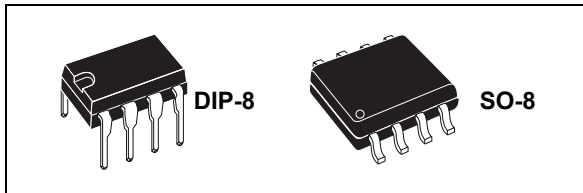


## High voltage high and low-side driver

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:
  - 400 mA source
  - 650 mA sink
- Switching times 70/40 nsec rise/fall with 1 nF load
- 3.3 V, 5 V, 15 V CMOS/TTL input comparators with hysteresis and pull-down
- Internal bootstrap diode
- Outputs in phase with inputs
- Deadtime and interlocking function

### Applications

- Home appliances
- Industrial applications and drives
- Motor drivers
  - DC, AC, PMDC and PMAC motors
- Induction heating
- HVAC
- Factory automation
- Lighting applications
- Power supply systems

### Description

The L6388E is a high voltage gate driver, manufactured with the BCD™ “offline” technology, and able to drive a half-bridge of power MOSFET/IGBT devices. The high-side (floating) section is enabled to work with voltage rail up to 600 V. Both device outputs can sink and source 650 mA and 400 mA respectively and cannot be simultaneously driven high thanks to an integrated interlocking function. Further prevention from outputs cross conduction is guaranteed by the deadtime function.

The L6388E device has two input and two output pins, and guarantees the outputs switch in phase with inputs. The logic inputs are CMOS/TTL compatible (3.3 V, 5 V and 15 V) to ease the interfacing with controlling devices.

The bootstrap diode is integrated in the driver allowing a more compact and reliable solution.

The L6388E device features the UVLO protection on both supply voltages ( $V_{CC}$  and  $V_{BOOT}$ ) ensuring greater protection against voltage drops on the supply lines.

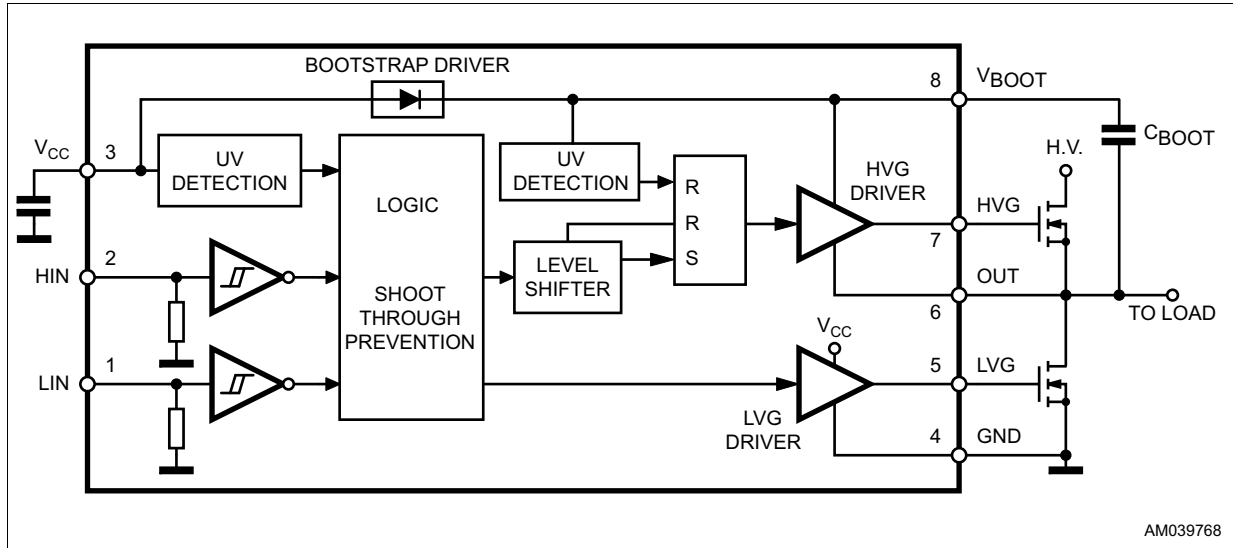
The device is available in a DIP-8 tube and SO-8 tube, and tape and reel packaging options.

# Contents

- 1      Block diagram ..... 3**
- 2      Electrical data ..... 4**
  - 2.1 Absolute maximum ratings ..... 4
  - 2.2 Thermal data ..... 4
  - 2.3 Recommended operating conditions ..... 4
- 3      Pin connection ..... 5**
- 4      Electrical characteristics ..... 6**
  - 4.1 AC operation ..... 6
  - 4.2 DC operation ..... 6
- 5      Waveform definitions ..... 8**
- 6      Input logic ..... 9**
- 7      Bootstrap driver ..... 9**
  - C<sub>BOOT</sub> selection and charging ..... 9
- 8      Typical characteristics ..... 11**
- 9      Package information ..... 13**
  - 9.1 DIP-8 package information ..... 13
  - 9.2 SO-8 package information ..... 15
- 10     Order codes ..... 16**
- 11     Revision history ..... 17**

# 1 Block diagram

Figure 1. Block diagram



## 2 Electrical data

### 2.1 Absolute maximum ratings

Table 1. Absolute maximum ratings

Symbol	Parameter	Value		Unit
		Min.	Max.	
$V_{OUT}$	Output voltage	$V_{BOOT} - 18$	$V_{BOOT}$	V
$V_{CC}$	Supply voltage	- 0.3	18	V
$V_{BOOT}$	Floating supply voltage	- 0.3	618	V
$V_{hvg}$	High-side gate output voltage	$V_{OUT} - 0.3$	$V_{BOOT}$	V
$V_{lvg}$	Low-side gate output voltage	-0.3	$V_{CC} + 0.3$	V
$V_i$	Logic input voltage	-0.3	$V_{CC} + 0.3$	V
$dV_{OUT}/dt$	Allowed output slew rate		50	V/ns
$P_{tot}$	Total power dissipation ( $T_J = 85\text{ °C}$ )	750	750	mW
$T_j$	Junction temperature	150	150	°C
$T_s$	Storage temperature	-50	150	°C
ESD	Human body model	2		kV

### 2.2 Thermal data

Table 2. Thermal data

Symbol	Parameter	SO-8	DIP-8	Unit
$R_{th(JA)}$	Thermal resistance junction to ambient	150	100	°C/W

### 2.3 Recommended operating conditions

Table 3. Recommended operating conditions

Symbol	Pin	Parameter	Test condition	Min.	Typ.	Max.	Unit
$V_{OUT}$	6	Output voltage		(1)		580	V
$V_{BS}^{(2)}$	8	Floating supply voltage		(1)		17	V
$f_{sw}$		Switching frequency	HVG, LVG load $C_L = 1\text{ nF}$			400	kHz
$V_{CC}$	3	Supply voltage				17	V
$T_J$		Junction temperature		-45		125	°C

1. If the condition  $V_{BOOT} - V_{OUT} < 18\text{ V}$  is guaranteed,  $V_{OUT}$  can range from -3 to 580 V.

2.  $V_{BS} = V_{BOOT} - V_{OUT}$ .

### 3 Pin connection

Figure 2. Pin connection (top view)

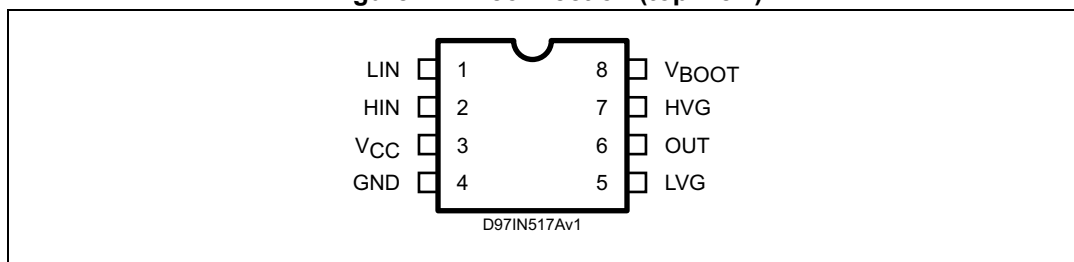


Table 4. Pin description

No.	Pin	Type	Function
1	LIN	I	Low-side driver logic input
2	HIN	I	High-side driver logic input
3	V <sub>CC</sub>	P	Low-voltage power supply
4	GND	P	Ground
5	LVG <sup>(1)</sup>	O	Low-side driver output
6	OUT	P	High-side driver floating reference
7	HVG <sup>(1)</sup>	O	High-side driver output
8	V <sub>BOOT</sub>	P	Bootstrap supply voltage

1. The circuit guarantees 0.3 V maximum on the pin (at  $I_{\text{sink}} = 10 \text{ mA}$ ). This allows the omission of the "bleeder" resistor connected between the gate and the source of the external MOSFET normally used to hold the pin low.

## 4 Electrical characteristics

### 4.1 AC operation

Table 5. AC operation electrical characteristics ( $V_{CC} = 15\text{ V}$ ;  $T_J = 25\text{ }^\circ\text{C}$ )

Symbol	Pin	Parameter	Test condition	Min.	Typ.	Max.	Unit
$t_{on}$	1 vs. 5	High/low-side driver turn-on propagation delay	$V_{OUT} = 0\text{ V}$		225	300	ns
$t_{off}$	2 vs. 7	High/low-side driver turn-off propagation delay	$V_{OUT} = 0\text{ V}$		160	220	ns
$t_r$	5, 7	Rise time	$C_L = 1000\text{ pF}$		70	100	ns
$t_f$	5, 7	Fall time	$C_L = 1000\text{ pF}$		40	80	ns
DT	5, 7	Deadtime		220	320	420	ns

### 4.2 DC operation

Table 6. DC operation electrical characteristics

Symbol	Pin	Parameter	Test condition	Min.	Typ.	Max.	Unit
<b>Low supply voltage section</b>							
$V_{CCth1}$	3	$V_{CC}$ UV turn-on threshold		9.1	9.6	10.1	V
$V_{CCth2}$		$V_{CC}$ UV turn-off threshold		7.9	8.3	8.8	V
$V_{CChys}$		$V_{CC}$ UV hysteresis		0.9			V
$I_{QCCU}$		Undervoltage quiescent supply current	$V_{CC} \leq 9\text{ V}$		250	330	$\mu\text{A}$
$I_{QCC}$		Quiescent current	$V_{CC} = 15\text{ V}$		350	450	$\mu\text{A}$
$R_{DS(on)}$		Bootstrap driver on resistance <sup>(1)</sup>	$V_{CC} \geq 12.5\text{ V}$		125		$\Omega$
<b>Bootstrapped supply voltage section</b>							
$V_{BSth1}$	8	$V_{BS}$ UV turn-on threshold		8.5	9.5	10.5	V
$V_{BSth2}$		$V_{BS}$ UV turn-off threshold		7.2	8.2	9.2	V
$V_{BS hys}$		$V_{BS}$ UV hysteresis		0.9			V
$I_{QBS}$		$V_{BS}$ quiescent current	HVG ON			250	$\mu\text{A}$
$I_{LK}$		High voltage leakage current	$V_{hvg} = V_{OUT} = V_{BOOT} = 600\text{ V}$			10	$\mu\text{A}$
<b>High/low-side driver</b>							
$I_{so}$	5, 7	Source short-circuit current	$V_{IN} = V_{ih} (t_p < 10\text{ }\mu\text{s})$	300	400		mA
$I_{si}$		Sink short-circuit current	$V_{IN} = V_{il} (t_p < 10\text{ }\mu\text{s})$	500	650		mA

Table 6. DC operation electrical characteristics (continued)

Symbol	Pin	Parameter	Test condition	Min.	Typ.	Max.	Unit
<b>Logic inputs</b>							
$V_{il}$	1, 2	Low logic level input voltage				1.1	V
$V_{ih}$		High logic level input voltage		1.8			V
$I_{ih}$		High logic level input current	$V_{IN} = 15\text{ V}$		20	70	$\mu\text{A}$
$I_{il}$		Low logic level input current	$V_{IN} = 0\text{ V}$	-1			$\mu\text{A}$

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

$$R_{DS(on)} = \frac{(V_{CC} - V_{BOOT1}) - (V_{CC} - V_{BOOT2})}{I_1(V_{CC}, V_{BOOT1}) - I_2(V_{CC}, V_{BOOT2})}$$

where:

$I_1$  is pin 8 current when  $V_{BOOT} = V_{BOOT1}$ ,  $I_2$  when  $V_{BOOT} = V_{BOOT2}$ .

## 5 Waveform definitions

Figure 3. Deadtime time waveform definition

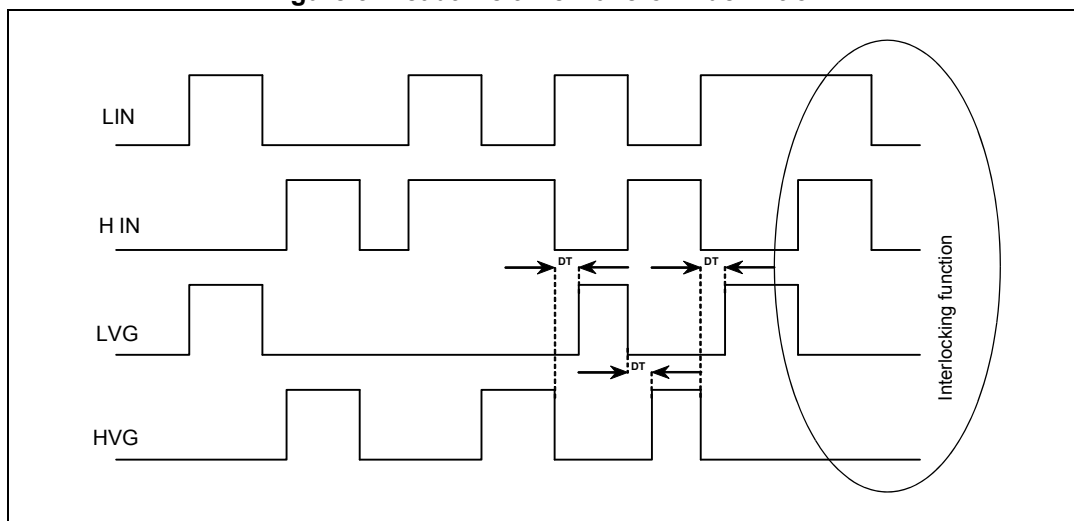
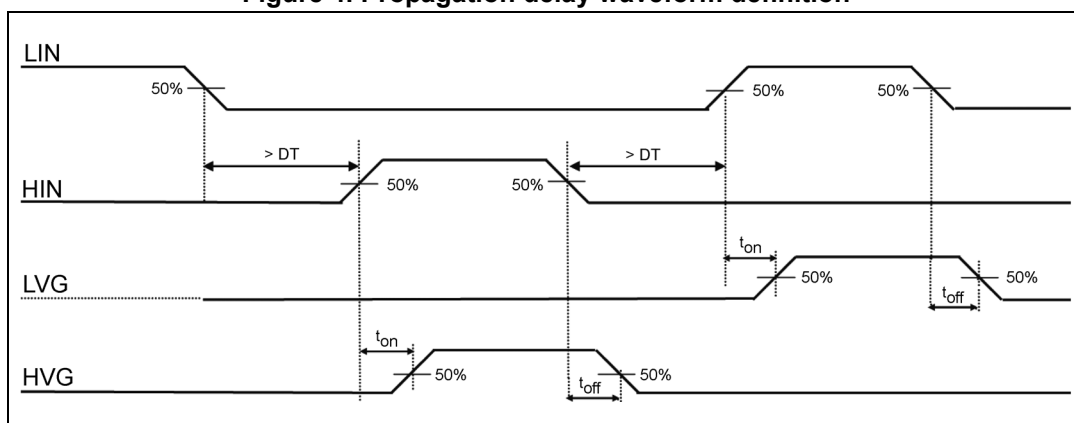


Figure 4. Propagation delay waveform definition





## 6 Input logic

Input logic is provided with an interlocking circuitry which avoids the two outputs (LVG, HVG) being active at the same time when both the logic input pins (LIN, HIN) are at a high logic level. In addition, to prevent cross conduction of the external MOSFETs, after each output is turned off, the other output cannot be turned on before a certain amount of time (DT) (see [Figure 3](#)).

## 7 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 5 a](#)). In the L6388E 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 5 b](#). An internal charge pump ([Figure 5 b](#)) provides the DMOS driving voltage. The diode connected in series to the DMOS has been added to avoid an undesirable turn-on.

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

To choose the proper  $C_{BOOT}$  value, the external MOSFET can be seen as an equivalent capacitor. This capacitor  $C_{EXT}$  is related to the MOSFET 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 must be:

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

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 is 300 mV.

If HVG must be supplied for a long period, the  $C_{BOOT}$  selection must also take the leakage losses into account.

E.g.: HVG steady-state consumption is typical 250  $\mu$ A, so, if HVG  $T_{ON}$  is 5 ms,  $C_{BOOT}$  must supply 1.25  $\mu$ C to  $C_{EXT}$ . This charge on a 1  $\mu$ F capacitor means a voltage drop of 1.25 V.

The internal bootstrap driver offers important advantages: the external fast recovery diode can be avoided (it usually has a high leakage current).

This structure can work only if  $V_{OUT}$  is close to GND (or lower) and, at the same time, the LVG is on. The charging time ( $T_{charge}$ ) of the  $C_{BOOT}$  is the time in which both conditions are fulfilled and it must be long enough to charge the capacitor.

The bootstrap driver introduces a voltage drop due to the DMOS  $R_{DS(on)}$  (typical value: 125  $\Omega$ ). This drop can be neglected at low switching frequency, but it should be taken into account when operating at high switching frequency.

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

**Equation 2**

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

where  $Q_{\text{gate}}$  is the gate charge of the external power MOSFET,  $R_{\text{DS(on)}}$  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 MOSFET 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  $\mu\text{s}$ .

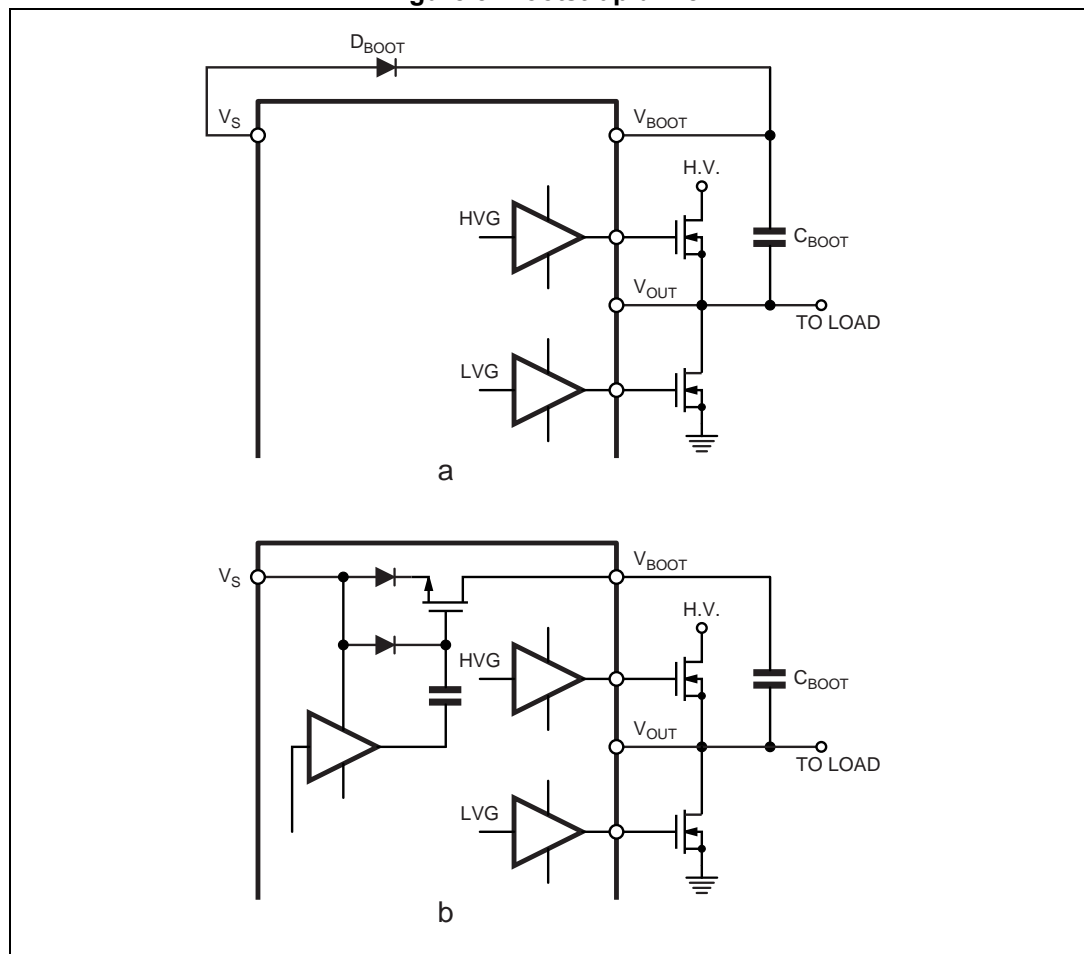
In fact:

**Equation 3**

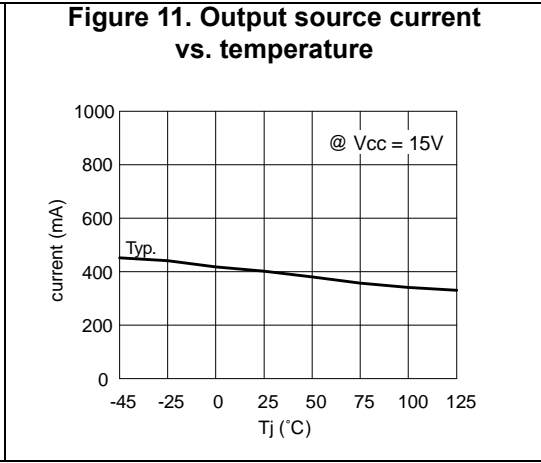
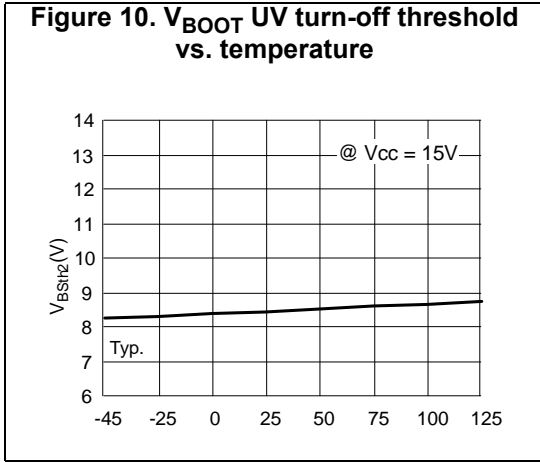
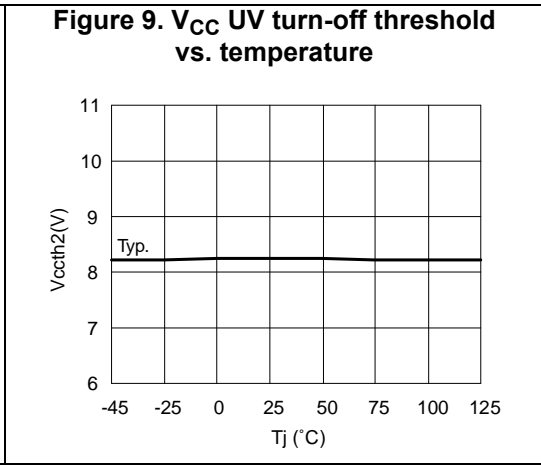
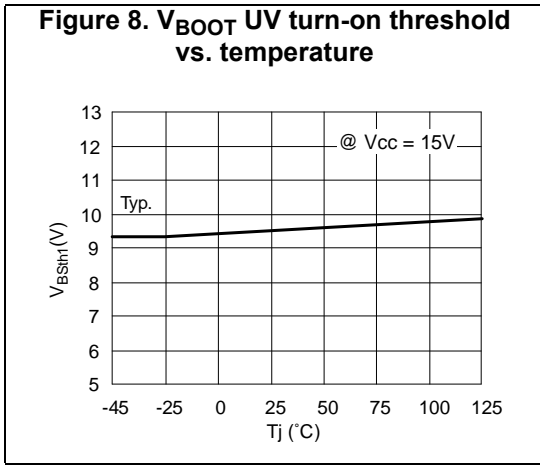
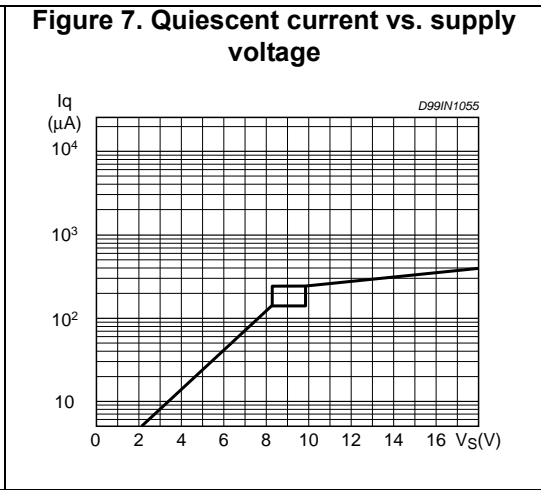
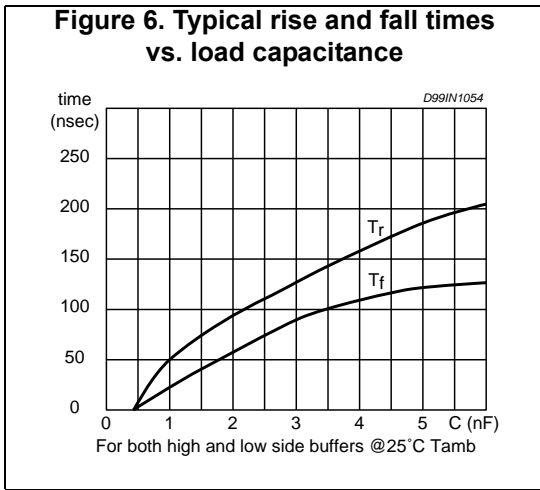
$$V_{\text{drop}} = \frac{30\text{nC}}{5\mu\text{s}} \cdot 125\Omega \sim 0.8\text{V}$$

$V_{\text{drop}}$  should 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.

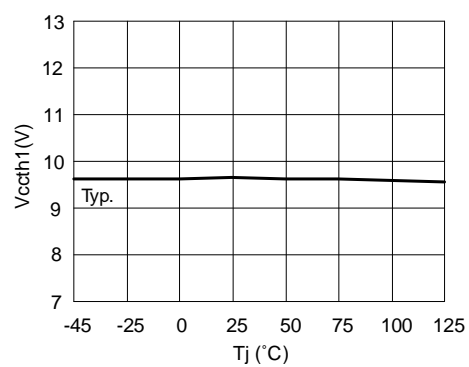
**Figure 5. Bootstrap driver**



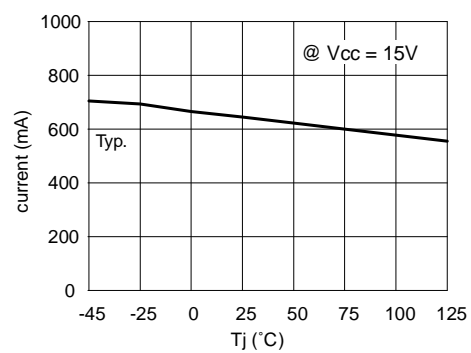
# 8 Typical characteristics



**Figure 12.  $V_{CC}$  UV turn-on threshold vs. temperature**



**Figure 13. Output sink current vs. temperature**



## 9 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK<sup>®</sup> 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.

### 9.1 DIP-8 package information

Figure 14. DIP-8 package outline

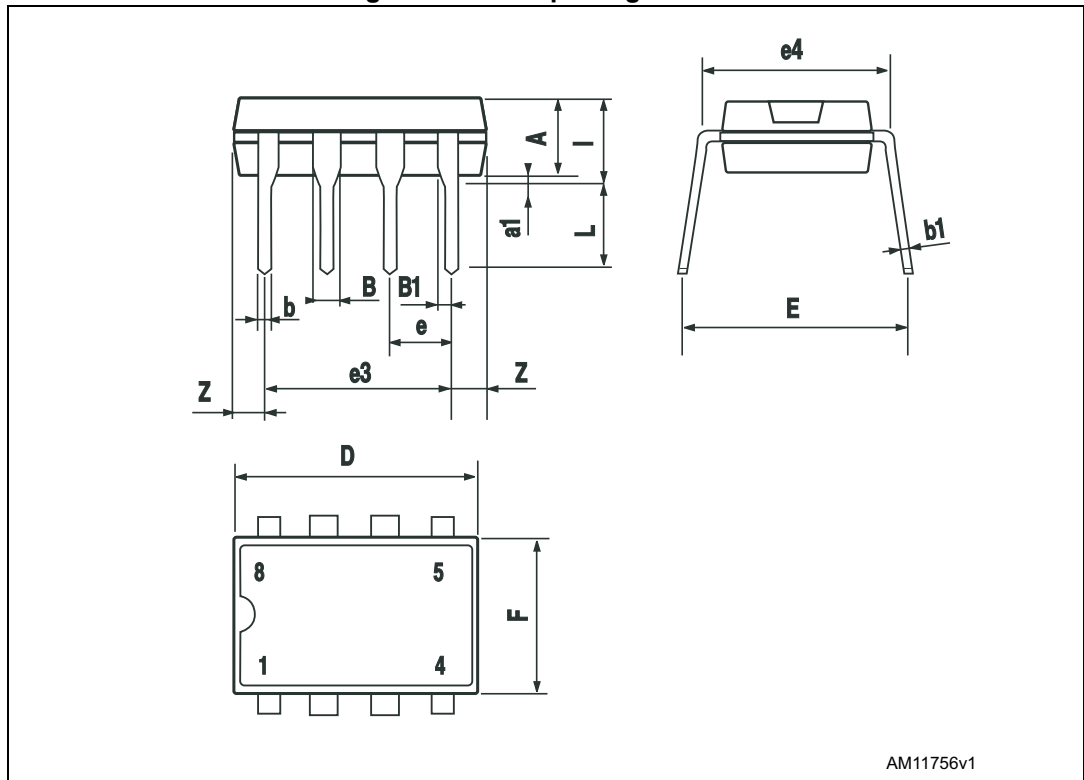


Table 7. DIP-8 package mechanical data

Symbol	Dimensions (mm)		
	Min.	Typ.	Max.
A		3.32	
a1	0.51		
B	1.15		1.65
b	0.356		0.55
b1	0.204		0.304
D			10.92
E	7.95		9.75
e		2.54	
e3		7.62	
e4		7.62	
F			6.6
I			5.08
L	3.18		3.81
Z			1.52

## 9.2 SO-8 package information

Figure 15. SO-8 package outline

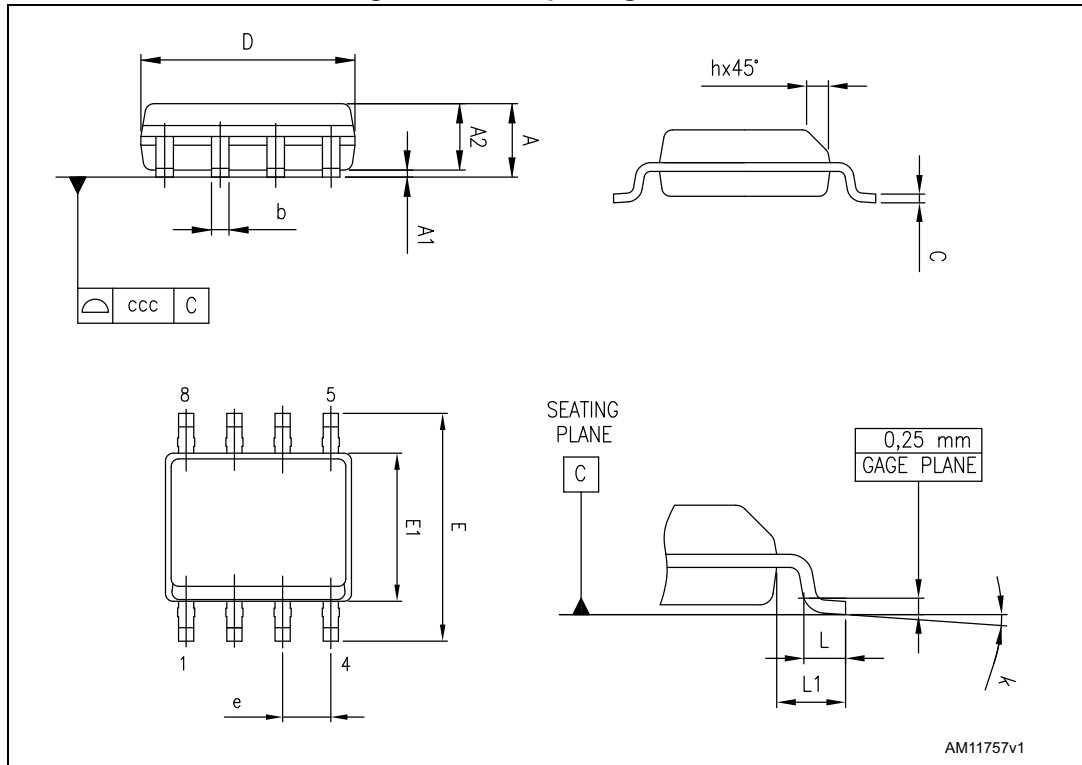


Table 8. SO-8 package mechanical data

Symbol	Dimensions (mm)		
	Min.	Typ.	Max.
A			1.75
A1	0.10		0.25
A2	1.25		
b	0.28		0.48
c	0.17		0.23
D	4.80	4.90	5.00
E	5.80	6.00	6.20
E1	3.80	3.90	4.00
e		1.27	
h	0.25		0.50
L	0.40		1.27
L1		1.04	
k	0°		8°
ccc			0.10

## 10 Order codes

**Table 9. Order codes**

<b>Part number</b>	<b>Package</b>	<b>Packaging</b>
L6388E	DIP-8	Tube
L6388ED	SO-8	Tube
L6388ED013TR	SO-8	Tape and reel



# 11 Revision history

**Table 10. Document revision history**

Date	Revision	Changes
11-Oct-2007	1	First release
29-Feb-2012	2	Updated <a href="#">Table 2</a> , <a href="#">Table 7</a> and <a href="#">Section 6.1</a> . DIP-8 mechanical data and package dimensions have been updated. SO-8 mechanical data and package dimensions have been updated.
31-Jan-2013	3	Update note in <a href="#">Section 2.1</a> .
19-Jun-2014	4	Added <a href="#">Section : Applications on page 1</a> . Updated <a href="#">Section : Description on page 1</a> (replaced by new description). Updated <a href="#">Table 1: Device summary on page 1</a> (moved from page 17 to page 1, renamed title of <a href="#">Table 1</a> ). Updated <a href="#">Figure 1: Block diagram on page 3</a> (moved from page 1 to page 3, added <a href="#">Section 1: Block diagram on page 3</a> ). Updated <a href="#">Section 2.1: Absolute maximum ratings on page 4</a> (removed note below <a href="#">Table 2: Absolute maximum ratings</a> ). Updated <a href="#">Table 5: Pin description on page 5</a> (added "Type" for several pins). Updated <a href="#">Section 9: Package information on page 14</a> (added/updated titles, reversed order of <a href="#">Figure 14</a> and <a href="#">Table 8</a> , <a href="#">Figure 15</a> and <a href="#">Table 9</a> minor modifications). Minor modifications throughout document.
21-Oct-2015	5	Updated <a href="#">Table 1 on page 4</a> (added ESD row). Updated note <a href="#">1</a> . below <a href="#">Table 6 on page 6</a> (replaced $V_{\text{BOOTx}}$ by $V_{\text{BOOTx}}$ ). Added <a href="#">Section 10: Order codes on page 16</a> (moved <a href="#">Table 9</a> from page 1, updated title). Minor modifications throughout document.

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