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SSL1623PH

SMPS IC for mains LED drivers

Rev. 02 — 13 September 2010 **Product data sheet**

1. General description

The SSL1623PH is a Switched Mode Power Supply (SMPS) controller IC that operates directly from the rectified universal AC mains. It is implemented in the high voltage Easy High Voltage Silicon-On-Insulator (EZ-HV SOI) process, combined with a low voltage Bipolar Complementary Metal Oxide Semiconductor (BiCMOS) process.

The device includes a high voltage power switch and a start-up circuit that operates directly from the rectified mains voltage. A dedicated circuit for valley switching is built in, which makes a very efficient slim-line electronic LED driver concept possible.

The SSL1623PH can operate in LED applications with a power range of up to 25 W. Applications below 15 W are more suited to the SSL152x family of mains LED drivers.

In its most basic version of application the SSL1623PH acts as a voltage source. Here no additional secondary electronics are required. A combined voltage and current source can be realized with minimum costs for external components. Implementation of the SSL1623PH renders an efficient and low cost LED power supply system.

2. Features and benefits

- Integrated power switch: 6.5 Ω and 650 V
- Operates from universal AC mains supplies, 80 V to 276 V
- Adjustable frequency for flexible design
- RC oscillator for load insensitive regulation loop constant
- Valley switching for minimum switch-on loss
- Adjustable overcurrent protection
- Undervoltage protection
- Temperature protection
- Short-circuit winding protection
- Safe restart mode for system fault conditions
- Simple application with both primary and secondary (opto) feedback
- 16-pin DIP package

3. Applications

- LED ballasts
- Contour lighting
- LED spotlights
- Channel letter lighting
- Down lighting
- Commercial lighting (retail displays)

4. Quick reference data

Table 1. Quick reference data

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
V_{CC}	supply voltage	continuous	[1]	–0.4	-	+40	V
V_{DRAIN}	voltage on pin DRAIN			–0.4	-	+650	V
I_{DRAIN}	current on pin DRAIN	no auxiliary supply		-	0.5	-	mA
R_{DSon}	drain-source on-state resistance	I_{source} = –0.5 A					
		T_j = 25 °C		-	6.5	7.5	Ω
		T_j = 100 °C		-	9.0	10.0	Ω
f_{osc}	oscillator frequency			10	-	200	kHz

[1] Pins V_{CC} and RC are not allowed to be current driven.

5. Ordering information

Table 2. Ordering information

Type number	Package		
	Name	Description	Version
SSL1623PH	DIP16	plastic dual in-line package; 16 leads (300 mil); long body	SOT38-1

6. Block diagram

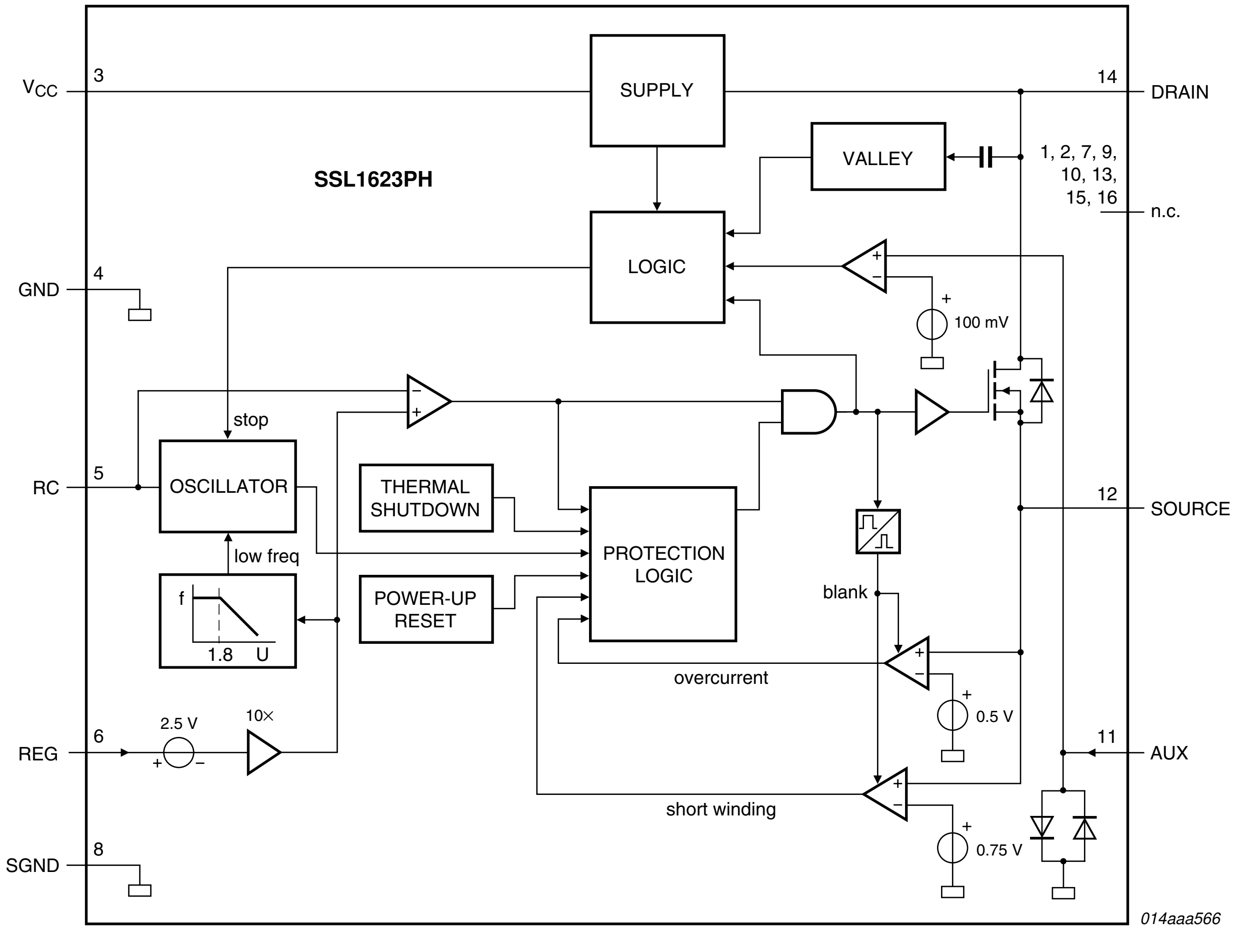


Fig 1. Block diagram of SSL1623PH

7. Pinning information

7.1 Pinning

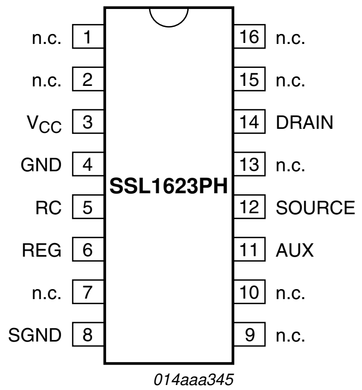


Fig 2. Pin configuration

7.2 Pin description

Table 3. Pin description

Symbol	Pin	Description
V_{CC}	3	supply voltage
GND	4	ground
RC	5	frequency setting
REG	6	regulation input
SGND	8	signal ground; preferably connect to pin GND
AUX	11	input for voltage from auxiliary winding for timing (demagnetization)
SOURCE	12	source of internal Metal-Oxide Semiconductor (MOS) switch
n.c.	1, 2, 7, 9, 10, 13, 15, 16.	not connected
DRAIN	14	drain of internal MOS switch; input for start-up current and valley sensing

8. Functional description

The SSL1623PH is the heart of a compact flyback converter, with the IC placed at the primary side. The auxiliary winding of the transformer can be used for indirect feedback to control the isolated output. This additional winding also powers the IC. A more accurate control of the output voltage and/or current can be implemented with an additional secondary sensing circuit and optocoupler feedback. The SSL1623PH can be used in a constant power mode or in a constant current mode to drive LEDs.

The SSL1623PH uses voltage mode control. The frequency is determined by the maximum transformer demagnetizing time and the time of the oscillator. In the first case, the converter operates in the Self-Oscillating Power Supply (SOPS) mode. In the latter case, it operates at a constant frequency, which can be adjusted with external components R_{RC} and C_{RC}. Furthermore, a primary stroke is started only in a valley of the secondary ringing. This valley switching principle minimizes capacitive switch-on losses.

8.1 Start-up and undervoltage lockout

Initially, the IC is self-supplying from the rectified mains voltage. The IC starts switching as soon as the voltage on pin V_{CC} passes the $V_{CC(startup)}$ level. The supply is taken over by the auxiliary winding of the transformer as soon as V_{CC} is high enough and the supply from the line is stopped for high efficiency operation.

As soon as the voltage on pin V_{CC} drops below the $V_{CC(stop)}$ level, the IC stops switching and restarts from the rectified mains voltage.

8.2 Oscillator

The frequency of the oscillator is set by the external resistor and capacitor on pin RC. The external capacitor is charged rapidly to the $V_{RC(max)}$ level and, starting from a new primary stroke, it discharges to the $V_{RC(min)}$ level. Because the discharge is exponential, the relative sensitivity of the duty factor to the regulation voltage at low duty factor is almost equal to the sensitivity at high duty factors. This results in a more constant gain over the duty factor range compared to systems with a linear sawtooth oscillator. Stable operation at low duty factors is easily realized. For high efficiency, the frequency is reduced as soon as the duty factor drops below a certain value. This is accomplished by increasing the oscillator charge time.

To ensure that the capacitor can be charged within the charge time, the value of the oscillator capacitor should be limited to approximately 1 nF.

8.3 Duty factor control

The duty factor is controlled by the internal regulation voltage and the oscillator signal on pin RC. The internal regulation voltage is equal to the external regulation voltage (–2.5 V) multiplied by the gain of the error amplifier (typically 20 dB).

The minimum duty factor of the switched mode power supply is 0 %. The maximum duty factor is set to 75 % (typical value at 100 kHz oscillation frequency).

8.4 Valley switching

A new cycle is started at the primary stroke when the switch is switched on (see Figure 3). After a certain time (determined by the RC oscillator voltage and the internal regulation level), the switch is turned off and the secondary stroke starts. The internal regulation level is determined by the voltage on pin REG. After the secondary stroke, the DRAIN voltage shows an oscillation with a frequency approximately equal to the value given by Equation 1.

$$\frac{1}{2\pi \times \sqrt{L_p C_p}} \qquad (1)$$

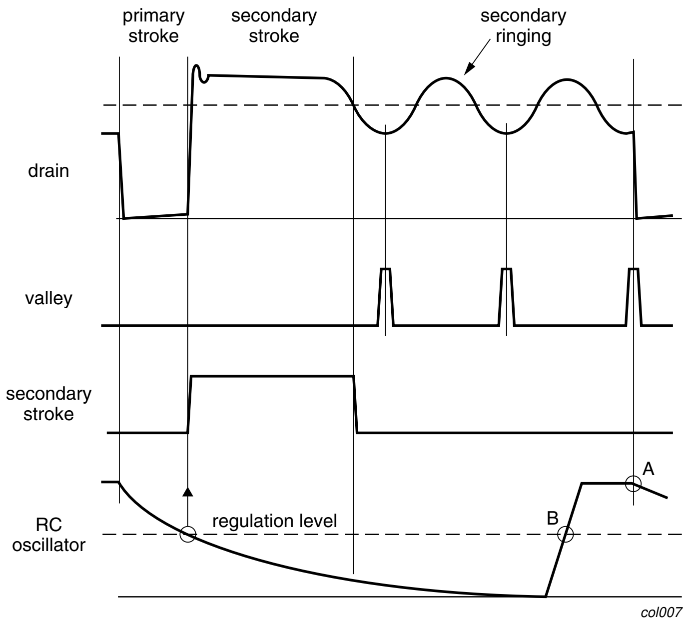
Where:

L_p is the primary self-inductance on the drain node.

C_p is the parasitic capacitance on the drain node.

As soon as the oscillator voltage is high again and the secondary stroke has ended, the circuit waits for a low drain voltage before starting a new primary stroke.

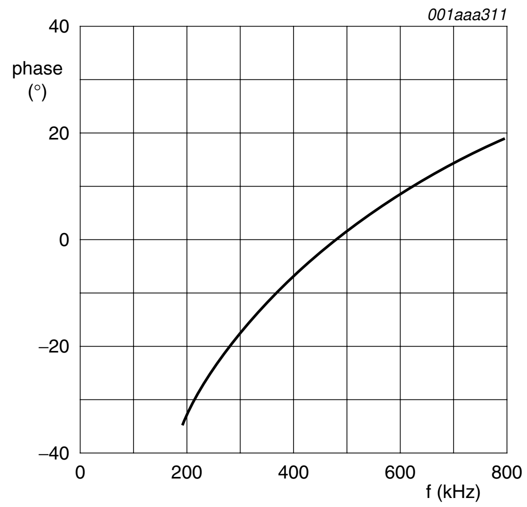
The primary stroke starts some time before the actual valley at low ringing frequencies, and some time after the actual valley at high ringing frequencies. Figure 4 shows a typical curve for a reflected voltage N × V_o of 80 V. This voltage is the output voltage V_o (see Figure 5) transferred to the primary side of the transformer with the factor N (determined by the turns ratio of the transformer). Figure 4 shows that the system switches exactly at minimum drain voltage for ringing frequencies of 480 kHz, thus reducing the switch-on losses to a minimum. At 200 kHz, the next primary stroke is started at 33 ° before the valley. The switch-on losses are still reduced significantly.



A: Start of new cycle with valley switching.

B: Start of new cycle in a classical system.

Fig 3. Signals for valley switching



Reflected voltage at N × V_o = 80 V.

Fig 4. Typical phase of drain ringing at switch-on

8.5 Demagnetization

The system operates in discontinuous conduction mode all the time. As long as the secondary stroke has not ended, the oscillator will not start a new primary stroke. During the suppression time $t_{sup(xfmr\_ring)}$, demagnetization recognition is suppressed. This suppression may be necessary in applications where the transformer has a large leakage inductance and at low output voltages.

8.6 Protection

8.6.1 Overcurrent protection

The cycle-by-cycle peak drain current limit circuit uses the external source resistor R_I (see Figure 5) to measure the current. The circuit is activated after the leading edge blanking time t_{leb}. The protection circuit limits the source voltage to $V_{SOURCE(max)}$ and thus limits the primary peak current.

8.6.2 Short-winding protection

The short-winding protection circuit is also activated after the leading edge blanking time. If the source voltage exceeds the short-winding protection voltage V_{swp}, the SSL1623PH stops switching. Only a power-on reset will restart normal operation. The short-winding protection also protects against a secondary diode short-circuit.

8.6.3 Overtemperature protection

An accurate temperature protection is provided in the SSL1623PH. When the junction temperature exceeds the thermal shutdown temperature, the IC stops switching. During thermal protection the IC current is lowered to the start-up current. The IC continues normal operation as soon as the overtemperature situation has disappeared.

8.6.4 Overvoltage protection

Overvoltage protection can be achieved in the application by pulling pin REG above its normal operation level or by keeping the level of pin AUX above $V_{det(demag)}$. The current primary stroke is terminated immediately and no new primary stroke is started until the voltage on pin REG drops to its normal operation level. Pin REG has an internal clamp. The current feed into pin REG must be limited.

8.7 Characteristics of the complete LED power supply

8.7.1 Input

The input voltage range comprises the universal AC mains from 80 V to 276 V.

8.7.2 Accuracy

The accuracy of the complete converter, functioning as a voltage source with primary sensing, is approximately 8 % (mainly dependent on the transformer coupling). The accuracy with secondary sensing is defined by the accuracy of the external components. For safety requirements in case of optocoupler feedback loss, the primary sensing remains active when an overvoltage circuit is connected.

8.7.3 Efficiency

An efficiency of over 80 % at maximum output power can be achieved for a complete converter designed for universal mains.

8.7.4 Ripple

A minimum ripple is obtained in a system designed for a maximum duty factor of 50 % under normal operating conditions and a minimized dead time. The magnitude of the ripple in the output voltage is determined by the frequency and duty factor of the converter, the output current level, and the value and Equivalent Series Resistance (ESR) of the output capacitor.

9. Limiting values

Table 4. Limiting values

In accordance with the Absolute Maximum Rating System (IEC 60134).

Symbol	Parameter	Conditions		Min	Max	Unit
Voltage						
V_{CC}	supply voltage	continuous	[1]	−0.4	+40	V
V_{RC}	voltage on pin RC		[1]	−0.4	+3	V
V_{SOURCE}	voltage on pin SOURCE			−0.4	+5	V
V_{DRAIN}	voltage on pin DRAIN			−0.4	+650	V
Current						
I_{REG}	current on pin REG		[2]	-	6	mA
I_{AUX}	current on pin AUX		[2]	−10	+5	mA
I_{ch}	charge current	oscillator capacitor		−3	-	mA
I_{source}	source current			−2	+2	A
I_{DRAIN}	current on pin DRAIN			−2	+2	A

Table 4. Limiting values *...continued*

In accordance with the Absolute Maximum Rating System (IEC 60134).

Symbol	Parameter	Conditions		Min	Max	Unit
General						
P_{tot}	total power dissipation	T_{amb} < 50 °C		-	1.7	W
T_{stg}	storage temperature			–55	+150	°C
T_j	junction temperature			–20	+145	°C
V_{ESD}	electrostatic discharge voltage	human body model	[3]			
		pin DRAIN		–1500	+1500	V
		all other pins		–2000	+2000	V
		machine model	[4]	-	-	-
		all pins		–200	+200	V

[1] Pins V_{CC} and RC are not allowed to be current driven.

[2] Pins REG and AUX are not allowed to be voltage driven.

[3] Human body model: equivalent to discharging a 100 pF capacitor through a 1.5 kΩ series resistor.

[4] Machine model: equivalent to discharging a 200 pF capacitor through a 0.75 μH coil and a 10 Ω series resistor.

10. Thermal characteristics

Table 5. Thermal characteristics

Symbol	Parameter	Conditions		Typ	Unit
$R_{th(j-a)}$	thermal resistance from junction to ambient	in free air	[1]	55	K/W

[1] Thermal resistance $R_{th(j-a)}$ can be lower when pin GND is connected to sufficient copper area on the printed-circuit board.

11. Characteristics

Table 6. Characteristics

Measurement valid data T_{amb} = 25 °C; no overtemperature; all voltages are measured with respect to ground; currents are positive when flowing into the IC; unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Supplies						
Pin V_{CC}						
$V_{CC(startup)}$	start-up supply voltage		9	9.5	10	V
$V_{CC(stop)}$	stop supply voltage	undervoltage lockout	7.0	7.5	8.0	V
$I_{CC(oper)}$	operating supply current	normal operation	-	1.3	1.9	mA
$I_{CC(startup)}$	start-up supply current	start-up	-	180	400	μA
I_{ch}	charge current	V_{DRAIN} > 60 V	-	-	-	-
		V_{CC} = 0 V	–650	–520	–390	μA
		V_{CC} = 8.5 V	–375	–275	–175	μA

Table 6. Characteristics *...continued*

Measurement valid data T_{amb} = 25 °C; no overtemperature; all voltages are measured with respect to ground; currents are positive when flowing into the IC; unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Pin DRAIN						
I_{DRAIN}	current on pin DRAIN	no auxiliary supply	-	0.5	-	mA
		with auxiliary supply; V_{DRAIN} > 60 V	-	30	125	μA
Pulse-width modulator mode						
δ_{min}	minimum duty factor		-	0	-	%
δ_{max}	maximum duty cycle	f_{osc} = 100 kHz	-	75	-	%
Self-oscillating power supply mode						
$V_{det(demag)}$	demagnetization detection voltage		50	100	150	mV
$t_{sup(xfmr\_ring)}$	transformer ringing suppression time		1.0	1.5	2.0	μs
Oscillator: pin RC						
$V_{RC(min)}$	minimum voltage on pin RC		60	75	90	mV
$V_{RC(max)}$	maximum voltage on pin RC		2.4	2.5	2.6	V
t_{ch}	charge time		-	1	-	μs
f_{osc}	oscillator frequency		10	-	200	kHz
Duty factor regulator: pin REG						
V_{REG}	voltage on pin REG		2.4	2.5	2.6	V
G_v	voltage gain		-	20	-	dB
$V_{clamp(REG)}$	clamp voltage on pin REG	I_{REG} = 6 mA	-	-	7.5	V
Valley switching recognition						
$(\Delta V/\Delta t)_{vrec}$	valley recognition voltage change with time		−102	-	+102	V/μs
f_{ring}	ringing frequency	N × V_o = 100 V	200	550	800	kHz
$t_{d(vrec-swon)}$	valley recognition to switch-on delay time		-	150	-	ns
Output stage (FET)						
$I_{L(DRAIN)}$	leakage current on pin DRAIN	V_{DRAIN} = 650 V	-	-	125	μA
$V_{BR(DRAIN)}$	breakdown voltage on pin DRAIN	T_j > 0 °C	650	-	-	V
R_{DSon}	drain-source on-state resistance	I_{source} = −0.5 A	-	-	-	-
		T_j = 25 °C	-	6.5	7.5	Ω
		T_j = 100 °C	-	9.0	10.0	Ω
$t_{f(DRAIN)}$	fall time on pin DRAIN	V_{DRAIN} = 300 V; no external capacitor at pin DRAIN	-	75	-	ns
Temperature protection						
T_{prot}	protection temperature		150	160	170	°C
$T_{prot(hys)}$	hysteresis of protection temperature		-	2	-	°C
Overcurrent and short-winding protection: pin SOURCE						
$V_{SOURCE(max)}$	maximum voltage on pin SOURCE	ΔV/Δt = 0.1 V/μs	0.47	0.50	0.53	V

Table 6. Characteristics *…continued*

Measurement valid data T_{amb} = 25 °C; no overtemperature; all voltages are measured with respect to ground; currents are positive when flowing into the IC; unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{swp}	short-winding protection voltage	$\Delta V/\Delta t$ = 0.5 V/µs	0.7	0.75	0.8	V
t_d	delay time	$\Delta V/\Delta t$ = 0.5 V/µs	-	160	185	ns
t_{leb}	leading edge blanking time	both overcurrent and short-winding protection	250	350	450	ns

12. Application information

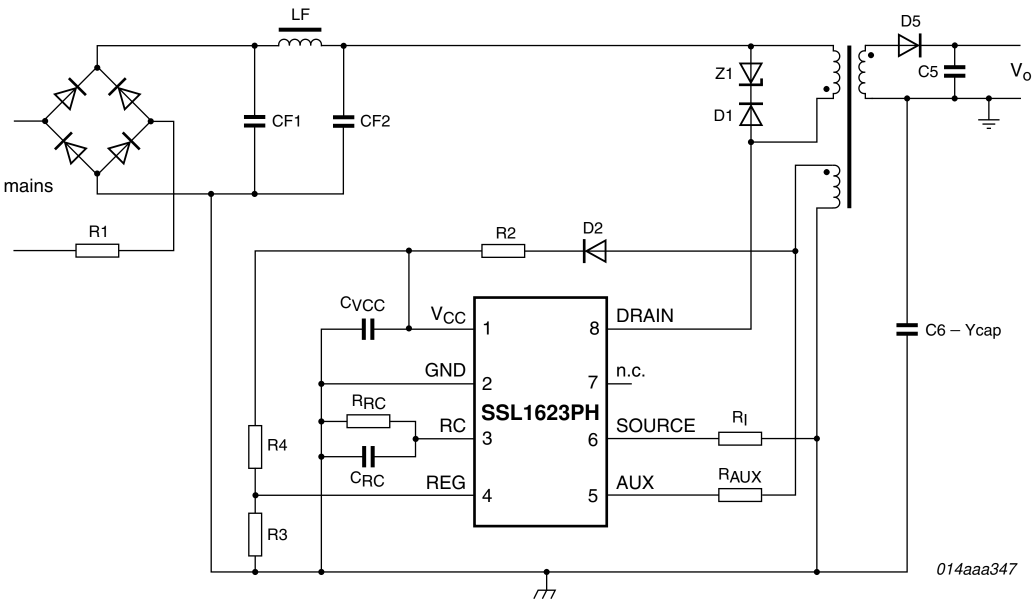
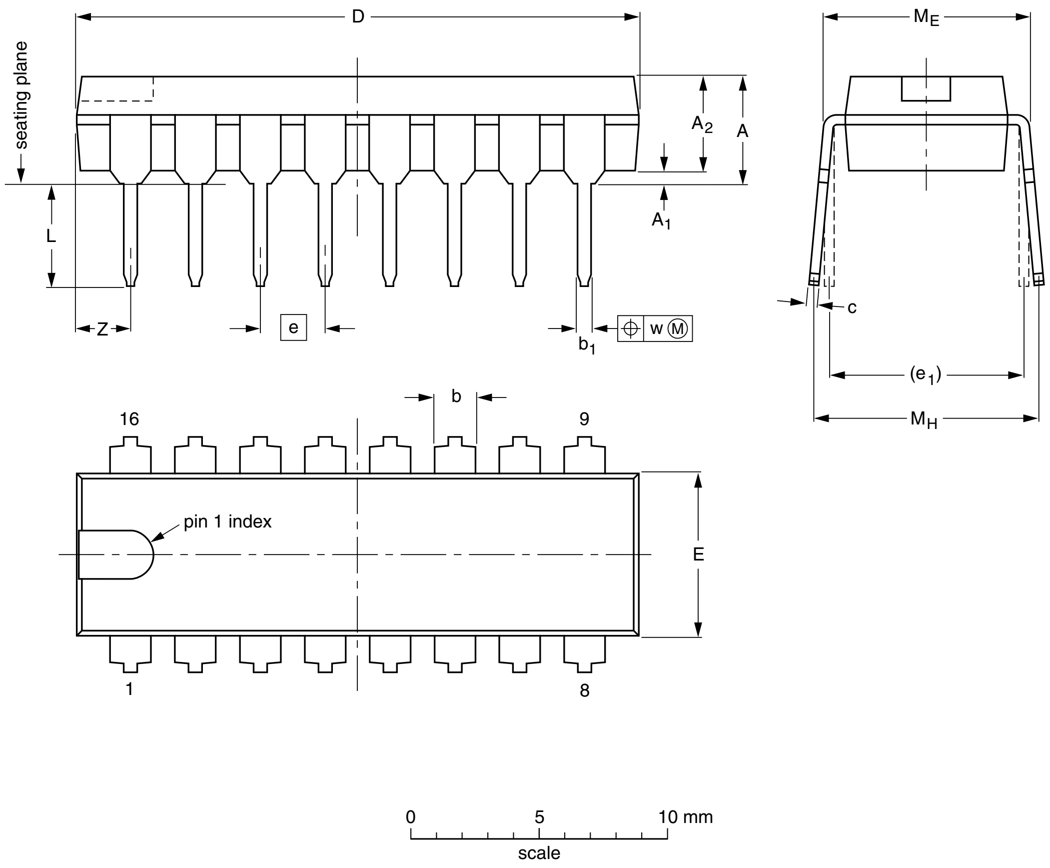


Fig 5. Typical configuration of SSL1623PH - primary sensing

13. Package outline

DIP16: plastic dual in-line package; 16 leads (300 mil); long body **SOT38-1**



DIMENSIONS (inch dimensions are derived from the original mm dimensions)

UNIT	A max.	A_1 min.	A_2 max.	b	b_1	c	D (1)	E (1)	e	e_1	L	M_E	M_H	w	Z (1) max.
mm	4.7	0.51	3.7	1.40 1.14	0.53 0.38	0.32 0.23	21.8 21.4	6.48 6.20	2.54	7.62	3.9 3.4	8.25 7.80	9.5 8.3	0.254	2.2
inches	0.19	0.02	0.15	0.055 0.045	0.021 0.015	0.013 0.009	0.86 0.84	0.26 0.24	0.1	0.3	0.15 0.13	0.32 0.31	0.37 0.33	0.01	0.087

Note

1. Plastic or metal protrusions of 0.25 mm (0.01 inch) maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	JEITA			
SOT38-1	050G09	MO-001	SC-503-16			~~99-12-27~~ 03-02-13

Fig 6. Package outline DIP16

14. Revision history

Table 7. Revision history

Document ID	Release date	Data sheet status	Change notice	Order number	Supersedes
SSL1623PH v.2	20100913	Product data sheet	-	-	SSL1623PH v.1
Modifications:	• Table 1 “Quick reference data” updated • Table 4 “Limiting values” updated				
SSL1623PH v.1	20080915	Product data sheet	-	-	-

15. Legal information

15.1 Data sheet status

Document status[1][2]	Product status[3]	Definition
Objective [short] data sheet	Development	This document contains data from the objective specification for product development.
Preliminary [short] data sheet	Qualification	This document contains data from the preliminary specification.
Product [short] data sheet	Production	This document contains the product specification.

[1] Please consult the most recently issued document before initiating or completing a design.

[2] The term 'short data sheet' is explained in section "Definitions".

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17. Tables

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18. Figures

continued >>

19. Contents

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Date of release: 13 September 2010

Document identifier: SSL1623PH