UM10841

SSL5021BDB1268 120 V 6 W candle non-isolated low ripple buck LED driver demo board with bipolar switch

Rev. 1.1 — 17 December 2014 **User manual**

Document information

Info	Content
Keywords	SSL5021BDB1268, SSL5021BTS, LED driver, non-isolated buck topology, candle-form applications, TSOP6 package, bipolar switch
Abstract	This user manual describes the performance, technical data, and the connection of the SSL5021BDB1268 demo board. The demo board uses a bipolar switching transistor in a non-isolated buck topology. The SSL5021BTS is an NXP Semiconductors driver IC in a TSOP6 package. It is intended to provide a low-cost, small form factor LED driver design. This SSL5021BDB1268 demo board is designed for candle-form applications. It operates at 120 V (AC), with an output voltage of approximately 60 V.

Revision history

Rev	Date	Description
v.1.1	20141217	updated issue
v.1	20141022	first issue

Contact information

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1. Introduction

WARNING

Lethal voltage and fire ignition hazard

The non-insulated high voltages that are present when operating this product, constitute a risk of electric shock, personal injury, death and/or ignition of fire.

This product is intended for evaluation purposes only. It shall be operated in a designated test area by personnel qualified according to local requirements and labor laws to work with non-insulated mains voltages and high-voltage circuits. This product shall never be operated unattended.

This user manual describes the operation of the SSL5021BDB1268 demo board featuring LED driver SSL5021BTS in a 120 V/6 W non-isolated application.

The SSL5021BDB1268 demo board is designed for driving LED loads from 40 V to 65 V with a nominal value of 60 V.

The PCB dimensions are compatible with candle applications.

The SSL5021BDB1268 demo board provides a simple and effective solution with a low output current ripple and high efficiency for Solid-State Lighting (SSL) applications.

1.1 Features

- Low-cost design
- Candle form/GU-10 applications
- Open LED string protection (optional)
- Short LED string protection
- OverCurrent Protection (OCP)
- OverTemperature Protection (OTP)
- Efficiency > 88 % at 230 V (AC) nominal input
- Compliant with IEC61000-3-2 harmonic standard
- Compliant with EN55015 and FCC15 conducted EMI

2. Safety warning

The demo board input is connected to the mains voltage. 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.

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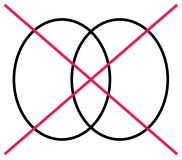
a. Isolated



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b. Not isolated

Fig 1. Isolation symbols

3. Specifications

Table 1 lists the specification of the SSL5021BDB1268 demo board.

Table 1. SSL5021BDB1268 specifications

Symbol	Parameter	Value
V_{mains}	AC mains supply voltage	120 V (AC); ±10 %
P_{out}	output power	5.1 W
V_{LED}	output voltage	40 V to 65 V (60 V nominal)
I_{LED}	output current	85 mA
$I_{LED(ripple)}$	output current ripple	< 3 % (120 Hz)
$\Delta I_{LED}/\Delta I_{LED(nom)Vmains}$	line regulation	1.0 % at V_{mains}; ±10 %
$\Delta I_{LED}/\Delta I_{LED(nom)VLED}$	load regulation	0.5 % at V_{LED}; ±10 %
η	efficiency	88 % at 120 V (AC)/60 Hz
PF	power factor	> 0.55 at 120 V (AC)/60 Hz
T_{oper}	operating temperature	−40 °C to +105 °C
-	board dimensions	60 mm × 40 mm
-	conducted electrostatic Interference (EMI)	EN55015; FCC15
-	IEC61000-3-2	class D (for P_{in} < 25 W limit)

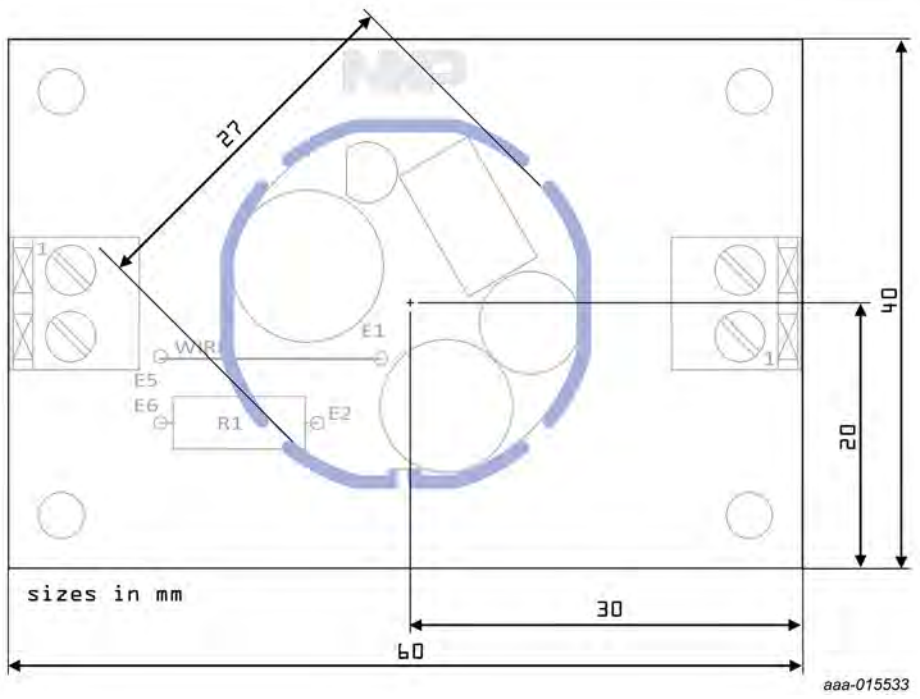
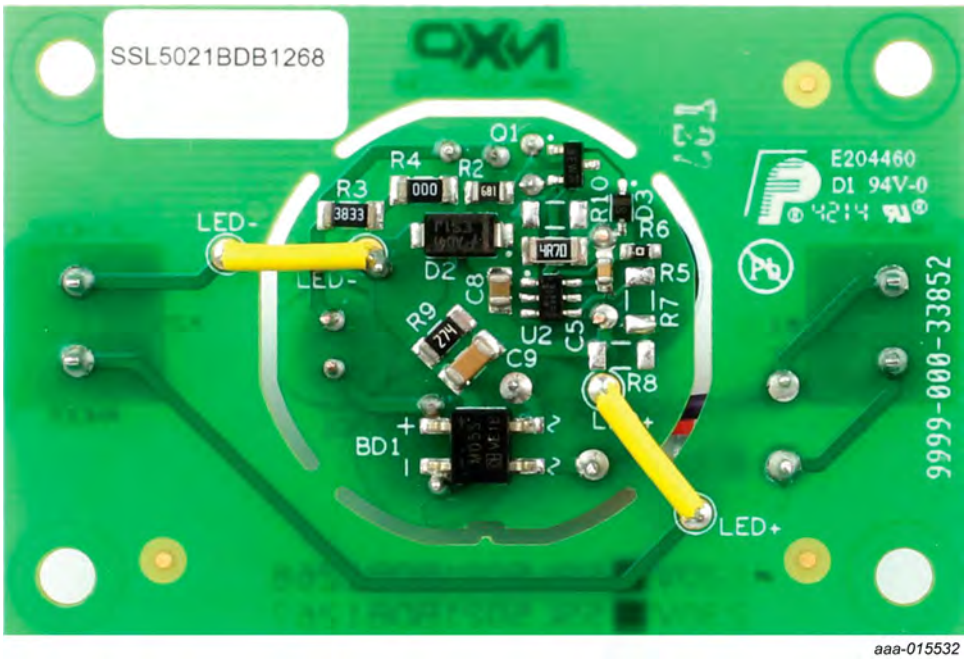


Fig 2. SSL5021BDB1268 demo board dimensions

4. Board photographs

a. Top view



b. Bottom view

Fig 3. SSL5021BDB1268 demo board photographs

5. Board connections

The SSL5021BDB1268 demo board is optimized for a 120 V/60 Hz supply. It is designed to work with multiple LEDs or an LED module.

Under the expected conditions, the output current is 85 mA when using an LED string with a 60 V forward voltage (V_F). The current can be adjusted using resistor R5 (and R10 in parallel if a more accurate adjustment is required). 60 V LED voltage gives a good efficiency and line regulation at 120 V (AC).

K1 is the connection for the mains voltage. Anode and cathode at K2 are the connections for the LED load. Figure 4 shows the connections.

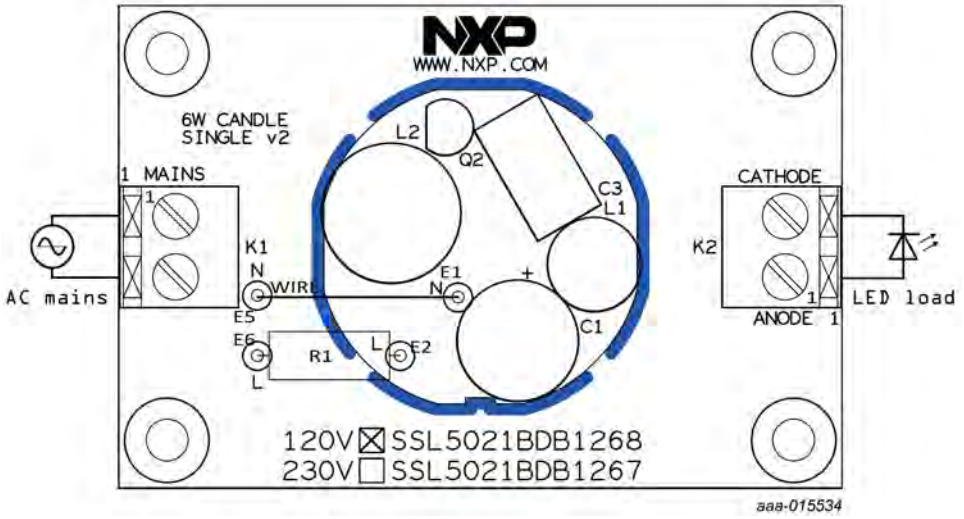


Fig 4. SSL5021BDB1268 board connections

6. Functional description

6.1 Input filtering

Capacitors C1 and C3 and inductor L1 filter the switching current from the buck converter to the line. Capacitors C1 and C3 also provide a low-impedance path for the switching current. The value of C1 is selected to have no more than a 30 % ripple on the bus voltage at −15 % of typical mains.

The input series resistance of 27 Ω and capacitor C1 together provide adequate protection against transient surge voltages. For immunity to the line surge, the input resistance is added (see Figure 11 and Figure 12). Do not omit this resistor or lower its value.

6.2 Efficiency improvement for universal mains

The SSL5021BTS is supplied via start-up resistor R3. To keep the temperature low and retain ease of adjustment of the desired value, the power losses in these resistors can be divided over two resistors by replacing the 0 Ω of resistor R4.

For mains voltages up to 120 V (AC), a single 1206 size SMD resistor (R3) is sufficient. The maximum voltage and the power rating are not exceeded.

6.3 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. It recovers when the LED string is reconnected. The LED current is not controlled when reconnecting which could destroy the LED string. Therefore turn off the mains before reconnecting the LED load. Two circuits set the open-load output voltage. One circuit (R9) sets the open-load output voltage when the IC does not operate because of a defect. The other circuit (OVP option) 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.

IC not operating

The voltage divider, consisting of resistor R3, sets the output voltage from the VCC pin of the IC to the GND pin of the IC and resistor R9.

$$V_{out} = \frac{(V_{bus} - 13) \cdot R9}{R3 + R4 + R9} \quad (1)$$

As a rule of thumb, limit resistor R9 to $\frac{n \times 2.5\ V}{2 \times 190\ \mu A}$. In this way, the voltage is not sufficient to turn on 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 with OVP option

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 when the optional resistors R7 and R8 are placed and a 5.6 kΩ resistor replaces R6. It triggers when four consecutive high-frequency cycles at 1.8 V are detected at the DEMOVP pin.

$V_{out} = 1.8 \times \left(1 + \frac{R7 + R8}{R6}\right)$ sets the output voltage. The output voltage must never exceed the rated DC voltage of the output capacitor.

For resistor R6, do not use a value that exceeds 5.6 kΩ. The DEMOVP pin is a high ohmic input. It is sensitive to disturbance causing false OVP triggering.

IC operating without OVP option

When the foldback option is not used, resistor R6 can be shorted and R7 and R8 can be set to not mounted. As a result of shorting the DEMOVP pin, switching of the converter does not have proper valley detection anymore, giving an efficiency decrease of approximately 1 %. At open output, the converter is operating but the output voltage remains well below the 200 V voltage rating of C9. By default, the OVP option is not mounted on the SSL5021BDB1268 demo board.

6.4 LED current and sense resistors

To optimally profit from the excellent current stability of the SSL5021BTS over temperature, 50 ppm MELF type resistors are recommended to sense the LED current. The output current stability range drops to 3 % compared to 7 % over the full temperature range for normal 200 ppm 1206 type resistors.

In most low-power, low-cost applications with LED currents < 150 mA, 200 ppm resistors are fine. $I_{LED(AV)}$ = 0.4 / R5 can adjust the average LED current. If the change is small (±10 %), changing the inductor is not required. At the lowest mains voltage, the maximum ON-time of Q1 must not exceed 15 μs.

7. Performance

V_{mains} = 96 V to 138 V (AC); 25 °C; I_{LED} = 85 mA typical; V_{LED} = 60 V unless otherwise specified.

7.1 Efficiency

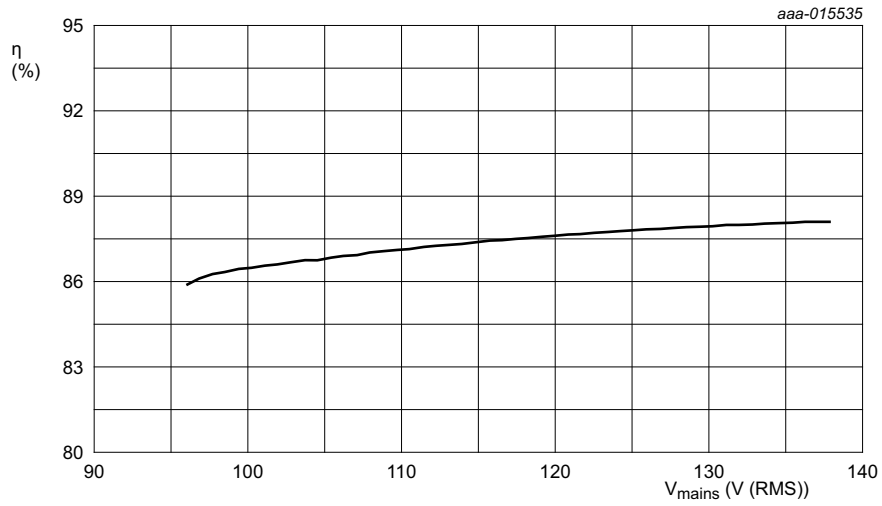


Fig 5. Efficiency as a function of V_{mains}

7.2 Input power

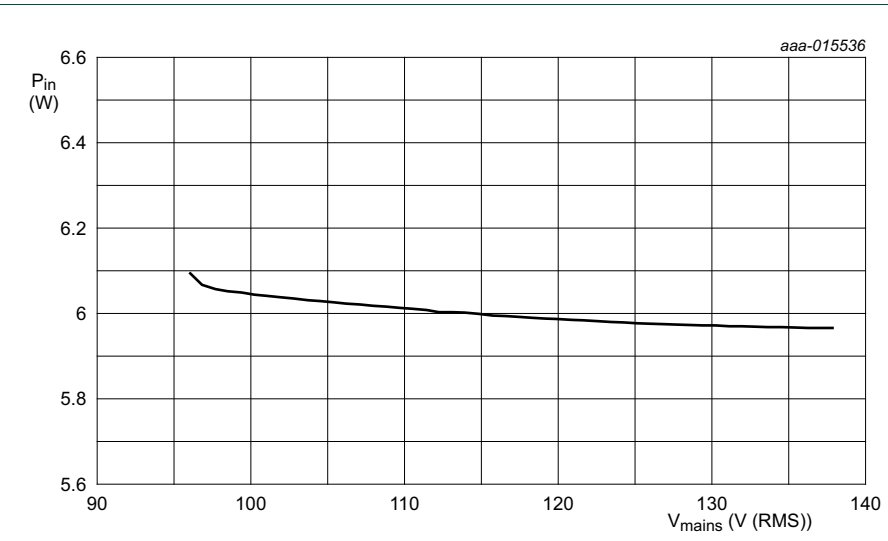


Fig 6. Power factor as a function of V_{mains}

7.3 Line regulation

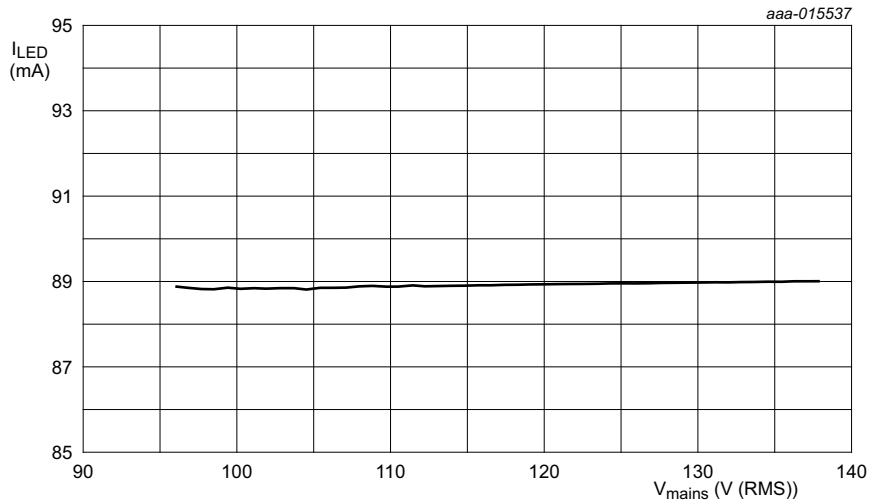
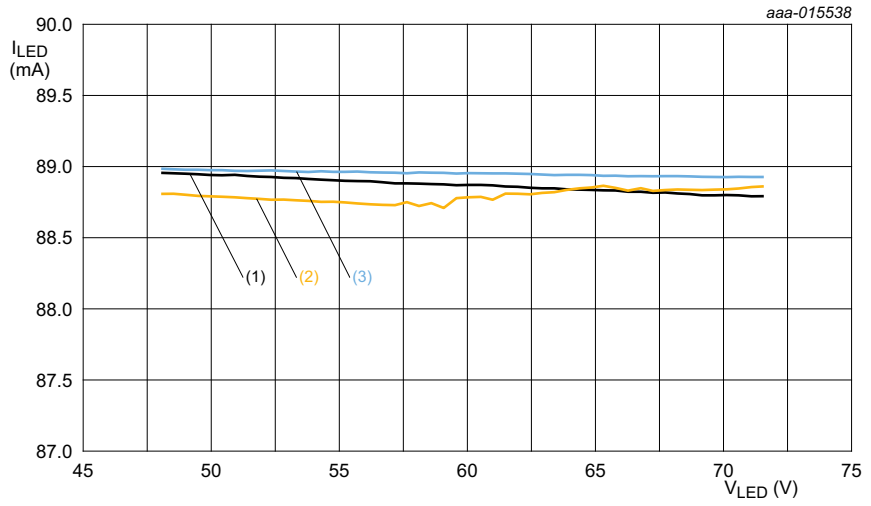


Fig 7. Line regulation

7.4 Load regulation



(1) V_{mains} = 230 V

(2) V_{mains} = 170 V

(3) V_{mains} = 265 V

Fig 8. Load regulation

7.5 Output ripple

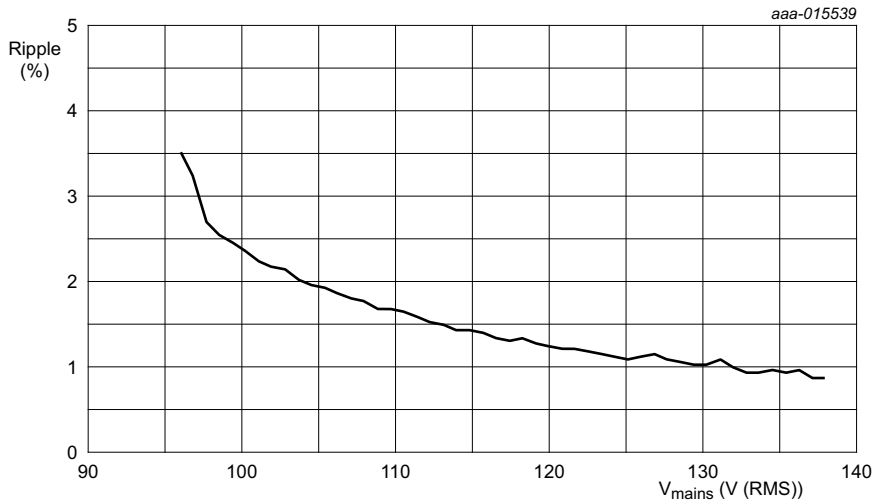
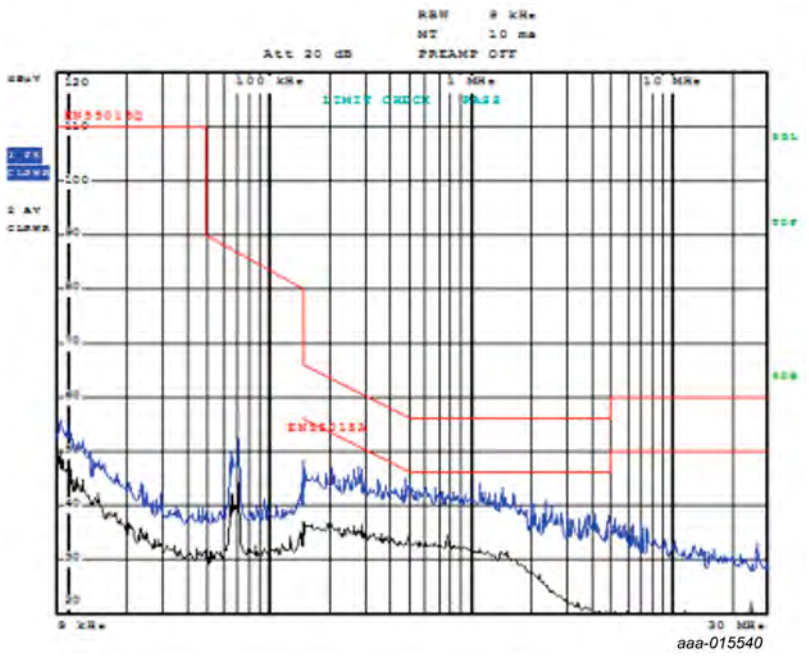


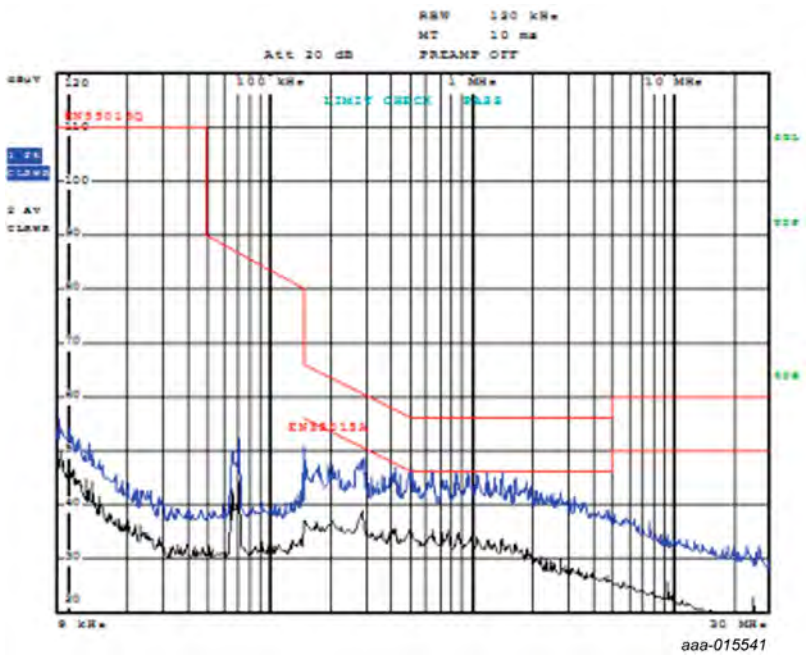
Fig 9. Output ripple as a function of V_{mains}

7.6 ElectroMagnetic Interference (EMI)

Figure 10 shows the conducted EMI result of the SSL5021BDB1268 demo board.



a. Line



b. Neutral

Fig 10. Conducted EMI

8. Schematic

8.1 Functional schematic

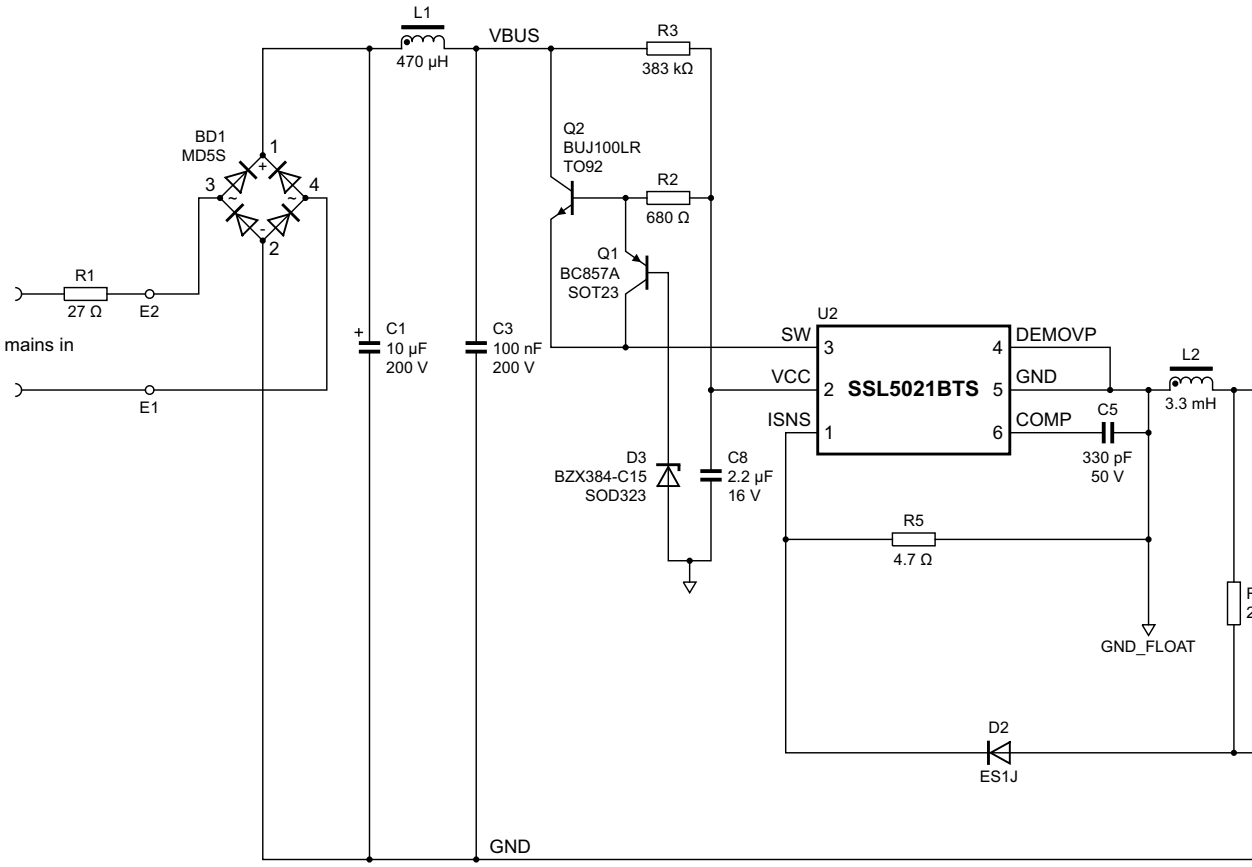


Fig 11. SSL5021BDB1268 demo board schematic diagram

8.2 Demo board schematic

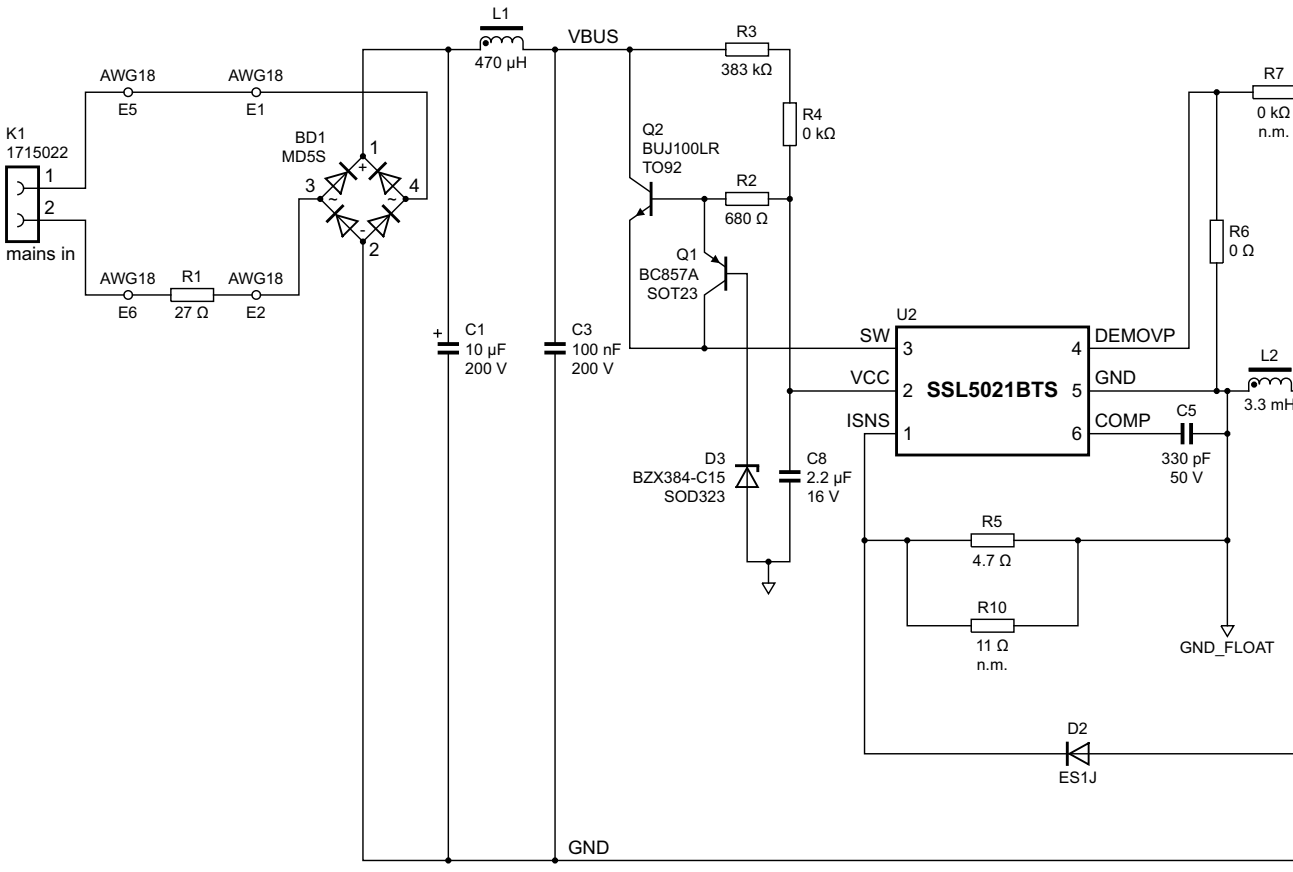


Fig 12. SSL5021BDB1268 demo board schematic

9. Bill Of Materials (BOM)

9.1 Functional BOM

Figure 11 shows the functional application as it is implemented on this demo board. It has a component count of 18 items, including the IC. Table 2 contains the corresponding BOM.

Table 2. Functional bill of materials

Reference	Description and values	Part number	Manufacturer
BD1	bridge rectifier; 1000 V; 500 mA;	MD5S	Rectron
C1	capacitor; 10 μF; 20 % 200 V	ECA2DHG100	Panasonic
C3	capacitor; 100 nF; 10 %; 200 V	ECQ@2104JF	Panasonic
C5	capacitor; 330 pF; 10 %; 50 V; X7R; 0805	-	-
C8	capacitor; 2.2 μF; 10 %; 16 V; X7R; 0805	CC0805KKX7R7BB225	Yageo
C9	capacitor; 100 nF; 10 %; 200 V; X7R; 1206	C1206C104K2RACTU	KEMET
D2	diode; 600 V; 1 A	ES1J	Fairchild
D3	diode; Zener; 15 V; 250 mA	BZX384-C15	NXP Semiconductors
L1	inductor; 470 μH; 310 mA	22R474C	Murata
L2	Inductor; 3.3 mH; 260 mA	TSL1112RA-332JR26-PF	TDK
Q1	transistor; PNP; 45 V; 100 mA	BC857A,215	NXP Semiconductors
Q2	transistor; NPN; 700 V; 0.8 A	BUJ100LR	NXP Semiconductors
R1	resistor; 27 Ω; 10 %; 2 W; THT	EMC2-27R0K	Welwyn Components
R2	resistor; 680 Ω; 5 %; 100 mW; 0805	-	-
R3	resistor; 383 kΩ; 5 %; 250 mW; 1206	-	-
R5	resistor; 4.7 Ω; 1 %; 250 mW; 1206	-	-
R9	resistor; 330 kΩ; 5 %; 250 mW; 1206	-	-
U2	LED driver; TSOP6	SSL5021BTS	NXP Semiconductors

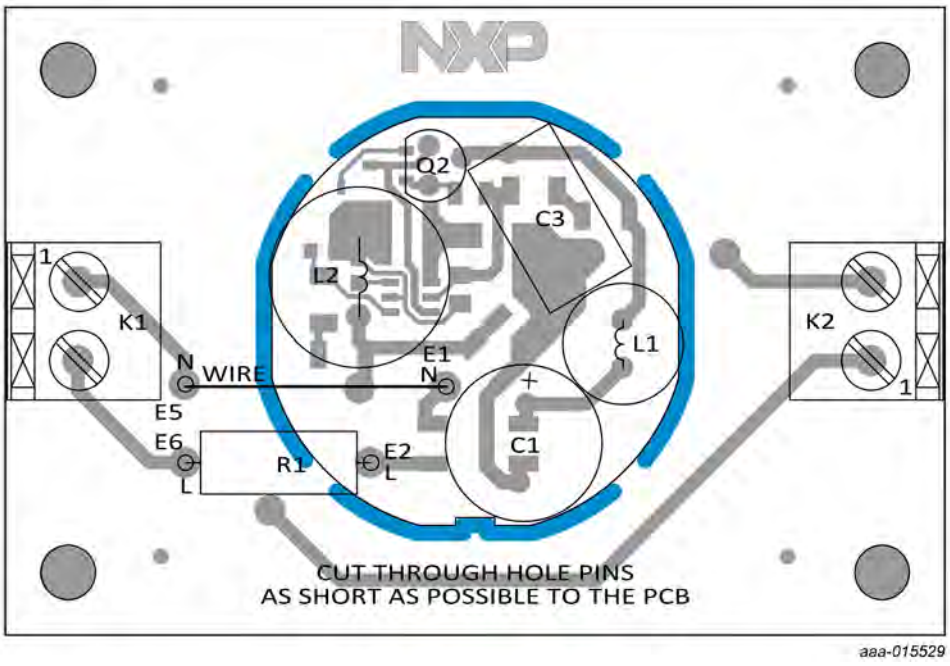
9.2 Demo board BOM

Figure 12 shows the actual application as it is implemented on this demo board. Table 3 contains the corresponding BOM.

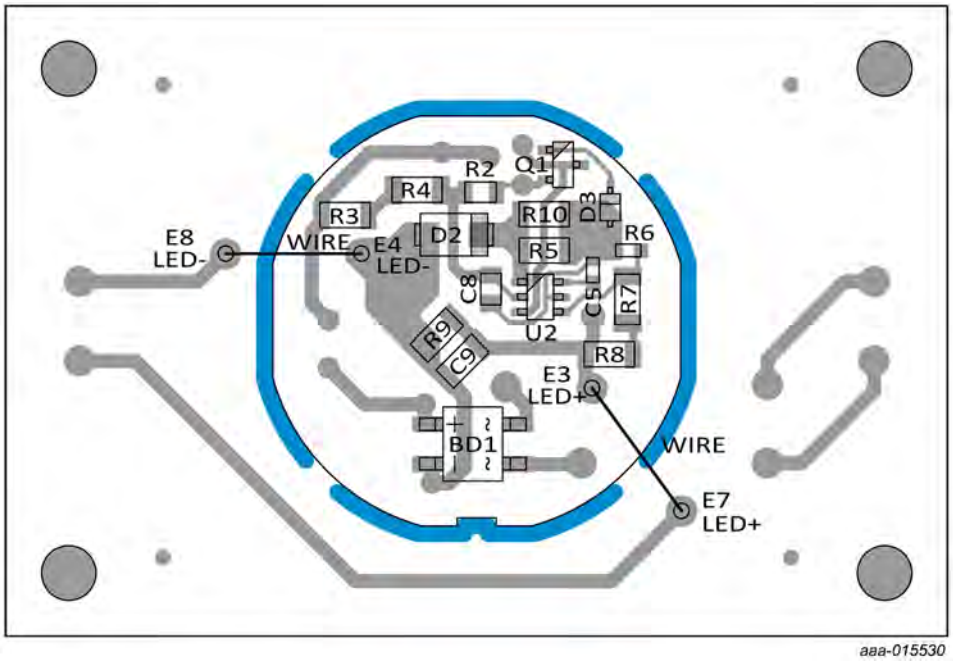
Table 3. SSL5021BDB1268 demo board bill of materials

Reference	Description and values	Part number	Manufacturer
BD1	bridge rectifier; 1000 V; 500 mA;	MD5S	Rectron
C1	capacitor; 10 μF; 20 %; 200 V	ECA2DHG100	Panasonic
C3	capacitor; 100 nF; 10 %; 200 V	ECQ@2104JF	Panasonic
C5	capacitor; 330 pF; 10 %; 50 V; X7R; 0805	-	-
C8	capacitor; 2.2 μF; 10 %; 16 V; X7R; 0805	CC0805KKX7R7BB225	Yageo
C9	capacitor; 100 nF; 10 %; 200 V; X7R; 1206	C1206C104K2RACTU	KEMET
D2	diode; 600 V; 1 A	ES1J	Fairchild
D3	diode; Zener; 15 V; 250 mA	BZX384-C15	NXP Semiconductors
K1; K2	connector; terminal block; 5.00 mm	1715022	Phoenix
L1	inductor; 470 μH; 310 mA	22R474C	Murata
L2	inductor; 3.3 mH; 260 mA	TSL1112RA-332JR26-PF	TDK
Q1	transistor; PNP; 45 V; 100 mA	BC857A,215	NXP Semiconductors
Q2	transistor; NPN; 700 V; 0.8 A	BUJ100LR	NXP Semiconductors
R1	resistor; 27 Ω; 10 %; 2 W; THT	EMC2-27R0K	Welwyn Components
R2	resistor; 680 Ω; 5 %; 100 mW; 0805	-	-
R3	resistor; 383 kΩ; 5 %; 250 mW; 1206	-	-
R4	resistor; 0 Ω; 1206	-	-
R5	resistor; 4.7 Ω; 1 %; 250 mW; 1206	-	-
R6	resistor; 0 Ω; 0603	-	-
R7	resistor; not mounted; 0 Ω; 1206	-	-
R8	resistor; not mounted; 220 kΩ; 5 %; 250 mW; 1206	-	-
R9	resistor; 270 kΩ; 5 %; 250 mW; 1206	-	-
R10	resistor; not mounted; 1 %; 250 mW; 1206	-	-
U2	LED driver; TSOP6	SSL5021BTS	NXP Semiconductors

10. Board layout



a. Top view



b. Bottom view

Fig 13. SSL5021BDB1268 demo board layout

11. Abbreviations

Table 4. Abbreviations

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

12. References

[1] SSL5021BTS data sheet — Compact low-ripple buck LED driver IC

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