



# SSL5031BTS

Compact high power factor/low-THD buck LED driver IC

Rev. 1 — 15 October 2014

Preliminary data sheet

## 1. General description

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The SSL5031BTS is a highly integrated, high-precision, non-isolated buck controller with external MOSFET. It is intended to drive LED lamps in universal mains non-dimmable lighting applications up to 25 W. The SSL5031BTS is designed for high power factor/low-THD applications.

The SSL5031BTS operates in Boundary Conduction Mode (BCM) with on-time regulation. Operating in BCM provides a constant output current control with high accuracy. Adaptive switching frequency gives freedom to choose the inductor, which enables the optimization of inductor size, efficiency and EMI.

The SSL5031BTS starts up and operates in switching mode directly from an external resistor without  $dV/dt$  supply or auxiliary supply. This feature simplifies the  $V_{CC}$  supply. It allows a low-cost off-the-shelf inductor to be used, providing flexibility in application design.

The SSL5031BTS comes in a compact TSOP6 package.

The SL5021BTS is suitable for Low-ripple applications. The SSL5031CTS is best for high power factor/Low-THD applications without high temperature foldback function.

## 2. Features and benefits

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- Driving LED strings from a rectified mains supply, high power factor/low-THD
- Small electronic Bill of Materials (BOM) enabling a compact solution and a small, single layer Printed-Circuit Board (PCB) footprint
- Excellent line and load regulation and LED output current accuracy
- Efficient BCM operation with:
  - ◆ No reverse recovery losses in freewheel diode
  - ◆ Zero Current Switching (ZCS) and valley switching for switch turn-on
  - ◆ Minimal inductance value and size required
  - ◆ High efficiency (up to 93 %)
  - ◆ Ultra low IC current during operation ( $< 150 \mu\text{A}$ )
- Many auto-recovery protections:
  - ◆ UnderVoltage LockOut (UVLO)
  - ◆ Cycle-by-cycle OverCurrent Protection (OCP)
  - ◆ Internal OverTemperature Protection (OTP)
  - ◆ Output OverVoltage Protection (OVP)
  - ◆ Output Short Protection (OSP)



- ◆ Thermal foldback protection via a single PTC or NTC resistor
- Compatible with wall switches with built-in standby indicator lights (Hotaru switch)
- IC lifetime meets and exceeds the required LED lamp lifetime

### 3. Applications

- The SSL5031BTS is intended for low-cost, non-isolated LED lighting applications with accurate fixed current output up to 25 W for single mains or universal mains voltage (90 V (AC) to 277 V (AC)).

### 4. Quick reference data

Table 1. Quick reference data

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{CC}$	supply voltage	operating range <a href="#">[1]</a>	9.5	-	16	V
$R_{DSon}$	on-state resistance	of internal switch				
		$T_J = 25\text{ °C}$	-	0.75	-	$\Omega$
		$T_J = 125\text{ °C}$	-	1.20	-	$\Omega$
$I_{i(SW)}$	input current in pin SW	duty cycle < 5 %	-2	-	+2	A
$V_{i(SW)}$	input voltage on pin SW	current limited at 8.8 mA; internal switch off	-0.4	-	+22	V

[1] An internal clamp sets the supply voltage. The current into the VCC pin must not exceed the maximum  $I_{VCC}$  value (see [Table 4](#)).

### 5. Ordering information

Table 2. Ordering information

Type number	Package		Version
	Name	Description	
SSL5031BTS	TSOP6	plastic surface-mounted package; 6 leads	SOT457

## 6. Block diagram

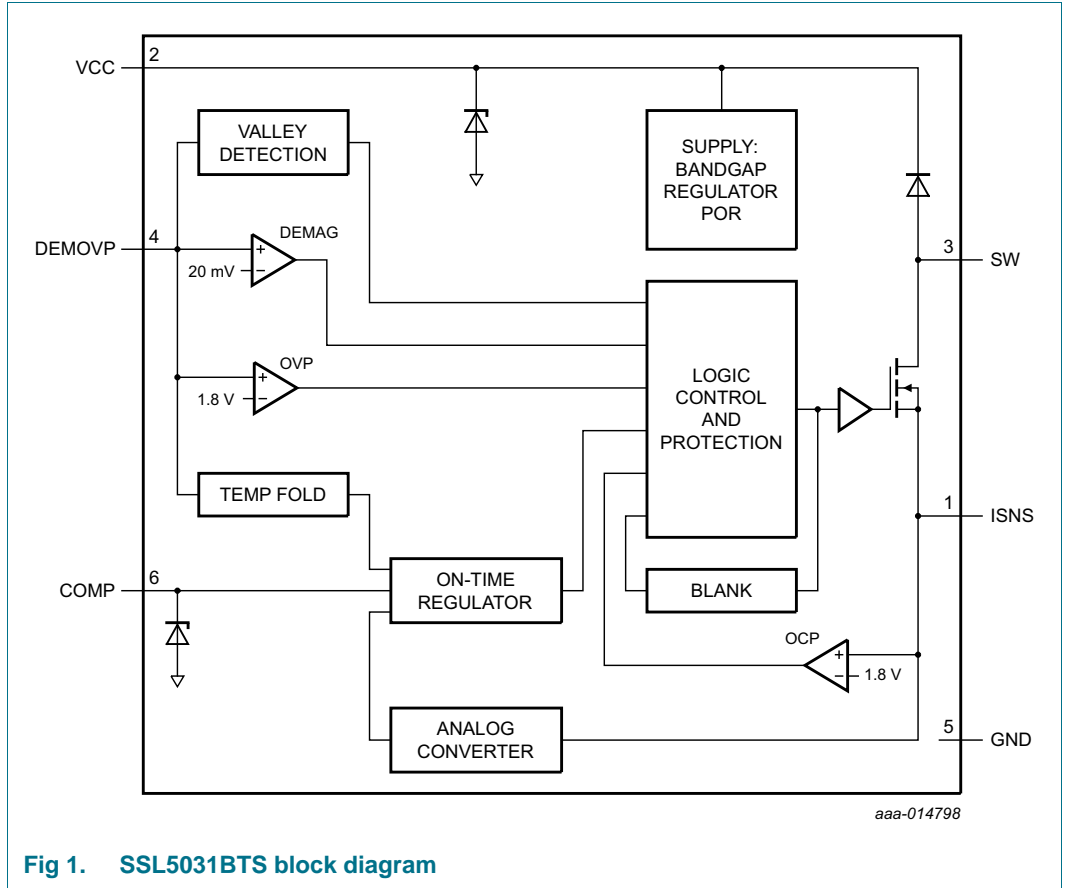


Fig 1. SSL5031BTS block diagram

## 7. Pinning information

### 7.1 Pinning

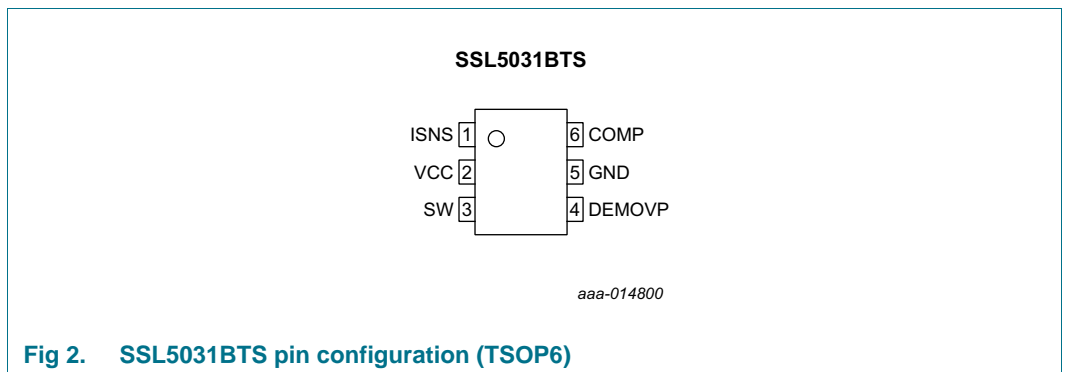


Fig 2. SSL5031BTS pin configuration (TSOP6)

## 7.2 Pin description

Table 3. Pin description

Symbol	Pin	Description
ISNS	1	current sense input
VCC	2	supply voltage
SW	3	internal switch drain
DEMOVP	4	input from LED output for demagnetization timing, valley detection, temperature foldback, and OVP
GND	5	ground
COMP	6	loop compensation to provide a stable response

## 8. Functional description

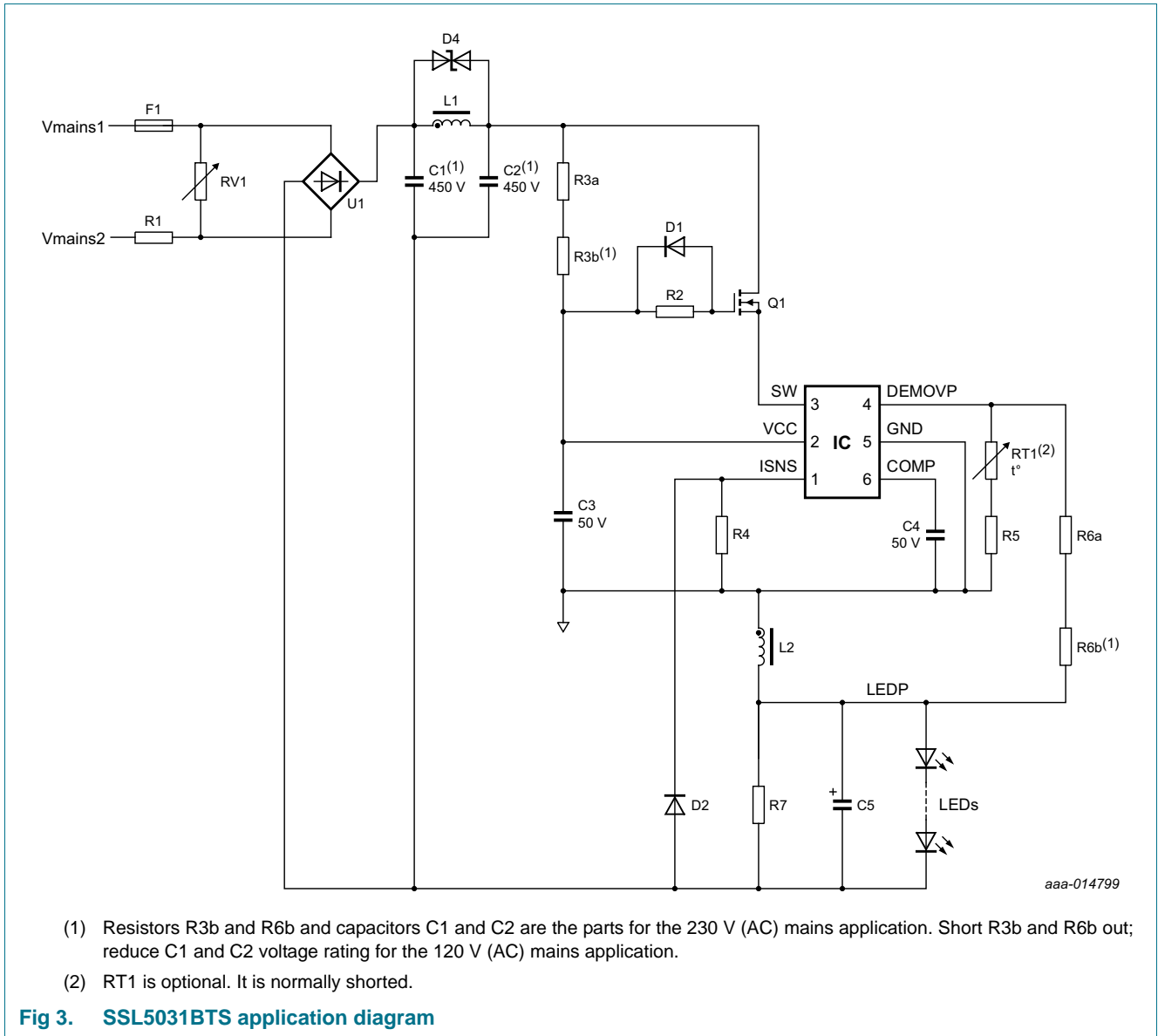
### 8.1 Converter operation

The converter in the SSL5031BTS is a switch, Boundary Conduction Mode (BCM), on-time controlled system. [Figure 3](#) shows the basic application diagram.

The integrated switch is used to save IC supply current. It enables the use a single external resistor as supply even in switching mode. This converter operates at the boundary between Continuous Conduction Mode (CCM) and Discontinuous Conduction Mode (DCM). [Figure 4](#) shows the waveforms.

When the internal switch is switched on at  $t_0$ , the inductor current  $I_L$  builds up from zero in proportional with  $V_{IN} - V_{OUT}$  during the switch-on time ( $t_0$  to  $t_1$ ). Energy is stored in the inductor.

When the internal switch switches off at  $t_1$ ,  $I_L$  drops proportionally to the value of  $V_{OUT}$ . The current flows through the freewheeling diode and the output capacitor ( $t_2$  to  $t_3$ ). When  $I_L$  reaches zero, after a short delay ( $t_3$  to  $t_0$ ), a new switching cycle starts.



### 8.2 On-time control

When measuring the inductor current  $I_L$  using sense resistor R4, the on-time is regulated so that the average regulation voltage on pin ISNS ( $V_{reg(AV)ISNS}$ ) equals an internal reference voltage (0.4 V).  $I_L$  can be calculated with [Equation 1](#):

$$I_L = 0.4 \text{ V} / (R4 + 0.06) \tag{1}$$

Where:

- 0.06 = bond wire resistance of ISNS pin.

### 8.3 Valley detection

After  $I_L$  has decreased to zero at  $t_3$ , the LEDP voltage starts to oscillate around the bus voltage ( $V_{IN}$ ) minus output voltage ( $V_{OUT}$ ) level, with amplitude output voltage ( $V_{OUT}$ ) and frequency ( $f_{ring}$ ). Valley detection is a special circuit that is integrated in the SSL5031BTS. It senses when the LEDP voltage reaches its lowest level (valley) through DEMOVP pin connection. If a valley is detected, the internal switch is switched on again. As a result, the switch-on switching losses are reduced.

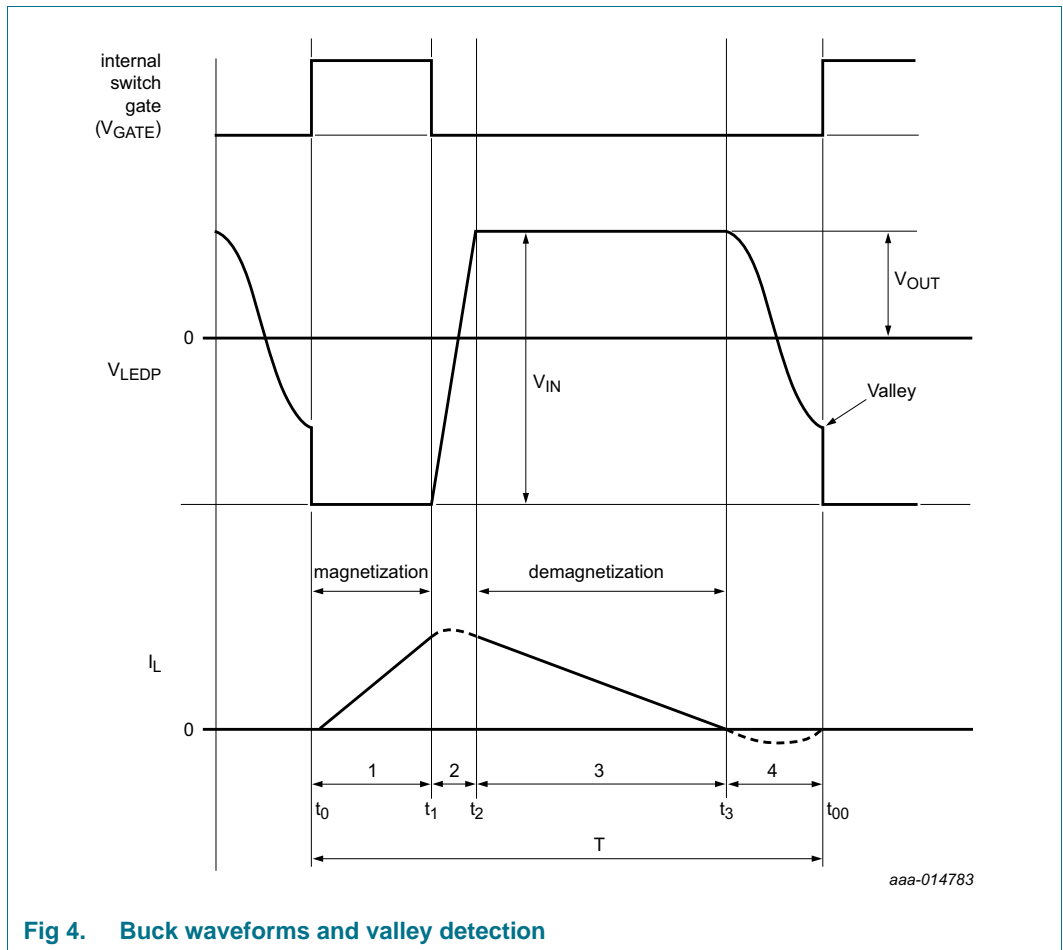


Fig 4. Buck waveforms and valley detection

### 8.4 Start-up current

The supply current for the IC is supplied by resistors R3a and R3b. The IC draws an additional start-up current ( $I_{CC(startup)}$ ) just before  $V_{CC}$  reaches the start-up voltage level ( $V_{startup}$ ). So the supply current in operating mode is lower than during start-up conditions, preventing lamp flicker when the mains voltage is increased or decreased slowly. [Figure 5](#) shows the basic behavior.

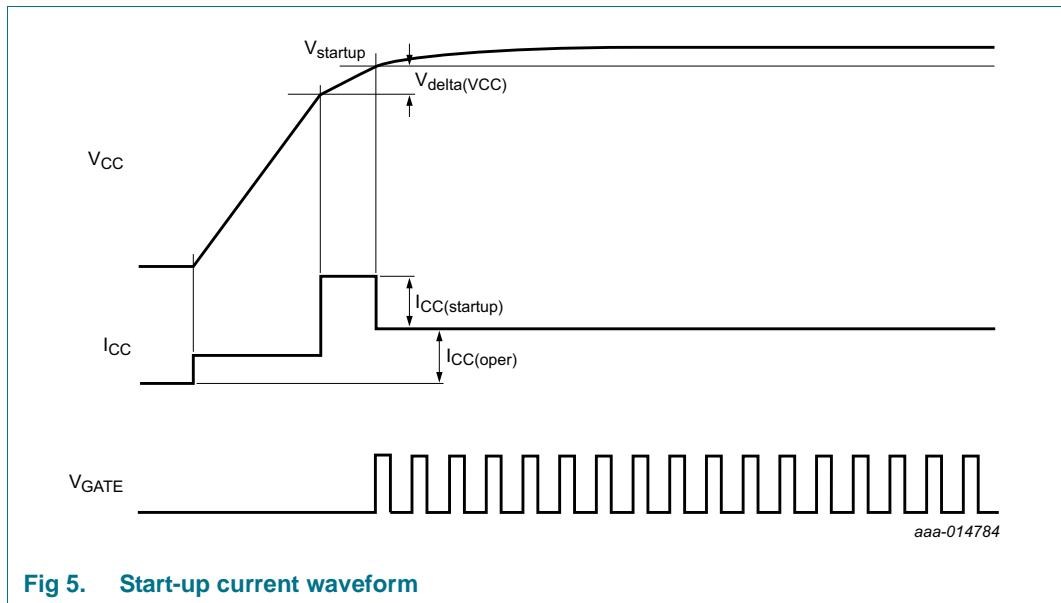


Fig 5. Start-up current waveform

### 8.5 Leading-Edge Blanking (LEB)

To prevent false detection of overcurrent, a blanking time following switch-on is implemented. When the internal switch turns on, a short current spike can occur because of the discharge capacitance of the MOSFET (Q1) drain node.

### 8.6 Magnetization switching

When the mains voltage is very low and close to the LED voltage (V<sub>OUT</sub>), the system hardly delivers any energy to the LED. To improve efficiency, the maximum off-time (T<sub>off(max)</sub>) switching limits the switching frequency to < 25 kHz.

### 8.7 Protections

The IC incorporates the following protections:

- UnderVoltage LockOut (UVLO)
- Cycle-by-cycle OverCurrent Protection (OCP)
- Internal OverTemperature Protection (OTP)
- Cycle-by-cycle maximum on-time protection
- Output OverVoltage Protection
- Output Short Protection (OSP)

#### 8.7.1 UnderVoltage LockOut (UVLO)

When voltage on VCC pin drops to below V<sub>th(UVLO)</sub>, the IC stops switching. An attempt is made to restart IC when the voltage on the VCC pin > V<sub>startup</sub>.

### 8.7.2 Cycle-by-cycle OverCurrent Protection (OCP)

The SSL5031BTS incorporates a built-in peak current detector. It triggers when the voltage at the ISNS pin reaches the peak level  $V_{i(ISNS)max}$ . A resistor connected to ISNS pin senses the current through inductor  $I_L$ . The maximum current in inductor  $I_L$ ,  $I_{L(max)}$  equals:

$$I_{L(max)} = \frac{V_{i(ISNS)max}}{R4 + 0.06} \quad (2)$$

The sense circuit is activated after the leading-edge blanking time ( $t_{leb}$ ). Because the LED current is half the peak current by design, the sense circuit automatically provides protection for the maximum LED current during operation. A propagation delay exists between the overcurrent detection and the actual switch switch-off. Due to this delay, the actual peak current is slightly higher than the OCP level set by the resistor connected in series with the ISNS pin.

### 8.7.3 OverTemperature Protection (OTP)

The converter stops switching when the internal OTP function is triggered at the IC temperature  $T_{pl(IC)}$ . The safe-restart protection is triggered and the IC resumes switching when the IC temperature drops to below  $T_{rst(IC)}$ .

### 8.7.4 Cycle-by-cycle maximum on-time protection

Measuring the inductor current  $I_L$  using sense resistor R4 regulates the on-time. The on-time is limited to a fixed value ( $t_{on(max)}$ ). It protects the system and the IC when the ISNS pin is shorted or when the system works at very low mains voltage.

### 8.7.5 Output OverVoltage Protection (OVP)

An accurate output OVP is implemented by measuring the voltage at the DEMOVP pin during the secondary stroke. The resistive divider connected between the LEDP node and the DEMOVP pin sets the maximum LED voltage.

An internal counter prevents false OVP detection because of noise on the DEMOVP pin. After three continuous cycles with a DEMOVP pin voltage above the OVP level, the OVP protection is triggered.

The over voltage protection triggers a restart sequence: A discharge current ( $I_{CC(dch)}$ ) is enabled and discharges the voltage on the VCC pin to below  $V_{rst(latch)}$ . When  $V_{rst(latch)}$  is reached, the system restarts.

### 8.7.6 Output Short Protection (OSP)

The converter operates in Discontinuous Conduction Mode (DCM). A new cycle is only started after the previous cycle has ended. The end of the cycle is detected by measuring the voltage on the DEMOVP pin. When the DEMOVP pin voltage drops to below the demagnetization level ( $V_{th(comp)DEMOVP}$ ) and a valley is detected, a new cycle starts. When output is shorted, the demagnetization is not finalized within the 40  $\mu$ s. The converter still regulates the adjusted output current and the on-time is reduced to a safe value by this feedback. The reduced on-time in combination with very long demagnetization time prevents that the converter is damaged or excessive dissipation occurs.



A blanking time ( $t_{sup(ring)}$ ) is implemented at the start of the secondary stroke to prevent false demagnetization detection.

### 8.8 Supply management

The IC starts up when the voltage on the VCC pin increases to exceed  $V_{startup}$ . The IC locks out (stops switching) when the voltage on the VCC pin drops to below  $V_{th(UVLO)}$ . The hysteresis between the start and stop levels allows the VCC capacitor to supply the IC during zero-crossings of the mains.

The SSL5031BTS incorporates an internal clamping circuit to limit the voltage on the VCC pin. The clamp limits the voltage on the VCC pin to the maximum value,  $V_{clamp(VCC)}$ . If the maximum current of the external resistor minus the current consumption of the IC is lower than the limiting value of  $I_{VCC}$  in [Table 4](#), no external Zener diode is required.

### 8.9 PTC or NTC function and high-temperature foldback

The PTC function or NTC function can be used as a control method for LED thermal protection. The PTC resistor which is connected to DEMOVP pin senses the temperature. When the voltage on DEMOVP pin is higher than the foldback level ( $V_{fold(DEMOVP)}$ ), the on-time is reduced with the increased DEMOVP pin voltage. Then the average LED current is reduced.

When the temperature keeps increasing, the  $V_{th(OVP)}$  is exceeded. The converter stops switching. The IC restarts when OVP is triggered.

This feature is optional as shown in [Figure 3](#). PTC is normally shorted.

## 9. Limiting values

**Table 4. Limiting values**

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

Symbol	Parameter	Conditions	Min	Max	Unit
<b>Voltages</b>					
$V_{CC}$	supply voltage	current limited <a href="#">[1][2]</a>	-0.4	+18	V
$V_{i(SW)}$	input voltage on pin SW	current limited to 8.8 mA; internal switch off <a href="#">[2]</a>	-0.4	+22	V
$V_{i(ISNS)}$	input voltage on pin ISNS		-0.4	+5	V
$V_{i(COMP)}$	input voltage on pin COMP		-0.4	+5.3	V
$V_{i(DEMOVP)}$	input voltage on pin DEMOVP		-5	+5	V
<b>Currents</b>					
$I_{i(VCC)}$	input current on pin VCC		-	8.8	mA
$I_{i(SW)}$	input current on pin SW	RMS current	-	380	mA
		duty cycle < 5 %	-2	+2	A
$I_{i(ISNS)}$	input current on pin ISNS	duty cycle < 5 %	-2	+2	A

**Table 4. Limiting values ...continued**  
 In accordance with the Absolute Maximum Rating System (IEC 60134).

Symbol	Parameter	Conditions	Min	Max	Unit
<b>General</b>					
P <sub>tot</sub>	total power dissipation	T <sub>amb</sub> < 75 °C	-	0.28	W
T <sub>stg</sub>	storage temperature		-55	+150	°C
T <sub>j</sub>	junction temperature		-40	+160	°C
<b>ESD</b>					
ESD	electrostatic discharge	class 1			
		human body model [3]	-2000	+2000	V
		charged device model [4]	-500	+500	V

- [1] The current into the VCC pin must not exceed the maximum I<sub>(VCC)</sub> value.
- [2] An internal clamp sets the supply voltage and current limits.
- [3] Equivalent to discharge a 100 pF capacitor through a 1.5 kΩ series resistor.
- [4] Charged device model: equivalent to charging the IC up to 1 kV and the subsequent discharging of each pin down to 0 V over a 1 Ω resistor.

## 10. Thermal characteristics

**Table 5. Thermal characteristics**

Symbol	Parameter	Conditions	Typ	Unit
R <sub>th(j-a)</sub>	thermal resistance from junction to ambient	In free air; JEDEC test board	259	K/W
R <sub>th(j-c)</sub>	thermal resistance from junction to case	In free air; JEDEC test board	152	K/W

## 11. Characteristics

**Table 6. Characteristics**

T<sub>amb</sub> = 25 °C; V<sub>CC</sub> = 15 V; all voltages are measured with respect to ground pin (pin 5); currents are positive when flowing into the IC; unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
<b>Supply (pin VCC)</b>						
V <sub>startup</sub>	start-up voltage		-	12.6	-	V
V <sub>th(UVLO)</sub>	undervoltage lockout threshold voltage		-	9.9	-	V
V <sub>delta(VCC)</sub>	delta voltage on pin VCC		-	0.30	-	V
V <sub>clamp(VCC)</sub>	clamp voltage on pin VCC	I <sub>i(VCC)</sub> = 2.6 mA	-	15.8	-	V
V <sub>rst(latch)</sub>	latched reset voltage		-	6.2	-	V
I <sub>CC(oper)</sub>	operating supply current	switching at 100 kHz	-	-	150	μA
I <sub>CC(startup)</sub>	start-up supply current		-	148	-	μA
I <sub>CC(dch)</sub>	discharge supply current	V <sub>CC</sub> = V <sub>rst(latch)</sub>	2.2	-	-	mA

**Table 6. Characteristics ...continued**

$T_{amb} = 25\text{ °C}$ ;  $V_{CC} = 15\text{ V}$ ; all voltages are measured with respect to ground pin (pin 5); currents are positive when flowing into the IC; unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
<b>Loop compensation (pin COMP)</b>						
$V_{ton(COMP)zero}$	zero on-time voltage on pin COMP		-	2.0	-	V
$V_{ton(COMP)max}$	maximum on-time voltage on pin COMP		-	4.0	-	V
$V_{clamp(COMP)}$	clamp voltage on pin COMP		-	4.7	-	V
$t_{on(max)}$	maximum on-time	$V_{i(COMP)} = 4\text{ V}$	-	15.4	-	$\mu\text{s}$
$I_{O(COMP)}$	output current on pin COMP	$V_{i(ISNS)} = 0\text{ V}$	-	3.9	-	$\mu\text{A}$
<b>Valley detection and overvoltage detection (pin DEMOVP)</b>						
$V_{th(ovp)}$	overvoltage protection threshold voltage		-	1.82	-	V
$N_{cy(ovp)}$	number of overvoltage protection cycles		-	3	-	-
$V_{fold(DEMOVP)}$	foldback voltage on pin DEMOVP		-	1.64	-	V
$gm_{DEMOVP}$	transconductance on pin DEMOVP	$V_{i(DEMOVP)}$ to $I_{i(COMP)}$	-	28.5	-	$\mu\text{A/V}$
$V_{th(comp)DEMOVP}$	comparator threshold voltage on pin DEMOVP		-	18	-	mV
$(dV/dt)_{vrec}$	valley recognition voltage change with time		[1]	-3.8	-	V/ $\mu\text{s}$
$t_{sup(xmfr\_ring)}$	transformer ringing suppression time		-	1.5	-	$\mu\text{s}$
<b>Current sensing (pin ISNS)</b>						
$V_{i(ISNS)max}$	maximum input voltage on pin ISNS		-	1.81	-	V
$t_{leb}$	leading edge blanking time		-	420	-	ns
$gm_{ISNS}$	transconductance on pin ISNS	$V_{i(ISNS)}$ to $I_{i(COMP)}$	-	9.5	-	$\mu\text{A/V}$
$V_{reg(AV)ISNS}$	average regulation voltage on pin ISNS		-	0.41	-	V
<b>Driver (pin SW)</b>						
$R_{DSon}$	on-state resistance	$T_j = 25\text{ °C}$	-	0.75	-	$\Omega$
		$T_j = 125\text{ °C}$	-	1.20	-	$\Omega$
$t_{off(max)}$	maximum turn-off time		-	40.7	-	$\mu\text{s}$
<b>Temperature protection</b>						
$T_{pl(IC)}$	IC protection level temperature		-	150	-	$^{\circ}\text{C}$
$T_{rst(IC)}$	IC reset level temperature		-	120	-	$^{\circ}\text{C}$

[1] Guaranteed by design.

12. Package outline

Plastic surface-mounted package (TSOP6); 6 leads

SOT457

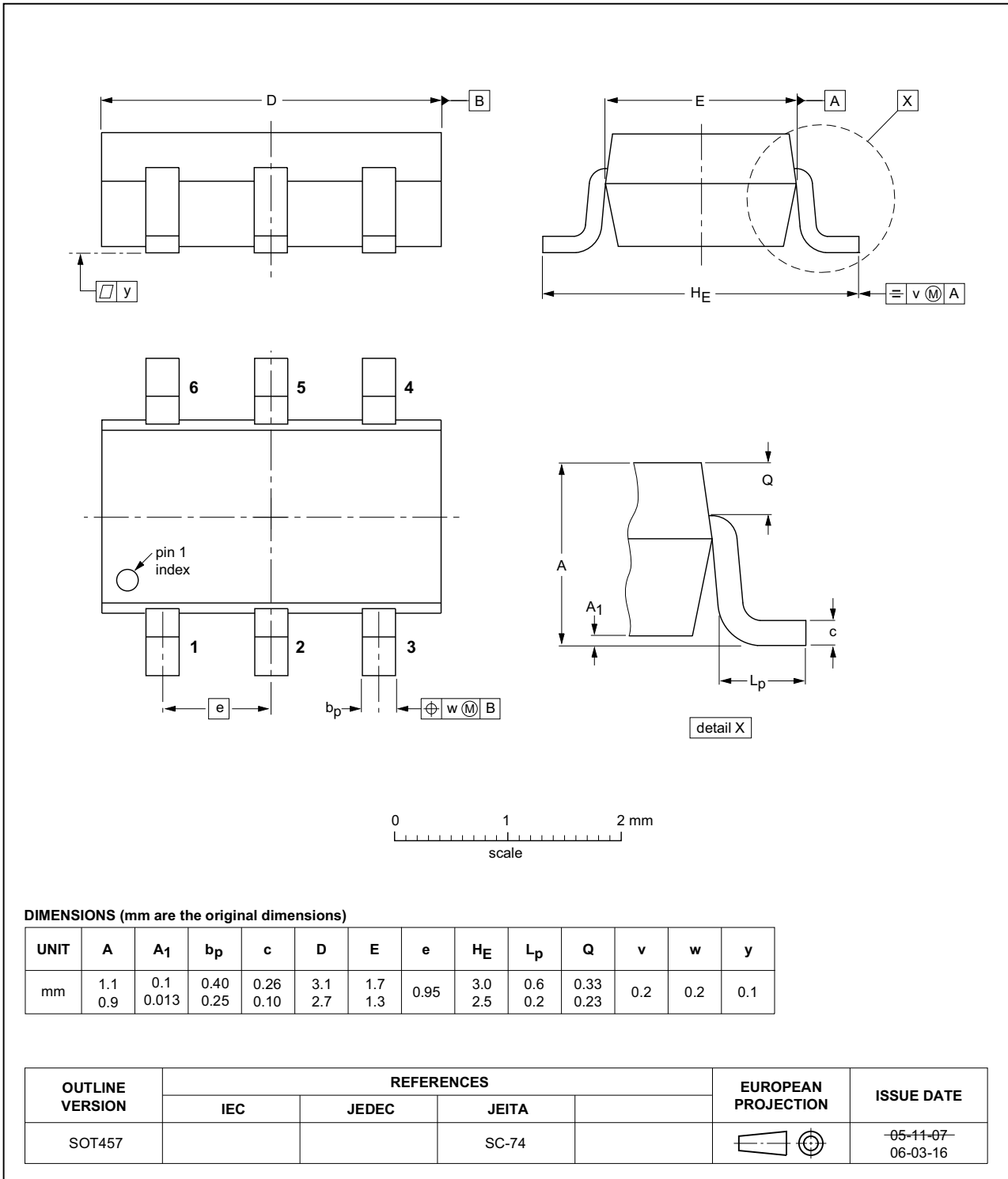


Fig 6. Package outline SOT457 (TSOP6)

## 13. Abbreviations

Table 7. Abbreviations

Acronym	Description
BCM	Boundary Conduction Mode
BOM	Bill Of Materials
LEB	Leading-Edge Blanking
OCP	OverCurrent Protection
OSP	Output Short Protection
OTP	OverTemperature Protection
OVP	OverVoltage Protection
PCB	Printed-Circuit Board
UVLO	UnderVoltage LockOut
ZCS	Zero Current Switching

## 14. Revision history

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Table 8. Revision history

Document ID	Release date	Data sheet status	Change notice	Supersedes
SSL5031BTS v.1	20141015	Preliminary data sheet	-	-

## 15. Legal information

### 15.1 Data sheet status

Document status <sup>[1][2]</sup>	Product status <sup>[3]</sup>	Definition
Objective [short] data sheet	Development	This document contains data from the objective specification for product development.
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For sales office addresses, please send an email to: [salesaddresses@nxp.com](mailto:salesaddresses@nxp.com)

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