

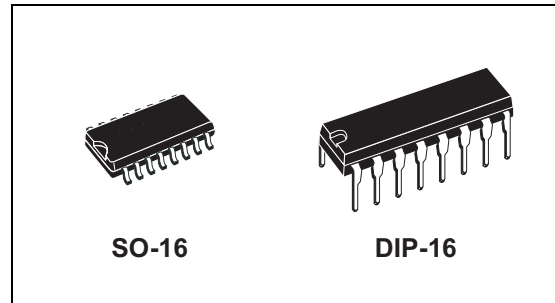
## High-voltage high and low side driver

### Features

- High voltage rail up to 600 V
- $dV/dt$  immunity  $\pm 50$  V/nsec in full temperature range
- Driver current capability:
  - 290 mA source,
  - 430 mA sink
- Switching times 75/35 nsec rise/fall with 1 nF load
- 3.3 V, 5 V TTL/CMOS inputs with hysteresis
- Integrated bootstrap diode
- Operational amplifier for advanced current sensing
- Comparator for fault protections
- Smart shut down function
- Adjustable dead-time
- Interlocking function
- Compact and simplified layout
- Bill of material reduction
- Effective fault protection
- Flexible, easy and fast design

### Applications

- Motor driver for home appliances, factory automation, industrial drives.
- HID ballasts, power supply units.



### Description

The L6390 is a high-voltage device manufactured with the BCD "OFF-LINE" technology. It is a single chip half-bridge gate driver for N-channel power MOSFET or IGBT.

The high side (floating) section is designed to stand a voltage rail up to 600 V. The logic inputs are CMOS/TTL compatible down to 3.3 V for easy interfacing microcontroller/DSP.

The IC embeds an operational amplifier suitable for advanced current sensing in applications such as field oriented motor control.

An integrated comparator is available for protections against overcurrent, overtemperature, etc.

**Table 1. Device summary**

Order codes	Package	Packaging
L6390N	DIP-16	Tube
L6390D	SO-16	Tube
L6390DTR	SO-16	Tape and reel

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## 2 Pin connection

Figure 2. Pin connection (top view)

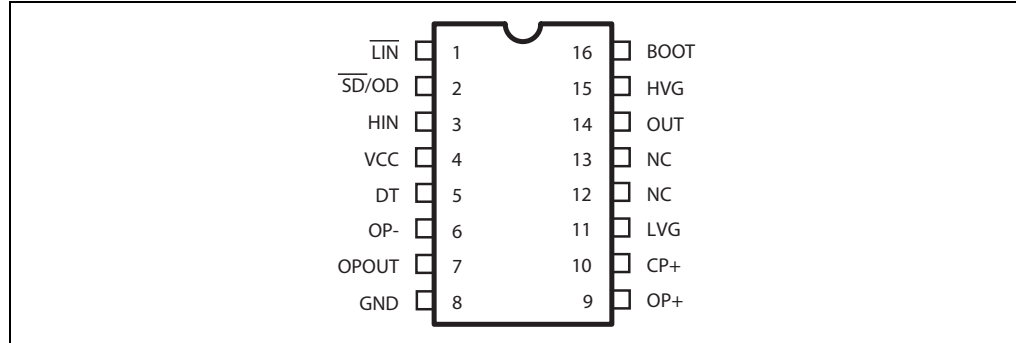


Table 2. Pin description

Pin n #	Pin name	Type	Function
1	$\overline{\text{LIN}}$	I	Low side driver logic input (active low)
2	$\overline{\text{SD/OD}}$ <sup>(1)</sup>	I/O	Shut down logic input (active low)/open drain (comparator output)
3	HIN	I	High side driver logic input (active high)
4	VCC	P	Lower section supply voltage
5	DT	I	Dead time setting
6	OP-	I	Opamp inverting input
7	OPOUT	O	Opamp output
8	GND	P	Ground
9	OP+	I	Opamp non inverting input
10	CP+	I	Comparator input
11	LVG <sup>(1)</sup>	O	Low side driver output
12, 13	NC		Not connected
14	OUT	P	High side (Floating) common voltage
15	HVG <sup>(1)</sup>	O	High side driver output
16	BOOT	P	Bootstrap supply voltage

1. The circuit provides less than 1 V on the LVG and HVG pins (@  $I_{\text{sink}} = 10 \text{ mA}$ ), with  $V_{\text{CC}} > 3 \text{ V}$ . This allows omitting the "bleeder" resistor connected between the gate and the source of the external MOSFET normally used to hold the pin low; the gate driver assures low impedance also in SD condition.

### 3 Truth table

**Table 3. Truth table**

Input			Output	
$\overline{SD}$	$\overline{LIN}$	HIN	LVG	HVG
L	X	X	L	L
H	H	L	L	L
H	L	H	L	L
H	L	L	H	L
H	H	H	L	H

Note: X: don't care

## 4 Electrical data

### 4.1 Absolute maximum ratings

Table 4. Absolute maximum rating

Symbol	Parameter	Value		Unit
		Min	Max	
$V_{cc}$	Supply voltage	- 0.3	21	V
$V_{out}$	Output voltage	$V_{boot} - 21$	$V_{boot} + 0.3$	V
$V_{boot}$	Bootstrap voltage	- 0.3	620	V
$V_{hvg}$	High side gate output voltage	$V_{out} - 0.3$	$V_{boot} + 0.3$	V
$V_{lvg}$	Low side gate output voltage	- 0.3	$V_{cc} + 0.3$	V
$V_{op+}$	OPAMP non-inverting input	- 0.3	$V_{cc} + 0.3$	V
$V_{op-}$	OPAMP inverting input	- 0.3	$V_{cc} + 0.3$	V
$V_{cp+}$	Comparator input voltage	- 0.3	$V_{cc} + 0.3$	V
$V_i$	Logic input voltage	- 0.3	15	V
$V_{od}$	Open drain voltage	- 0.3	15	V
$dV_{out}/dt$	Allowed output slew rate		50	V/ns
$P_{tot}$	Total power dissipation ( $T_A = 25\text{ °C}$ )		800	mW
$T_J$	Junction temperature		150	°C
$T_{stg}$	Storage temperature	-50	150	°C

Note: ESD immunity for pins 14, 15 and 16 is guaranteed up to 1 kV (human body model)

### 4.2 Thermal data

Table 5. Thermal data

Symbol	Parameter	SO-16	DIP-16	Unit
$R_{th(JA)}$	Thermal resistance junction to ambient	155	100	°C/W

### 4.3 Recommended operating conditions

**Table 6. Recommended operating conditions**

Symbol	Pin	Parameter	Test condition	Min	Max	Unit
$V_{cc}$	4	Supply voltage		12.5	20	V
$V_{BO}^{(1)}$	16-14	Floating supply voltage		12.4	20	V
$V_{out}$	14	DC output voltage		- 9 <sup>(2)</sup>	580	V
$f_{sw}$		Switching frequency	HVG, LVG load $C_L = 1$ nF		800	kHz
$T_J$		Junction temperature		-40	125	°C

1.  $V_{BO} = V_{boot} - V_{out}$
2. LVG off.  $V_{cc} = 12.5$  V  
Logic is operational if  $V_{boot} > 5$  V  
Refer to AN2738 for more details

## 5 Electrical characteristics

### 5.1 AC operation

**Table 7. AC operation electrical characteristics ( $V_{CC} = 15\text{ V}$ ;  $T_J = +25\text{ °C}$ )**

Symbol	Pin	Parameter	Test condition	Min	Typ	Max	Unit
$t_{on}$	1 vs 11	High/low side driver turn-on propagation delay	$V_{out} = 0\text{ V}$ $V_{boot} = V_{CC}$ $C_L = 1\text{ nF}$ $V_i = 0\text{ to }3.3\text{ V}$ See <a href="#">Figure 3</a> .	50	125	200	ns
$t_{off}$	3 vs 15	High/low side driver turn-off propagation delay		50	125	200	ns
$t_{sd}$	2 vs 11, 15	Shut down to high/low side driver propagation delay		50	125	200	ns
$t_{isd}$		Comparator triggering to high/low side driver turn-off propagation delay	Measured applying a voltage step from 0 V to 3.3 V to pin CP+.	50	200	250	ns
MT		Delay matching, HS and LS turn-on/off				30	ns
DT	5	Dead time setting range <sup>(1)</sup>	$R_{DT} = 0, C_L = 1\text{ nF}, C_{DT} = 100\text{ nF}$	0.1	0.18	0.25	$\mu\text{s}$
			$R_{DT} = 37\text{ k}\Omega, C_L = 1\text{ nF}, C_{DT} = 100\text{ nF}$	0.48	0.6	0.72	$\mu\text{s}$
			$R_{DT} = 136\text{ k}\Omega, C_L = 1\text{ nF}, C_{DT} = 100\text{ nF}$	1.35	1.6	1.85	$\mu\text{s}$
			$R_{DT} = 260\text{ k}\Omega, C_L = 1\text{ nF}, C_{DT} = 100\text{ nF}$	2.6	3.0	3.4	$\mu\text{s}$
MDT		Matching dead time <sup>(2)</sup>	$R_{DT} = 0, C_L = 1\text{ nF}, C_{DT} = 100\text{ nF}$			80	ns
			$R_{DT} = 37\text{ k}\Omega, C_L = 1\text{ nF}, C_{DT} = 100\text{ nF}$			120	ns
			$R_{DT} = 136\text{ k}\Omega, C_L = 1\text{ nF}, C_{DT} = 100\text{ nF}$			250	ns
			$R_{DT} = 260\text{ k}\Omega, C_L = 1\text{ nF}, C_{DT} = 100\text{ nF}$			400	ns
$t_r$	11, 15	Rise time	$C_L = 1\text{ nF}$		75	120	ns
$t_f$		Fall time	$C_L = 1\text{ nF}$		35	70	ns

1. See [Figure 4 on page 9](#)

2.  $MDT = |DT_{LH} - DT_{HL}|$  see [Figure 5 on page 13](#)



Figure 3. Timing

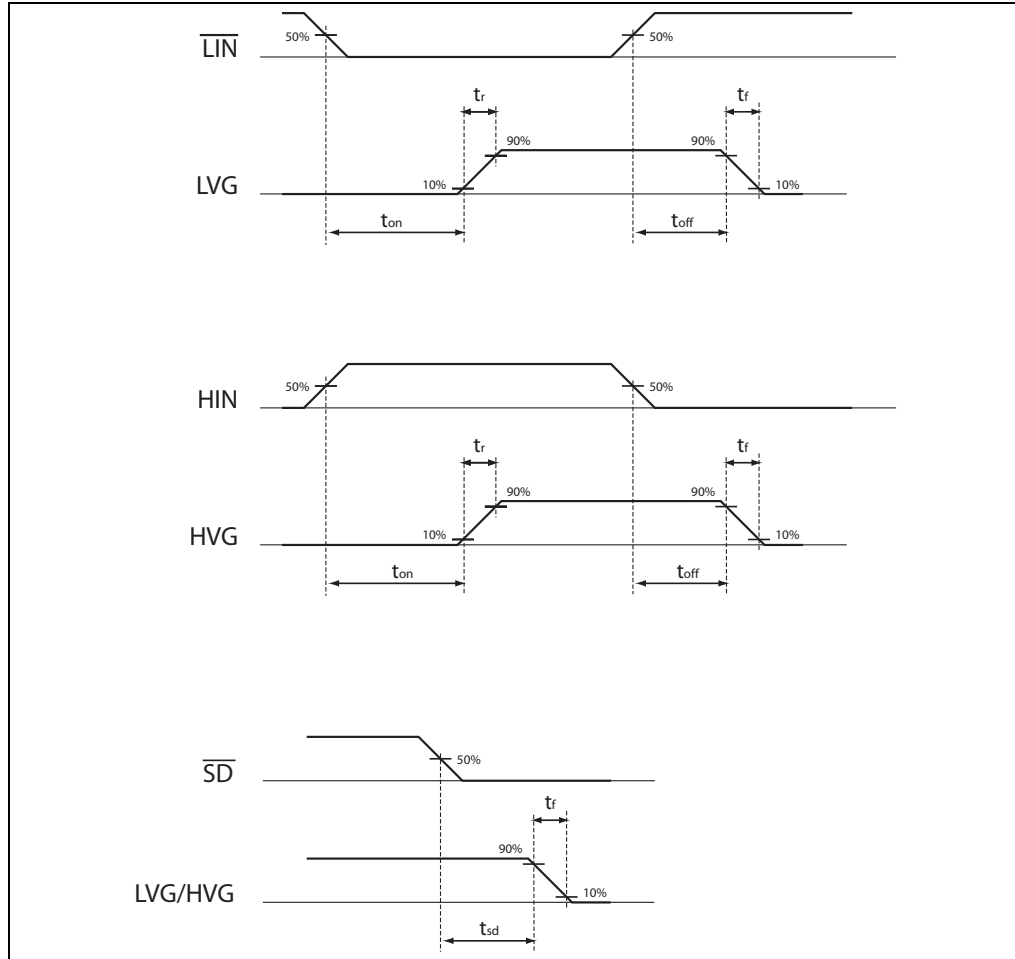
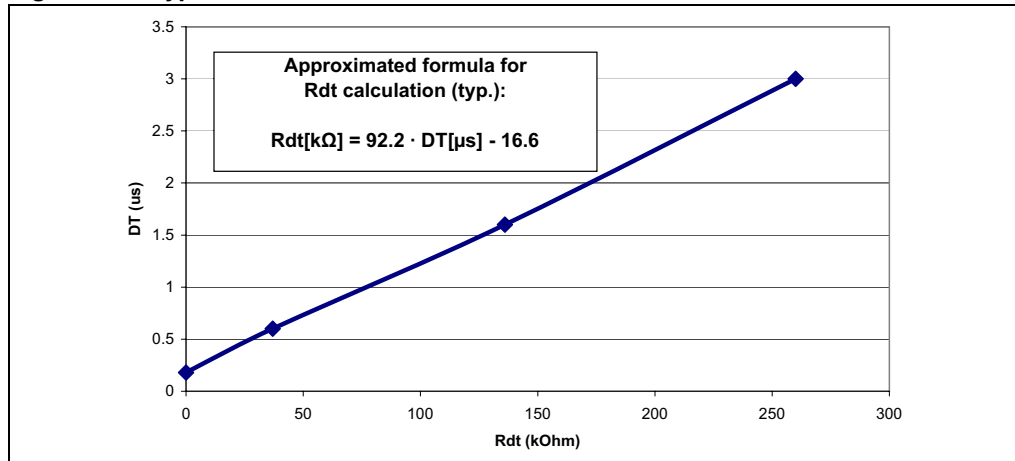


Figure 4. Typical dead time vs. DT resistor value



## 5.2 DC operation

**Table 8. DC operation electrical characteristics ( $V_{CC} = 15\text{ V}$ ;  $T_J = +25\text{ °C}$ )**

Symbol	Pin	Parameter	Test condition	Min	Typ	Max	Unit	
<b>Low supply voltage section</b>								
$V_{CC\_hys}$	4	$V_{CC}$ UV hysteresis		1200	1500	1800	mV	
$V_{CC\_thON}$		$V_{CC}$ UV turn ON threshold		11.5	12	12.5	V	
$V_{CC\_thOFF}$		$V_{CC}$ UV turn OFF threshold		10	10.5	11	V	
$I_{QCCU}$		Undervoltage quiescent supply current	$V_{CC} = 10\text{ V}$ $\overline{SD} = 5\text{ V}$ ; $\overline{LIN} = 5\text{ V}$ ; $HIN = GND$ ; $R_{DT} = 0\ \Omega$ ; $CP+=OP+=GND$ ; $OP-=5\text{ V}$			120	150	$\mu\text{A}$
$I_{QCC}$		Quiescent current	$V_{CC} = 15\text{ V}$ $\overline{SD} = 5\text{ V}$ ; $\overline{LIN} = 5\text{ V}$ ; $HIN = GND$ ; $R_{DT} = 0\ \Omega$ ; $CP+=OP+=GND$ ; $OP-=5\text{ V}$			720	1000	$\mu\text{A}$
$V_{ref}$		Internal reference voltage		500	540	580	mV	
<b>Bootstrapped supply voltage section <sup>(1)</sup></b>								
$V_{BO\_hys}$	16	$V_{BO}$ UV hysteresis		1200	1500	1800	mV	
$V_{BO\_thON}$		$V_{BO}$ UV turn ON threshold		10.6	11.5	12.4	V	
$V_{BO\_thOFF}$		$V_{BO}$ UV turn OFF threshold		9.1	10	10.9	V	
$I_{QBOU}$		Undervoltage $V_{BO}$ quiescent current	$V_{BO} = 9\text{ V}$ $\overline{SD} = 5\text{ V}$ ; $\overline{LIN}$ and $HIN = 5\text{ V}$ ; $R_{DT} = 0\ \Omega$ ; $CP+=OP+=GND$ ; $OP-=5\text{ V}$			70	110	$\mu\text{A}$
$I_{QBO}$		$V_{BO}$ quiescent current	$V_{BO} = 15\text{ V}$ $\overline{SD} = 5\text{ V}$ ; $\overline{LIN}$ and $HIN = 5\text{ V}$ ; $R_{DT} = 0\ \Omega$ ; $CP+=OP+=GND$ ; $OP-=5\text{ V}$			150	210	$\mu\text{A}$
$I_{LK}$		High voltage leakage current	$V_{hvg} = V_{out} = V_{boot} = 600\text{ V}$			10	$\mu\text{A}$	
$R_{DS(on)}$		Bootstrap driver on resistance <sup>(2)</sup>	LVG ON			120	$\Omega$	
<b>Driving buffers section</b>								
$I_{so}$	11, 15	High/low side source short circuit current	$V_{IN} = V_{ih}$ ( $t_p < 10\ \mu\text{s}$ )	200	290		mA	
$I_{si}$		High/low side sink short circuit current	$V_{IN} = V_{il}$ ( $t_p < 10\ \mu\text{s}$ )	250	430		mA	
<b>Logic inputs</b>								

**Table 8. DC operation electrical characteristics ( $V_{CC} = 15\text{ V}$ ;  $T_J = +25\text{ °C}$ ) (continued)**

Symbol	Pin	Parameter	Test condition	Min	Typ	Max	Unit
$V_{il}$	1, 2, 3	Low logic level voltage				0.8	V
$V_{ih}$		High logic level voltage		2.25			V
$V_{il\_S}$	1, 3	Single input voltage	$\overline{LIN}$ and HIN connected together and floating			0.8	V
$I_{HINh}$	3	HIN logic "1" input bias current	HIN = 15 V	110	175	260	$\mu\text{A}$
$I_{HINI}$		HIN logic "0" input bias current	HIN = 0 V			1	$\mu\text{A}$
$I_{LINI}$	1	$\overline{LIN}$ logic "0" input bias current	$\overline{LIN} = 0\text{ V}$	3	6	20	$\mu\text{A}$
$I_{LINh}$		$\overline{LIN}$ logic "1" input bias current	$\overline{LIN} = 15\text{ V}$			1	$\mu\text{A}$
$I_{SDh}$	2	$\overline{SD}$ logic "1" input bias current	$\overline{SD} = 15\text{ V}$	10	40	100	$\mu\text{A}$
$I_{SDI}$		$\overline{SD}$ logic "0" input bias current	$\overline{SD} = 0\text{ V}$			1	$\mu\text{A}$

1.  $V_{BO} = V_{boot} - V_{out}$

2.  $R_{DS(on)}$  is tested in the following way:

$$R_{DS(on)} = [(V_{CC} - V_{CBOOT1}) - (V_{CC} - V_{CBOOT2})] / [I_1(V_{CC}, V_{CBOOT1}) - I_2(V_{CC}, V_{CBOOT2})]$$

where  $I_1$  is pin 16 current when  $V_{CBOOT} = V_{CBOOT1}$ ,  $I_2$  when  $V_{CBOOT} = V_{CBOOT2}$ .

**Table 9. OPAMP characteristics ( $V_{CC} = 15\text{ V}$ ,  $T_J = +25\text{ °C}$ )**

Symbol	Pin	Parameter	Test condition	Min	Typ	Max	Unit
$V_{io}$	6, 9	Input offset voltage	$V_{ic} = 0\text{ V}$ , $V_o = 7.5\text{ V}$			6	mV
$I_{io}$		Input offset current	$V_{ic} = 0\text{ V}$ , $V_o = 7.5\text{ V}$		4	40	nA
$I_{ib}$		Input bias current <sup>(1)</sup>			100	200	nA
$V_{icm}$		Input common mode voltage range		0		$V_{CC}-4$	V
$V_{OL}$	7	Low level output voltage	$R_L = 10\text{ k}\Omega$ to $V_{CC}$		75	150	mV
$V_{OH}$		High level output voltage	$R_L = 10\text{ k}\Omega$ to GND	14	14.7		V
$I_o$		Output short circuit current	Source, $V_{id} = +1$ ; $V_o = 0\text{ V}$	16	30		mA
	Sink, $V_{id} = -1$ ; $V_o = V_{CC}$	50	80		mA		
SR		Slew rate	$V_i = 1 \div 4\text{ V}$ ; $C_L = 100\text{ pF}$ ; unity gain	2.5	3.8		V/ $\mu$ s
GBWP		Gain bandwidth product	$V_o = 7.5\text{ V}$	8	12		MHz
$A_{vd}$		Large signal voltage gain	$R_L = 2\text{ k}\Omega$	70	85		dB
SVR		Supply voltage rejection ratio	vs. $V_{CC}$	60	75		dB
CMRR		Common mode rejection ratio		55	70		dB

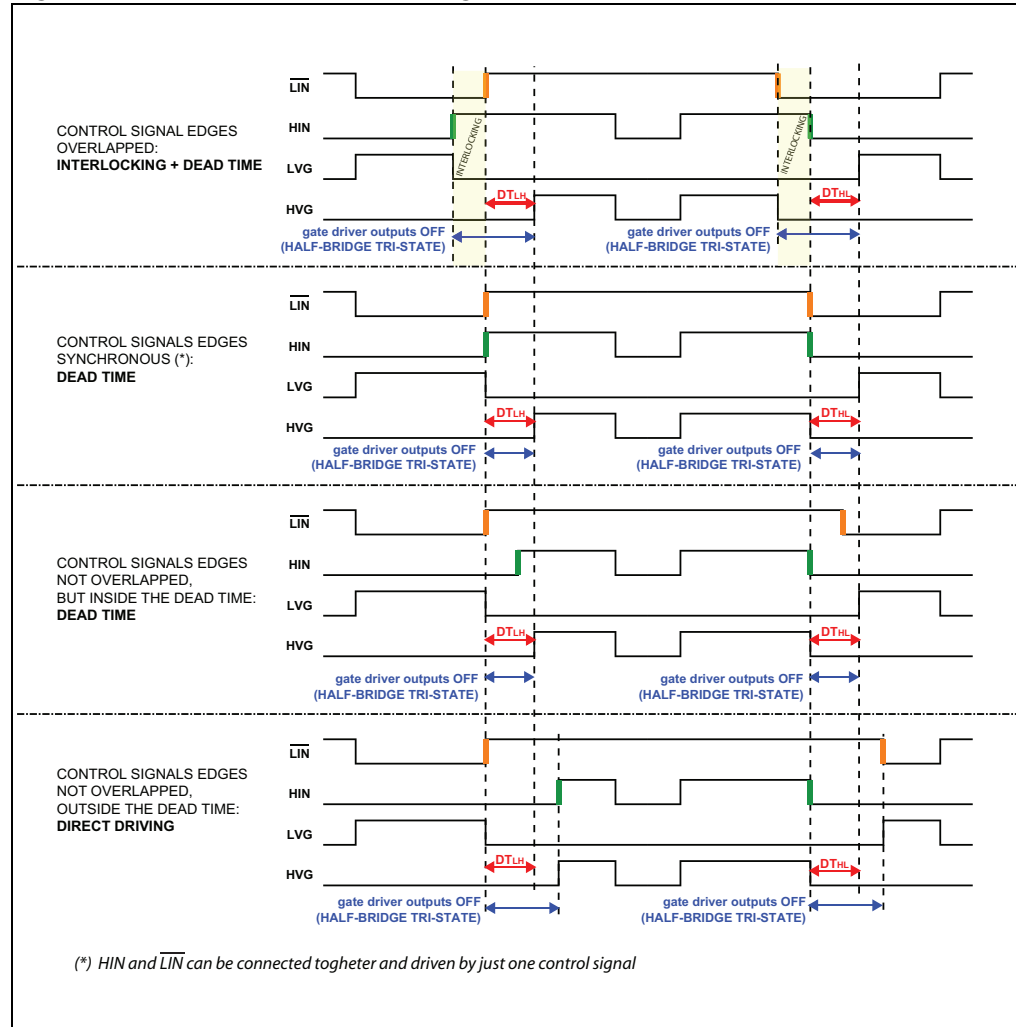
1. The direction of input current is out of the IC.

**Table 10. Sense comparator characteristics ( $V_{CC} = 15\text{ V}$ ,  $T_J = +25\text{ °C}$ )**

Symbol	Pin	Parameter	Test conditions	Min	Typ	Max	Unit
$I_{ib}$	10	Input bias current	$V_{CP+} = 1\text{ V}$			1	$\mu$ A
$V_{ol}$	2	Open drain low level output voltage	$I_{od} = -3\text{ mA}$			0.5	V
$t_{d\_comp}$		Comparator delay	$\overline{SD}/OD$ pulled to 5 V through 100 k $\Omega$ resistor		90	130	ns
SR	2	Slew rate	$C_L = 180\text{ pF}$ ; $R_{pu} = 5\text{ k}\Omega$		60		V/ $\mu$ s

## 6 Waveforms definitions

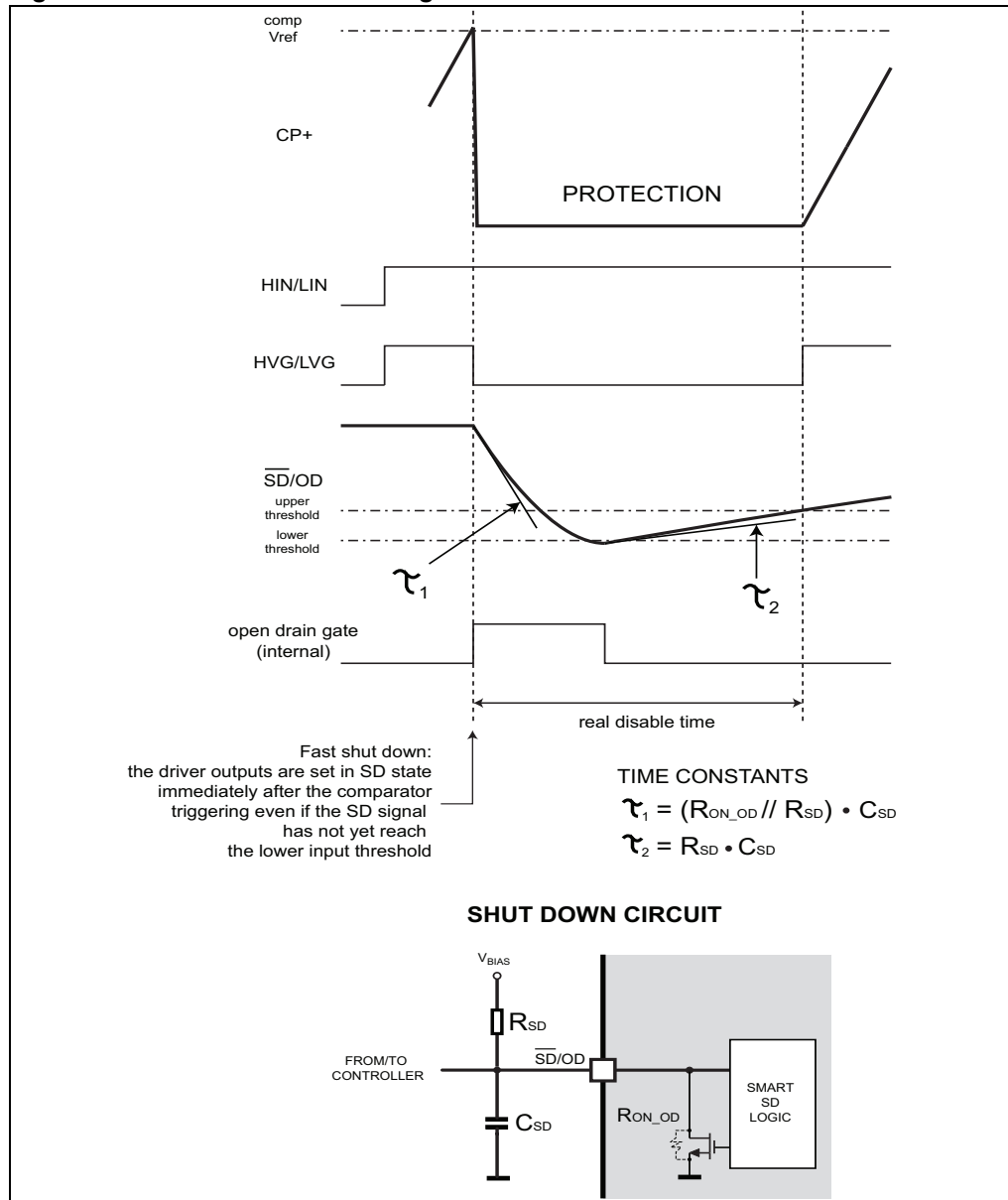
Figure 5. Dead time and interlocking waveforms definitions



## 7 Smart shut down function

L6390 integrates a comparator committed to the fault sensing function. The comparator has an internal voltage reference  $V_{ref}$  connected to the inverting input, while the non-inverting input is available on pin 10. The comparator input can be connected to an external shunt resistor in order to implement a simple over-current detection function. The output signal of the comparator is fed to an integrated MOSFET with the open drain output available on pin 2, shared with the  $\overline{SD}$  input. When the comparator triggers, the device is set in shut down state and both its outputs are set to low level leaving the half-bridge in tri-state.

Figure 6. Smart shut down timing waveforms

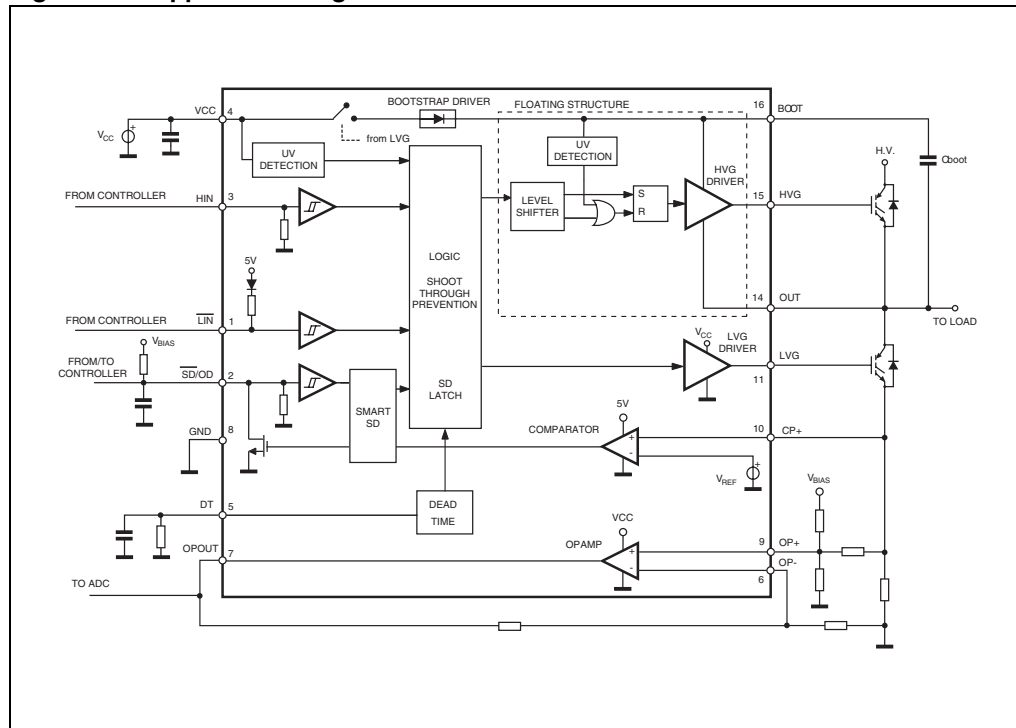


In common over-current protection architectures the comparator output is usually connected to the  $\overline{SD}$  input and an RC network is connected to this  $\overline{SD}/OD$  line in order to provide a mono-stable circuit, which implements a protection time that follows the fault condition. Differently from the common fault detection systems, L6390 Smart shut down architecture allows to immediately turn-off the outputs gate driver in case of fault, by minimizing the propagation delay between the fault detection event and the actual outputs switch-off. In fact the time delay between the fault and the outputs turn off is no more dependent on the RC value of the external network connected to the pin. In the smart shut down circuitry, the fault signal has a preferential path which directly switches off the outputs after the comparator triggering. At the same time the internal logic turns on the open drain output and holds it on until the  $\overline{SD}$  voltage goes below the  $\overline{SD}$  logic input lower threshold. The Smart shut down system provides the possibility to increase the time constant of the external RC network (that is the disable time after the fault event) up to very large values without increasing the delay time of the protection.

Any external signal provided to the  $\overline{SD}$  pin is not latched and can be used as control signal in order to perform, for instance, PWM chopping through this pin. In fact when a PWM signal is applied to the  $\overline{SD}$  input and the logic inputs of the gate driver are stable, the outputs switch from the low level to the state defined by the logic inputs and vice versa.

# 8 Typical application diagram

Figure 7. Application diagram





## 9 Bootstrap driver

A bootstrap circuitry is needed to supply the high voltage section. This function is normally accomplished by a high voltage fast recovery diode (*Figure 8.a*). In the L6390 a patented integrated structure replaces the external diode. It is realized by a high voltage DMOS, driven synchronously with the low side driver (LVG), with diode in series, as shown in *Figure 8.b*. An internal charge pump (*Figure 8.b*) provides the DMOS driving voltage.

### 9.1 C<sub>BOOT</sub> selection and charging

To choose the proper C<sub>BOOT</sub> value the external MOS can be seen as an equivalent capacitor. This capacitor C<sub>EXT</sub> is related to the MOS total gate charge:

#### Equation 1

$$C_{EXT} = \frac{Q_{gate}}{V_{gate}}$$

The ratio between the capacitors C<sub>EXT</sub> and C<sub>BOOT</sub> is proportional to the cyclical voltage loss. It has to be:

#### Equation 2

$$C_{BOOT} \gg C_{EXT}$$

e.g.: if Q<sub>gate</sub> is 30 nC and V<sub>gate</sub> is 10 V, C<sub>EXT</sub> is 3 nF. With C<sub>BOOT</sub> = 100 nF the drop would be 300 mV.

If HVG has to be supplied for a long time, the C<sub>BOOT</sub> selection has to take into account also the leakage and quiescent losses.

e.g.: HVG steady state consumption is lower than 200 μA, so if HVG T<sub>ON</sub> is 5 ms, C<sub>BOOT</sub> has to supply 1 μC to C<sub>EXT</sub>. This charge on a 1 μF capacitor means a voltage drop of 1V.

The internal bootstrap driver gives a great advantage: the external fast recovery diode can be avoided (it usually has great leakage current).

This structure can work only if V<sub>OUT</sub> is close to GND (or lower) and in the meanwhile the LVG is on. The charging time (T<sub>charge</sub>) of the C<sub>BOOT</sub> is the time in which both conditions are fulfilled and it has to be long enough to charge the capacitor.

The bootstrap driver introduces a voltage drop due to the DMOS R<sub>DSon</sub> (typical value: 120 Ω). At low frequency this drop can be neglected. Anyway increasing the frequency it must be taken in to account.

The following equation is useful to compute the drop on the bootstrap DMOS:

**Equation 3**

$$V_{\text{drop}} = I_{\text{charge}} R_{\text{dson}} \rightarrow V_{\text{drop}} = \frac{Q_{\text{gate}}}{T_{\text{charge}}} R_{\text{dson}}$$

where  $Q_{\text{gate}}$  is the gate charge of the external power MOS,  $R_{\text{dson}}$  is the on resistance of the bootstrap DMOS and  $T_{\text{charge}}$  is the charging time of the bootstrap capacitor.

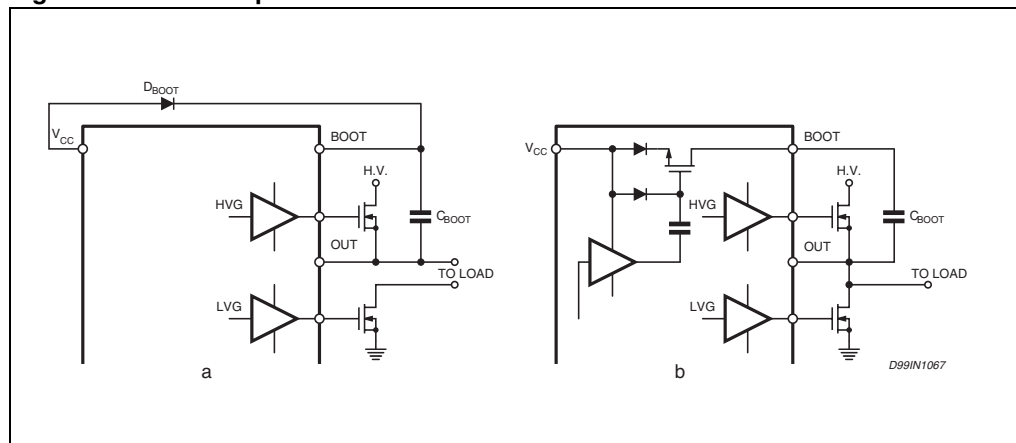
For example: using a power MOS with a total gate charge of 30nC the drop on the bootstrap DMOS is about 1 V, if the  $T_{\text{charge}}$  is 5  $\mu\text{s}$ . In fact:

**Equation 4**

$$V_{\text{drop}} = \frac{30\text{nC}}{5\mu\text{s}} \cdot 120\Omega \sim 0.7\text{V}$$

$V_{\text{drop}}$  has to be taken into account when the voltage drop on  $C_{\text{BOOT}}$  is calculated: if this drop is too high, or the circuit topology doesn't allow a sufficient charging time, an external diode can be used.

**Figure 8. Bootstrap driver**



## 10 Package mechanical data

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK® packages, depending on their level of environmental compliance. ECOPACK® specifications, grade definitions and product status are available at: [www.st.com](http://www.st.com). ECOPACK® is an ST trademark.

**Figure 9. DIP-16 mechanical data and package dimensions**

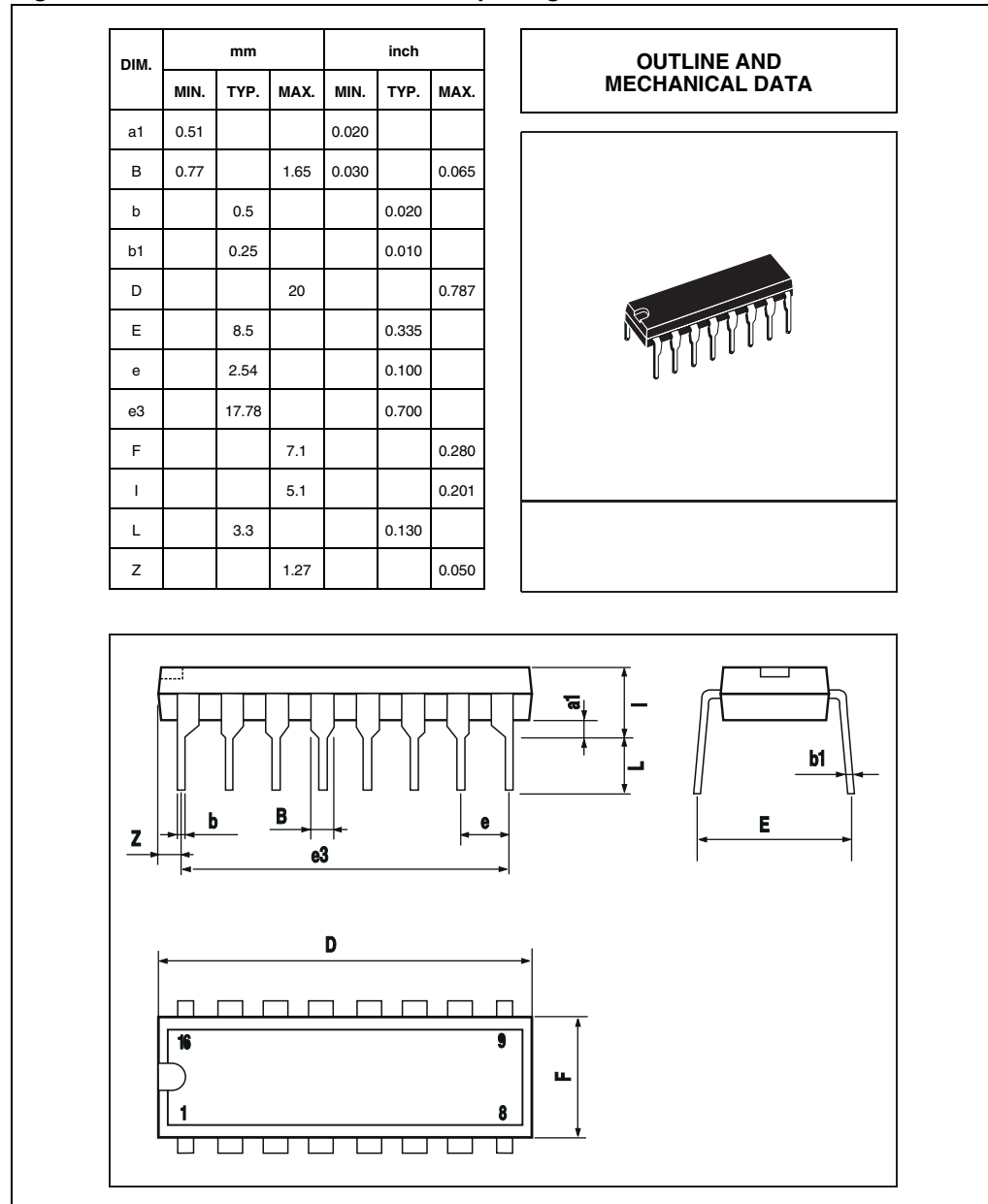
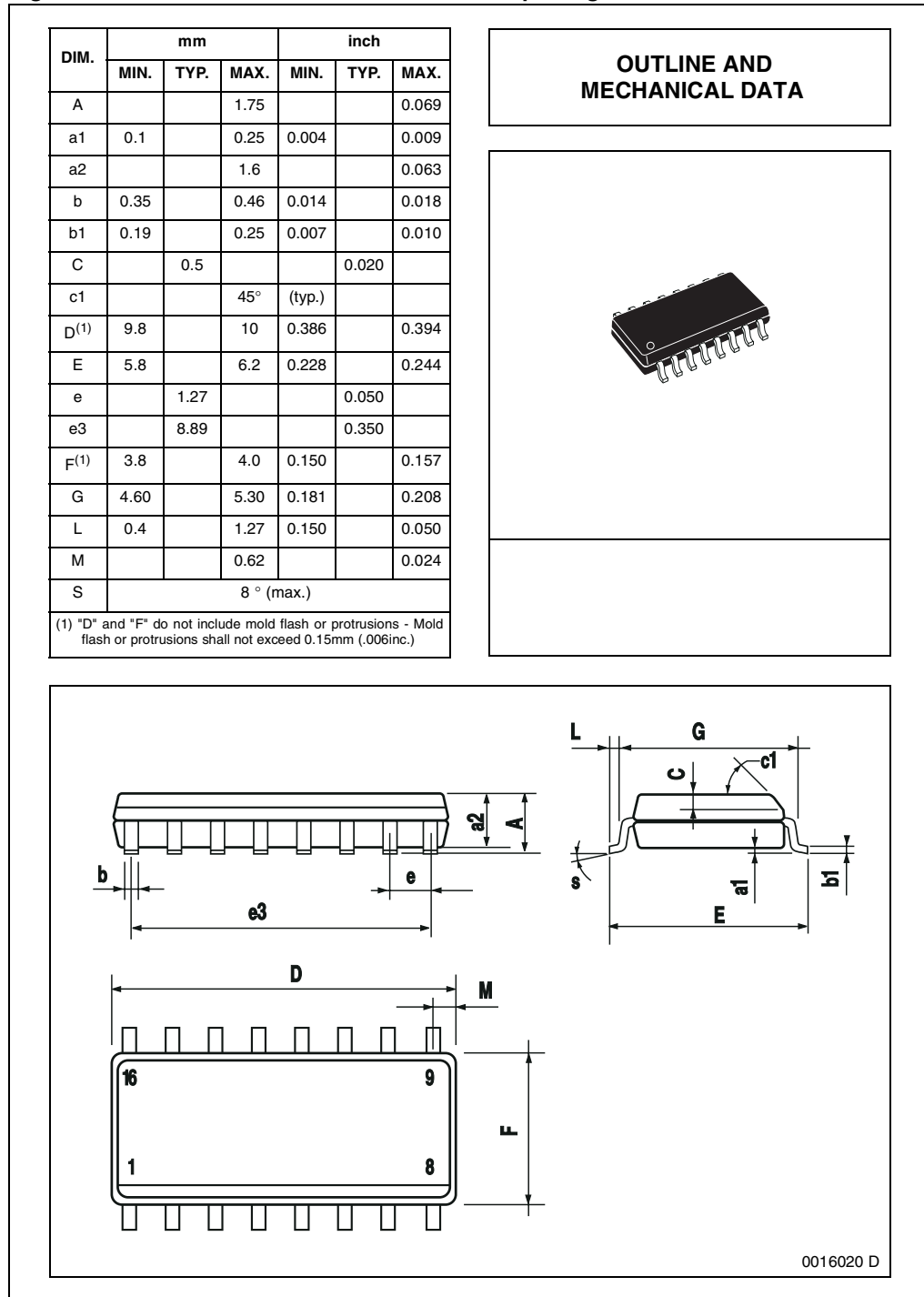


Figure 10. SO-16 narrow mechanical data and package dimensions



## 11 Revision history

**Table 11. Document revision history**

Date	Revision	Changes
29-Feb-2008	1	First release
09-Jul-2008	2	Updated: Cover page, <a href="#">Table 2 on page 4</a> , <a href="#">Table 3 on page 5</a> , <a href="#">Section 4 on page 6</a> , <a href="#">Section 5 on page 8</a> , <a href="#">Section 9.1 on page 17</a>
17-Sep-2008	3	Updated test condition values on <a href="#">Table 8</a> and <a href="#">Table 9</a>
17-Feb-2009	4	Updated <a href="#">Table 7 on page 8</a> , <a href="#">Table 8 on page 10</a> , <a href="#">Table 9 on page 11</a> Added <a href="#">Table 4 on page 9</a>
11-Aug-2010	5	Updated <a href="#">Table 1 on page 1</a> , <a href="#">Table 7 on page 8</a> , <a href="#">Table 9 on page 12</a> , <a href="#">Table 10 on page 12</a>

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