

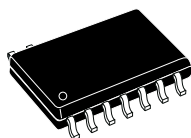


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High voltage high and low-side driver

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
- Comparator for fault protections
- Smart shutdown function
- Adjustable deadtime
- 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 and fans
- HID ballasts, power supply units

Description

The L6391 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 the microcontroller/DSP.

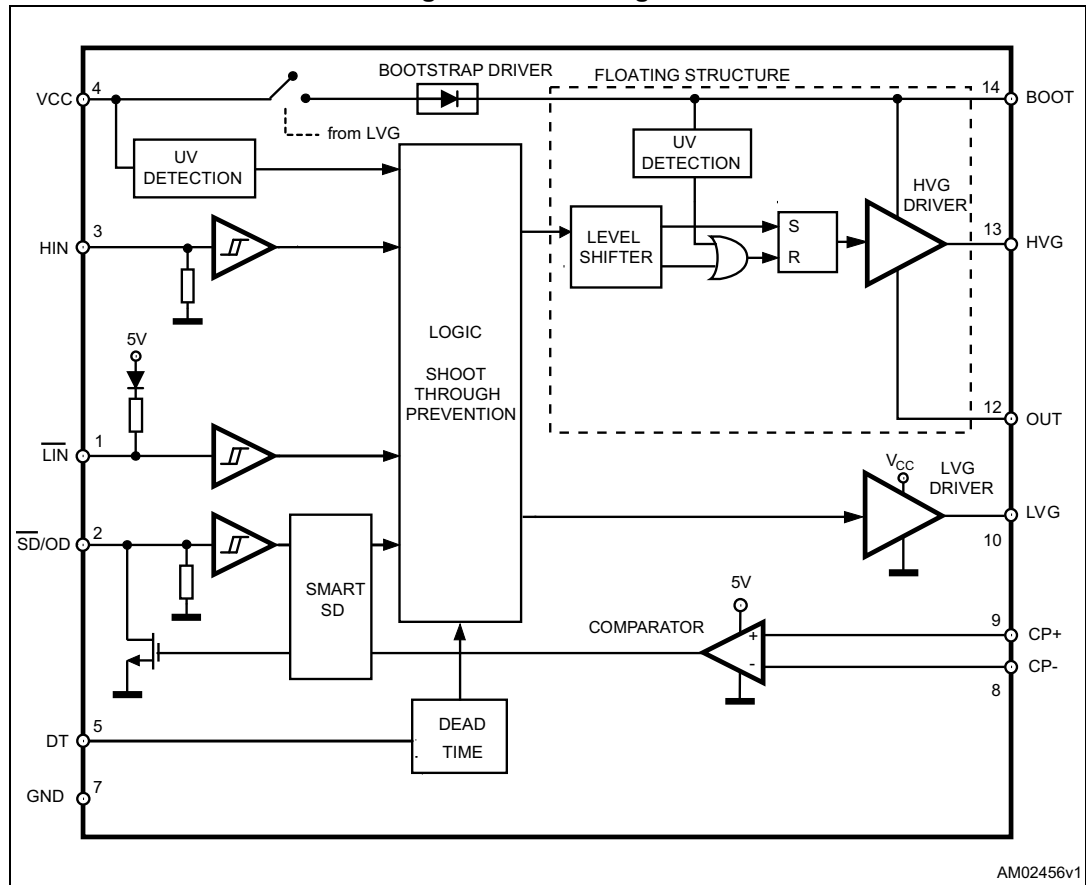
An integrated comparator is available for protections against overcurrent, overtemperature, etc.

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1 Block diagram

Figure 1. Block diagram



2 Pin connection

Figure 2. Pin connection (top view)

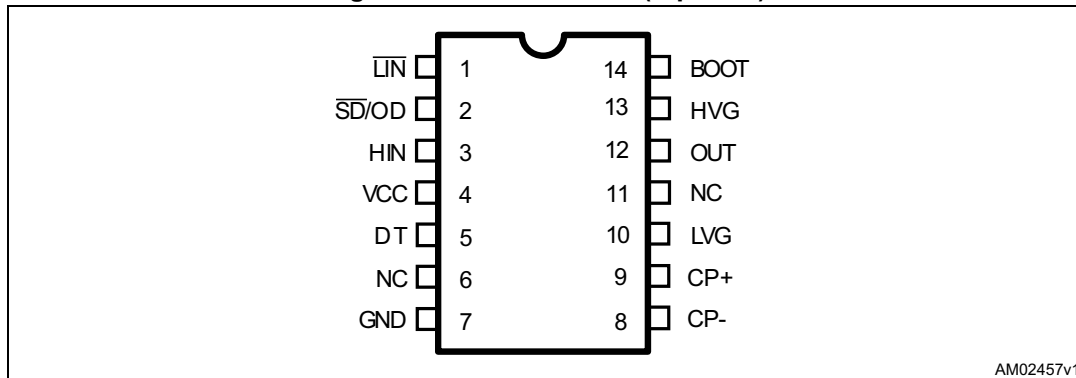


Table 1. Pin description

Pin number	Pin name	Type	Function
1	LIN	I	Low-side driver logic input (active low)
2	SD/OD ⁽¹⁾	I/O	Shutdown 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	Deadtime setting
6	NC		Not connected
7	GND	P	Ground
8	CP-	I	Comparator negative input
9	CP+	I	Comparator positive 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 guarantees 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 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 2. Truth table

Input			Output	
$\overline{\text{SD}}$	$\overline{\text{LIN}}$	HIN	LVG	HVG
L	X ⁽¹⁾	X ⁽¹⁾	L	L
H	H	L	L	L
H	L	H	L	L
H	L	L	H	L
H	H	H	L	H

1. X: don't care.

4 Electrical data

4.1 Absolute maximum ratings

Table 3. Absolute maximum ratings

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_{cp-}	Comparator negative input voltage	-0.3	$V_{CC} + 0.3$	V
V_{cp+}	Comparator positive 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
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 conditions	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
V_{CP-}	8	Comparator negative input voltage	V_{CP+} [2.5 V]		$V_{CC}^{(3)}$	V
V_{CP+}	9	Comparator positive input voltage	V_{CP-} [2.5 V]		$V_{CC}^{(3)}$	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.

3. At least one of the comparator's inputs must be lower than 2.5 V to guarantee proper operation.

5 Electrical characteristics

5.1 AC operation

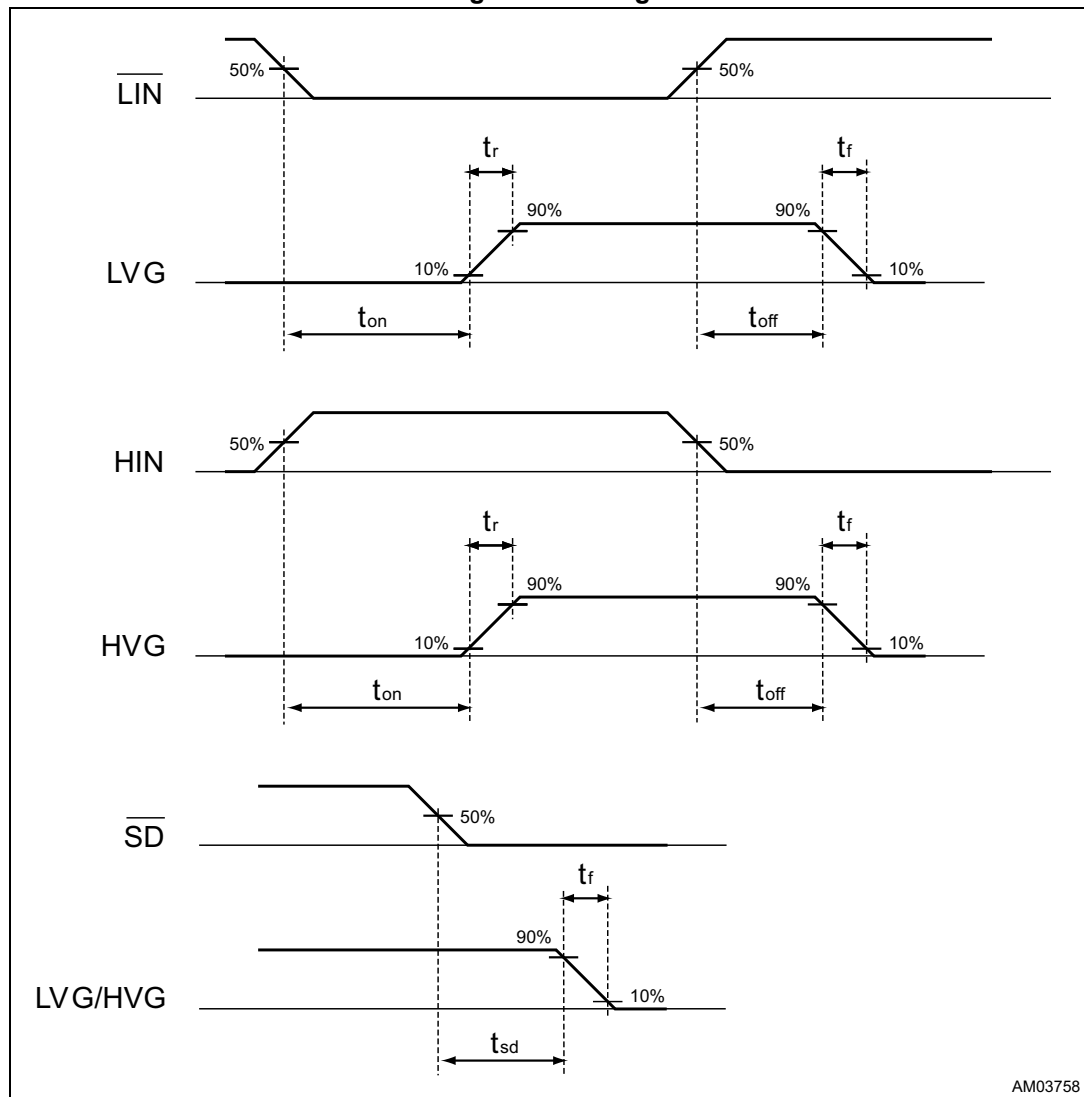
Table 6. AC operation electrical characteristics ($V_{CC} = 15\text{ V}$; $T_J = +25\text{ }^\circ\text{C}$)

Symbol	Pin	Parameter	Test conditions	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 Figure 3	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	Shutdown 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+; CP- = 0.5 V		200	250	ns
MT		Delay matching, HS and LS turn-on/off				30	ns
DT	5	Deadtime setting range ⁽¹⁾	$R_{DT} = 0\text{ }\Omega$, $C_L = 1\text{ nF}$	0.1	0.18	0.25	μs
			$R_{DT} = 37\text{ k}\Omega$, $C_L = 1\text{ nF}$, $C_{DT} = 100\text{ nF}$	0.48	0.6	0.72	μs
			$R_{DT} = 136\text{ k}\Omega$, $C_L = 1\text{ nF}$, $C_{DT} = 100\text{ nF}$	1.35	1.6	1.85	μs
			$R_{DT} = 260\text{ k}\Omega$, $C_L = 1\text{ nF}$, $C_{DT} = 100\text{ nF}$	2.6	3.0	3.4	μs
MDT		Matching deadtime ⁽²⁾	$R_{DT} = 0\text{ }\Omega$, $C_L = 1\text{ nF}$			80	ns
			$R_{DT} = 37\text{ k}\Omega$, $C_L = 1\text{ nF}$, $C_{DT} = 100\text{ nF}$			120	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	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](#).

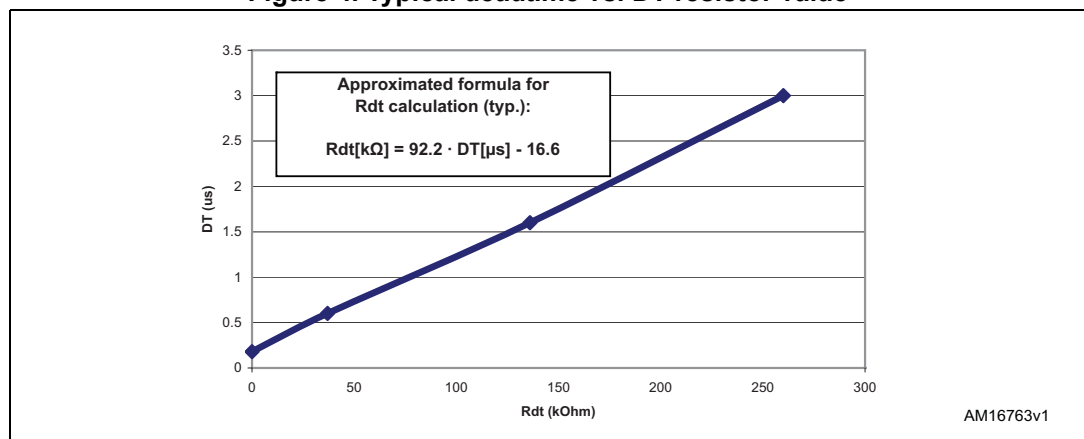
2. $MDT = |DT_{LH} - DT_{HL}|$ (see [Figure 5 on page 12](#)).

Figure 3. Timing



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Figure 4. Typical deadtime vs. DT resistor value



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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 conditions	Min.	Typ.	Max.	Unit
V _{cc_hys}	4	V _{cc} UV hysteresis		1.2	1.5	1.8	V
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} = 9.5 V SD = 5 V; LIN = 5 V; HIN = GND; R _{DT} = 0 Ω; CP+ = GND; CP- = 5 V		100	150	μA
I _{qcc}		Quiescent current	V _{cc} = 15 V SD = 5 V; LIN = 5 V; HIN = GND; R _{DT} = 0 Ω; CP+ = GND; CP- = 5 V		500	1000	μA
Bootstrapped supply voltage section ⁽¹⁾							
V _{BO_hys}	14 - 12	V _{BO} UV hysteresis		1.2	1.5	1.8	V
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 SD = 5 V; LIN and HIN = 5 V; R _{DT} = 0 Ω; CP+ = GND; CP- = 5 V		70	110	μA
I _{QBO}		V _{BO} quiescent current	V _{BO} = 15 V SD = 5 V; LIN and HIN = 5 V; R _{DT} = 0 Ω; CP+ = GND; CP- = 5 V		200	240	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		W
Driving buffer section							
I _{so}	10, 13	High/low-side source short-circuit current	V _{IN} = V _{ih} (t _p < 10 μs)	200	290		mA
I _{si}		High/low-side sink short-circuit current	V _{IN} = V _{il} (t _p < 10 μs)	250	430		mA
Logic inputs							
V _{il}	1, 2, 3	Low level logic threshold		0.8		1.1	V
V _{ih}		High level logic threshold voltage		1.9		2.25	V
V _{il_S}	1, 3	Single input voltage	LIN and HIN connected together and floating			0.8	V

Table 7. DC operation electrical characteristics ($V_{CC} = 15\text{ V}$; $T_J = +25\text{ }^\circ\text{C}$) (continued)

Symbol	Pin	Parameter	Test conditions	Min.	Typ.	Max.	Unit
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	$\overline{\text{LIN}}$ logic "0" input bias current	$\overline{\text{LIN}} = 0\text{ V}$	3	6	20	μA
I_{LINh}		$\overline{\text{LIN}}$ logic "1" input bias current	$\overline{\text{LIN}} = 15\text{ V}$			1	μA
I_{SDh}	2	$\overline{\text{SD}}$ logic "1" input bias current	$\overline{\text{SD}} = 15\text{ V}$	10	40	100	μA
I_{SDl}		$\overline{\text{SD}}$ logic "0" input bias current	$\overline{\text{SD}} = 0\text{ V}$			1	μA

1. $V_{BO} = V_{BOOT} - V_{OUT}$.

2. $R_{DS(on)}$ is tested in the following way: $R_{DS(on)} = [(V_{CC} - V_{BOOT1}) - (V_{CC} - V_{BOOT2})] / [I_1(V_{CC}, V_{BOOT1}) - I_2(V_{CC}, V_{BOOT2})]$
where I_1 is pin 14 current when $V_{BOOT} = V_{BOOT1}$, I_2 when $V_{BOOT} = V_{BOOT2}$.

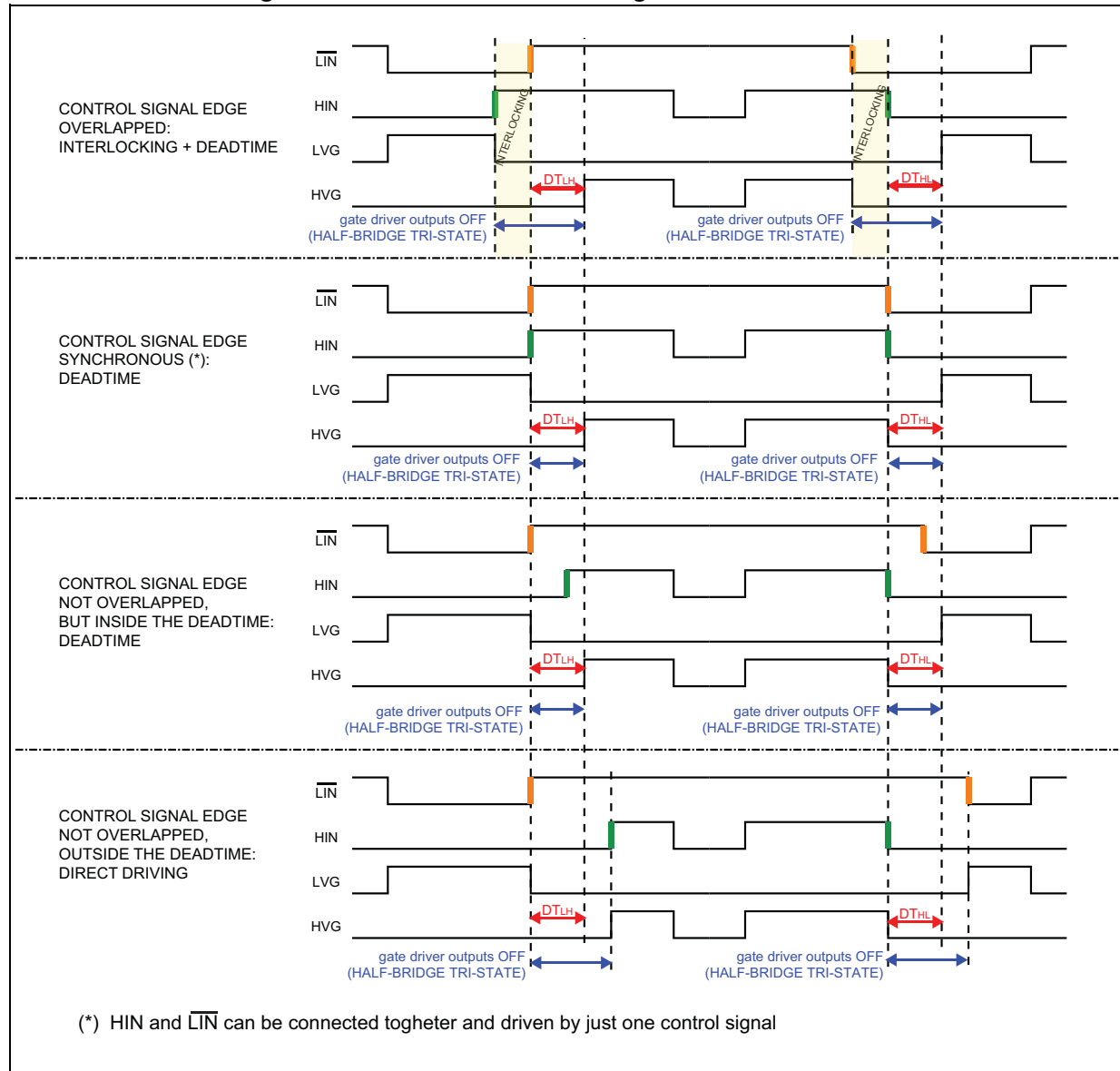
Table 8. Sense comparator⁽¹⁾ ($V_{CC} = 15\text{ V}$, $T_J = +25\text{ }^\circ\text{C}$)

Symbol	Pin	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_{io}	8, 9	Input offset voltage		-15		15	mV
I_{ib}	8, 9	Input bias current	$V_{CP+} = 1\text{ V}$, $V_{CP-} = 0.5\text{ V}$			1	μA
V_{ol}	2	Open-drain low level output voltage	$I_{od} = -3\text{ mA}$, $V_{CP+} = 1\text{ V}$; $V_{CP-} = 0.5\text{ V}$;			0.5	V
t_{d_comp}		Comparator delay	$R_{pull} = 100\text{ k}\Omega$ to 5 V on $\overline{\text{SD/OD}}$ pin; $V_{CP-} = 0.5\text{ V}$; voltage step on $CP+ = 0$ to 3.3 V		90	130	ns
SR	2	Slew rate	$C_L = 180\text{ pF}$; $R_{pu} = 5\text{ k}\Omega$		60		V/ μs

1. Comparator is disabled when V_{CC} is in UVLO condition.

6 Waveform definitions

Figure 5. Deadtime and interlocking waveform definitions

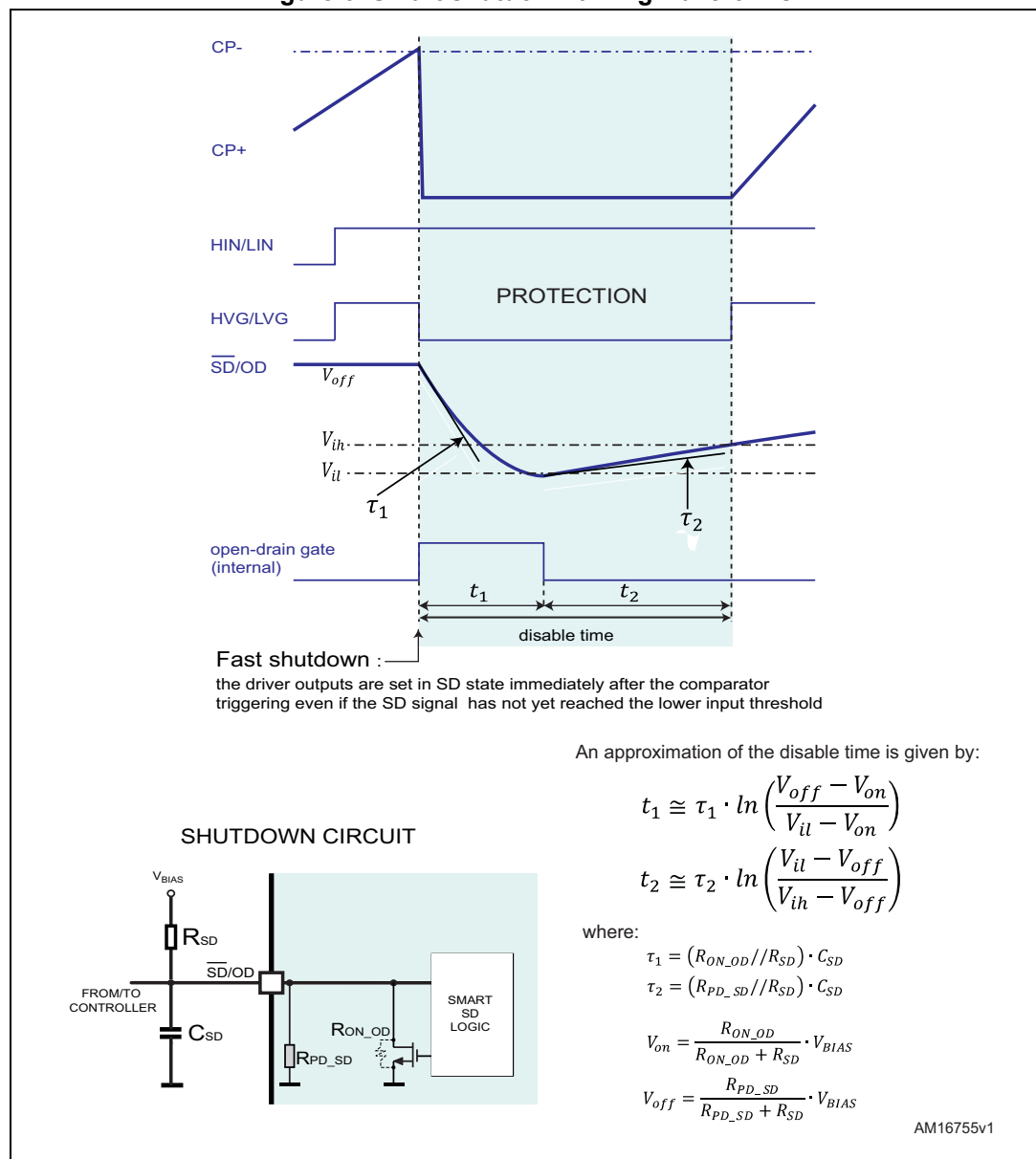


7 Smart shutdown function

The L6391 device integrates a comparator committed to the fault sensing function. Both comparator's inputs are available on pins 8 and 9. For example, applying a voltage reference to CP- and connecting the CP+ to an external shunt resistor, a simple overcurrent detection function can be implemented.

The output signal of the comparator is fed to an integrated MOSFET with the open-drain output available on the pin 2, shared with the $\overline{\text{SD}}$ input. When the comparator triggers, the device is set in shutdown state and both its outputs are set to low level leaving the half-bridge in tristate.

Figure 6. Smart shutdown timing waveforms



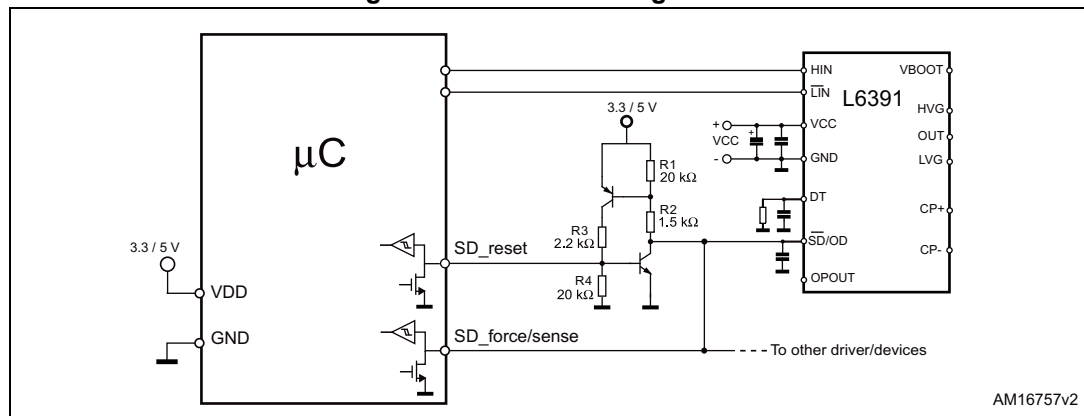
In some applications, it may be useful to latch the driver in the shutdown condition for an arbitrary time, until the controller decides to reset it to normal operation. This may, for example, be achieved by a circuit as the one shown in [Figure 7](#). When the open-drain starts pulling down the $\overline{\text{SD/OD}}$ pin, the external latch turns on and keeps the pin to GND, preventing it from being pulled up again once the $\overline{\text{SD}}$ logic input lower threshold is reached and the internal open-drain turns off. One pin of the controller is used to release the external latch, and one to externally force a shutdown condition and also to read the status of the $\overline{\text{SD/OD}}$ pin.

The schematic shows a microcontroller (μC) connected to an L6391 HV driver. The μC has VDD and GND pins. It controls the SD force and SD sense signals through inverters. The SD force signal is connected to the DT pin of the L6391 via a resistor R1 (9R). The SD sense signal is connected to the SD/OD pin via a resistor R2 (2R). A third resistor R3 (2R) connects the SD/OD pin to ground. The L6391 has pins for VIN, LTIN, VCC, GND, DT, SD/OD, OP/OUT, VBOOT, VHV, OUT, LVG, CP+, and CP-. The VCC pin is connected to a +VCC supply through a diode and to ground through another diode. The DT pin is connected to a capacitor C1 to ground. The SD/OD pin is connected to a capacitor C2 to ground. The OP/OUT pin is connected to a capacitor C3 to ground. The L6391 drives two L639x modules, each consisting of a MOSFET and a diode. The output of the first module is connected to the HV BUS. The second module's output is also connected to the HV BUS. The HV BUS is connected to the VBOOT pin of the L6391.

C1: disable time setting capacitor
C2, C3: small noise filtering capacitors

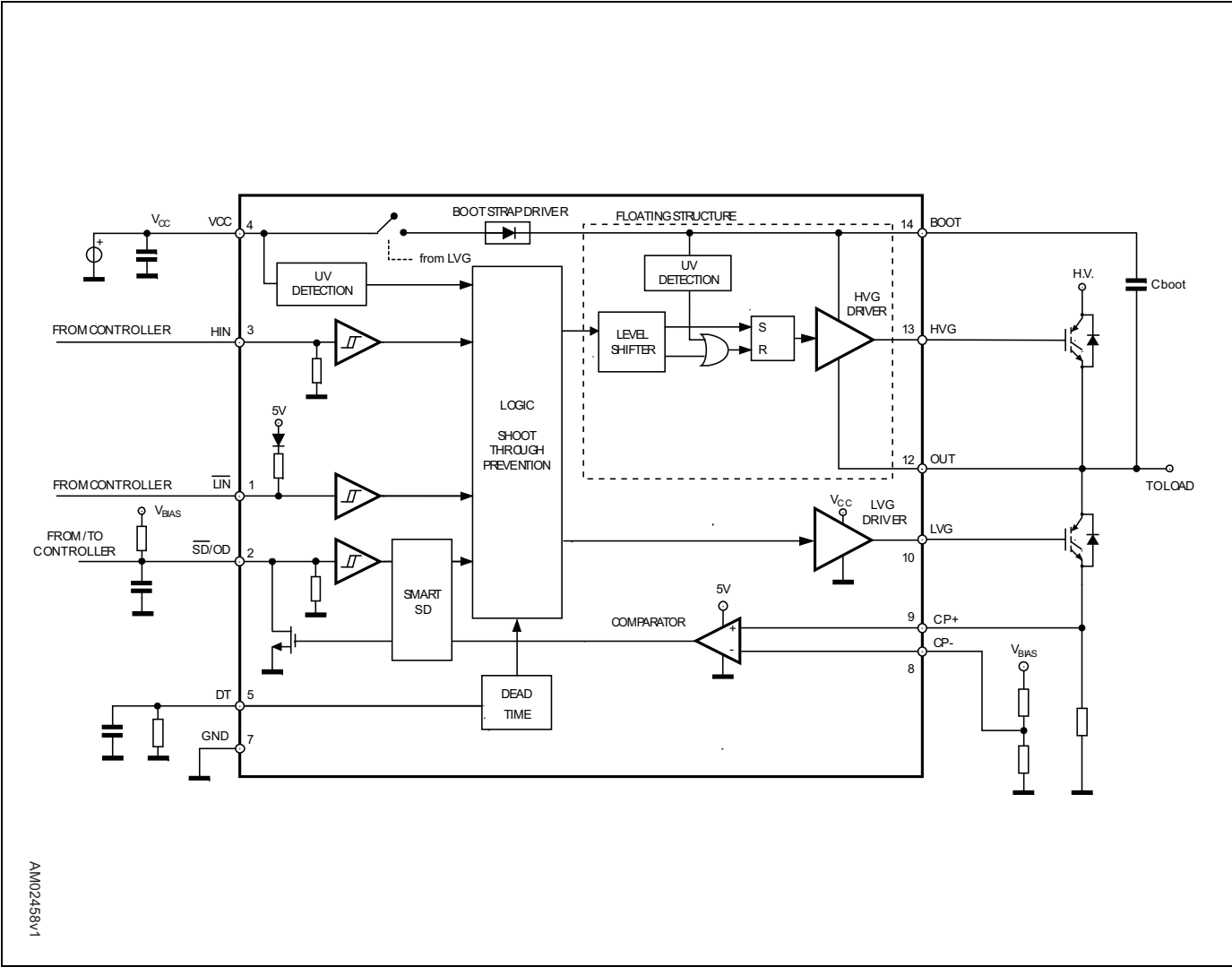
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Figure 8. $\overline{\text{SD}}$ level shifting circuit

8 Typical application diagram

Figure 9. Application diagram



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9 Bootstrap driver

A bootstrap circuitry is needed to supply the high voltage section. This function is usually accomplished by a high voltage fast recovery diode ([Figure 10](#)). In the L6391 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 diode in series, as shown in [Figure 11](#). An internal charge pump ([Figure 11](#)) 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:

Equation 2

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

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

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

HVG steady-state consumption is lower than 240 μA, so if HVG T_{ON} is 5 ms, C_{BOOT} has to supply C_{EXT} with 1.2 μC. This charge on a 1 μF capacitor means a voltage drop of 1.2 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_{DS(on)} (typical value: 120 Ω). At low frequency this drop can be neglected. Anyway, the rise of frequency has to take into account.

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

Equation 3

$$V_{drop} = I_{charge} R_{DS(on)} \rightarrow V_{drop} = \frac{Q_{gate}}{T_{charge}} R_{DS(on)}$$

where Q_{gate} is the gate charge of the external power MOS, R_{DS(on)} 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 4

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

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 10. Bootstrap driver with high voltage fast recovery diode

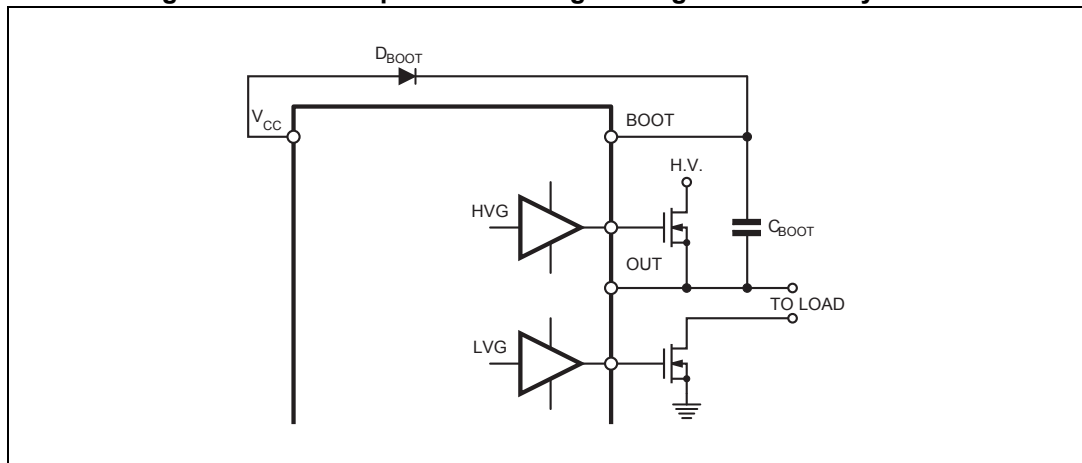
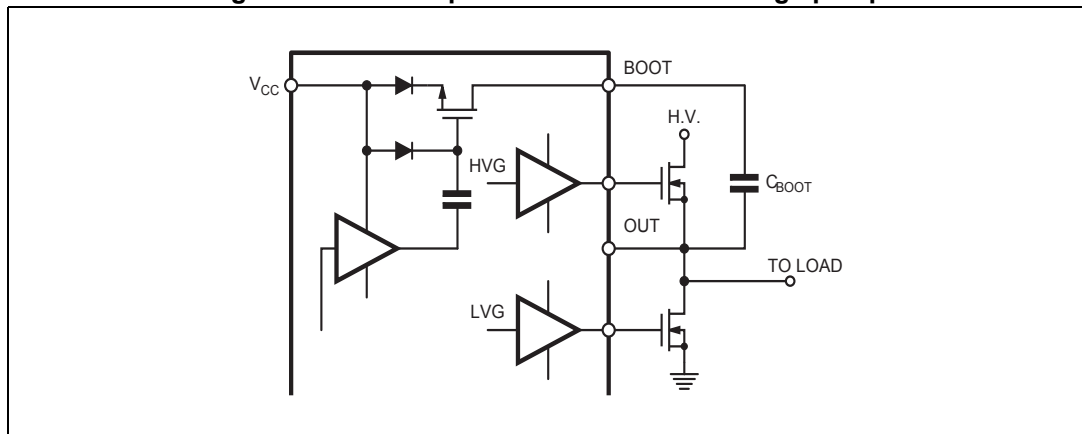


Figure 11. Bootstrap driver with internal charge pump



10 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 12. SO-14 package outline

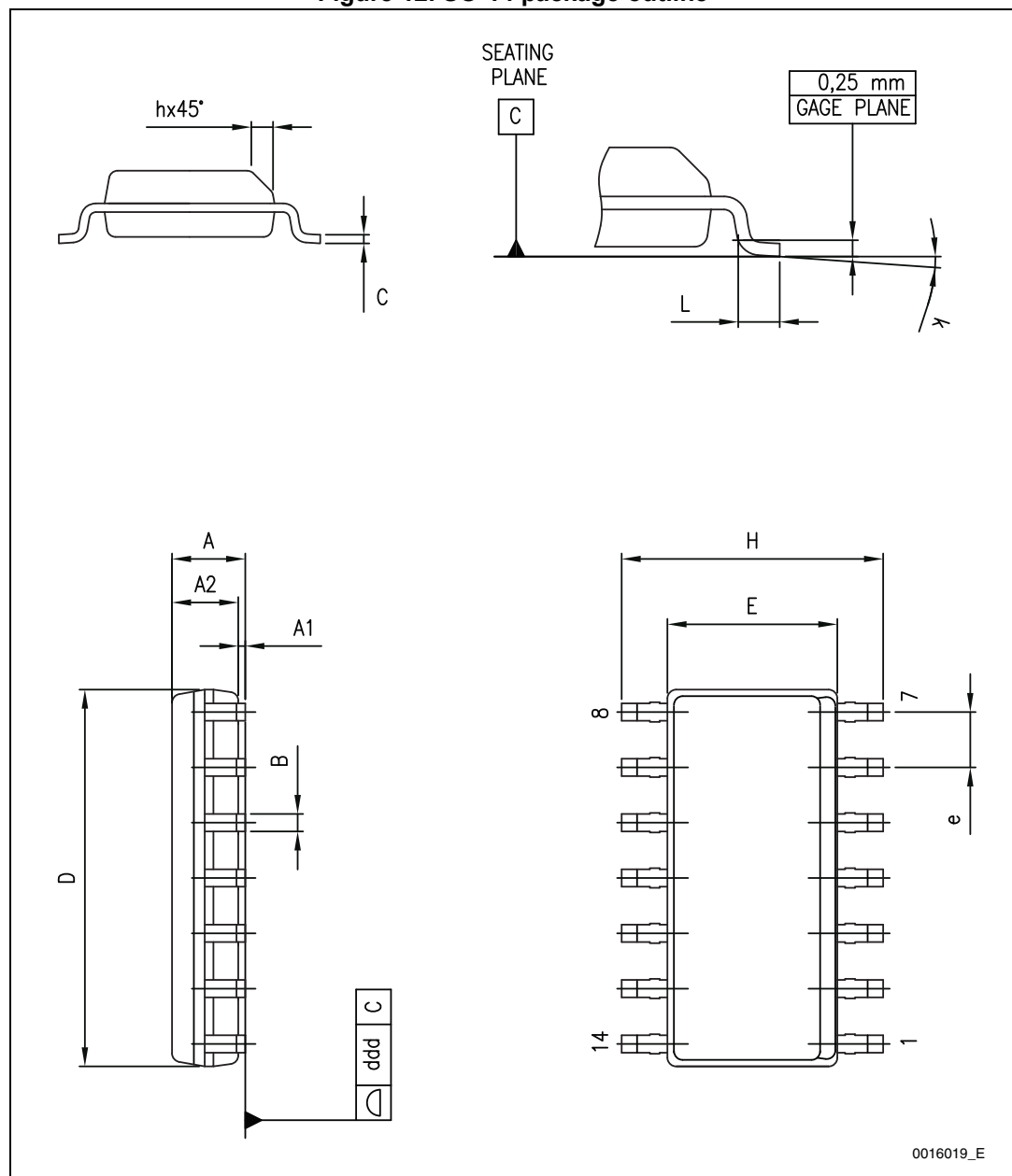
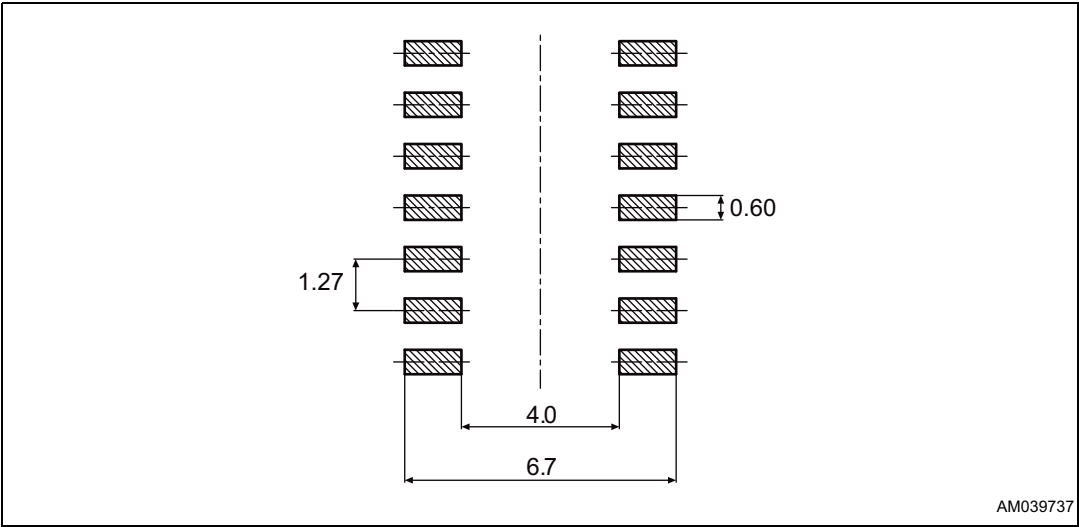


Table 9. SO-14 package mechanical data

Symbol	Dimensions (mm)		
	Min.	Typ.	Max.
A	1.35		1.75
A1	0.10		0.25
A2	1.10		1.65
B	0.33		0.51
C	0.19		0.25
D	8.55		8.75
E	3.80		4.00
e		1.27	
H	5.80		6.20
h	0.25		0.50
L	0.40		1.27
K	0		8
e		0.40	
ddd			0.10

Figure 13. SO-14 footprint



11 Order codes

Table 10. Order codes

Order code	Package	Packaging
L6391D	SO-14	Tube
L6391DTR	SO-14	Tape and reel

12 Revision history

Table 11. Document revision history

Date	Revision	Changes
14-Dec-2010	1	First release.
10-May-2013	2	Added HBM parameter to Table 3. Added I_{QBO} max. value to Table 7. Changed V_{il} and V_{ih} min. and max. values in Table 7. Added note to Table 8. Updated Section 7 and Section . Changed Figure 6 and added Figure 7 and Figure 8. Updated SO-14 mechanical data. Updated DIP-14 mechanical data.
11-Sep-2015	3	Removed DIP-14 package from the entire document. Updated Table 4 on page 6 (updated $R_{th(JA)}$ value). Moved Table 10 on page 21 (moved from page 1 to page 21, updated titles). Updated Table 3 on page 6 (updated ESD parameter and value). Updated note 1.and 2. below Table 7 on page 10 (minor modifications, replaced V_{CBOOTx} by V_{BOOTx}). Added Figure 13 on page 20. Updated cross-references throughout document. Minor modifications throughout document.

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