UM10588

SSL2109AT 18 W buck high-power factor T8 demo board

Rev. 1 — 21 January 2013 **User manual**

Document information

Info	Content
Keywords	SSL2109, buck, controller, demo board, LED driver, LED retrofit lamp, high-power factor, non-dimmable, non-isolated, SSL2109ADB1096, SSL2109ADB1097
Abstract	This manual describes the performance, technical data and connections of the SSL2109AT demo board. This board was designed for high PF (>0.9) and low THD (<30 %). The SSL2109AT is an NXP Semiconductors controller IC intended to provide a low-cost, small form factor LED driver. This board is intended to operate at 230 V (AC), and can be optimized for universal mains, using an output voltage of 30 V or more.

Revision history

Rev	Date	Description
v.1	20130121	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 manual describes the performance, technical data and connection of the SSL2109AT 18 W buck high-power factor demo board. The SSL2109AT is a highly integrated switching mode LED controller which enables constant current driving from the mains input. It is a solution for small to medium LED retrofit lamp applications, and can be optimized for high-power factor requirements. The SSL2109DB1096/7 is a buck converter controller suitable for non-isolated, non-dimmable LED retrofit lamps. It can drive long LED strings with, typically, 70 V forward voltages. The SSL2109AT is intended to operate with high output voltages, as present in modern LED modules.

The board comes in two variants; SSL2109ADB1096 for 230 V (AC) mains applications, and SSL2109ADB1097 for universal mains applications.

a. Top view

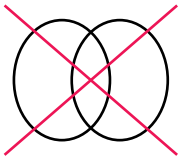
b. Bottom view

Fig 1. SSL2109AT 18 W demo board

2. Safety Warning

This board is connected to a high mains voltage. Avoid touching the board while it is connected to the mains voltage. An isolated housing is mandatory when used in uncontrolled, non-laboratory environments. Galvanic isolation of the mains phase using a variable transformer is always recommended.

a. isolated



b. non-isolated

Fig 2. Variable transformer isolation symbols

3. Specifications

Table 1. Specifications for the SSL2109AT 18 W demo board

Symbol	Parameter	Value
V_{mains}	mains voltage	200 V (AC) to 264 V (AC); 230 V (AC) version
		100 V (AC) to 264 V (AC); universal mains version
$V_{O(LED)}$	LED output voltage	30 V (DC) to 130 V (DC); 230 V (AC) version
		30 V (DC) to 90 V (DC); universal mains version
$I_{O(LED)}$	LED output current	230 mA at $V_{O(LED)}$ = 70 V (DC); 230 V (AC) version
		230 mA at $V_{O(LED)}$ = 70 V (DC); universal mains version
$P_{LED(max)}$	maximum LED power	18 W
η	efficiency	91 %; 230 V (AC) version (see Figure 6)
		86 %; universal mains version (see Figure 6)
$\Delta I_{LED}/I_{LED}$	line regulation	less than ±5 % at 18 W (see Figure 7)
$\Delta I_{LED}/\Delta V_{LED}$	load regulation	0.4 mA/V at 230 V 18 W; 230 V version
		2.2 mA/V at 110 V 18 W; universal mains version
		1.1 mA/V at 230 V 18 W; universal mains version
PF	Power Factor	>0.9 at 18 W (see Figure 5)
THD	Total Harmonic Distortion	<30 % at 18 W (see Figure 5)
T_{oper}	operating temperature	-40 °C to +100 °C
$T_{th(NTC)}$	NTC threshold temperature	80 °C; ± 15 °C
PCB size	L × W × H	250 mm × 15 mm × 15 mm

Table 1. Specifications for the SSL2109AT 18 W demo board *...continued*

Symbol	Parameter	Value
-	mains harmonics	IEC61000-3-2; P_{out} >13 W
-	EMC compliant	IEC55015; 230 V version
		FFC15; universal mains version
-	surge testing	IEC61000-4-5; Level 3
-	lifetime	26000 hours at t_{amb} = 60 °C

4. Functional description

4.1 Universal input adjustment

Figure 9 shows the schematic for the SSL2109AT demo board. The SSL2109AT demo board supports universal mains input (100 V (AC) to 264 V (AC)) applications. To maintain accurate line regulation, components D5 and R12 are required. These components provide a compensation for the modulated peak current, with respect to the input voltage.

Furthermore, several other components must be changed to maintain the high-power factor and low THD over the universal mains input voltage range. Table 2 shows the components changes for universal input.

Table 2. Component differences between 230 V version and universal mains version

Reference	Version	Component	Package
R2	230 V	resistor; chip; 680 kΩ; ±1 %	SMD 1206
	universal mains	resistor; chip; 390 kΩ; ±1 %	SMD 1206
R3	230 V	resistor; chip; 680 kΩ; ±1 %	SMD 1206
	universal mains	resistor; chip; 390 kΩ; ±1 %	SMD 1206
R9B	230 V	resistor; chip; 1.2 Ω; ±1 %	SMD 0805
	universal mains	resistor; chip; 0.68 Ω; ±1 %	SMD 0805
R12	230 V	n.c	SMD 0805
	universal mains	resistor; chip; 1 MΩ; ±5 %	SMD 0805
D5	230 V	n.c	-
	universal mains	Zener diode; 18 V	SMD, SOD12
D6	230 V	n.c	-
	universal mains	diode; ,PMEG6020EP	SMD 80
C5	230 V	capacitor; ceramic; 220 pF; 630 V; COG; Murata	SMD 80
	universal mains	capacitor; ceramic; 1 nF; 630 V; COG; Murata	SMD 1206

4.2 Power Factor adjustment

This demo board is designed for high-power operation (PF > 0.9 at 230 V (AC)) and low THD performance (THD < 30 % at 230 V (AC)). The application circuit that enables these performances is shown in Figure 3.

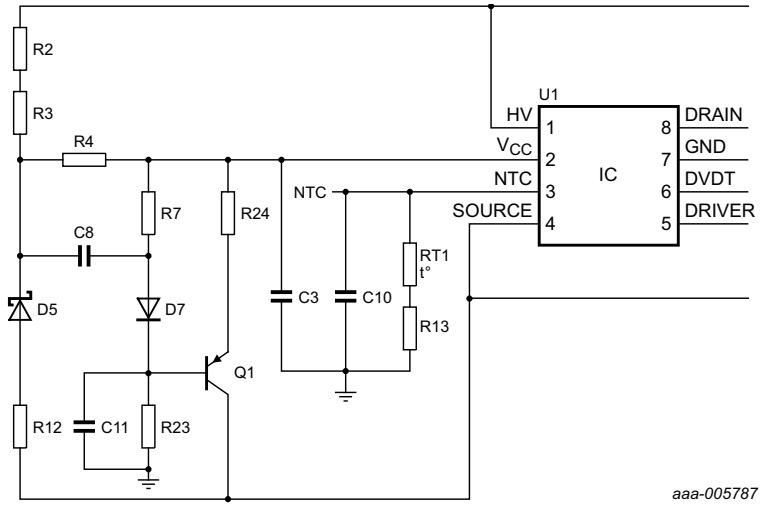


Fig 3. Power factor improvement circuit

The rectified bus voltage is connected through R2. R2, R3, C8, R7, D7 and R23 act as the bus voltage divider that modulates the base of transistor Q1. The VCC pin delivers current through R24 and Q1 into the source pin of the controller. The peak current of the controller is thus modulated. This modulation makes the input current track the input voltage, and greatly improves the system PF and THD values.

The AC couple capacitor (C8) must have a relatively large capacitance for reliable start-up, especially with large output capacitors (C9A, C9B). The value of 470 nF gives good results in combination with large output capacitors.

4.3 LED current ripple

In a single-stage high PF design the input buffer capacitance must be relatively small to get good PF. Therefore, a relatively large output capacitor is required to get low LED current ripple. Table 3 shows the trade-off between the current ripple and the output capacitor value on the demo board.

Table 3. Current ripple versus output capacitance (230 V (AC) mains input voltage)

V_{mains} (V)	P_{in} (W)	PF	$I_{O(LED)}$ (A)	$V_{O(LED)}$ (V)	Ripple	C_{out}
230	19.29	0.948	0.259	68.42	75 %	200 μF
230	19.29	0.947	0.259	68.43	50 %	330 μF
230	19.27	0.945	0.259	68.4	30 %	680 μF

4.4 External over temperature protection (OTP)

The SSL2109AT supports external OTP by adding an external Negative Temperature Coefficient (NTC) resistor. This feature is delivered by detecting a voltage on the NTC pin. The NTC pin has an integrated current source. The resistance of the NTC resistor decreases when the temperature increases.

When the NTC temperature rises and the voltage on the NTC pin falls below 0.5 V, the SSL2109AT lowers the threshold level for detecting peak current in the buck inductor. Decreasing the peak current in the buck inductor decreases the power in the LED string. The output current is regulated to the point where a balance between temperature and output current is retained (thermal management).

If the temperature on the NTC increases continuously and the voltage on the pin drops below 0.3 V, the SSL2109AT starts the NTC time-out timer. If the voltage on the NTC pin does not drop below 0.2 V within the time-out, the SSL2109AT detects an abnormal condition and stops switching. If the voltage reaches 0.2 V within the time-out period, a PWM signal is assumed.

An NTC resistor can be connected directly to the NTC pin.

It is also possible to tune the protection temperature by adding a resistor in parallel or in series with the NTC. One NTC and one resistor are installed on the demo board. The values of these components can be changed depending on the protection temperature requirement and component availability.

Mount the NTC so it is in thermal contact with the LED string.

4.5 LED open protection considerations

An optional LED open-circuit protection is implemented on the demo board. The protection consists of T1, D22, D4 and C6. If no LED open protection is required, these components can be left out. In order to keep total buck inductance the same, T2 then has double the inductance.

With this LEDs open-circuit approach, the controller shuts down immediately the LED output is (left) open. This solution uses the negative level sensing of the auxiliary winding to bring down the SSL2109AT NTC pin level to 0 V with a too-high output voltage.

Select the Zener diode D4 to so that the protection voltage is not too-high, or the output capacitor could be damaged.

5. SSL2109AT 18 W demo board connections

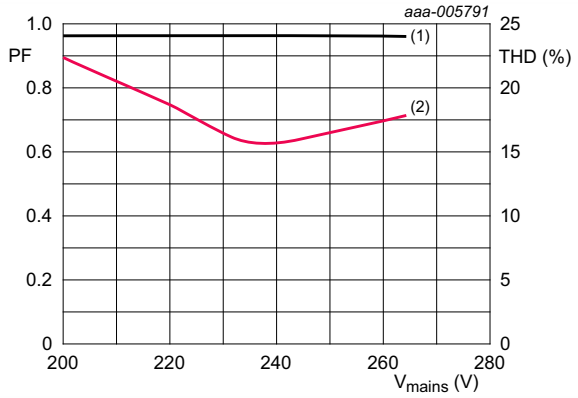
The SSL2109AT board is optimized for 230 V (AC) at 50 Hz. But it can also be optimized for 120 V (AC) at 50 Hz or 60 Hz mains, or universal mains supply. In addition, the board is designed to work with multiple LEDs in series or an LED module with a high forward voltage.

The anode of the LED load is connected to the LED+ connector and the cathode is connected to the LED− connector. Use an LED string with a V_F greater than 30 V on this board. Under typical conditions, the output current is 230 mA. If the rated current of the LED does not meet this specification, the current can be adjusted, by changing R9A and/or R9B.

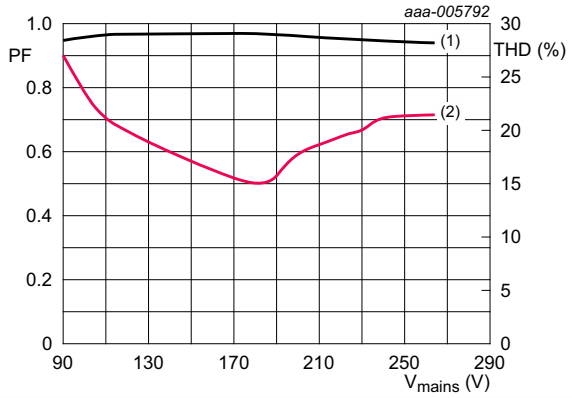
Fig 4. Connections to the SSL2109AT 18 W demo board (top view)

6. Performance data

6.1 Power Factor and Total Harmonic Distortion



a. 230 V version



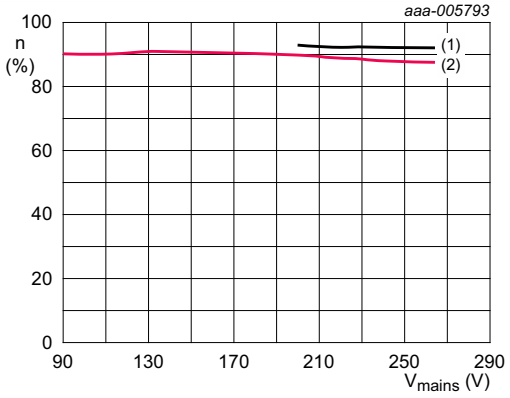
b. universal mains version

(1) PF

(2) THD

Fig 5. Power Factor (PF) and Total Harmonic Distortion (THD)

6.2 Efficiency

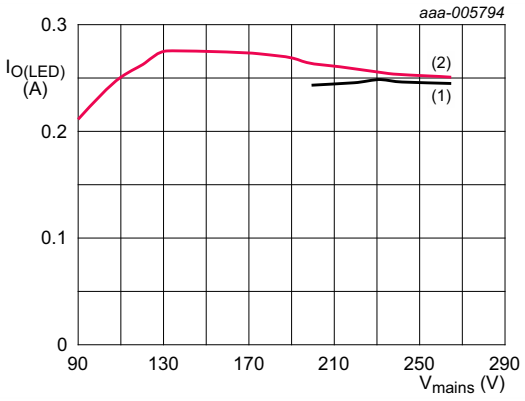


(1) 230 V version

(2) universal mains version

Fig 6. Efficiency

6.3 Line regulation



(1) 230 V version

(2) universal mains version

Fig 7. Line regulation

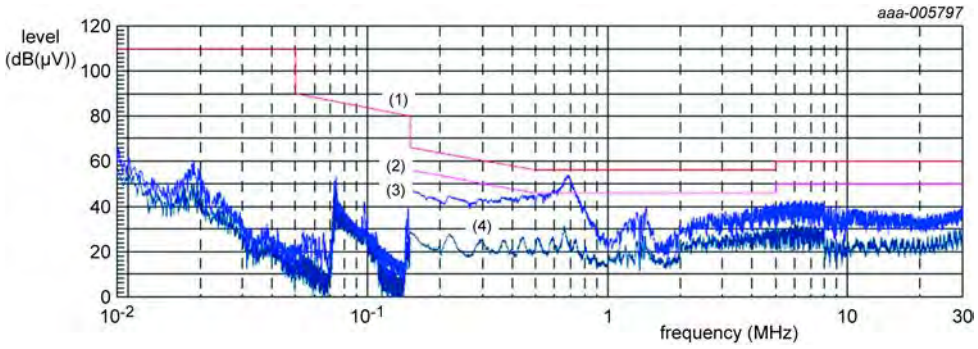
7. Electromagnetic Interference (EMI)

The SSL2109 series operates as a boundary conduction mode converter. A special feature, called valley detection is an integrated part of the SSL2109 series circuitry. Dedicated built-in circuitry connected to the DRAIN pin, senses when the voltage on the drain of the switch has reached its lowest value. This feature reduces switching losses, but also greatly benefits the EMI performance of the LED driver.

In the 18 W T8 solution, EMI measurements are taken for conducted emission. Components CX1, L1, L2. L3. CX2, C1, C2 and L4 attenuate the conducted emission.

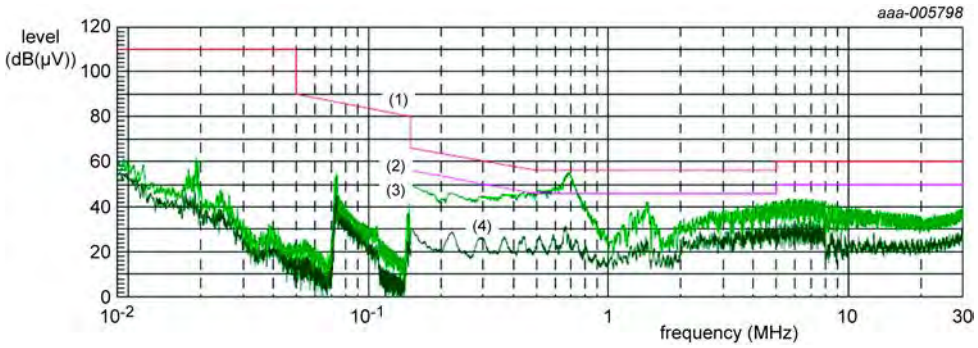
The capacitance of the PI filter C1, C2 and L4 makes a large difference to the low-ripple configuration. For the high PF solution, the input capacitance must be as low as possible to achieve a high PF. However, EMI benefits more from a PI filter with a relatively large capacitance. The other point of the inductor L2 has a very important role in suppressing the noise around 30 MHz. The test results show that an inductance of 50μH to 100μH has the best effect.

Figure 8 shows the relevant EMI test results of the 18 W T8 board.



(1) Limit (QP)
(2) Limit (average)
(3) Spectrum (L1; peak)
(4) Spectrum (L1; average)

a. L-phase



(1) Limit (QP)
(2) Limit (average)
(3) Spectrum (N; peak)
(4) Spectrum (N; average)

b. N-phase

Fig 8. EMI Performance: conducted emission (230 V version)

8. SSL2109AT 18 W demo board schematic

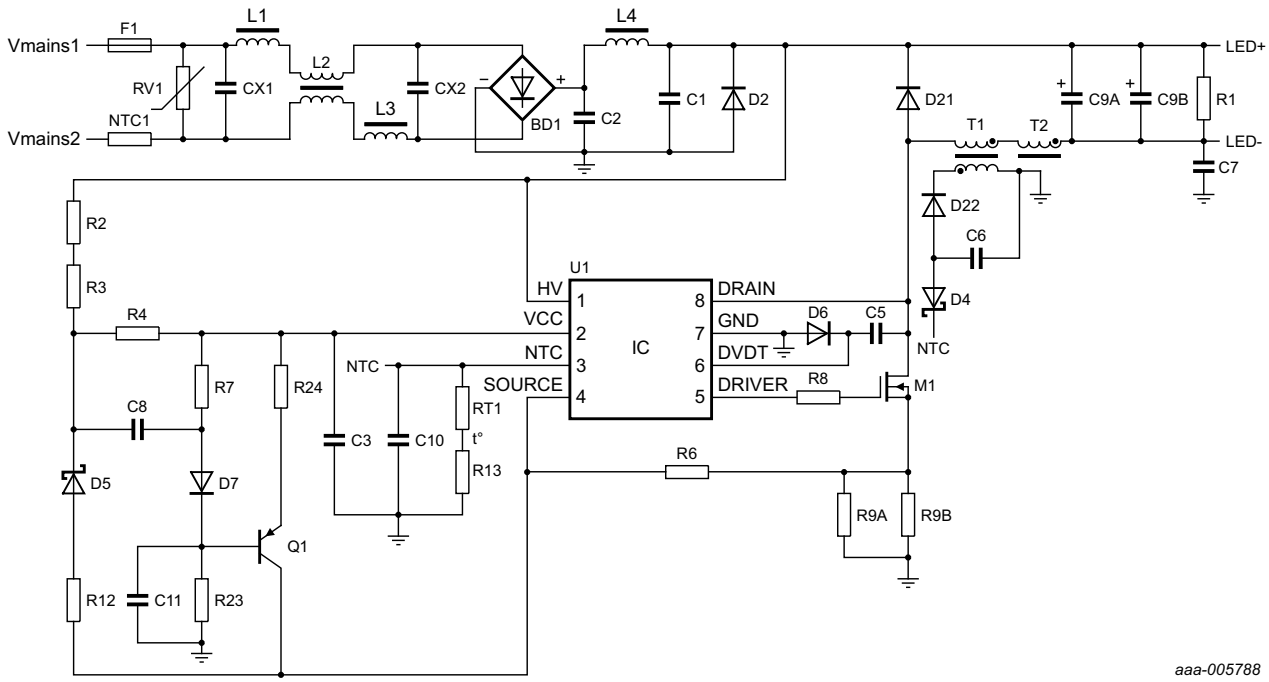
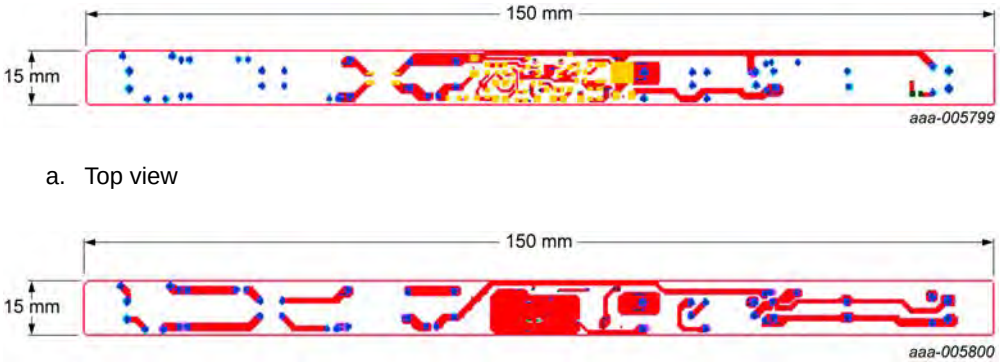


Fig 9. SSL2109AT 18 W buck high-power factor T8 demo board schematic

9. PCB Layout



a. Top view

b. Bottom view

Fig 10. SSL2109AT 18 W demo board layout

10. Bill of Materials (BOM)

Table 4. Bill of Materials for 230 V version

Reference	Description and Value	Package; Part number	Manufacturer
BR1	bridge rectifier; 0.5 A; 600 V	TO-269AA; MB6S	Vishay
C1	capacitor; polyester; 100 nF; 400 V	Pitch = 7.5 mm; MB6S	-
C2	capacitor; polyester; 47 nF; 400 V	Pitch = 7.5 mm	-
C3	capacitor; ceramic; 4.7 μF; 25 V; X7R	SMD 0805	Murata
C5	capacitor; ceramic; 220 pF; 630 V; COG	SMD 1206; GHM1030U2J221J630D 505	Murata
C6	capacitor; ceramic; 100 nF; 50 V	SMD 0805; GRM2195C1H103JA01D	-
C7	capacitor; polyester; 100 nF; 400 V	Pitch = 7.5 mm	-
C8	capacitor; ceramic; 470 nF; 50 V	SMD 1206	Murata
C9A	capacitor; electrolyte; 100 μF; 100 V	radial; Pitch = 5 mm	-
C9B	capacitor; electrolyte; 100 μF; 100 V	radial; Pitch = 5 mm	-
C10	capacitor; ceramic; 100 nF; 25 V; X7R	SMD 0603	Murata
C11	n.c	-	-
CX1	capacitor; X2; 10 nF; 250 V (AC)	-	-
CX2	capacitor; X2; 10 nF; 250 V (AC)	-	-
D2	diode; TVS	SMA	-
D4	diode; Zener; 15 V	SOD-80; P6KE400A	NXP Semiconductors
D5	n.c	-	-
D6	n.c	-	-
D7	diode; 1N4148	SMD; SOD123; BAS16H	NXP Semiconductors
D21	diode; ultra fast; ES1J; 1 A; 600 V	DO-214AC	On-semi
D22	diode	SOD-80; BAS16H	NXP Semiconductors
F1	fuse; slow blow; 1 A; 250 V (AC)	Ø3.43 mm × 7.11 mm	Littelfuse
L1	inductor; filter; 1.8 mH	744772182	Würth Elektronik
L2	choke; common; 100 μH	T 10 × 5 × 5	-
L3	inductor; filter; 1.8 mH	744772182	Würth Elektronik
L4	inductor; filter; 1.8 mH	744772182	Würth Elektronik
M1	N-MOSFET; 2 A; 600 V	TO-251; IPD60R3K3C6	Infineon
NTC1	resistor; metal oxide film; 7.1 Ω; 1 W	axial; Ø2.8 mm × 9 mm	-
Q1	50 V; 100 mA	SOT-23; BC857	NXP Semiconductors
R1	resistor; chip; 100 kΩ; ± 5 %	SMD 0805	-
R2	resistor; chip; 680 kΩ; ± 1 %	SMD 1206	-
R3	resistor; chip; 680 kΩ; ± 1 %	SMD 1206	-
R4	resistor; chip; 33 kΩ; ± 5 %	SMD 0603	-
R6	resistor; chip; 4.7 kΩ; ± 5 %	SMD 0805	-

Table 4. Bill of Materials for 230 V version *...continued*

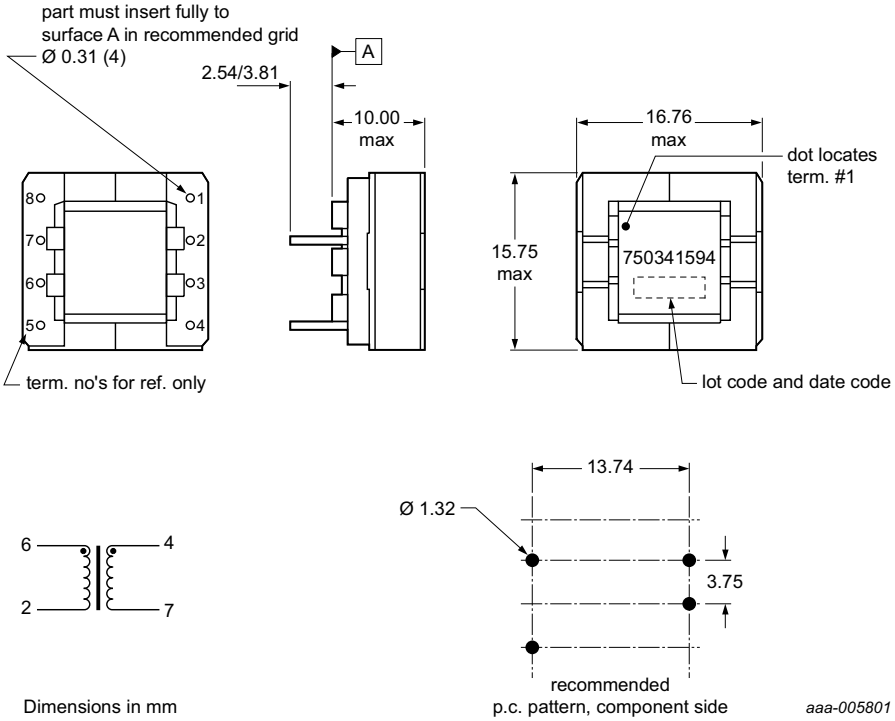
Reference	Description and Value	Package; Part number	Manufacturer
R7	resistor; chip; 68 kΩ; ± 1 %	SMD 0603	-
R8	resistor; chip; 100 Ω; ± 5 %	SMD 0805	-
R9A	resistor; chip; 1 Ω; ± 1 %	SMD 1206	-
R9B	resistor; chip; 1.2 Ω; ± 1 %	SMD 1206	-
R12	n.c	-	-
R13	resistor; chip; 10 kΩ; ± 1 %	SMD 0603	-
R23	resistor; chip; 560 kΩ; ± 1 %	SMD 0603	-
R24	resistor; chip; 33 kΩ; ± 1 %	SMD 0603	-
R28	resistor; chip; 100 Ω; ± 5 %	SMD 0805	-
RT1	thermistor; NTC; 100 kΩ; ± 1 %	DIP; pitch = 2.5 mm	-
RV1	varistor; 471 kΩ	pitch = 7.5 mm	-
T1, T2	inductor; 350 μH; 1.5 A	-	Würth Elektronik
U1	IC driver	S08; SSL2109AT	NXP Semiconductors

Table 5. Additional Bill of Materials for universal mains version

Reference	Description and Value	Package; Part number	Manufacturer
C5	capacitor; ceramic; 1 nF; 630 V; COG	SMD, 1206	Murata
D5	diode; Zener; 18 V	BZT52H18B	-
D6	diode	SMD 80; PMEG6020EP	-
R2	resistor; chip; 390 kΩ; ± 1 %	SMD 1206	-
R3	resistor; chip; 390 kΩ; ± 1 %	SMD 1206	-
R9B	resistor; chip; 0.68 Ω; ± 1 %	SMD 1206	-
R12	resistor; chip; 1 MΩ; ± 5 %	SMD 0805	-

11. Inductor specifications

11.1 Inductor layout and dimensions



(1) Dimensions in mm.

Fig 11. Inductor layout and dimensions

11.2 Electrical specifications

Table 6. Test Specifications

At 25 °C unless stated otherwise

Parameter	Test conditions	Value
DC resistance; 6 to 2	at 20 °C	0.717 Ω maximum
DC resistance; 4 to 7	at 20 °C	0.272 Ω maximum
Inductance; 6 to 2	20 kHz; 1 V (AC); La	350 μH; ±5 %
Dielectric; 2 to 4	1800 V (AC); 1 second	-
Turns ratio	(6 to 2):(4 to 7)	6.6:1 ±2 %

Remark: Operating temperature range: −40 °C to +125 °C including temperature range.

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