

## Quad intelligent power low side switch

- Four low-side output driver with protection diagnostics designed as a conventional switch
  - 2 channels with 5 A output current capability and  $r_{ON} = 0.2 \Omega$  typ.
  - 2 channels with 3 A output current capability and  $r_{ON} = 0.3 \Omega$  typ.
- Integrated 60 V Zener diodes output clamping structure
- Output slope control
- Short circuit protection
- Open load detection in ON and OFF condition
- Load bypass detection
- Overload disable
- Signal and power ground loss shutdown
- Selective overtemperature shutdown
- Electrostatic discharge (ESD) protection

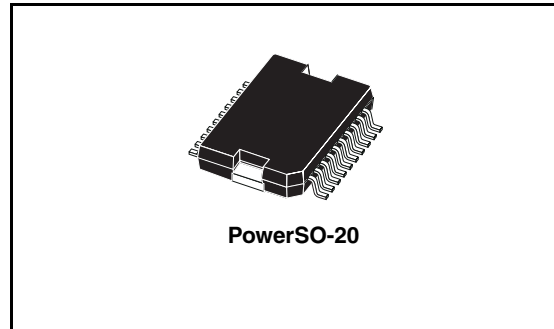
### Description

The L9349 is a monolithic IC designed to drive inductive loads in low side configurations like hydraulic valves used in ABS systems.

Particular care has been taken to protect the device against failures, to avoid electromagnetic interferences and to offer extensive real time diagnostics.

The internal pull down current source at the ENable and INput pins assures, that the device is switched off, in case of open input conditions.

An output voltage slope limitation is implemented to reduce the EMI.



The device is equipped with an integrated Zener diodes clamp for fast inductive load current recirculation. This structure limits the output voltage during the recirculation phase to 50V.

The device is self-protected against short circuit at the outputs and overtemperature.

For the real time error diagnosis, the voltage and the current of the outputs are compared with internally fixed thresholds to recognize open load in OFF and ON conditions.

The output voltages are also compared with each other in OFF condition with a fixed offset, in order to recognize load bypasses.

If the over load current threshold is exceeded, the output current will be limited internally during the diagnostic overload delay switch-off time.

All four channels are monitored with a status output. The diagnostic output level in connection with different enable and input conditions allows it to recognize the different fail states.

**Table 1. Device summary**

| Order code | Package <sup>(1)</sup> | Packing       |
|------------|------------------------|---------------|
| L9349-LF   | PowerSO-20             | Tray          |
| L9349TR-LF | PowerSO-20             | Tape and reel |

1. ECOPACK® package (see [Section 4: Package information](#))

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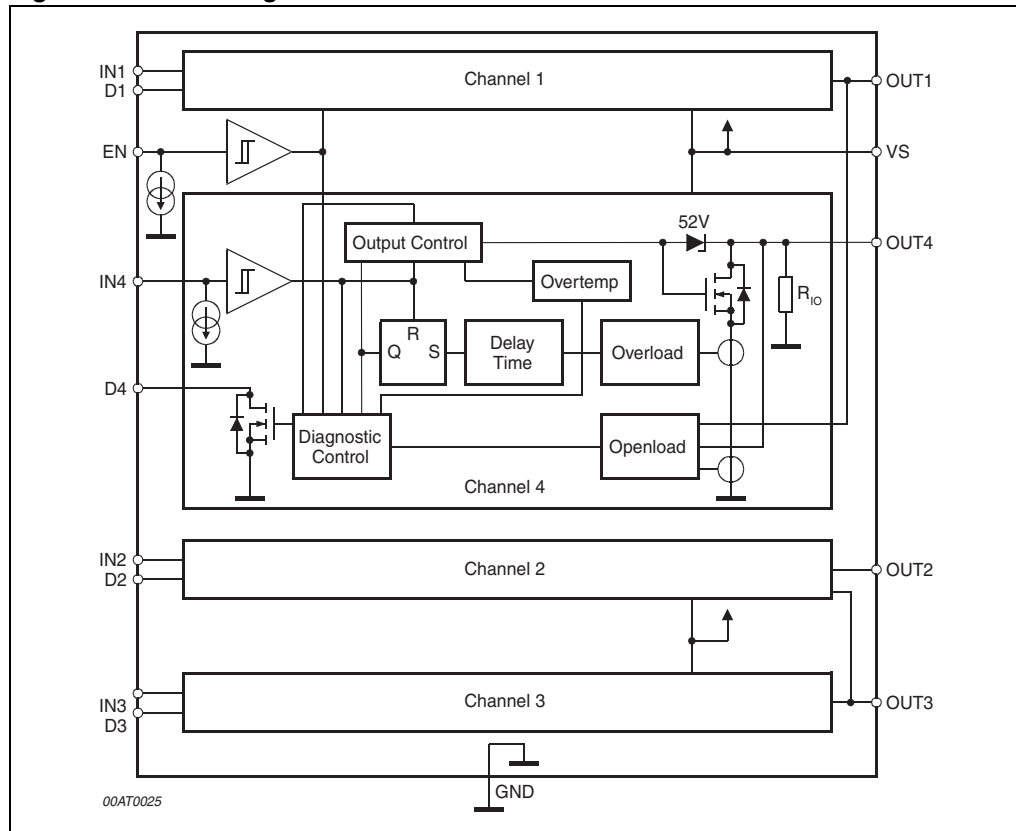
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# 1 Block diagram

Figure 1. Block diagram



## 2 Pins description

Figure 2. Pins connection (top view)

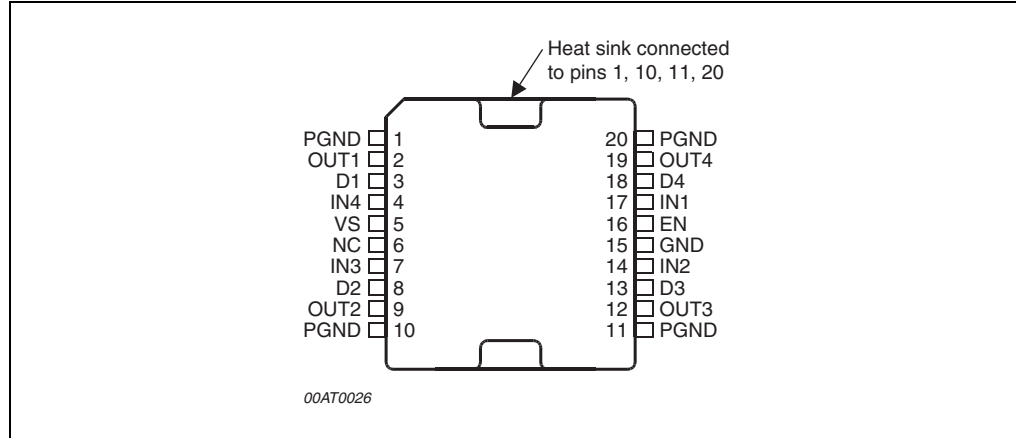


Table 2. Pins description

| N° | Pin  | Function       |
|----|------|----------------|
| 1  | PGND | Power Ground   |
| 2  | Out1 | Output 1 (5A)  |
| 3  | D1   | Diagnostic 1   |
| 4  | IN4  | Input 4        |
| 5  | VS   | Supply Voltage |
| 6  | NC   | Not Connected  |
| 7  | IN3  | Input 3        |
| 8  | D2   | Diagnostic 2   |
| 9  | Out2 | Output 2 (5A)  |
| 10 | PGND | Power Ground   |
| 11 | PGND | Power Ground   |
| 12 | Out3 | Output 3 (3A)  |
| 13 | D3   | Diagnostic 3   |
| 14 | IN2  | Input 2        |
| 15 | GND  | Signal Ground  |
| 16 | EN   | Common Enable  |
| 17 | IN1  | Input 1        |
| 18 | D4   | Diagnostic 4   |
| 19 | Out4 | Output 4 (3A)  |
| 20 | PGND | Power Ground   |

## 3 Electrical specifications

### 3.1 Absolute maximum ratings

**Table 3. Absolute maximum ratings**

| Symbol           | Parameter                                      | Conditions                                | Value                                | Unit             |
|------------------|--|---|--------------------------------------|------------------|
| $V_S$            | DC supply voltage                              |   | -0.3 to 32                           | V                |
| $V_{SP}$         | Supply voltage pulse<br>(duration <200ms)      |   | -0.3 to 45                           | V                |
| $ dV_S/dt $      | Supply voltage slope                           |   | 10                                   | V/ $\mu$ s       |
| $V_{IN, EN}$     | Input voltage                                  | $I_{IN} = 10\text{mA}$                    | -1.5 to 6                            | V                |
| $V_D$            | Diagnostic DC output voltage                   | $I_{DOUT} = 50\text{mA}$                  | -0.3 to 16                           | V                |
| $V_{ODC}$        | DC output voltage                              |   | -0.3 to 45                           | V                |
| $I_{O1, 2}$      | DC output current out 1, 2                     |   | >5 (Min.)<br>internal limited (Max.) | A                |
| $I_{O3, 4}$      | DC output current out 3, 4                     |   | >3 (Min.)<br>internal limited (Max.) | A                |
| $I_{OR1, 2}$     | Reverse output current                         |   | -5                                   | A                |
| $I_{OR3, 4}$     | Reverse output current                         |   | -3                                   | A                |
| $E_{O1, 2}$      | Switch-off energy for inductive loads          | $t_{EO} = 250\mu\text{s},^{(1)}$          | 50                                   | mJ               |
| $E_{O3, 4}$      |  | $T = 5\text{ms}$                          | 30                                   | mJ               |
| $\Delta V_{GND}$ | GND potential difference                       | $T_j = -40 \text{ to } 150^\circ\text{C}$ | $\pm 0.3$                            | V                |
| $T_{jEO}$        | Junction temperature during switch-off         | $\Sigma t \leq 30 \text{ min}$            | 175                                  | $^\circ\text{C}$ |
|                  |  | $\Sigma t \leq 15 \text{ min}$            | 190                                  | $^\circ\text{C}$ |
| $T_j$            | Junction temperature                           |   | -40 to $T_{jDIS}$                    | $^\circ\text{C}$ |
| $T_{stg}$        | Storage temperature                            |   | -55 to 150                           | $^\circ\text{C}$ |
| $T_{jDIS}$       | Thermal disable junction temperature threshold |   | 180 to 210                           | $^\circ\text{C}$ |
| ESD              | Electrostatical discharging                    | MIL883C                                   | +/-2                                 | kV               |
| ESD              | OUT1 - 4                                       | vs. Common-GND<br>(PGNDs + GND)           | +/-4                                 | kV               |

1.  $t_{EO}$  is the clamping time (see [Figure 3](#))

### 3.2 Thermal data

**Table 4. Thermal data**

| Symbol          | Parameter                           | Value | Unit                      |
|-----------------|-------------------------------------|-------|---------------------------|
| $R_{Th j-case}$ | Thermal resistance junction to case | 3     | $^\circ\text{C}/\text{W}$ |

### 3.3 Electrical characteristics (operating range)

The electrical characteristics are valid within the below defined operating range, unless otherwise specified.

**Table 5. Electrical characteristics (operating range)**

| Symbol   | Parameter            | Test Condition                                    | Min. | Typ. | Max.       | Unit |
|----------|----------------------|---|------|------|------------|------|
| $V_S$    | Board supply voltage |   | 4.5  | 12   | 32         | V    |
| $T_{j1}$ | Junction temperature |   | -40  |      | 150        | °C   |
| $T_{j2}$ |                      | $\Sigma t \leq 15\text{min}^{(1)}$ over life time | 150  |      | $T_{jDIS}$ | °C   |

1. Parameters guaranteed by correlation

### 3.4 Electrical characteristics

**Table 6. Electrical characteristics**

( $V_S = 4.5$  to  $32\text{V}$ ;  $-40^\circ\text{C} \leq T_{j1} \leq 150^\circ\text{C} < T_{j2} \leq T_{jDIS}$ , unless otherwise specified.)

| Symbol                            | Parameter                         | Test conditions  | Values $T_{j1}$    |                   |                    | Values $T_{j2}$ |      | Unit             |
|-----------------------------------|-----------------------------------|--|--------------------|-------------------|--------------------|-----------------|------|------------------|
|                                   |                                   |  | Min.               | Typ.              | Max.               | Min.            | Max. |                  |
| <b>Supply</b>                     |                                   |  |                    |                   |                    |                 |      |                  |
| $I_{VS\ OFF}$                     | DC supply current Off             | EN = 1.0V  |                    | 5                 | 10                 |                 |      | mA               |
| $I_{VS\ ON}$                      | DC supply current On              | $V_S \leq 14\text{V}$ ; $V_{IN}$ , $V_{EN} = 2\text{V}$  |                    | 8                 |                    |                 |      | mA               |
| <b>Diagnostic outputs D1 - D4</b> |                                   |  |                    |                   |                    |                 |      |                  |
| $V_{DL}$                          | Diagnostic output low voltage     | $I_D \leq 3\text{mA}$  |                    | 0.65              | 1.0                |                 | 1.5  | V                |
| $I_{DLE}$                         | Diagnostic output leakage current | $V_D = 14\text{V}^{(1)}$   |                    | 0.1               | 2                  |                 | 20   | $\mu\text{A}$    |
| <b>Outputs Out 1 - Out 4</b>      |                                   |  |                    |                   |                    |                 |      |                  |
| $R_{DSON\ 1,2}$                   | Output On resistance              | $T_j = 25^\circ\text{C}$<br>$T_j = 150^\circ\text{C}$<br>$V_S > 9.5\text{V}$ $I_{O1,2} = 2\text{A}$      |                    | 200               | 300<br>500         |                 |      | $\text{m}\Omega$ |
| $R_{DSON\ 3,4}$                   |                                   | $T_j = 25^\circ\text{C}$<br>$T_j = 150^\circ\text{C}$<br>$V_S > 9.5\text{V}$<br>$I_{O3,4} = 1.3\text{A}$ |                    | 300               | 450<br>750         |                 |      | $\text{m}\Omega$ |
| $V_Z$                             | Z-diode clamping voltage          | $I_{OCL} \geq 200\text{mA}$  | 45                 |                   | 60                 |                 |      | V                |
| $R_O$                             | Output pull down resistor         | $V_S > 9.5\text{V}$<br>EN = 0V   | 10                 |                   | 40                 |                 | 50   | $\text{k}\Omega$ |
| $V_{OUV\ 1-4}$                    | Open load voltage threshold       | $V_{IN} = 1\text{V}$   | $0.525 \times V_S$ | $0.55 \times V_S$ | $0.575 \times V_S$ |                 |      | V                |



**Table 6. Electrical characteristics (continued)**(V<sub>S</sub> = 4.5 to 32V; -40°C ≤ T<sub>j1</sub> ≤ 150°C < T<sub>j2</sub> ≤ T<sub>JDIS</sub>, unless otherwise specified.)

| Symbol                                   | Parameter                              | Test conditions   | Values T <sub>j1</sub> |                         |                        | Values T <sub>j2</sub> |      | Unit |
|--|--|---|------------------------|-------------------------|------------------------|------------------------|------|------|
|  |  |   | Min.                   | Typ.                    | Max.                   | Min.                   | Max. |      |
| V <sub>OUV hys 1-4</sub>                 | Hysteresis                             |   |                        | 0.003 x V <sub>S</sub>  |                        |                        |      | V    |
| ΔV <sub>OUV 1-4, 2-3, 4-1, 3-2</sub>     | Open load difference voltage threshold | V <sub>IN1,4/2,3</sub> = 1V V <sub>S</sub> ≤ 16V<br>V <sub>OC</sub> ≥ 4.5V<br>V <sub>OC</sub> = output voltage of other channel | V <sub>OC</sub> - 1.0V | V <sub>OC</sub> - 1.25V | V <sub>OC</sub> - 1.5V |                        |      | V    |
| ΔV <sub>OUV hys 1-4, 2-3, 4-1, 3-2</sub> | Open load hysteresis                   |   |                        | 40                      |                        |                        |      | mV   |
| I <sub>IOC 1, 2, 3, 4</sub>              | Open load current threshold            | V <sub>EN</sub> =V <sub>IN</sub> =2V;<br>V <sub>S</sub> =6.5 - 16V  | 160                    | 320                     | 480                    |                        |      | mA   |
| I <sub>IOC 1, 2</sub>                    | Over load current threshold            | V <sub>S</sub> > 6.5V;<br>V <sub>OUT</sub> = 32V  | 5                      | 10                      |                        |                        |      | A    |
| I <sub>IOC 3, 4</sub>                    |  |   | 3                      | 6                       |                        |                        |      | A    |
| T <sub>SD</sub>                          | Thermal shut down                      |   | 180                    | 195                     | 210                    |                        |      | °C   |
| T <sub>SD-hys</sub>                      | Thermal shut down hysteresis           |   |                        | 20                      |                        |                        |      | °C   |
| I <sub>OUT-LE</sub>                      | OUT leakage current                    | V <sub>OUT</sub> = 20V<br>V <sub>S</sub> = 0V   |                        |                         | 5                      |                        |      | μA   |
| <b>Inputs IN1-4, EN</b>                  |  |   |                        |                         |                        |                        |      |      |
| V <sub>IN,EN L</sub>                     | Logic input/enable low voltage         |   | -0.3                   |                         | 1                      |                        |      | V    |
| V <sub>IN,EN H</sub>                     | Logic input/enable high voltage        | IN, EN  | 2.0                    |                         | 6                      |                        |      | V    |
| V <sub>EN,IN hys</sub>                   | Logic input hysteresis                 |   | 50                     | 100                     |                        |                        |      | mV   |
| I <sub>IN</sub>                          | Input sink current                     | 2V < V <sub>IN</sub> , V <sub>EN</sub> < 6V <sup>(2)</sup>  | 10                     | 20                      | 40                     |                        |      | μA   |
| I <sub>EN</sub>                          | Enable sink current                    | V <sub>IN</sub> , V <sub>EN</sub> < V <sub>S</sub>  | 10                     | 20                      | 40                     |                        |      | μA   |
| <b>Timing</b>                            |  |   |                        |                         |                        |                        |      |      |
| t <sub>ON</sub>                          | Output delay ON time                   | I <sub>O</sub> = 1A<br>V <sub>S</sub> = 12V<br><sup>(3)</sup> <a href="#">Figure 4</a>  |                        | 4                       | 25                     |                        |      | μs   |
| t <sub>f,r</sub>                         | Output fall and rise time              | I <sub>O</sub> = 1A<br>V <sub>S</sub> = 12V<br><a href="#">Figure 4</a>   | 3                      | 10                      | 30                     |                        |      | μs   |
| t <sub>OFF</sub>                         | Output delay OFF time                  | I <sub>O</sub> = 1A<br>V <sub>S</sub> = 12V<br><sup>(3)</sup> <a href="#">Figure 4</a>  | 5                      | 15                      | 30                     |                        |      | μs   |

**Table 6. Electrical characteristics (continued)**(V<sub>S</sub> = 4.5 to 32V; -40°C ≤ T<sub>j1</sub> ≤ 150°C < T<sub>j2</sub> ≤ T<sub>jDIS</sub>, unless otherwise specified.)

| Symbol                  | Parameter                                 | Test conditions                            | Values T <sub>j1</sub> |      |      | Values T <sub>j2</sub> |      | Unit |
|-------------------------|---|--|------------------------|------|------|------------------------|------|------|
|                         |   |  | Min.                   | Typ. | Max. | Min.                   | Max. |      |
| t <sub>DH-L, Diag</sub> | Diag. delay output OFF time               | (3) <i>Figure 4</i>                        | 8                      |      | 65   |                        | 90   | μs   |
| t <sub>D IOU</sub>      | Diagnostic open load delay time           | 9V < V <sub>S</sub> < 16V, <i>Figure 5</i> |                        | 8    | 50   |                        |      | μs   |
| t <sub>DOL</sub>        | Diagnostic overload delay switch-OFF time | 9V < V <sub>S</sub> < 16V, <i>Figure 5</i> | 6                      |      | 65   |                        |      | μs   |
| t <sub>filt</sub>       | Filter time                               |  | 4                      |      | 24   |                        |      | μs   |
| <b>PGND</b>             |   |  |                        |      |      |                        |      |      |
| PGND <sub>loss,h</sub>  | Power GND loss threshold high             |  |                        | 3    |      |                        |      | V    |
| PGND <sub>loss,l</sub>  | Power GND loss threshold low              |  |                        | 2    |      |                        |      | V    |

1. The diagnostic output is short circuit protected up to V<sub>D</sub> = 16V
2. Open pins (EN, IN) are detected as low
3. V<sub>S</sub> = 9 to 16V ∧ I<sub>OUC</sub> ≤ I<sub>O</sub> ≤ I<sub>OOC</sub>

### 3.5 Diagnostic

**Table 7. Diagnostic**

| Conditions                                |  | EN | IN | OUT | DIAG. |
|---|--|----|----|-----|-------|
| Normal function                           |  | L  | X  | off | L     |
|   |  | H  | L  | off | L     |
|   |  | H  | H  | on  | H     |
| GND short                                 | V <sub>Otyp</sub> < 0.55V <sub>S</sub>                   | L  | X  | off | H     |
| Load bypass                               | ΔV <sub>O1-4/2-3</sub> ≥ 1.25V                           | H  | L  | off | H     |
| Open load                                 | I <sub>O1,2,3,4typ</sub> < 320mA                         | H  | H  | on  | L     |
| T <sub>jtyp</sub> ≥ 190°C Overtemperature |  | X  | X  | off | L     |
| Over load                                 | I <sub>Omin 1,2</sub> > 5A<br>I <sub>Omin 3,4</sub> > 3A | H  | H  | off | L     |
| SGND or PGND loss                         | channel off  | X  | L  | off | H     |
| SGND or PGND loss                         | channel on   | H  | H  | off | L     |

### 3.6 Circuit description

The L9349 is a quad low side driver for inductive loads like valves in automotive environment. The internal pull down current sources at the ENable and INput pins assure in case of open input conditions that the device is switched off. An output voltage slope limitation for  $du/dt$  is implemented to reduce the EMI. An integrated active flyback voltage limitation clamps the output voltage during the flyback phase to 50 V.

Each driver is protected against short circuit at  $V_{OUT} < 32V$  and thermal overload. In short circuit condition the output will be disabled after a short delay time  $t_{DOL}$ . The thermal disable for  $T_J > 180^{\circ}C$  of the output will be reset if the junction temperature decreases about  $20^{\circ}C$  below the disable threshold temperature.

The overtemperature, overload and groundloss information is stored until IN is low.

For the real time error diagnosis the voltage and the current of the outputs are compared with internal fixed values  $V_{OUV}$  for OFF and  $I_{OUC}$  for ON conditions to recognize open load ( $R_L \geq 20K\Omega$ ,  $R_L > 38\Omega$ ) in OFF and ON conditions.

Also the output voltages  $V_{O1-4}$  are compared to each other output in OFF condition with a fixed offset of  $\Delta V_{OUV}$  to recognize load bypasses. The  $\Delta V_{OUV}$  diagnoses is suppressed during the flyback phases of the compared output. The outputs 1 and 4 are compared for  $\Delta V_{OUV}$  and also outputs 2 and 3 are compared.

The diagnostic output level in connection with different ENable and INput conditions allows to recognize different fail states, like overtemp, short to  $V_S$ , short to GND, bypass to GND and disconnected load (see [Table 7: Diagnostic](#)).

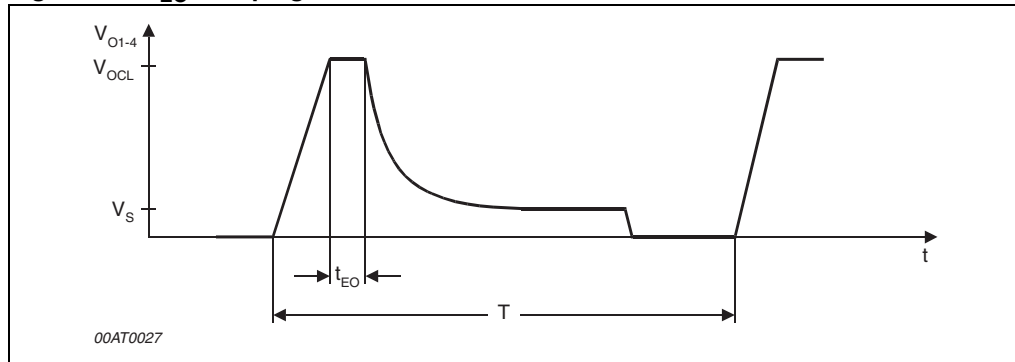
The diagnostic output is protected against short circuit. Exceeding the over load current threshold  $I_{OOC}$ , the output current will be limited internally during the diagnostic overload delay switch-off time  $t_{DOL}$ .

The device complies the  $I_{SO}$  pulses imposed to the supply voltage of the valves without any failures of the functionality. Therefore some diagnostic functions are internal filtered. The following table shows the corresponding filter time for each detected signal.

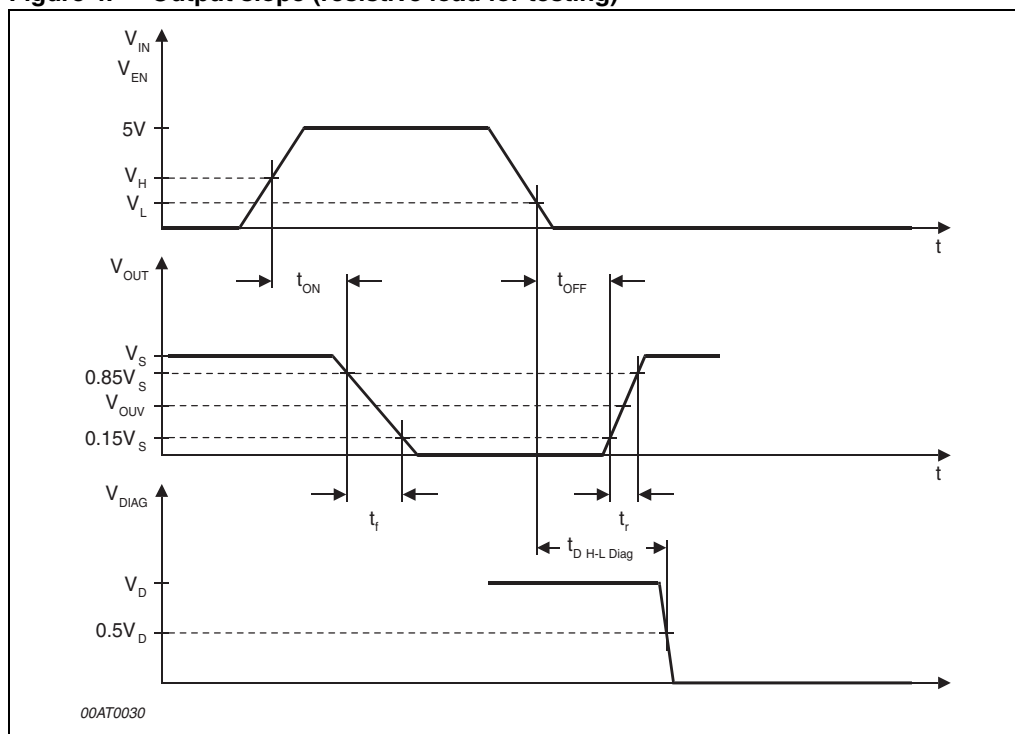
**Table 8. Corresponding filter time for each detected signal**

|  | ON State<br>EN and IN =<br>HIGH | OFF State<br>EN or IN,<br>= LOW | min.<br>Filter<br>time | Reset done by |
|--|---------------------------------|---------------------------------|------------------------|---------------|
| Overloading of output<br>(also shorted load to supply) | X                               |                                 | 4 $\mu$ s              | INx = "LOW"   |
| Open load<br>(under voltage detection)                 |                                 | X                               | -                      |               |
| Open load<br>(under current detection)                 | X                               |                                 | -                      |               |
| Overtemperature  | X                               |                                 | 4 $\mu$ s              | INx = "LOW"   |
| Power-signal GND-loss                                  | X                               |                                 | 4 $\mu$ s              | INx = "LOW"   |
| Power-signal GND-loss                                  |                                 | X                               | 4 $\mu$ s              |               |
| Openload difference                                    |                                 | X                               | 4 $\mu$ s              |               |

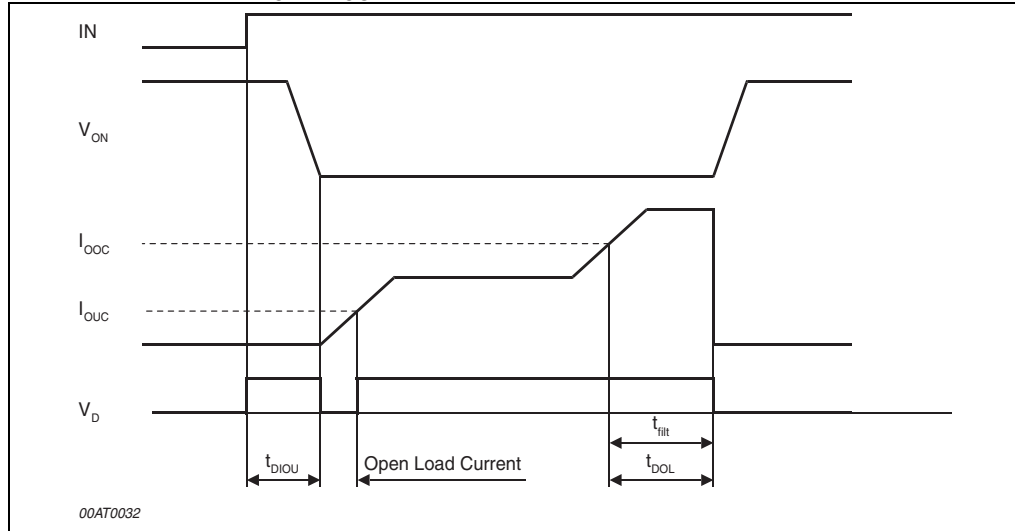
**Figure 3.  $t_{EO}$  clamping time**



**Figure 4. Output slope (resistive load for testing)**



**Figure 5. Timing ( $t_{DOL}$ ,  $t_{DIOU}$ )**



**Figure 6. Block diagram - Open load voltage detection**

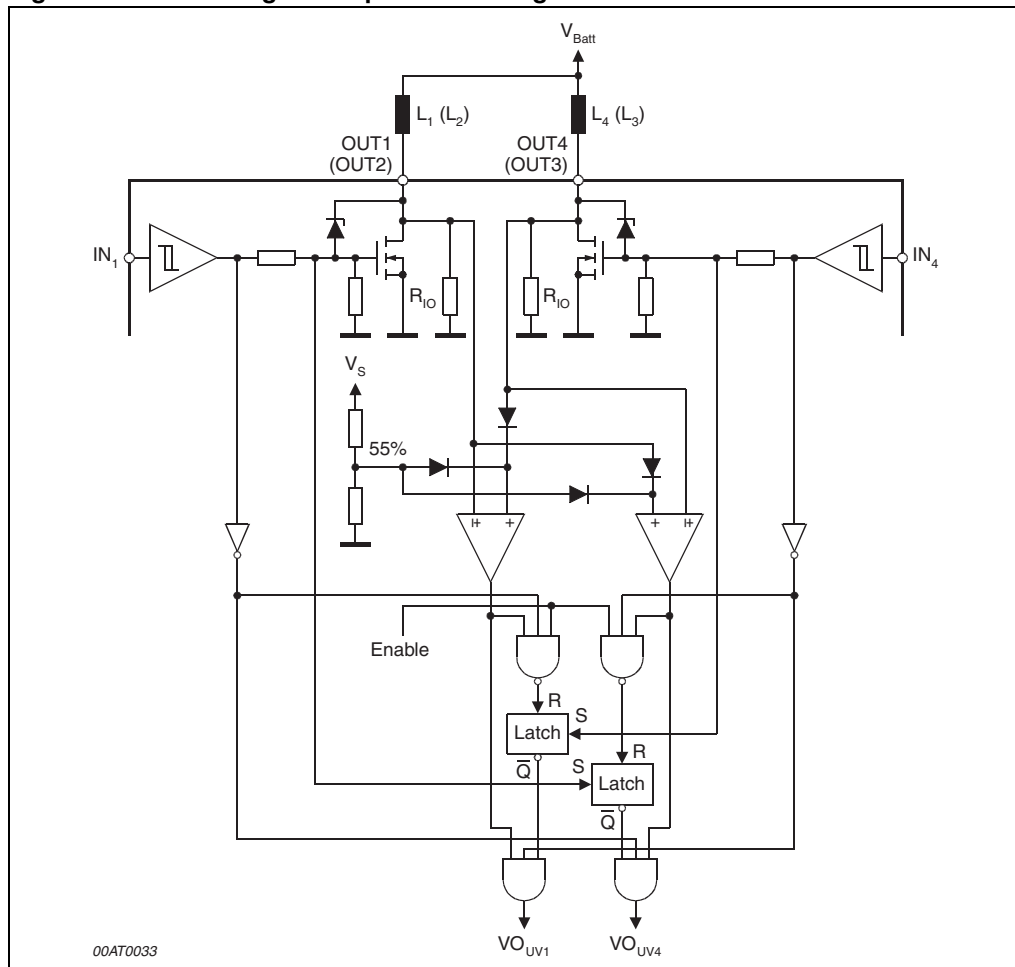


Figure 7. Logic diagram

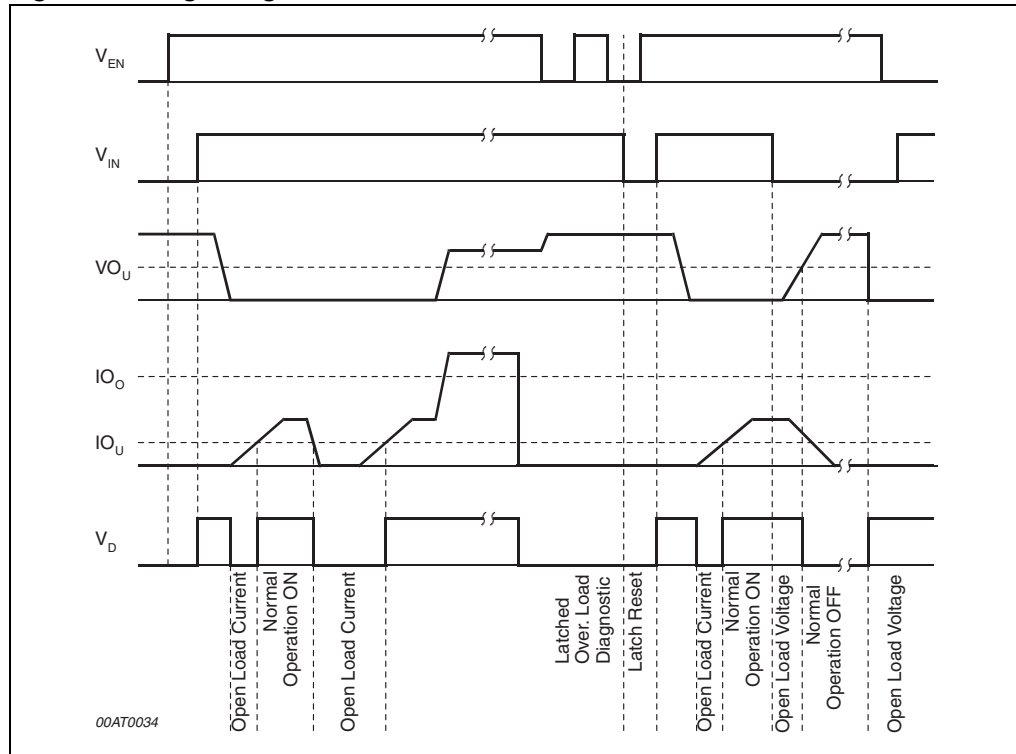
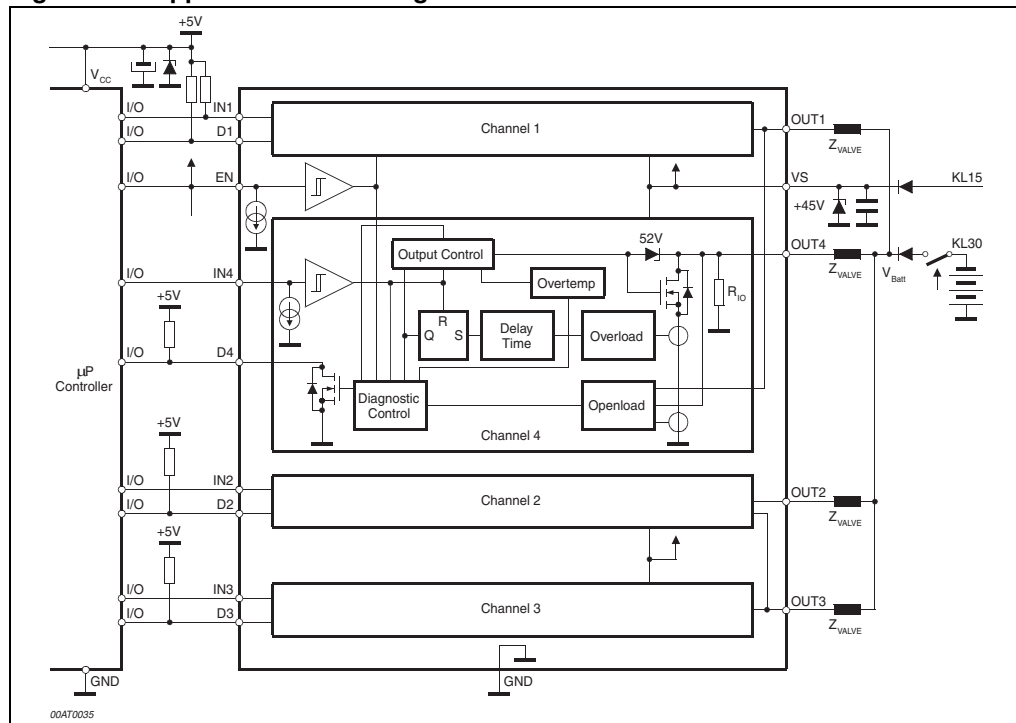


Figure 8. Application circuit diagram

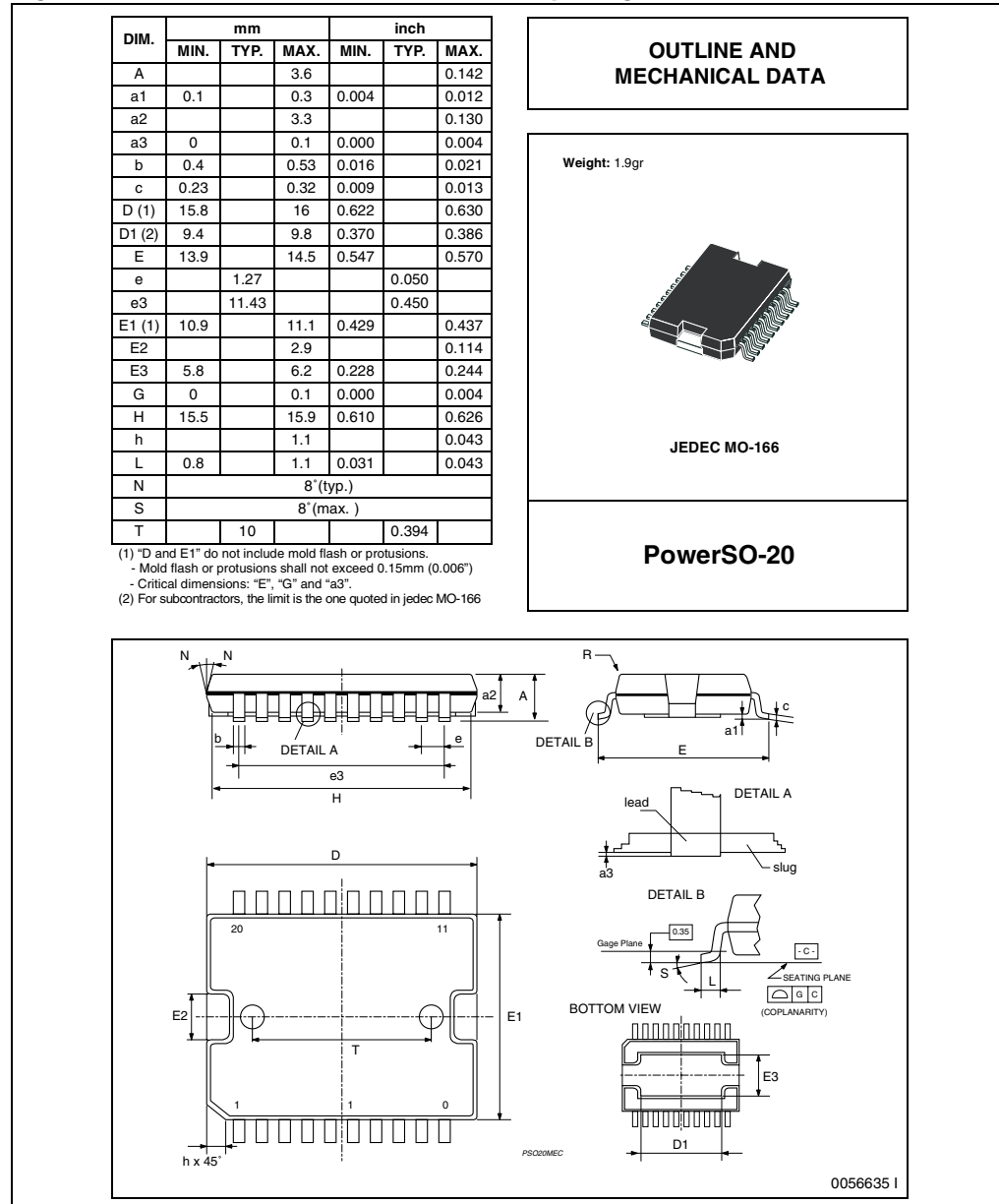


## 4 Package information

In order to meet environmental requirements, ST (also) offers these devices in ECOPACK<sup>®</sup> packages. ECOPACK<sup>®</sup> packages are lead-free. The category of second Level Interconnect is marked on the package and on the inner box label, in compliance with JEDEC Standard JESD97. The maximum ratings related to soldering conditions are also marked on the inner box label.

ECOPACK is an ST trademark. ECOPACK specifications are available at: [www.st.com](http://www.st.com).

**Figure 9. PowerSO-20 mechanical data and package dimensions**



## 5 Revision history

Table 9. Document revision history

| Date        | Revision | Changes   |
|-------------|----------|---|
| 20-Sep-2002 | 4        | Initial release.  |
| 09-Sep-2008 | 5        | Document reformatted.<br>Updated feature and description on page 1.<br>Added <a href="#">Table 1: Device summary on page 1</a> .<br>Updated <a href="#">Table 3: Absolute maximum ratings on page 7</a> . |



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