UM10481

SSL21082 reference board

Rev. 2.1 — 28 November 2011 **User manual**

Document information

Info	Content
Keywords	SSL21082, buck converter, reference board, LED driver, LED retrofit lamp, low power
Abstract	This document describes the performance, technical data and the connection of the SSL21082 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 100 V (AC) or 120 V (AC), using an output voltage of 30 V or more.

Revision history

Rev	Date	Description
v.2.1	20111128	fourth issue
Modifications:		• Figure 12 “Schematic” on page 13: changed.
v.2	20111109	third issue
v.1.1	20110826	second issue
v.1	20110719	first issue

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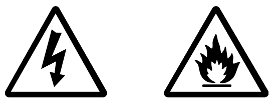
1. Introduction

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 SSL21082 is a highly integrated switching mode LED driver which enables constant current driving from mains input. It is a solution for small LED retrofit lamp application, especially for low-power factor design.

The SSL21082 supports buck converter topology, and is suitable for non-isolated, non-dimmable LED retrofit lamp. It can drive long LED string with, for example, a 70 V forward voltage. The SSL2108 series is intended to operate with higher output voltages, as present in modern LED modules.

This reference board is an example that can be used in applications up to E26 form factor lamp fittings.

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 100 V (AC, 60 Hz) mains supply. Besides the mains voltage optimization, the board is designed to work with multiple LEDs or an LED module with a high forward voltage.

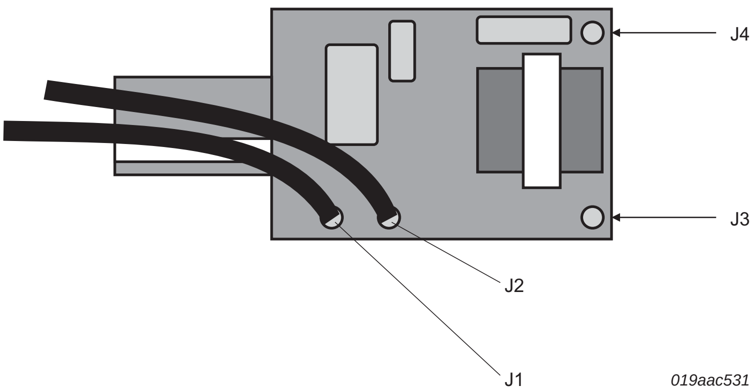
Mains connection of this reference board is different from other general evaluation/demo boards. Connect the mains to an axial lead resistor and fuse which are connected to J1 and J2. In the application, it is possible that one side of these components is directly connected to the socket.

Remark: The maximum rated voltage of the board is 141 V (limited by the value of electrolytic capacitor C1) or 200 V (DC).

Remark: The rated voltage of fuse F1 is 125 V (AC).

An anode of the LED string is connected to J3 and a cathode is connected to J4. Use an LED string with a V_F greater than 20 volt on this board. Under the expected conditions, the output current is 125 mA. If the rated current of the LED does not meet this specification, the current can be adjusted. See Section 5 for instructions.

The electrolytic capacitor is mounted outside the board so it can be mounted in the screw cap of the lamp. The temperature around screw cap is the lowest in the lamp. When the capacitor is placed in the screw cap, the life time of the electrolytic capacitor is improved.



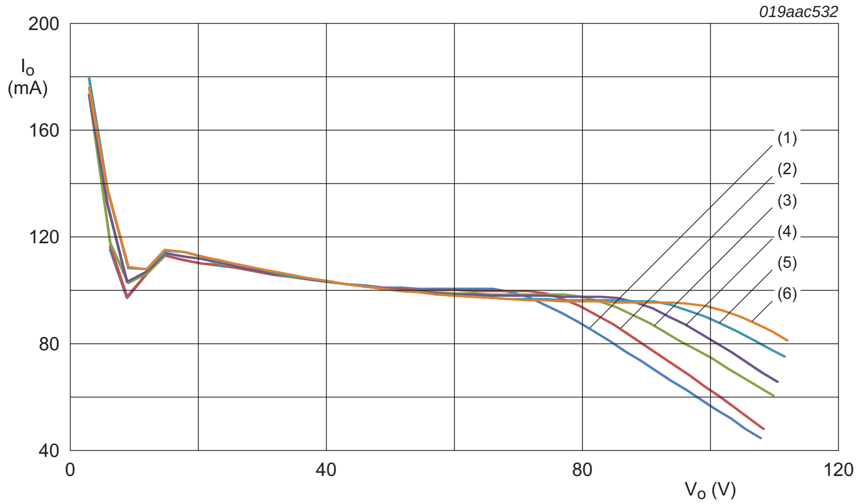
(1) J2: connect the flying lead end of R1 to the AC mains supply.
(2) J1: connect the flying lead end of F1 to the AC mains supply.
(3) J3: Anode.
(4) J4: Cathode.

Fig 2. Board connection diagram

4. Specification

Table 1. Specifications for the reference board

Parameter	Value	Comment
AC line input voltage	85 V (AC) to 138 V (AC)	the board is optimized for 100 V (AC), 60 Hz.
output voltage	> 20 V (DC)	
output current	125 mA	at 100 V (AC) mains; 70 V LED
output current dependency	±5 %	100 V (AC) ±10 %; at 70 V; 125 mA output (see Figure 3)
efficiency	> 90 %	at 70 V; 125 mA output
power factor	0.6	at 70 V; 125 mA output
board dimension	30 mm × 19 mm × 12 mm	length × width × height



(1) 100 V (AC); 50 Hz

(2) 100 V (AC); 60 Hz

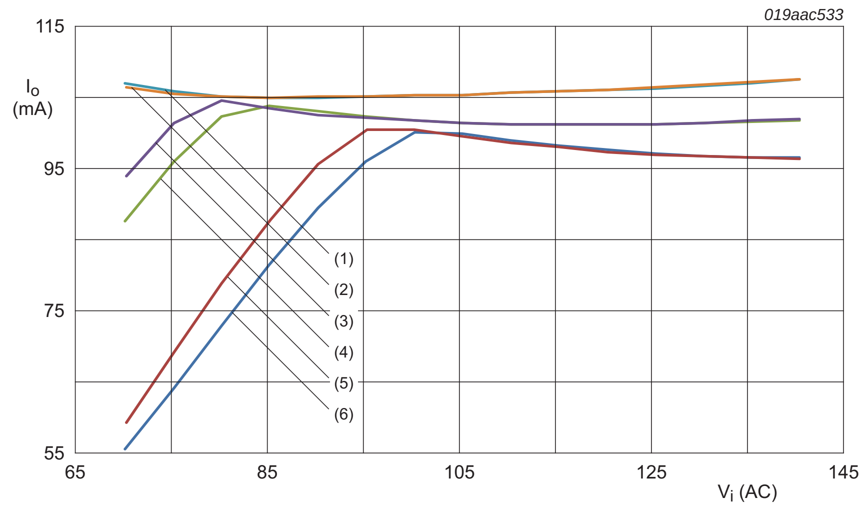
(3) 110 V (AC); 50 Hz

(4) 110 V (AC); 60 Hz

(5) 120 V (AC); 50 Hz

(6) 120 V (AC); 60 Hz

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



(1) 35 V; 50 Hz

(2) 35 V; 60 Hz

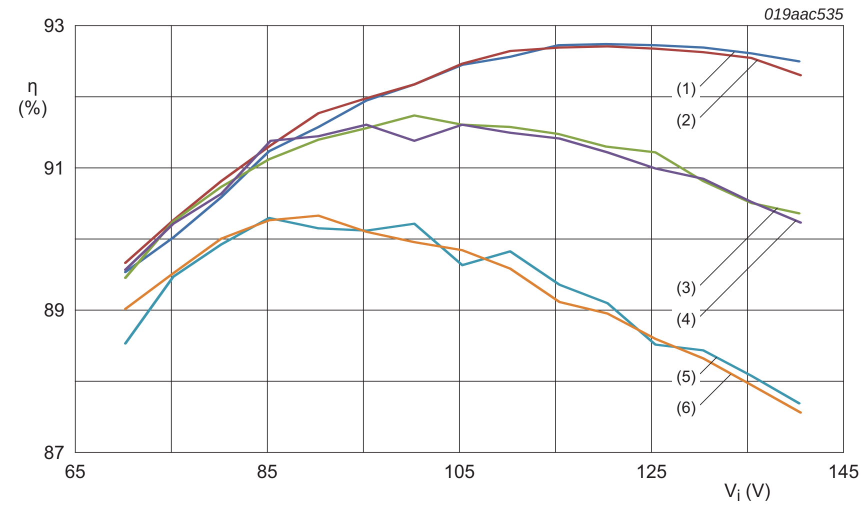
(3) 48 V; 60 Hz

(4) 48 V; 50 Hz

(5) 70 V; 60 Hz

(6) 70 V; 50 Hz

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



(1) 70 V; 50 Hz

(2) 70 V; 60 Hz

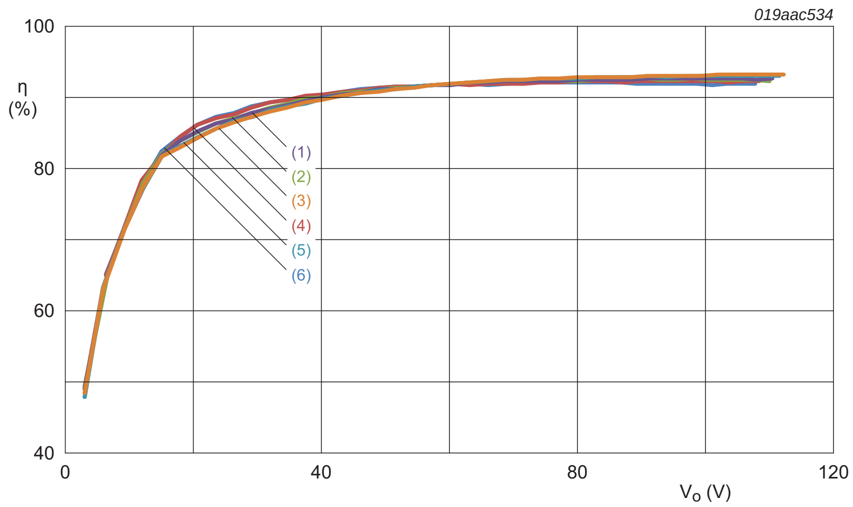
(3) 48 V; 50 Hz

(4) 48 V; 60 Hz

(5) 35 V; 50 Hz

(6) 35 V; 60 Hz

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



(1) 100 V (AC); 50 Hz

(2) 100 V (AC); 60 Hz

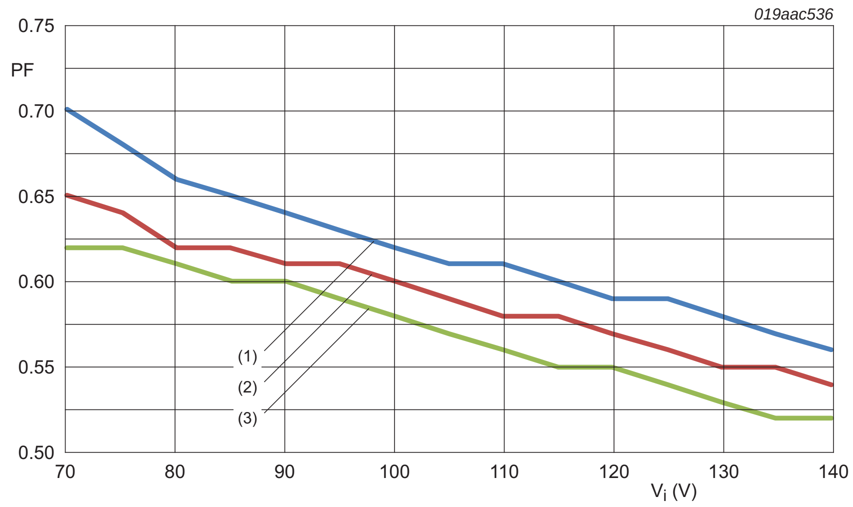
(3) 110 V (AC); 50 Hz

(4) 110 V (AC); 60 Hz

(5) 120 V (AC); 50 Hz

(6) 120 V (AC); 60 Hz

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



(1) V_o = 70 V

(2) V_o = 48 V

(3) V_o = 35 V

Fig 7. Load regulation: power factor as a function of input voltage

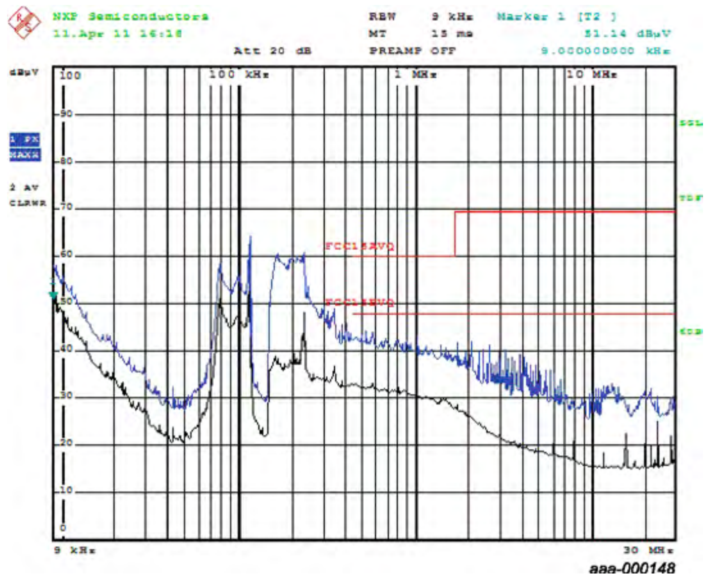


Fig 8. SSL21082 EMC measurement L-phase according to FCC15 norm

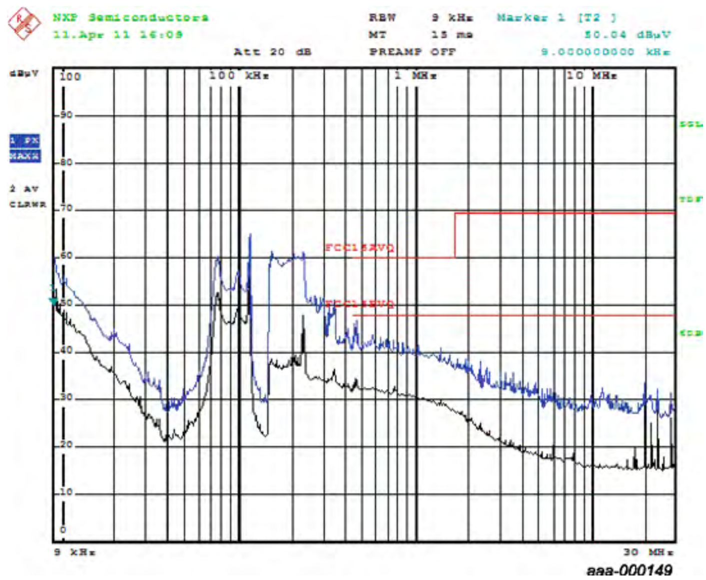


Fig 9. SSL21082 EMC measurement N-phase according to FCC15 norm

5. Changing the output current

The SSL21082 monitors the charging current in the inductor using the sense resistors R2 and R3. It controls a MOSFET to retain a constant peak current. In addition, the IC supports valley detection.

These features enable a driver to operate in Boundary Conduction Mode (BCM) with valley switching where the average current in the inductor is an output current.

The SSL21082 turns off the MOSFET when the voltage on pin SOURCE reaches 500 mV. If resistors R2 and R3 are between pin SOURCE and GND is 2 Ω, the peak current is limited to 250 mA.

$$I_{peak} = \frac{0.5 \times (R2 + R3)}{R2 \times R3} \quad (1)$$

When the MOSFET is turned off, inductor L2 is discharged and the current flowing through the inductor is decreased. When the current in the inductor reaches 0 mA, the voltage on pin DRAIN starts to oscillate. SSL21082 waits for a valley of this oscillation. When the voltage on pin DRAIN reaches it lowest value, the MOSFET is turned on again.

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 oscillating. Consider the oscillation frequency when adjusting the output current. It is calculated using Equation 4:

$$f_{ring} = \frac{1}{2 \times \pi \times \sqrt{L2 \times (C_{FET} \pm C6)}} \quad (4)$$

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:

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

6. External OverTemperature Protection (OTP)

The SSL21082 supports external OTP by adding an external Negative Temperature Coefficient (NTC) thermistor. This feature is delivered by detecting a voltage on pin NTC. Pin NTC has an integrated current source, which provides the pin with an offset. The Resistance of the NTC thermistor is decreased as the temperature is raised. When the NTC temperature rises and the voltage on pin NTC falls to below 0.5 V, the SSL21082 lowers the threshold level for detecting peak current in the inductor. Decreasing the peak current in the inductor causes the power consumption in the system to decrease as well. The output current is adjusted to the point where a balance between safety 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 SSL21082 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 SSL21082 detects an abnormal condition and stops switching.

An NTC thermistor 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.

7. Power factor adjustment

The SSL21082 reference board is designed for a standard operation with a power factor of 0.6 at 100 V (AC). This option offers the highest efficiency. There are two ways of tuning the power factor to higher values. The first option is by increasing the value of R1, which raises the power factor to above 0.7, resulting in additional losses (see Table 2).

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

V_i (V (AC))	V_o (V_{avr})	I_o (mA)	R1 (Ω)	Efficiency (%)	Power factor	THD (%)
100	62.8	127	10	91.5	0.6131	111
100	62.8	127	33	85.0	0.701	90.5
120	62.5	123	68	84.7	0.711	94.2
120	63.1	124	100	81.9	0.75	84.3
120	43.5	129	100	82.7	0.715	95.1

Increasing R1 also results in a lower inrush current, allowing the board to be connected to leading-edge phase cut dimmers without damage to the dimmer or to the lamp (dimmer resistant). This adjustment is not intended for stable operation without flicker or a good dimming range, but is for safety only. Dimension the power rating of R1 to handle peak powers that occur using leading-edge dimmers. This power is between 2 W and 4 W. Alternatively, a thermal link can be made between the onboard NTC and resistor R1, causing the board to turn off at an overtemperature of resistor 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 10. Table 3 shows the results when using a 10 μF capacitor for C2X and C2Y.

Table 3. Power factor adjustment - valley fill circuit

V_i (V (AC))	V_o (V_{avr})	I_o (mA)	R1 (Ω)	Efficiency (%)	Power factor	THD (%)
120	42.4	133	120	86.0	0.904	43.8
120	20.9	137	220	82.4	0.908	43.1

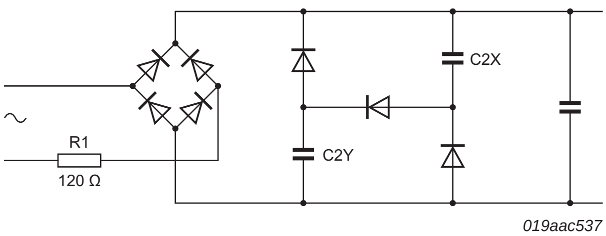


Fig 10. Valley fill circuit

The valley fill circuit can only be employed in buck converter mode if the output voltage is below half the peak input voltage. In practice, at 120 V (AC) input it operates up to 50 V (DC) output voltage.

8. Active bypass

An increased value for the inrush current resistor protects the board from damage with most phase cut dimmers, but also 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 11).

Table 4 shows the results when active bypass is used.

Table 4. Active bypass

V_i (V (AC))	V_o (V_{avr})	I_o (mA)	R1 (Ω)	Efficiency (%)	Power factor	THD (%)
100	22	143	56	86.2	0.566	135
100	43	130	56	89.0	0.618	109
120	22	142	56	85.0	0.533	151
120	43	130	56	89.2	0.585	125

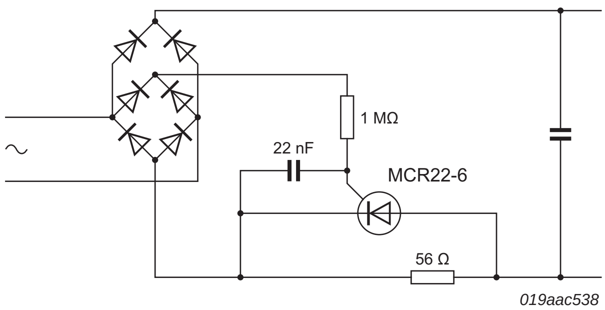


Fig 11. Active bypass

9. Schematic

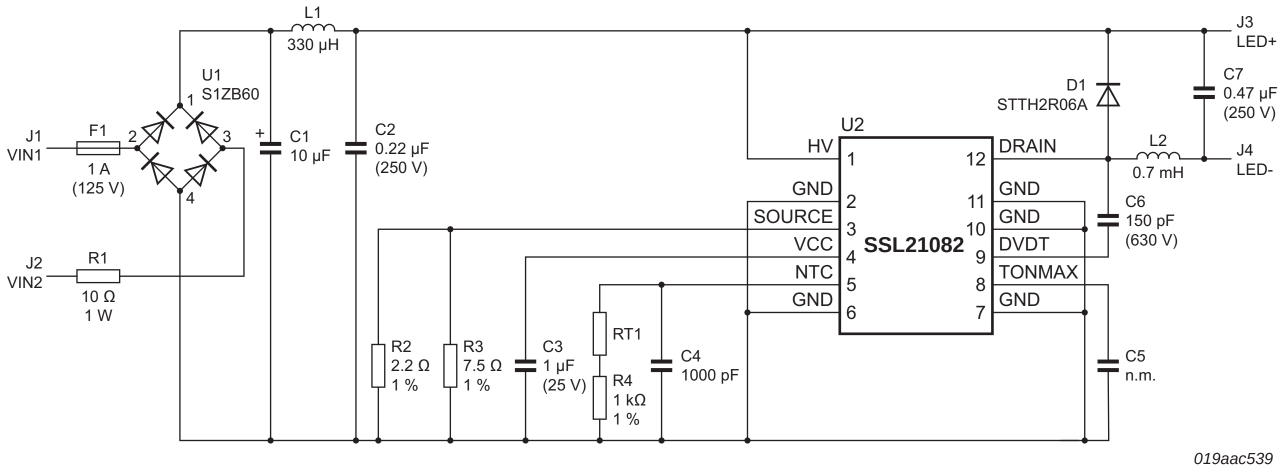


Fig 12. Schematic

10. Bill of materials

Table 5. Bill of materials

Component	Values	Amount	Manufacturer	Part number
C1	10 µF; 200 V	1	Rubycon	200BXC10M8X11.5
C2	0.22 µF; X7R; 250 V	1	Murata	RDER72E224K8K1C11B
C3	1 µF; F; 25 V	1	Murata	GRM188F51E105ZA12D
C4	1000 pF; X7R; 50 V	1	Murata	GRM188R71H102KA01D
C5	not mounted	0	-	-
C6	150 pF; C0G; 630 V	1	Murata	GRM31A5C2J151JW01D
C7	0.47 µF; X7R; 250 V	1	Murata	RDER72E474K5B1C13B
D1	600 V; 1 A; fast recovery	1	ST Micro	STTH2R06A
F1	1 A; 125 V	1	Littelfuse	473001
L1	330 µH	1	Taiyo-Yuden	CAL45VB331K
L2	0.7 mH	1	TDK-EPC	SRL8EE-202V001
R1	10 Ω; 1 W	1	Panasonic	ERG-1SJ100A
R2	2.2 Ω; 1 %; 2012	1	Dale	CRCW08052R20FKEA
R3	7.5 Ω; 1 %; 1608	1	Dale	CRCW06037R50FKEA
R4	1 kΩ; 1 %; 1608	1	Panasonic	ERJ-3EKF1001V
RT1	100 kΩ	1	Murata	NXFT15WF104FA2B020
U1	600 V; 0.8 A	1	Shindengen	S1ZB60
U2	SSL21082	1	NXP Semiconductors	SSL21082

11. Inductor appearance and dimensions

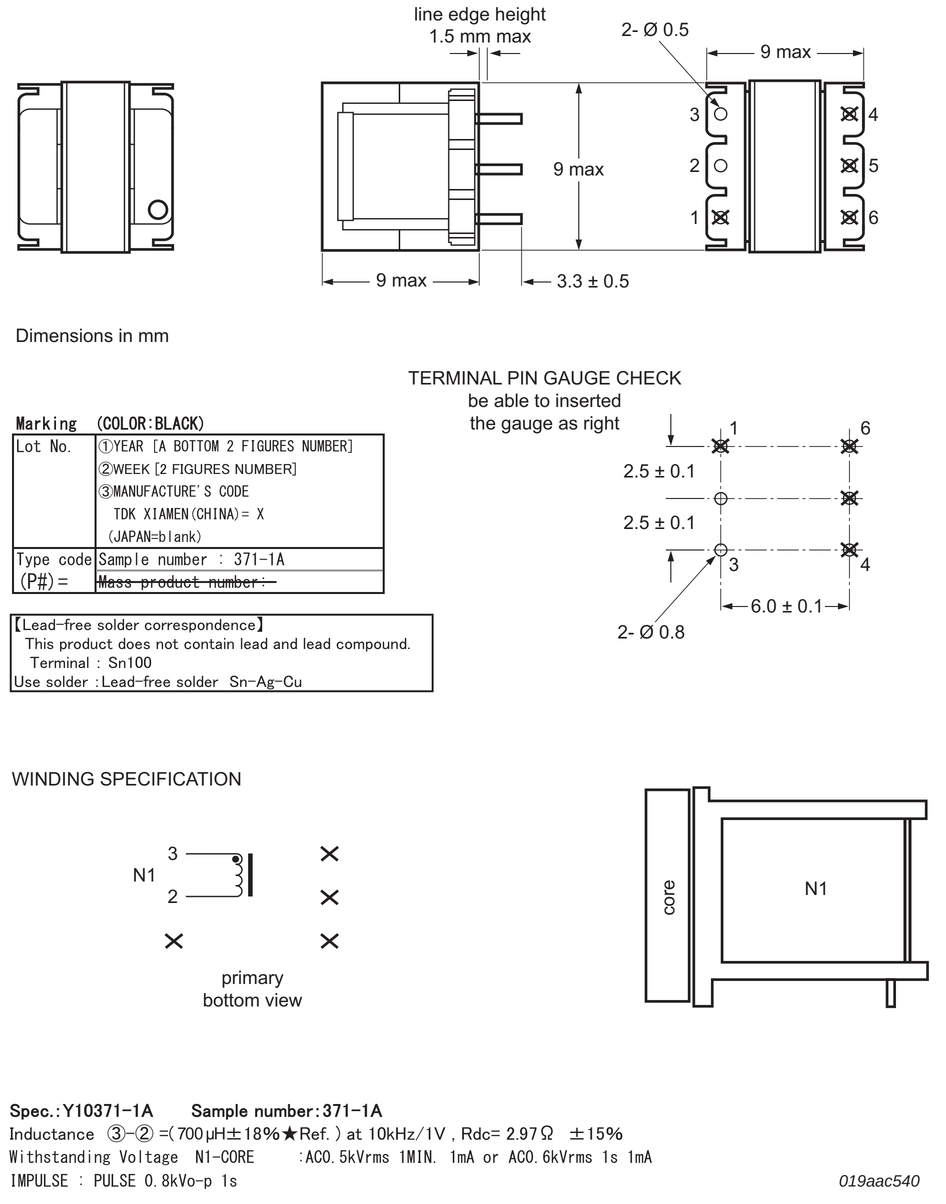
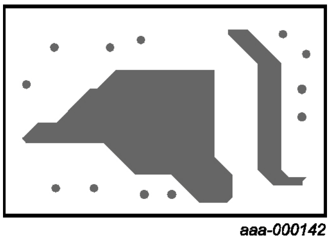
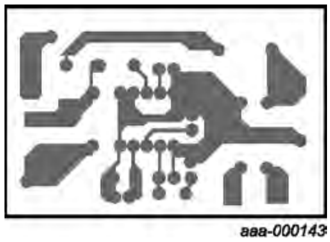


Fig 13. Inductor appearance and dimensions

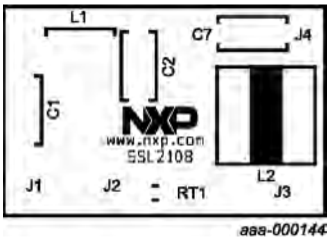
12. Board layout



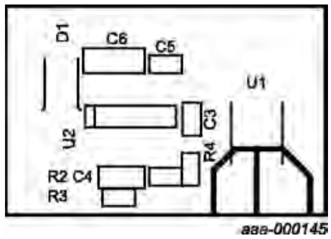
a. Top layer



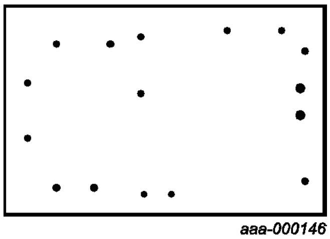
b. Bottom layer



c. Top silk



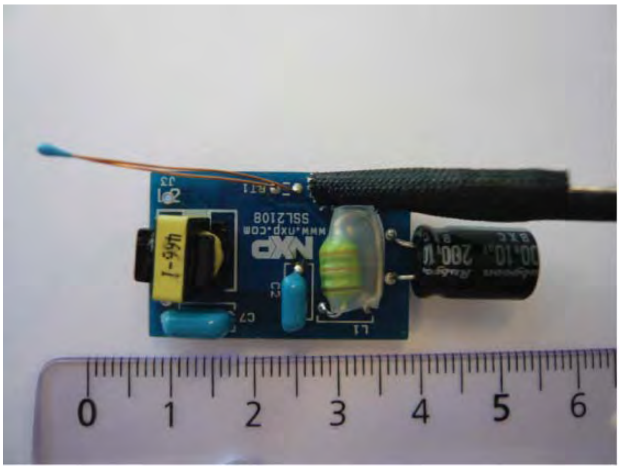
d. Bottom silk



e. Drill

Fig 14. Board layout

13. Board photographs



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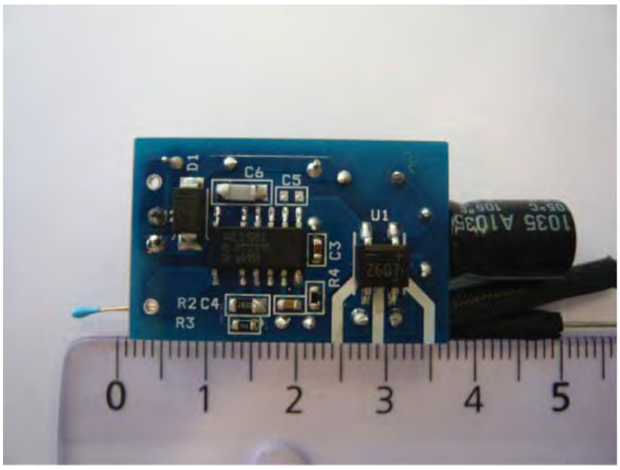
a. Front view



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b. Back view

Fig 15. Photographs of the board

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