

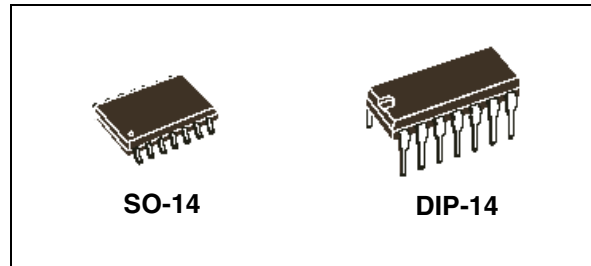
## High-voltage high and low side driver

### 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
- Adjustable dead-time
- Interlocking function
- Compact and simplified layout
- Bill of material reduction
- Flexible, easy and fast design

### Applications

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



### Description

The L6392 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.

**Table 1. Device summary**

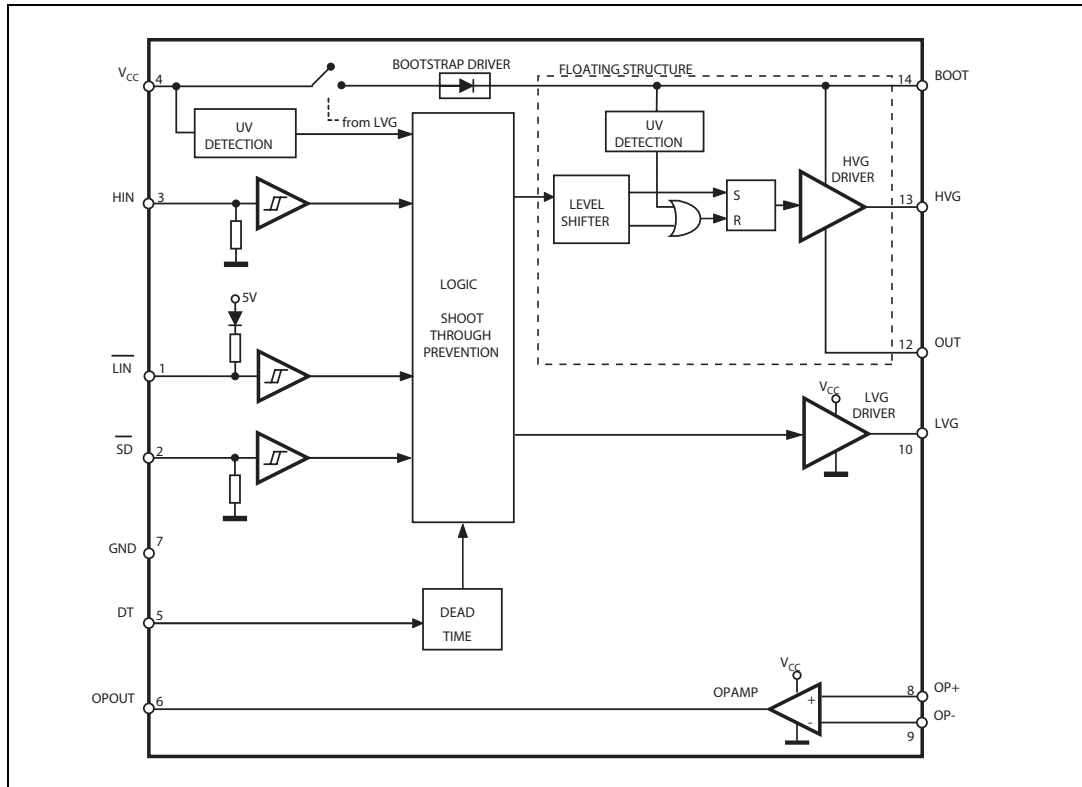
Order codes	Package	Packaging
L6392N	DIP-14	Tube
L6392D	SO-14	Tube
L6392DTR	SO-14	Tape and reel

# Contents

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# 1 Block diagram

Figure 1. Block diagram



## 2 Pin connection

Figure 2. Pins connection (top view)

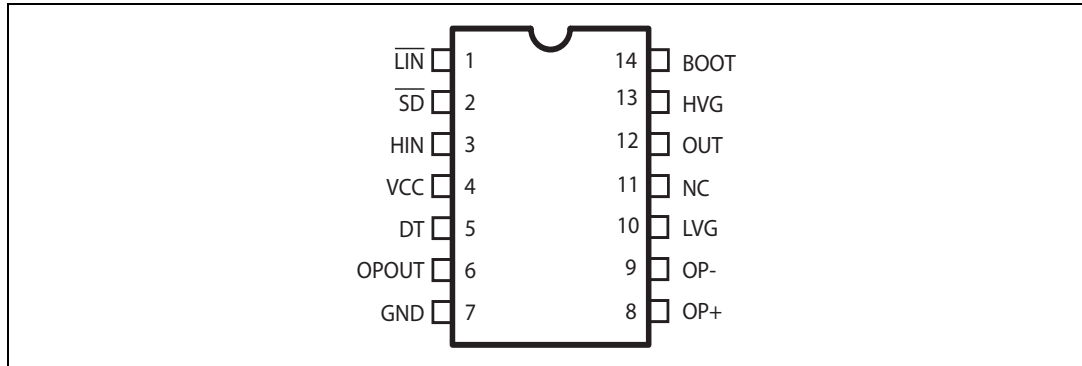


Table 2. Pin description

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

Inputs			Outputs	
$\overline{SD}$	$\overline{LIN}$	HIN	LVG	HVG
L	X	X	L	L
H	L	L	H	L
H	L	H	L	L
H	H	L	L	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
$V_i$	Logic input 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 12, 13 and 14 is guaranteed up to 1 kV (Human body model)

### 4.2 Thermal data

Table 5. Thermal data

Symbol	Parameter	SO-14	DIP-14	Unit
$R_{th(JA)}$	Thermal resistance junction to ambient	165	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
$V_{BO}^{(1)}$	14-12	Floating supply voltage		12.4	20	V
$V_{out}$	12	DC output voltage		-9 <sup>(2)</sup>	580	V
$f_{sw}$		Switching frequency	HVG, LVG load $C_L = 1nF$		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  $V_{boot} > 5 V$ .

## 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 10	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 13	High/low side driver turn-off propagation delay		50	125	200	ns
$t_{sd}$	2 vs 10, 13	Shut down to high/low side propagation delay		50	125	200	ns
MT		Delay matching, HS and LS turn-on/off			30	ns	
DT	5	Dead time setting range <sup>(1)</sup>	$R_{DT} = 0\ \Omega$ ; $C_L = 1\text{ nF}$ ; $C_{DT} = 100\text{ nF}$	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	
			$R_{DT} = 136\text{ k}\Omega$ ; $C_L = 1\text{ nF}$ ; $C_{DT} = 100\text{ nF}$	1.35	1.6	1.85	
			$R_{DT} = 260\text{ k}\Omega$ ; $C_L = 1\text{ nF}$ ; $C_{DT} = 100\text{ nF}$	2.6	3.0	3.4	
MDT		Matching dead time <sup>(2)</sup>	$R_{DT} = 0\ \Omega$ ; $C_L = 1\text{ nF}$ ; $C_{DT} = 100\text{ nF}$			80	ns
			$R_{DT} = 37\text{ k}\Omega$ ; $C_L = 1\text{ nF}$ ; $C_{DT} = 100\text{ nF}$			120	
			$R_{DT} = 136\text{ k}\Omega$ ; $C_L = 1\text{ nF}$ ; $C_{DT} = 100\text{ nF}$			250	
			$R_{DT} = 260\text{ k}\Omega$ ; $C_L = 1\text{ nF}$ ; $C_{DT} = 100\text{ nF}$			400	
$t_r$	10, 13	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 characteristics

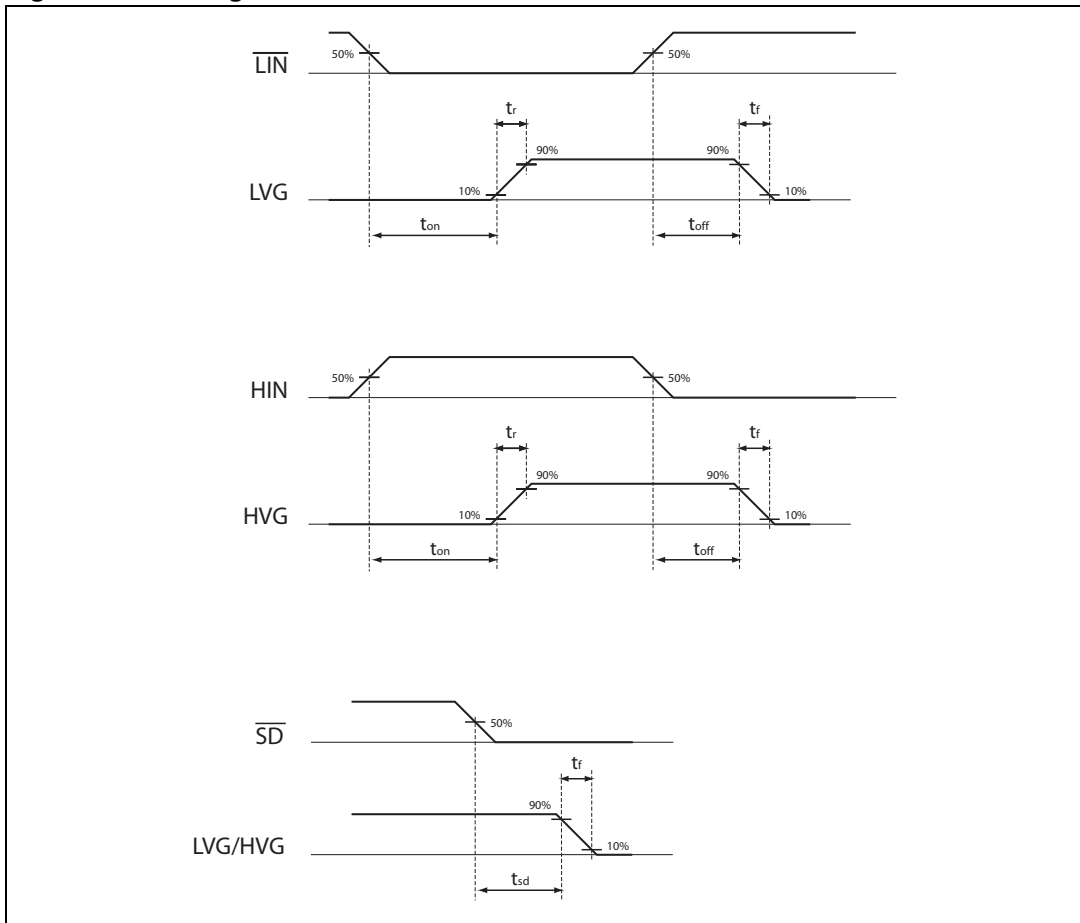
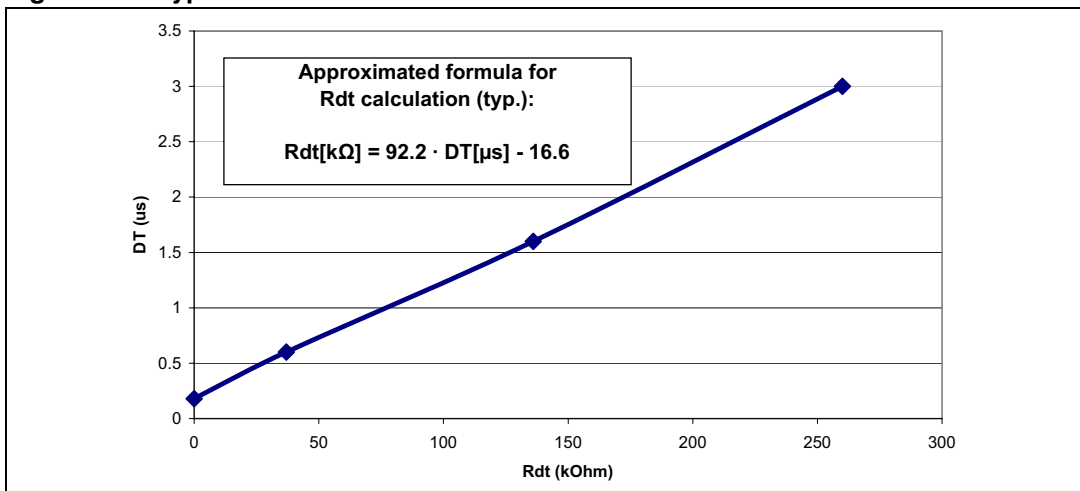


Figure 4. Typical dead time vs. DT resistor value



## 5.2 DC operation

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

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	$V_{CC} = 10\text{ V}$ $\overline{SD} = 5\text{ V}$ ; $\overline{LIN} = 5\text{ V}$ ; $HIN = GND$ ; $R_{DT} = 0\ \Omega$ ; $OP + = GND$ ; $OP - = 5\text{ V}$		120	150	$\mu\text{A}$
$I_{qcc}$		Quiescent current	$V_{CC} = 15\text{ V}$ $\overline{SD} = 5\text{ V}$ ; $\overline{LIN} = 5\text{ V}$ ; $HIN = GND$ ; $R_{DT} = 0\ \Omega$ ; $OP + = GND$ ; $OP - = 5\text{ V}$		680	1000	$\mu\text{A}$
<b>Bootstrapped supply voltage section <sup>(1)</sup></b>							
$V_{BO\_hys}$	14	$V_{BO}$ 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 $HIN = 5\text{ V}$ ; $R_{DT} = 0\ \Omega$ ; $OP + = GND$ ; $OP - = 5\text{ V}$		70	110	$\mu\text{A}$
$I_{QBO}$		$V_{BO}$ quiescent current	$V_{BO} = 15\text{ V}$ $\overline{SD} = 5\text{ V}$ ; $\overline{LIN}$ and $HIN = 5\text{ V}$ ; $R_{DT} = 0\ \Omega$ ; $OP + = GND$ ; $OP - = 5\text{ V}$		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		$\Omega$

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

Symbol	Pin	Parameter	Test condition	Min	Typ	Max	Unit
<b>Driving buffers section</b>							
$I_{so}$	10, 13	High/low side source short circuit current	$V_i = V_{ih} (t_p < 10\text{ ms})$	200	290		mA
$I_{si}$		High/low side sink short circuit current	$V_i = V_{il} (t_p < 10\text{ ms})$	250	430		mA
<b>Logic inputs</b>							
$V_{il}$	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	30	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.  $R_{DSon}$  is tested in the following way:

$$R_{DSon} = \frac{(V_{CC} - V_{CBOOT1}) - (V_{CC} - V_{CBOOT2})}{[I_1(V_{CC} - V_{CBOOT1}) - I_2(V_{CC} - V_{CBOOT2})]}$$

where  $I_1$  is pin 14 current when  $V_{CBOOT} = V_{CBOOT1}$ ,  $I_2$  when  $V_{CBOOT} = V_{CBOOT2}$

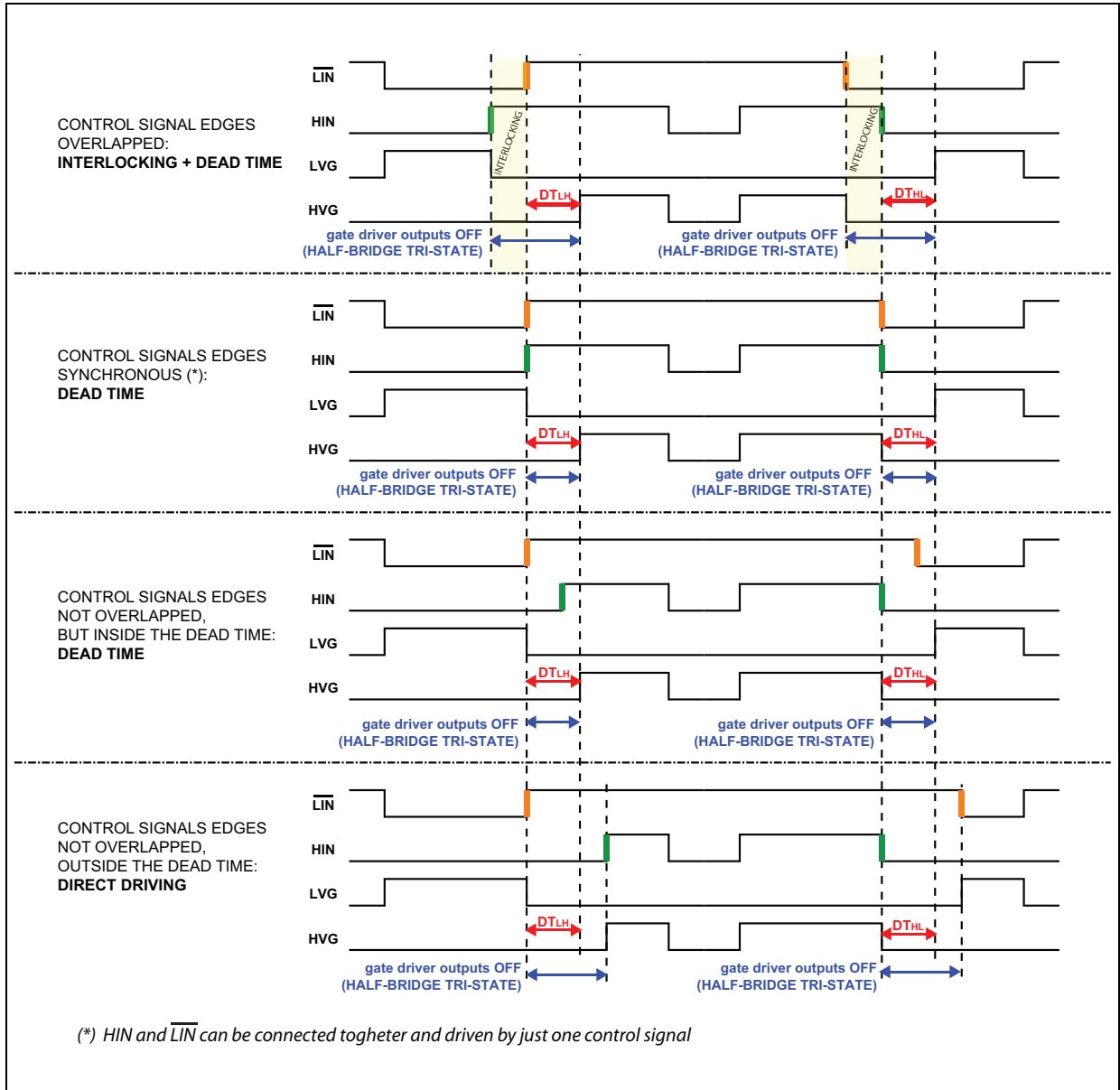
Table 9. OPAMP characteristics ( $V_{CC} = 15\text{ V}$ ,  $T_J = +25\text{ °C}$ )

Symbol	Pin	Parameter	Test condition	Min	Typ	Max	Unit
$V_{io}$	8, 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
$V_{OL}$	6	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, $V_{id} = +1\text{ V}$ ; $V_o = 0\text{ V}$	16	30		mA
	Sink $V_{id} = -1\text{ V}$ ; $V_o = V_{CC}$	50	80		mA		
SR		Slew rate	$V_i = 1\div 4$ ; $C_L = 100\text{ pF}$ ; 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
SRV		Power supply 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.

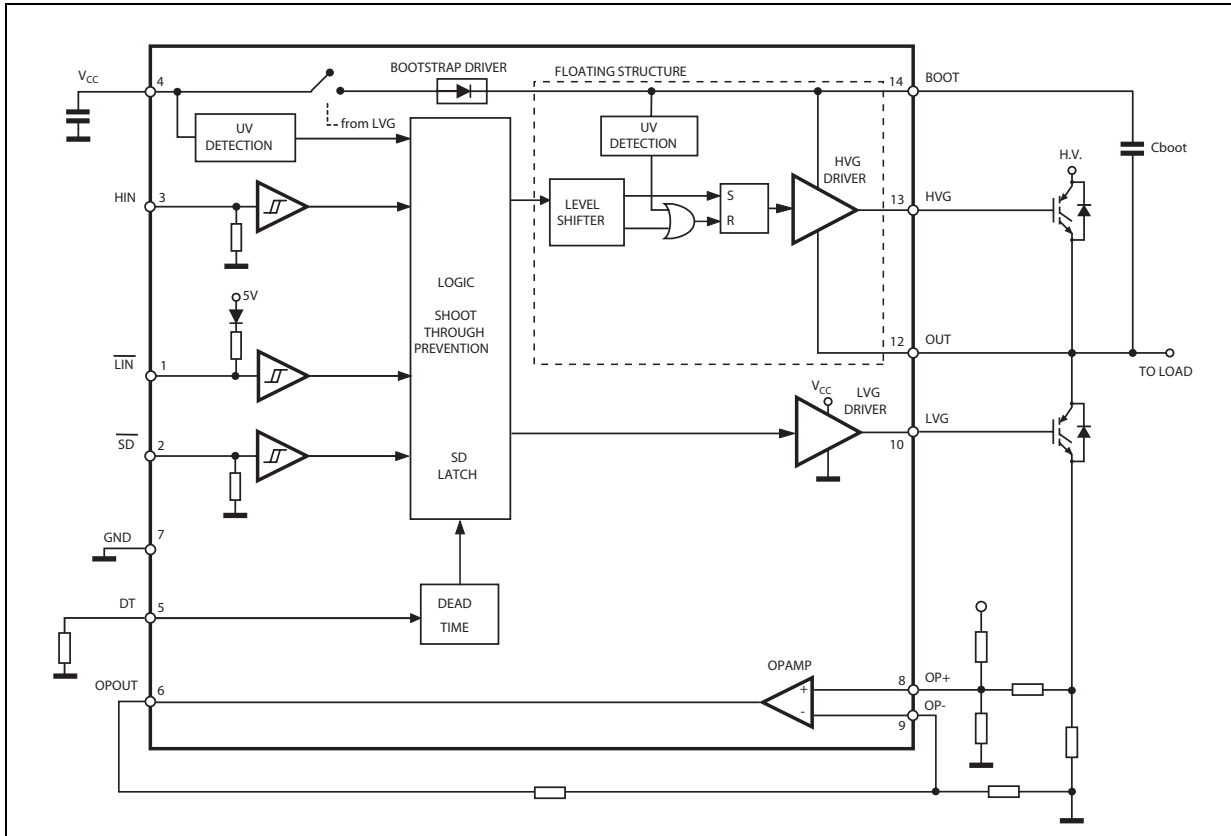
## 6 Waveforms definitions

Figure 5. Dead time - timing waveforms



# 7 Typical application diagram

Figure 6. Application diagram



## 8 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 7 a*). In the L6392 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 7 b*.

An internal charge pump (*Figure 7 b*) provides the DMOS driving voltage.

### 8.1 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:

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

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:

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

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 1 V.

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:

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

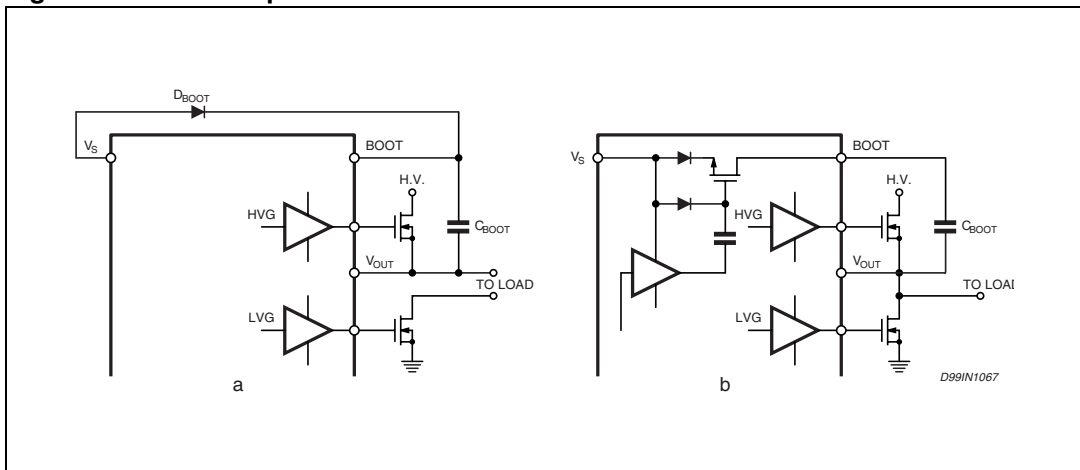
where Q<sub>gate</sub> is the gate charge of the external power MOS, R<sub>dson</sub> is the on resistance of the bootstrap DMOS, and T<sub>charge</sub> is the charging time of the bootstrap capacitor.

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

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

$V_{drop}$  has to be taken into account when the voltage drop on  $C_{BOOT}$  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 7. Bootstrap driver**





## 9 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 8. DIP-14 mechanical data and package dimensions**

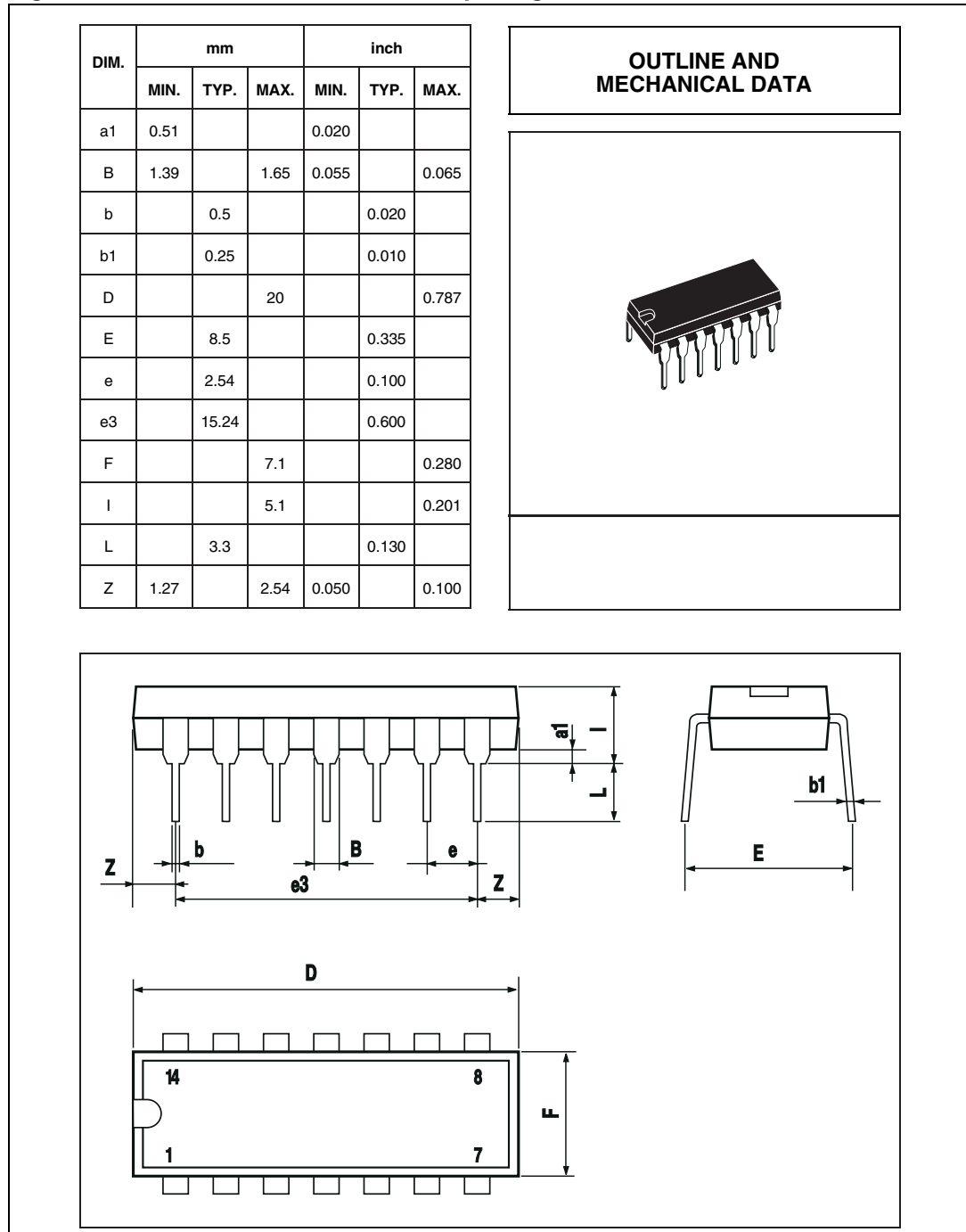
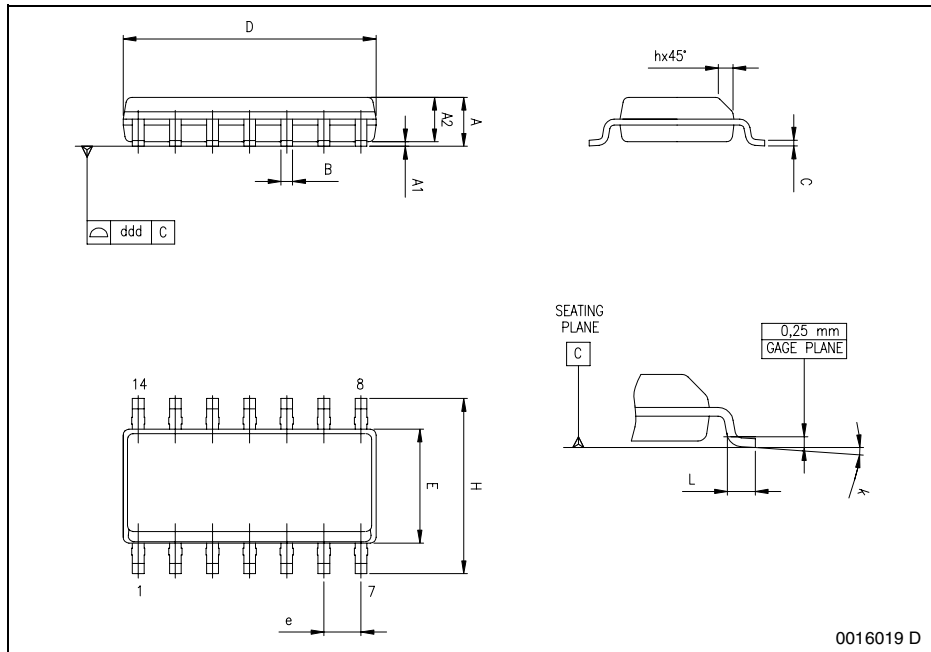
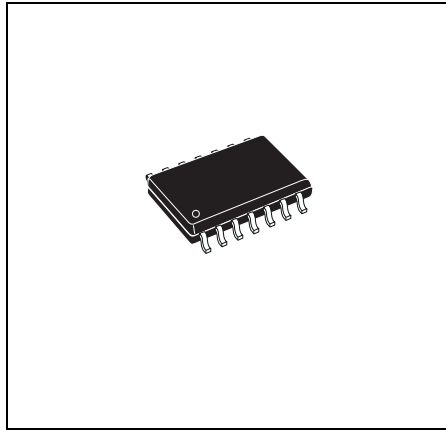


Figure 9. SO-14 mechanical data and package dimensions

DIM.	mm			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A	1.35		1.75	0.053		0.069
A1	0.10		0.30	0.004		0.012
A2	1.10		1.65	0.043		0.065
B	0.33		0.51	0.013		0.020
C	0.19		0.25	0.007		0.01
D (1)	8.55		8.75	0.337		0.344
E	3.80		4.0	0.150		0.157
e		1.27			0.050	
H	5.8		6.20	0.228		0.244
h	0.25		0.50	0.01		0.02
L	0.40		1.27	0.016		0.050
k	0° (min.), 8° (max.)					
ddd			0.10			0.004

(1) "D" dimension does not include mold flash, protusions or gate burrs. Mold flash, protusions or gate burrs shall not exceed 0.15mm per side.

**OUTLINE AND MECHANICAL DATA**



## 10 Revision history

**Table 10. Document revision history**

<b>Date</b>	<b>Revision</b>	<b>Changes</b>
29-Feb-2008	1	Initial release
18-Mar-2008	2	Cover page updated
17-Sep-2008	3	Updated <i>Table 4 on page 6</i> , <i>Table 4 on page 6</i> , <i>Table 9 on page 12</i>
17-Feb-2009	4	Updated <i>Table 7 on page 8</i> , <i>Table 8 on page 10</i> , <i>Table 9 on page 12</i> Added <i>Table 4 on page 9</i>
11-Aug-2010	5	Updated cover page, <i>Table 1 on page 1</i> , <i>Table 7 on page 8</i> , <i>Table 9 on page 12</i>

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