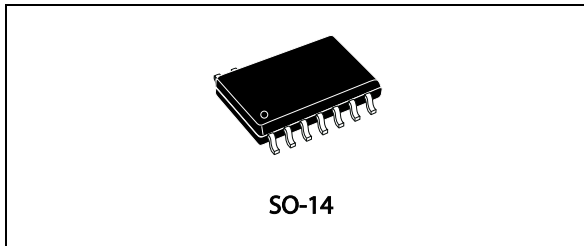


## High voltage high and low-side driver

Datasheet - production data



### 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 deadtime
- 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™ “offline” technology. It is a single chip half bridge gate driver for the 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.

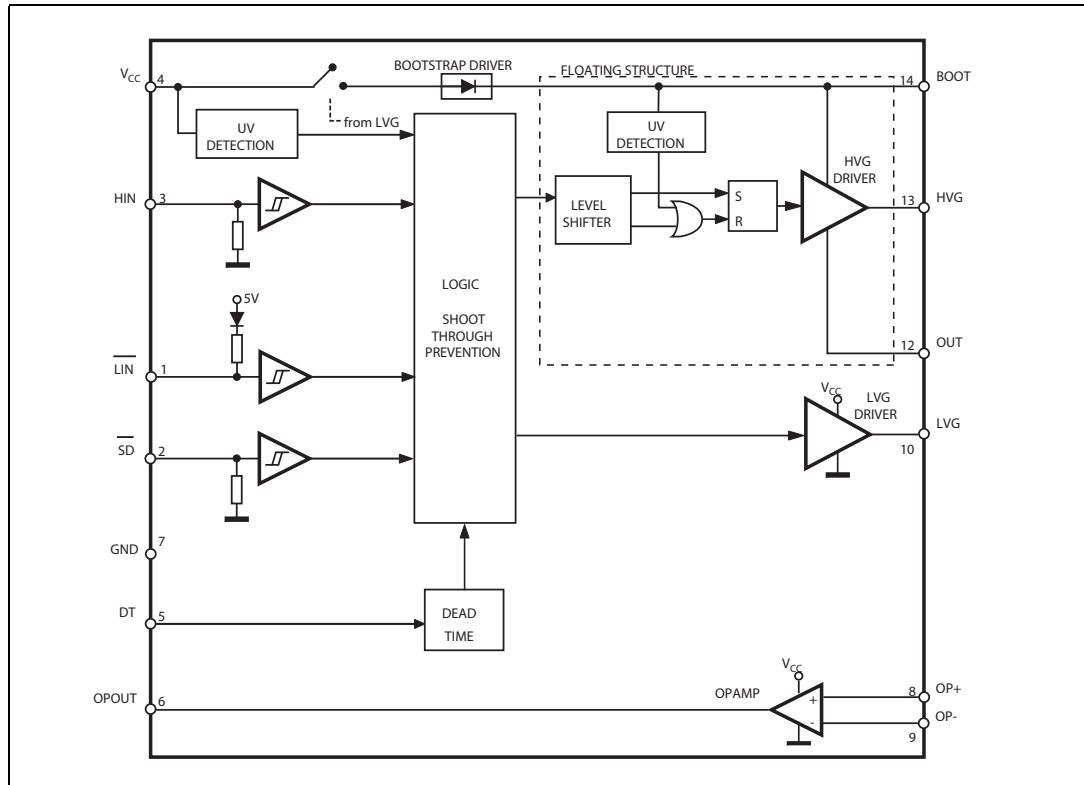
The IC embeds an operational amplifier suitable for advanced current sensing in applications such as field oriented motor control.

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# 1 Block diagram

Figure 1. Block diagram



## 2 Pin connection

Figure 2. Pin connections (top view)

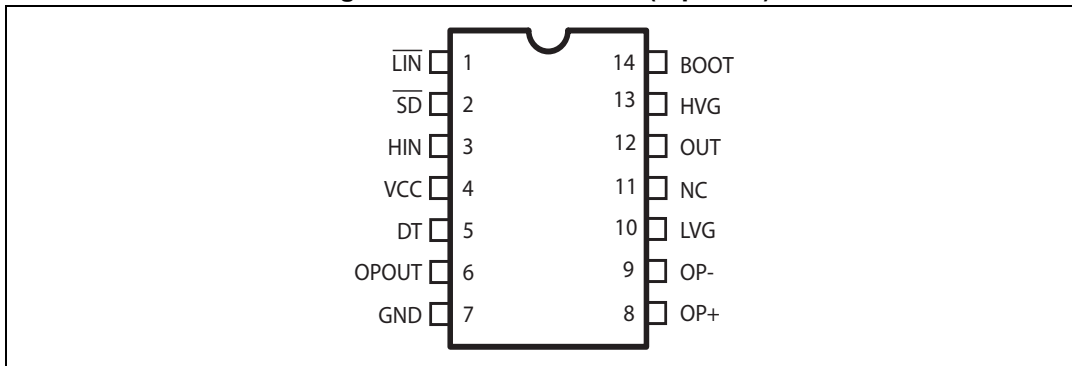


Table 1. Pin description

Pin no.	Pin name	Type	Function
1	$\overline{\text{LIN}}$	I	Low-side driver logic input (active low)
2	$\overline{\text{SD}}$ <sup>(1)</sup>	I	Shutdown logic input (active low)
3	HIN	I	High-side driver logic input (active high)
4	VCC	P	Lower section supply voltage
5	DT	I	Deadtime 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 (at  $I_{\text{sink}} = 10 \text{ mA}$ ), with  $V_{\text{CC}} > 3 \text{ V}$ . This allows to omit 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  $\overline{\text{SD}}$  condition.

### 3 Truth table

Table 2. Truth table

Inputs			Outputs	
$\overline{SD}$	$\overline{LIN}$	HIN	LVG	HVG
L	X <sup>(1)</sup>	X <sup>(1)</sup>	L	L
H	L	L	H	L
H	L	H	L	L
H	H	L	L	L
H	H	H	L	H

1. X: don't care.

## 4 Electrical data

### 4.1 Absolute maximum ratings

Table 3. 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
ESD	Human body model	2		kV

### 4.2 Thermal data

Table 4. Thermal data

Symbol	Parameter	SO-14	Unit
$R_{th(JA)}$	Thermal resistance junction to ambient	120	°C/W

### 4.3 Recommended operating conditions

Table 5. 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 $C_L = 1$ nF		800	kHz
$T_J$		Junction temperature		-40	125	°C

- $V_{BO} = V_{BOOT} - V_{OUT}$
- LVG off.  $V_{CC} = 12.5$  V.  
Logic is operational if  $V_{BOOT} > 5$  V.

## 5 Electrical characteristics

### 5.1 AC operation

Table 6. 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	Deadtime setting range <sup>(1)</sup>	$R_{DT} = 0\text{ }\Omega$ ; $C_L = 1\text{ nF}$	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 deadtime <sup>(2)</sup>	$R_{DT} = 0\text{ }\Omega$ ; $C_L = 1\text{ nF}$			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](#).

2.  $MDT = |DT_{LH} - DT_{HL}|$  | see [Figure 5 on page 12](#).



Figure 3. Timing characteristics

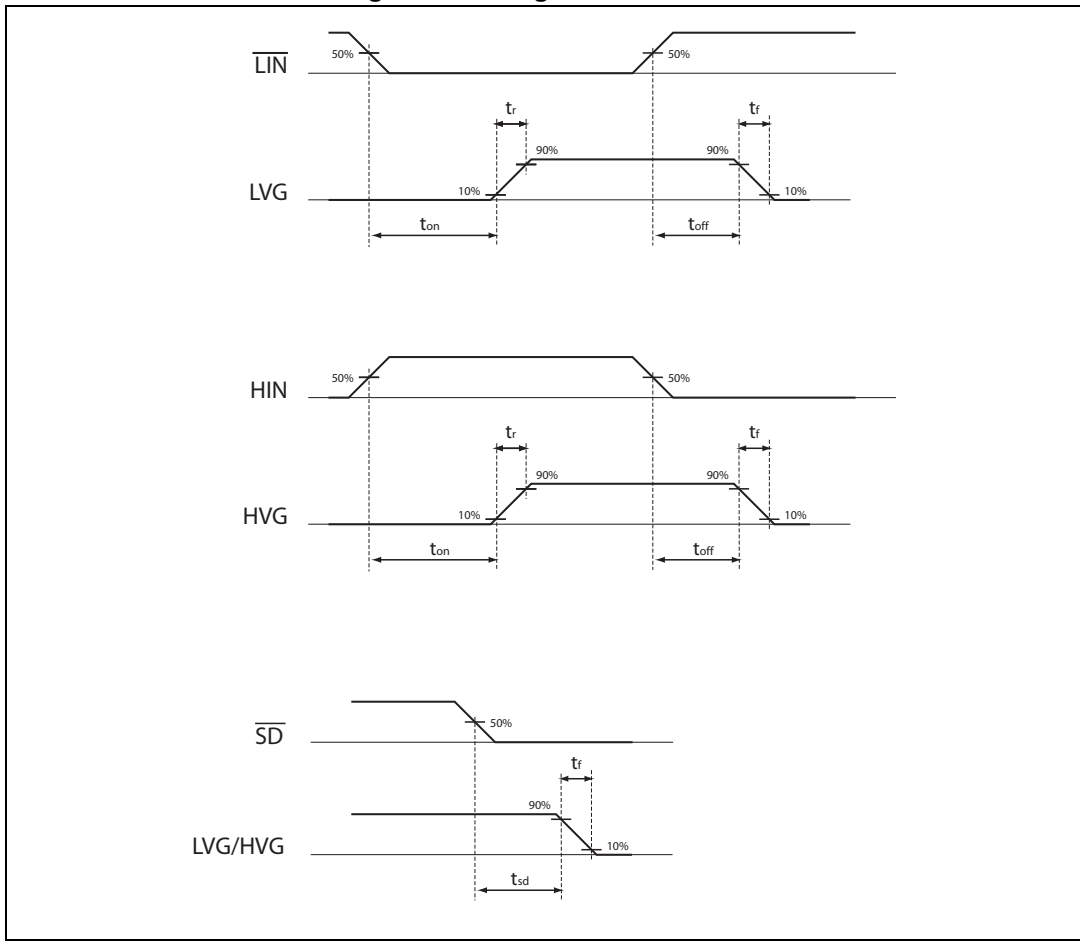
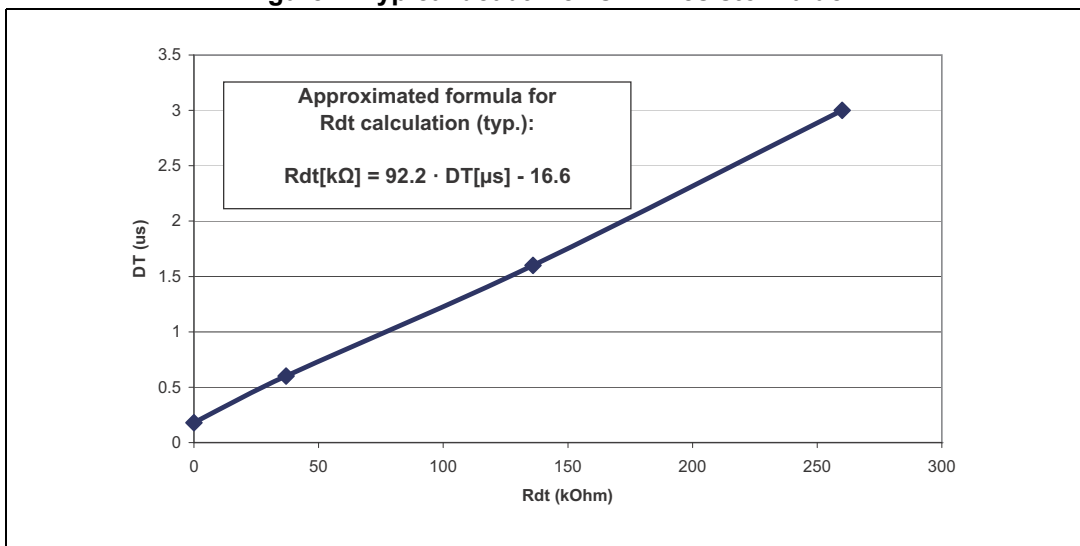


Figure 4. Typical deadtime vs. DT resistor value



## 5.2 DC operation

Table 7. 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; $R_{DT} = 0\text{ }\Omega$ ; OP + = GND; OP - = 5 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; $R_{DT} = 0\text{ }\Omega$ ; OP + = GND; OP - = 5 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 V; $R_{DT} = 0\text{ }\Omega$ ; OP + = GND; OP - = 5 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 V; $R_{DT} = 0\text{ }\Omega$ ; OP + = GND; OP - = 5 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>								
$I_{so}$	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 level logic threshold voltage		0.8		1.1	V	
$V_{ih}$		High level logic threshold voltage		1.9		2.25	V	

Table 7. 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
$V_{il\_S}$	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:

$$R_{DSon} = [(V_{CC} - V_{BOOT1}) - (V_{CC} - V_{BOOT2})] / [I_1(V_{CC}, V_{BOOT1}) - I_2(V_{CC}, V_{BOOT2})]$$

where  $I_1$  is pin 14 current when  $V_{BOOT} = V_{BOOT1}$ ,  $I_2$  when  $V_{BOOT} = V_{BOOT2}$ .

Table 8. Op amp characteristics<sup>(1)</sup> ( $V_{CC} = 15\text{ V}$ ,  $T_J = +25\text{ }^\circ\text{C}$ )

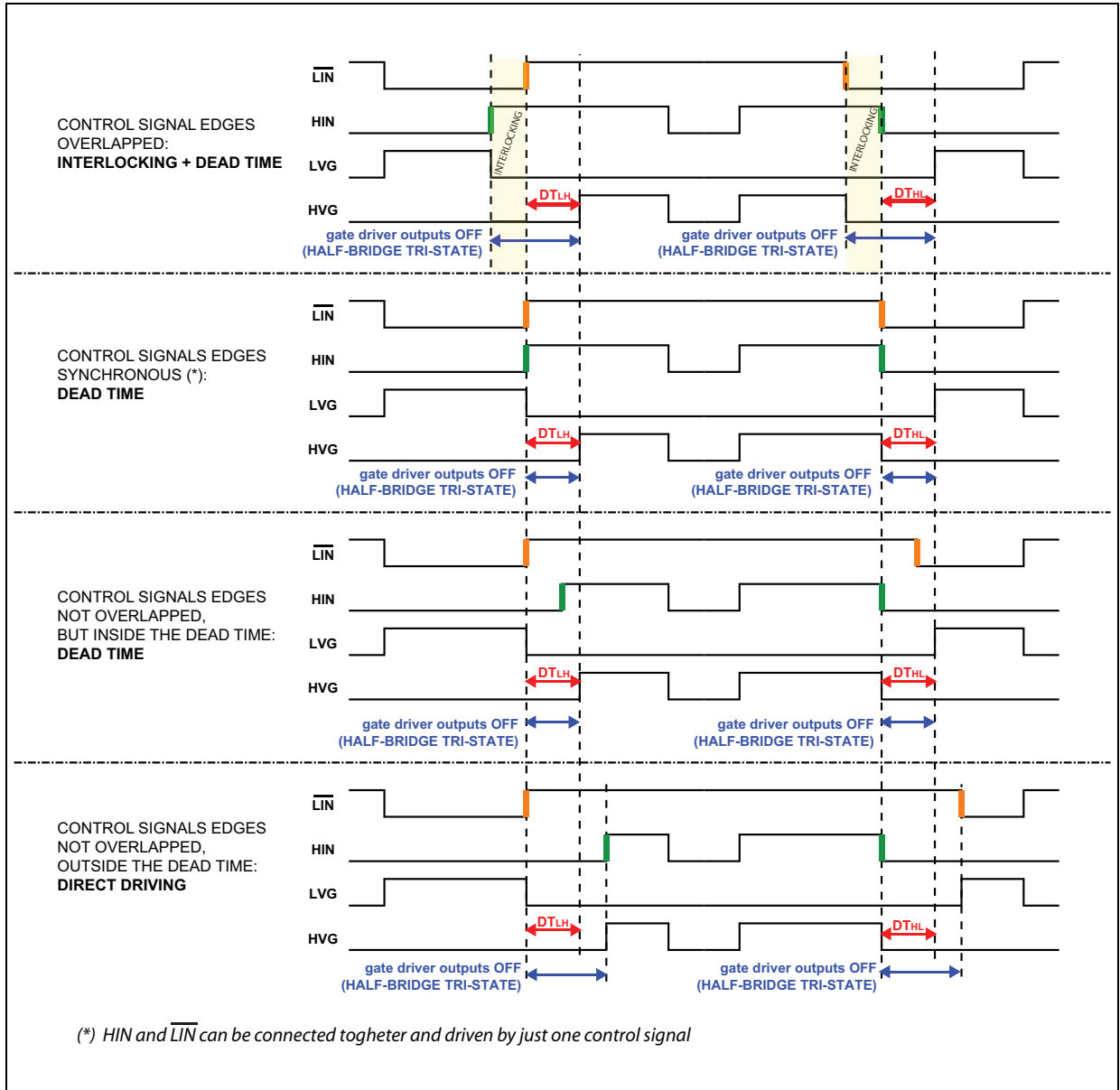
Symbol	Pin	Parameter	Test condition	Min.	Typ.	Max.	Unit
$V_{io}$	6, 9	Input offset voltage	$V_{ic} = 0\text{ V}$ , $V_o = 7.5\text{ V}$			6	mV
$I_{io}$		Input offset current	$V_{ic} = 0\text{ V}$ , $V_o = 7.5\text{ V}$		4	40	nA
$I_{ib}$		Input bias current <sup>(2)</sup>			100	200	nA
$V_{icm}$		Input common mode voltage range		0		$V_{CC}-4$	V
$V_{OPOUT}$	7	Output voltage swing	OPOUT = OP-; no load	0.07		$V_{CC}-4$	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/ $\mu\text{s}$
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 operational amplifier is disabled when  $V_{CC}$  is in UVLO condition.

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

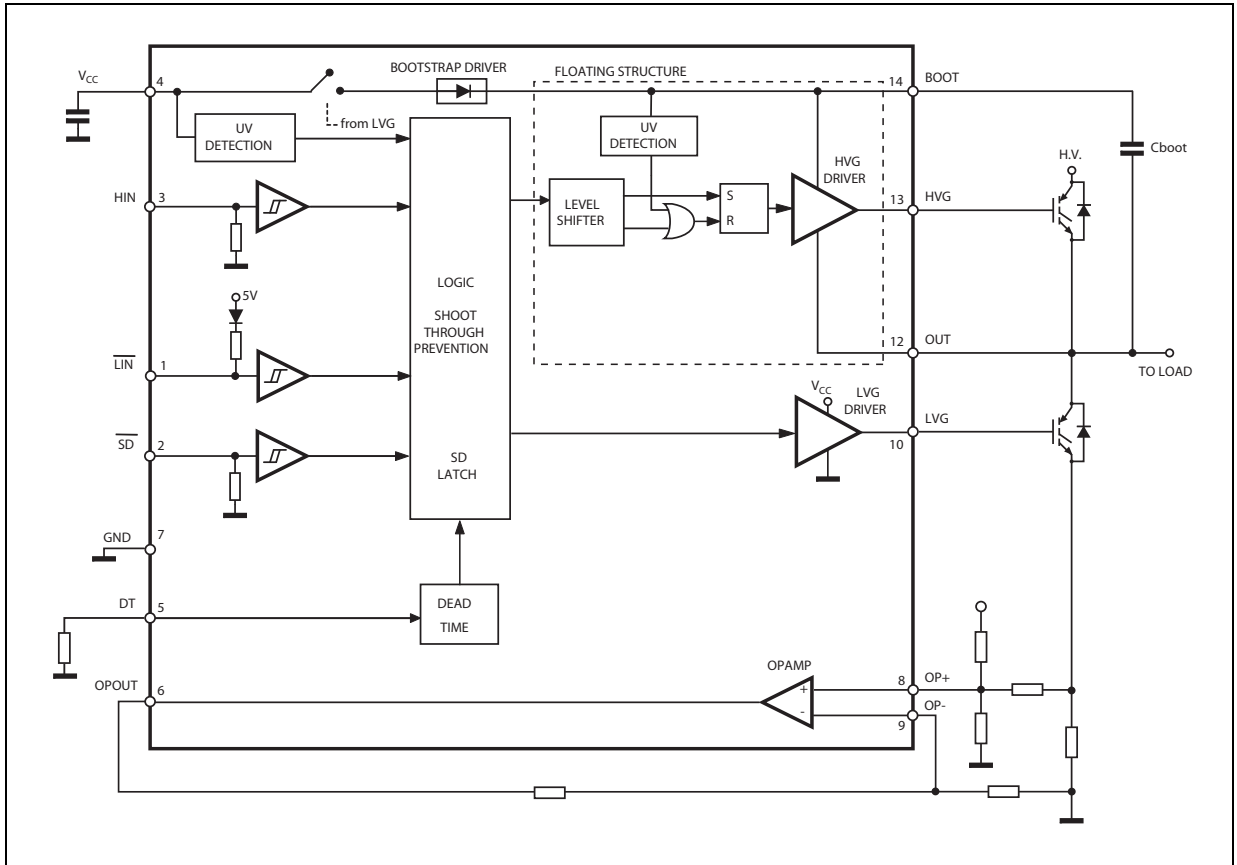
# 6 Waveforms definitions

Figure 5. Deadtime - 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 device 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 a diode in series, as shown in *Figure 7 b*.

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

### $C_{BOOT}$ selection and charging

To choose the proper  $C_{BOOT}$  value the external MOS can be seen as an equivalent capacitor. This capacitor  $C_{EXT}$  is related to the MOS total gate charge:

**Equation 1**

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

The ratio between the capacitors  $C_{EXT}$  and  $C_{BOOT}$  is proportional to the cyclical voltage loss. It has to be:

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

E.g.: if  $Q_{gate}$  is 30 nC and  $V_{gate}$  is 10 V,  $C_{EXT}$  is 3 nF. With  $C_{BOOT} = 100$  nF the drop would be 300 mV.

If HVG has to be supplied for a long time, the  $C_{BOOT}$  selection has to take into account also the leakage and quiescent losses.

E.g.: HVG steady state consumption is lower than 200  $\mu$ A, so if HVG  $T_{ON}$  is 5 ms,  $C_{BOOT}$  has to supply 1  $\mu$ C to  $C_{EXT}$ . This charge on a 1  $\mu$ F 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  $V_{OUT}$  is close to GND (or lower) and in the meanwhile the LVG is on. The charging time ( $T_{charge}$ ) of the  $C_{BOOT}$  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  $R_{DSON}$  (typical value: 120  $\Omega$ ). 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 2**

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

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

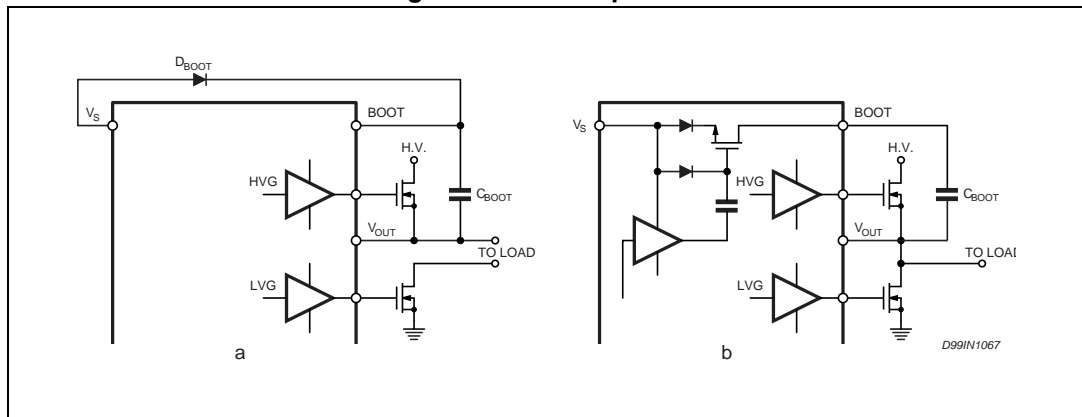
For example: using a power MOS with a total gate charge of 30 nC the drop on the bootstrap DMOS is about 1 V, if the  $T_{\text{charge}}$  is 5  $\mu\text{s}$ . In fact:

**Equation 3**

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

$V_{\text{drop}}$  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 7. Bootstrap driver**



## 9 Package information

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.

### SO-14 package information

Figure 8. SO-14 package outline

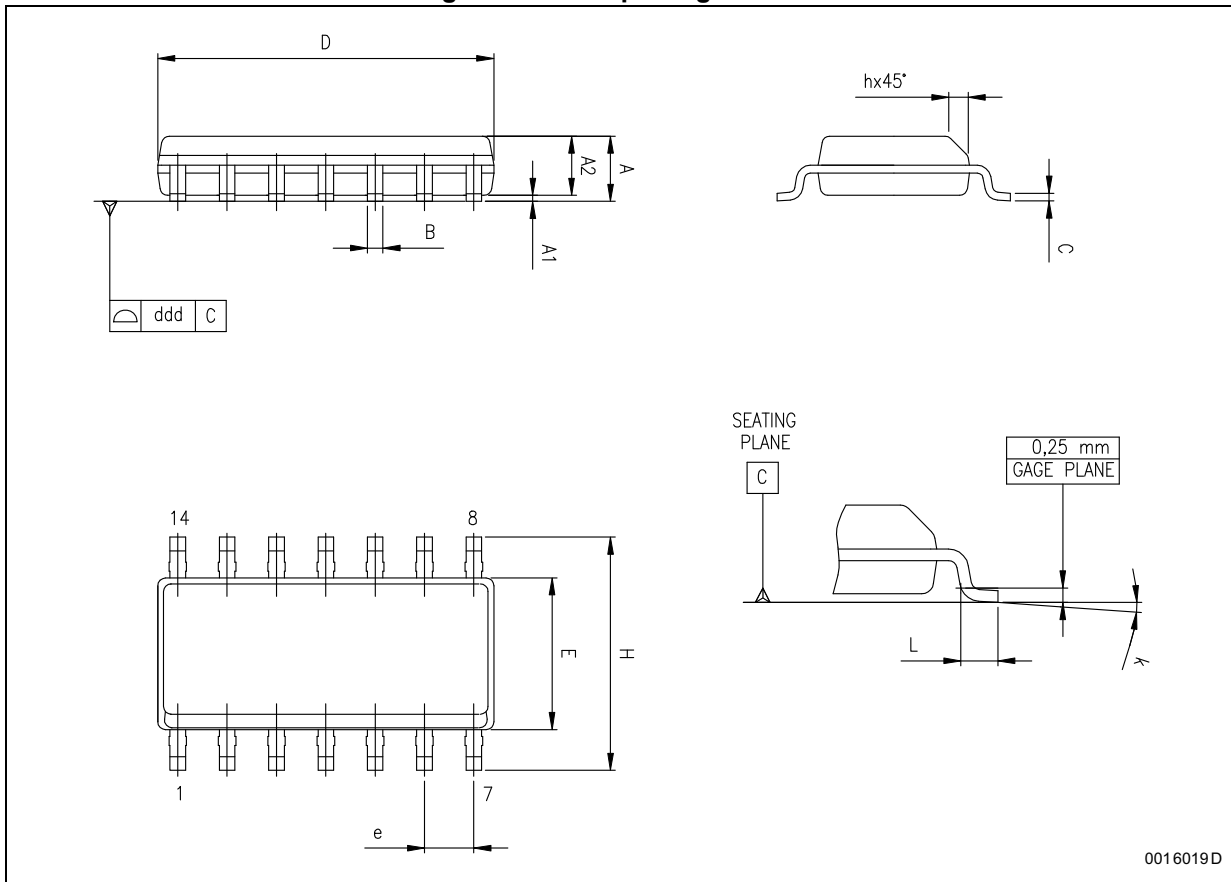


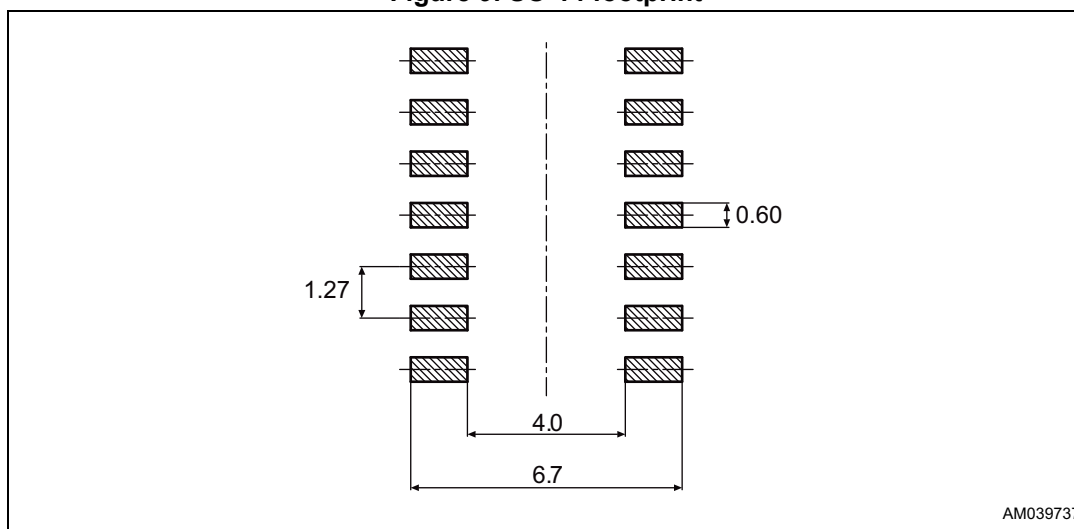


Table 9. SO-14 package mechanical data

Symbol	Dimensions					
	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 <sup>(1)</sup>	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, protrusions or gate burrs. Mold flash, protrusions or gate burrs shall not exceed 0.15 mm per side.

Figure 9. SO-14 footprint



## 10 Order codes

Table 10. Order codes

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

# 11 Revision history

**Table 11. Document revision history**

Date	Revision	Changes
29-Feb-2008	1	Initial release
18-Mar-2008	2	Cover page updated
17-Sep-2008	3	Updated <a href="#">Table 3 on page 6</a> , <a href="#">Table 3 on page 6</a> ,
17-Feb-2009	4	Updated <a href="#">Table 6 on page 8</a> , <a href="#">Table 7 on page 10</a> , <a href="#">Table 8 on page 11</a> Added <a href="#">Table 4 on page 9</a>
11-Aug-2010	5	Updated cover page, <a href="#">Table 1 on page 1</a> , <a href="#">Table 6 on page 8</a> , <a href="#">Table 8 on page 11</a> .
11-Sep-2015	6	Removed DIP-14 package from the entire document. Updated <a href="#">Table 3 on page 6</a> (added ESD parameter and value, removed note below <a href="#">Table 3</a> ). Updated <a href="#">Table 4 on page 6</a> (updated $R_{th(JA)}$ value). Updated <a href="#">Table 6 on page 8</a> (updated DT and MDT test conditions). Updated <a href="#">Table 7 on page 10</a> (updated $V_{il}$ and $V_{ih}$ parameter and values, updated note <a href="#">1</a> . and <a href="#">2</a> . below <a href="#">Table 7</a> - minor modifications, replaced $V_{CBOOTx}$ by $V_{BOOTx}$ ). Updated <a href="#">Table 8 on page 11</a> . Named and numbered <a href="#">Equation 1 on page 14</a> , <a href="#">Equation 2 on page 14</a> and <a href="#">Equation 3 on page 15</a> . Updated <a href="#">Section 9 on page 16</a> (added <a href="#">Figure 9 on page 17</a> , minor modifications). Updated <a href="#">Table 10 on page 18</a> (moved from page 1 to page 18, added and updated titles). Minor modifications throughout document.

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