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SPIDER - TLE7232G

SPI Driver for Enhanced Relay Control

Eight Channel Low-Side Switch

Automotive Power

Never stop thinking

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SPI Driver for Enhanced Relay Control **SPIDER - TLE7232G**

The SPIDER - TLE7232G is an eight channel low-side power switch in PG-DSO-24-13 package providing embedded protective functions. It is especially designed for standard relays in automotive applications.

A serial peripheral interface (SPI) is utilized for control and diagnosis of the device and the load. For direct control, there is an input pin available.

The power transistors are built by N-channel vertical power MOSFETs. The device is monolithically integrated in Smart Power Technology.

PG-DSO-24-13

Product Summary

Supply voltage	V_{dd}	4.5 … 5.5 V
Supply voltage for SO buffer	V_{VSO}	3.0 … 5.5 V
On-State resistance at 25 °C	$R_{DS(ON,max)}$	1.2 Ω
Nominal load current	$I_{L(nom, max)}$	240 mA
Over load current limitation	$I_{DS(LIM, min)}$	1 A
Output leakage current per channel at 25 °C	$I_{DS(OFF, max)}$	1 µA
Drain to source clamping voltage	$V_{DS(CL, min)}$	48 V
SPI clock frequency	$f_{SCLK(max)}$	5 MHz

Type	Ordering Code	Package
SPIDER - TLE7232G	on request	PG-DSO-24-13

Basic Features

- 16 bit SPI for diagnostics and control
- SPI providing daisy chain capability
- 3.3 V and 5 V compatible SPI
- A configurable input pin offers complete flexibility for PWM operation
- Stable behavior at under voltage
- Green Product (RoHS compliant)
- AEC Qualified

Protective Functions

- Short circuit protection
- Over load protection, configurable behavior (limitation or shutdown)
- Thermal shutdown, configurable behavior (latch or restart)
- Electrostatic discharge protection (ESD)

Diagnostic Functions

- Diagnostic information via SPI
- Open load detection in OFF-state
- Shorted to GND detection in OFF-state
- Over temperature in ON-state
- Over load in ON-state

Applications

- Especially designed for driving relays in automotive applications
- All types of capacitive, resistive and inductive loads

1 Overview

The SPIDER - TLE7232G is an eight channel low-side relay switch (1.2 Ω per channel) in PG-DSO-24-13 package providing embedded protective functions. The 16 bit serial peripheral interface (SPI) is utilized for control and diagnosis of the device and the loads. The SPI interface provides daisy-chain capability in order to assemble multiple devices in one SPI chain by using the same number of micro-controller pins.

The SPIDER - TLE7232G is equipped with one input pin that can be individually routed to the output control of each channel thus offering complete flexibility in design and PCB-layout. The input mapping as well as the boolean operation between input signal an output control signal is configured via SPI.

The device provides full diagnosis of the load, which is open load, short to GND as well as short circuit to V_{bat} detection and over load / over temperature indication. The SPI diagnosis flags indicate latched fault conditions that may have occurred.

Each output stage is protected against short circuit. In case of over load, the current of the affected channel is limited. There is a temperature sensor available for each channel to protect the device in case of over temperature. The shut down behavior in case of over load or over temperature can be configured via SPI for each channel individually.

1.1 Block Diagram

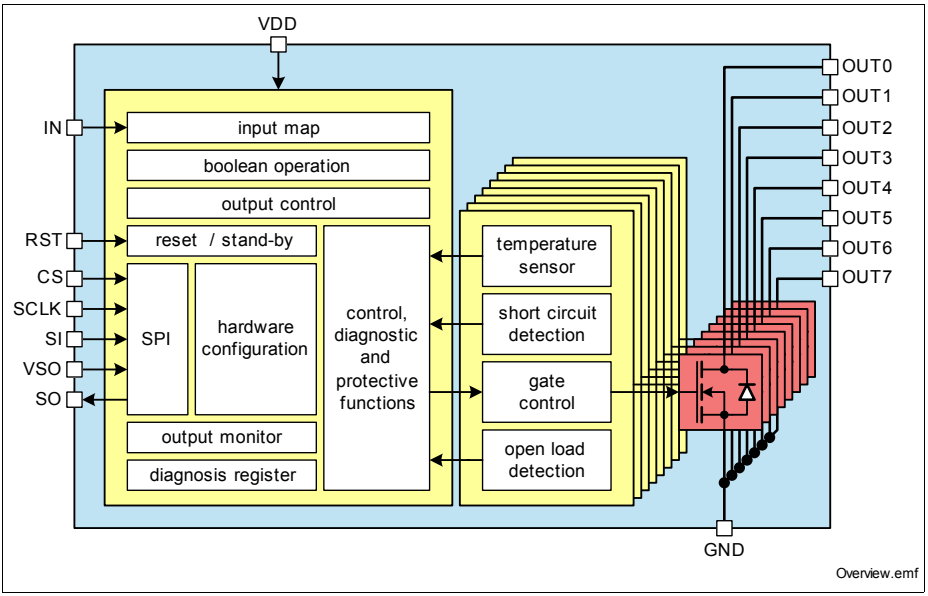

Figure 1 Block Diagram

1.2 Terms

Following figure shows all terms used in this data sheet.

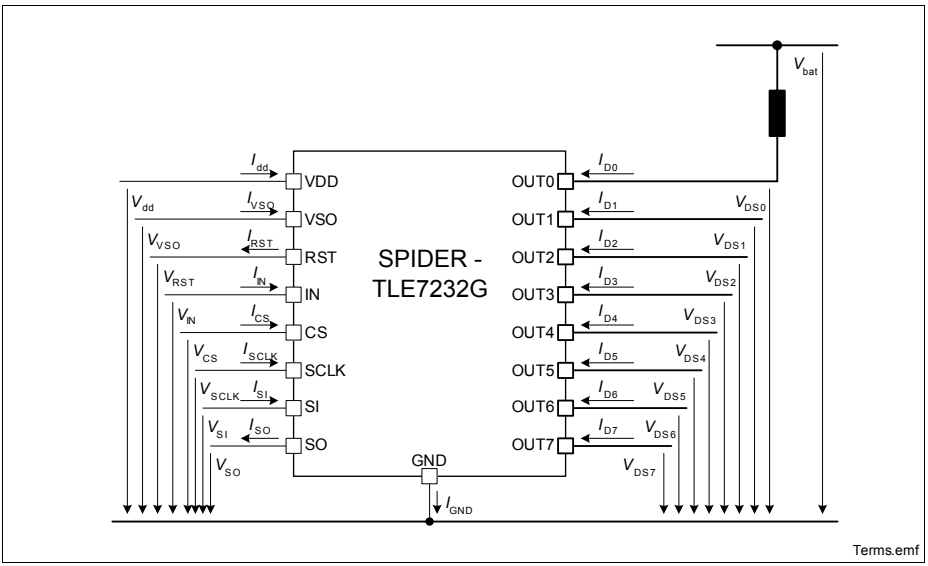

Figure 2 Terms

In all tables of electrical characteristics is valid: Channel related symbols without channel number are valid for each channel separately (e.g. V_{DS} specification is valid for V_{DS0} … V_{DS7}).

All SPI register bits are marked as follows: `ADDR.PARAMETER` (e.g. `CTL.OUT0`). In SPI register description, the values in bold letters (e.g. **0**) are default values.

2 Pin Configuration

2.1 Pin Assignment SPIDER - TLE7232G

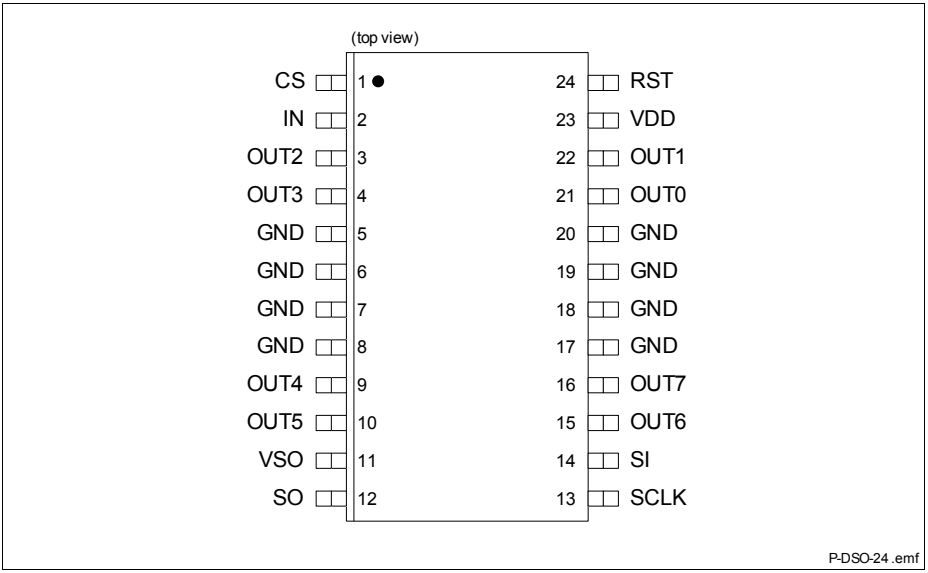

Figure 3 Pin Configuration PG-DSO-24-13

2.2 Pin Definitions and Functions

Pin	Symbol	I/O	Function
Power Supply			
23	VDD	-	Power supply
11	VSO	-	Power supply for SO buffer
5, 6, 7, 8, 17, 18, 19, 20	GND	-	Ground
Power Stages			
21	OUT0	O	Drain of power transistor channel 0
22	OUT1	O	Drain of power transistor channel 1
3	OUT2	O	Drain of power transistor channel 2

Pin	Symbol	I/O	Function
4	OUT3	O	Drain of power transistor channel 3
9	OUT4	O	Drain of power transistor channel 4
10	OUT5	O	Drain of power transistor channel 5
15	OUT6	O	Drain of power transistor channel 6
16	OUT7	O	Drain of power transistor channel 7
Inputs			
24	RST	I	Reset input pin (active low)
2	IN	I	Input multiplexer input pin
SPI			
1	CS	I	SPI Chip select (active low)
13	SCLK	I	Serial clock
14	SI	I	Serial data in
12	SO	O	Serial data out

3 Electrical Characteristics

3.1 Maximum Ratings

Stresses above the ones listed here may affect device reliability or may cause permanent damage to the device.

Unless otherwise specified: V_{dd} = 4.5 V to 5.5 V, T_j = -40 °C to 150 °C

Pos.	Parameter	Symbol	Limit Values		Unit	Test Conditions
			min.	max.		
Power Supply						
3.1.1	Power supply voltage	V_{dd}	-0.3	5.5	V	
3.1.2	VSO supply voltage	V_{VSO}	-0.3	V_{dd} + 0.3	V	1)
3.1.3	Power supply voltage for full short circuit protection (single pulse)	$V_{bat(SC)}$	0	20 28	V	OVL = 0 2) OVL = 1
Power Stages						
3.1.4	Load current	I_D	-1	1	A	
3.1.5	Voltage at power transistor	V_{DS}		48	V	
3.1.6	Maximum energy dissipation one channel single pulse	E_{AS}		 65 30	mJ	3) $T_{j(0)}$ = 85 °C $I_{D(0)}$ = 0.35 A $T_{j(0)}$ = 150 °C $I_{D(0)}$ = 0.25 A
	Maximum energy dissipation one channel repetitive pulses $1 \cdot 10^4$ cycles $1 \cdot 10^6$ cycles	E_{AR}		 18 13	mJ	3) $T_{j(0)}$ = 150 °C $I_{D(0)}$ = 0.20 A $I_{D(0)}$ =0.17 A
Logic Pins						
3.1.7	Voltage at input pin	V_{IN}	-0.3	5.5	V	
3.1.8	Voltage at reset pin	V_{RST}	-0.3	5.5	V	
3.1.9	Voltage at chip select pin	V_{CS}	-0.3	5.5	V	
3.1.10	Voltage at serial clock pin	V_{SCLK}	-0.3	5.5	V	

Unless otherwise specified: V_{dd} = 4.5 V to 5.5 V, T_j = -40 °C to 150 °C

Pos.	Parameter	Symbol	Limit Values		Unit	Test Conditions
			min.	max.		
3.1.11	Voltage at serial input pin	V_{SI}	-0.3	5.5	V	
3.1.12	Voltage at serial output pin	V_{SO}	-0.3	5.5	V	
Temperatures						
3.1.13	Junction Temperature	T_j	-40	150	°C	
3.1.14	Dynamic temperature increase while switching	ΔT_j		60	°C	
3.1.15	Storage Temperature	T_{stg}	-55	150	°C	
ESD Susceptibility						
3.1.16	ESD susceptibility HBM	V_{ESD}	-2	2	kV	according to EIA/JESD 22-A 114B

1) V_{dd} + 0.3 V < 5.5 V

2) Details on configuration of protective function OLCR.OVL can be found in **Section 4.2.5**

3) Pulse shape represents inductive switch off: $I_D(t) = I_D(0) \times (1 - t / t_{pulse})$; $0 < t < t_{pulse}$

4 Block Description and Electrical Characteristics

4.1 Power Stages

The SPIDER - TLE7232G is an eight channel low-side relay switch. The power stages are built by N-channel vertical power MOSFET transistors.

4.1.1 Power Supply

The SPIDER - TLE7232G is supplied by power supply line V_{dd} which is used for the digital as well as the analog functions of the device including the gate control of the power stages. There is a power-on reset function implemented for the supply line. After start-up of the power supply, all SPI registers are reset to their default values. A capacitor at pins VDD to GND is recommended.

The voltage at pin VSO is used by the driver of the SO line at the SPI. It is designed to be functional at a wide voltage range.

There is a reset pin available. At low level at this pin, all registers are set to their default values and the quiescent supply current is minimized.

4.1.2 Input Circuit

There is an input pin available at SPIDER - TLE7232G to control the output stages.

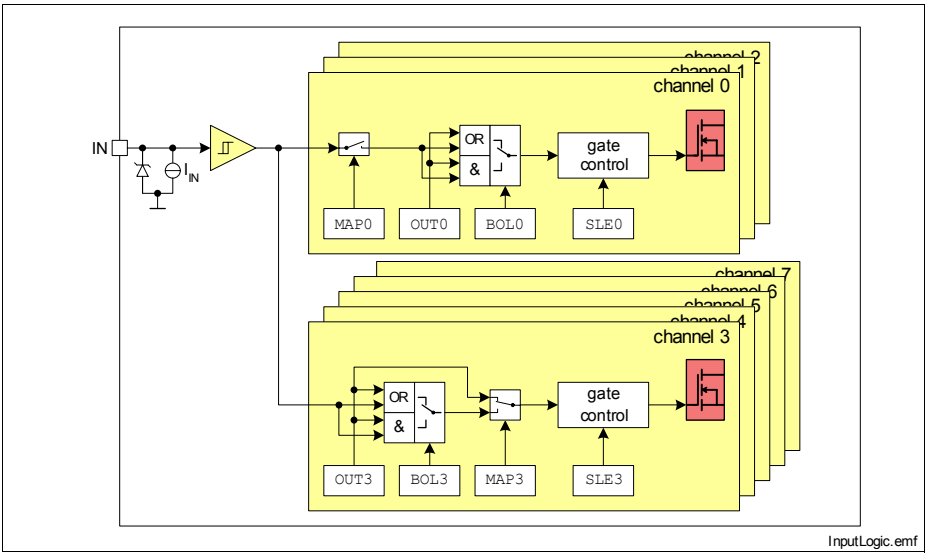

Figure 4 Input Mapping and Boolean Operator

The input signal can be configured to be used as control signal of the output stages for each channel separately. The channels 0 to 3 differ from the channels 4 to 7 in the mapping behavior. Please refer to **Figure 4** for details.

The current sink to ground at the input pin ensures that the channels switch off in case of open pin. The zener diode protects the input circuit against ESD pulses.

4.1.3 Inductive Output Clamp

When switching off inductive loads, the potential at pin OUT rises to $V_{DS(CL)}$ potential, because the inductance intends to continue driving the current. The voltage clamping is necessary to prevent destruction of the device, see **Figure 5** for details. Nevertheless, the maximum allowed load inductance is limited.

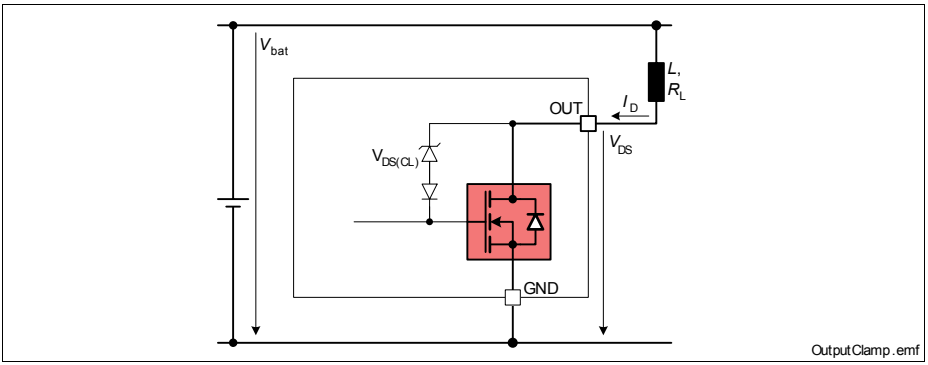

Figure 5 Output Clamp Implementation

Maximum Load Inductance

During demagnetization of inductive loads, energy has to be dissipated in the SPIDER - TLE7232G. This energy can be calculated with following equation:

$$E = V_{DS(CL)} \cdot \left[\frac{V_{bat} - V_{DS(CL)}}{R_L} \cdot \ln\left(1 - \frac{R_L \cdot I_D}{V_{bat} - V_{DS(CL)}}\right) + I_D \right] \cdot \frac{L}{R_L} \quad (1)$$

The equation simplifies under the assumption of R_L = 0:

$$E = \frac{1}{2} L I_D^{\,2} \cdot \left(1 - \frac{V_{bat}}{V_{bat} - V_{DS(CL)}}\right) \quad (2)$$

The energy, which is converted into heat, is limited by the thermal design of the component.

4.1.4 Timing Diagrams

The power transistors are switched on and off with a dedicated slope via the OUT bits of the serial peripheral interface SPI. The switching times t_{ON} and t_{OFF} are designed equally.

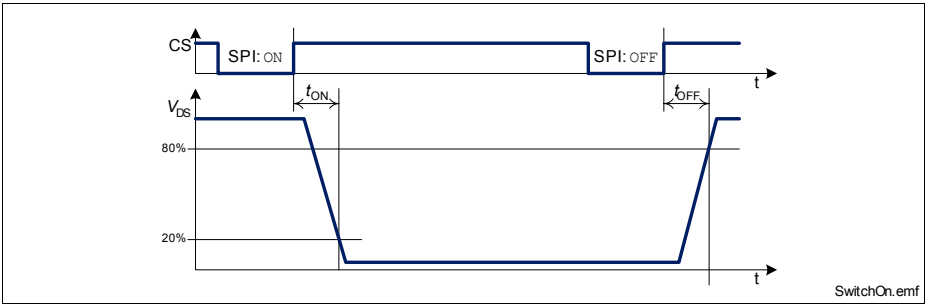

Figure 6 Switching a Resistive Load

When the input mapping is configured accordingly, a high signal at the input pin is equivalent to a SPI ON command.

4.1.5 Electrical Characteristics

Unless otherwise specified: V_{dd} = 4.5 V to 5.5 V, T_j = -40 °C to 150 °C
typical values: V_{dd} = 5.0 V, T_j = 25 °C

Pos.	Parameter	Symbol	Limit Values			Unit	Test Conditions
			min.	typ.	max.		
Power Supply							
4.1.1	Power supply voltage	V_{dd}	4.5		5.5	V	
4.1.2	Power supply current	$I_{dd(ON)}$		3	5	mA	all channels ON
4.1.3	Power supply reset current	$I_{dd(RST)}$			10	µA	V_{RST} = 0 V V_{IN} = 0 V V_{SCLK} = 0 V V_{SI} = 0 V V_{CS} = V_{dd}
4.1.4	Power-on reset threshold voltage	$V_{dd(PO)}$			4.5	V	
Output Characteristics							
4.1.5	On-State resistance per channel	$R_{DS(ON)}$		 1.0	 1.2 2.1	Ω	I_L = 300 mA V_{dd} = 5 V T_j = 25 °C [1] T_j = 150 °C
4.1.6	Output leakage current in stand-by mode (per channel)	$I_{D(RST)}$			 1 2 5	µA	V_{DS} = 13.5 V T_j = 25 °C [1] T_j = 125 °C T_j = 150 °C [1]
4.1.7	Output clamping voltage	$V_{DS(CL)}$	48		60	V	
Input Characteristics							
4.1.8	L level of pin IN	$V_{IN(L)}$	0		1.0	V	
4.1.9	H level of pin IN	$V_{IN(H)}$	2.0		V_{dd}	V	
4.1.10	Input voltage hysteresis at pin IN	ΔV_{IN}		0.1		V	[1]
4.1.11	L-input pull-down current through pin IN	$I_{IN(L)}$	10		100	µA	[1] V_{IN} = 1 V
4.1.12	H-input pull-down current through pin IN	$I_{IN(H)}$	20	50	100	µA	V_{IN} = 5 V

Unless otherwise specified: V_{dd} = 4.5 V to 5.5 V, T_j = -40 °C to 150 °C
typical values: V_{dd} = 5.0 V, T_j = 25 °C

Pos.	Parameter	Symbol	Limit Values			Unit	Test Conditions
			min.	typ.	max.		
Reset							
4.1.13	L level of pin RST	$V_{RST(L)}$	0		1	V	
4.1.14	H level of pin RST	$V_{RST(H)}$	2		V_{dd}	V	
4.1.15	L-input pull-up current through pin RST	$I_{RST(L)}$	0		10	µA	V_{RST} = 1 V
4.1.16	H-input pull-up current through pin RST	$I_{RST(H)}$	20	50	100	µA	V_{RST} = 2 V
Thermal Resistance							
4.1.17	Junction to ambient all channels active	R_{thja}		75		K/W	1) 2)
Timings							
4.1.18	Power-on wake up time	$t_{wu(PO)}$			200	µs	
4.1.19	Reset duration	$t_{RST(L)}$	10			µs	
4.1.20	Turn-on time V_{DS} = 20% V_{bat}	t_{ON}			 15 60	µs	V_{bat} = 14 V I_{DS} = 300 mA, resistive load SLE = 0 SLE = 1
4.1.21	Turn-off time V_{DS} = 80% V_{bat}	t_{OFF}			 15 60	µs	V_{bat} = 14 V I_{DS} = 300 mA, resistive load SLE = 0 SLE = 1

1) Not subject to production test, specified by design

2) Device mounted on PCB (100 mm x 100 mm x 1.5 mm). PCB without blown air. All channels with balanced loads.

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

4.1.6 Command Description

IMCR
Input Mapping Configuration Register **Reset Value: 08_H**

7	6	5	4	3	2	1	0
MAP7	**MAP6**	**MAP5**	**MAP4**	**MAP3**	**MAP2**	**MAP1**	**MAP0**
rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
MAPn (n = 7-0)	n	rw	**Input Mapping Configuration Channel n** 0 Channel n can not be controlled with input pin. (default value) 1 Channel n can be controlled with input pin, depending on additional set-up.

BOCR
Boolean Operator Configuration Register **Reset Value: 00_H**

7	6	5	4	3	2	1	0
BOL7	**BOL6**	**BOL5**	**BOL4**	**BOL3**	**BOL2**	**BOL1**	**BOL0**
rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
BOLn (n = 7-0)	n	rw	**Boolean Operator Configuration Channel n** 0 Logic “OR” for channel n (default value). 1 Logic “AND” for channel n.

SRCR
Slew Rate Configuration Register

Reset Value: 00_H

7	6	5	4	3	2	1	0
SLE7	SLE6	SLE5	SLE4	SLE3	SLE2	SLE1	SLE0
rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
SLEn (n = 7-0)	n	rw	**Slew Rate Configuration Channel n** 0 Channel n is switched fast (default value). 1 Channel n is switched slowly.

CTL
Output Control Register

Reset Value: 00_H

7	6	5	4	3	2	1	0
OUT7	OUT6	OUT5	OUT4	OUT3	OUT2	OUT1	OUT0
rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
OUTn (n = 7-0)	n	rw	**Output Control Channel n** 0 Channel n is switched off (default value). 1 Channel n is switched on, depending on additional set-up.

4.2 Protection Functions

The device provides embedded protective functions. Integrated protection functions are designed to prevent IC destruction under fault conditions described in this data sheet. Fault conditions are considered as “outside” normal operating range. Protection functions are not designed for continuous repetitive operation.

There is an over load and over temperature protection implemented in the SPIDER - TLE7232G. The behavior of the protective functions can be set-up via SPI. Following figure gives an overview about the protective functions.

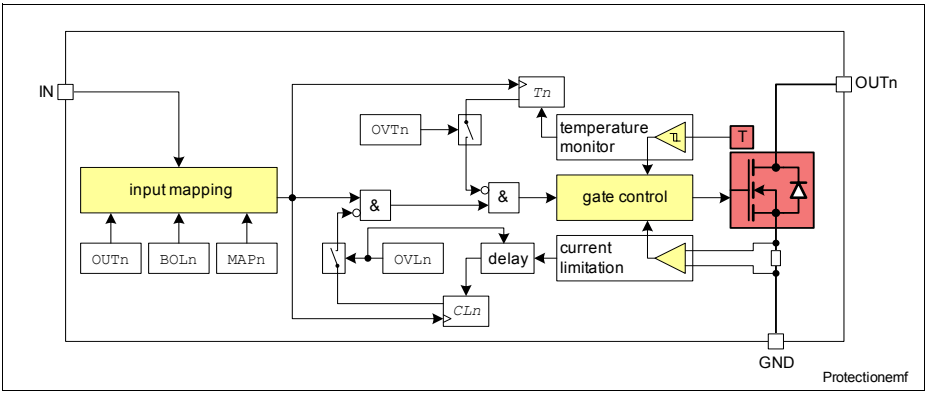

Figure 7 Protective Functions

4.2.1 Over Load Protection

The SPIDER - TLE7232G is protected in case of over load or short circuit of the load. The behavior in case of over load can be configured as follows:

a) The current is limited to $I_{DS(LIM)}$. After time $t_{d(fault)}$, the according over load flag Ln is set. The channel may shut down due to over temperature.

b) The current is limited to $I_{DS(LIM)}$. After time $t_{d(off)}$, the over loaded channel n switches off and the according over load flag Ln is set.

The over load flag (CLn) of the affected channel is cleared by a low-high transition of the input signal. For timing information, please refer to **Figure 8** for details.

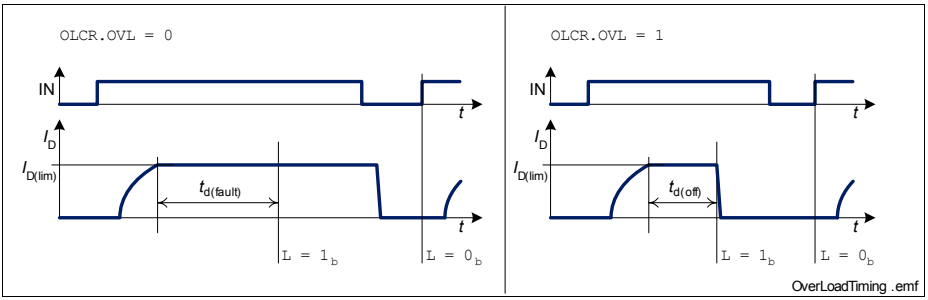

Figure 8 Over Load Behavior

4.2.2 Over Temperature Protection

A temperature sensor for each channel causes an overheated channel n to switch off immediately to prevent destruction. The behavior in case of over temperature can be configured as follows:

a) After cooling down, the channel is switched on again with thermal hysteresis ΔT_j.
b) The affected channel stays switched off until the over temperature flag is cleared.

The over temperature flag of the affected channel is cleared by a low-high transition of the input signal.

4.2.3 Reverse Polarity Protection

In case of reverse polarity, the intrinsic body diode of the power transistor causes power dissipation. The reverse current through the intrinsic body diode has to be limited by the connected load. The V_{dd} supply pin must be protected against reverse polarity externally. The over-temperature protection as well as other protective functions are not active during reverse polarity.

4.2.4 Electrical Characteristics

Unless otherwise specified: V_{dd} = 4.5 V to 5.5 V, T_j = -40 °C to 150 °C
typical values: V_{dd} = 5.0 V, T_j = 25 °C

Pos.	Parameter	Symbol	Limit Values			Unit	Test Conditions
			min.	typ.	max.		
Over Load Protection							
4.2.1	Over load current limitation	$I_{D(lim)}$	1		2	A	OVL = 0
4.2.2	Over load shut-down delay time	$t_{d(off)}$	10		50	µs	OVL = 1
Over Temperature Protection							
4.2.3	Over temperature shut-down threshold	$T_{j(OT)}$	170		200	°C	1)
4.2.4	Thermal hysteresis	$\Delta T_{j(OT)}$		10		K	1)

1) Not subject to production test, specified by design

4.2.5 Command Description

OLCR
Over Load Configuration Register **Reset Value: 00_H**

7	6	5	4	3	2	1	0
OVL7	**OVL6**	**OVL5**	**OVL4**	**OVL3**	**OVL2**	**OVL1**	**OVL0**
rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
OVLn (n = 7-0)	n	rw	**Over Load Configuration Channel n** 0 Channel n limits the current in case of over load (default value). 1 Channel n shuts down in case of over load.

OTCR
Over Temperature Configuration Register **Reset Value: 00_H**

7	6	5	4	3	2	1	0
OVT7	**OVT6**	**OVT5**	**OVT4**	**OVT3**	**OVT2**	**OVT1**	**OVT0**
rw	rw	rw	rw	rw	rw	rw	rw

Field	Bits	Type	Description
OVTn (n = 7-0)	n	rw	**Over Temperature Configuration Channel n** 0 Autorestart (default value) 1 Latched shut down

4.3 Diagnostic Features

The SPI of SPIDER - TLE7232G provides diagnosis information about the device and about the load. There are following diagnosis flags implemented:

- The diagnosis information of the protective functions (flags *CLn* and *Tn*) of channel n is latched in the diagnosis flag *Pn*.
- The open load diagnosis of channel n is latched in the diagnosis flag *OLn*.
- The short to gnd monitor information of channel n is latched in the diagnosis flag *SGn*.

All flags are cleared after a successful SPI transmission.

There is an output state monitor implemented in the device that indicates the switch state of the device in register STA. Depending on the voltage level at input pin and protective functions the bits are high or low.

Please see **Figure 9** for details:

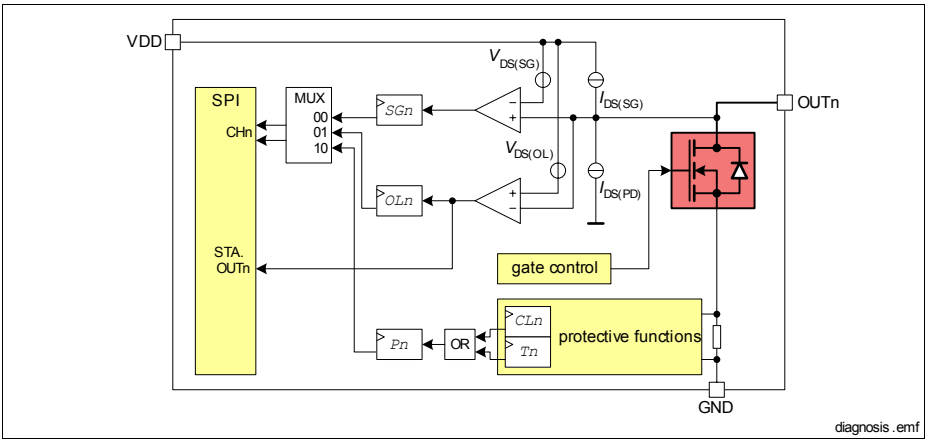

Figure 9 Block Diagram Diagnosis

4.3.1 Electrical Characteristics

Unless otherwise specified: V_{dd} = 4.5 V to 5.5 V, T_j = -40 °C to 150 °C
typical values: V_{dd} = 5.0 V, T_j = 25 °C

Pos.	Parameter	Symbol	Limit Values			Unit	Test Conditions
			min.	typ.	max.		
OFF State Diagnosis							
4.3.1	Open load detection threshold voltage	$V_{DS(OL)}$	V_{dd} - 2.5	V_{dd} - 2	V_{dd} - 1.3	V	
4.3.2	Output pull-down diagnosis current per channel	$I_{D(PD)}$	50	90	150	µA	
4.3.3	Short to gnd detection threshold voltage	$V_{DS(SG)}$	V_{dd} - 3.6	V_{dd} - 3.0	V_{dd} - 2.6	V	
4.3.4	Output diagnosis current for short to gnd per channel	$I_{D(SG)}$	-150	-100	-50	µA	V_{DS} = 0 V
4.3.5	Fault delay time	$t_{d(fault)}$	50	100	200	µs	

4.3.2 Command Description

STA
Output Status Monitor **Reset Value: 00_H**

7	6	5	4	3	2	1	0
OUT7	**OUT6**	**OUT5**	**OUT4**	**OUT3**	**OUT2**	**OUT1**	**OUT0**
r	r	r	r	r	r	r	r

Field	Bits	Type	Description
OUTn (n = 7-0)	n	r	**Output Status** 0 Voltage level at channel n: $V_{DS} > V_{DS(OL)}$. 1 Voltage level at channel n: $V_{DS} < V_{DS(OL)}$.

4.4 Serial Peripheral Interface (SPI)

The diagnosis and control interface is based on a serial peripheral interface (SPI).

The SPI is a full duplex synchronous serial slave interface, which uses four lines: SO, SI, SCLK and $\overline{CS}$. Data is transferred by the lines SI and SO at the data rate given by SCLK. The falling edge of $\overline{CS}$ indicates the beginning of a data access. Data is sampled in on line SI at the falling edge of SCLK and shifted out on line SO at the rising edge of SCLK. Each access must be terminated by a rising edge of $\overline{CS}$. A modulo 8 counter ensures that data is taken only, when a multiple of 8 bit has been transferred. The interface provides daisy chain capability.

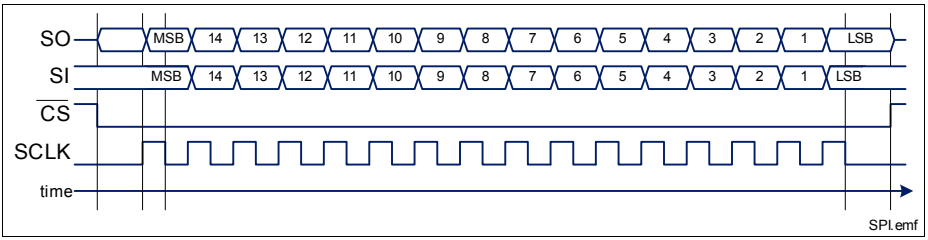

Figure 10 Serial Peripheral Interface

The SPI protocol is described in **Section 4.4.5**. It is reset to the default values after power-on reset or a low signal at pin RST.

4.4.1 SPI Signal Description

$\overline{CS}$ - Chip Select: The system micro controller selects the SPIDER - TLE7232G by means of the $\overline{CS}$ pin. Whenever the pin is in low state, data transfer can take place. When $\overline{CS}$ is in high state, any signals at the SCLK and SI pins are ignored and SO is forced into a high impedance state.

$\overline{CS}$ High to Low transition:

- The diagnosis information is transferred into the shift register.

$\overline{CS}$ Low to High transition:

- Command decoding is only done, when after the falling edge of $\overline{CS}$ exactly a multiple (1, 2, 3, …) of eight SCLK signals have been detected.
- Data from shift register is transferred into the input matrix register.
- The diagnosis flags are cleared.

SCLK - Serial Clock: This input pin clocks the internal shift register. The serial input (SI) transfers data into the shift register on the falling edge of SCLK while the serial output