SSL5031BTS

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

Rev. 2 — 11 March 2015 **Product data sheet**

1. General description

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

- 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:
    - Minimal 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 91 %)
    - Ultra low IC current during operation (< 150 μA)
- 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)
- Extended IC 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 [1]	9.5	-	16	V
R_{DSon}	on-state resistance	of internal switch				
		T_j = 25 °C	-	0.75	0.90	Ω
		T_j = 125 °C	-	1.20	-	Ω
$I_{I(SW)}$	input current in pin SW	triangle wave; duty cycle < 20 %	−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		
	Name	Description	Version
SSL5031BTS	TSOP6	plastic surface-mounted package; 6 leads	SOT457

6. Block diagram

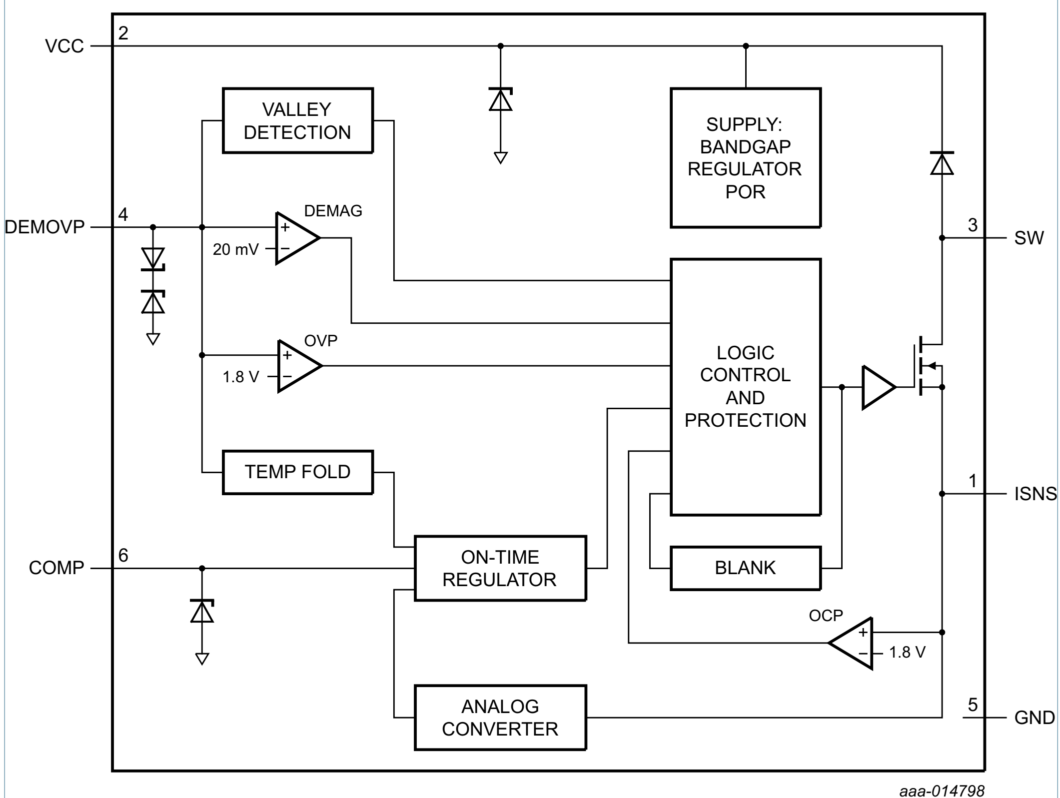


Fig 1. SSL5031BTS block diagram

7. Pinning information

7.1 Pinning

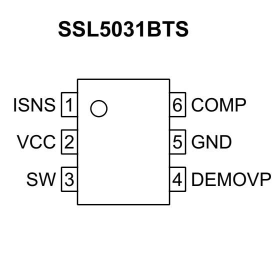


Fig 2. SSL5031BTS pin configuration (TSOP6)

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 SSL5031BTS is a power MOSFET controller. 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 t0, the inductor current I_L builds up from zero in proportional with V_{IN} - V_{OUT} during the switch-on time (t0 to t1). Energy is stored in the inductor.

When the internal switch switches off at t1, I_L drops proportionally to the value of V_{OUT}. The current flows through the freewheeling diode and the output capacitor (t2 to t3). When I_L reaches zero, after a short delay (t3 to t00), a new switching cycle starts.

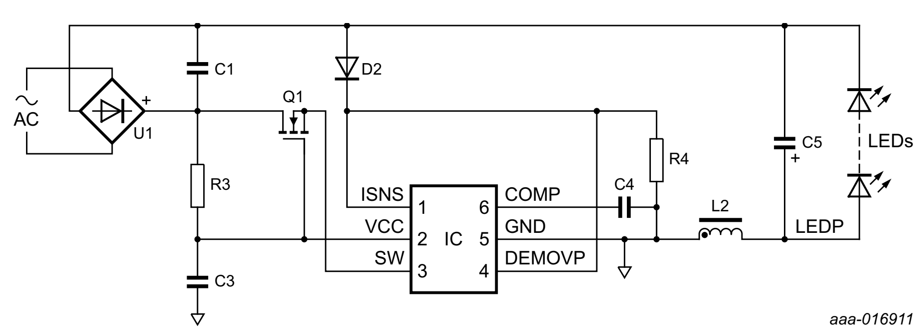


Fig 3. SSL5031BTS basic application diagram

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 regulated voltage on pin ISNS ($V_{intregd(AV)ISNS}$) equals an internal reference voltage. I_L can be calculated with Equation 1:

$$I_L = \frac{V_{intregd(AV)ISNS}}{R4 + 0.09 \times \delta} \quad (1)$$

Where:

- 0.09 = ISNS bond wire resistance.
- δ is the buck topology duty cycle.

8.3 Valley detection

After I_L has decreased to zero at t3, 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.

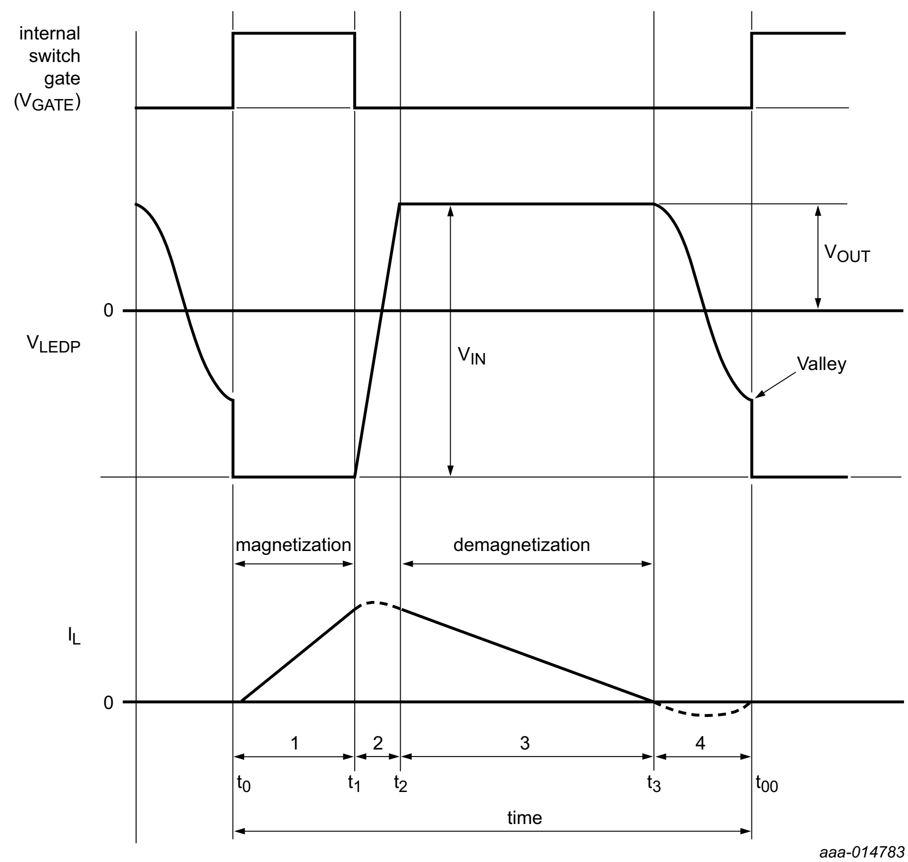


Fig 4. Buck waveforms and valley detection

8.4 Start-up current

The supply current for the IC is supplied by resistor R3. 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.

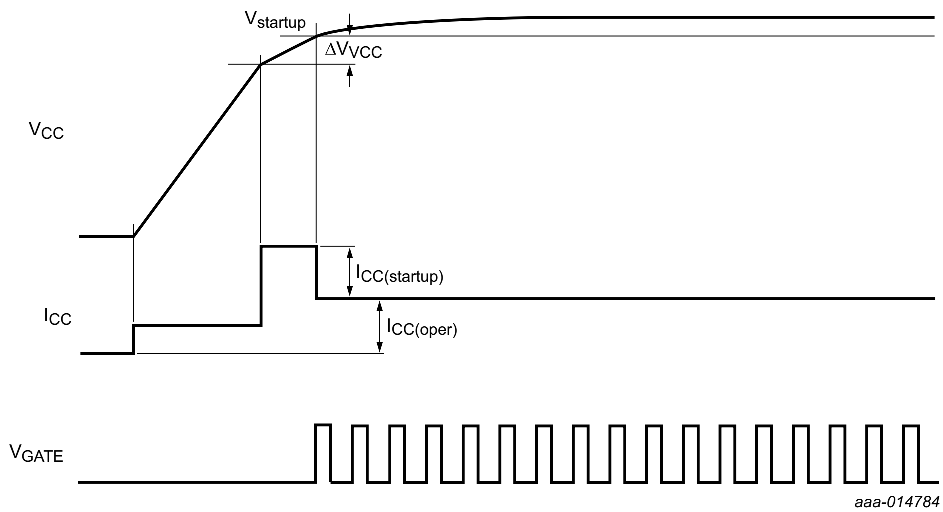


Fig 5. Start-up current waveform

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 around the zero crossing of the mains, the system hardly delivers any energy to the LED. To improve efficiency, the maximum off-time ($t_{off(max)}$) switching limits the switching frequency to < 25 kHz. A peak voltage on the ISNS pin below the $V_{I(min)ISNS}$ voltage indicates a low mains voltage.

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 $V_{th(UVLO)}$, the IC stops switching. An attempt is made to restart IC when the voltage on the VCC pin > $V_{startup}$.

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 $V_{I(max)ISNS}$. A resistor connected to ISNS pin senses the current through inductor I_L. The maximum current in inductor, $I_{L(max)}$ equals:

$$I_{L(max)} = \frac{V_{I(max)ISNS}}{R4 + 0.09} \quad (2)$$

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 junction 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 μs. 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 ($V_{th(fold)}$), 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 6. 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
Voltages						
V_{CC}	supply voltage	current limited	[1][2]	–0.4	+18	V
$V_{I(SW)}$	input voltage on pin SW	current limited to 8.8 mA; internal switch off	[2]	–0.4	+22	V
$V_{I(ISNS)}$	input voltage on pin ISNS			–0.4	+5	V
$V_{IO(COMP)}$	input/output voltage on pin COMP			–0.4	+5.3	V
$V_{I(DEMOVP)}$	input voltage on pin DEMOVP			–6	+6	V
Currents						
$I_{I(VCC)}$	input current on pin VCC			-	8.8	mA
$I_{I(SW)}$	input current on pin SW	RMS current		-	380	mA
		triangle wave; duty cycle < 20%		–2	+2	A
$I_{I(ISNS)}$	input current on pin ISNS	triangle wave; duty cycle < 20%		–2	+2	A
General						
P_{tot}	total power dissipation	T_{amb} < 75 °C		-	0.28	W
T_{stg}	storage temperature			–55	+150	°C
T_j	junction temperature			–40	+160	°C
ESD						
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 $I_{(VCC)}$ 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
$R_{th(j-a)}$	thermal resistance from junction to ambient	In free air; JEDEC test board	259	K/W
$R_{th(j-c)}$	thermal resistance from junction to case	In free air; JEDEC test board	152	K/W

11. Characteristics

Table 6. Characteristics

T_{amb} = 25 °C; V_{CC} = 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
Supply (pin VCC)							
$V_{startup}$	start-up voltage			12.25	12.65	13.05	V
$V_{th(UVLO)}$	undervoltage lockout threshold voltage			9.6	9.9	10.2	V
ΔV_{VCC}	voltage difference on pin VCC			0.17	0.30	0.43	V
$V_{clamp(VCC)}$	clamp voltage on pin VCC	$I_{I(VCC)}$ = 2.6 mA	[1]	15.2	15.8	16.4	V
$V_{rst(latch)}$	latched reset voltage			6.0	6.2	6.4	V
$I_{CC(oper)}$	operating supply current	switching at 100 kHz		100	125	150	μA
$I_{CC(startup)}$	start-up supply current			120	145	170	μA
$I_{CC(dch)}$	discharge supply current	V_{CC} = $V_{rst(latch)}$		3.7	4.8	5.5	mA
Loop compensation (pin COMP)							
$V_{ton(zero)COMP}$	zero on-time voltage on pin COMP			1.96	2.04	2.12	V
$V_{ton(max)COMP}$	maximum on-time voltage on pin COMP			3.8	4.0	4.2	V
$V_{clamp(COMP)}$	clamp voltage on pin COMP			4.3	4.7	5.1	V
$t_{on(max)}$	maximum on-time	$V_{IO(COMP)}$ = 4 V		12.3	15.5	18.7	μs
$I_{O(COMP)}$	output current on pin COMP	$V_{I(ISNS)}$ = 0 V		3.2	4.0	4.8	μA
Valley detection and overvoltage detection (pin DEMOVP)							
$I_{prot(DEMOVP)}$	protection current on pin DEMOVP	open current; $V_{I(DEMOVP)}$ = 0 V		−250	−180	−50	nA
$V_{th(ovp)}$	overvoltage protection threshold voltage			1.74	1.81	1.88	V
$N_{cy(ovp)}$	number of overvoltage protection cycles			-	3	-	-
$V_{th(fold)}$	foldback threshold voltage			1.56	1.64	1.72	V
gm_{DEMOVP}	transconductance on pin DEMOVP	$V_{I(DEMOVP)}$ to $I_{O(COMP)}$		24	29	34	μA/V
$V_{th(comp)DEMOVP}$	comparator threshold voltage on pin DEMOVP			4	18	32	mV
$(dV/dt)_{vrec}$	valley recognition voltage change with time		[2]	-	-3.8	-	V/μs
$t_{sup(xmfr\_ring)}$	transformer ringing suppression time			1.2	1.5	1.8	μs
Current sensing (pin ISNS)							
$V_{I(min)ISNS}$	minimum input voltage on pin ISNS			75	100	125	mV
$V_{I(max)ISNS}$	maximum input voltage on pin ISNS			1.7	1.8	1.9	V
$t_{on(min)}$	minimum on-time		[3]	310	410	510	ns

Table 6. Characteristics *…continued*

T_{amb} = 25 °C; V_{CC} = 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
t_d	delay time	[2][4]	-	100	-	ns
gm_{ISNS}	transconductance on pin ISNS	$V_{I(ISNS)}$ to $I_{O(COMP)}$	8.4	9.7	11.0	μA/V
$V_{intregd(AV)ISNS}$	average internal regulated voltage on pin ISNS		0.396	0.410	0.424	V
Driver (pin SW)						
R_{DSon}	on-state resistance	T_j = 25 °C	-	0.75	0.90	Ω
		T_j = 125 °C	-	1.20	-	Ω
$t_{off(max)}$	maximum turn-off time		30	40	50	μs
Temperature protection						
$T_{pl(IC)}$	IC protection level temperature		140	150	165	°C
$T_{rst(IC)}$	IC reset level temperature		106	118	130	°C

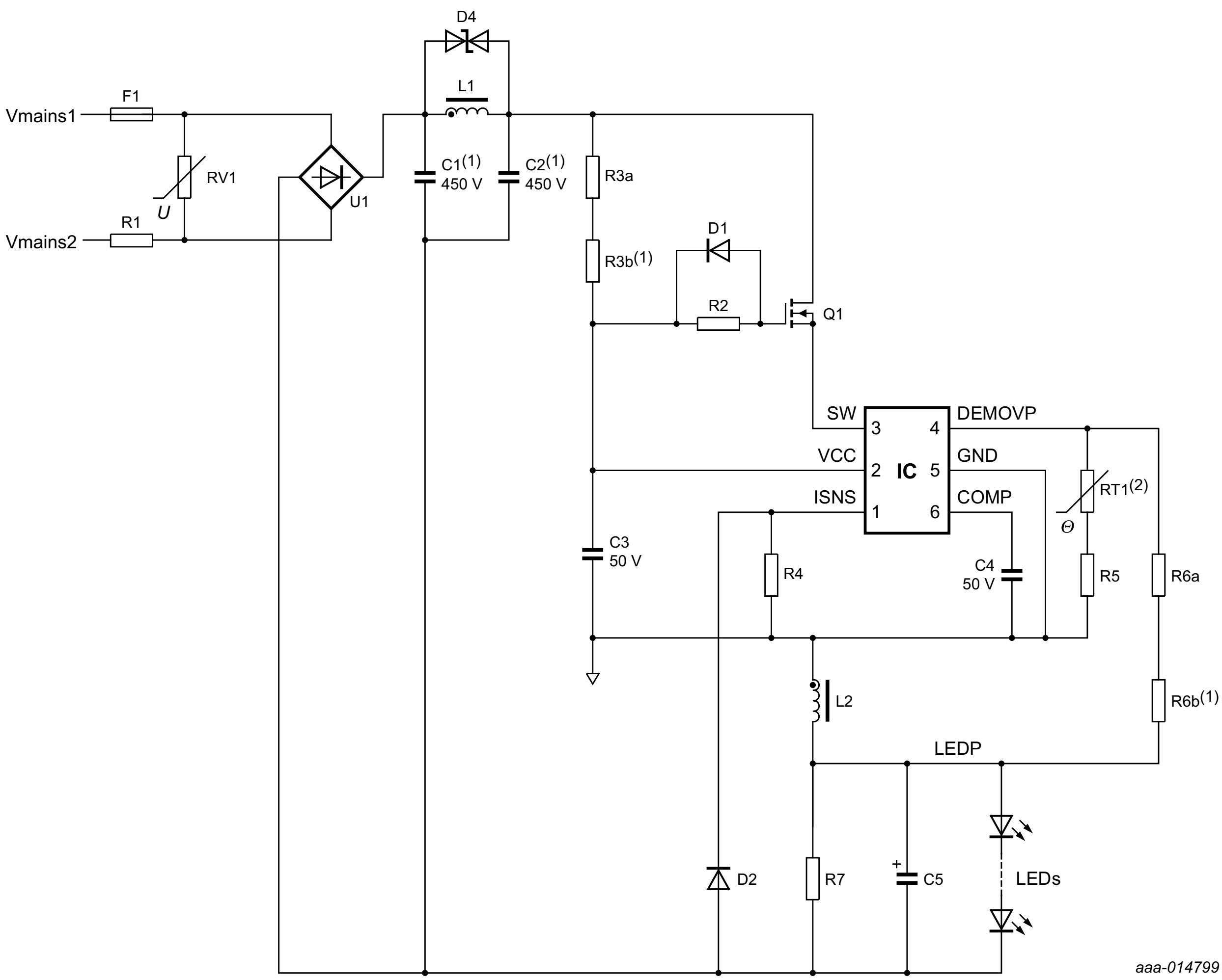
[1] The start-up voltage and the clamp voltage are correlated.

[2] Guaranteed by design.

[3] The minimum on-time is only effective when OCP is triggered.

[4] $t_{leb} = t_{on(min)} - t_d$

12. Application information



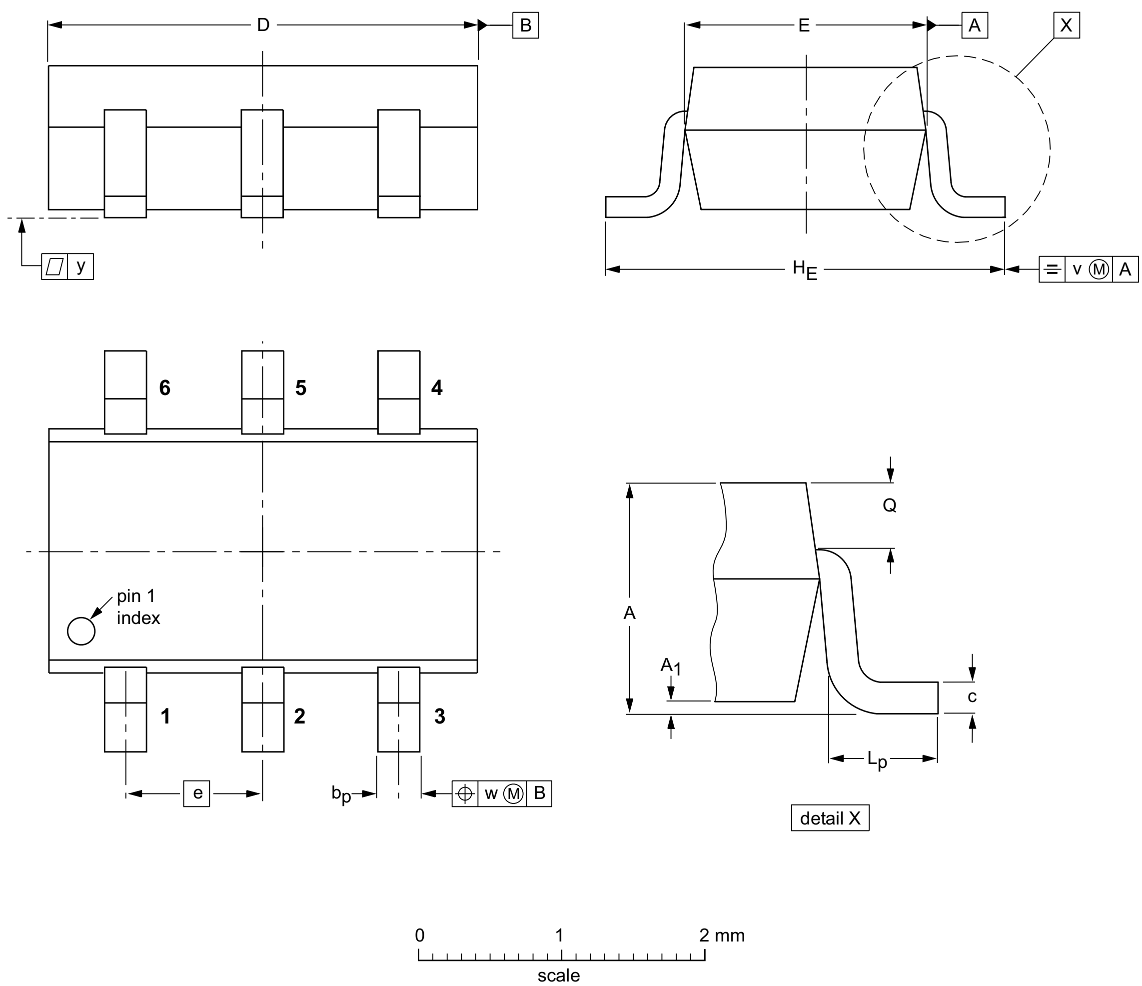
(1) R3b, R6b, C1 and C2 are the parts for the 230 V (AC) mains application. Short R3b and R6b out and reduce C1 and C2 voltage rating for the 120 V (AC) mains application.

(2) RT1 is optional. It is normally shorted.

Fig 6. SSL5031BTS application diagram

13. Package outline

Plastic surface-mounted package (TSOP6); 6 leads **SOT457**



DIMENSIONS (mm are the original dimensions)

UNIT	A	A_1	b_p	c	D	E	e	H_E	L_p	Q	v	w	y
mm	1.1 0.9	0.1 0.013	0.40 0.25	0.26 0.10	3.1 2.7	1.7 1.3	0.95	3.0 2.5	0.6 0.2	0.33 0.23	0.2	0.2	0.1

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	JEITA			
SOT457			SC-74			~~05-11-07~~ 06-03-16

Fig 7. Package outline SOT457 (TSOP6)