



# Smart Six Channel Low-Side Switch

## Features

- Short Circuit Protection up to 24 V
- Over-temperature Protection
- Over-voltage Protection
- 16 bit Serial Data Input and Diagnostic Output (2 bit/ch. acc. SPI protocol)
- Direct Parallel Control of all six Channels for PWM Applications
- General Fault Flag
- Low Quiescent Current
- Compatible with 3V Micro Controllers
- **E**lectrostatic **D**ischarge (ESD) Protection
- Parallel Inputs High or Low Active Programmable
- Green Product (RoHS compliant)
- AEC qualified

## Product Summary

|                               |                  |           |          |
|-------------------------------|------------------|-----------|----------|
| Supply voltage                | $V_S$            | 4.5 – 5.5 | V        |
| Drain source clamping voltage | $V_{DS(AZ)typ.}$ | 53        | V        |
| On resistance                 | $R_{ON1-4}$      | 0.25      | $\Omega$ |
|                               | $R_{ON5,6}$      | 0.45      | $\Omega$ |
| Output current (Channel 1-4)  | $I_{D(NOM)}$     | 2         | A        |
| (Channel 5,6)                 | $I_{D(NOM)}$     | 1         | A        |

## Application

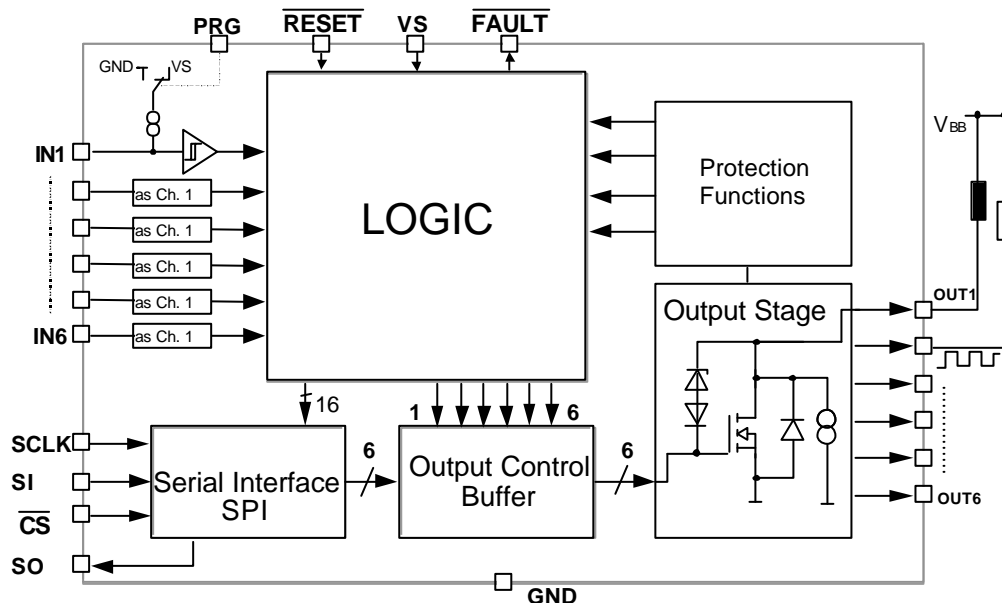
- $\mu$ C Compatible Power Switch for 12 V and 24V Applications
- Switch for Automotive and Industrial System
- Solenoids, Relays and Resistive Loads
- Robotic Controls



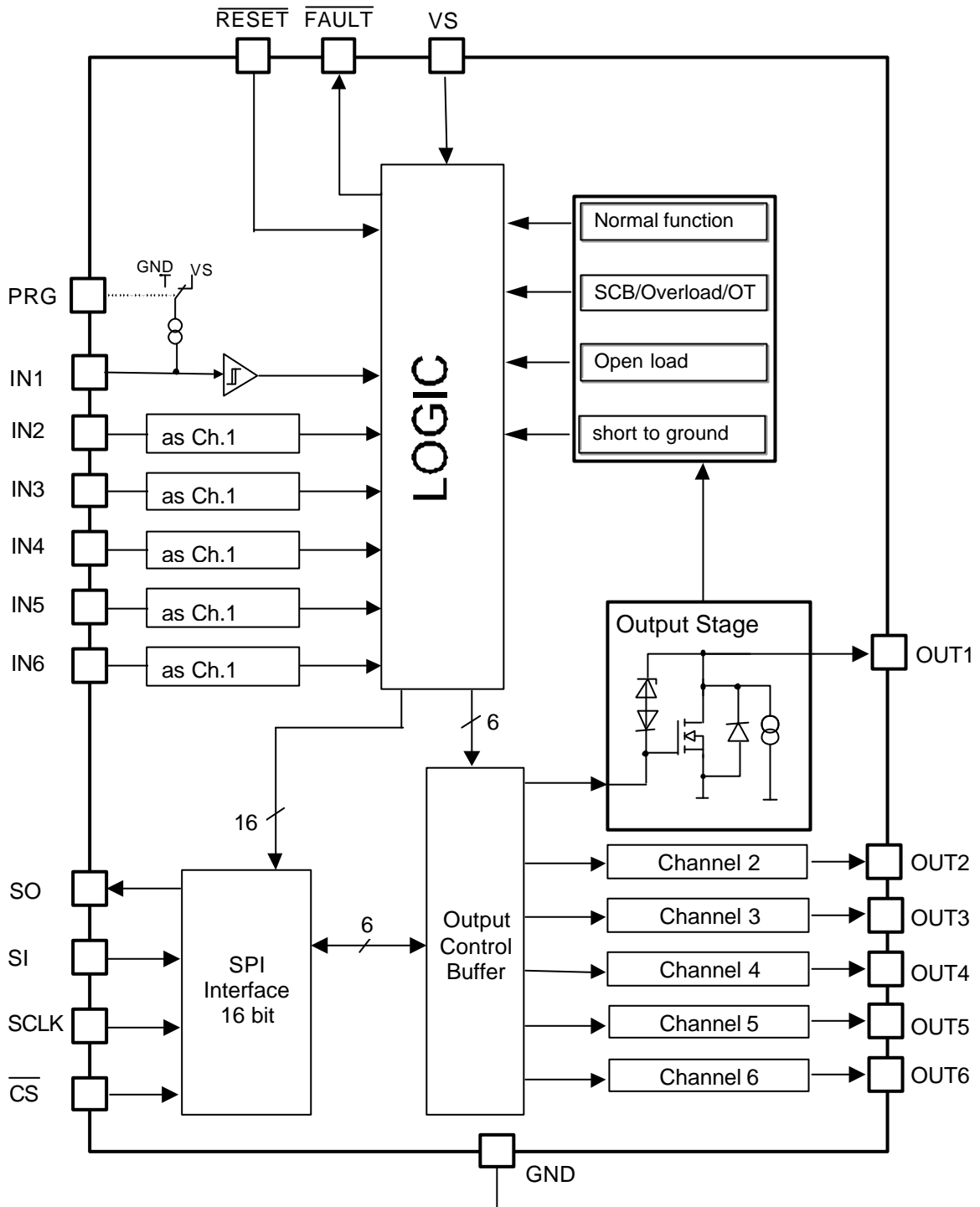
## General description

Six Channel Low-Side Switch in Smart Power Technology (SPT) with a **S**erial **P**eripheral **I**nterface (SPI) and six open drain DMOS output stages. The TLE 6232 GP is protected by embedded protection functions and designed for automotive and industrial applications. The output stages are controlled via an SPI Interface. Additionally all six channels can be controlled direct in parallel for PWM applications. Therefore the TLE 6232 GP is particularly suitable for engine management and powertrain systems.

## Block Diagram



### Detailed Block Diagram



**Pin Description**

| Pin | Symbol                    | Function                            |
|-----|---------------------------|-------------------------------------|
| 1   | GND                       | Ground                              |
| 2   | NC                        | not connected                       |
| 3   | OUT5                      | Power Output Channel 5              |
| 4   | NC                        | not connected                       |
| 5   | OUT1                      | Power Output Channel 1              |
| 6   | IN5                       | Input Channel 5                     |
| 7   | IN1                       | Input Channel 1                     |
| 8   | Vs                        | Supply Voltage                      |
| 9   | $\overline{\text{RESET}}$ | Reset                               |
| 10  | $\overline{\text{CS}}$    | Slave Select                        |
| 11  | PRG                       | Program (inputs high or low-active) |
| 12  | IN2                       | Input Channel 2                     |
| 13  | IN6                       | Input Channel 6                     |
| 14  | OUT2                      | Power Output Channel 2              |
| 15  | NC                        | not connected                       |
| 16  | OUT6                      | Power Output Channel 6              |
| 17  | NC                        | not connected                       |
| 18  | GND                       | Ground                              |
| 19  | GND                       | Ground                              |
| 20  | NC                        | not connected                       |
| 21  | NC                        | not connected                       |
| 22  | NC                        | not connected                       |
| 23  | OUT3                      | Power Output Channel 3              |
| 24  | NC                        | not connected                       |
| 25  | IN3                       | Input Channel 3                     |
| 26  | $\overline{\text{FAULT}}$ | General Fault Flag                  |
| 27  | SO                        | Serial Data Output                  |
| 28  | SCLK                      | Serial Clock                        |
| 29  | SI                        | Serial Data Input                   |
| 30  | IN4                       | Input Channel 4                     |
| 31  | NC                        | not connected                       |
| 32  | OUT4                      | Power Output Channel 4              |
| 33  | NC                        | not connected                       |
| 34  | NC                        | not connected                       |
| 35  | NC                        | not connected                       |
| 36  | GND                       | Ground                              |

**Pin Configuration (Top view)**

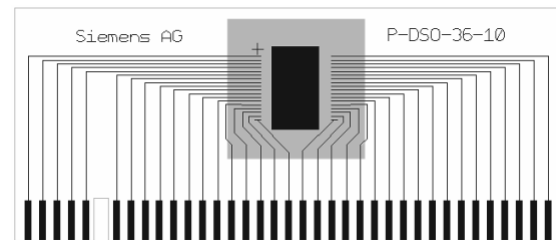
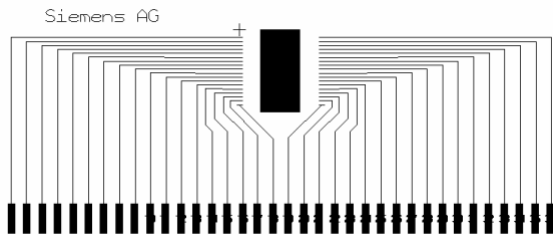
|                           |    |    |                           |
|---------------------------|----|----|---------------------------|
| GND                       | 1● | 36 | GND                       |
| NC                        | 2  | 35 | NC                        |
| OUT5                      | 3  | 34 | NC                        |
| NC                        | 4  | 33 | NC                        |
| OUT1                      | 5  | 32 | OUT4                      |
| IN5                       | 6  | 31 | NC                        |
| IN1                       | 7  | 30 | IN4                       |
| VS                        | 8  | 29 | SI                        |
| $\overline{\text{RESET}}$ | 9  | 28 | SCLK                      |
| $\overline{\text{CS}}$    | 10 | 27 | SO                        |
| PRG                       | 11 | 26 | $\overline{\text{FAULT}}$ |
| IN2                       | 12 | 25 | IN3                       |
| IN6                       | 13 | 24 | NC                        |
| OUT2                      | 14 | 23 | OUT3                      |
| NC                        | 15 | 22 | NC                        |
| OUT6                      | 16 | 21 | NC                        |
| NC                        | 17 | 20 | NC                        |
| GND                       | 18 | 19 | GND                       |

Power SO 36

Heat Slug internally connected to ground pins

**Maximum Ratings for  $T_j = -40^{\circ}\text{C}$  to  $150^{\circ}\text{C}$** 

| Parameter   | Symbol                     | Values           | Unit               |
|---|----------------------------|------------------|--------------------|
| Supply Voltage  | $V_S$                      | -0.3 ... +7      | V                  |
| Continuous Drain Source Voltage (OUT1...OUT8)   | $V_{DS}$                   | 45               | V                  |
| Input Voltage, All Inputs and Data Lines  | $V_{IN}$                   | - 0.3 ... + 7    | V                  |
| Operating Temperature Range   | $T_j$                      | - 40 ... + 150   | $^{\circ}\text{C}$ |
| Storage Temperature Range   | $T_{stg}$                  | - 55 ... + 150   |                    |
| Output Current per Channel (see el. characteristics)  | $I_{D(lim)}$               | $I_{D(lim) min}$ | A                  |
| Single pulse inductive Energy (internal clamping)<br>$T_j=125^{\circ}\text{C}$ ,<br>Ch1-4: 3A linear decreasing<br>Ch5,6: 1,5A linear decreasing                                | $E$                        | 40<br>20         | mJ                 |
| Output Current per Channel @ $T_A = 25^{\circ}\text{C}$<br>(All 6 Channels ON; Mounted on PCB ) <sup>1)</sup>   | $I_{D 1-4}$<br>$I_{D 5,6}$ | 1.1<br>0.55      | A                  |
| Power Dissipation (mounted on PCB) @ $T_A = 25^{\circ}\text{C}$   | $P_{tot}$                  | 3.3              | W                  |
| Electrostatic Discharge Voltage (Human Body Model)<br>according to MIL STD 883D, method 3015.7 and EOS/ESD<br>assn. standard S5.1 - 1993  | $V_{ESD}$                  | 2000             | V                  |
| DIN Humidity Category, DIN 40 040   |                            | E                |                    |
| IEC Climatic Category, DIN IEC 68-1   |                            | 40/150/56        |                    |
| Thermal Resistance<br>junction – case (die soldered on the frame)<br>junction - ambient @ min. footprint<br>junction - ambient @ 6 cm <sup>2</sup> cooling area with heat pipes | $R_{thJC}$<br>$R_{thJA}$   | 2<br>50<br>38    | K/W                |



PCB with heat pipes,  
backside 6 cm<sup>2</sup> cooling area

Minimum footprint

<sup>1)</sup> Output current rating so long as maximum junction temperature is not exceeded. At  $T_A = 125^{\circ}\text{C}$  the output current has to be calculated using  $R_{thJA}$  according mounting conditions.

**Electrical Characteristics**

| Parameter and Conditions<br>$V_S = 4.5$ to $5.5$ V ; $T_J = -40$ °C to $+150$ °C ; Reset = H<br>(unless otherwise specified) | Symbol | Values |     |     | Unit |
|--|--------|--------|-----|-----|------|
|  |        | min    | typ | max |      |

**1. Power Supply, Reset**

|  |                 |     |    |     |    |
|--|-----------------|-----|----|-----|----|
| Supply Voltage <sup>2</sup>                | $V_S$           | 4.5 | -- | 5.5 | V  |
| Supply Current                             | $I_S$           | --  | -- | 10  | mA |
| Supply Current in Standby Mode (RESET = L) | $I_{S(stdy)}$   | --  | -- | 10  | μA |
| Minimum Reset Duration                     | $t_{Reset,min}$ | 1   | -- | --  | μs |

**2. Power Outputs**

|  |                                 |                  |     |            |             |      |
|--|---------------------------------|------------------|-----|------------|-------------|------|
| ON Resistance $V_S = 5$ V ; $I_D = 1$ A<br>Channel 1-4                                 | $T_J = 25$ °C<br>$T_J = 150$ °C | $R_{DS(ON)}$     | --  | 0.25<br>-- | 0.28<br>0.5 | Ω    |
| ON Resistance $V_S = 5$ V ; $I_D = 500$ mA<br>Channel 5,6                              | $T_J = 25$ °C<br>$T_J = 150$ °C | $R_{DS(ON)}$     | --  | 0.45<br>-- | 0.55<br>1   | Ω    |
| Output Clamping Voltage<br>Output OFF  |                                 | $V_{DS(AZ)}$     | 45  | 53         | 60          | V    |
| Current Limit Channel 1-4  |                                 | $I_{D(lim) 1-4}$ | 3   | 4          | 6           | A    |
| Current Limit Channel 5,6  |                                 | $I_{D(lim) 5,6}$ | 1.5 | 2          | 3           |      |
| Output Leakage Current<br>$V_{Reset} = L$  |                                 | $I_{D(lkg)}$     | --  | --         | 10          | μA   |
| Turn-On Time Ch 1-4 $I_D = 2$ A, resistive load<br>Ch 5,6 $I_D = 1$ A, resistive load  |                                 | $t_{ON}$         | --  | 5          | 10          | μs   |
| Turn-Off Time Ch 1-4 $I_D = 2$ A, resistive load<br>Ch 5,6 $I_D = 1$ A, resistive load |                                 | $t_{OFF}$        | --  | 5          | 10          | μs   |
| Switch-On Slew Rate (resistive load)   |                                 | $s_{on}$         | 1   | 4          | 20          | V/μs |
| Switch-Off Slew Rate (resistive load)  |                                 | $s_{on}$         | 1   | 4          | 20          | V/μs |

**3. Digital Inputs**

|  |                   |       |     |     |    |
|--|-------------------|-------|-----|-----|----|
| Input Low Voltage                        | $V_{INL}$         | - 0.3 | --  | 1.0 | V  |
| Input High Voltage                       | $V_{INH}$         | 2.0   | --  | --  | V  |
| Input Voltage Hysteresis                 | $V_{INHys}$       | 100   | 200 | 400 | mV |
| Input Pull Down/Up Current (IN1 ... IN6) | $I_{IN(1..6)}$    | 10    | 20  | 50  | μA |
| Input Pull Up Current (Reset)            | $I_{IN(Res)}$     | 10    | 20  | 50  | μA |
| Input Pull Down Current (PRG)            | $I_{IN(PRG)}$     | 10    | 20  | 50  | μA |
| Input Pull Up Current (CS, SI, SCLK)     | $I_{IN(SI,SCLK)}$ | 10    | 20  | 50  | μA |

**4. Digital Outputs (SO,  $\overline{FAULT}$ )**

|   |              |           |    |     |    |
|---|--------------|-----------|----|-----|----|
| SO High State Output Voltage<br>$I_{SOH} = -2$ mA                               | $V_{SOH}$    | $V_S - 1$ | -- | --  | V  |
| SO Low State Output Voltage<br>$I_{SOL} = 2$ mA                                 | $V_{SOL}$    | --        | -- | 0.4 | V  |
| Output Tri-state Leakage Current<br>$\overline{CS} = H, 0 \leq V_{SO} \leq V_S$ | $I_{SOlkg}$  | -10       | 0  | 10  | μA |
| FAULT Output Low Voltage<br>$I_{FAULT} = 2$ mA                                  | $V_{FAULTL}$ | --        | -- | 0.4 | V  |

<sup>2</sup> For  $V_S < 4.5$ V the power stages are switched according the input signals and data bits or are definitely switched off. This under-voltage reset gets active at  $V_S = 3$ V (typ. value) and is specified by design.

**Electrical Characteristics cont.**

| Parameter and Conditions<br><i>V<sub>S</sub></i> = 4.5 to 5.5 V ; <i>T<sub>j</sub></i> = - 40 °C to + 150 °C ; Reset = H<br>(unless otherwise specified) | Symbol | Values |     |     | Unit |
|--|--------|--------|-----|-----|------|
|  |        | min    | typ | max |      |

**5. Diagnostic Functions**

|  |                                 |                             |                      |                      |     |    |
|--|---------------------------------|-----------------------------|----------------------|----------------------|-----|----|
| Open Load Detection Voltage                    | <i>V<sub>DS(OL)</sub></i>       | 0.52*                       | 0.6*                 | 0.68*                | V   |    |
|  |                                 | <i>V<sub>S</sub></i>        | <i>V<sub>S</sub></i> | <i>V<sub>S</sub></i> |     |    |
| Short to Ground Detection Voltage              | <i>V<sub>DS(SHG)</sub></i>      | 0.32*                       | 0.4*                 | 0.48*                | V   |    |
|  |                                 | <i>V<sub>S</sub></i>        | <i>V<sub>S</sub></i> | <i>V<sub>S</sub></i> |     |    |
| Diagnostic Current (incl. Leakage)             | <i>U<sub>OUTi,j</sub></i> = 14V | <i>I<sub>OUTi,j</sub></i>   | 325                  | 580                  | 980 | μA |
|  | <i>U<sub>OUTi,j</sub></i> = 0V  | - <i>I<sub>OUTi,j</sub></i> | 50                   | 130                  | 250 | μA |
| Current Limitation; Overload Threshold Current | <i>I<sub>D(lim)</sub></i> 1-4   | 3                           | 4                    | 6                    | A   |    |
|  | <i>I<sub>D(lim)</sub></i> 5,6   | 1.5                         | 2                    | 3                    | A   |    |
| Over-temperature Shutdown Threshold            | <i>T<sub>th(sd)</sub></i>       | 170                         | --                   | 200                  | °C  |    |
| Hysteresis                                     | <i>T<sub>hys</sub></i>          | 5                           | 10                   | 20                   | K   |    |
| Fault Delay Time                               | <i>t<sub>d(fault)</sub></i>     | 60                          | 120                  | 240                  | μs  |    |

**6. SPI-Timing**

|   |                              |                          |     |     |     |    |
|---|------------------------------|--------------------------|-----|-----|-----|----|
| Serial Clock Frequency (@ <i>C<sub>SO</sub></i> ≤ 50pF)                               | <i>f<sub>SCK</sub></i>       | DC                       | --  | 5   | MHz |    |
| Serial Clock Period (1/fclk)  | <i>t<sub>p(SCK)</sub></i>    | 200                      | --  | --  | ns  |    |
| Serial Clock High Time  | <i>t<sub>SCKH</sub></i>      | 50                       | --  | --  | ns  |    |
| Serial Clock Low Time   | <i>t<sub>SCKL</sub></i>      | 100                      | --  | --  | ns  |    |
| Enable Lead Time (falling edge of $\overline{CS}$ to rising edge of CLK)              | <i>t<sub>lead</sub></i>      | 100                      | --  | --  | ns  |    |
| Enable Lag Time (falling edge of CLK to rising edge of $\overline{CS}$ )              | <i>t<sub>lag</sub></i>       | 150                      | --- | --  | ns  |    |
| Data Setup Time (required time SI to falling of CLK)                                  | <i>t<sub>SU</sub></i>        | 20                       | --  | --  | ns  |    |
| Data Hold Time (falling edge of CLK to SI)  | <i>t<sub>H</sub></i>         | 20                       | --  | --  | ns  |    |
| Disable Time  | <i>t<sub>DIS</sub></i>       | --                       | --  | 100 | ns  |    |
| Transfer Delay Time <sup>3</sup><br>( $\overline{CS}$ high time between two accesses) | <i>t<sub>dt</sub></i>        | 150                      | --  | --  | ns  |    |
| Data Valid Time <sup>4</sup>  | <i>C<sub>L</sub></i> = 50 pF | <i>t<sub>valid</sub></i> | --  | --  | 100 | ns |
|   |                              |                          | --  | --  | 120 | ns |
|   |                              |                          | --  | --  | 150 | ns |

<sup>3</sup> This time is necessary between two write accesses. To get the correct diagnostic information, the transfer delay time has to be extended to the maximum fault delay time *t<sub>d(fault)max</sub>* = 200μs.

<sup>4</sup> This parameter will not be tested but specified by design

## Description of the Power Stages

4 low side power switches for nominal currents up to 3A (power stages OUT1 to OUT4). Control is possible by input pins or via SPI. For  $T_J = 150^\circ\text{C}$  the on-resistance of the power switches is below  $500\text{m}\Omega$ .

2 low side power switches for nominal currents up to 1.5A (power stages OUT5 and OUT6). Control is possible by input pins or via SPI. For  $T_J = 150^\circ\text{C}$  the on-resistance of the power switches is below  $1\Omega$ .

In order to increase the switching current or to reduce the power dissipation parallel connection of power stages is possible.

Each of the 6 output stages is equipped with its own zener clamp, which limits the output voltage to a maximum of 60V. The outputs are provided with a current limitation set to a minimum of 1.5A resp. 3A. Each power stage is equipped with an own temperature sensor.

Each output is protected by embedded protection functions<sup>5)</sup>. In case of overload or short-circuit to  $U_{\text{Batt}}$  the current is internally limited and the corresponding bit combination is set (early warning). If this operation leads to an over-temperature condition, a second protection level (about  $170^\circ\text{C}$ ) will change the output into a low duty cycle PWM (selective thermal shut-down with restart) to prevent critical chip temperatures.

The following faults can be detected (individually for each output):

- |                     |  |           |
|---------------------|--|-----------|
| - short to UBatt:   | (SCB/overload) can be detected when switches are | On state  |
| - short to ground:  | (SCG) can be detected when switches are          | Off state |
| - open load:        | (OL) can be detected when switches are           | Off state |
| - over-temperature: | (OT) will only be detected when switches are     | On state  |

The fault conditions SCB, SCG and OL will not be stored until an integrated filtering time is expired (please note for PWM application). If, at one output, several errors occur in a sequence, always the last detected error will be stored (with filtering time). All fault conditions are encoded in two bits per switch and are stored in the corresponding SPI registers. Additionally there are two central diagnostic bits: one especially for over-temperature (latched result of an OR-operation out of the 6 signals of the temperature sensor) and one for fault occurrence at any output. A fault that has been detected and stored in the fault register must not be replaced by o.k.-state (11) unless it is read out by the RD\_DIAG command sent by the microcontroller or an internal or external reset has been applied. I.e. the fault register will be cleared only by the RD\_DIAG command.

**PRG** - Program pin.      PRG = High ( $V_S$ ):      Parallel inputs Channel 1 to 6 are high active  
    PRG = Low (GND):      Parallel inputs Channel 1 to 6 are low active.

If the parallel input pins are not connected (independent of high or low activity), channels 1 to 6 are switched OFF.

PRG pin itself is internally pulled down when it is not connected.

<sup>5)</sup> The integrated protection functions prevent device destruction under fault conditions and may not be used in normal operation or permanently.

The effect of the integrated under-voltage detection is similar to the effect of an external reset at pin Reset (except low current consumption):

- locks all power switches regardless of their input signals
- clears the fault registers
- resets SPI control register

### Parallel Connection of Power Stages

The power stages which are connected in parallel have to be switched on and off simultaneously.

In case of overload the ground current and the power dissipation are increasing. The application has to take into account that all maximum ratings are observed (e.g. operating temperature  $T_J$  and total ground current  $I_{GND}$ , see Maximal Ratings).

The maximum current limitation value (or overload detection threshold) of the parallel connected power stages is the summation of the corresponding maximum values of the power stages ( $I_{OUT(lim)x} + I_{OUT(lim)y} + \dots$ ).

|   | Max. Nominal Current                                      | Max. Clamping Energy            | On Resistance  |
|---|---|---------------------------------|--|
| 2 power stages of the same type<br>(see note 1)   | $(I_{max,OUTx} + I_{max,OUTy}) \times 0.9$                | $0.8 \times (E_x + E_y)$        | $0.5 \times R_{ON,OUTx,y}$   |
| 3 power stages of the same type<br>(see note 1,2)   | $(I_{max,OUTx} + I_{max,OUTy} + I_{max,OUTz}) \times 0.8$ | $0.7 \times (E_x + E_y + E_z)$  | $0.34 \times R_{ON,OUTx,y,z}$                                      |
| 2 power stages with the same clamping voltage, but different nominal current (see note 3) | $(I_{max,OUTx} + I_{max,OUTy}) \times 0.8$                | Min ( $E_{clpx}$ , $E_{clpy}$ ) | $\frac{R_{ON,OUTx} \times R_{ON,OUTy}}{R_{ON,OUTx} + R_{ON,OUTy}}$ |

Note 1: Power stages of the same type have the same nominal current

Note 2: Only for 3A power stages

Note 3: Parallel connection of power stage type 3A/53V with type 1.5A/53V

### SPI Interface

The serial SPI interface makes possible communication between TLE6232 and the microcontroller.

TLE 6232 GP always works in slave mode whereas the microcontroller provides the master function. The maximum baud rate is 5Mbaud.

Applying a chip select signal at CS and setting bit 7 and bit 6 of the instruction byte to „1“ and „0“ TLE 6232 GP is selected by the SPI master. SI is the data input (Signal In), SO the data output (Signal Out). Via SCLK (Serial Clock Input) the SPI clock is given by the master.



## SPI Signal Description

**$\overline{\text{CS}}$**  - Chip Select. The system microcontroller selects the TLE 6232 GP by means of the  $\overline{\text{CS}}$  pin. Whenever the pin is in a logic low state, data can be transferred from the  $\mu\text{C}$  and vice versa.

**$\overline{\text{CS}}$  High to Low transition:** - diagnostic status information is transferred from the power outputs into the shift register.  
 - serial input data can be clocked in from then on  
 - SO changes from high impedance state to logic high or low state corresponding to the SO bits

**$\overline{\text{CS}}$  Low to High transition:** - transfer of SI bits from shift register into output buffers  
 - reset of diagnosis register

To avoid any false clocking the serial clock input pin SCLK should be logic low state during high to low transition of  $\overline{\text{CS}}$ . When  $\overline{\text{CS}}$  is in a logic high state, any signals at the SCLK and SI pins are ignored and SO is forced into a high impedance state.

**SCLK** - Serial Clock. The system clock pin clocks the internal shift register of the TLE 6232 GP. The serial input (SI) accepts data into the input shift register on the falling edge of SCLK while the serial output (SO) shifts diagnostic information out of the shift register on the rising edge of serial clock. It is essential that the SCLK pin is in a logic low state whenever chip select  $\overline{\text{CS}}$  makes any transition. The number of clock pulses will be counted during a chip select cycle. The received data will only be accepted, if exactly 16 clock pulses were counted during  $\overline{\text{CS}}$  is active.

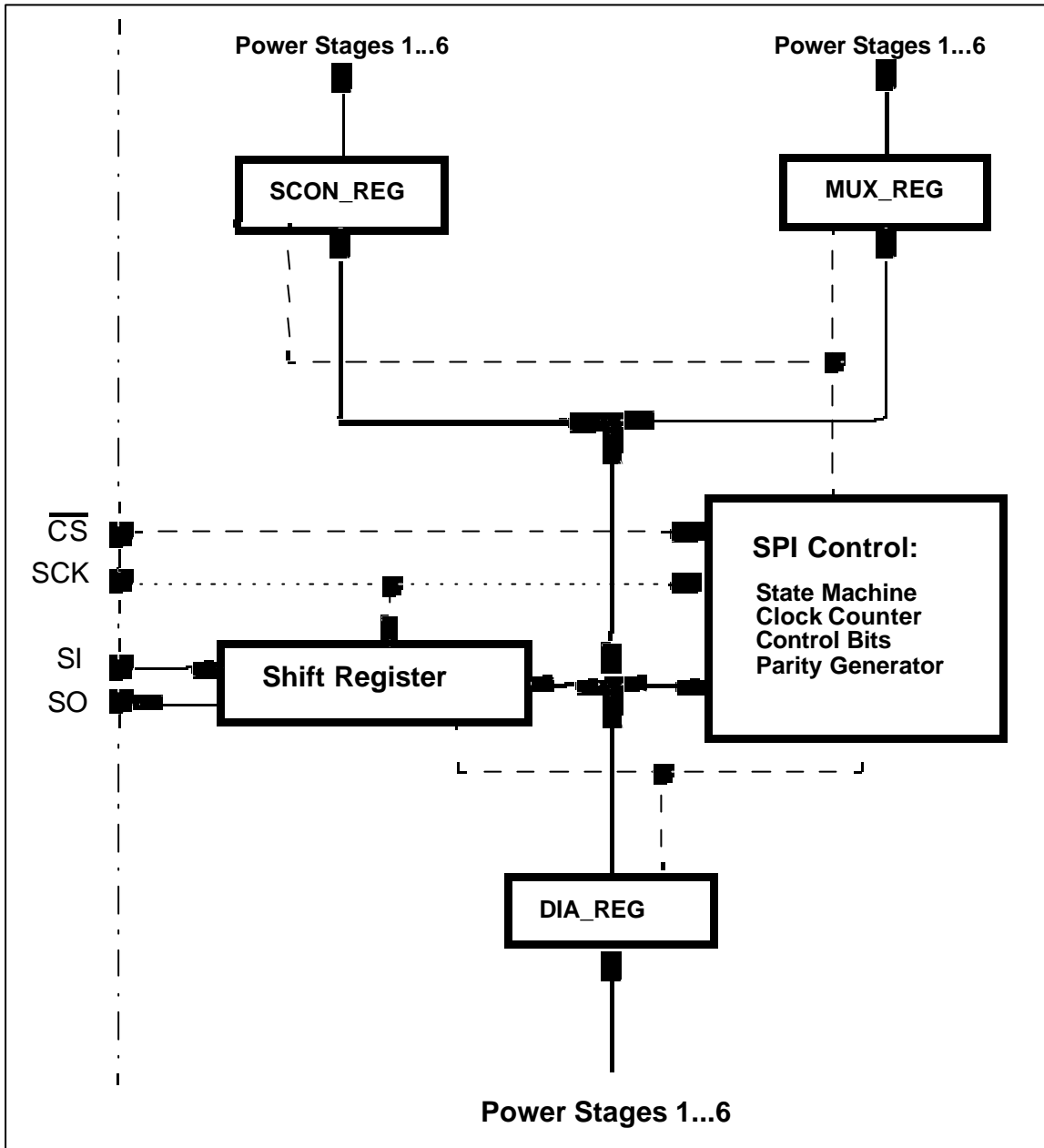
**SI** - Serial Input. Serial data bits are shifted in at this pin, the most significant bit first. SI information is read in on the falling edge of SCLK. Input data is latched in the shift register and then transferred to the control buffer of the output stages.

The input data consists of two bytes - a "control byte" followed by a "data byte". The control byte contains the information as to whether the data byte will be accepted or ignored (see diagnostics section). The data byte contains the input information for the six channels. A logic high level at this pin (within the data byte) will switch on the power switch, provided that the corresponding parallel input is also switched on (AND-operation for channel 1 to 6).

**SO** - Serial Output. Diagnostic data bits are shifted out serially at this pin, the most significant bit first. SO is in a high impedance state until the  $\overline{\text{CS}}$  pin goes to a logic low state. New diagnostic data will appear at the SO pin following the rising edge of SCLK.

**RESET** - Reset pin. If the reset pin is in a logic low state, it clears the SPI shift register and switches all outputs OFF. An internal pull-up structure is provided on chip. In case of inactive chip select signal (High) or bit 7 and bit 6 of the instruction byte differing from "1" and "0" the data output SO remains into tri-state.

## SPI Interface



## SPI Communication

A SPI communication starts with a SPI instruction (SI control word) sent from the controller to TLE 6232 GP. Simultaneously the device sends the first SO byte back to the  $\mu C$ . During a writing cycle the controller sends the data after the SPI instruction, beginning with the MSB. During a reading cycle, after having received the SPI instruction, TLE 6232 GP sends the corresponding data to the controller, also starting with the MSB.

The SPI Interface consists of three register:

- MUX\_REG: 8-bit (1 byte) length for parallel operation mode (IN1 ... IN6 enabled or not)
- SCON\_REG: 8-bit (1 byte) length for serial control of the outputs (serial data bits)

- DIAG\_REG: 16-bit (2 byte) length. Contains the diagnostic information (2 bits per channel), a common over-temperature bit and a common fault bit.

Registers MUX\_REG and SCON\_REG are writeable as well as readable from the microcontroller. The DIAG\_REG can only be read from the µC.

This leads to five different control bytes which are recognized by the IC. The following table shows the different modes.

|         |     | MSB | LSB | MSB | LSB |      |      |       |      |       |      |    |    |    |    |   |      |                         |
|---------|-----|-----|-----|-----|-----|------|------|-------|------|-------|------|----|----|----|----|---|------|-------------------------|
| WR_SCON | SI: | H   | L   | L   | H   | H    | L    | X     | X    | D6    | D5   | D4 | D3 | D2 | D1 | X | X    | Write to SCON Register. |
|         | SO: | Z   | Z   | F   | OT  | DIA6 | DIA5 | DIA4  | DIA3 | DIA2  | DIA1 |    |    |    |    |   |      |                         |
| RD_SCON | SI: | H   | L   | L   | H   | L    | H    | X     | X    | X     | X    | X  | X  | X  | X  | X | X    | Read SCON Register      |
|         | SO: | Z   | Z   | F   | OT  | DIA6 | DIA5 | SCON6 | ..   | SCON1 | H    | H  |    |    |    |   |      |                         |
| WR_MUX  | SI: | H   | L   | H   | L   | H    | L    | X     | X    | M6    | M5   | M4 | M3 | M2 | M1 | X | X    | Write to MUX Register.  |
|         | SO: | Z   | Z   | F   | OT  | DIA6 | DIA5 | DIA4  | DIA3 | DIA2  | DIA1 |    |    |    |    |   |      |                         |
| RD_MUX  | SI: | H   | L   | H   | L   | L    | H    | X     | X    | X     | X    | X  | X  | X  | X  | X | X    | Read MUX Register       |
|         | SO: | Z   | Z   | F   | OT  | DIA6 | DIA5 | MUX6  | ..   | MUX1  | H    | H  |    |    |    |   |      |                         |
| RD_DIAG | SI: | H   | L   | L   | L   | L    | L    | X     | X    | X     | X    | X  | X  | X  | X  | X | DIA4 | Read DIAG Register      |
|         | SO: | Z   | Z   | F   | OT  | DIA6 | DIA5 | DIA3  | DIA2 | DIA1  |      |    |    |    |    |   |      |                         |

**SI Control Byte**

**SI Data Byte**

Note:

- 'X' means 'don't care', because data will be ignored
- 'Dx' represents the serial data bits, either being H (= OFF) or L (= ON)
- 'Mx' enables parallel control of channel x H (=parallel) or L (=serial)
- 'Z' means tri-state
- 'F' is the common fault flag
- 'OT' is the common over-temperature flag
- 'DIAx' is the 2 bit diagnosis information per channel

All other possible control bytes will lead to an ignorance of the data bits, but the full diagnosis information (like RD\_DIAG command) is provided at the SO line. A reset of all fault registers (and OT bit) the will only be done if the RD\_DIAG command was clocked in.

### Characteristics of the SPI Interface

If the slave select signal at CS is High or bit 7 and bit 6 of the instruction byte differ from „1“ and „0“, the state machine is set on default condition, i.e. the state machine expects an instruction.

If the 5V-reset (RESET) is active, the SPI output SO is switched into tri-state.

In order to increase the possible number of SPI participants on one and the same CS signal, bits 7 and 6 of the instruction byte are fixed as shown above. While receiving the first two bits of the instruction byte the data output SO has to be in tri-state. After having received the first two bits TLE6232 has to decide if it is addressed (bit 7 = high, bit 6 = low). In this case the remaining 6 bits of the instruction byte and the data byte are accepted and the diagnostic feedback respectively the data byte content (MUX, SCON) is sent to the microcontroller. Otherwise instruction and data bits are rejected and SO remains in tri-state.

On a reading access the bit pattern of the data byte at the SPI input SI will be ignored. The first SO byte sent out simultaneously by the TLE 6232 GP always contains the common fault bit, the over-temperature bit and the diagnostic information of channels 6 and 5 (2 bits each). Depending on the SI control byte, the second SO byte contains the requested information.

- Read back of SCON\_REG (SCON bits 6 to 1 and two high bits)
- Read back of MUX\_REG (MUX information for channel 6 to 1 and two high bits)
- Diagnostic information of channel 4 to 1 (2 bits per channel)

On a writing access always the full diagnostic information of the 6 channels (2 bit per channel) and the over-temperature and common fault bit is performed.

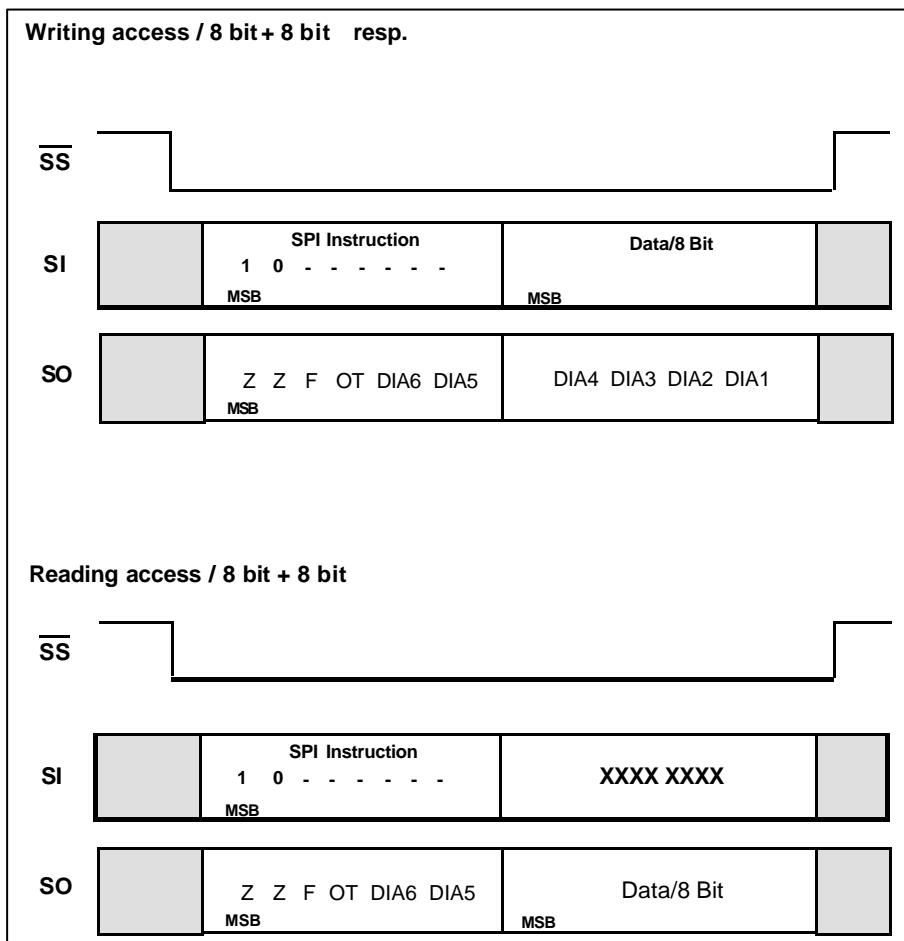
Invalid instruction/access:

An instruction is invalid, if the following condition is fulfilled:

- an unused instruction code is detected (see tables with SPI instructions).

If an invalid instruction is detected, a writing access on a register of TLE6232 GP is not allowed. In addition an access is invalid if the number of SPI clock pulses counted during active CS differs from exactly 16 clock pulses (falling edges are counted).

- On a writing access the received data is only taken over into the internal registers and
- the fault register is only cleared by the RD\_DIAG command, if exactly 16 SPI clock pulses were counted while CS active.



Serial/Parallel Control of the Power Stages 1...6

**(SPI-Instructions: WR\_MUX, RD\_MUX, WR\_SCON, RD\_SCON)**

The following table shows the truth table for the control of the power stages 1..6. The register MUX\_REG prescribes parallel or serial control of the power stages. The register SCON\_REG prescribes the state of the power stage in case of serial control.

| RST | PRG | INx | MUXx | SCONx | Output OUTx of Power Stage x, x = 1..6 |
|-----|-----|-----|------|-------|--|
| 0   | X   | X   | X    | X     | OUTx off                               |
| 1   | X   | X   | 0    | 0     | Serial Control: OUTx on                |
| 1   | X   | X   | 0    | 1     | Serial Control: OUTx off               |
| 1   | 0   | 0   | 1    | X     | Parallel Control: OUTx on              |
| 1   | 0   | 1   | 1    | X     | Parallel Control: OUTx off             |
| 1   | 1   | 0   | 1    | X     | Parallel Control: OUTx off             |
| 1   | 1   | 1   | 1    | X     | Parallel Control: OUTx on              |

**Note:** Serial Data bits are low active. Parallel Inputs are high or low active depending on the PRG pin.

**Description of the SPI Registers**

| Register:             | MUX_REG    |   |      |      |      |   |   |
|-----------------------|------------|---|------|------|------|---|---|
| 7                     | 6          | 5   | 4    | 3    | 2    | 1 | 0 |
| MUX6                  | MUX5       | MUX4  | MUX3 | MUX2 | MUX1 | 1 | 1 |
| State of Reset:       | FFH        |   |      |      |      |   |   |
| Access by Controller: | Read/Write |   |      |      |      |   |   |
| Bit                   | Name       | Description                                 |      |      |      |   |   |
| 7                     | MUX6       | Serial or parallel control of power stage 6 |      |      |      |   |   |
| 6                     | MUX5       | Serial or parallel control of power stage 5 |      |      |      |   |   |
| 5                     | MUX4       | Serial or parallel control of power stage 4 |      |      |      |   |   |
| 4                     | MUX3       | Serial or parallel control of power stage 3 |      |      |      |   |   |
| 3                     | MUX2       | Serial or parallel control of power stage 2 |      |      |      |   |   |
| 2                     | MUX1       | Serial or parallel control of power stage 1 |      |      |      |   |   |
| 1-0                   |            | No function: HIGH on reading                |      |      |      |   |   |

| Register:             | SCON_REG   |  |       |       |       |   |   |
|-----------------------|------------|--|-------|-------|-------|---|---|
| 7                     | 6          | 5  | 4     | 3     | 2     | 1 | 0 |
| SCON6                 | SCON5      | SCON4                                    | SCON3 | SCON2 | SCON1 | 1 | 1 |
| State of Reset:       | FFH        |  |       |       |       |   |   |
| Access by Controller: | Read/Write |  |       |       |       |   |   |
| Bit                   | Name       | Description                              |       |       |       |   |   |
| 7                     | SCON6      | State of serial control of power stage 6 |       |       |       |   |   |
| 6                     | SCON5      | State of serial control of power stage 5 |       |       |       |   |   |
| 5                     | SCON4      | State of serial control of power stage 4 |       |       |       |   |   |
| 4                     | SCON3      | State of serial control of power stage 3 |       |       |       |   |   |
| 3                     | SCON2      | State of serial control of power stage 2 |       |       |       |   |   |
| 2                     | SCON1      | State of serial control of power stage 1 |       |       |       |   |   |
| 1-0                   |            | No function: HIGH on reading             |       |       |       |   |   |

**Diagnostics/Encoding of Failures**
**Description of the SPI Registers**
**(SPI Instructions: RD\_DIAG)**

|                       |                  |                                  |     |     |     |     |     |
|-----------------------|------------------|----------------------------------|-----|-----|-----|-----|-----|
| <b>Register:</b>      | <b>DIAG_REG1</b> |                                  |     |     |     |     |     |
| 7                     | 6                | 5                                | 4   | 3   | 2   | 1   | 0   |
| ST7                   | ST6              | ST5                              | ST4 | ST3 | ST2 | ST1 | ST0 |
| State of Reset:       | FFH              |                                  |     |     |     |     |     |
| Access by Controller: | Read only        |                                  |     |     |     |     |     |
| Bit                   | Name             | Description                      |     |     |     |     |     |
| 7-6                   | DIA4             | Diagnostic Bits of power stage 4 |     |     |     |     |     |
| 5-4                   | DIA3             | Diagnostic Bits of power stage 3 |     |     |     |     |     |
| 3-2                   | DIA2             | Diagnostic Bits of power stage 2 |     |     |     |     |     |
| 1-0                   | DIA1             | Diagnostic Bits of power stage 1 |     |     |     |     |     |

Note: This byte is always clocked out (second SO-byte), except the SI control words says: RD\_SCON or RD\_MUX. But: The content of the fault register will only be deleted if the control command 'RD\_DIAG' was clocked in and 16 clock pulses were counted.

|                       |                 |                                  |    |      |      |     |     |
|-----------------------|-----------------|----------------------------------|----|------|------|-----|-----|
| <b>Register:</b>      | <b>DIA_REG2</b> |                                  |    |      |      |     |     |
| 7                     | 6               | 5                                | 4  | 3    | 2    | 1   | 0   |
| Z                     | Z               | F                                | OT | ST11 | ST10 | ST9 | ST8 |
| State of Reset:       | FFH             |                                  |    |      |      |     |     |
| Access by Controller: | Read only       |                                  |    |      |      |     |     |
| Bit                   | Name            | Description                      |    |      |      |     |     |
| 7-6                   | Z               | Bit 7 and 6 are always tri-state |    |      |      |     |     |
| 5                     | F               | Common error flag                |    |      |      |     |     |
| 4                     | OT              | Common over-temperature flag     |    |      |      |     |     |
| 3-2                   | DIA6            | Diagnostic Bits of power stage 6 |    |      |      |     |     |
| 1-0                   | DIA5            | Diagnostic Bits of power stage 5 |    |      |      |     |     |

| <b>Encoding of the Diagnostic (Status) Bits of the Power Stages</b> |           |   |
|---|-----------|---|
| ST(2*x-1)   | ST(2*x-2) | State of power stage x x = 1..6                                   |
| 1   | 1         | Power stage o.k.  |
| 1   | 0         | Overload, short circuit to battery (SCB) or over-temperature (OT) |
| 0   | 1         | Open load (OL)  |
| 0   | 0         | Short circuit to ground (SCG)                                     |

Note: DIA\_REG2 is always clocked out as first byte  
 F, OT Bit = 1: No Fault  
 F, OT Bit = 0: Fault, Over-temperature  
 The over-temperature bit is the latched result of an OR-operation out of the 6 signals of the temperature sensor)  
 The general fault bit shows the fault occurrence at any of the outputs.

**Reset of the Diagnostic Information**

The diagnostic information will only be reset after the RD\_DIAG command on the rising edge of slave select or a reset signal is applied (RESET = low).

### Timing Diagrams

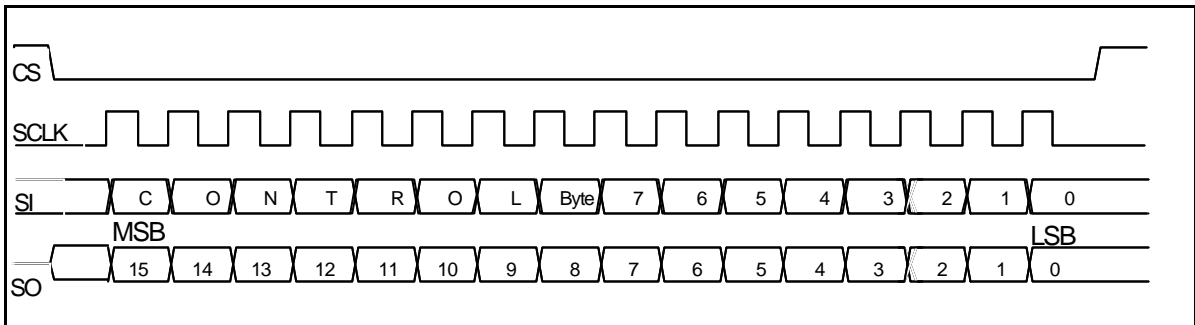


Figure 2: Serial Interface

Figure 3: Input Timing Diagram

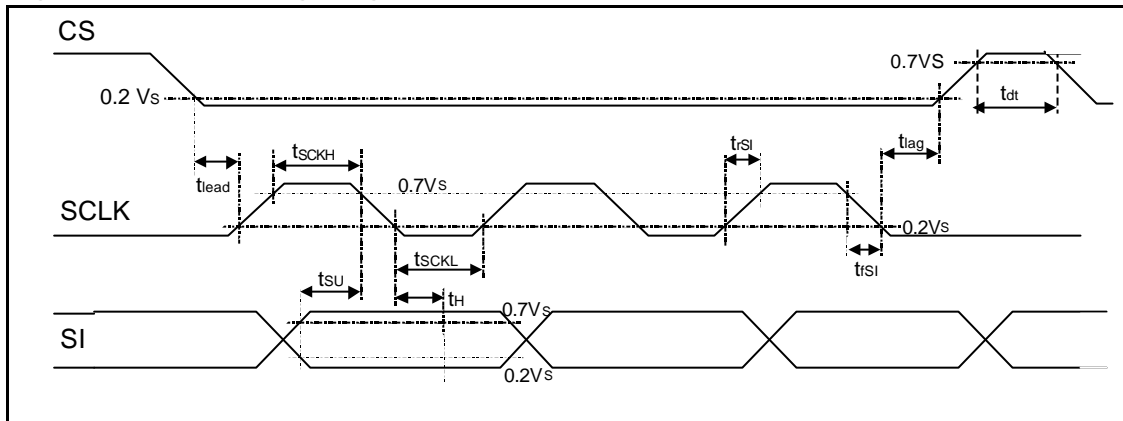
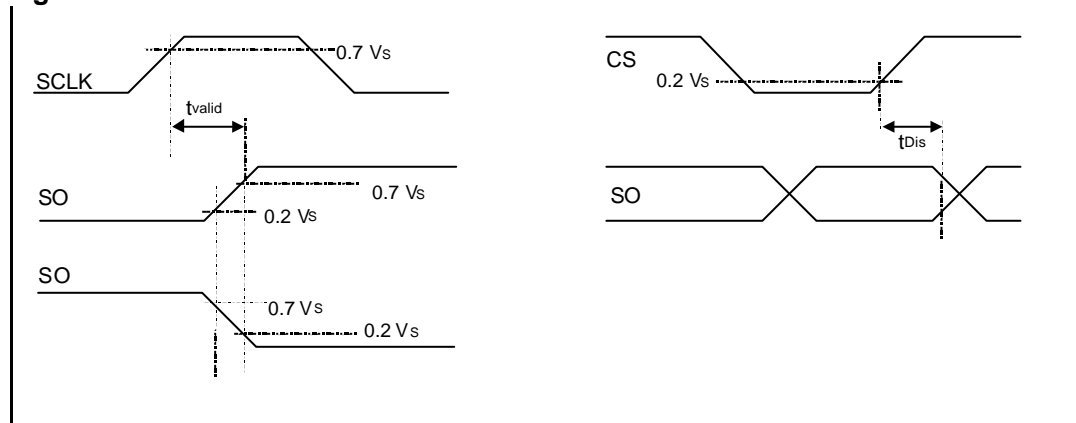


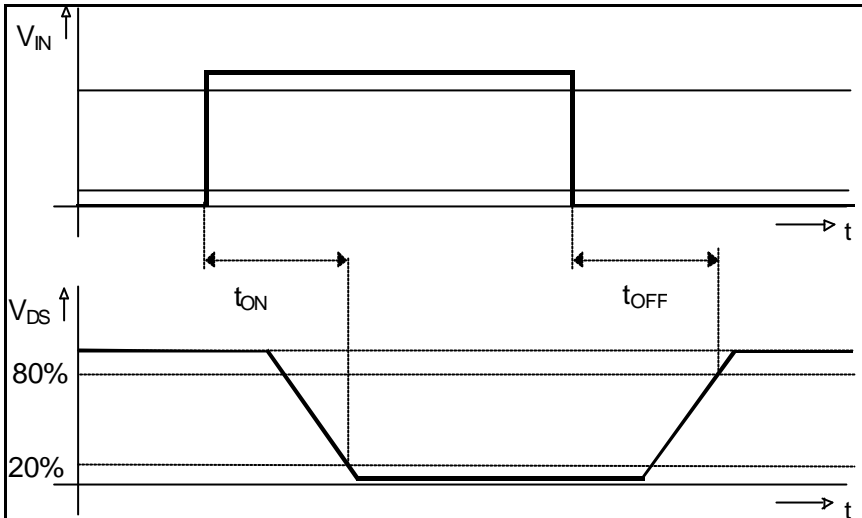
Figure 4:



SO Valid Time Waveforms

Enable and Disable Time Waveforms

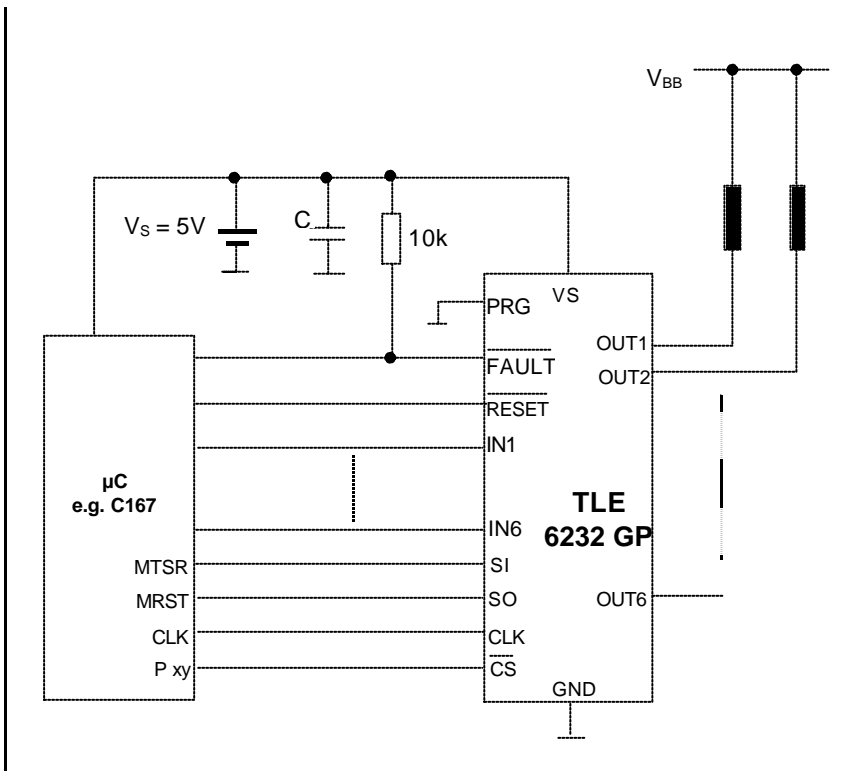




**Figure 5: Power Outputs**

Timing is valid for resistive load with parallel and serial control.  
Rising edge of chip select initiates the switching

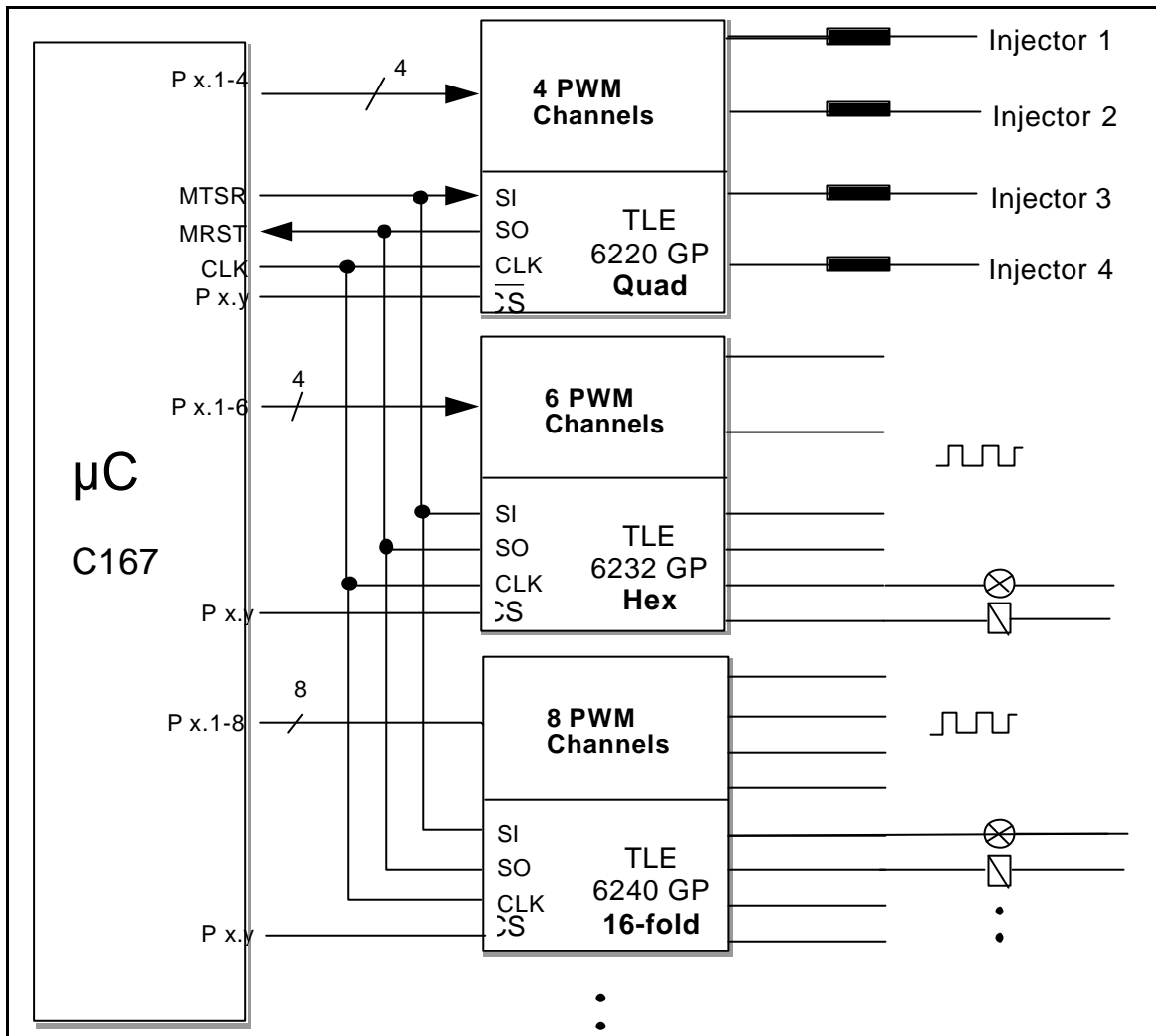
### Application Circuits



## Parallel SPI Configuration

### Engine Management Application

TLE 6232 GP in combination with TLE 6240 GP (16-fold switch) for relays and general purpose loads and TLE 6220 GP (quad switch) to drive the injector valves. This arrangement covers the numerous loads to be driven in a modern Engine Management/Powertrain system. From 26 channels in sum 18 can be controlled direct in parallel for PWM applications.



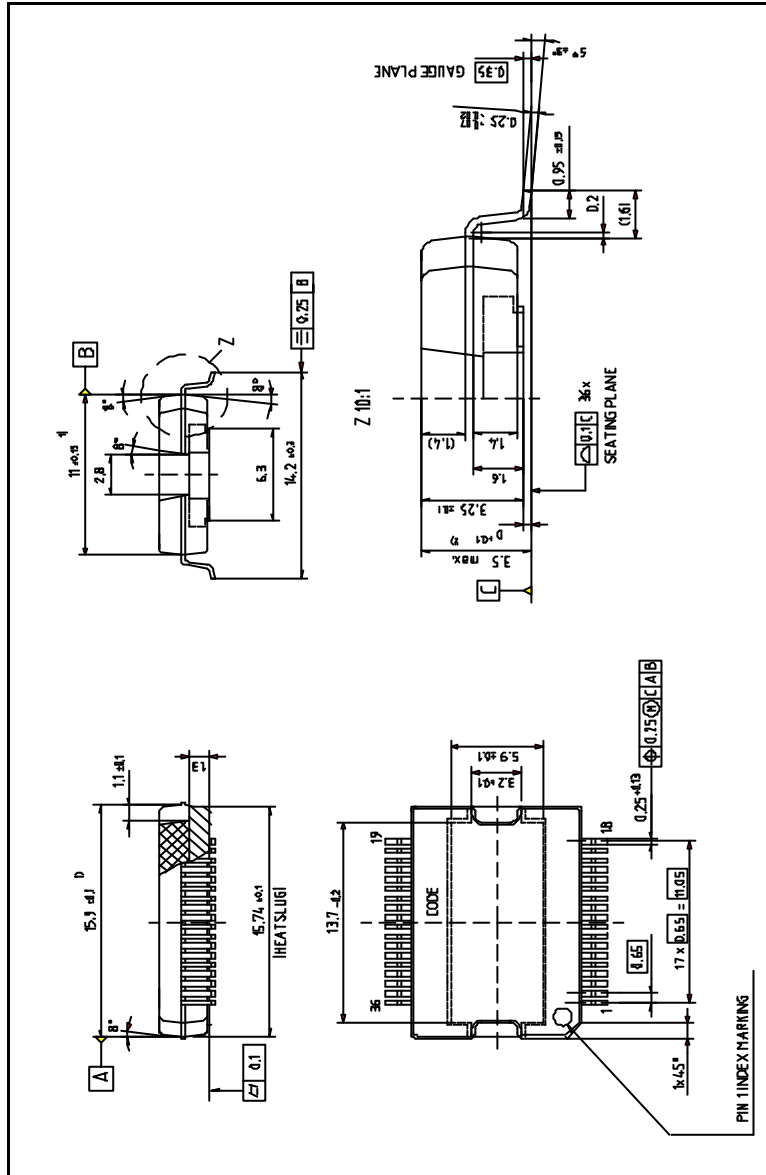
## Package and Ordering Code

(All dimensions in mm)

PG-DSO 36-26

Ordering Code

|             |                 |
|-------------|-----------------|
| TLE 6232 GP | Q67007A9397A702 |
|-------------|-----------------|



### 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).

## Revision History

| Version         | Date          | Changes  |
|-----------------|---------------|--|
| V2.0 -><br>V2.1 |               | Ordering Code / Q-Nr. removed  |
| V2.0 -><br>V2.1 | 05.04.2007    | Layout Changes, correct green package name implemented P-DSO-36-12 → PG-DSO-36-26  |
| V1.2 -><br>V2.0 | 05.03.2007    | Green Date sheet Version created   |
| V2.0            | 05.03.2007    | Changes to Green Product Version: <ul style="list-style-type: none"><li>- AEC, RoHS Logo and Feature List content added</li><li>- Package Name P-DSO -&gt; PG-DSO</li><li>- Change History added</li><li>- Disclaimer re-newed</li></ul> |
| V1.2            | 08. Oct. 2003 | Initial Version of "grey" product  |

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