UM10795

SSL5031BDB1209 18 W TLED universal mains non-isolated buck LED driver demo board

Rev. 1 — 4 November 2014 User manual

Document information

Info	Content
Keywords	SSL5031BDB1209, SSL5031BTS, LED driver, non-isolated buck topology, T8 applications, HSO8 package
Abstract	This user manual describes the performance, technical data and the connection of the SSL5031BDB1209 demo board, using a non-isolated buck topology. The SSL5031BTS is an NXP Semiconductors driver IC in a TSOP6 package, intended to provide a low cost, small form factor LED driver design. The SSL5031BDB1209 demo board is designed for T8 applications. It is intended to operate at 230 V(AC), with an output voltage around 60 V.

Revision history

Rev	Date	Description
v.1	20141104	first issue

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1. Introduction

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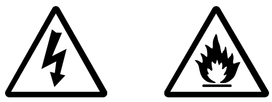
Lethal voltage and fire ignition hazard



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This user manual describes the operation of the SSL5031BDB1209 demo board featuring the SSL5031BTS LED driver in a 100 V to 277 V/18 W non-isolated application.

The SSL5031BDB1209 demo board is designed to drive LED loads from 40 V to 80 V with a nominal value of 550 V for best THD performance over universal mains input.

The PCB dimensions are compatible with T8 tube applications.

The SSL5031BDB1209 demo board provides a simple and effective solution with a high Power Factor (PF), low Total Harmonic Distortion (THD), and high efficiency for Solid-State Lighting (SSL) applications. When, in a buck topology, the LED voltage exceeds 60 V, it can influence THD at low mains voltages.

1.1 Features

- T8 LED tube application
- Open/short LED string protection
- OverCurrent Protection (OCP)
- OverTemperature Protection (OTP)
- PF > 0.92 at 100 V to 264 V (AC), 50 Hz/60 Hz input
- THD < 20 % at 100 V to 264 V (AC), 50 Hz/60 Hz input
- Efficiency > 88 % at 100 V to 264 V (AC) input
- Compliant with IEC61000-3-2 harmonic standard
- Compliant with EN55015 conducted EMI

2. Safety warning

The demo board input is connected to the 230 V mains. Avoid touching the board while it is connected to the mains voltage and when it is in operation. An isolated housing is obligatory when used in uncontrolled, non-laboratory environments. Galvanic isolation from the mains phase using a fixed or variable transformer is always recommended. Figure 1 shows the symbols on how to recognize these devices.

a. Isolated

b. Not isolated

Fig 1. Isolation symbols

3. Specifications

Table 1 lists the specification of the SSL5031BDB1209 demo board.

Table 1. SSL5031BDB1209 specifications

Symbol	Parameter	Value
V_{mains}	AC mains supply voltage	100 V to 240 V (AC); ±10 %
P_{out}	output power	16.1 W
V_{LED}	output voltage	50 V to 65 V (55 V optimum)
I_{LED}	output current	297 mA
I_{ripple}	output current ripple at 100 Hz	15 % (peak-to-peak)
$\Delta I_{LED(Vmains)}/I_{LED(nom)}$	line regulation	1.5 %; V_{mains} = 90 V to 264 V
$\Delta I_{LED(VLED)}/I_{LED(nom)}$	load regulation	0.7 %; V_{LED} = 10 %
η	efficiency	> 88 %; 90 V to 264 V (AC)/50 Hz/60 Hz
PF	power factor	>0.92; 100 V to 264 V (AC)/50 Hz/60 Hz
THD	total harmonic distortion	< 20 %; 90 V to 264 V (AC)/50 Hz/60 Hz
T_{oper}	operating temperature	–40 °C to +85 °C
-	board dimensions	180 mm × 15 mm
-	conducted electrostatic Interference (EMI)	EN55015
-	IEC61000-3-2	Class D (for P_{in} < 25 W limit)

Figure 2 shows the dimensions of the demo board.

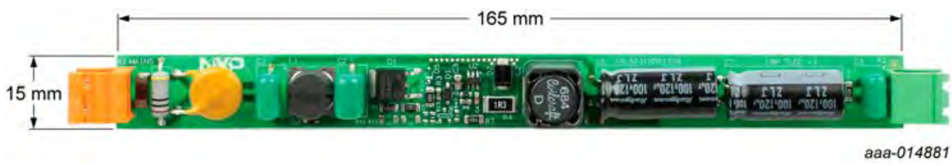


Fig 2. SSL5031BDB1209 demo board dimensions

4. Board photographs

a. Top view

b. Bottom view

Fig 3. SSL5031BDB1209 demo board photographs

5. Board connections

The SSL5031BDB1209 demo board is optimized for a 100 V to 264 V (AC)/50 Hz to 60 Hz mains supply. It is designed to work with multiple LEDs or an LED module.

Under the expected conditions, the output current is 297 mA when using an LED string with a 55 V forward voltage (V_F). The current can be adjusted using resistors R4 and R44. A 55 V LED voltage gives a good THD performance at 120 V (AC) and 230 V (AC). A lower LED voltage gives better THD at 120 V (AC). A higher LED voltage does better for the higher mains voltage.

W1 and W2 are the connections for the mains voltage. J1 (LED+) and J2 (LED–) are the connections for the LED load. Figure 4 shows the connections.

Fig 4. SSL5031BDB1209 board connections

6. Functional description

6.1 Input filtering

Capacitors C1 and C2 and inductor L1 filter the switching current from the buck converter to the line. Capacitors C1 and C2 also provide a low-impedance path for the switching current. To achieve high-frequency suppression to the mains, a high PF, and low THD in the design, the values of capacitors C1 and C2 are kept as low as necessary.

The 10 Ω input series resistance together with the varistor MOV1 across the AC bridge rectifier input provides protection against transient surge voltages. The input resistance is added to increase the immunity to the line surge (see Figure 12). Do not omit this resistor or lower its value.

6.2 Efficiency improvement for universal mains

For single mains, the SSL5031BTS is normally supplied using start-up resistors R1, R2, and R10. To keep the temperature at high mains voltage low, the power losses in these resistors are divided over resistors R1 and R2, while R10 = 0 Ω.

For universal mains, the start-up supply resistors must be set up to start the IC at 90 V (AC). This setup causes much unnecessary dissipation and efficiency loss at 230 V (AC).To avoid the extra loss at high mains, an optional circuit is used (see Figure 5). The efficiency improvement from this circuit is 3 % to 5 % at 230 V (AC). Transistor Q2 is set up as a current limited voltage source. The current limited voltage source is turned off using diode D4 and kept in off-state using capacitor C8 when the SSL5031BTS starts switching. The supply for the IC during switching is coming from the recovered turn-off charge in Q1 which charges capacitor C3.

Resistor R11 limits the current in Q2. Diode D4 and the internal diode in the SSL5031BTS between the SW and VCC pins set the reference voltage. The maximum current is limited to $\frac{D4}{R11} = 255\ \mu A$, the total start-up current required for the SSL5031BTS to start. To achieve flicker suppression at low mains voltages, a voltage control of Q1 is implemented using the voltage divider R11, R12, and R13. The divider is set up to start the SSL5031BTS at 70 V (AC) mains, when capacitors C6 and C7 are fully discharged. If the circuit is turned on just after it has been switched off, the AC mains start-up voltage is higher. The start-up voltage can shift up to 95 V (AC), because of the precharge in capacitors C6 and C7. Generally, there is n * 2.5 V left in output capacitors just after the circuit is switched off (where n = number of single LEDs in series in an LED string).

To switch off the optional circuit, remove resistor R11 and resistor R10 must be 0 Ω.

To protect Q2 from mains surges, resistors R1 and R2 are left in place. Replace resistor R10 with a 2.2 nF capacitor. A small efficiency penalty for the surge protection of Q2 exists.

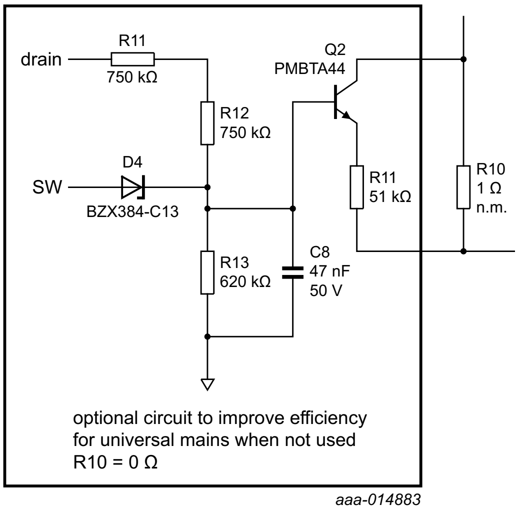


Fig 5. SSL5031BTS efficiency improvement circuit

6.3 THD and LED voltage

Because this application is a universal mains application, the output LED voltage chosen is important. If the chosen value is too low, THD at high voltage is too high. If it is too high, THD at low mains voltage is too high.

To obtain equal distribution of the THD, the optimum LED voltage for the universal mains application is 55 V to 60 V (see Figure 8).

6.4 Open-load protection

The driver board is protected when the LED load is accidentally left open. The open-load protection is a non-latched protection. Two circuits set the open-load output voltage. One circuit sets the open-load output voltage when the IC does not operate because of a defect. The other circuit sets it when the IC is operating normally. In all cases, the output voltage must never exceed the rated DC voltage of the output capacitor.

Do not reconnect the LEDs directly after an open load situation. The output capacitor is charged to a higher voltage than the total LED voltage, which forces an uncontrolled discharge current through the LEDs when connected. It can damage the LEDs permanently.

IC not operating:

The voltage divider consisting of R1, R2, and R10 sets the output voltage in the VCC pin of the IC referenced to the GND pin of the IC and resistor R9.

$$V_{out} = \frac{(V_{drain} - 15) \cdot R9}{(R1 + R2 + R9 + R10)} \qquad (1)$$

If the optional circuit (see Figure 5) is used, the current (set by $\frac{D4}{R11}$) and the parallel current path (set by resistors R11, R12, and R13 and diode D4) set the output voltage at 260 V (AC), the total current is about 285 μA.

As a rule of thumb, limit resistor R9 to $\frac{(n \times 2.5\ V)}{285\ \mu A}$. In this way, the voltage is not sufficient to illuminate the LEDs (n is the number of LEDs in series at the output).

The non-operating output voltage must not be equal to or exceed the voltage set by the operating mode. It is good practice to set the level in non-operating mode 5 V to 10 V lower than in operating mode.

IC operating:

When the voltage in the non-operating mode is set to a safe level for the output capacitor, the voltage in the operating mode can be set. The DEMOVP pin detects overvoltage. It triggers when 4 consecutive high-frequency cycles at 1.8 V are detected at the DEMOVP pin. $V_{out} = \frac{(R5 + R6 + R7 + R8)}{(R5 + R6)}$ sets the output voltage.

The output voltage must never exceed the rated DC voltage of the output capacitor.

6.5 External overtemperature protection and LED current foldback

Figure 12 shows the footprints of resistors R5 and R6. The purpose of these resistors is to provide thermal protection. To reduce light output when using output current foldback, the DEMOVP pin can be used as an input. Replace resistor R5 by a 470 Ω PTC resistor. Resistor R6 is kept at 5.1 kΩ. If the foldback option is not used, resistor R5 can be shorted and resistor R6 can be set to 5.6 kΩ. Do not use a value > 18 kΩ for resistor R6. If the value of resistor R6 is increased too much, the DEMOVP pin can cause false OVP triggering.

6.6 Sense resistors

To optimally profit from the excellent current stability of the SSL5031BTS, overtemperature 50 ppm MELF type resistors are preferred to sense the LED current. The output current stability drops to 3 % compared to 7 % over the full temperature range for normal 200 ppm 1206 type resistors.

When the sense resistor is operating at high temperatures, its power rating must be rated by a factor 2.

To keep the temperature at high power low (< 80 °C) when the board is operating at room temperature level, a 1 W power resistor is used.

7. Performance

7.1 Efficiency

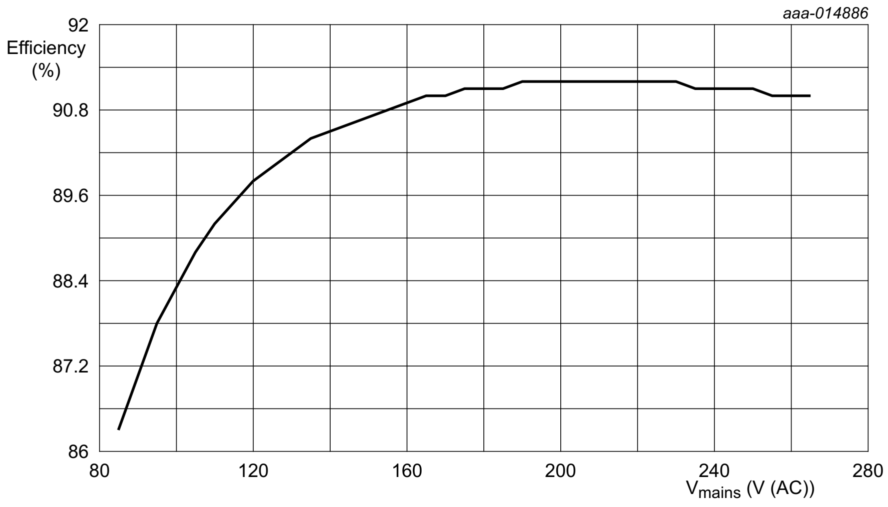


Fig 6. Efficiency as a function of mains voltage

7.2 Power factor

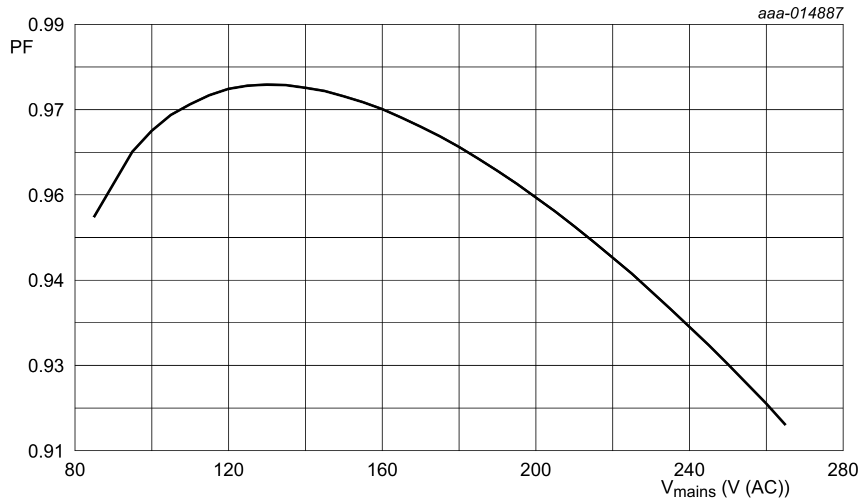


Fig 7. Power factor as a function of mains voltage

7.3 Total harmonic distortion

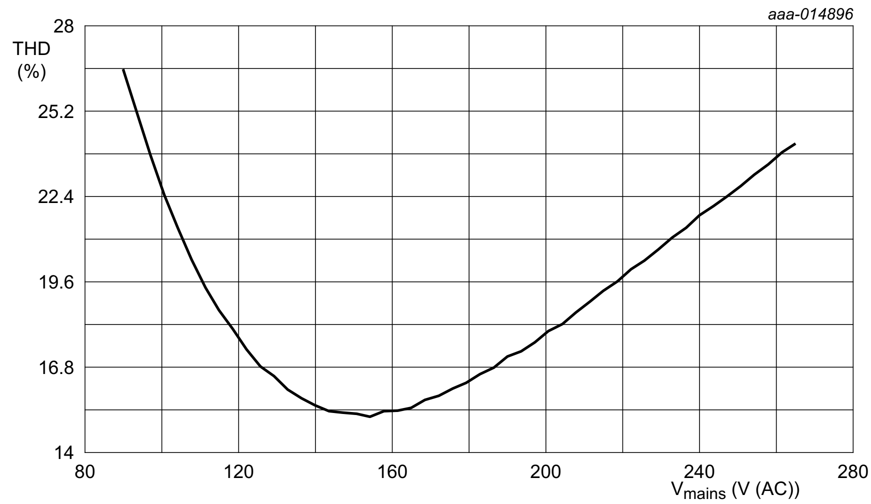


Fig 8. Total harmonic distortion as a function of mains voltage

7.4 Line regulation

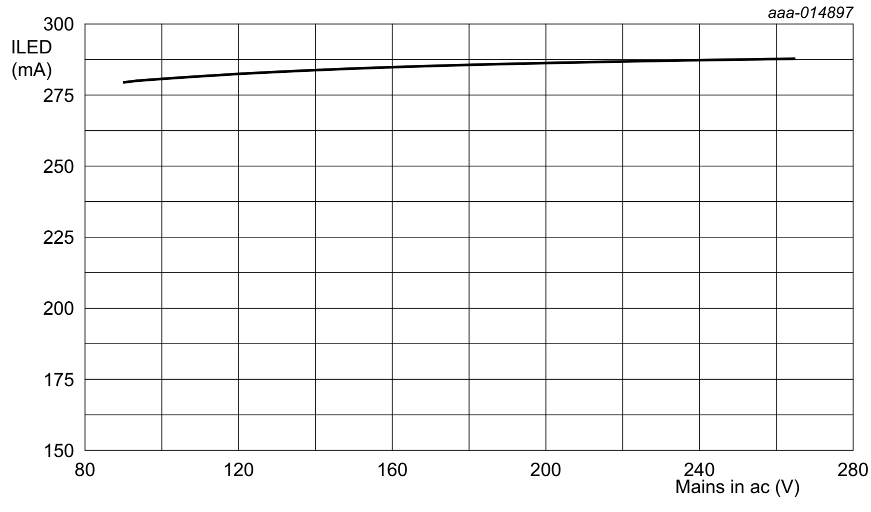
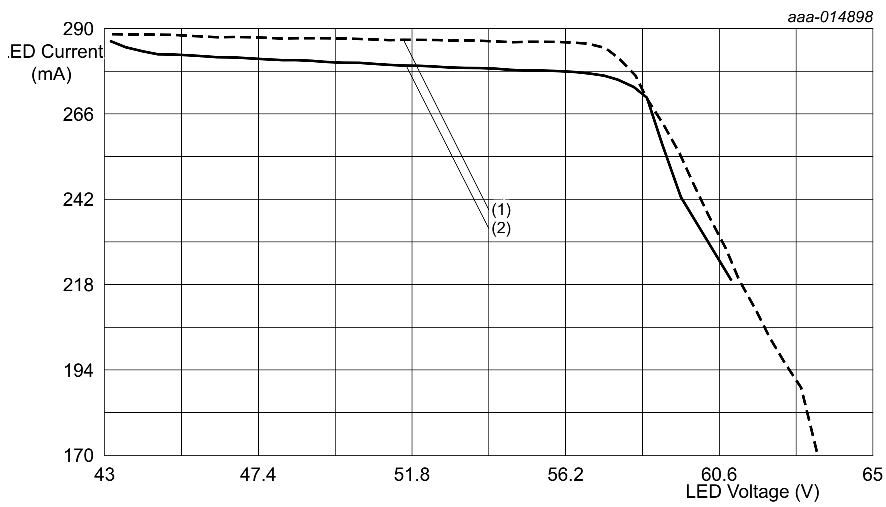


Fig 9. Output LED current as a function of mains voltage

7.5 Load regulation



(1) V_{mains} = 230 V (AC)

(2) V_{mains} = 90 V (AC)

Fig 10. LED current as a function of LED voltage

7.6 ElectroMagnetic Interference (EMI)

Figure 11 shows the conducted EMI result of the SSL5031BDB1209 demo board.

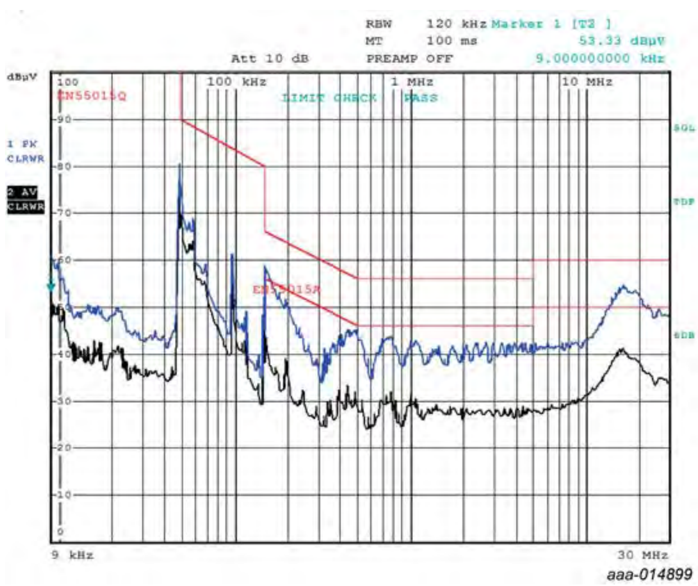


Fig 11. EMI performance

8. Schematic

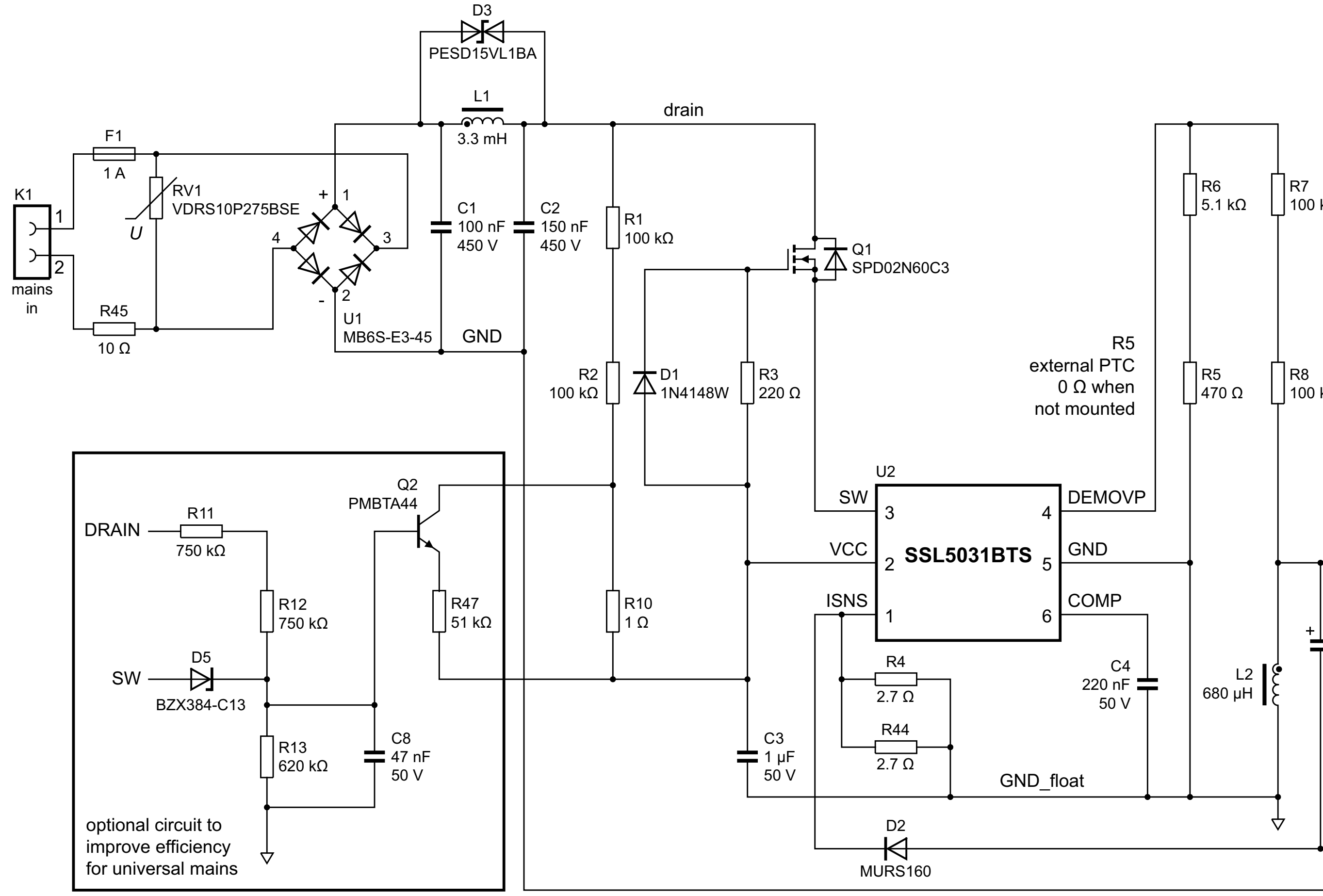


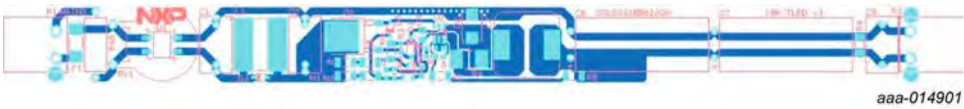
Fig 12. SSL5031BDB1209 demo board schematic

9. Bill Of Materials (BOM)

Table 2. SSL5031BDB1209 bill of materials

Reference	Description and values	Part number	Manufacturer
BD1	bridge rectifier; 600 V; 0.8 A	B6S-G	Comchip Tech
C1	capacitor; 0.1 μF; 450 V	CL21-450V-0.1μF-K	ZhongShan AIDI Electronics
C2	capacitor; 0.15 μF; 450 V	CL21-450V-0.15μF-K	ZhongShan AIDI Electronics
C3	capacitor; 1 μF; 50 V; X7R; 0805	UMK212B7105KG-T	Taiyo Yuden
C4	capacitor; 0.22 μF; 10 %; 50 V; X7R; 0603	UMK107B7224KA-TR	Taiyo Yuden
C6; C7	capacitor; 120 μF; 100 V	100ZLJ120M10X25	Rubycon
C8	capacitor; 47 nF; 10 %; 50 V; X7R; 0603	C0603C473K5RACTU	KEMET
C9	capacitor; 100 nF; 10 %; 450 V	CL21-450V-0.1μF-K	ZhongShan AIDI Electronics
D1	diode; 100 V; 300 mA	1N4148W-7-F	Diode Inc.
D2	diode; fast; 600 V; 1 A	MURS160-E3-52T	Vishay
D3	diode; TVS; 15 V; 5 A	PESD15VL1BA	NXP Semiconductors
D5	diode; Zener; 13 V; 250 mA	BZX384-C13	NXP Semiconductors
F1	fuse; 250 V (AC); 1 A; 2410	MF2410F1.000TM	AEM
K1	terminal block; 2p; 5.08 mm	1508060000	Weidmüller
K2	terminal block; 2p; 5.08 mm	20020109-H021A01LF	FCI
L1	inductor; 3300 μH	SDR1006-332KL	Bourns
L2	inductor, 680 μH	MSS1210-6824KLB	Coilcraft
Q1	MOSFET-N; 650 V; 1.8 A	SPD02N60C3	Infineon
Q2	transistor; 500 V; NPN	PMBT45	NXP Semiconductors
R1; R2; R7; R8	resistor; 100 kΩ; 1 %; 250 mW; 1206	-	-
R3	resistor; 220 Ω; 1 %; 125 mW; 0805	-	-
R4; R44	resistor; 2.7 Ω;	MCFRFTDV2R70	Multicomp
R5	resistor; 470 Ω; 1 %; 63 mW; 0603	-	-
R6	resistor; 5.1 kΩ; 1 %; 63 mW; 0603	-	-
R9	resistor; 82 kΩ; 1 %; 250 mW; 1206	-	-
R10	resistor; 1 Ω; 1 %; 250 mW; 1206	-	-
R11; R12	resistor; 750 kΩ; 1 %; 250 mW; 1206	-	-
R13	resistor; 620 kΩ; 1 %; 63 mW; 0603	-	-
R45	resistor; 10 Ω; 10 %; 2 W; EMC	EMC2-10RK	Welwyn Components
R47	resistor; 51 kΩ; 1 %; 63 mW; 0603		
RV1	resistor; VDR; 275 V; 63 J	VDRS10P275BSE	Bourns
U1	IC; SSL5031BTS; HSO8	SSL5031BTS	NXP Semiconductors

10. Board layout



a. Top view

b. Bottom view

Fig 13. SSL5031BDB1209 demo board layout

11. Abbreviations

Table 3. Abbreviations

Acronym	Description
EMI	ElectroMagnetic Interference
LED	Light-Emitting Diode
OCP	OverCurrent Protection
OTP	OverTemperature Protection
PF	Power Factor
SSL	Solid-State Lighting

12. References

[1] **SSL5031BTS data sheet —** Compact high power factor/low-THD buck LED driver IC

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