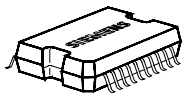
# Smart Quad Channel Low-Side Switch

**Features**

- Shorted Circuit Protection
- Overtemperature Protection
- Overvoltage Protection
- Parallel Control of the Inputs (PWM Applications)
- Seperate Diagnostic Pin for Each Channel
- Power - SO 20 - Package with integrated cooling area
- Standby mode with low current consumption
- µC compatible Input
- **E**lectro**s**tatic **D**ischarge (ESD) Protection

**Product Summary**

| | | | |
|---|---|---|---|
| Supply voltage | $V_S$ | 4.8 - 32 | V |
| Drain source voltage | $V_{DS(AZ)max}$ | 60 | V |
| On resistance($T_J$ =25°C) | $R_{ON(typ)\ 1,2}$ | 0.2 | Ω |
| | $R_{ON(typ)\ 3,4}$ | 0.35 | Ω |
| Output current | $I_{D\ 1,2}$ | 2 x 5 | A |
| | $I_{D\ 3,4}$ | 2 x 3 | A |



**P-DSO-20-10**

Ordering Code:
Q -A

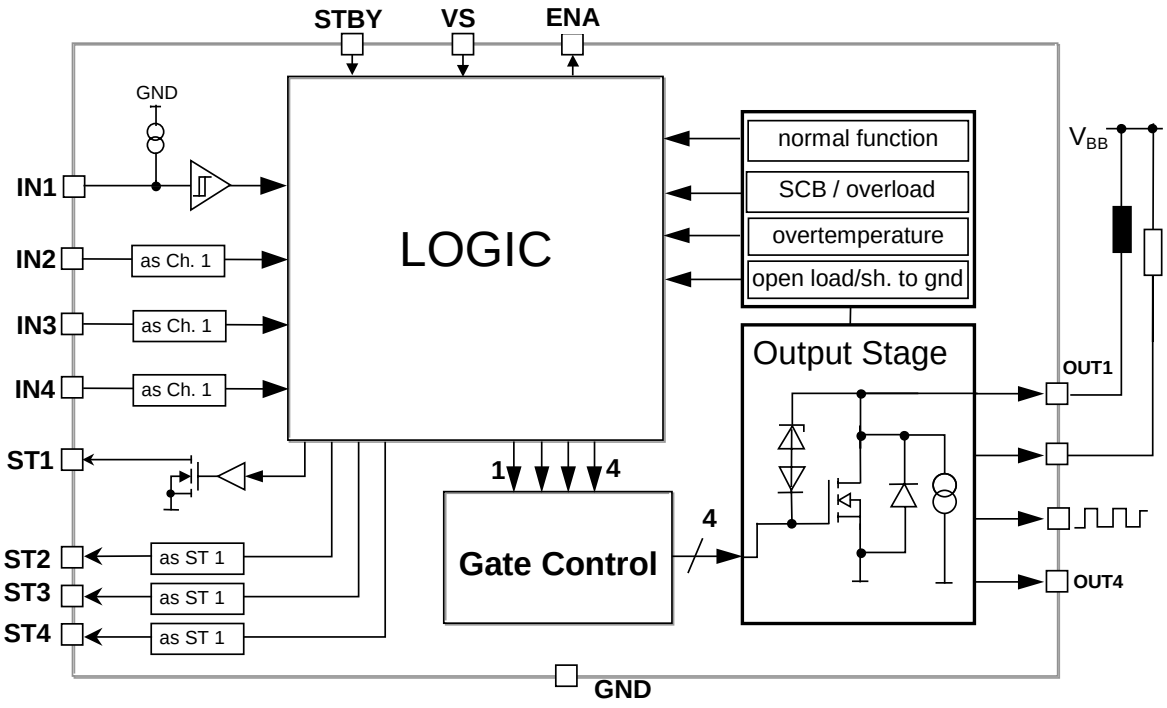
**Application**

- All kinds of resistive and inductive loads (relays,electromagnetic valves)
- µC compatible power switch for 12 and 24 V applications
- Solenoid control switch in automotive and industrial control systems
- Robotic Controls

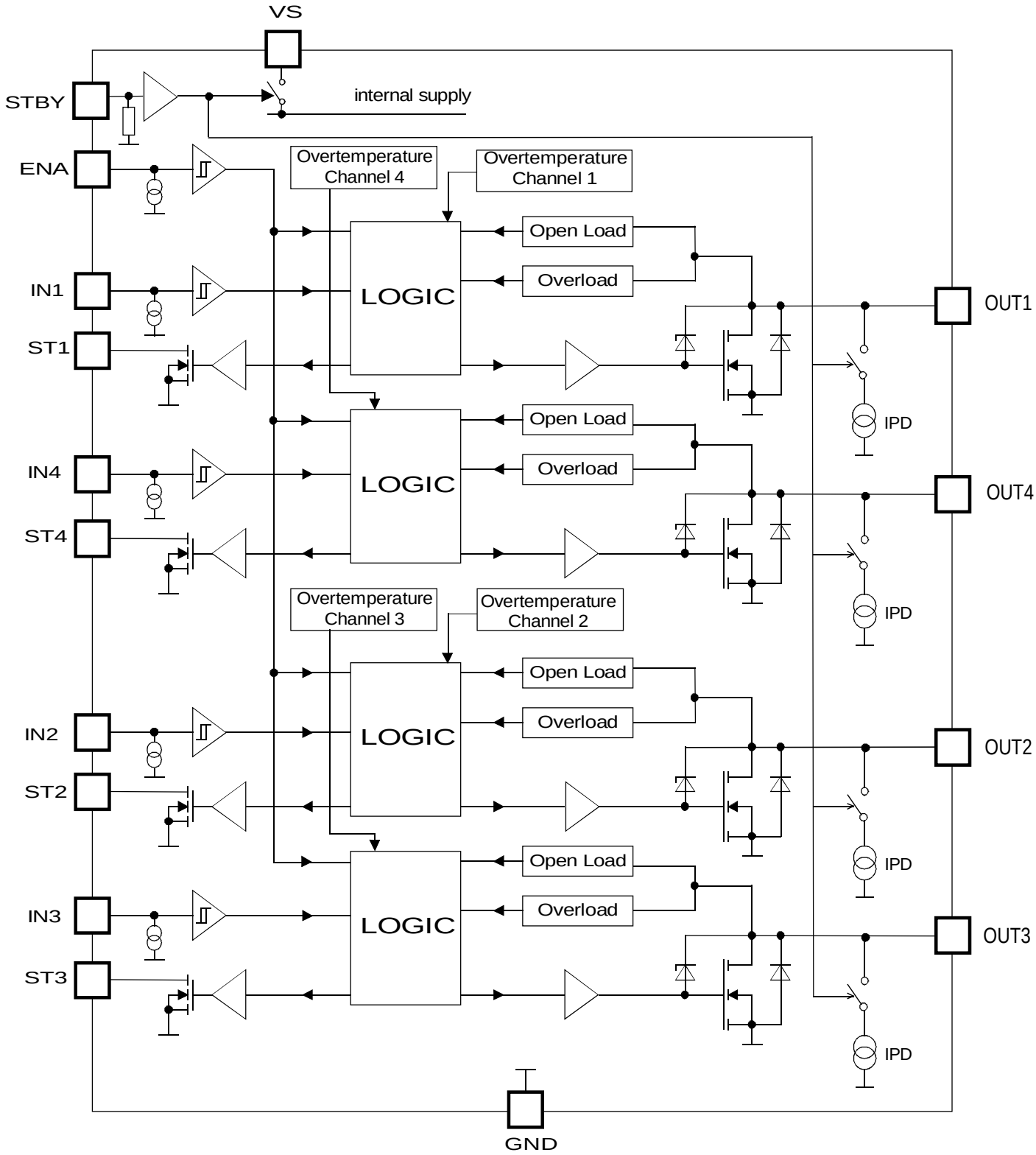
**General description**

Quad channel Low-Side-Switch (2x5A/2x3A) in Smart Power Technology (SPT) with four separate inputs and four open drain DMOS output stages. The TLE 6228 GP is fully protected by embedded protection functions and designed for automotive and industrial applications. Each channel has its own status signal for diagnostic feedback. Therefore the TLE 6228 GP is particularly suitable for ABS or Powertrain Systems.

**Block Diagram**



## Detailed Block Diagram

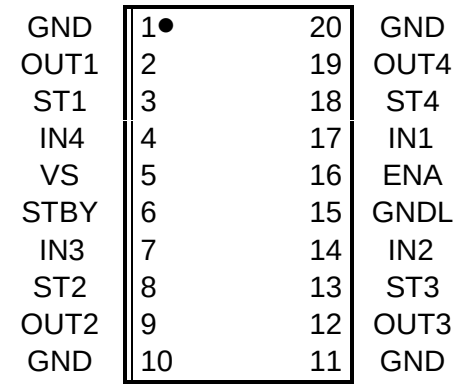


**Pin Description**

| Pin | Symbol | Function |
|---|---|---|
| 1 | GND | Ground |
| 2 | OUT1 | Power Output channel 1 |
| 3 | ST1 | Status Output channel 1 |
| 4 | IN4 | Control Input channel 4 |
| 5 | VS | Supply Voltage |
| 6 | STBY | Standby |
| 7 | IN3 | Control Input channel 3 |
| 8 | ST2 | Status Output channel 2 |
| 9 | OUT2 | Power Output channel 2 |
| 10 | GND | Ground |
| 11 | GND | Ground |
| 12 | OUT3 | Power Output channel 3 |
| 13 | ST3 | Status Output channel 3 |
| 14 | IN2 | Control Input channel 2 |
| 15 | GND | Ground Logic |
| 16 | ENA | Enable Input for all four channels |
| 17 | IN1 | Control Input channel 1 |
| 18 | ST4 | Status Output channel 4 |
| 19 | OUT4 | Power Output channel 4 |
| 20 | GND | Ground |

Heat slug internally connected to ground pins

**Pin Configuration (Top view)**

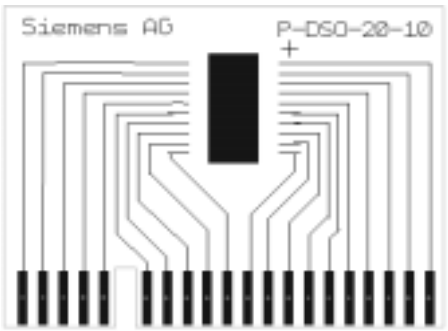



P - DSO - 20 - 10

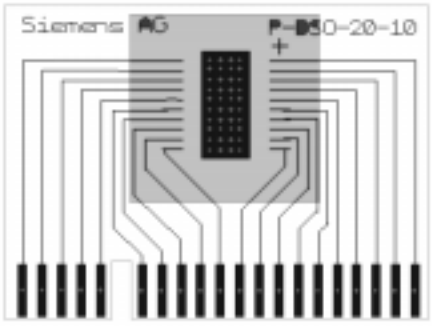
## Maximum Ratings for $T_j$ = – 40°C to 150°C

*The maximum ratings may not be exceeded under any circumstances, not even momentarily and individually, as permanent damage to the IC will result.*

| Parameter | Symbol | Values | Unit |
|---|---|---|---|
| Supply voltage | $V_S$ | -0.3 ... + 40 | V |
| Continuous drain source voltage (OUT1...OUT4) | $V_{DS}$ | 45 | V |
| Input voltage IN1 to IN4, ENA | $V_{IN}$ , $V_{ENA}$ | - 0.3 ... + 6 | V |
| Input voltage STBY | $V_{STBY}$ | - 0.3 ... + 40 | |
| Status output voltage | $V_{ST}$ | - 0.3 ... + 32 | V |
| Load Dump Protection $V_{Load\ Dump}$ = $U_P$+$U_S$; $U_P$=13.5 V<br>Load tbd<br>$R_I$[1)]=2 Ω; $t_d$=400ms; IN = low or high<br>With $R_L$= tbd Ω ($I_D$ = 2A)<br>$R_I$=2 Ω; $t_d$=400ms; IN = low or high | $V_{Load\ Dump}$[2)] | <br>tbd<br><br>tbd | V |
| Operating temperature range<br>Storage temperature range | $T_j$<br>$T_{stg}$ | - 40 ... + 150<br>- 55 ... + 150 | °C |
| Output current per channel (see page 6) | $I_{D(lim)}$ | overload<br>shutdown | A |
| Status output current | $I_{ST}$ | - 5 ... + 5 | mA |
| Inductive load switch off dissipation energy $T_j$ = 25°C | $E_{AS}$ | 50 | mJ |
| **E**lectro**s**tatic **D**ischarge Voltage (human body model)<br>according to MIL STD 883D, method 3015.7 and EOS/ESD 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<br>junction - ambient @ min. footprint<br>junction - ambient @ 6 cm$^2$ cooling area | <br>$R_{thJC}$<br>$R_{thJA}$<br> | <br>2<br>50<br>38 | K/W |




Minimum footprint




PCB with heat pipes,
backside 6 cm$^2$ cooling area

[1)] $R_I$=internal resistance of the load dump test pulse generator LD200
[2)] $V_{LoadDump}$ is setup without DUT connected to the generator per ISO 7637-1 and DIN 40 839.

## Electrical Characteristics

| Parameter and Conditions<br>$V_S$ = 4.8 to 18 V ; $T_j$ = - 40 °C to + 150 °C<br>(unless otherwise specified) | | Symbol | Values | | | Unit |
|---|---|---|---|---|---|---|
| | | | min | typ | max | |
| **1. Power Supply ($V_S$)** | | | | | | |
| Supply current (Outputs ON) | | $I_S$ | | | 8 | mA |
| Supply current (Outputs OFF)<br>$V_{ENA}$ = L, $V_{STBY}$ = H | | $I_S$ | | | 4 | mA |
| Standby current | $V_{STBY}$ = L | $I_S$ | | | 10 | µA |
| Operating voltage | | $V_S$ | 4.8 | | 32 | V |
| **2. Power Outputs** | | | | | | |
| ON state resistance Channel 1,2 | $T_j$ = 25 ° C | $R_{DS(ON)}$ | | 0.2 | 0.26 | Ω |
| $I_D$ = 1A; $V_S \geq$ 9.5 V | $T_j$ = 150°C | | | | 0.5 | |
| ON state resistance Channel 3,4 | $T_j$ = 25 ° C | $R_{DS(ON)}$ | | 0.35 | 0.4 | Ω |
| $I_D$ = 1A; $V_S \geq$ 9.5 V | $T_j$ = 150°C | | | | 0.75 | |
| Z-Diode clamping voltage (OUT1...4) | $I_D \geq$ 100 mA | $V_{DS(AZ)}$ | 45 | | 60 | V |
| Pull down current | $V_{STBY}$ = H, $V_{IN}$ = L | $I_{PD}$ | 10 | 20 | 50 | µA |
| Output leakage current | $V_{STBY}$ = L, 0V ≤ $V_{DS}$ ≤ 35V | $I_{Dlk}$ | | | 5 | µA |
| | $V_{STBY}$ = L, 35V ≤ $V_{DS}$ ≤ 45V | | | | 1 | mA |
| Output turn on time [3] | $I_D$ = 1 A | $t_{on}$ | 3 | 15 | 50 | µs |
| Output turn off time [3] | $I_D$ = 1 A | $t_{off}$ | 3 | 20 | 60 | |
| Output on fall time [3] | $I_D$ = 1 A | $t_{fall}$ | 3 | 10 | 30 | |
| Output off rise time [3] | $I_D$ = 1 A | $t_{rise}$ | 3 | 10 | 30 | |
| Overload switch-off delay time [3] | | $t_{DSO}$ | tbd | 60 | tbd | |
| Output off status delay time [3] | | $t_D$ | 500 | 1200 | 3000 | |
| Failure extension Time for Status Report | | $t_{D\text{-failure}}$ | 500 | 1200 | 3000 | |
| Input Suppression Time | | $t_{D\text{-IN}}$ | 500 | 1200 | 3000 | |
| Output on status delay time [4] | | $t_{dST}$ | 10 | 50 | 100 | |
| **3. Digital Inputs (IN1, IN2, IN3, IN4, ENA)** | | | | | | |
| Input low voltage | | $V_{INL}$ | - 0.3 | | 1.0 | V |
| Input high voltage | | $V_{INH}$ | 2.0 | | 6.0 | V |
| Input voltage hysteresis [4] | | $V_{INHys}$ | 50 | 100 | | mV |
| Input pull down current | $V_{IN}$ = 5 V; $V_S \geq$ 6.5 V | $I_{IN}$ | 10 | 30 | 60 | µA |
| Enable pull down current | $V_{ENA}$ = 5 V; $V_S \geq$ 6.5 V | $I_{ENA}$ | 10 | 20 | 40 | µA |
| **4. Digital Status Outputs (ST1 - ST4) Open Drain** | | | | | | |
| Output voltage low | $I_{ST}$ = 2 mA | $V_{STL}$ | | | 0.5 | V |
| Leakage current high | | $I_{STH}$ | | | 2 | µA |

[3] See timing diagram, resistive load condition; $V_S \geq$ 9 V

[4] This parameter will not be testet but assured by design

## Electrical Characteristics

| Parameter and Conditions<br>$V_S$ = 4.8 to 18 V ; $T_j$ = – 40 °C to + 150 °C<br>(unless otherwise specified) | | Symbol | Values | | | Unit |
|---|---|---|---|---|---|---|
| | | | min | typ | max | |
| **5. Standby Input (STBY)** | | | | | | |
| Input low voltage | | $V_{STBY}$ | 0 | | 1 | V |
| Input high voltage | | $V_{STBY}$ | 3.5 | | $V_S$ | V |
| Input current | $V_{STBY}$ = 18 V | $I_{STBY}$ | | | 300 | µA |
| **6. Diagnostic Functions** | | | | | | |
| Open load detection voltage<br>$V_{ENA}$ = X, $V_{IN}$ = L | $V_S \geq$ 6.5 V | $V_{DS(OL)}$ | 0.3*$V_S$ | 0.33*$V_S$ | 0.36*$V_S$ | V |
| Open load detection current channel 1,2<br>$V_{ENA}$ = $V_{IN}$ = H | $V_S \geq$ 6.5 V | $I_{D(OL)\ 1,2}$ | tbd | 160 | tbd | mA |
| Open load detection current channel 3,4<br>$V_{ENA}$ = $V_{IN}$ = H | $V_S \geq$ 6.5 V | $I_{D(OL)\ 3,4}$ | Tbd | 160 | tbd | mA |
| Overload detection current channel 1,2 | $V_S \geq$ 6.5 V | $I_{D(lim)\ 1,2}$ | 5 | 7.5 | | A |
| Overload detection current channel 3,4 | $V_S \geq$ 6.5 V | $I_{D(lim)\ 3,4}$ | 3 | 5 | | A |
| Overtemperature shutdown threshold [4] | | $T_{th}$ | 170 | | 200 | °C |
| Hysteresis | | $T_{hys}$ | | 10 | | K |
| Pulse Width for static diagnostic output | | $t_{IN}$ | | | 500 | µs |

[4] This parameter will not be tested but assured by design

# Application Description

This IC is especially designed to drive inductive loads (relays, electromagnetic valves).
Integrated clamp-diodes limit the output voltage when inductive loads are discharged.

Four open-drain logic outputs indicate the status of the integrated ciruit. The following conditions are monitored and signalled:

- overloading of output (also shorted load to supply) in active mode
- open and shorted load to ground in active and inactive mode
- overtemperature

# Circuit Description

### Input Circuits

The control and enable inputs, both active high, consist of schmitt triggers with hysteresis. All inputs are provided with pull-down current sources. Not connected inputs are interpreted as low and the respective output stages are switched off.

In standby mode (STBY = LOW ) the current consumption is greatly reduced.
The circuit is active when STBY = HIGH.
If the standby function is not used, it is allowed to connect the standby pin directly to VS.
Status Signals: The status signals are undefined for 2ms after a power up event or a STBY low to high transition.

### Output Stages

The four power outputs consist of DMOS-power transistors with open drains. The output stages are short circuit protected throughout the operating range. Each output has it's own zenerclamp. This causes a voltage limitation at the power transistor when inductive loads are switched off.
Parallel to the DMOS transistors there are internal pull down current sources. They are provided to detect an open load condition in the off state. They will be disconnected in the standby mode.
Due to EMI measures there is an internal zenerclamp in parallel to the output stage. It gets active above 35V drain source voltage. This leads to an increasing leakage current up to 1 mA @ $V_{DS}$ = 40V. See characteristics 3.5.

### Protective Circuits

The outputs are protected against current overload and overtemperature. If the output current increases above the overload detection threshold $I_{QO}$ for a longer time then $t_{DSO}$ or the temperature increases above $T_{th}$, then the power transistor is immediately switched off. It remains off until the control signal at the input is switched off and on again.

### Fault Detection

The status outputs indicate the switching state of the output stage. Under normal conditions is: ST = low $\Rightarrow$ Output off; ST = high $\Rightarrow$ Output on. If an error occurs, the logic level of the status output is inverted, as listed in the diagnostic table.

If current overload or overtemperature occurs for a longer time than $t_{DSO}$, the fault condition is latched into an internal register and the output is shutdown. The reset is done by switching off the corresponding control input.

Open load is detected for all four channels in on and off mode.

In the on mode the load current is monitored. If it drops below the specified threshold value IQU then an open load condition is detected.

In the off mode, the output voltage is monitored. An open load condition is detected when the output voltage of a given channel is below the threshold $V_{DS(OL)}$, which is typ. 33 % of the supply voltage VS.

**Status output at pulse width operation**

If the input is operated with a pulsed signal, the status does not follow each single pulse of the input signal. An internal delay $t_D$ of typ. 1.2ms ( min 500 µs) enables a continuous status output signal. See the timing diagrams on the following pages for further information.

This internal status delay simplifies diagnostic software for pwm applications.

## Diagnostic Table

In general the status follows the input signal in normal operating conditions.

If any error is detected the status is inverted.

| **Operating Condition** | Standby Input | Enable Input | Control Input | Power Output | Status Output |
|---|---|---|---|---|---|
| | **STBY** | **ENA** | **IN** | **Q** | **ST** |
| Standby | L | X | X | off | H |
| Normal function | H | L | X | off | L |
| | H | H | L | off | L |
| | H | H | H | ON | H |
| Open load or short to ground | H | L | L | off | H |
| | H | L | H | off | H |
| | H | H | L | off | H |
| | H | H | H | ON | L |
| Overload or short to supply[1)] | H | H | H | off | L |
| reset latch [2)] | H | H | H → L | off | L |
| | H | L | X | off | L |
| Overtemperature[1)] | H | H | H | off | L |
| reset latch [2)] | H | H | H → L | off | L |
| | H | L | X | off | L |

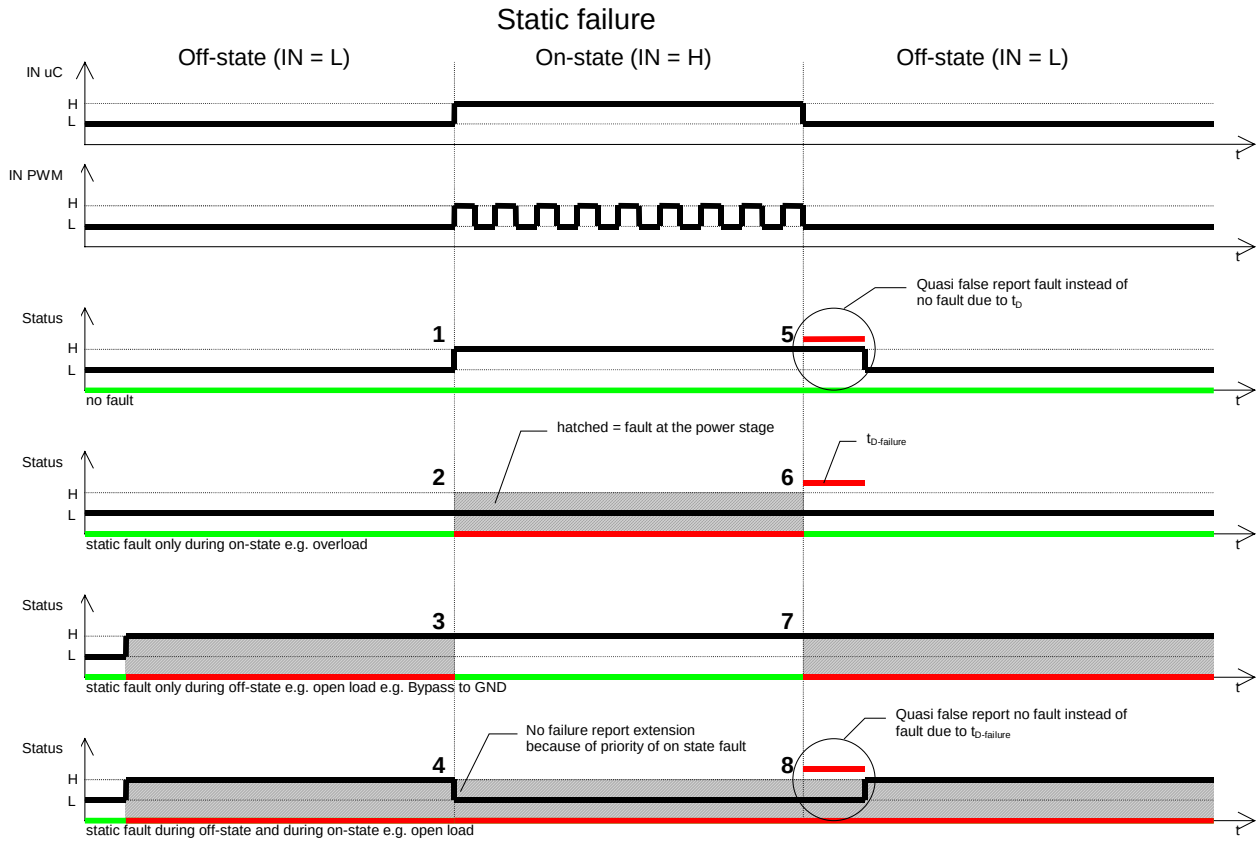
Note 1) : overload/short-to-supply/overtemperature - events shorter than min. time $t_{DSO}$ specified in 3.10 will not be latched and not reported at the status pin.

Note 2) : to reset latched status-output in case of overload/short-to-supply/overtemperature the control input has to go low and stay low for longer than max. input suppression time $t_{D\text{-}IN}$ specified in 3.13 of the characteristics

# Failure Situations and Status Report

## 1. Static failure

| Nr. | Off-state | On-state | Nr. | On-state | Off-state |
|---|---|---|---|---|---|
| 1 | no fault | no fault | 5 | no fault | no fault |
| 2 | no fault | fault | 6 | fault | no fault |
| 3 | fault | no fault | 7 | no fault | fault |
| 4 | fault | fault | 8 | fault | fault |



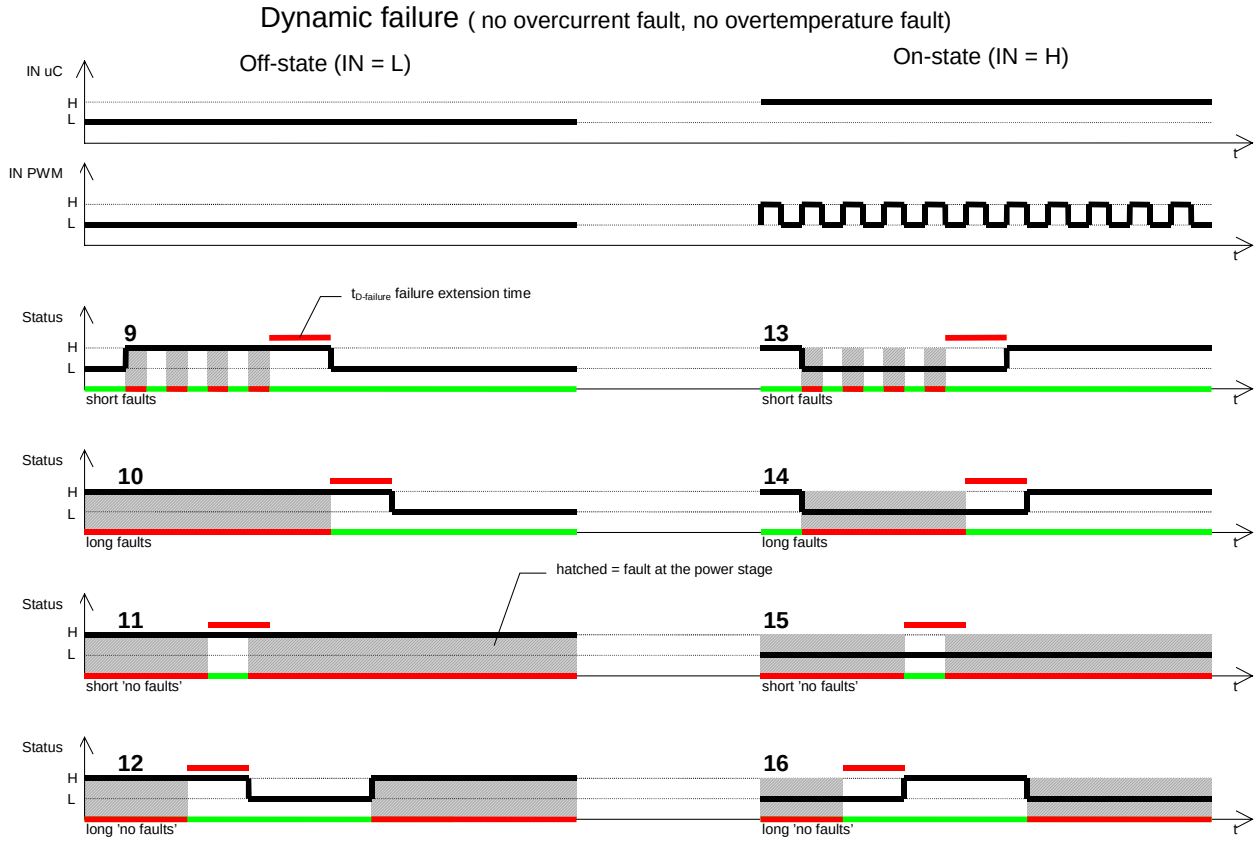

$t_D$ is the output off status delay time. This delay provides a steady status signal during PWM control (number 5).

$t_{D\text{-failure}}$ extends the failure status report (number 6 and 8).

$t_{D\_IN}$ is the input suppression time to suppress input signals for example after a overload condition (number 19).

## 2. Dynamic failure ( no overload faults, no overtemperature faults)

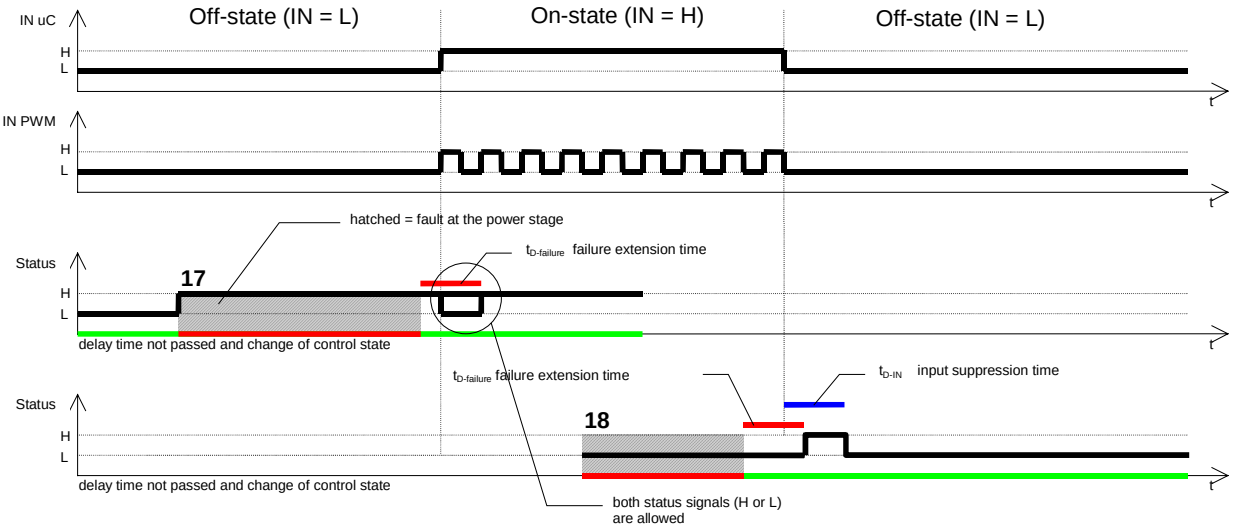
| Nr. | Off-state | Nr. | On-state |
|---|---|---|---|
| 9 | short term faults | 13 | short term faults |
| 10 | long term faults | 14 | long term faults |
| 11 | short term 'no faults' | 15 | short term 'no faults' |
| 12 | long term 'no faults' | 16 | long term 'no faults' |



## 3. Change of input state during fault delay time

| Nr. | Change from |
|---|---|
| 17 | Off-state (IN = L) to On-state (IN = H) |
| 18 | On-state (IN = H) to Off-state (IN = L) |

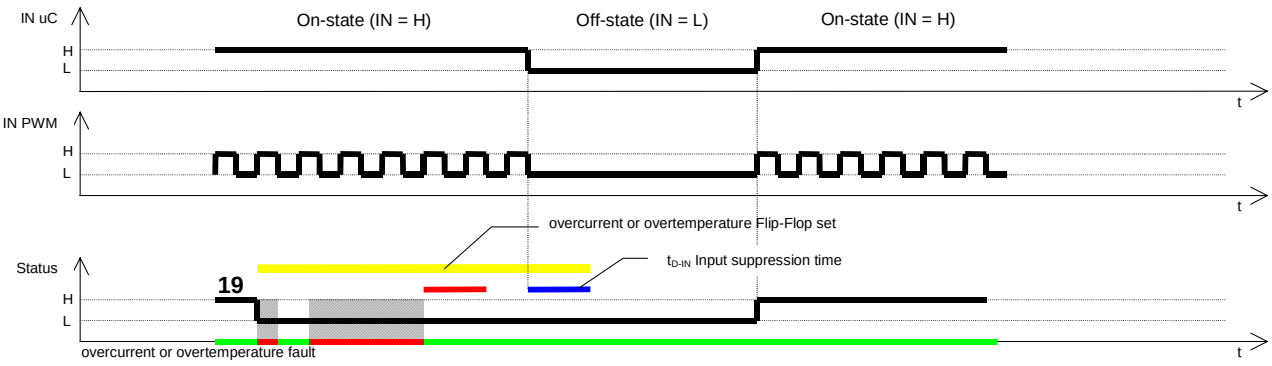
Change of Input State during Status Delay Time




## 4. Dynamic failure (Overload or overtemperature faults)

| Nr. | On-state (IN = H) |
|---|---|
| 19 | Overload or overtemperature faults |

Dynamic failure (overcurrent or overtemperature faults)




Note: The diagrams before do not show the 'output on status delay time' $t_{dST}$ and the 'overload switch off delay time' $t_{DSO}$. See timing diagram on page 12.

# Timing Diagrams

## Output Slope

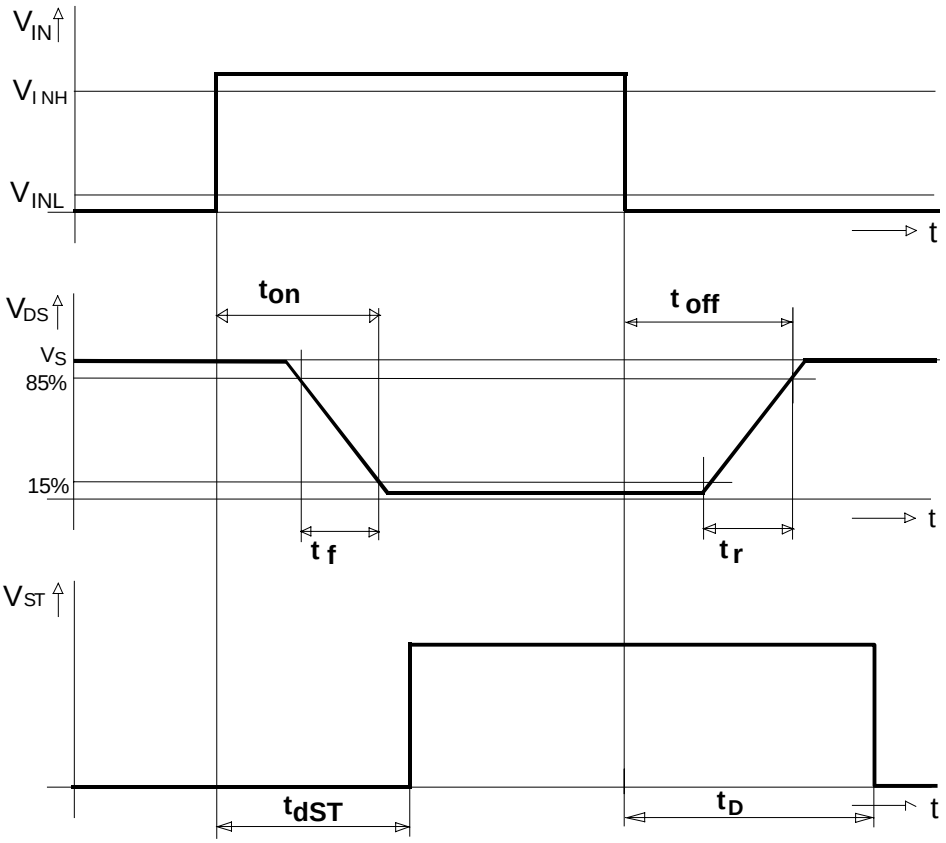



Fig. 1

## Overload Switch OFF Delay

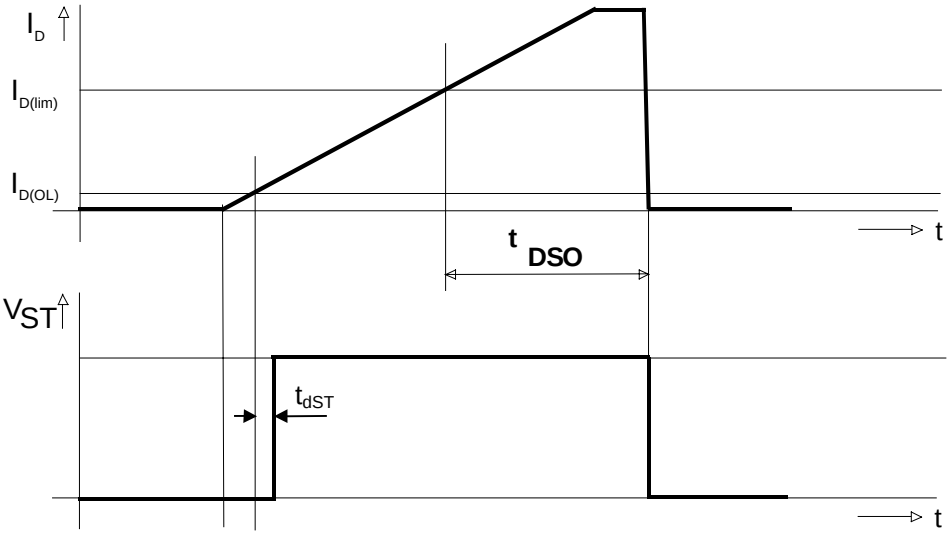
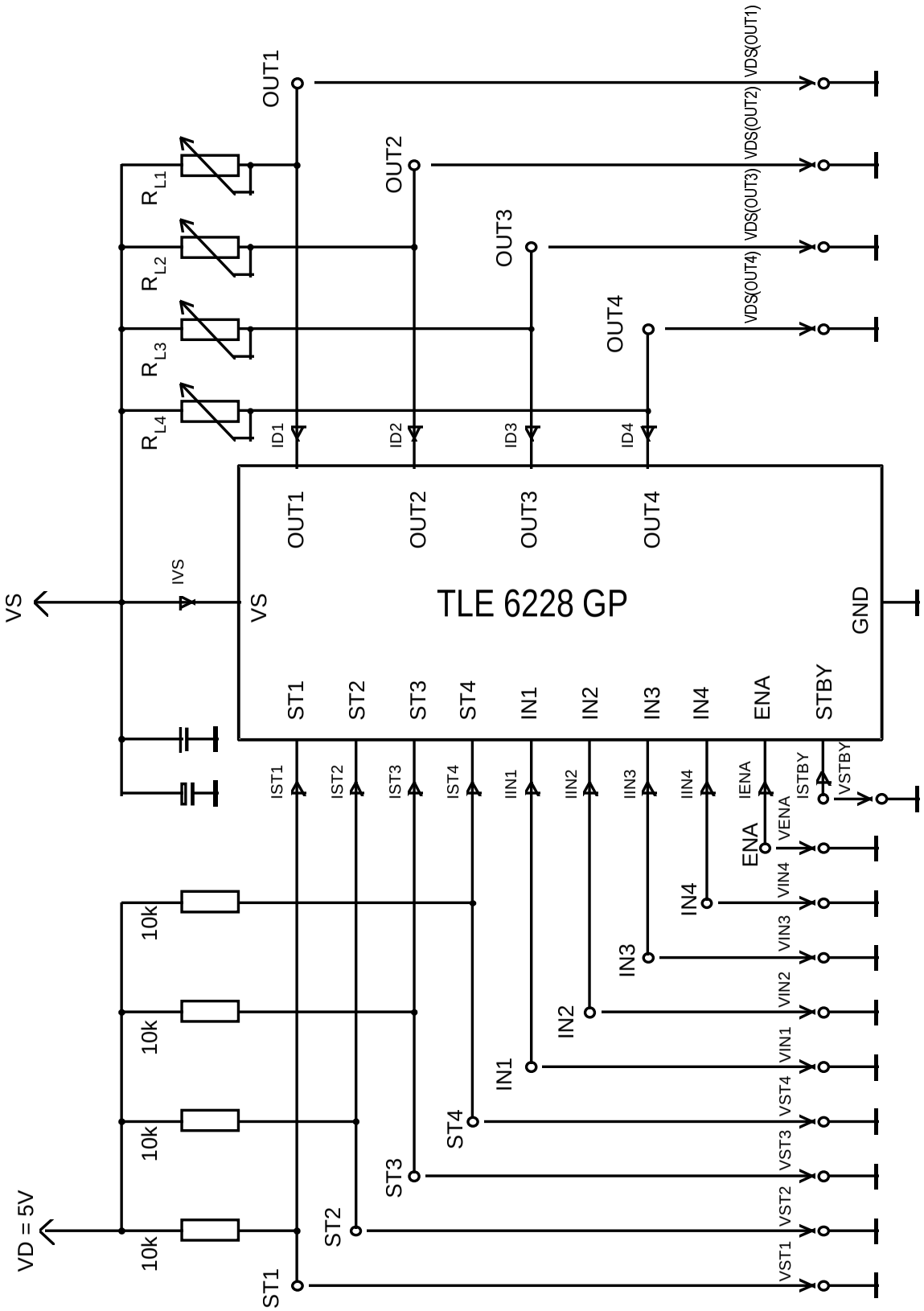
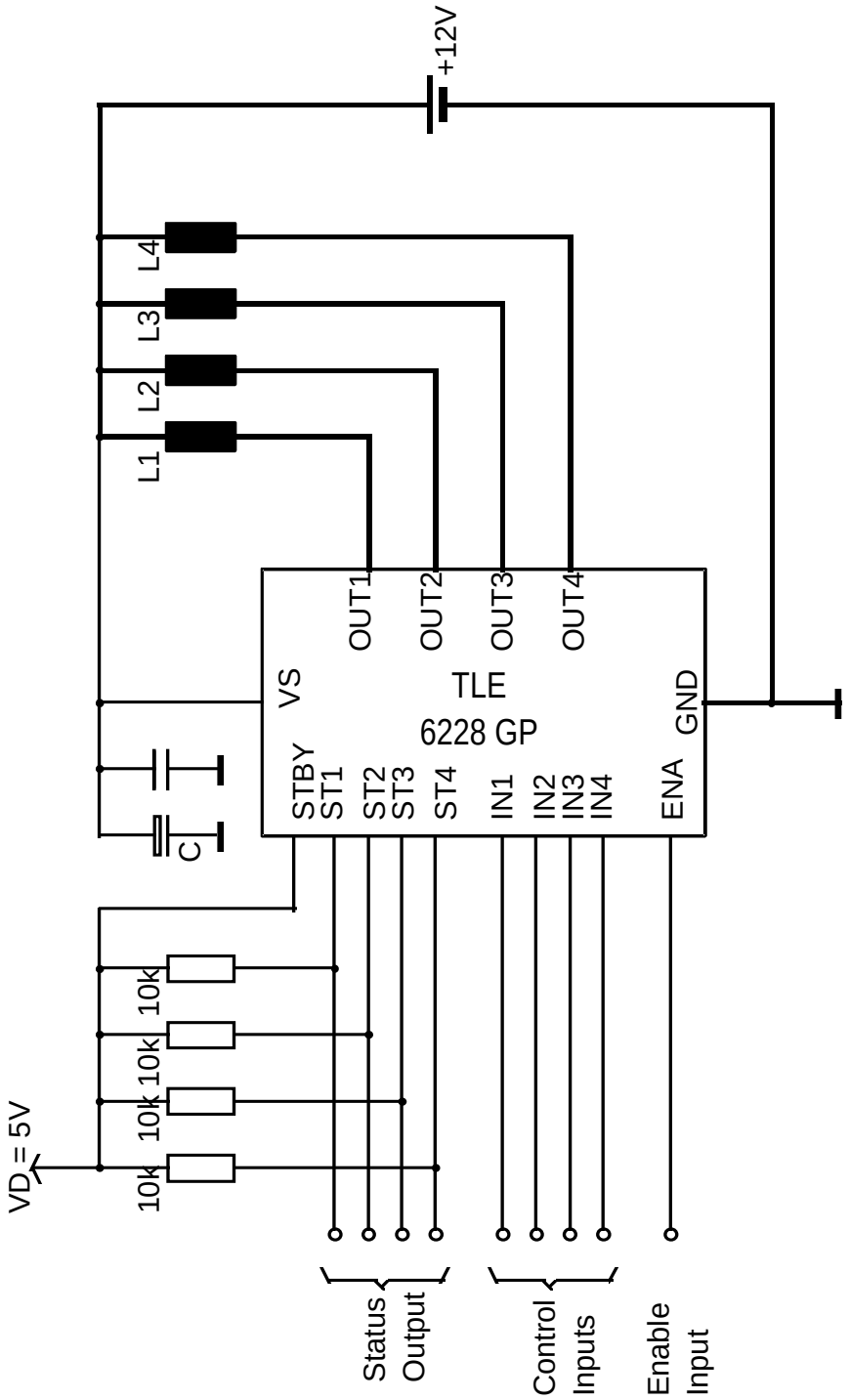



Fig. 2

## Test Circuit



## Application Circuit




The blocking capacitor C is recommended to avoid critical negative voltage spikes on VS in case of battery interruption during OFF-commutation.

# Timing Diagrams of Diagnostic with Pulsed Input Signal

## Normal condition, resistive load, pulsed input signal

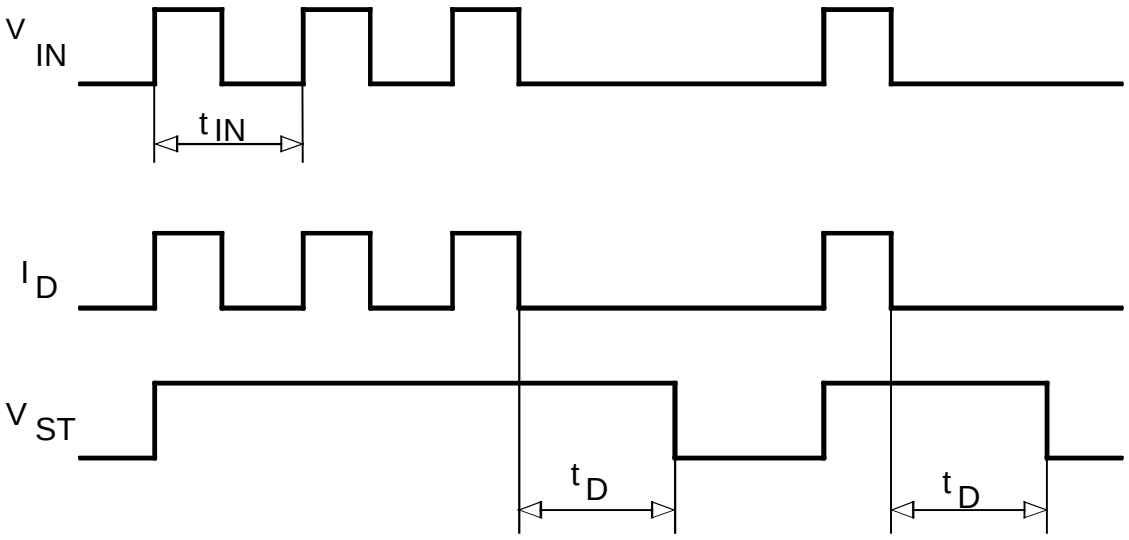
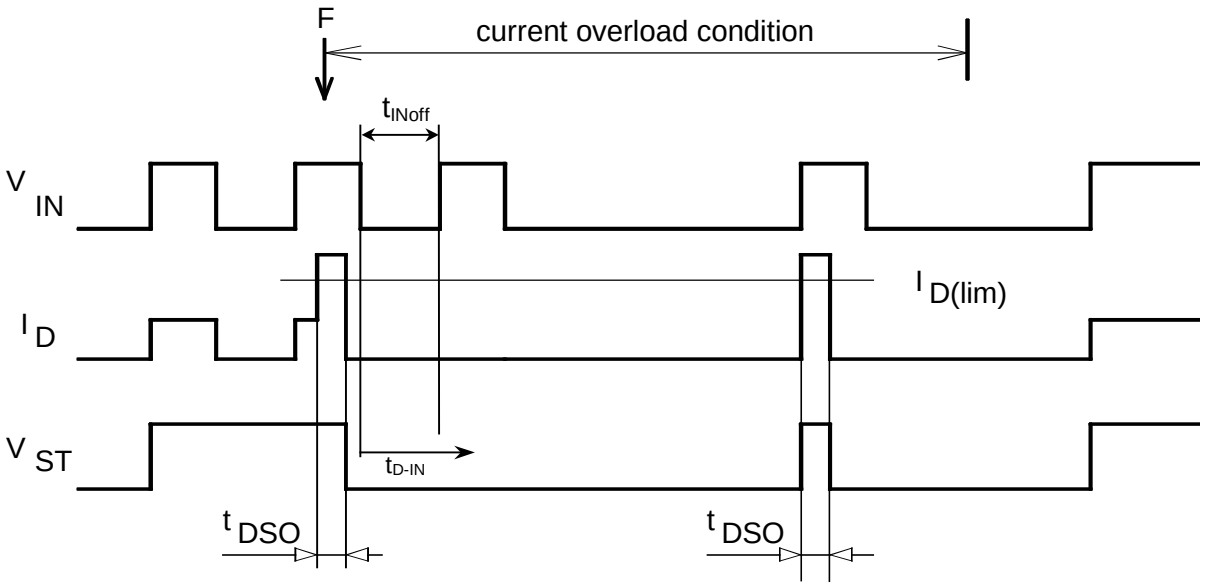



Fig. 3

## Current Overload




$t_{INoff} < t_{D-IN}$ : Input suppression time avoids a restart after overtemperature

Fig. 4

## Diagnostic status output at different open load current conditions

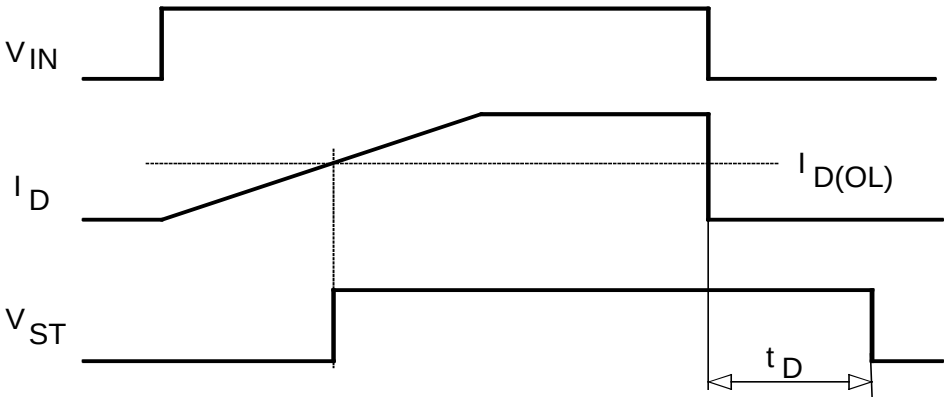
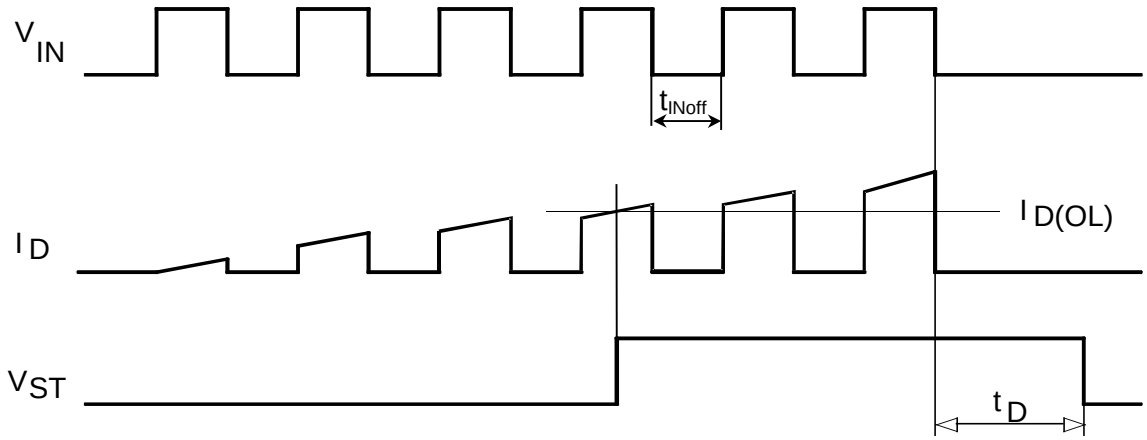
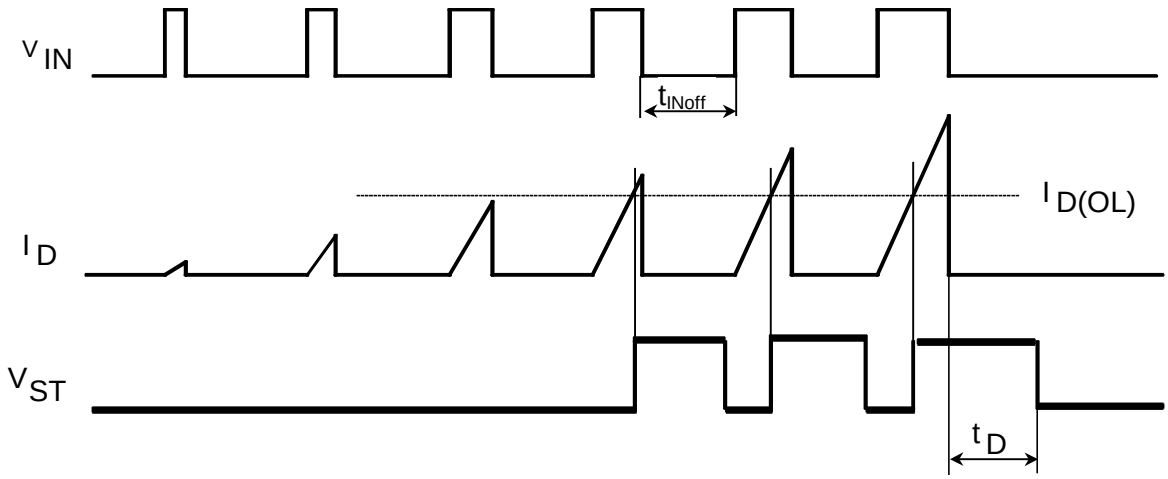



Fig. 5




$t_{INOFF} < t_D$ leads to a static status signal

Fig. 6




$t_{INoff} > t_D$ : Intermittend status signal

Fig. 7

**Normal operation, followed by open load condition**

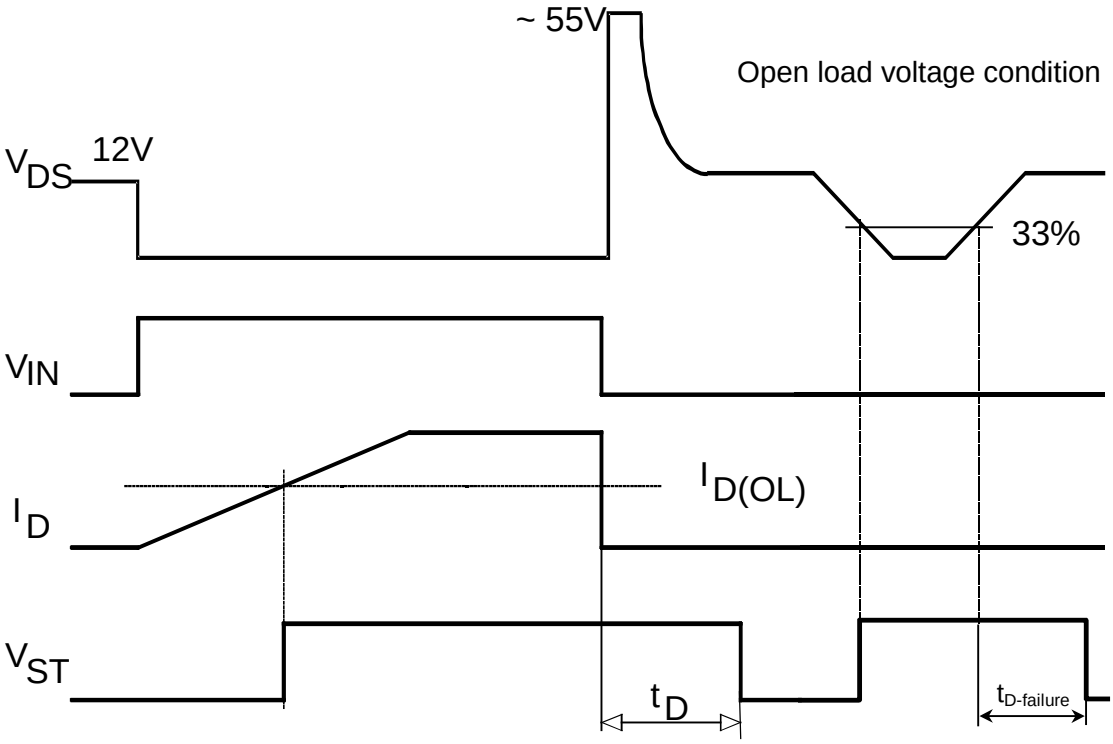



Fig. 8

**Overtemperature**

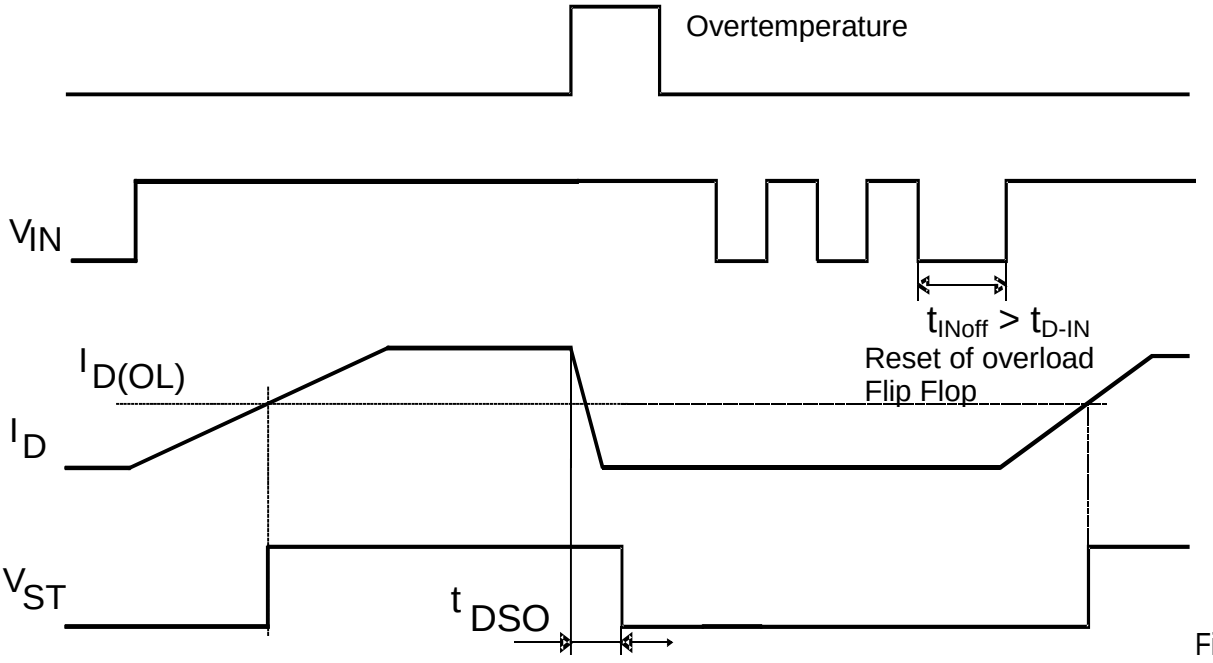
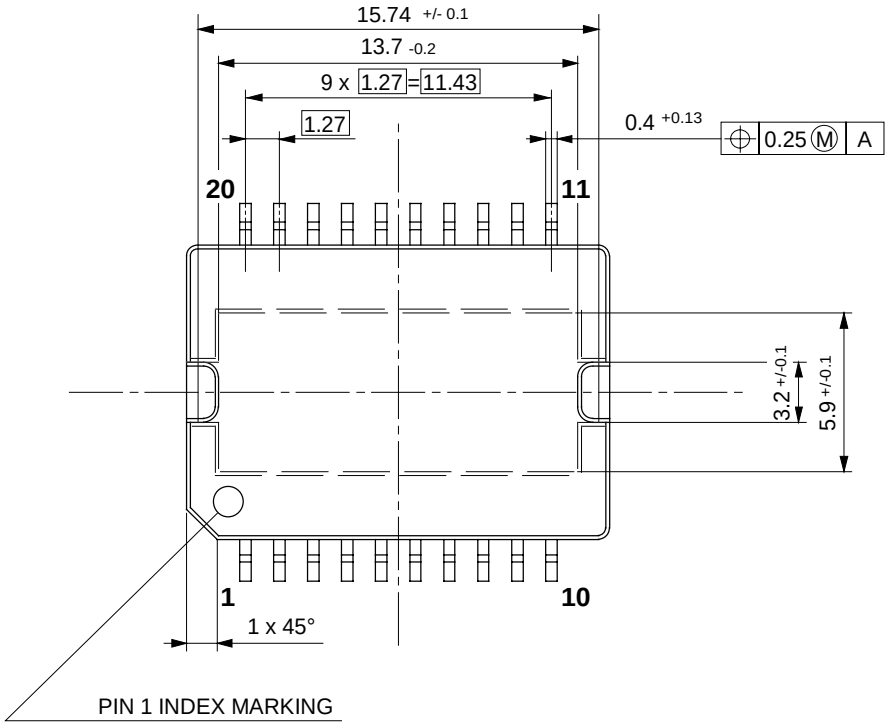


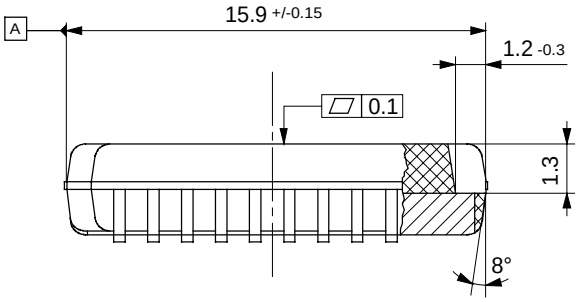

Fig. 9

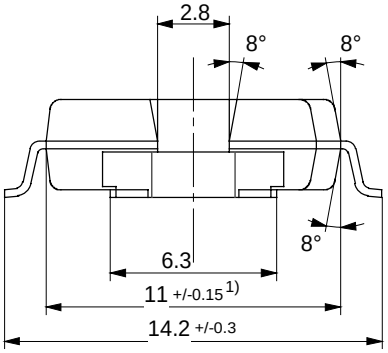
## Package and ordering code

**all dimensions in mm**

| **P - DSO - 20 - 10** | Ordering code |
|---|---|
| TLE 6228 GP | Q -A |



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