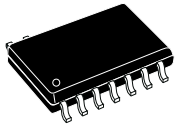
L6392

High voltage high and low-side driver

Datasheet - production data



SO-14

Features

- High voltage rail up to 600 V
- dV/dt immunity ± 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.

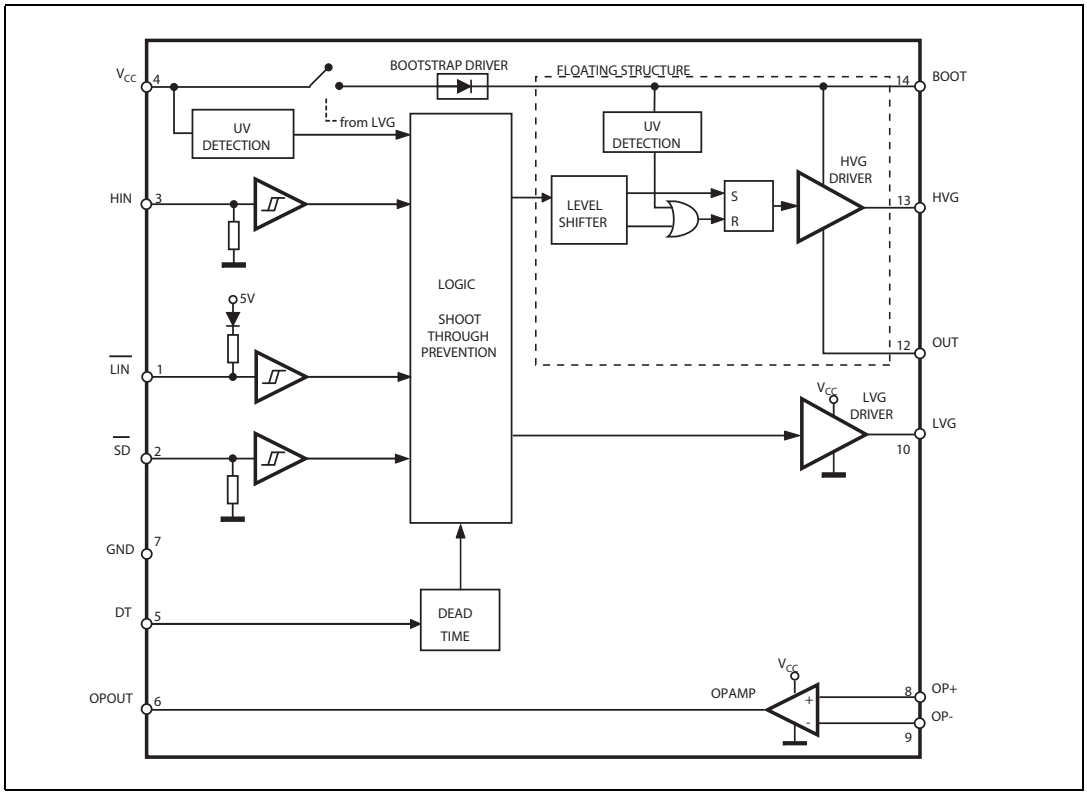
The high-side (floating) section is designed to stand a voltage rail up to 600 V. The logic inputs are CMOS/TTL compatible down to 3.3 V for easy interfacing microcontroller/DSP.

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

Contents

1 Block diagram

Figure 1. Block diagram



2 Pin connection

Figure 2. Pin connections (top view)

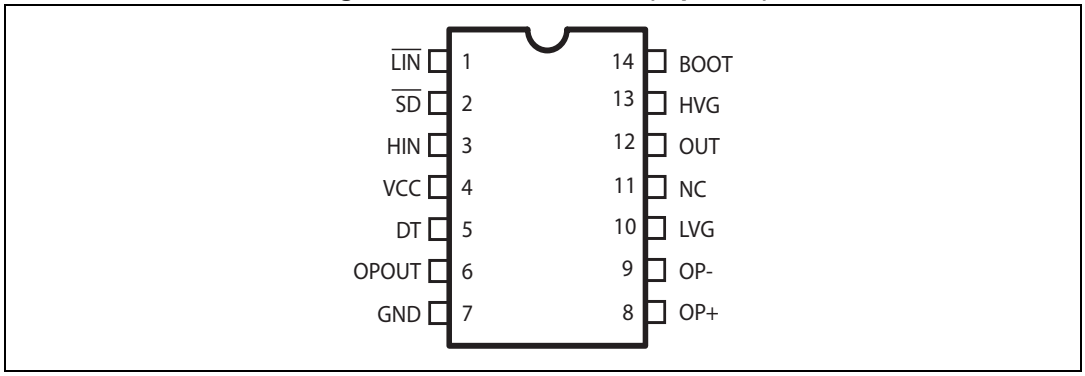


Table 1. Pin description

Pin no.	Pin name	Type	Function
1	$\overline{\text{LIN}}$	I	Low-side driver logic input (active low)
2	$\overline{\text{SD}}$ (1)	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 (1)	O	Low-side driver output
11	NC		Not connected
12	OUT	P	High-side (floating) common voltage
13	HVG (1)	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_{sink} = 10 mA), with V_{CC} > 3 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(1)	X(1)	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 °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(2)	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.

5 Electrical characteristics

5.1 AC operation

Table 6. AC operation electrical characteristics (V_{CC} = 15 V; T_J = +25 °C)

Symbol	Pin	Parameter	Test condition	Min.	Typ.	Max.	Unit
t_{on}	1 vs.10 3 vs. 13	High/low-side driver turn-on propagation delay	V_{OUT} = 0 V V_{BOOT} = V_{cc} C_L = 1 nF V_i = 0 to 3.3 V See *Figure 3*	50	125	200	ns
t_{off}		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(1)	R_{DT} = 0; C_L = 1 nF	0.1	0.18	0.25	µs
			R_{DT} = 37 kΩ;C_L = 1 nF; C_{DT}= 100 nF	0.48	0.6	0.72	
			R_{DT} = 136 kΩ;C_L =1 nF; C_{DT} = 100 nF	1.35	1.6	1.85	
			R_{DT} = 260 kΩ;C_L = 1 nF; C_{DT} = 100 nF	2.6	3.0	3.4	
MDT		Matching deadtime(2)	R_{DT} = 0 Ω; C_L = 1 nF			80	ns
			R_{DT} = 37 kΩ;C_L= 1 nF; C_{DT} = 100 nF			120	
			R_{DT} = 136 kΩ;C_L = 1 nF; C_{DT} = 100 nF			250	
			R_{DT} = 260 kΩ;C_L = 1 nF; C_{DT} = 100 nF			400	
t_r	10, 13	Rise time	C_L = 1 nF		75	120	ns
t_f		Fall time	C_L = 1 nF		35	70	ns

1. See *Figure 4*.
2. MDT = | DT_{LH} - DT_{HL} | see *Figure 5 on page 12*.

Figure 3. Timing characteristics

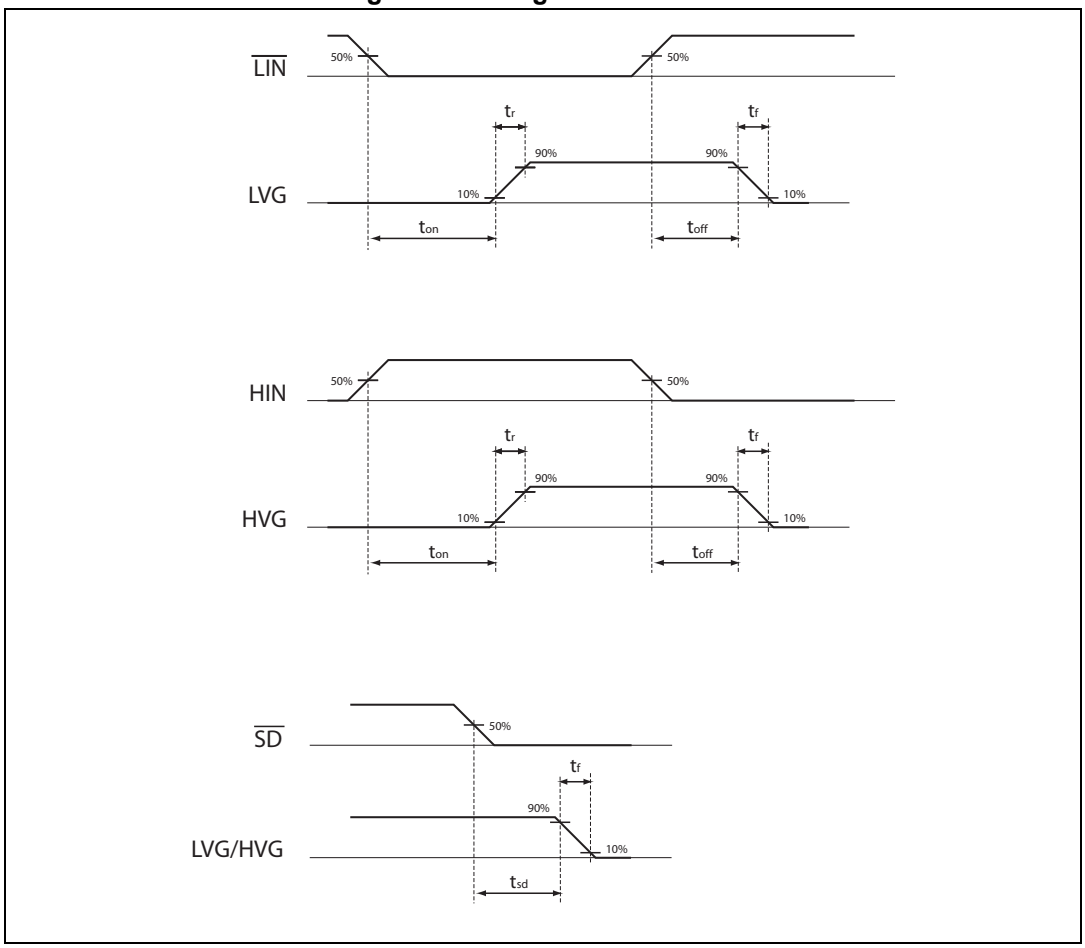
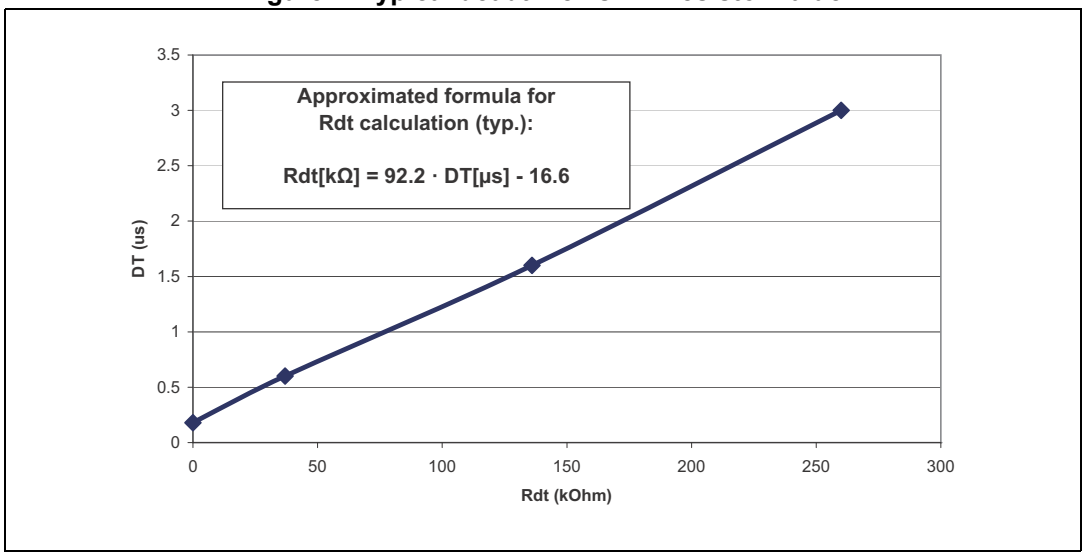


Figure 4. Typical deadtime vs. DT resistor value



5.2 DC operation

Table 7. DC operation electrical characteristics (V_{CC} = 15 V; T_J = +25 °C)

Symbol	Pin	Parameter	Test condition	Min.	Typ.	Max.	Unit
Low supply voltage section							
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 V; $\overline{SD}$ = 5 V; $\overline{LIN}$ = 5 V; HIN = GND; R_{DT} = 0 Ω; OP + = GND; OP - = 5 V		120	150	µA
I_{qcc}		Quiescent current	V_{CC} = 15 V; $\overline{SD}$ = 5 V; $\overline{LIN}$ = 5 V; HIN = GND; R_{DT} = 0 Ω; OP + = GND; OP - = 5 V		680	1000	µA
Bootstrapped supply voltage section(1)							
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 V; $\overline{SD}$ = 5 V; $\overline{LIN}$ and HIN = 5 V; R_{DT} = 0 Ω; OP + = GND; OP - = 5 V		70	110	µA
I_{QBO}		V_{BO} quiescent current	V_{BO} = 15 V; $\overline{SD}$ = 5 V; $\overline{LIN}$ and HIN = 5 V; R_{DT} = 0 Ω; OP + = GND; OP - = 5 V		150	210	µA
I_{LK}		High voltage leakage current	V_{hvg} = V_{OUT} = V_{BOOT} = 600 V			10	µA
$R_{DS(on)}$		Bootstrap driver on-resistance(2)	LVG ON		120		Ω
Driving buffers section							
I_{so}	10, 13	High/low-side source short-circuit current	V_i = V_{ih} (t_p < 10 ms)	200	290		mA
I_{si}		High/low side sink short-circuit current	V_i = V_{il} (t_p < 10 ms)	250	430		mA
Logic inputs							
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 V; T_J = +25 °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	µA
I_{HINl}		HIN logic “0” input bias current	HIN = 0 V			1	µA
I_{LINl}	1	$\overline{LIN}$ logic “0” input bias current	$\overline{LIN}$ = 0 V	3	6	20	µA
I_{LINh}		$\overline{LIN}$ logic “1” input bias current	$\overline{LIN}$ = 15 V			1	µA
I_{SDh}	2	$\overline{SD}$ logic “1” input bias current	$\overline{SD}$ = 15 V	10	30	100	µA
I_{SDl}		$\overline{SD}$ logic “0” input bias current	$\overline{SD}$ = 0 V			1	µA

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 $V_{BOOT} = V_{BOOT2}$.

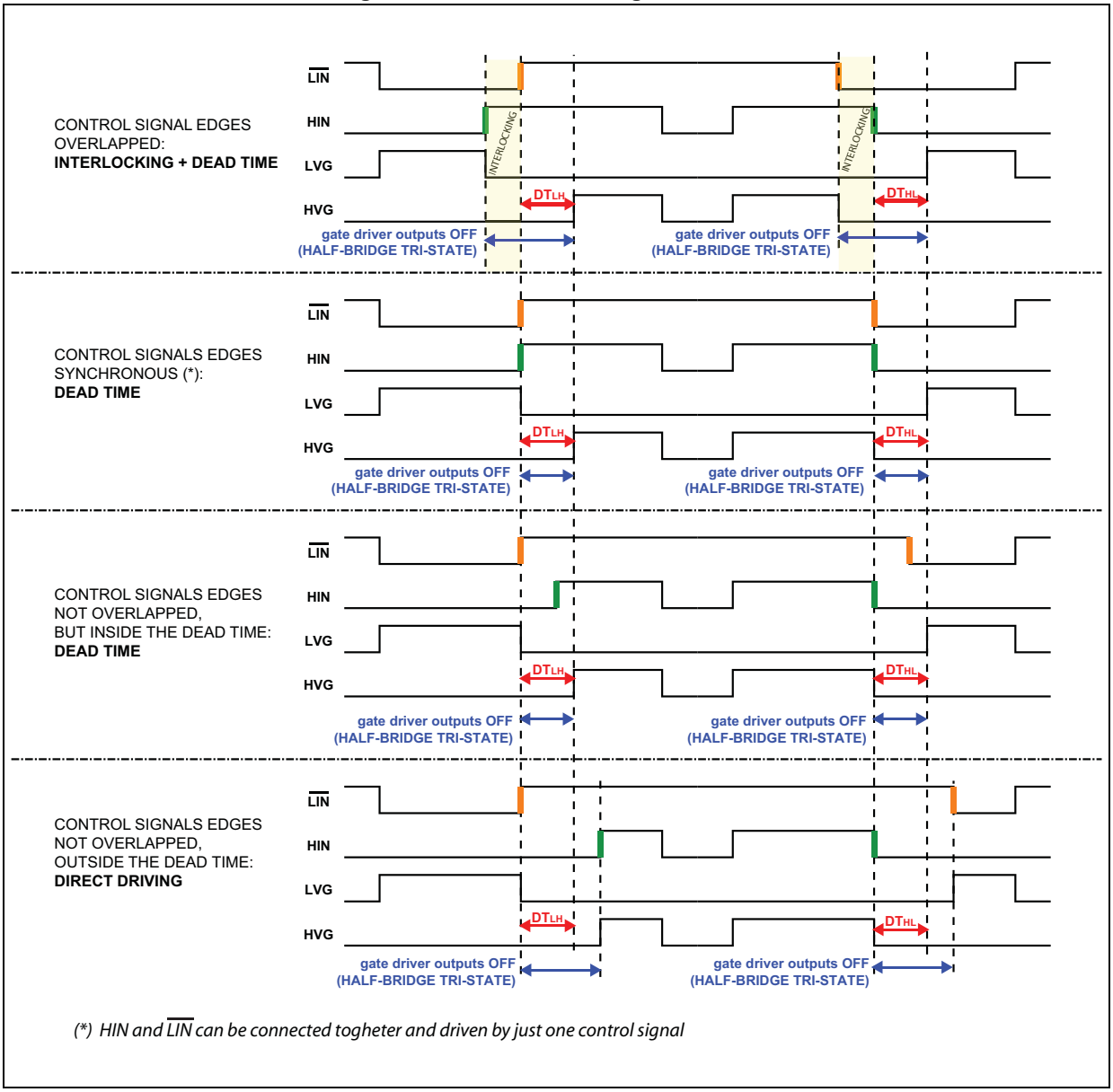
Table 8. Op amp characteristics(1) (V_{CC} = 15 V, T_J = +25 °C)

Symbol	Pin	Parameter	Test condition	Min.	Typ.	Max.	Unit
V_{io}	6, 9	Input offset voltage	V_{ic} = 0 V, V_o = 7.5 V			6	mV
I_{io}		Input offset current	V_{ic} = 0 V, V_o = 7.5 V		4	40	nA
I_{ib}		Input bias current(2)			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 V	16	30		mA
			Sink,V_{id} = -1; V_o = V_{CC}	50	80		mA
SR		Slew rate	V_i = 1 ÷ 4 V; C_L = 100 pF; unity gain	2.5	3.8		V/µs
GBWP		Gain bandwidth product	V_o = 7.5 V	8	12		MHz
A_{vd}		Large signal voltage gain	R_L = 2 kΩ	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

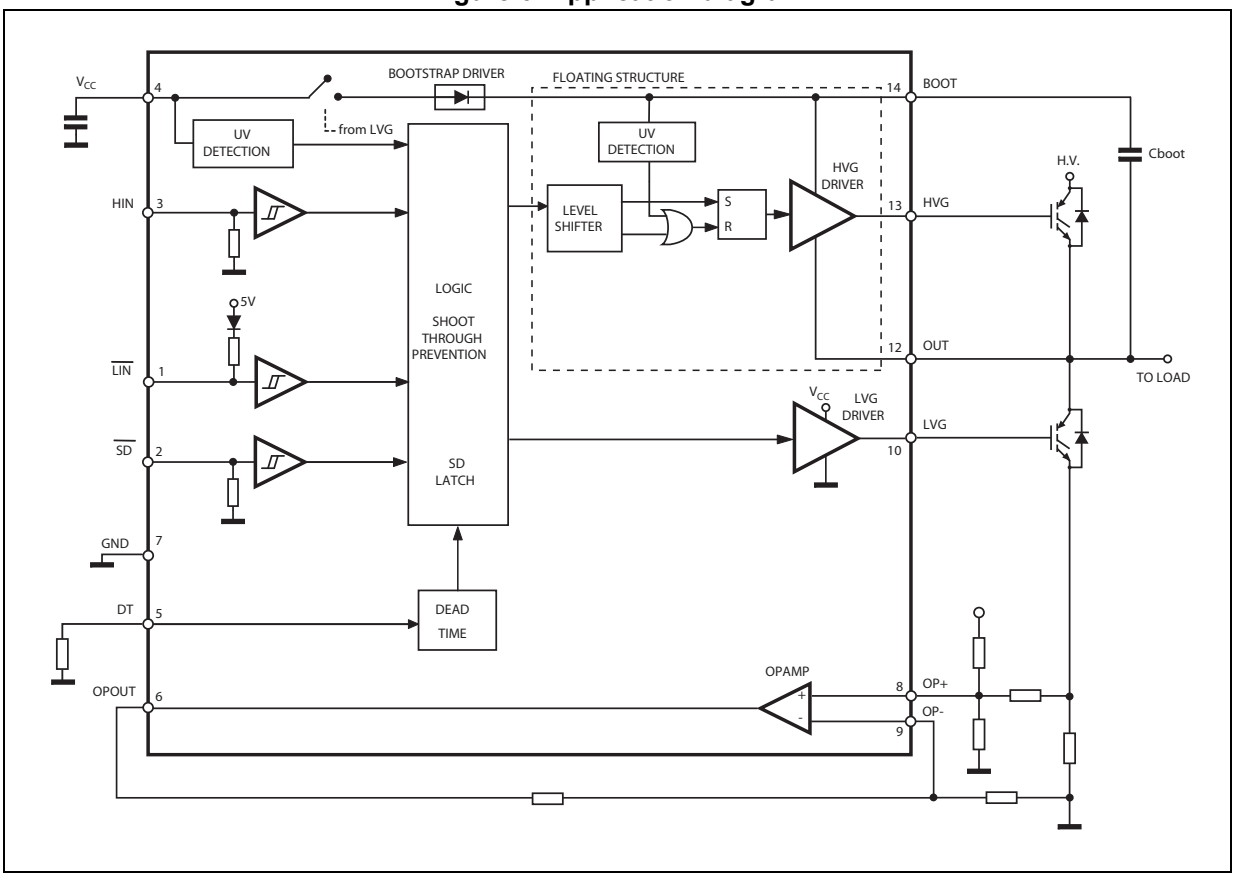
Figure 5. Deadtime - timing waveforms



(*) HIN and $\overline{LIN}$ can be connected togheter and driven by just one control signal

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:

$$C_{BOOT} >>> C_{EXT}$$

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 µA, so if HVG T_{ON} is 5 ms, C_{BOOT} has to supply 1 µC to C_{EXT}. 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_{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 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 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.

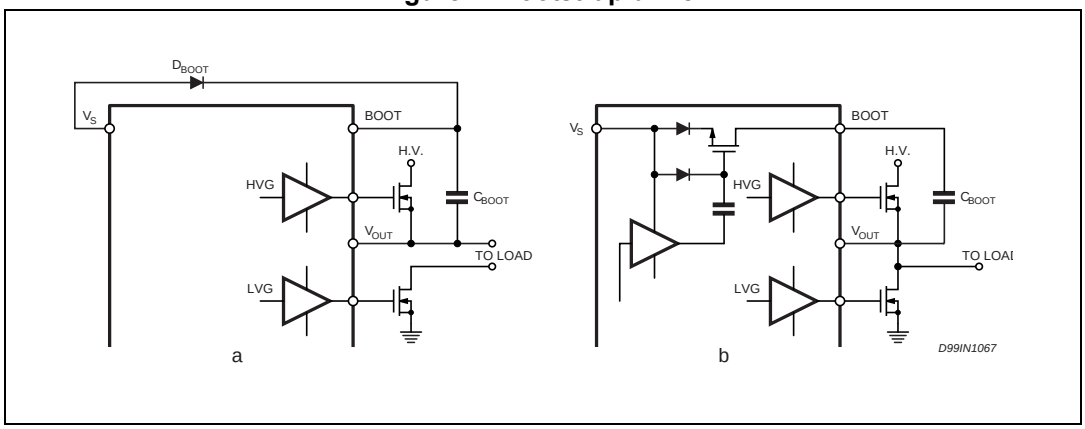
For example: using a power MOS with a total gate charge of 30 nC the drop on the bootstrap DMOS is about 1 V, if the T_{charge} is 5 µs. In fact:

Equation 3

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

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 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. ECOPACK is an ST trademark.

SO-14 package information

Figure 8. SO-14 package outline

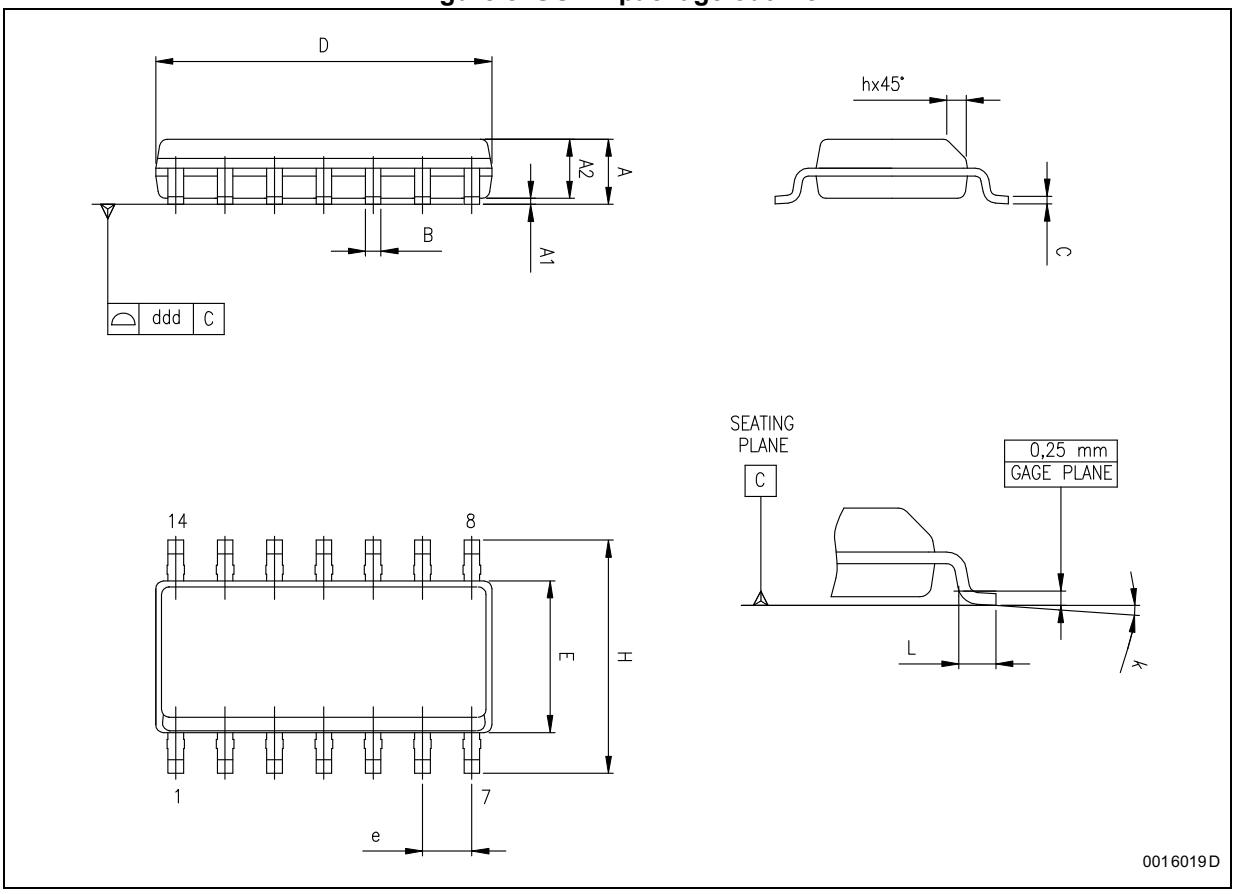
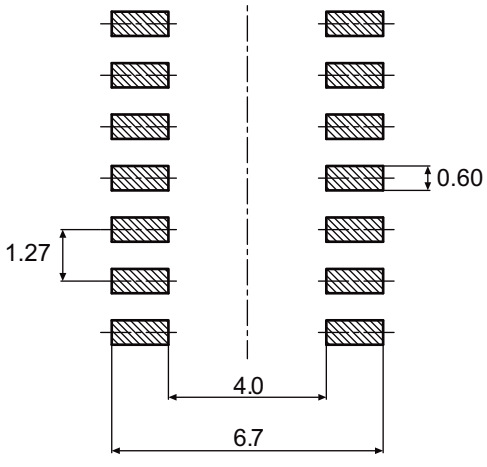


Table 9. SO-14 package mechanical data

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