UM10512

SSL2109 reference board

Rev. 1.1 — 19 April 2012 **User manual**

Document information

Info	Content
Keywords	SSL2109, buck, controller, reference board, LED driver, LED retrofit lamp
Abstract	This document describes the performance, technical data and the connection of the SSL2109 reference board. The SSL2109 is an NXP Semiconductors controller IC intended to provide a low cost, small form factor LED driver. The reference board is intended to operate at 230 V or 120 V (AC), using an output voltage of 30 V or greater.

Revision history

Rev	Date	Description
v.1.1	20120419	second issue
v.1	20120213	first issue

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.

1.1 Scope of this document

The SSL2109 is a highly integrated switching mode LED controller which enables Constant Current (CC) driving from the mains input. It is a solution for small to medium LED retrofit lamp application, especially for low-power factor design. The SSL2109 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 SSL2109 is intended to operate with higher output voltages, as in modern LED modules.

Remark: Unless otherwise stated all voltages are in V (AC).

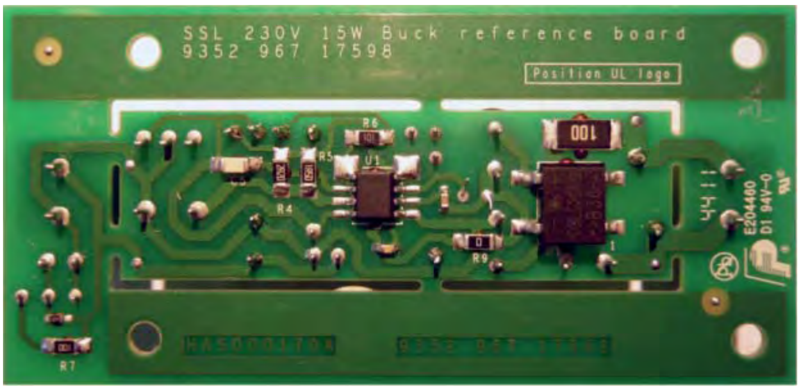

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Fig 1. Reference board (Bottom view)

Fig 2. Reference board (Top view)

2. Safety warning

This reference board is connected to a high AC voltage. Avoid touching the reference board during operation. An isolated housing is mandatory when used in uncontrolled, non-laboratory environments. Galvanic isolation of the mains phase using a fixed or variable transformer (Variac) is always recommended. Figure 3 shows the symbols on how to recognize these devices.

a. Isolated

b. Not isolated

Fig 3. Variable transformer isolation symbols

3. Board connectivity

3.1 Connecting to the board

The board is optimized for a 230 V (50 Hz) or 120 V (50 Hz or 60 Hz) mains supply. In addition to the mains voltage optimization, the board is designed to work with multiple LEDs or an LED module with a high forward voltage. Mains connection of the reference board is different from other general evaluation/reference boards. Connect the mains to the screw connector J6.

Remark: The maximum rated voltage of the board is 400 V (DC) or 175 V (DC).

The anode of the LED load is connected to pin 1 of connector J5. The cathode is connected to pin 2 of connector J5. Use an LED string with a VF greater than 20 V on this reference board. Under the expected conditions, the output current is 200 mA. If the rated current of the LED does not meet the specification, the current can be adjusted. See Section 6 for instructions.

(1) J6: connect the L of the AC mains supply

(2) J6: connect the N of the AC mains supply

(3) J5: Positive Anode connection

(4) J5: Negative cathode connection

Fig 4. Board connection diagram

4. Specification

Specifications for the reference board are listed in Table 1

Table 1. Reference board specifications

Parameter	Value	Comment
AC line input voltage	200 V to 250 V	Version 230 V 50 Hz
	100 V to 130 V	Version 120 V 60 Hz
Output voltage	30 V (DC) to 130 V (DC)	Version 230 V
	30 V (DC) to 90 V (DC)	Version 120 V
Output current	208 mA at V_o = 100 V (DC)	Version 230 V
	208 mA at V_o = 70 V (DC)	Version 120 V
Maximum power into LED load	23 W	-
Efficiency	>94 %	See Figure 5
Power Factor	>0.5	at > 12 W
THD	83 %	at 20 W
Board dimensions (length × width × height, mm)	57 × 17.5 × 17.5	Internal board
	83 × 40	External board
Operating temperature	−40 °C to +100 °C	-
NTC Threshold temperature	80 °C	±15 °C

Table 1. Reference board specifications

Parameter	Value	Comment
Mains harmonics	IEC61000-3-2	P_{out} > 13 W
EMC compliant	IEC55015	230 V model
	FCC15	120 V model
Surge testing	IEC61000-4-5	Level 3
Lifetime	26.000 hours	At t_{amb} = 60 °C

5. Performance data

Performance data is shown in Figure 5 to Figure 9

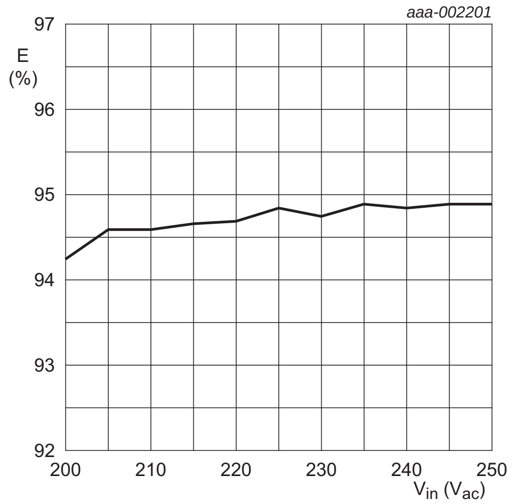
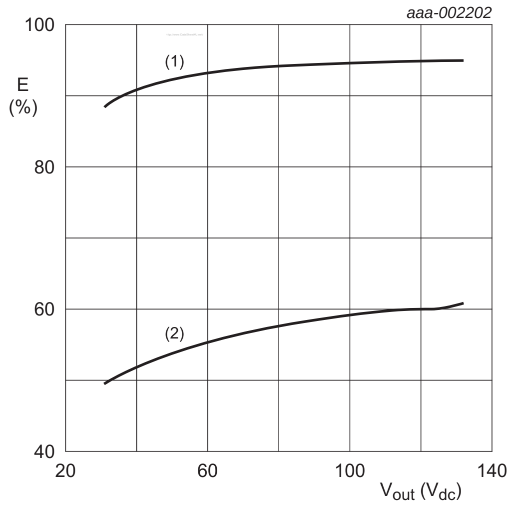


Fig 5. Efficiency versus V_{in}



(1) Efficiency

(2) PF

Fig 6. Efficiency and PF

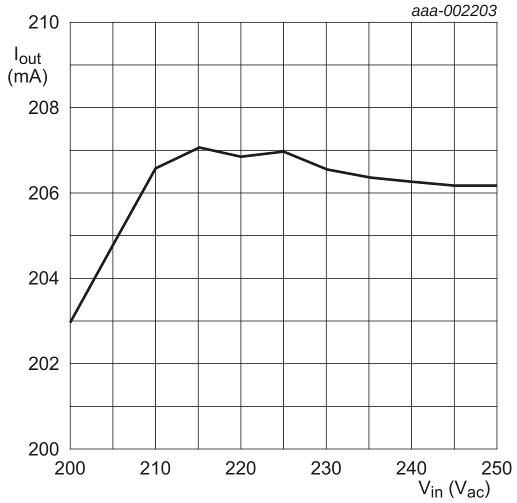


Fig 7. Line regulation

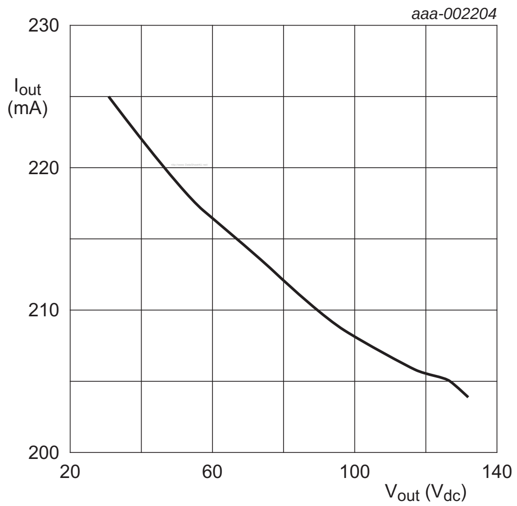


Fig 8. Output regulation

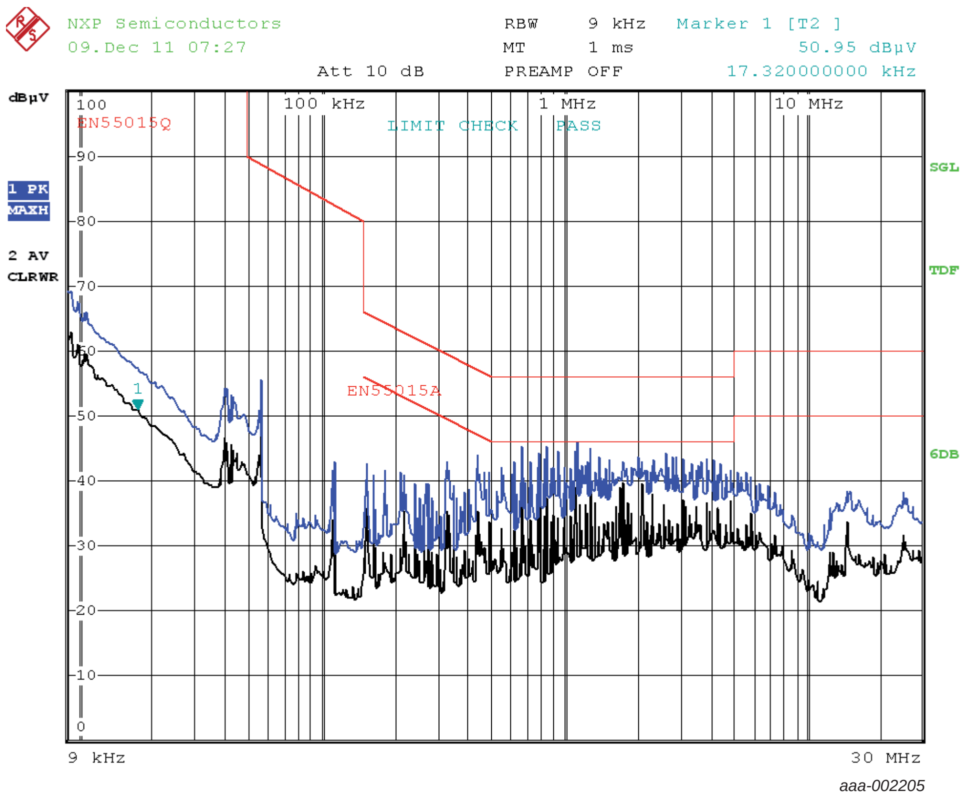


Fig 9. EMI performance

6. Changing the output current

The SSL2109 monitors the charging current in the inductor using the sense resistors R4 and R5. It controls a MOSFET to retain a constant peak current. In addition, the IC supports valley switching. These features enable a driver to operate in Boundary Conduction Mode (BCM) with valley switching where the average current in the inductor is the output current. The SSL2109 turns off the MOSFET when the voltage on pin SOURCE reaches 500 mV. If the value of R4 in parallel with R5 is 1, the peak current is limited to 500 mA. See Equation 1

$$I_{peak} = \frac{0.5 \times (R5 + R4)}{R5 \times R4} \quad (1)$$

When the MOSFET is turned off, inductor L2 is discharged and the current flowing through the inductor decreases. When the current in the inductor reaches 0 mA, the voltage on the DRAIN pin starts to oscillate due to the stray capacitance (ringing). The SSL2109 waits for a oscillation valley. The charge time of the inductor is calculated using Equation 2

$$t_{ch} = L2 \times \frac{2 \times I_{LED}}{V_1 - V_{LED}} \quad (2)$$

The discharge time of the inductor is calculated using Equation 3

$$t_{dch} = L2 \times \frac{2 \times I_{LED}}{V_{LED}} \quad (3)$$

When the inductor is charging/discharging, a current flows through the inductor. However, there is also an effective current when ringing. Consider the oscillation frequency when adjusting the output current. It is calculated using Equation 4

$$f_{ring} = \frac{1}{2 \times \pi \times \sqrt{L2 \times (C_{FET} + C5)}} \quad (4)$$

The time from the start of oscillation to the first valley is calculated using Equation 5

$$t_{ring} = \frac{1}{2 \times f_{ring}} \quad (5)$$

The output current is calculated using Equation 6. The resulting output current is:

$$I_{LED} = \frac{1}{2} \times I_{peak} \times \frac{t_{ch} + t_{dch}}{t_{ch} + t_{dch} + t_{ring}} \quad (6)$$

Therefore by changing I_{peak} we can change I_{LED}.

7. External OverTemperature Protection (OTP)

The SSL2109 supports external OTP by adding an external Negative Temperature Coefficient (NTC) resistor. This feature is delivered by detecting a voltage on pin NTC. The NTC pin has an integrated current source. The resistance of the NTC resistor is decreased as the temperature is increased. When the NTC temperature rises and the voltage on the NTC pin falls to less than 0.5 V, the SSL2109 lowers the threshold level for detecting peak current in the inductor. Decreasing the peak current in the inductor causes the power current to decrease. The output current is regulated to the point where a balance between temperature and output current can be retained (the so called thermal management).

If the temperature on NTC increases continuously and the voltage on the pin drops to less than 0.3 V, the SSL2109 starts the NTC time-out timer. If the voltage on the NTC pin does not drop to less than 0.2 V within the time-out, the SSL2109 detects an abnormal condition. As a result the SSL2109 stops switching. If the voltage reaches 0.2 V within the time-out period, a Pulse Width Modulation (PWM) signal is assumed.

An NTC resistor can be directly connected 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 reference board. The values of these components can be changed depending on the protection temperature requirement and component availability.

Mounted the NTC in thermal contact with the LED string.

8. Power Factor (PF) adjustment

The SSL2109 IC and SSL2109 reference design is designed for standard operation with a PF of 0.6 at 230 V. The choice offers the highest efficiency. It is possible to tune the PF to higher values using two methods.

Increasing the value of R1 raises the PF higher than 0.7 with additional losses. See Table 2.

Table 2. PF adjustment, increasing the value of resistor R1

V_I (V)	V_O (V_{av}r)	I_O (mA)	R1 (Ω)	Efficiency (%)	PF	THD (%)
230	45	222	220	83.3	0.71	97
230	109	209	100	86.2	0.70	86
120	45	219	56	84.7	0.70	99
120	62	214	47	84.8	0.71	93

A resistor value of 220 W for R1 also results in operation with most available phase cut dimmers without damaging the lamp or dimmer. This change is not intended to reach stable operation without flicker or a good dimming range.

Dimension the power rating of R1 to handle peak powers that occur using leading-edge dimmers. These powers range between 2 W to 6 W. Alternatively, make a thermal link between the onboard NTC and R1, causing the board to turn off at overtemperature of R1.

The second option is to increase PF using a valley fill circuit. Figure 10 shows the basic schematic for the circuit. Table 3 shows the results.

Table 3. PF adjustment, valley fill circuit

V_I (V)	V_O (V_{av}r)	I_O (mA)	C2X/Y (μF)	L1 (mH)	R1 (Ω)	Efficiency (%)	PF	THD (%)
120	44.5	212	47	0.82	100	83.1	0.9	43
230	62	216	22	2.2	47	92.9	0.81	63
230	62	215	22	2.2	390	80	0.9	40

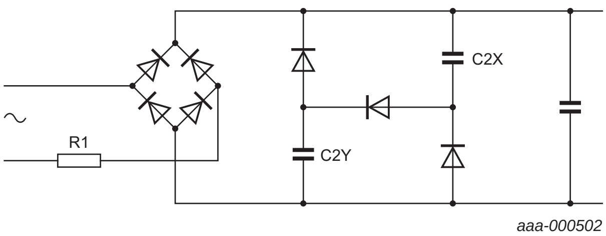


Fig 10. Valley fill circuit

The valley fill circuit can only be employed, if the output voltage is less than half the peak input voltage. At 230 V input, it operates up to 85 V (DC) output voltage, otherwise no power is delivered to the LEDs during the valley duration.

9. Active bypass

An increased value for the inrush current resistor protects the board from damage with phase cut dimmers, however lowers the efficiency. If a higher PF is not required, but leading-edge dimmer compatibility and high efficiency are important, the active bypass option is available. In this circuit, the inrush current resistor is bypassed using a Silicon Controlled Rectifier (SCR). See Figure 11.

Table 4 shows the results when active bypass is used.

Table 4. PF adjustment, valley circuit fill

V_I (V)	V_O (V_{av}r)	I_O (mA)	R1 (Ω)	Efficiency (%)	PF	THD (%)
230	45	217	100	92.6	0.52	144
120	62	215	100	89.5	0.52	153

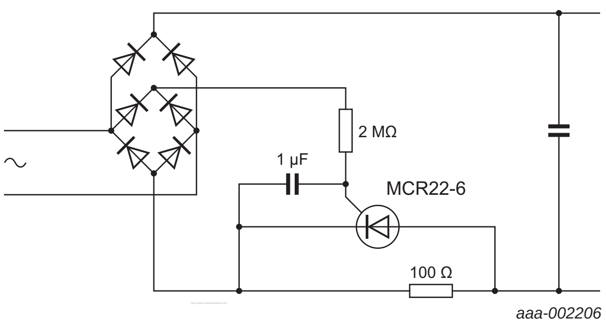


Fig 11. Active bypass

10. Schematic

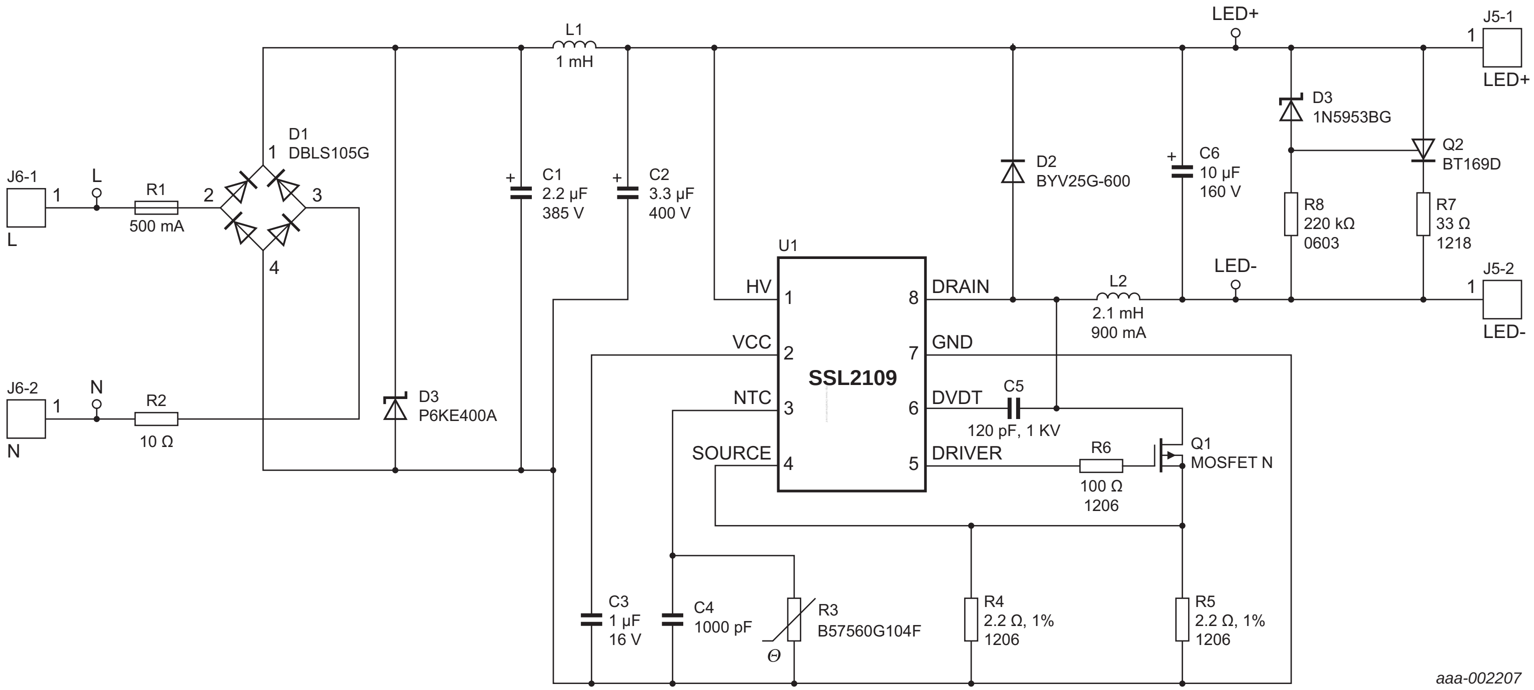


Fig 12. Reference board schematic

11. Bill Of Materials (BOM)

Table 5 provides detailed component information for the SSL2109 reference board.

Table 5. BOM for the high efficiencySSL2109 demo board

Reference	Component	Package	Part number	Manufacturer
J6	connector 2 pin	-	MKDSN 2.5/2-5.08	Phoenix
J5	connector 2 pin	-	MKDSN 2.5/2-5.08	Phoenix
R1	fuse; 500 mA; 250 AC		0263.500HAT 1L	Littelfuse
R2	10 W; 2 W; 600 V; 5 %	2512	CRM2512-JW-100ELF	Bourns
R3	100 kΩ;	-	B57560G104F	EPCOS
R4	2.2 W; 0.25 W; 200 V; 1 %	1206	RC1206FR-072R2L	Yageo
R5	2.2 W; 0.25 W; 200 V; 1 %	1206	RC1206FR-072R2L	Yageo
R6	100 W; 0.125 W; 200 V; 5 %	1206	MC0.125W12065% 100 R	Multicomp
R7	33 Ω; 1 W; 200 V; 5 %	1218	PRC201 1218 33 R	Yageo
R8	220 kΩ; 0.063 W; 50 V; 5 %	0603	MC0.063W0603 5 % 220 K	Multicomp
C1	2.2 μF; 400 V; 20 %	8 × 11.5	ECA2GHG2R2	Panasonic
C2	3.3 μF; 400 V; 20 %	10 × 12.5	ECA2GHG3R3	Panasonic
C3	1 μF; 16 V; 10 %	0603	0603YC105KAT2A	AVX
C4	1 nF; 100 V; 10 %	0603	06031C102KAT2A	AVX
C5	120 pF; 1000 V; 5 %	1206	CC1206JKNPOCBN121	Yageo
C6	10 μF; 105 °C; 160 V; 20 %	8 × 11.5	UVZ2C100MPD1TD	Nichicon
L1	1 mH; 10 %	-	768772102	Würth Elektronik
L2	2.1 mH; 10 %	RM6	750312626	Würth Elektronik
RV1	WE-VD; 275 V	10 mm	80412711	Würth Elektronik
Q1	3 A; 400 V; 1.5 Ω	I-Pak	STD5NK40Z-1	ST Micro Electronics
Q2	0.8 A; 400 V	TO92	BT169D	NXP
D1	bridge; 1 A; 600 V	SOIC-4	DBLS105G	Multicomp
D2	5 A; 600 V	SOT226A	BYV25G-600	NXP
D4	Zener; 3 W; 150 V	DO-41	1N5953BG	On-semi
U1	IC; 600 V	SO8	SSL2109	NXP
120 VAC				
C1	10 μF; 105 °C; 160 V; 20 %	8 × 11.5	UVZ2C100MPD1TD	Nichicon
C2	10μF; 105 °C; 160 V; 20 %	8 × 11.5	UVZ2C100MPD1TD	Nichicon
RV1	WE-VD; 130 V	10 mm	820511311	Würth Elektronik

12. Board layout

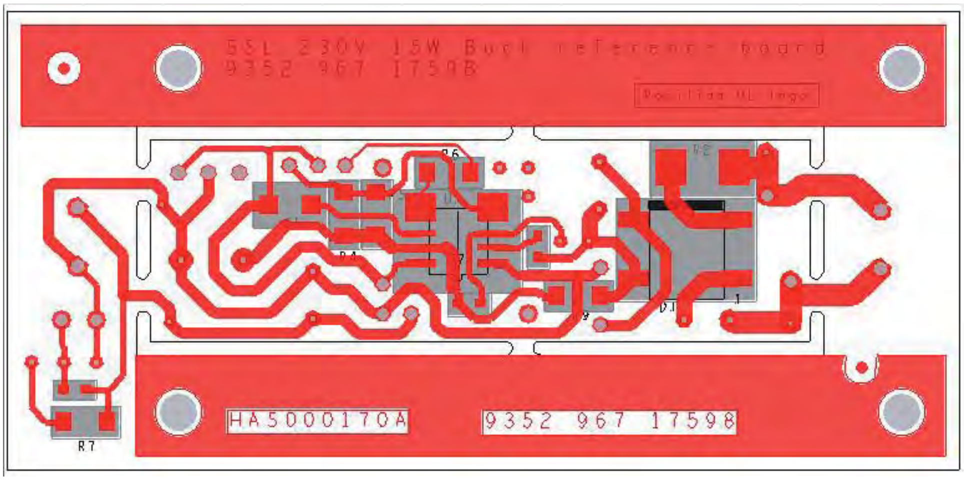


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Fig 13. Reference board PCB (Bottom view)

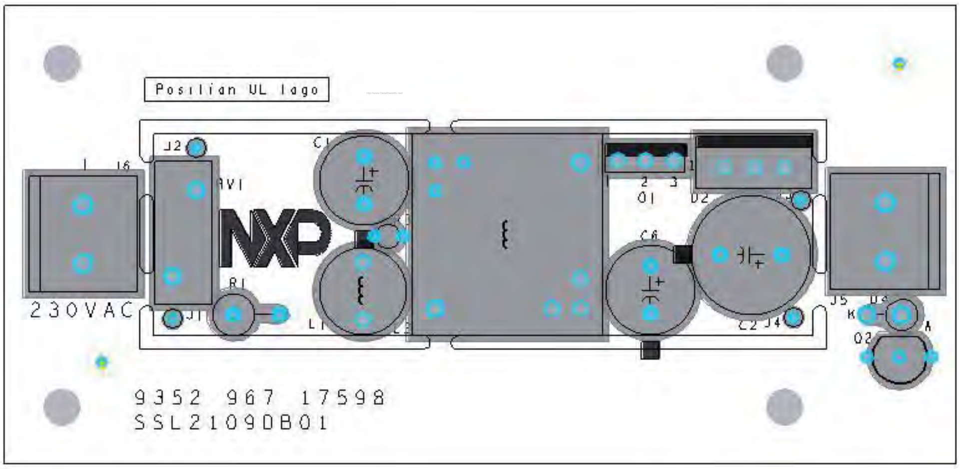

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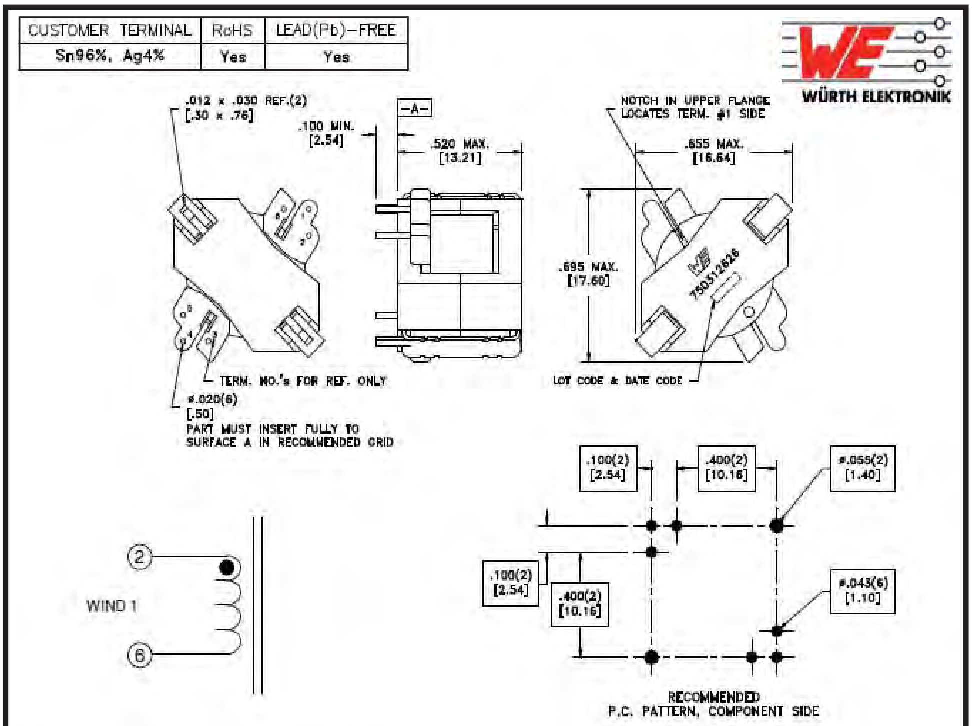
Fig 14. Reference board PCB (Top view)

13. Inductor specification



ELECTRICAL SPECIFICATIONS @ 25°C unless otherwise noted:

D.C. RESISTANCE (@20°C):	2-6 , 1.53 Ohms ±10%.
INDUCTANCE:	2.10 mH ±10%, 10kHz, 100mVAC, 0mADC, 2-6, Ls.
SATURATION CURRENT:	900mA saturating current that causes 20% rolloff from initial inductance.

OPERATING TEMPERATURE RANGE: -40°C to 125°C including temp. rise.

Safety Standard Undefined

PC1_0_5757_D_0222

WE-Midcom, Inc. Watertown, SD USA Toll Free: 800-643-2661 Fax: 605-886-4486	Unless otherwise specified, tolerances are as follows: Angles: ±1° Fractions: ±1/64 Decimals: ±.005(.127mm)	WE-Midcom, Inc.	
	Drawing Title Transformer	Drawing Number 750312626	Rev. 00
This drawing is dual dimensioned. Dimensions in brackets are in millimeters	Revisions: See Sheet 1	Scale ----	Sheet 2 of 5

Engineer:LJG 09/23/2011

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Fig 15. Inductor specification

14. Abbreviations

Table 6. Abbreviations

Acronym	Description
BCM	Boundary Conduction Mode
CC	Constant Current
DCM	Discontinuous Conduction Mode
EMC	ElectroMagnetic Compatibility
EMI	ElectroMagnetic Interference
LED	Light Emitting Diode
MOSFET	Metal-Oxide Semiconductor Field-Effect Transistor
NTC	Negative Temperature Coefficient
PF	Power Factor
PWM	Pulse-width Modulation
SCR	Silicon Controlled Rectifier

15. References

[1] **SSL2108X —** Data sheet: Drivers for LED lighting

[2] **AN11041 —** Application Note: SSL2108X driver for SSL applications

[3] **AN10876 —** Application Note: Buck converter for SSL applications

[4] **SSL2109 —** Data sheet: SSL2109 reference board

[5] **AN11136 —** Application note: Buck convertor driver for SSL applications

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