UM10501

SSL21083 reference board user manual

Rev. 2 — 16 November 2011 **User manual**

Document information

Info	Content
Keywords	SSL21083, buck converter, reference board, LED driver, LED retrofit lamp, low power
Abstract	This document describes the performance, technical data and the connection of the SSL21083 reference board. The SSL2108 series is an NXP Semiconductors driver IC intended to provide a low cost, small form factor LED driver. This board is intended to operate at 230 V (AC), using an output voltage of 30 V or more.

Revision history

Rev	Date	Description
v.2	20111116	second issue
Modifications:		• Section 9 “Active bypass” on page 11: minor text changes • Section 10 “Known issues” on page 12: section added.
v.1	20110908	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.

The SSL21083 is a highly integrated switching mode LED driver which enables constant current driving from the mains input. It is a solution for small LED retrofit lamp application, especially for low-power factor design.

The SSL21083 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 voltage. The SSL2108 series is intended to operate with higher output voltages, as present in modern LED modules.

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

2. Safety warning

This demo 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. These devices are recognized by the symbols shown in Figure 1.

a. Isolated

b. Not isolated

Fig 1. Variac isolation symbols

3. Connecting to the board

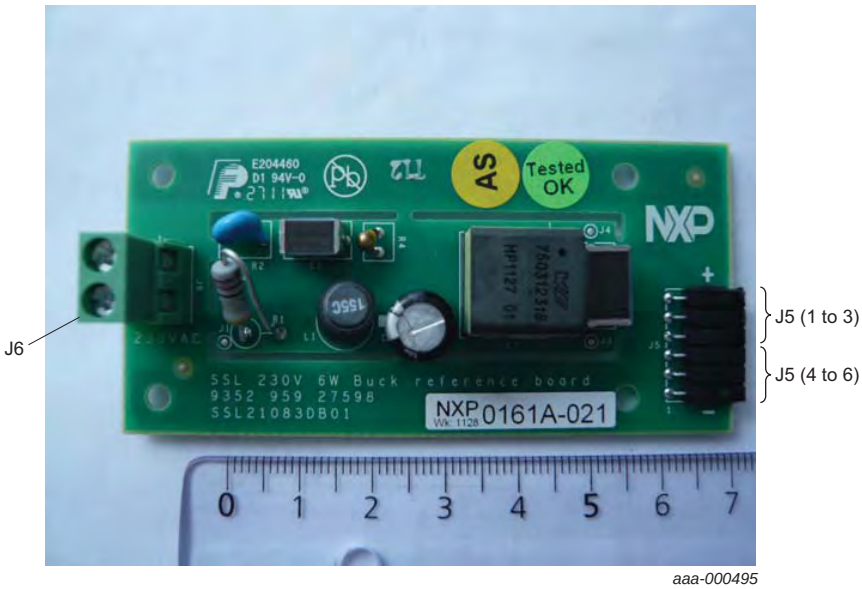
The board is optimized for a 230 V (AC, 50 Hz) mains supply. In addition to the mains voltage optimization, the board is designed to work with multiple LEDs or an LED module with a high forward voltage.

Mains connection of this reference board is different from other general evaluation/demo boards. Connect the mains to the screw connector J6.

Remark: The maximum rated voltage of the board is 280 V (limited by the value of electrolytic capacitor C1) or 400 V (DC).

The anode of the LED load is connected to positive positions 1 to 3 of connector J5. The cathode is connected to negative 4 to 6 of connector J5.

Use an LED string with a V_F greater than 20 volt on this board. Under the expected conditions, the output current is 96 mA. If the rated current of the LED does not meet this 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 (1 to 3): Positive anode positions.

(4) J5 (4 to 6): Negative cathode positions.

Fig 2. Board connection diagram

4. Specification

Table 1. Specifications for the reference board

Parameter	Value	Comment
AC line input voltage	170 V (AC) to 260 V (AC)	the board is optimized for 230 V (AC), 50 Hz
output voltage	20 V (DC) to 130 V (DC)	-
output current	96 mA at V_O = 92 V (DC)	±4 % V_O = 60 V (DC) to 120 V (DC)
Maximum power in to LED load ($P_{O(load)}$)	12.5 W	-
efficiency	> 94 %	96 mA
power factor	0.6	at 10 W; 70 V; 96 mA output
	0.5	at 3 W; 70 V; 96 mA output
board dimensions	17.5 mm × 53.5 mm × 17.5 mm	length × width × height (internal)
	40 mm × 83 mm	length × width (external)
operating temperature	–40 °C to +100 °C	-
NTC threshold temperature ($T_{th(NTC)}$)	60 °C	onboard NTC activates above 60 °C
IEC61000-3-2 compliant	yes	P_o > 8.5 W
IEC55015 compliant	yes	see Figure 7 and Figure 8

5. Performance data

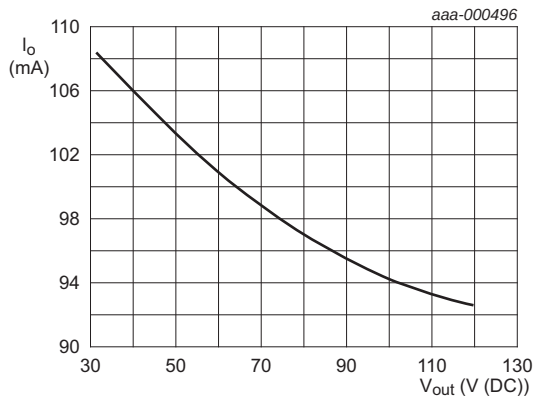


Fig 3. Load regulation: output current as a function of output voltage

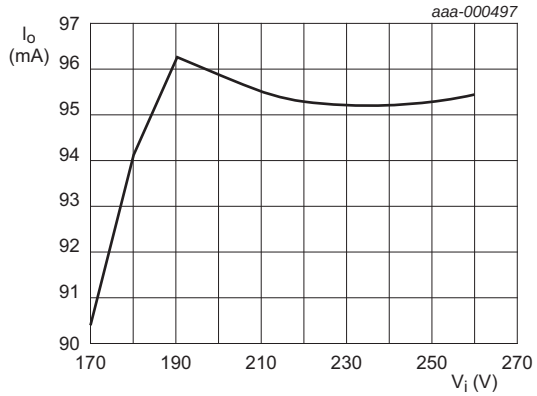


Fig 4. Line regulation: output current as a function of input voltage

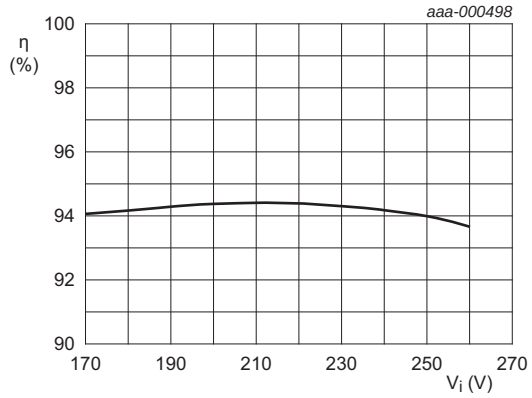
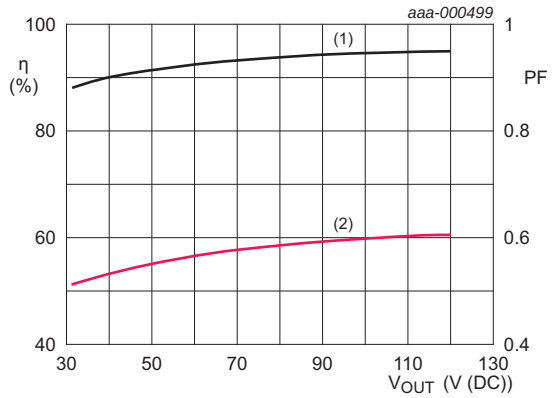


Fig 5. Line regulation: efficiency as a function of input voltage



(1) Efficiency

(2) Power factor

Fig 6. Load regulation: efficiency and power factor as a function of output voltage

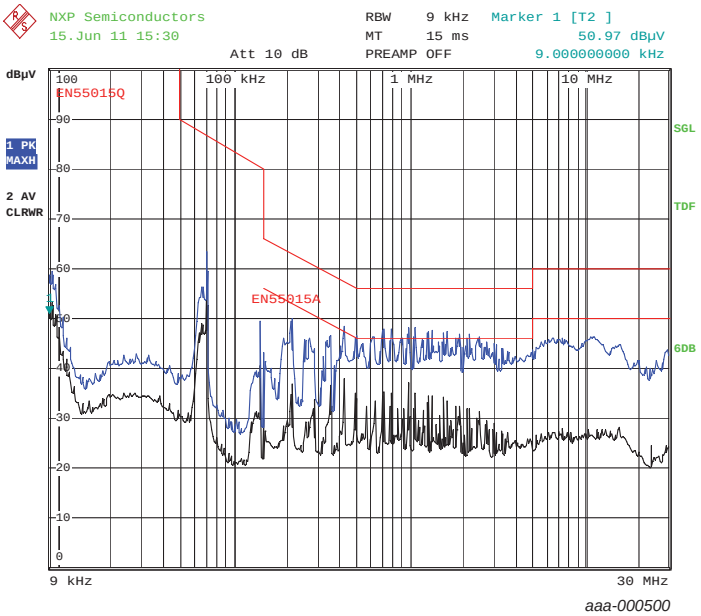


Fig 7. SSL21083 EMC measurement L-phase according to EN55015 norm

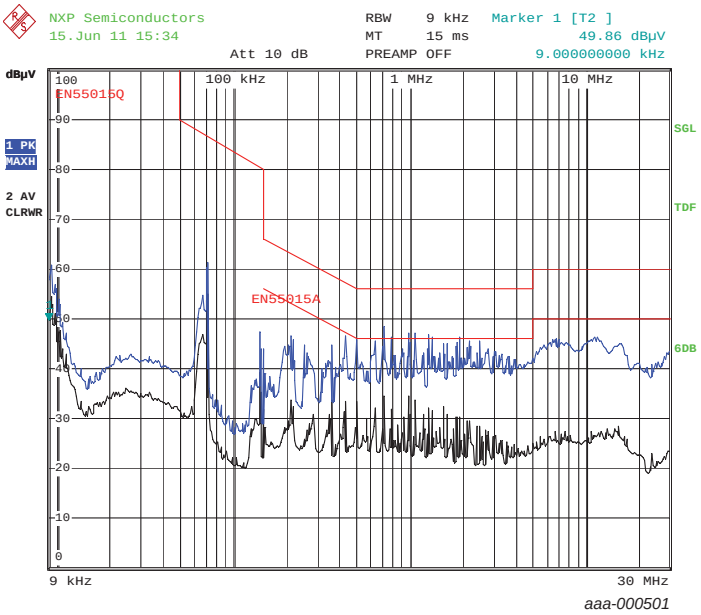


Fig 8. SSL21083 EMC measurement N-phase according to EN55015 norm

6. Changing the output current

The SSL21083 monitors the charging current in the inductor using the sense resistors R5 and R6. 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 SSL21083 turns off the MOSFET when the voltage on pin SOURCE reaches 500 mV. If the value of R5 in parallel with R6 is 2 Ω, the peak current is limited to 250 mA.

$$I_{peak} = \frac{0.5 \times (R5 + R6)}{R5 \times R6} \quad (1)$$

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 because of the stray capacitance (ringing). SSL21083 waits for a valley of this oscillation.

The charge time of the inductor is calculated using Equation 2:

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

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 it. However, there is also an effective current when ringing. Consider the oscillation frequency when adjusting the output current. It is calculated using Equation 4:

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

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 SSL21083 supports external OTP by adding an external Negative Temperature Coefficient (NTC) resistor. This feature is delivered by detecting a voltage on pin NTC. Pin NTC has an integrated current source. The Resistance of the NTC resistor is decreased as the temperature is raised. When the NTC temperature rises and the voltage on pin NTC falls below 0.5 V, the SSL21083 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 below 0.3 V, the SSL21083 starts the NTC time-out timer. If the voltage on pin NTC pin does not drop below 0.2 V within the time-out, the SSL21083 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 directly connected to pin NTC. 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.

The NTC should be mounted in thermal contact with the LED string.

8. Power factor adjustment

The SSL21083 IC and SSL21083 reference designs are designed for standard operation with a power factor of 0.6 at 230 V (AC). This choice offers highest efficiency. It is possible to tune the power factor to higher values using two methods.

Increasing the value of R1 raises the power factor above 0.7 with additional losses. (see Table 2).

Table 2. Power factor adjustment - increasing the value of resistor R1

V_{IN} (V (AC))	V_o (V_{avr})	I_o (mA)	R1 (Ω)	Efficiency (%)	Power factor	THD (%)
230	101.5	94	10	95.2	0.59	109.2
230	102.9	127	10	94.7	0.6	94
230	98	46	22	91.6	0.52	150
230	100.6	94	22	94.4	0.6	107
230	100.8	94	270	85.2	0.71	84

A resistor value of 270 Ω 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 4 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 power factor is using a valley fill circuit. The basic schematic for this circuit is shown in Figure 9. Table 3 shows the results when using a 4.7 μF capacitor for C2X and C2Y.

Table 3. Power factor adjustment - valley fill circuit

V_{IN} (V (AC))	V_o (V_{avr})	I_o (mA)	R1 (Ω)	Efficiency (%)	Power factor	THD (%)
230	85	97	22	95.1	0.78	66
230	61	100	270	89.3	0.8	58

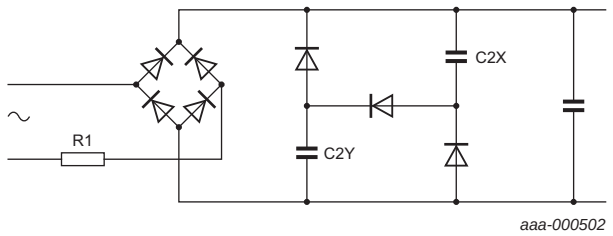


Fig 9. Valley fill circuit

The valley fill circuit can only be employed, if the output voltage is below half the peak input voltage. At 230 V (AC) 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, but lowers the efficiency. If a higher power factor is not required, but leading-edge dimmer resistance 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 10).

Table 4 shows the results when active bypass is used.

Table 4. Active bypass

V_{IN} (V (AC))	V_o (V_{avr})	I_o (mA)	R1 (Ω)	Efficiency (%)	Power factor	THD (%)
230	121	92	100	93.5	0.57	114
230	61	100	100	91.3	0.54	140

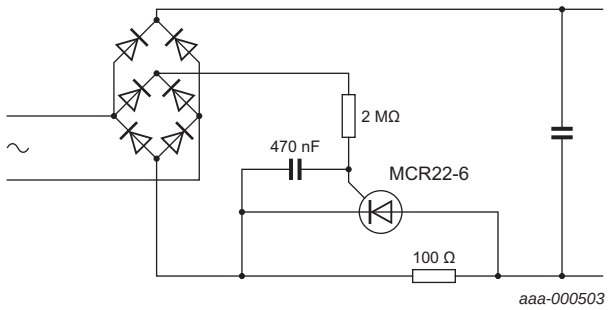


Fig 10. Active bypass

10. Known issues

10.1 Latch up on fast mains toggle

It can be observed that the board latches up when the mains voltage is switched on, off, and then on again within a 1.6 s time period.

The cause of this is a crossing of the ground trace between buffer capacitor C1 and source resistors R5/R6. This causes a spike between the IC source and GND greater than 1.5 V. This in-turn activates SWP.

To overcome this problem, a modification can be implemented. Connect a wire bridge between R5/R6, GND and the IC GND pin to bypass the crossed traces and reduce switch on spike. See Figure 11 for a pictorial view of the modification.

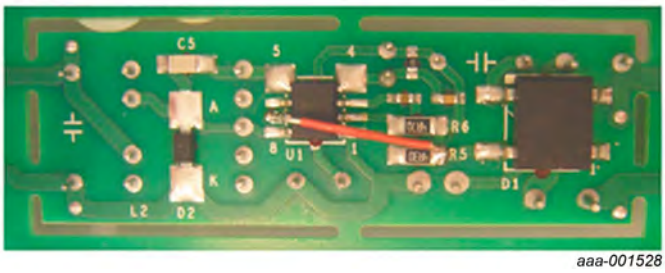


Fig 11. Board modification

11. Schematic

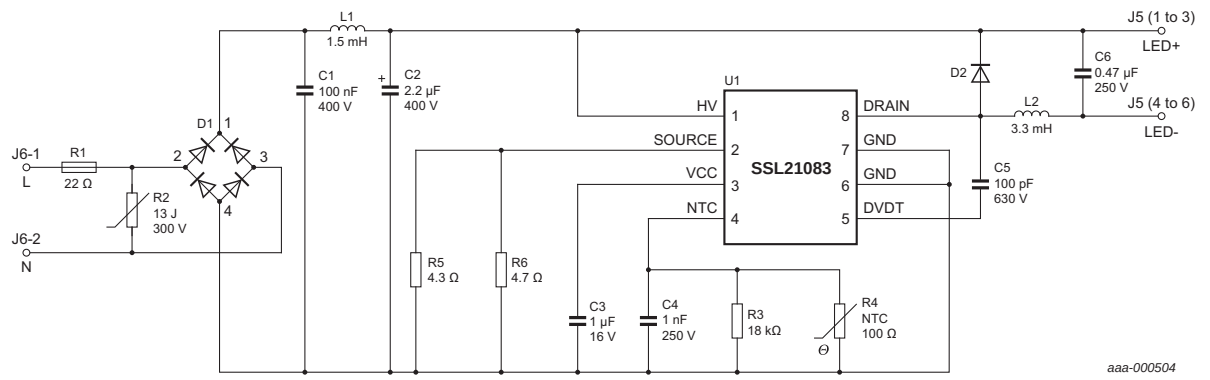


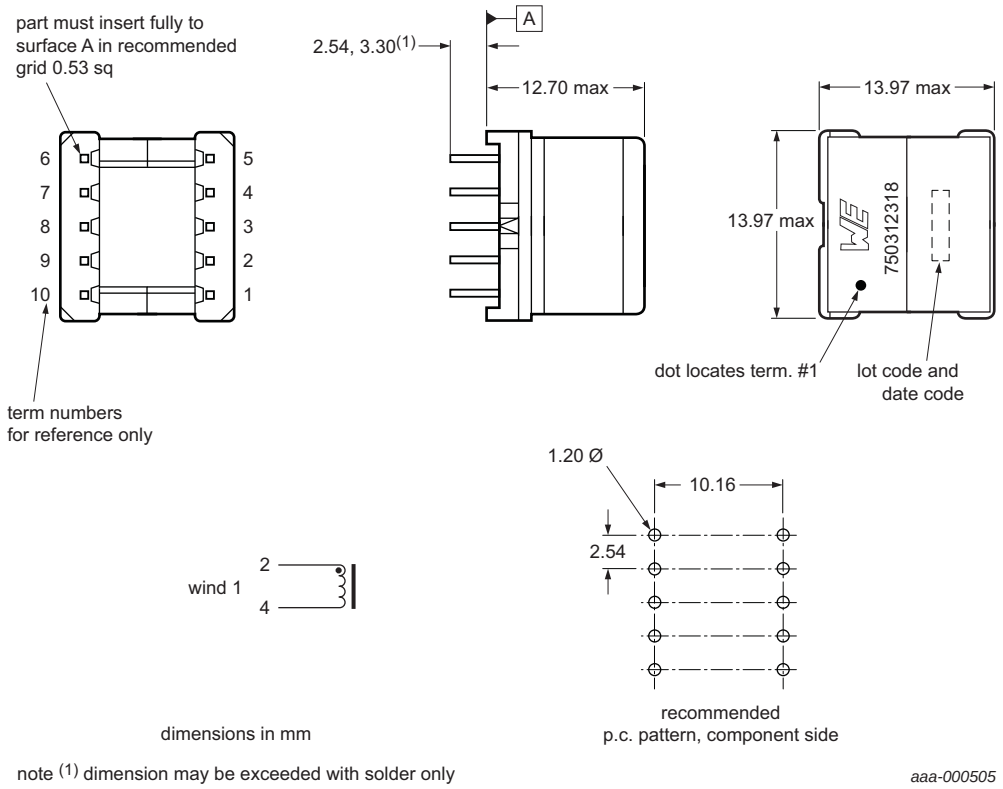
Fig 12. Schematic

12. Bill of materials

Table 5. Bill of materials

Component	Values	Manufacturer/Part number
C1	capacitor; 100 nF; 10 %; 400 V	EPCOS; B32560J6104K
C2	capacitor; 2.2 µF; 105 °C; 400 V	Panasonic; ECA2GHG2R2
C3	capacitor; 1 µF; 10 %; 16 V; 0603	AVX; 0603YC105KAT2A
C4	capacitor; 1 nF; 10 %; 100 V; 0603	AVX; 06031C102KAT2A
C5	capacitor; 100 pF; 5 %; 630 V; 1206	Yageo; CC1206JRNPOBBN101
C6	capacitor; 0.47 µF; 250 V	EPCOS; B32561J3474K
D1	bridge rectifier; 1 A; 600 V; SOIC-4	Multicomp; DBLS105G
D2	diode; 1 A; 600 V; SMA	Taiwan Semiconductor; ES1JL
J6	connector; 2-pin male	Phoenix; MKDSN 2,5/2-5.08
J5	connector; 6-pin female	Fischer; BL 3.36Z
R1	fused resistor; 22 Ω; 2 W; 10 %; 500 V	Welwyn Components; EMC2-22RKI
R2	variable resistor; 13 J; 300 V	Multicomp; MCFT000228
R3	resistor; 18 kΩ; 0.25 W; 1 %; 0603	free
R4	NTC; 100 kΩ; 25 °C	Vishay; NTCLE100E3104JB0
R5	resistor; 4.3 Ω; 0.25 W; 1 %; 1206	free
R6	resistor; 4.7 Ω; 0.25 W; 1 %; 1206	free
L1	inductor; 1.5 mH; 10 %	Murata; 22R155C
L2	inductor; 3.3 mH; 10 %	Würth Elektronik; 750312318
U1	IC; 600 V; SO8	NXP Semiconductors; SSL21083

13. Inductor appearance and dimensions



Electrical specifications at 25 °C unless otherwise stated.

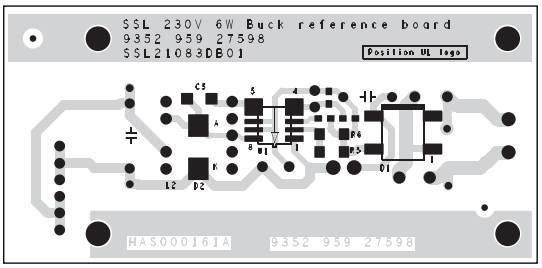
Fig 13. Inductor appearance and dimensions

Table 6. Inductor electrical specifications

Electrical specifications at 25 °C unless otherwise stated.

Parameter	Comment
DC resistance at 20 °C	2 to 4; 2.13 Ω ±10 %
dielectric rating	500 V (AC) 60 s; tested by applying 625 V (AC) for 1 s between pins 2 to core
inductance	3.3 μH ±10 %; 1- kHz 100 mV (AC); 0 mA (DC) 2 to 4; Ls
saturation current	330 mA saturation current causes 20 % roll-off from initial inductance
operating temperature range	-40 °C to +125 °C

14. Board layout



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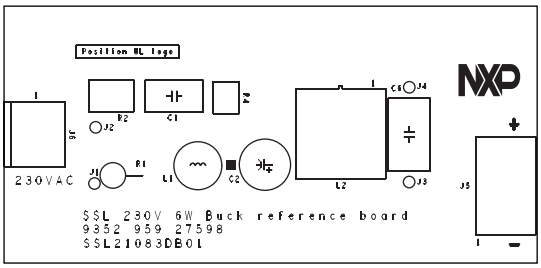
a. Bottom layer



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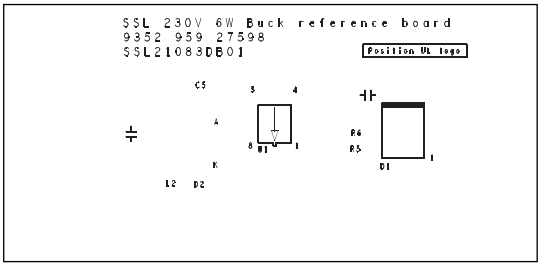
b. Top silk



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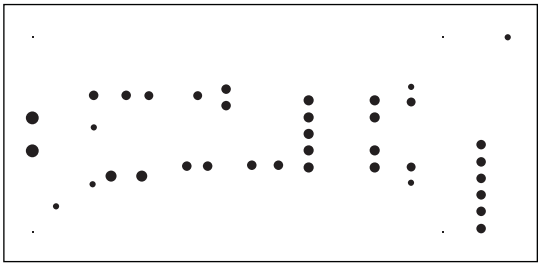
c. Bottom silk



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d. Drill mask

Fig 14. Board layout

15. Board photographs

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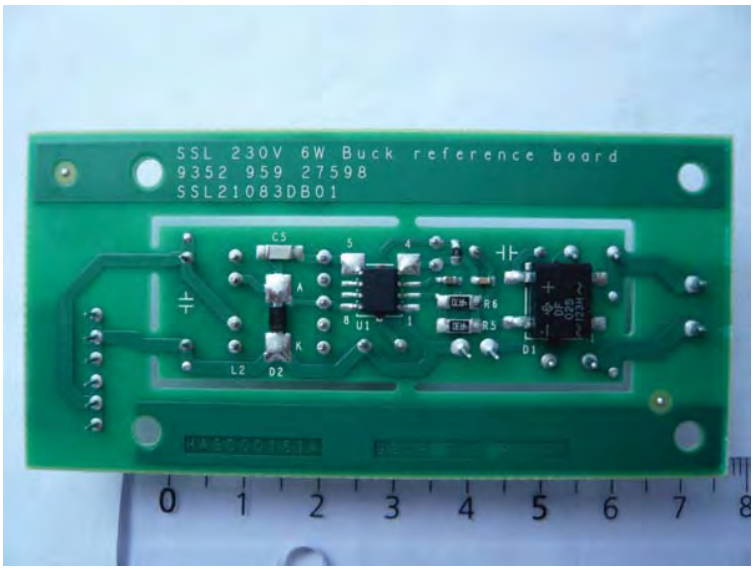
a. Front view



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b. Back view

Fig 15. Photographs of the board

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