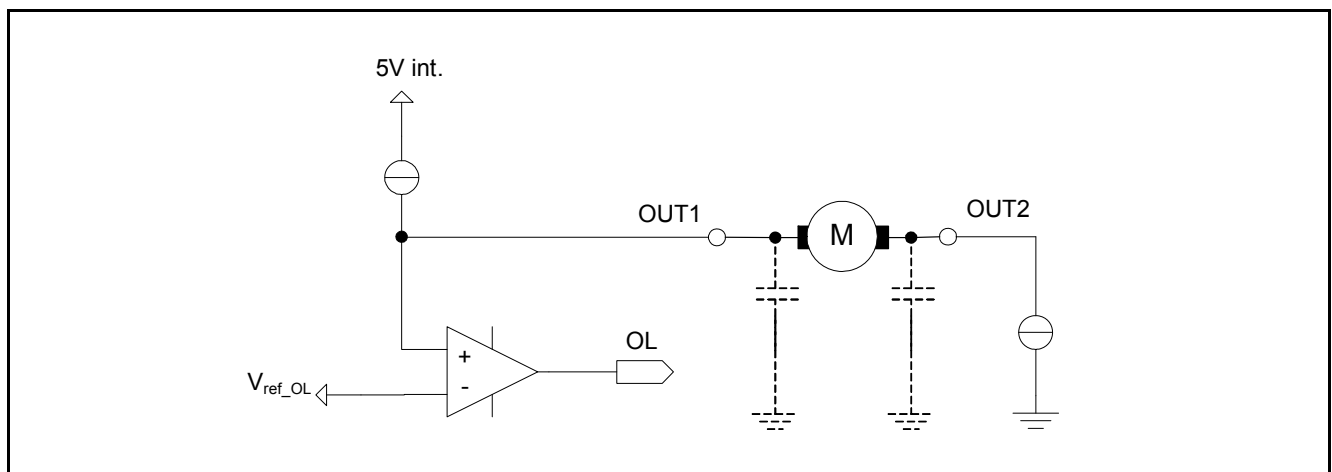


Figure 4-5 Open Load Detection in OFF state

4.11.2 Open Load Detection in ON state

The TLE9201SG contains an open load diagnosis during operation for inductive loads. It evaluates whether freewheeling occurs in the switching phase. In order to avoid inadvertent triggering of the open load diagnosis a failure counter is implemented. There have to be at least 5 occurrences of the internal open load signal (i.e. 5 PWM pulses without freewheeling detected) before open load is reported in the SPI diagnosis register.

Depending on the operation conditions and on external circuitry like the output capacitors it is possible that open load is indicated although the load is present. This might be the case for example during a direction change or for small load currents respectively small PWM duty cycles. Therefore it is recommended to evaluate the open load diagnosis only in known suitable operating conditions and to ignore it otherwise.

The open load diagnosis is not latching.

4.12 Serial Peripheral Interface (SPI)

For diagnosis purposes the TLE9201SG is equipped with a “Serial Peripheral Interface“ (SPI).

The SPI of several TLE9201SGs can be connected in daisy chain configuration in order to save microcontroller interface pins.

The TLE9201SG is configured as a “slave” device. This means that the μ C as the master is providing the chip select (CSN) and clock signal (SCK).

A data transfer on the SPI bus is initiated with a falling edge on CSN and is terminated by a rising edge on CSN. The data on the serial input pin SI is sampled with the falling edge of SCK, the serial data output at SO is determined by the rising clock edge. The data is transferred “MSB first”.

The word length of the SPI is 8 bit. Please note that there is no check for the number of clocks within a SPI frame. Any low pulse at CSN will be regarded as one frame.

4.12.1 Error Flag

Between the falling edge of CSN and the first rising edge of SCK an additional error flag signal is set asynchronously at the SO pin. The error flag signal set to high whenever the output stages are shut down (tristate) due to a failure or due to disabling of the output stages. Additionally the EF signal is OR’ed with the SI input signal. By connecting the SO of one device to the SI of the next device the EF signal can be routed through similar to a SPI daisy chain configuration.

This flag can be used for simple error feedback without SPI communication by connecting SCK and CSN to GND permanently (see [Figure 5 “Application Example H-Bridge with Error Flag” on Page 22](#)).

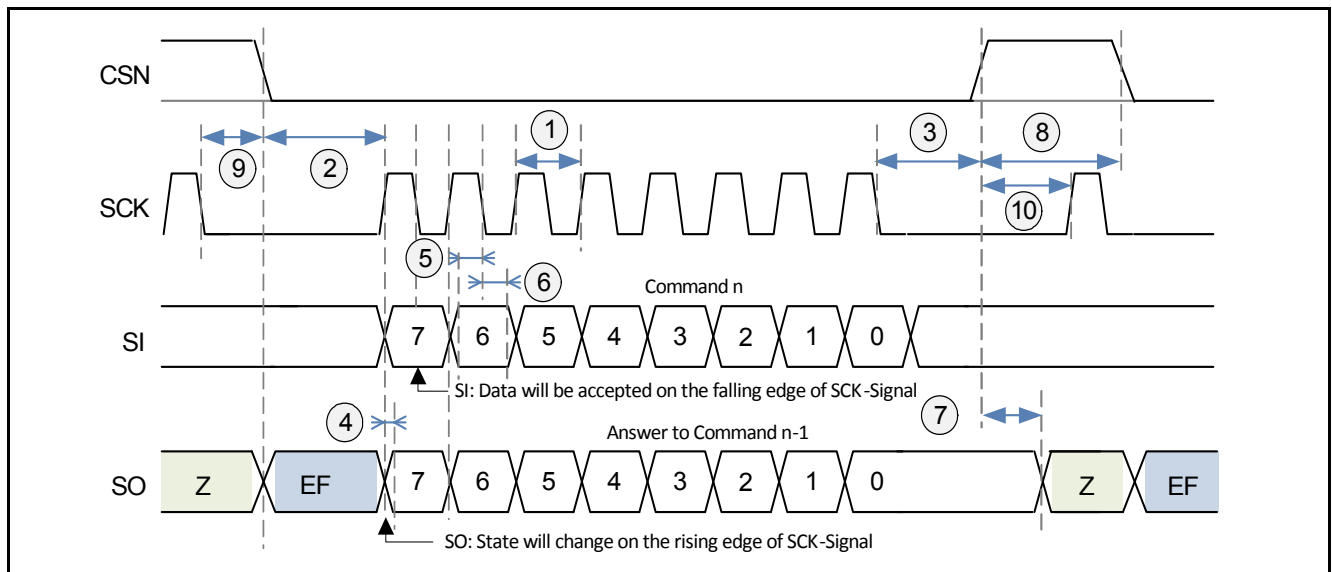


Figure 4-6 SPI Timing Definition (drawing not to scale)

4.12.2 SPI Register Description

The TLE9201SG provides detailed diagnosis and the option to control the outputs via SPI. Following commands are available (x=don't care, d=data):

Table 4-2 SPI Command Set

| Command | Input Byte | Description |
|----------------|------------|--|
| RD_DIA | 000x xxxx | Read Diagnosis Register |
| RES_DIA | 100x xxxx | Reset Diagnosis Register |
| RD_REV | 001x xxxx | Read Device Revision Number |
| RD_CTRL | 011x xxxx | Read Control Register |
| WR_CTRL | 111d dddd | Write Control - sets and returns Control Register values |
| WR_CTRL_RD_DIA | 110d dddd | Write Control and Read Diagnosis- sets Control Register values and returns Diagnosis Register values |

The first SPI response provided after power up is the device revision number (RD_REV). For any unspecified commands the device will respond with the content of the diagnosis register (RD_DIA).

4.12.2.2 Diagnosis Register

Diagnosis Register

| DIA_REG | | Offset | | Reset Value | | | |
|--------------------|----|-----------------|----|-----------------|------|------|------|
| Diagnosis Register | | 00 _H | | DF _H | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| EN | OT | TV | CL | DIA4 | DIA3 | DIA2 | DIA1 |
| r | r | r | r | r | r | r | r |

| Field | Bits | Type | Description |
|-------|------|------|---|
| EN | 7 | r | 1= outputs enabled by low signal on pin DIS 0 = outputs disabled by high signal on pin DIS |
| OT | 6 | r | 0 = overtemperature shutdown |
| TV | 5 | r | Always 0 - used for transmission validation |
| CL | 4 | r | 0 = current limitation active |
| DIA4 | 3 | r | Diagnosis bit 4 |
| DIA3 | 2 | r | Diagnosis bit 3 |
| DIA2 | 1 | r | Diagnosis bit 2 |
| DIA1 | 0 | r | Diagnosis bit 1 |

Diagnosis Truth Table

The short circuit and VS undervoltage diagnosis is coded in the DIA bits according to the following truth table. Together with transmission validation bit TV (always 0) it is ensured that there is always at least one 1->0 change at SO during a valid transmission. Therefore a “stuck at” failure of the SO pin can be detected.

Table 4-3 Encoding of Diagnosis Bits (sorted by hex value, only listed combinations are valid)

| Type | DIA4 | DIA3 | DIA2 | DIA1 | Hex | Comment |
|---|------|------|------|------|-----|-------------|
| No failure | 1 | 1 | 1 | 1 | 0xF | - |
| Short to GND at OUT1 (SCG1) | 1 | 1 | 1 | 0 | 0xE | latched |
| Short to Battery at OUT1 (SCB1) | 1 | 1 | 0 | 1 | 0xD | latched |
| Open Load (OL) | 1 | 1 | 0 | 0 | 0xC | not latched |
| Short to GND at OUT2 (SCG2) | 1 | 0 | 1 | 1 | 0xB | latched |
| Short to GND at OUT1 and OUT2 (SCG1, SCG2) | 1 | 0 | 1 | 0 | 0xA | latched |
| Short to Bat. at OUT1 and short to GND at OUT2 (SCB1, SCG2) | 1 | 0 | 0 | 1 | 0x9 | latched |
| Short to Battery at OUT2 (SCB2) | 0 | 1 | 1 | 1 | 0x7 | latched |
| Short to GND at OUT1 and short to Bat. at OUT2 (SCG1, SCB2) | 0 | 1 | 1 | 0 | 0x6 | latched |
| Short to Battery at OUT1 and OUT2 (SCB1, SCB2) | 0 | 1 | 0 | 1 | 0x5 | latched |
| VS Undervoltage (VS_UV) | 0 | 0 | 1 | 1 | 0x3 | not latched |

Reset Behavior of Diagnosis Register

The diagnosis register is reset by the following events

Table 4-4 Diagnosis Reset Types

| Name | Type | Comment |
|------|----------------|--|
| POR | Power On Reset | Reset due to power up, undervoltage or sleep mode |
| ENR | Enable Reset | Reset due to disabling/enabling of the outputs by DIS pin or bit SEN in CTRL_REG |
| SPIR | SPI Reset | Reset by sending the RES_DIA command via SPI |

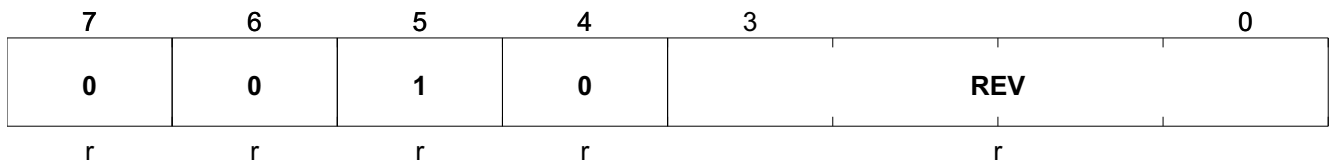
A change of the DIR signal will lead to a reset of current limitation (CL) or open load in on (OL) error messages. The open load in on failure will also be reset automatically if the open load condition no longer persists, i.e. freewheeling is detected for five or more consecutive pulses.

4.12.2.3 Revision Register

The Revision Register contains the device revision corresponding to the mask set.

Revision Register

| | | |
|--------------------------|-----------------------|-----------------------|
| REV_REG | Offset | Reset Value |
| Revision Register | 01_H | 00_H |



| Field | Bits | Type | Description |
|-------|------|------|---|
| 0 | 7 | r | fixed to 0 |
| 0 | 6 | r | fixed to 0 |
| 1 | 5 | r | fixed to 1 |
| 0 | 4 | r | fixed to 0 |
| REV | 3:0 | r | Device Revision corresponding to mask set |

5 General Product Characteristics

5.1 Absolute Maximum Ratings

Table 1 Absolute Maximum Ratings¹⁾

$T_j = -40\text{ °C to }150\text{ °C}$

| Parameter | Symbol | Values | | | Unit | Note / Test Condition | Number |
|----------------------------|-----------|------------|------|-------------------|------|----------------------------------|---------|
| | | Min. | Typ. | Max. | | | |
| Junction temperature | T_j | -40 150 | – | 150 175 | °C | – 100h cumulative | P_5.1.1 |
| Storage temperature | T_s | -55 | – | 150 | °C | – | P_5.1.2 |
| Ambient temperature | T_a | -40 | – | 125 | °C | – | P_5.1.3 |
| Supply voltage | V_{VS} | -0.3 | – | 40 | V | – | P_5.1.4 |
| Supply for logic output | V_{VSO} | -0.3 | – | 5.5 | V | – | P_5.1.5 |
| Voltage at logic inputs | V_{IN} | -0.3 | – | 5.5 | V | – | P_5.1.6 |
| Voltage at logic output SO | V_{SO} | -0.3 | – | V_{VSO} +0.3 | V | both conditions must be observed | P_5.1.7 |
| | | -0.3 | – | 5.5 | | | |

ESD Susceptibility

| | | | | | | | |
|---|-----------|------|---|-----|----|---------------------------------|----------|
| ESD Susceptibility to GND acc. HBM | V_{ESD} | -2 | – | 2 | kV | HBM ²⁾ | P_5.1.8 |
| ESD Susceptibility to GND acc. CDM | V_{ESD} | -500 | – | 500 | V | CDM ³⁾ | P_5.1.9 |
| ESD Susceptibility to GND acc. CDM, Corner Pins | V_{ESD} | -750 | – | 750 | V | CDM ³⁾ , Corner Pins | P_5.1.10 |

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

2) ESD susceptibility HBM according to EIA/JESD22-A114-B (1.5kΩ, 100pF)

3) ESD susceptibility, Charged Device Model "CDM" EIA/JESD22-C101

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.
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.

5.2 Functional Range

Table 2 Functional Range¹⁾

| Parameter | Symbol | Values | | | Unit | Note / Test Condition | Number |
|--------------------------------|-----------|---------------|------|------|--------------|-----------------------|---------|
| | | Min. | Typ. | Max. | | | |
| Supply voltage range | V_S | V_{UV_OFF} | – | 28 | V | – | P_5.2.1 |
| V_S supply voltage slew rate | dV_S/dt | -10 | – | 10 | V/ μ s | – | P_5.2.2 |
| SO buffer supply voltage | V_{SO} | 2.9 | – | 5.5 | V | – | P_5.2.3 |
| Junction Temperature | T_j | -40 | – | 150 | $^{\circ}$ C | – | P_5.2.4 |

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

Note: Within the functional or operating range, the IC operates as described in the circuit description. The electrical characteristics are specified within the conditions given in the Electrical Characteristics table.

5.3 Thermal Resistance

Note: This thermal data was generated in accordance with JEDEC JESD51 standards. For more information, go to www.jedec.org.

Table 3 Thermal Resistance¹⁾

| Parameter | Symbol | Values | | | Unit | Note / Test Condition | Number |
|---------------------|------------|--------|------|------|------|-----------------------|---------|
| | | Min. | Typ. | Max. | | | |
| Junction to Case | R_{thJC} | – | – | 2 | K/W | – | P_5.3.1 |
| Junction to Ambient | R_{thJA} | – | 30 | – | K/W | 2) | P_5.3.2 |

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

2) Specified R_{thJA} value is according to Jedec JESD51-2,-5,-7 at natural convection on FR4 2s2p board; The Product (Chip+Package) was simulated on a 76.2 × 114.3 × 1.5 mm board with 2 inner copper layers (2 × 70 mm Cu, 2 × 35 mm Cu). Where applicable a thermal via array under the exposed pad contacted the first inner copper layer.

6 Electrical Characteristics

Table 4 Electrical Characteristics
 $V_S = 8\text{ V to }28\text{ V}; V_{VSO} = 2.9\text{ V to }5.5\text{ V}; T_j = -40\text{ }^\circ\text{C to }150\text{ }^\circ\text{C}$

| Parameter | Symbol | Values | | | Unit | Note / Test Condition | Number |
|---|------------------|--------|------|------|------|--|----------|
| | | Min. | Typ. | Max. | | | |
| Supply | | | | | | | |
| Supply Current | I_{VS} | – | 5 | 13 | mA | $f_{PWM} = 2\text{ kHz}; I_{OUT} = 0\text{ A}; V_{VS} = 13.5\text{ V};$ | P_6.0.1 |
| Supply Current Sleep Mode 25 °C | I_{VS} | – | 19 | 30 | µA | $V_{VS} = 13.5\text{ V}; V_{VSO} = 0\text{ V}; V_{OUTx} = 0\text{ V}; T_j = 25\text{ }^\circ\text{C}$ | P_6.0.2 |
| Supply Current Sleep Mode 150 °C ¹⁾ | | – | – | 50 | µA | $V_{VS} = 13.5\text{ V}; V_{VSO} = 0\text{ V}; V_{OUTx} = 0\text{ V}; T_j = 150\text{ }^\circ\text{C}$ | P_6.0.3 |
| VSO Sleep Mode Threshold | V_{VSO_sleep} | 0.5 | – | 2.0 | V | – | P_6.0.4 |
| VSO Input Current, CSN high | I_{VSO} | – | – | 100 | µA | $I_{SO} = 0\text{ A}; V_{CSN} > 2\text{ V}$ | P_6.0.5 |
| VSO Input Current, CSN low | I_{VSO} | – | – | 1.0 | mA | $I_{SO} = 0\text{ A}; V_{CSN} = 0\text{ V}$ | P_6.0.6 |
| VS Undervoltage | | | | | | | |
| Undervoltage at V_S | $V_{UV\ OFF}$ | 3.5 | 4.2 | 5.0 | V | Switch Off Threshold | P_6.0.7 |
| Undervoltage at V_S | $V_{UV\ ON}$ | 3.6 | 4.4 | 5.2 | V | Switch On Threshold | P_6.0.8 |
| Undervoltage at V_S | $V_{UV\ HY}$ | 100 | 200 | 500 | mV | Hysteresis | P_6.0.9 |
| VS Undervoltage Detection Filter Time ¹⁾ | t_{UV} | – | 1 | – | µs | – | P_6.0.10 |
| Inputs PWM, DIR, SCK, SI | | | | | | | |
| Low level | V_{input_L} | – | – | 0.8 | V | – | P_6.0.11 |
| High level | V_{input_H} | 2.0 | – | – | V | – | P_6.0.12 |
| Hysteresis | V_{input_HYS} | 0.1 | 0.3 | – | V | – | P_6.0.13 |
| Pull Down Current | I_{in_pd} | 9 | 38 | 85 | µA | $V_{in} = 5.5\text{ V}$ | P_6.0.14 |
| Input Capacity ¹⁾ | C_{in} | – | – | 15 | pF | $V_{bias} = 2\text{ V}; V_{test} = 20\text{ mVpp}; f = 1\text{ MHz}$ | P_6.0.15 |
| Inputs DIS, CSN | | | | | | | |
| Low level | V_{input_L} | – | – | 0.8 | V | – | P_6.0.16 |
| High level | V_{input_H} | 2.0 | – | – | V | – | P_6.0.17 |
| Hysteresis | V_{input_HYS} | 0.1 | 0.3 | – | V | – | P_6.0.18 |
| Pull Up Current | I_{in_pu} | 9 | 38 | 85 | µA | $V_{in} = 0\text{ V}$ | P_6.0.19 |
| Input Capacity ¹⁾ | C_{in} | – | – | 15 | pF | $V_{bias} = 2\text{ V}; V_{test} = 20\text{ mVpp}; f = 1\text{ MHz}$ | P_6.0.20 |

Table 4 Electrical Characteristics
 $V_S = 8\text{ V to }28\text{ V}; V_{VSO} = 2.9\text{ V to }5.5\text{ V}; T_j = -40\text{ }^\circ\text{C to }150\text{ }^\circ\text{C}$

| Parameter | Symbol | Values | | | Unit | Note / Test Condition | Number |
|---|------------------------------------|------------------|------|-----------|---------------|--|----------|
| | | Min. | Typ. | Max. | | | |
| Output SO | | | | | | | |
| Low level | V_{SO_L} | 0.0 | – | 0.4 | V | $I_{SO} = -1\text{ mA}$ | P_6.0.21 |
| High level | V_{SO_H} | $V_{VSO} - 0.75$ | – | V_{VSO} | V | $I_{SO} = 1\text{ mA};$ $2.9\text{ V} < V_{VSO} < 5.5\text{ V}$ | P_6.0.22 |
| Tristate Leakage Current | I_{SO} | -5 | – | 5 | μA | $0\text{V} < V_{SO} < V_{VSO};$ $V_{VSO} = 5.5\text{ V}$ | P_6.0.23 |
| Output Capacity ¹⁾ | C_{SO} | – | – | 19 | pF | $V_{bias} = 2\text{ V};$ $V_{test} = 20\text{ mVpp};$ $f = 1\text{ MHz}$ | P_6.0.24 |
| Power Outputs OUT1, OUT2 | | | | | | | |
| On resistance low side | R_{OUTL} | – | 100 | – | m Ω | $I_{OUT} = 2\text{ A}; T_j = 25\text{ }^\circ\text{C}$ | P_6.0.25 |
| | | – | – | 200 | m Ω | $I_{OUT} = 2\text{ A}; T_j = 150\text{ }^\circ\text{C}$ | |
| On resistance high side | R_{OUTH} | – | 100 | – | m Ω | $I_{OUT} = 2\text{ A}; T_j = 25\text{ }^\circ\text{C}$ | P_6.0.26 |
| | | – | – | 200 | m Ω | $I_{OUT} = 2\text{ A}; T_j = 150\text{ }^\circ\text{C}$ | |
| Leakage current | $I_{OUT1(off)}$ $I_{OUT2(off)}$ | -25 | – | 25 | μA | $V_{VS} = 13.5\text{ V};$ Outputs off; OLDIS high | P_6.0.27 |
| | | -100 | – | 25 | μA | $V_{VS} = 13.5\text{ V};$ Sleep Mode | |
| Free-wheel diode forward voltage | U_D | – | 0.9 | 1.0 | V | $I_D = 2\text{ A}$ | P_6.0.28 |
| Output Switching Times ²⁾ | | | | | | | |
| Rise time HS | $t_r (HS)$ | 5 | – | 40 | μs | $V_{VS} = 13.5\text{ V};$ $R_{Load} = 6.8\text{ }\Omega$ | P_6.0.29 |
| Fall time HS | $t_f (HS)$ | 5 | – | 40 | μs | | P_6.0.30 |
| Rise time LS | $t_r (LS)$ | 1.0 | – | 7.0 | μs | | P_6.0.31 |
| Fall time LS | $t_f (LS)$ | 1.0 | – | 7.0 | μs | | P_6.0.32 |
| PWM Frequency ¹⁾ | f_{PWM} | 0 | – | 20 | kHz | – | P_6.0.33 |
| Output Delay Times ²⁾ | | | | | | | |
| Output on-delay HS | $t_{d_on(HS)}$ | – | – | 80 | μs | $V_{VS} = 13.5\text{ V};$ $R_{Load} = 6.8\text{ }\Omega$ | P_6.0.34 |
| Output off-delay HS | $t_{d_off(HS)}$ | – | – | 80 | μs | | P_6.0.35 |
| Output on-delay LS | $t_{d_on(LS)}$ | – | – | 10 | μs | | P_6.0.36 |
| Output off-delay LS | $t_{d_off(LS)}$ | – | – | 10 | μs | | P_6.0.37 |
| Disable delay time | t_{d_dis} | – | – | 80 | μs | | P_6.0.38 |
| Enable delay time | t_{d_en} | – | – | 80 | μs | | P_6.0.39 |
| Disable/Enable filter time ¹⁾ | t_{f_en} | 0.4 | – | 3 | μs | | P_6.0.40 |
| Wake Up delay time ¹⁾ | t_{wu} | – | – | 1 | ms | VSO high --> OUT high | P_6.0.41 |
| Chopper Current Limitation | | | | | | | |
| Current Limit | I_L | 6.0 | 8.0 | 10.0 | A | $V_{VS} = 13.5\text{ V}$ | P_6.0.42 |
| Blanking time ¹⁾ | t_b | 5 | 8 | 13 | μs | – | P_6.0.43 |
| Minimum transition time ¹⁾ | t_{trans} | – | 95 | – | μs | – | P_6.0.44 |

Table 4 Electrical Characteristics
 $V_S = 8\text{ V to }28\text{ V}; V_{VSO} = 2.9\text{ V to }5.5\text{ V}; T_j = -40\text{ }^\circ\text{C to }150\text{ }^\circ\text{C}$

| Parameter | Symbol | Values | | | Unit | Note / Test Condition | Number |
|--|-------------------|--------|------|------------|------------------|---|----------|
| | | Min. | Typ. | Max. | | | |
| Short Circuit Detection | | | | | | | |
| Short circuit detection threshold high side switch | I_{SC_H} | 8.0 | 11.5 | 14.5 | A | $V_{VS} = 13.5\text{ V}$ | P_6.0.45 |
| Short circuit detection threshold low side switch | I_{SC_L} | 8.0 | 11.5 | 14.5 | A | | P_6.0.46 |
| Current tracking high side | $I_{SC_H} - I_L$ | 2.0 | 4.0 | 5.2 | A | | P_6.0.47 |
| Current tracking low side | $I_{SC_L} - I_L$ | 1.8 | 3.5 | 5.2 | A | | P_6.0.48 |
| Short Circuit detection filter time ¹⁾ | t_{sdf} | – | 2 | – | μs | – | P_6.0.49 |
| Open Load Detection in OFF State | | | | | | | |
| Pull up Current at OUT1 | I_{OUT1_OL} | 60 | 140 | 200 | μA | $V_{VS} = 13.5\text{ V}; V_{OUT1} = 0\text{ V}$ | P_6.0.50 |
| Pull down Current at OUT2 | I_{OUT2_OL} | 200 | 350 | 500 | μA | $V_{VS} = V_{OUT2} = 13.5\text{ V}$ | P_6.0.51 |
| Ratio of current sources | $Ratio_I_{OL}$ | 1.8 | 2.5 | 3.5 | – | – | P_6.0.52 |
| Open load detection in OFF filter time ¹⁾ | t_{f_OL} | 40 | – | – | μs | – | P_6.0.53 |
| SPI Timing (see Figure 4-6)¹⁾ | | | | | | | |
| Cycle-time (1) | t_{cyc} | 490 | – | – | ns | Referred to master | P_6.0.54 |
| Enable Lead Time (2) | t_{lead} | 50 | – | – | ns | Referred to master | P_6.0.55 |
| Enable Lag Time (3) | t_{lag} | 150 | – | – | ns | Referred to master | P_6.0.56 |
| Data Valid (4) ³⁾ | t_v | – | – | 150 230 | ns | $C_L = 200\text{ pF}$ $C_L = 350\text{ pF}$ Referred to TLE9201SG | P_6.0.57 |
| Data Setup Time (5) | t_{su} | 40 | – | – | ns | Referred to master | P_6.0.58 |
| Data Hold Time (6) | t_h | 40 | – | – | ns | Referred to master | P_6.0.59 |
| Disable Time (7) | t_{dis} | – | – | 100 | ns | Referred to TLE9201SG | P_6.0.60 |
| Transfer Delay (8) | t_{dt} | 2 | – | – | μs | Referred to master | P_6.0.61 |
| Disable Lead Time (9) | t_{dld} | 250 | – | – | ns | Referred to master | P_6.0.62 |
| Disable Lag Time (10) | t_{dlg} | 250 | – | – | ns | Referred to master | P_6.0.63 |
| Thermal Shutdown | | | | | | | |
| Thermal Shutdown Junction Temperature ¹⁾ | T_{jSD} | 150 | 175 | – | $^\circ\text{C}$ | – | P_6.0.64 |
| Thermal Switch-On Junction Temperature ¹⁾ | T_{jSO} | 125 | – | – | $^\circ\text{C}$ | – | P_6.0.65 |

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

2) Output switching times are measured between 20% and 80% of the output swing

3) V_{SO} timing thresholds are 20% / 80% of V_{VSO} for $4.5\text{ V} < V_{VSO} < 5.5\text{ V}$ and 30% / 70% of V_{VSO} for $2.9\text{ V} < V_{VSO} < 4.5\text{ V}$

7 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. The function of the described circuits must be verified in the real application

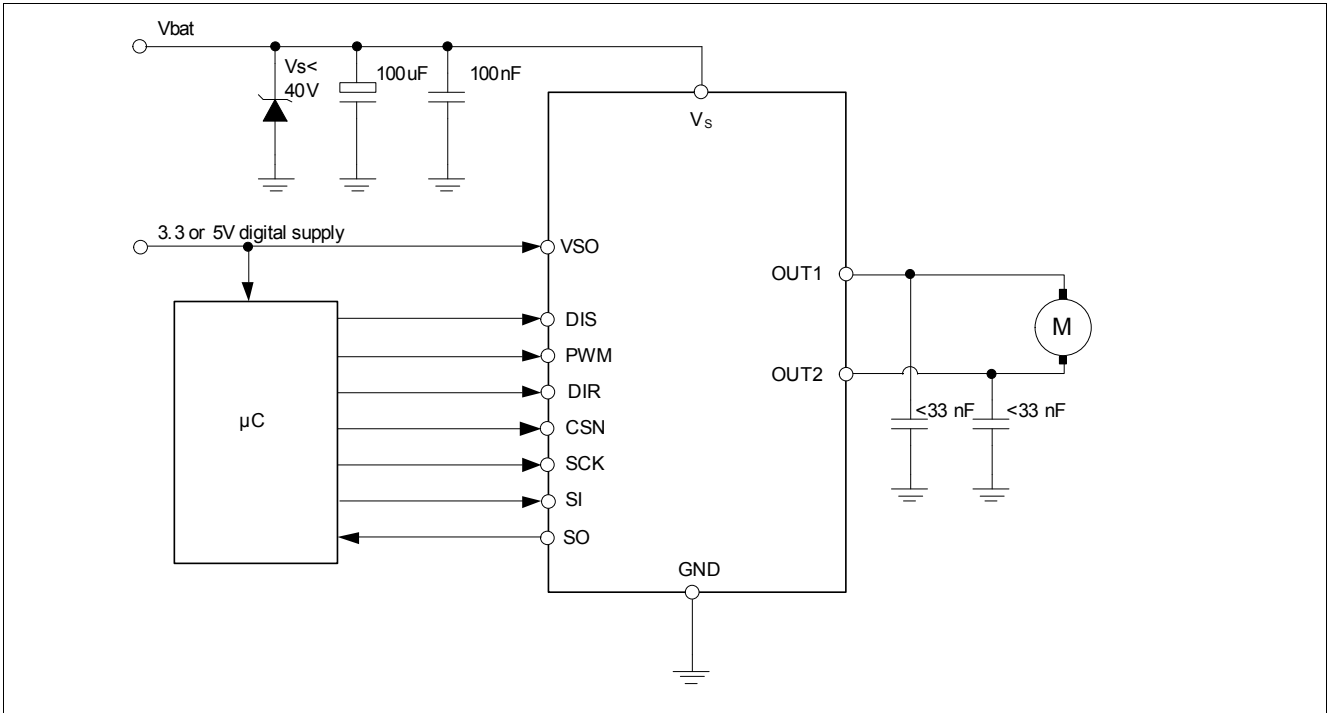


Figure 4 Application Example H-Bridge with SPI interface

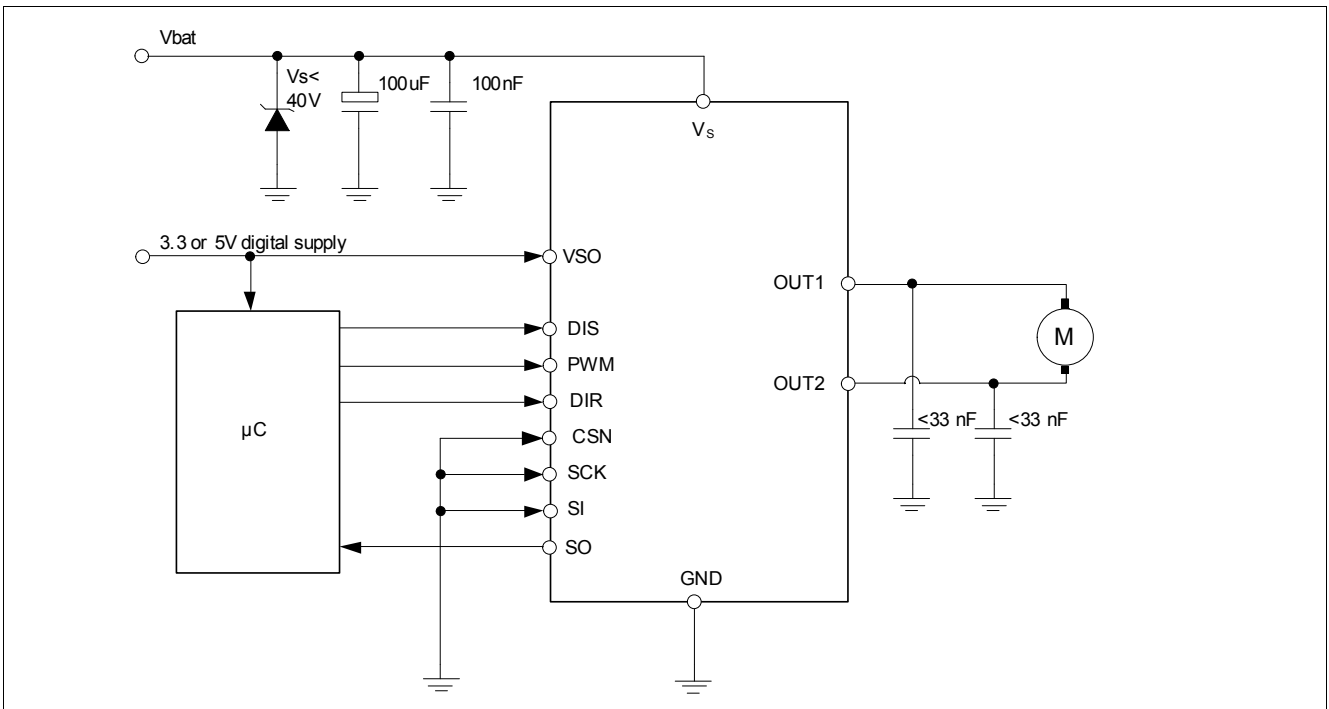


Figure 5 Application Example H-Bridge with Error Flag

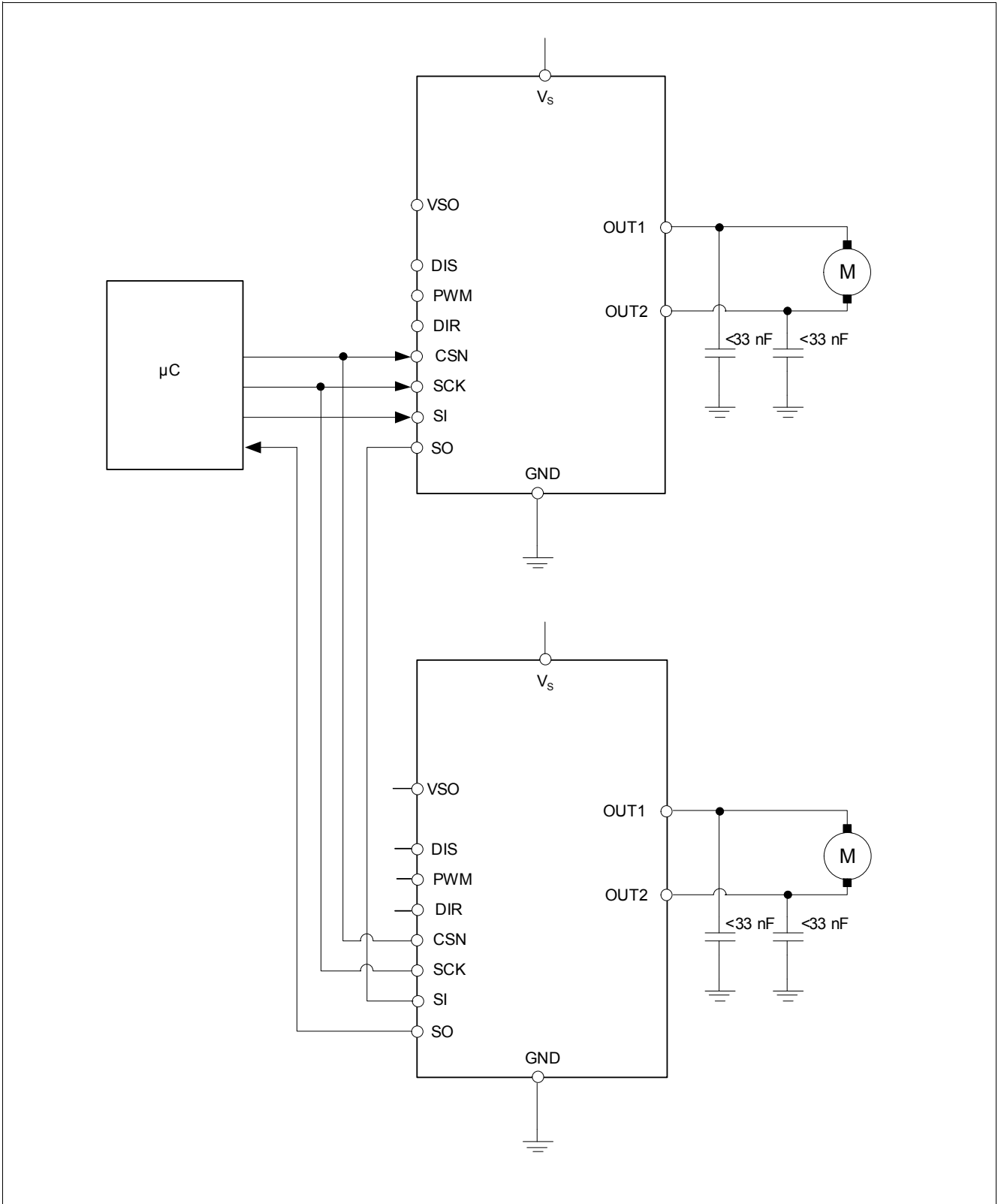


Figure 6 SPI Daisy Chain Konfiguration (other signals omitted for clarity)

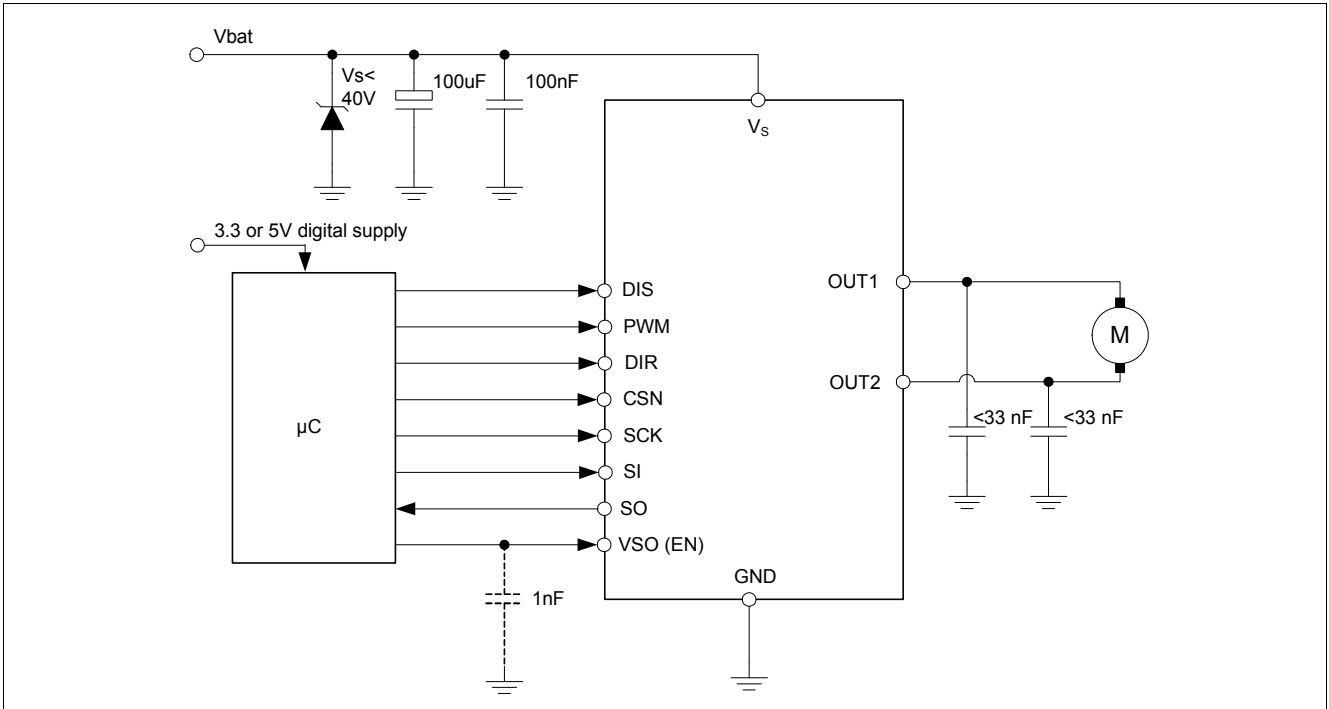


Figure 7 Application Example VSO as Enable Input

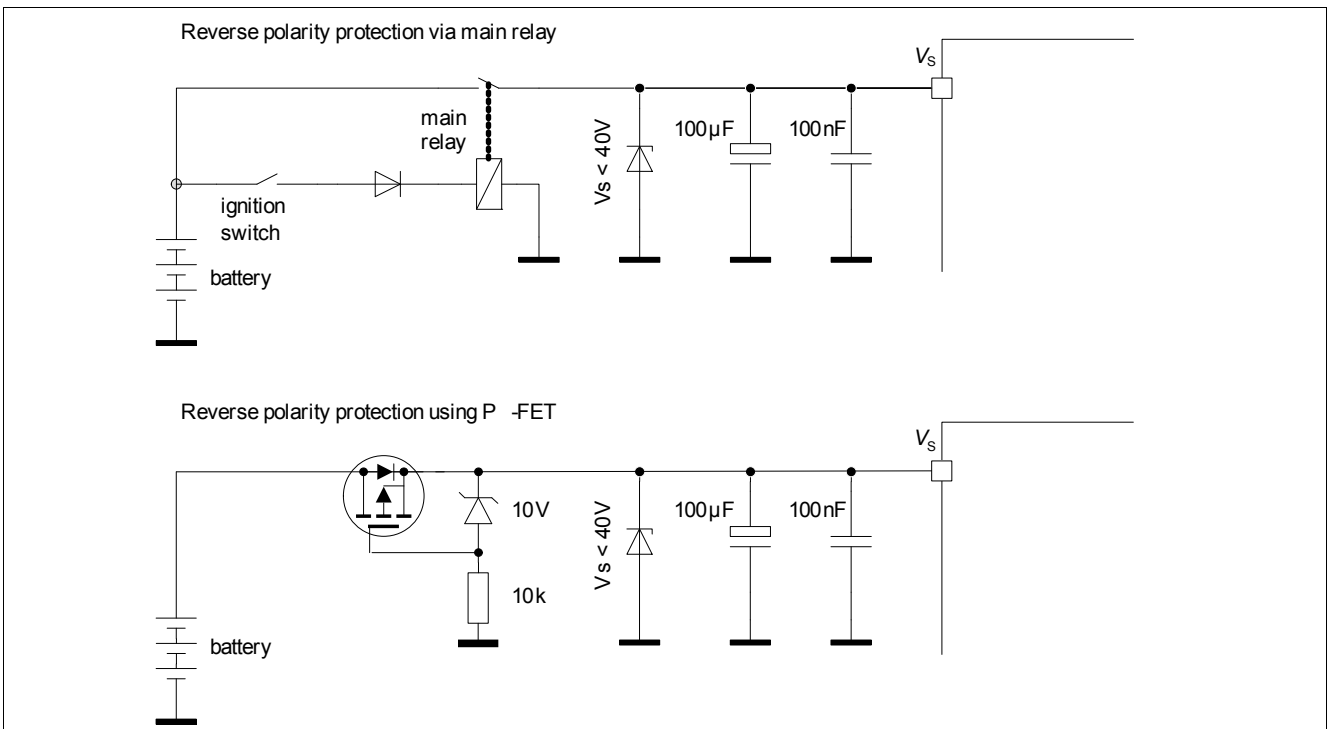


Figure 8 Examples for Reverse Polarity Protection

The TLE9201SG is not protected against reverse polarity. External measures have to be taken to ensure the right polarity of the supply voltage.

8 Package Outlines

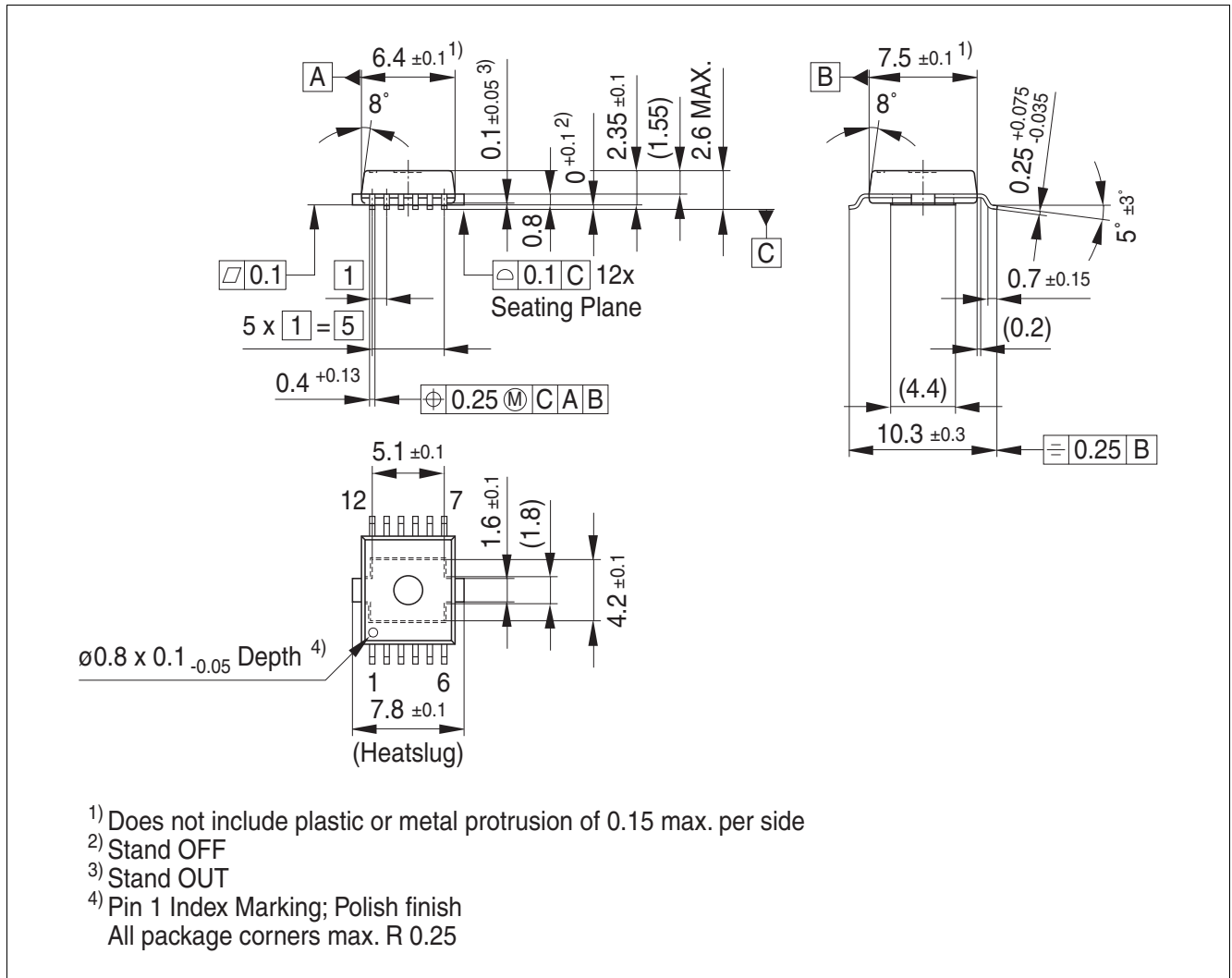


Figure 9 PG-DSO-12-17

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).

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