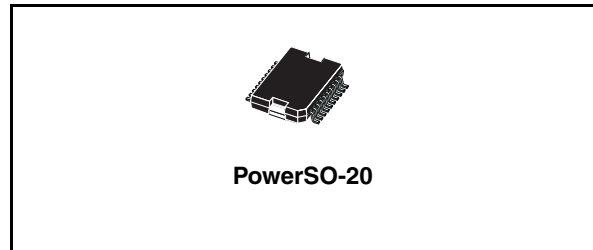


## 2.5A high-side driver industrial intelligent power switch

### Features

- 2.5A output current
- 9.5V to 35V supply voltage range
- Internal current limiting
- Thermal shutdown
- Open ground protection
- Internal negative voltage clamping to  $V_S - 50V$  for fast demagnetization
- Differential inputs with large common mode range and threshold hysteresis
- Undervoltage lockout with hysteresis
- Open load detection
- Two diagnostic outputs
- Output status led driver
- Non dissipative short circuit protection
- Protection against and surge transient (IEC 61000-4-5)
- Immunity against burst transient (IEC 61000-4-4)
- ESD protection (human body model  $\pm 2kV$ )



### Description

The L6370 is a monolithic Intelligent Power Switch in Multipower BCD Technology, for driving inductive or resistive loads. An internal Clamping Diode enables the fast demagnetization of inductive loads. Diagnostic for CPU feedback and extensive use of electrical protections make this device extremely rugged and specially suitable for industrial automation applications.

**Table 1. Device summary**

| Part number | Op. Temp. range, °C | Package    | Packaging   |
|-------------|---------------------|------------|-------------|
| L6370D      | -25 to +85          | PowerSO-20 | Tube        |
| L6370D013TR | -25 to +85          | PowerSO-20 | Tape & Reel |

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# 1 Block diagram and pin description

Figure 1. Block diagram

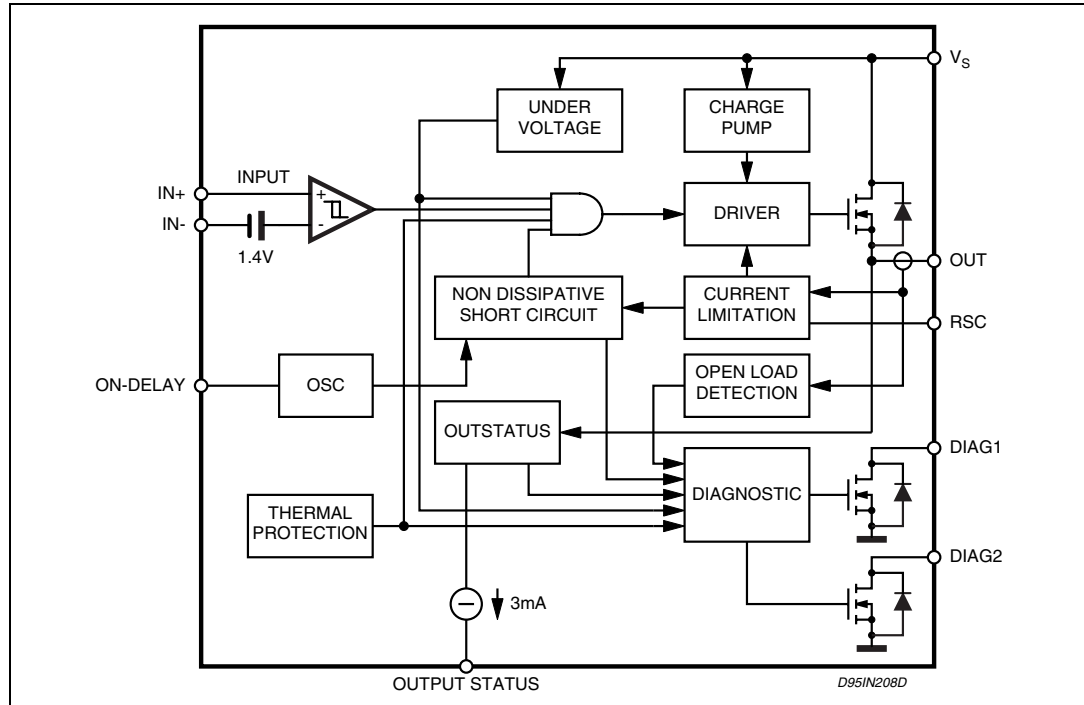
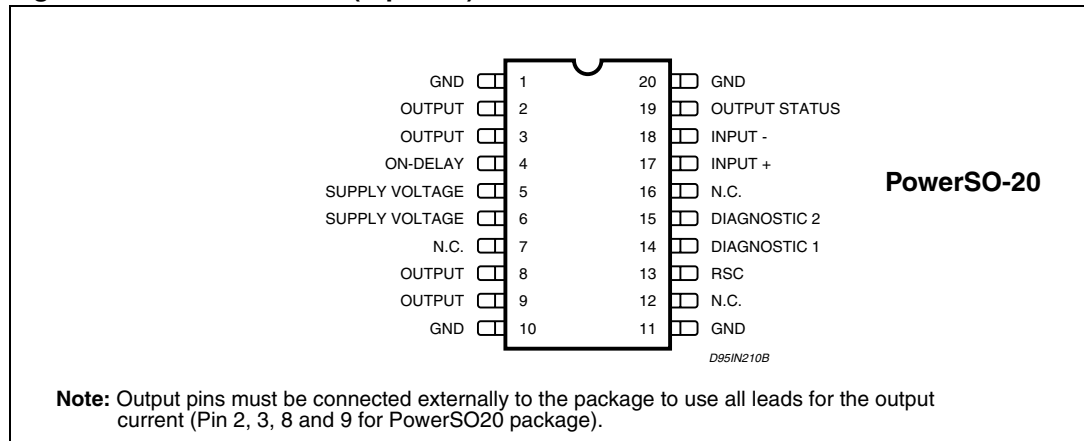


Figure 2. Pin connection (top view)



## 1.1 Pin description

**Table 2. Pin description**

| Pin N°           | Pin name       | Function   |
|------------------|----------------|--|
| 14               | DIAG1          | DIAGNOSTIC 1 output. This open drain reports the IC working conditions. (See Diagnostic truth <a href="#">Table 7</a> )  |
| 15               | DIAG2          | DIAGNOSTIC 2 output. This open drain reports the IC working conditions. (See Diagnostic truth <a href="#">Table 7</a> )  |
| 18               | IN-            | Comparator non inverting input   |
| 17               | IN+            | Comparator inverting input   |
| 19               | OUTSTATUS      | This current source output is capable of driving a LED to signal the status of the output pin. The pin is active (source current) when the output pin is considered high (See <a href="#">Figure 3</a> ) |
| 1, 10,<br>11, 20 | GND            | Ground   |
| 4                | ON-DELAY       | Programmable ON time interval duration during short circuit operation  |
| 13               | RSC            | Current limitation setting.  |
| 8, 9             | OUTPUT         | High Side output with built-in current limitation  |
| 5, 6             | V <sub>S</sub> | Supply Voltage Input, the value of the supply voltage is monitored to detect under voltage condition   |

## 2 Electrical specifications

### 2.1 Absolute maximum ratings

Table 3. Absolute maximum ratings

| Symbol      | Parameter   | Value              | Unit |
|-------------|---|--------------------|------|
| $V_S$       | Supply Voltage ( $T_W < 10\text{ms}$ )                      | 50                 | V    |
| $V_S - V_O$ | Supply to Output Differential Voltage.<br>See also $V_{CI}$ | internally limited | V    |
| $V_{od}$    | Externally Forced Voltage                                   | -0.3 to 7          | V    |
| $I_{od}$    | Externally Forced Voltage                                   | +1                 | mA   |
| $V_i$       | Input Voltage   | -10 to $V_S+10$    | V    |
| $V_i$       | Differential Input Voltage                                  | 43                 | V    |
| $I_i$       | Input Current   | 20                 | mA   |
| $I_O$       | Output Current . See also ISC                               | internally limited | A    |
| $P_{TOT}$   | Power Dissipation.<br>See also Thermal Characteristics.     | internally limited | W    |
| $T_{OP}$    | Operating Temperature Range ( $T_{amb}$ )                   | -25 to +85         | °C   |
| $T_{STG}$   | Storage Temperature   | -55 to 150         | °C   |
| $E_I$       | Energy Induct. Load $T_J = 85^\circ\text{C}$                | 1                  | J    |

### 2.2 Thermal data

Table 4. Thermal data

| Symbol     | Description                            |      | Value | Unit |
|------------|--|------|-------|------|
| $R_{thJC}$ | Thermal Resistance Junction to case    | Max. | 1.5   | °C/W |
| $R_{thJA}$ | Thermal Resistance Junction to ambient | Max. | -     |      |

## 2.3 Electrical characteristics

**Table 5. Electrical characteristics**  
( $V_S = 24V$ ;  $T_J = -25$  to  $+125^\circ C$ , unless otherwise specified)

| Symbol     | Parameter                                   | Test condition   | Min.                  | Typ.     | Max.     | Unit      |
|------------|---|--|-----------------------|----------|----------|-----------|
| $V_{smin}$ | Supply Voltage for Valid Diagnostics        | $I_{diag} > 0.5mA$ ; $V_{dg1} = 1.5V$                                  | 4                     |          | 35       | V         |
| $V_S$      | Supply Voltage (operative)                  |  | 9.5                   | 24       | 35       | V         |
| $I_q$      | Quiescent Current<br>$I_{out} = I_{os} = 0$ | $V_{il}$<br>$V_{ih}$   |                       | 0.8<br>3 | 1.4<br>4 | mA        |
| $V_{sth1}$ | Undervoltage Threshold 1                    | (See <i>Figure 3</i> ), $T_{amb} = 0$ to $+85^\circ C$                 | 8.5                   | 9        | 9.5      | V         |
| $V_{sth2}$ | Undervoltage Threshold 2                    |  | 8                     | 8.5      | 9        | V         |
| $V_{sth3}$ | Supply Voltage Hysteresis                   |  | 300                   | 500      | 700      | mV        |
| $I_{sc}$   | Short Circuit Current                       | $V_S = 9.5$ to $35V$ ; $R_L = 2\Omega$ $5k\Omega < R_{SC} < 30k\Omega$ | 15/ $R_{SC}(k\Omega)$ |          |          | A         |
|            |   | $0 < R_{SC} < 5k\Omega$  | 2.6                   | 3.2      | 4        | A         |
| $V_{don}$  | Output Voltage Drop                         | $I_{out} = 2.0A$ $T_j = 25^\circ C$                                    |                       | 200      | 280      | mV        |
|            |   | $I_{out} = 2.5A$ $T_j = 25^\circ C$                                    |                       | 320      | 440      | mV        |
|            |   | $I_{out} = 2.5A$ $T_j = 25^\circ C$                                    |                       | 250      | 350      | mV        |
|            |   | $I_{out} = 2.5A$ $T_j = 25^\circ C$                                    |                       | 400      | 550      | mV        |
| $I_{oslk}$ | Output Leakage Current                      | $V_i = V_{il}$ ; $V_o = 0V$  |                       |          | 500      | $\mu A$   |
| $V_{ol}$   | Low State Out Voltage                       | $V_i = V_{il}$ ; $R_L = \infty$  |                       | 0.8      | 1.5      | V         |
| $V_{cl}$   | Internal Voltage Clamp ( $V_S - V_O$ )      | $I_O = 1A$<br>Single Pulsed: $T_p = 300\mu s$                          | 48                    | 53       | 58       | V         |
| $I_{old}$  | Open Load Detection Current                 | $V_i = V_{ih}$ ; $T_{amb} = 0$ to $+85^\circ C$                        | 1                     | 3        | 6        | mA        |
| $V_{id}$   | Common Mode Input Voltage Range (Operative) | $V_S = 18$ to $35V$  | -7                    |          | 15       | V         |
| $I_{ib}$   | Input Bias Current                          | $V_i = -7$ to $15V$ ; $-In = 0V$                                       | -250                  |          | 250      | $\mu A$   |
| $V_{ith}$  | Input Threshold Voltage                     | $V + In > V - In$  | 0.8                   | 1.4      | 2        | V         |
| $V_{iths}$ | Input Threshold Hysteresis Voltage          | $V + In > V - In$  | 50                    |          | 400      | mV        |
| $R_{id}$   | Diff. Input Resistance                      | $0 < +In < +16V$ ; $-In = 0V$  |                       | 400      |          | $K\Omega$ |
|            |   | $-7 < +In < 0V$ ; $-In = 0V$   |                       | 150      |          |           |
| $I_{ilk}$  | Input Offset Current                        | $V + In = V - In$ +li  | -20                   |          | +20      | $\mu A$   |
|            |   | $0V < V_i < 5.5V$ -li  | -75                   | -25      |          |           |
|            |   | $-In = GND$ +li  |                       | +10      | +50      |           |
|            |   | $0V < V + In < 5.5V$ -li   | -250                  | -125     |          |           |
|            |   | $+In = GND$ +li  | -100                  | -30      |          |           |
|            |   | $0V < V - In < 5.5V$ -li   | -50                   | -15      |          |           |

**Table 5. Electrical characteristics (continued)**  
 ( $V_S = 24V$ ;  $T_J = -25$  to  $+125^\circ C$ , unless otherwise specified)

| Symbol                          | Parameter                                | Test condition   | Min. | Typ.      | Max. | Unit       |
|---------------------------------|--|--|------|-----------|------|------------|
| $V_{oth1}$                      | Output Status Threshold 1 Voltage        | (See <a href="#">Figure 3</a> )  | 4.5  | 5         | 5.5  | V          |
| $V_{oth2}$                      | Output Status Threshold 2 Voltage        |  | 4    | 4.5       | 5.0  | V          |
| $V_{ohys}$                      | Output Status Threshold Hysteresis       |  | 300  | 500       | 700  | mV         |
| $I_{osd}$                       | Output Status Source Current             | $V_{out} > V_{oth1}$ ; $V_{os} = 2.5V$                                 | 2    |           | 4    | mA         |
| $V_{osd}$                       | Active Output Status Driver Drop Voltage | $V_S - V_{os}$ ; $I_{os} = 2mA$<br>$T_{amb} = 0$ to $+85^\circ C$      |      | 1.5       | 3    | V          |
| $I_{oslk}$                      | Output Status Driver Leakage Current     | $V_{out} < V_{oth2}$ ; $V_{os} = 0V$<br>$V_S = 9.5$ to $35V$           |      |           | 25   | $\mu A$    |
| $V_{dgl}$                       | Diagnostic Drop Voltage                  | $D1 / D2 = L$ ; $I_{diag} = 0.5mA$<br>$D1 / D2 = L$ ; $I_{diag} = 3mA$ |      | 40<br>250 |      | mV         |
| $I_{dglk}$                      | Diagnostic Leakage Current               | $D1 / D2 = H$ ; $0 < V_{dgl} < V_S$<br>$V_S = 9.5$ to $35V$            |      |           | 5    | $\mu A$    |
| <b>Source drain NDMOS diode</b> |  |  |      |           |      |            |
| $V_{fSD}$                       | Forward On Voltage                       | @ $I_{fSD} = 2.5A$   |      | 1         | 1.5  | V          |
| $I_{fp}$                        | Forward Peak Current                     | $t = 10ms$ ; $d = 20\%$  |      |           | 6    | A          |
| $t_{rr}$                        | Reverse Recovery Time                    | $I_f = 2.5A$ $di/dt = 25A/\mu s$                                       |      | 200       |      | ns         |
| $t_{fr}$                        | Forward Recovery Time                    |  |      | 100       |      | ns         |
| <b>Thermal characteristics</b>  |  |  |      |           |      |            |
| $\Theta_{Lim}$                  | Junction Temp. Protect.                  |  | 135  | 150       |      | $^\circ C$ |
| $\Theta_{TH}$                   | Thermal Hysteresis                       |  |      | 20        |      | $^\circ C$ |

Note:  $V_{il} \leq 0.8V$ ,  $V_{ih} \geq 2V$  @ ( $V+In > V-In$ )

## 2.4 AC operation

Table 6. AC operation

| Symbol      | Parameter                              | Test condition                                      | Min. | Typ. | Max. | Unit       |
|-------------|--|---|------|------|------|------------|
| $t_r - t_f$ | Rise or Fall Time                      | $V_S = 24V$ ; $R_I = 70\Omega$ ;<br>$R_I$ to ground |      | 20   |      | $\mu s$    |
| $t_d$       | Delay Time                             |   |      | 5    |      | $\mu s$    |
| dV/dt       | Slew Rate (Rise and Fall Edge)         |   | 0.7  | 1    | 1.5  | V/ $\mu s$ |
| $t_{ON}$    | On time during Short Circuit Condition | $50pF < C_{DON} < 2nF$                              |      | 1.28 |      | $\mu s/pF$ |
| $t_{OFF}$   | Of time during hort Circuit Condition  |   |      | 64   |      | $t_{ON}$   |
| $f_{max}$   | Maximum Operating Frequency            |   |      | 25   |      | KHz        |



### 3 Circuit description

Figure 3. Output status hysteresis

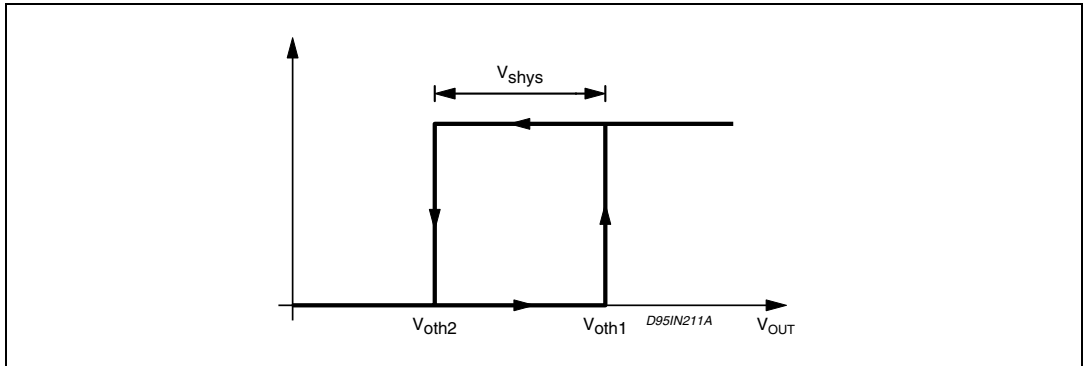


Figure 4. Undervoltage comparator hysteresis

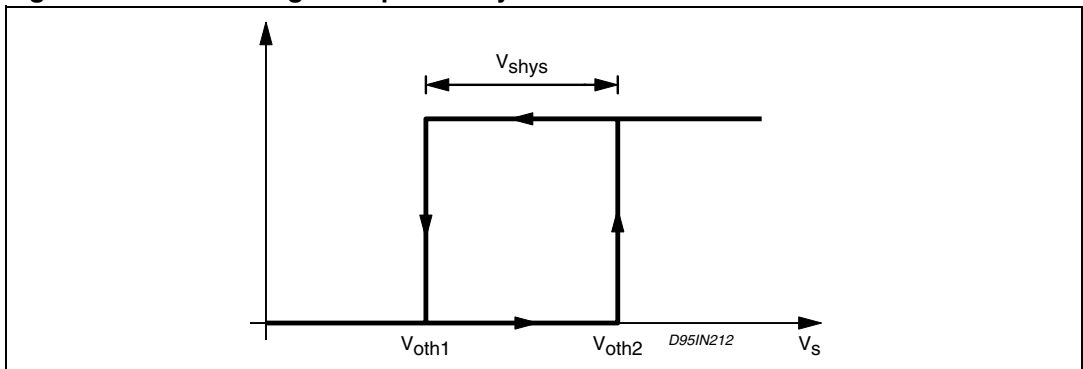
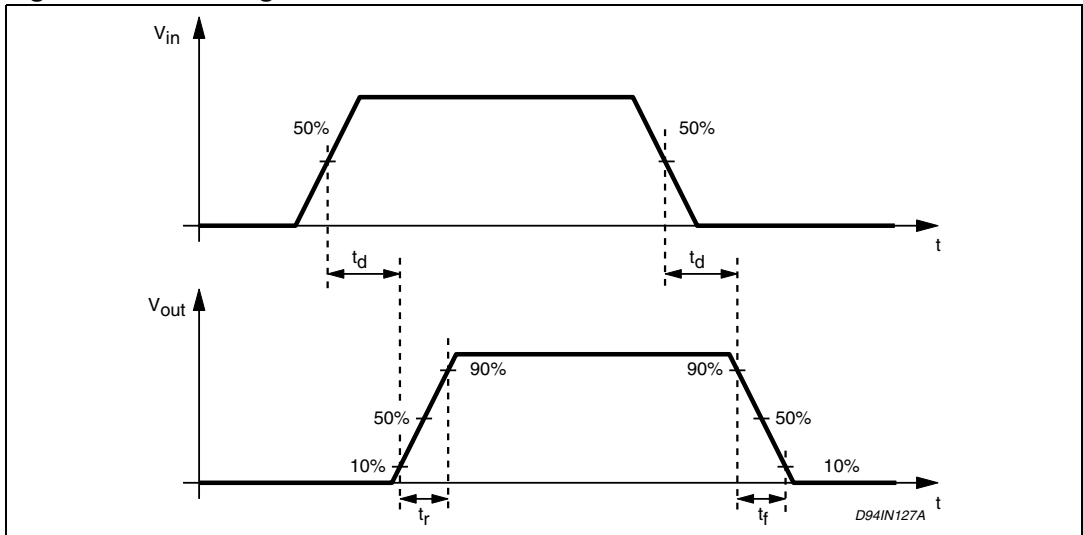


Figure 5. Switching waveforms



### 3.1 Diagnostic truth table

Table 7. Diagnostic truth table

| Diagnostic conditions  | Input | Output | Diag1 | Diag2 |
|--|-------|--------|-------|-------|
| Normal Operation   | L     | L      | H     | H     |
|  | H     | H      | H     | H     |
| Open Load Condition ( $I_o < I_{old}$ )  | L     | L      | H     | H     |
|  | H     | H      | L     | H     |
| Short to $V_S$   | L     | H      | L     | H     |
|  | H     | H      | L     | H     |
| Short Circuit to Ground ( $I_O = I_{SC}$ ) <sup>(1)</sup><br>(pin ON-DELAY grounded) | H     | X      | H     | H     |
|  | L     | L      | H     | H     |
| Output DMOS Open   | L     | L      | H     | H     |
|  | H     | L      | L     | H     |
| Overtemperature  | L     | L      | H     | L     |
|  | H     | L      | H     | L     |
| Supply Undervoltage ( $V_S < V_{sth2}$ )   | L     | L      | L     | L     |
|  | H     | L      | L     | L     |

1. A cold lamp filament, or a capacitive load may activate the current limiting circuit of the IPS, when the IPS is initially turned on.

### 3.2 Input section

The input section is an high impedance differential stage with high common and differential mode range. There's built-in offset of +1.4V (typical value) and an hysteresis of 400mV (maximum value), to ensure high noise immunity.

### 3.3 Diagnostic logic

The operating conditions of the device are permanently monitored and the following occurrences are signalled via the DIAG1/DIAG2 open-drain output pins:

- Short Circuit versus ground. A current limiting circuit fixes at  $I_{sc} = 3.2A$  (typical value) the maximum current that can be sourced from the OUTPUT pin (for more details see short circuit operation section).
- Short Circuit versus  $V_S$ .
- Under Voltage(UV)
- Over Temperature (OVT)
- Open Load, if the output current is less than 3mA (typical value).
- Output DMOS Open according to the diagnostic Truth [Table 7](#)

### 3.4 Short circuit operation

In order to minimise the power dissipation when the output is shorted to grounded, an innovative, non dissipative short circuit protection (patent pending) is implemented, avoiding, thus the intervention of the thermal protection in most cases.

Whenever the output is shorted to ground, or, generally speaking, an over current is sinked by the load, the output devices is driven in linear mode, sourcing the  $I_{sc}$  current (typically 3.2A) for a time interval ( $t_{on}$ ) defined by means of the external  $C_{ON}$  capacitor connected between the ONDELAY pin and GND. Whether the short circuit crease within the  $t_{on}$  interval the DIAG2 output status is not affected, acting as a Programmable Diagnostic Delay.

This function allow the device to drive a capacitive load or a filament lamp (that exhibits a very low resistance during the initial heading phase) without the intervention of the diagnostic. If the short circuit lasts for the whole  $t_{ON}$  interval, the output DMOS is switched OFF and the DIAG2 goes low, for a time interval  $t_{OFF}$  lasting 64 times  $t_{ON}$ .

At the end of the  $t_{OFF}$  interval if the short circuit condition is still present, the output DMOS is turned ON (and the DIAG2 goes high - see [Figure 7](#)) for another  $t_{ON}$  interval and the sequence starts again, or, whether not, the normal condition operation is resumed.

The  $t_{ON}$  interval can be set to lasts between 64ms and 2.56ms for a  $C_{ON}$  capacitor value ranging between 50pF and 2nF to have:

$$t_{ON} (\mu s) = 1.28 C_{ON} (pF)$$

If the ON-DELAY pin is grounded the non dissipative short circuit protection is disabled, and the  $I_{sc}$  current is delivered until the Overtemperature Protection shuts the device off. The behaviour of the DIAG2 output is, in this situation, showed in the Diagnostic Truth [Table 7](#).

### 3.5 Overtemperature protection (OVT)

If the chip temperature exceeds  $Q_{lim}$  (measured in a central position in the chip) the chip deactivates itself.

The following actions are taken:

all the output stage is switched off;

the signal DIAG2 is activated (active low).

Normal operation is resumed as soon as (typically after some seconds) the chip temperature monitored goes back below  $\Theta_{lim-\Theta_H}$ .

The different thresholds with hysteretic behavior assure that no intermittent conditions can be generated.

### 3.6 Undervoltage protection (UV)

The supply voltage is expected to range from 9.5V to 35V, even if its reference value is considered to be 24V.

In this range the device operates correctly. Below 9.5V the overall system has to be considered not reliable.

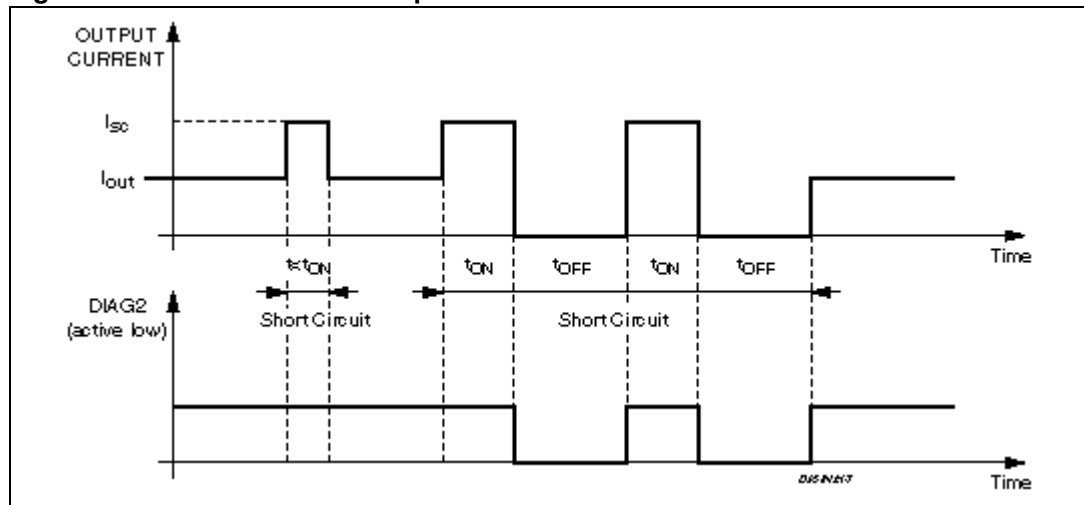
Protection will thus shut off the output whenever the supply voltage falls below the mask fixed by the  $V_{sth1}$  (9V typ.) and  $V_{sth2}$  (8.5V typ.).

The hysteresis (see [Figure 4](#)) ensures a non intermittent behavior at low supply voltage with a superimposed ripple. The Under Voltage status is signalled via the DIAG1 and DIAG2 outputs (see the Diagnostic Truth [Table 7](#)).

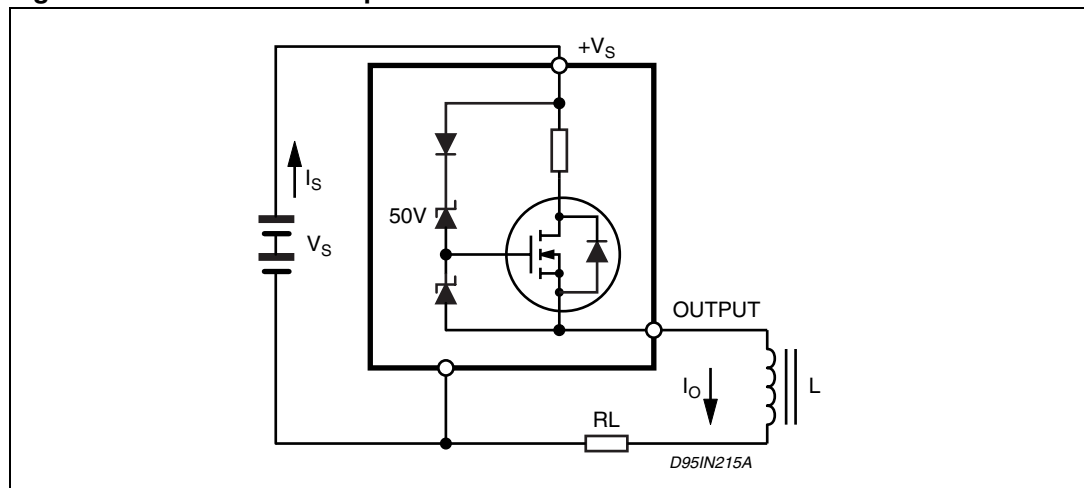
### 3.7 Demagnetization of inductive loads

An internal zener diode, limiting the voltage across the Power MOS to between 50 and 60V ( $V_{ci}$ ), provides safe and fast demagnetization of inductive loads without external clamping devices. The maximum energy that can be absorbed from an inductive load is specified as 1J (at  $T_j = 85^\circ\text{C}$ ) (see [Figure 4](#)).

**Figure 6. L6370 short circuit operation waveforms**



**Figure 7. Inductive load equivalent circuit**



## 4 Package mechanical data

In order to meet environmental requirements, ST offers these devices in ECOPACK® packages. These packages have a Lead-free second level interconnect . 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)

### 4.1 PowerSO-20 mechanical data & package dimensions

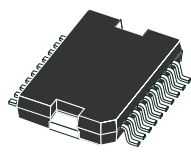
Figure 8. PowerSO-20 mechanical data & package dimensions

| DIM.   | mm         |       |      | inch  |       |       |
|--------|------------|-------|------|-------|-------|-------|
|        | MIN.       | TYP.  | MAX. | MIN.  | TYP.  | MAX.  |
| A      |            |       | 3.6  |       |       | 0.142 |
| a1     | 0.1        |       | 0.3  | 0.004 |       | 0.012 |
| a2     |            |       | 3.3  |       |       | 0.130 |
| a3     | 0          |       | 0.1  | 0.000 |       | 0.004 |
| b      | 0.4        |       | 0.53 | 0.016 |       | 0.021 |
| c      | 0.23       |       | 0.32 | 0.009 |       | 0.013 |
| D (1)  | 15.8       |       | 16   | 0.622 |       | 0.630 |
| D1 (2) | 9.4        |       | 9.8  | 0.370 |       | 0.386 |
| E      | 13.9       |       | 14.5 | 0.547 |       | 0.570 |
| e      |            | 1.27  |      |       | 0.050 |       |
| e3     |            | 11.43 |      |       | 0.450 |       |
| E1 (1) | 10.9       |       | 11.1 | 0.429 |       | 0.437 |
| E2     |            |       | 2.9  |       |       | 0.114 |
| E3     | 5.8        |       | 6.2  | 0.228 |       | 0.244 |
| G      | 0          |       | 0.1  | 0.000 |       | 0.004 |
| H      | 15.5       |       | 15.9 | 0.610 |       | 0.626 |
| h      |            |       | 1.1  |       |       | 0.043 |
| L      | 0.8        |       | 1.1  | 0.031 |       | 0.043 |
| N      | 8' (typ.)  |       |      |       |       |       |
| S      | 8' (max. ) |       |      |       |       |       |
| T      |            | 10    |      |       | 0.394 |       |

(1) "D and E1" do not include mold flash or protusions.  
 - Mold flash or protusions shall not exceed 0.15mm (0.006")  
 - Critical dimensions: "E", "G" and "a3".  
 (2) For subcontractors, the limit is the one quoted in jedec MO-166

**OUTLINE AND MECHANICAL DATA**

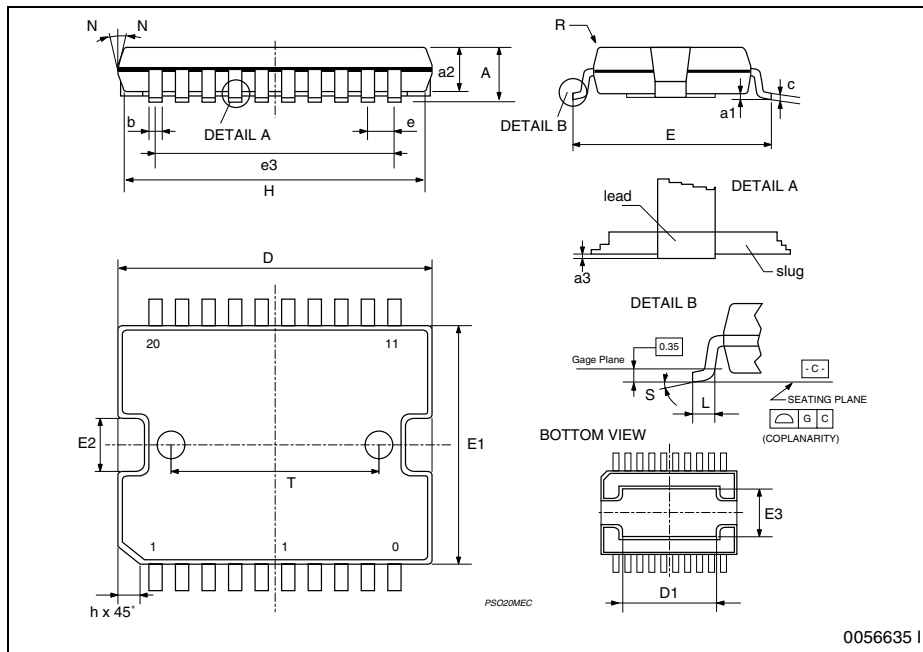
Weight: 1.9gr



**JEDEC MO-166**

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**PowerSO-20**



## 4.2 PowerSO-20 packing information

Figure 9. PowerSO-20 tube shipment information

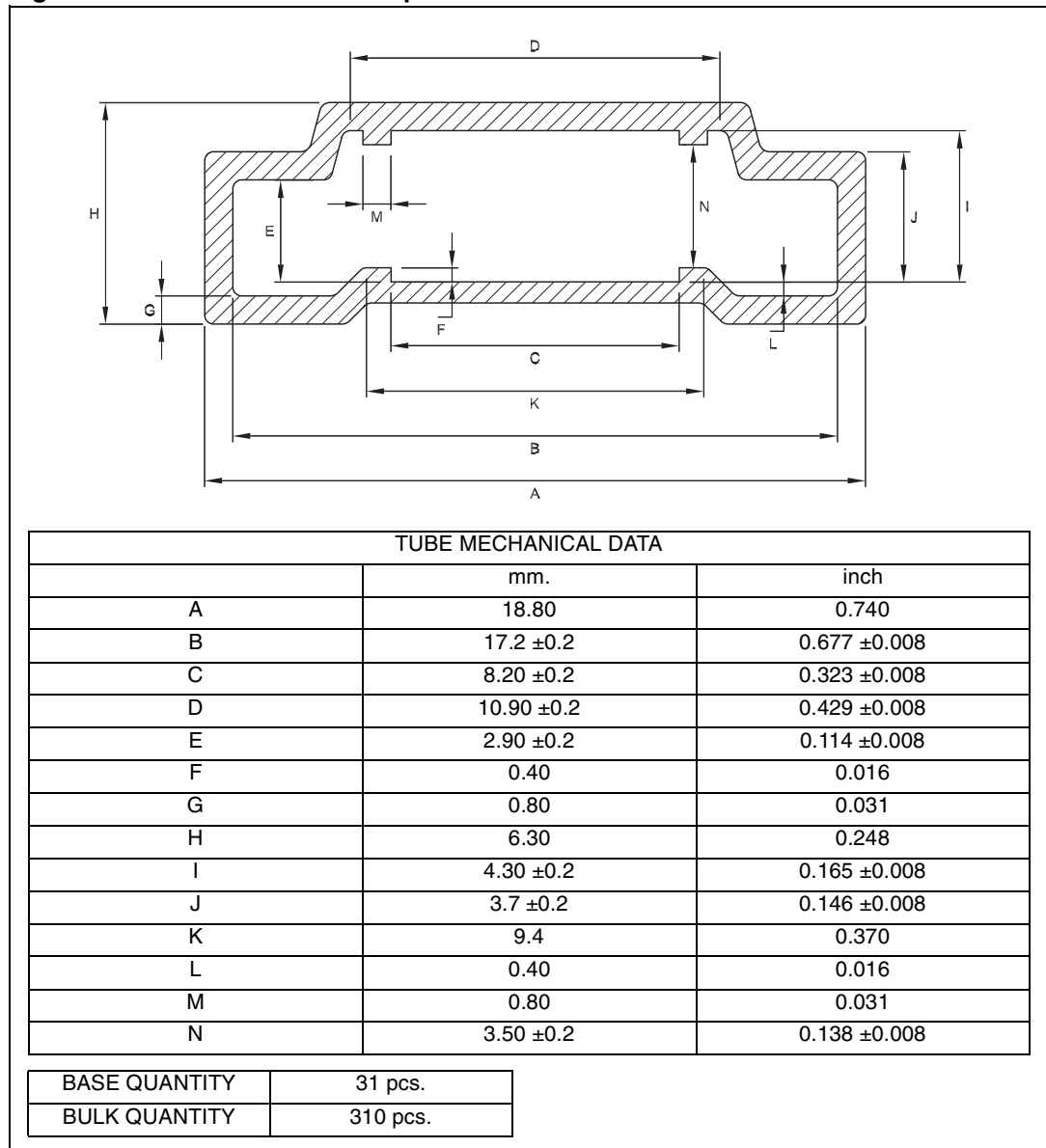


Figure 10. PowerSO-20 tape shipment specification

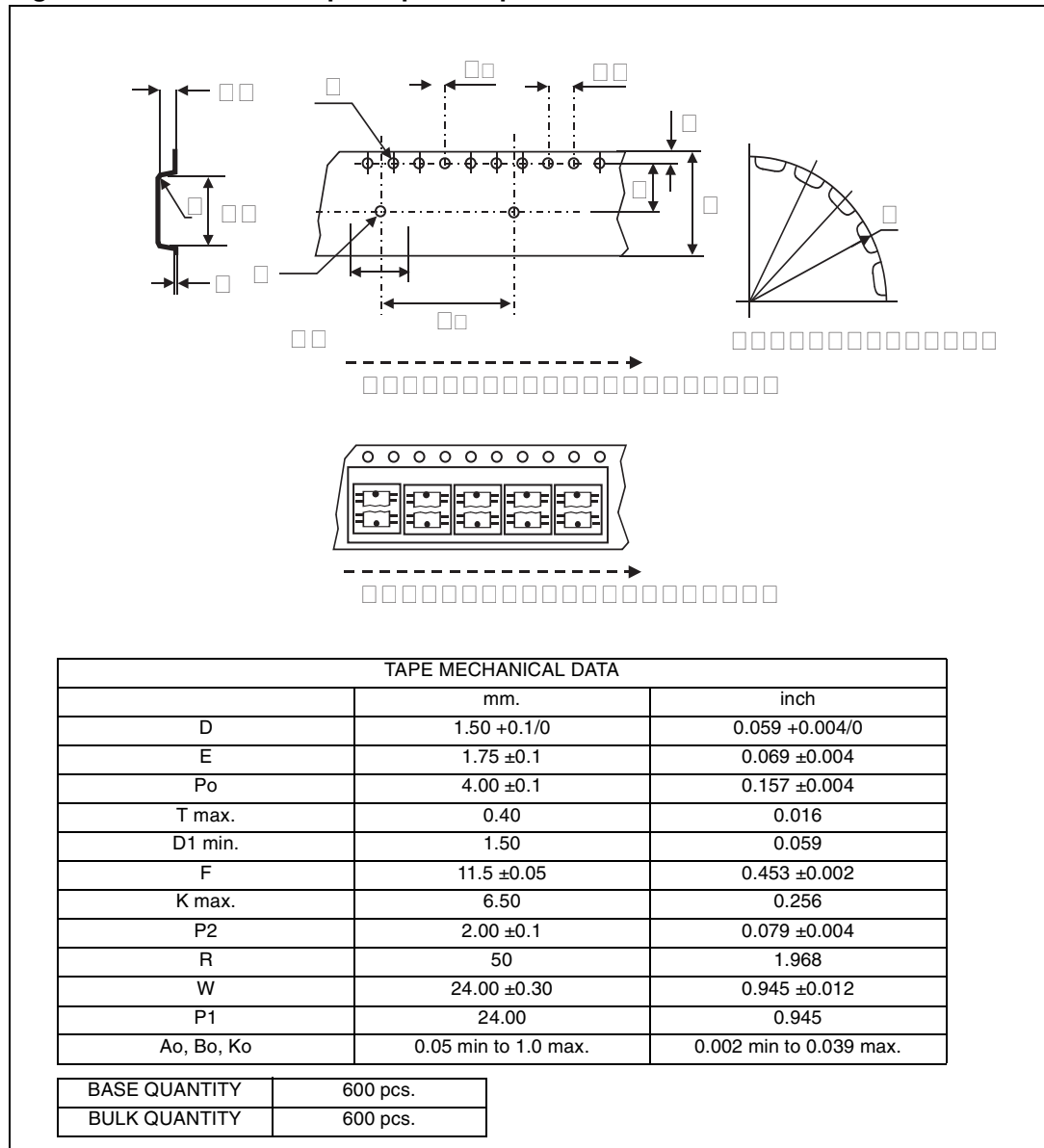




Figure 11. PowerSO-20 reel shipment specification

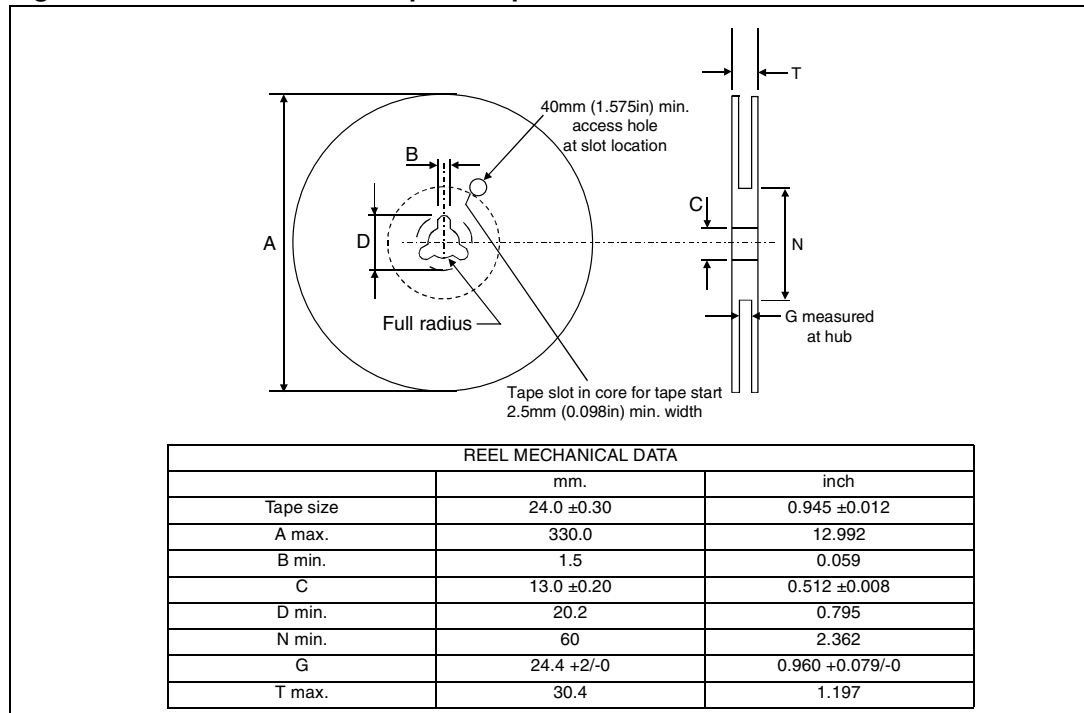
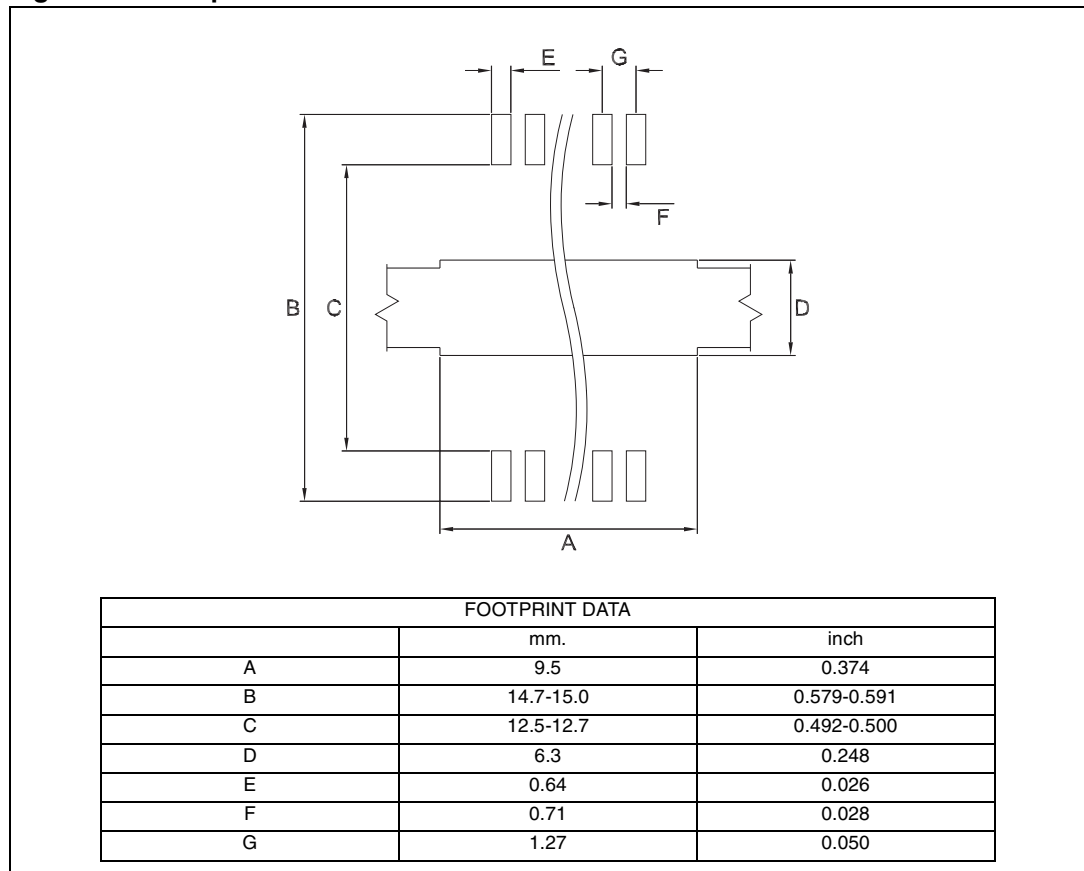


Figure 12. Footprint recommended data



## 5 Revision history

**Table 8. Revision history**

| Date        | Revision | Changes  |
|-------------|----------|--|
| 10-Aug-2003 | 3        | Initial release.   |
| 12-Dec-2005 | 4        | Applied new Look & Feel Style Sheet.<br>Added L6370D013TR part number.<br>Updated Package and Packing section. |
| 26-Apr-2006 | 5        | Document has been reformatted  |
| 19-Feb-2007 | 6        | Typo in <a href="#">Figure 2 on page 3</a> .   |
| 19-Jun-2007 | 7        | Truth table updated, deleted Multiwatt mechanical information  |

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