# UM10485

## 120 V (AC) 7 W GU10 buck LED driver reference board using the SSL2101

**Rev. 1.1 — 26 August 2011** **User manual**

### Document information

| Info | Content |
| --- | --- |
| **Keywords** | SSL2101, buck, LED driver, dimmable, GU10 |
| **Abstract** | This document describes the application and operation of a 7 W 120 V (AC) dimmable LED driver featuring SSL2101. The reference board has a form factor that is compatible with the base of a GU10 LED lamp. |

**Revision history**

| Rev | Date | Description |
|---|---|---|
| v.1.1 | 20110826 | second issue |
| Modifications: | | • Section 10 “Inductor specification” on page 13 has been added. |
| v.1 | 20110705 | first issue |

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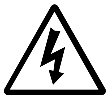
# 1. Introduction

**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.

This document describes the application and operation of a 7 W 120 V (AC) dimmable LED driver featuring SSL2101. The reference board has a form factor that is compatible with the base of a GU10 LED lamp. The buck converter topology provides a simple and efficient solution for mains dimmable LED recessed light applications not requiring galvanic isolation.

The board is designed to drive a 5-LED load, delivering an output power of approximately 7 W. The typical operating frequency is 54 kHz and the reference board produces a steady output current of 440 mA at an efficiency > 73%. The board is fully compliant with EMC regulations. Key features of the reference board include:

- Deep dimming capability
- Wide dimmer compatibility
- Small form factor tailored to fit a GU10 lamp
- Cost-effectiveness

The board dimensions are shown in Figure 1. The GU10 LED lamp shaped board is designed such that the components allow enough headroom when the board is inserted into the base of the lamp.

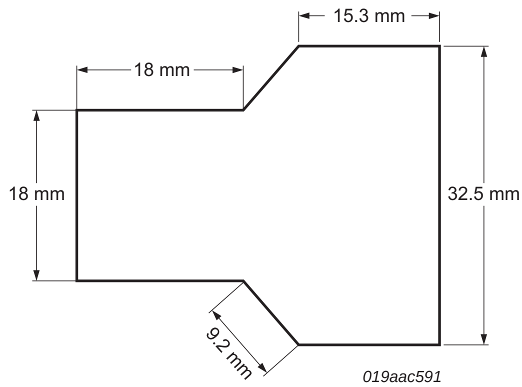



**Fig 1. Dimensions of the reference board**

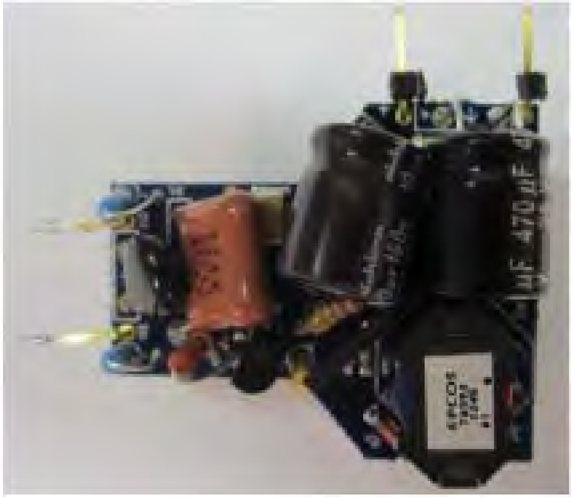


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**Fig 2. Reference board (top view)**

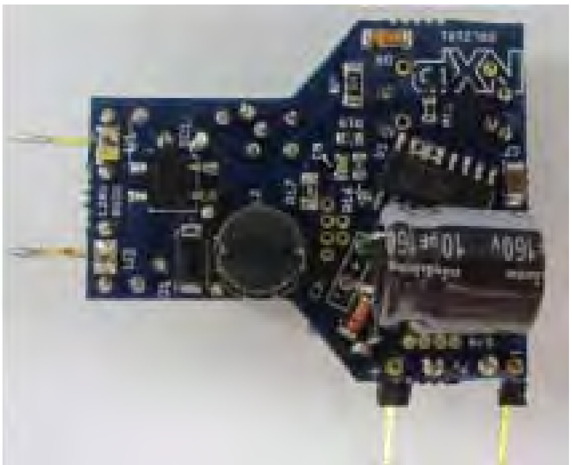

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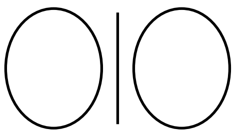
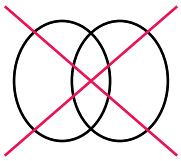
**Fig 3. Reference board (bottom view)**

## 2. Safety warning

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




a. Isolated




b. Not isolated

Fig 4. Variac isolation symbols

## 3. Specifications

Table 1. Specifications for the reference board

| Symbol | Parameter | Value | Comment |
|---|---|---|---|
| $V_{mains}$ | AC mains supply voltage | 108 V (AC) to 132 V (AC) | nominal line input 120 V (AC), 60 Hz |
| $V_{LED}$ | output voltage | 16 V | load: 5-LED string |
| $I_{LED}$ | output current | 440 mA | - |
| $I_{o(ripple)}$ | output current ripple | 11.4 % | - |
| $I_{o(reg)}$ | output current regulation | +11.8 %; −10 % | ± 10 % offset nominal line voltage |
| η | efficiency | >73 % | - |
| PF | Power Factor | 0.924 | - |
| $f_{sw}$ | switching frequency | 54 kHz | - |

# 4. Functional description

## 4.1 General

The LED driver uses the SSL2101 control IC. The SSL2101 is a Switched Mode Power Supply (SMPS) controller with an integrated MOSFET. Detailed information about the operation of SSL2101 can be found in the *SSL2101 SMPS IC for dimmable LED lighting data sheet* available to download from www.nxp.com.

The driver employs buck converter topology. The converter operates in Discontinuous Conduction Mode (DCM) or Boundary Conduction Mode (BCM). In BCM, valley switching detection is used to minimize magnetic component and switching losses while enhancing efficiency. A valley-fill circuit is added to obtain high power factor on the input side.

The reference board is triac dimmable. When dimmers are used, the circuit detects the rectified voltage change and reduces the switching duty cycle to reduce the output current. SSL2101's own internal strong and weak bleeders are used to supplement the current in the circuit to provide for the hold and latch currents required by triac dimmers. The circuit shows great dimmer compatibility as can be seen in Table 2.

## 4.2 Dimmer compatibility

**Table 2. Dimmer compatibility test results**

| Manufacturer | Model number | Voltage; type | Compatible |
|---|---|---|---|
| Lutron | S-600 | 120 V; incandescent | yes |
| Lutron | S-600P | 120 V; incandescent | yes |
| Lutron | S600-H | 120 V; incandescent | yes |
| Lutron | TG-600PH | 120 V; incandescent | yes |
| Lutron | DVW-600PH | 120 V; incandescent | yes |
| Lutron | DVW-603GH | 120 V; incandescent | yes |
| Lutron | DVM-600PH | 120 V; incandescent | yes |
| Lutron | DV-603PG | 120 V; incandescent | yes |
| Lutron | DV-600P | 120 V; incandescent | yes |
| Lutron | DV Beta Build | 120 V; incandescent | yes |
| Lutron | CTCL-153PDH | 120 V; incandescent | yes |
| Lutron | GL-600PH | 120 V; incandescent | yes |
| Lutron | Credenza S31 | 120 V; incandescent | yes |
| Leviton | 6631 | 120 V; incandescent [1] | yes |
| Leviton | 6602 | 120 V; incandescent | yes |
| Leviton | 6602-I | 120 V; incandescent | yes |
| Leviton | RPI06 | 120 V; incandescent | yes |
| Unknown | GL410A | 120 V; incandescent | yes |
| GE | 18021 | 120 V; incandescent [1] | flicker |
| GE | 52136 | 120 V; incandescent | flicker |

[1] Lamp.

# 5. Reference board connections

The GU10 LED driver board takes a 120 V (AC), 60 Hz mains supply and supports a 5-LED load. Setting up the board for evaluation is straightforward, as can be seen in Figure 5. Input pins W1 and W2 are connected to the AC input power (live and neutral) and an LED string connected in series with a current meter is to the two output pins LED+ and LED–. The current flows from pin LED+ to pin LED–.

The connection must ensure that the current enters the LED string from the first LED's anode and exits from the last LED's cathode. A voltage meter should be connected across pins LED+ and LED– for a more accurate reading.

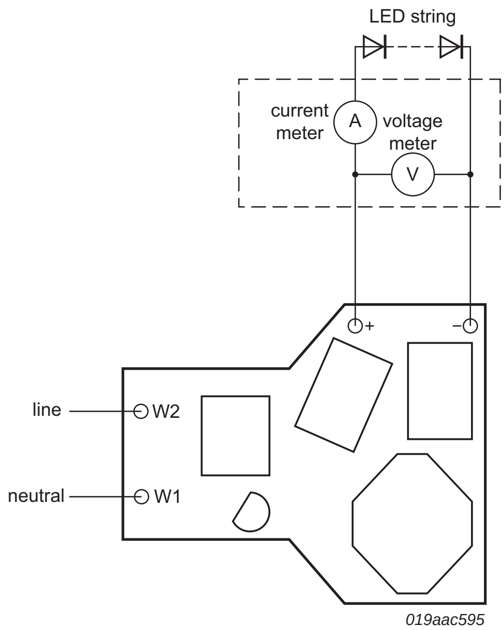



**Fig 5. Connection to the reference board**

**Remark:** All these connections must be made when the input power is switched off.

After the board is set up for testing, some typical measurement procedures are:

1. Turn on the power supply.
2. Check for the correct LED current and voltage. If there is no output, turn off the power supply and recheck all connections. Once the correct voltage and current are established, move to step 3.
3. Adjust input voltage within the operating range and observe performance metrics such as the output current regulation, efficiency, current ripple and power factor.
4. To test dimmer compatibility:
   a. Turn off the input power supply.
   b. Connect a dimmer between input power supply and the input of the driver board.
   c. Turn on the power supply and adjust the dimmer to observe the output current and LED light for a smooth, flicker-free dimming operation.

**Remark:** When the output current and voltage are correctly established, the current and voltage meters, as shown in Figure 5, can be removed. The LED string is then connected directly to the output pins LED+ and LED–.

# 6. Performance data

All performance data was obtained using CREE’s XPE LEDs.

## 6.1 Efficiency

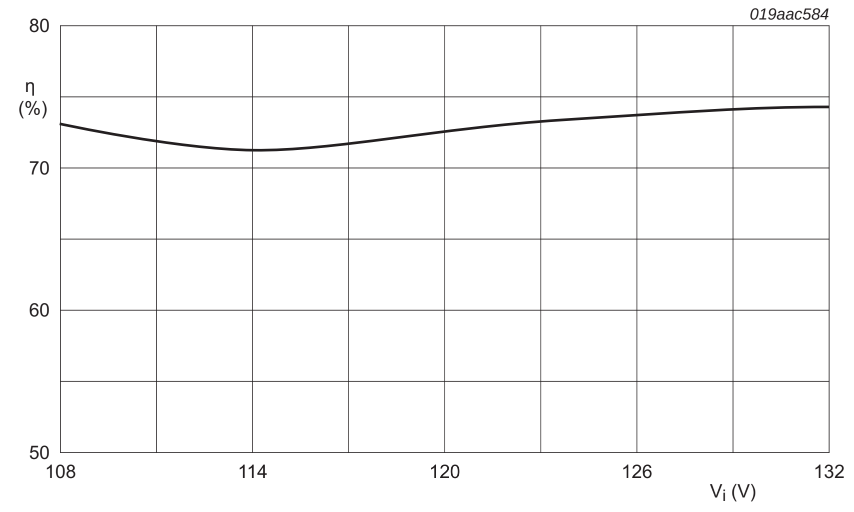



**Fig 6. Efficiency as a function of AC mains input voltage**

## 6.2 Output current

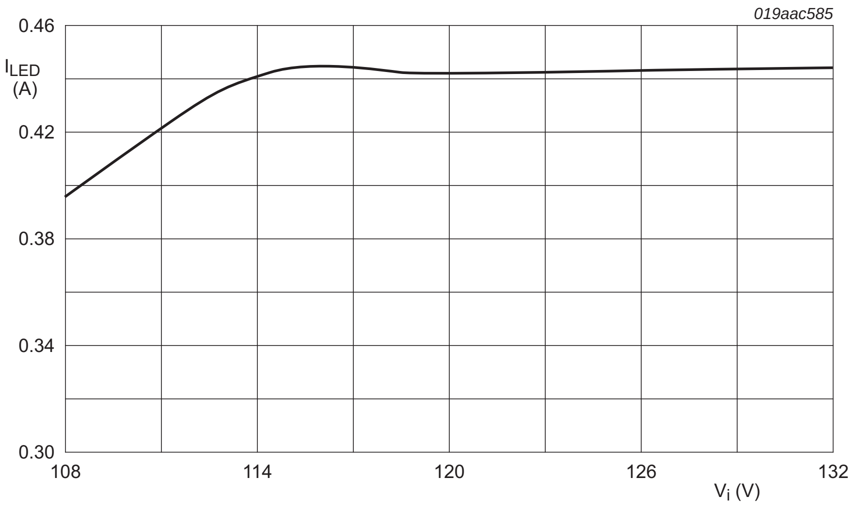



**Fig 7. Output current as a function of AC mains input voltage**

## 6.3 Power factor

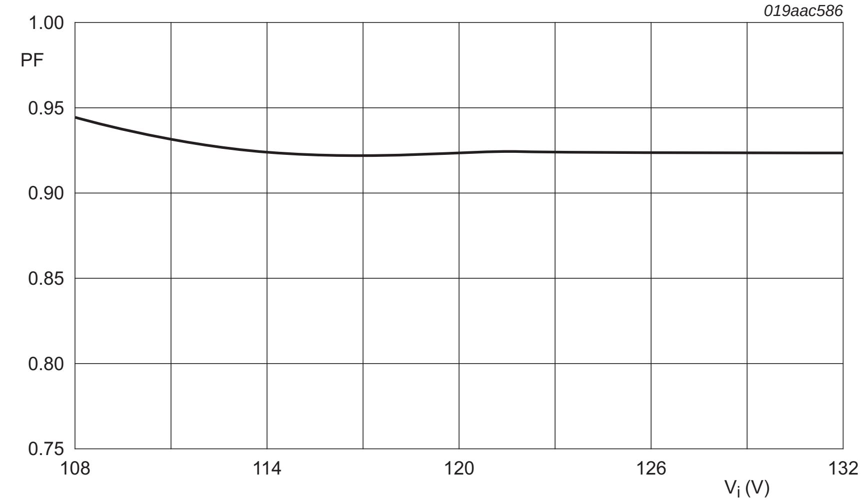



**Fig 8. Power factor as a function of AC mains input voltage**

## 6.4 Output Current ripple

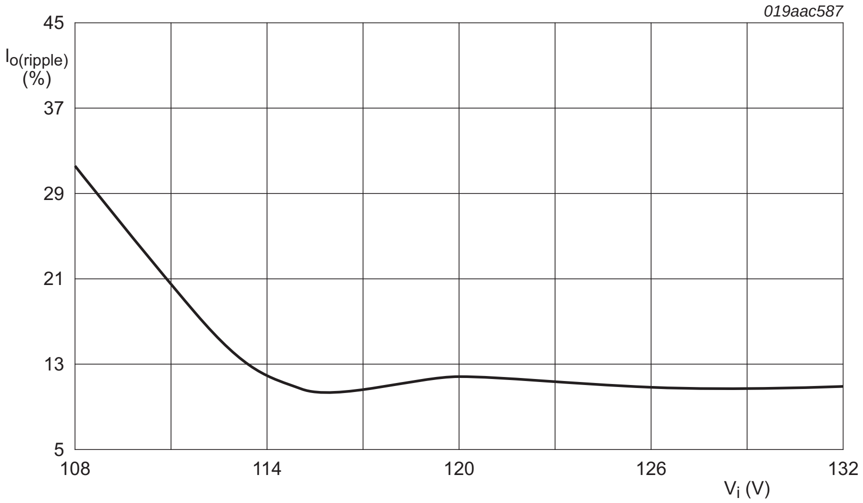



**Fig 9. Output current ripple as a function of AC mains input voltage**

## 7. Schematic

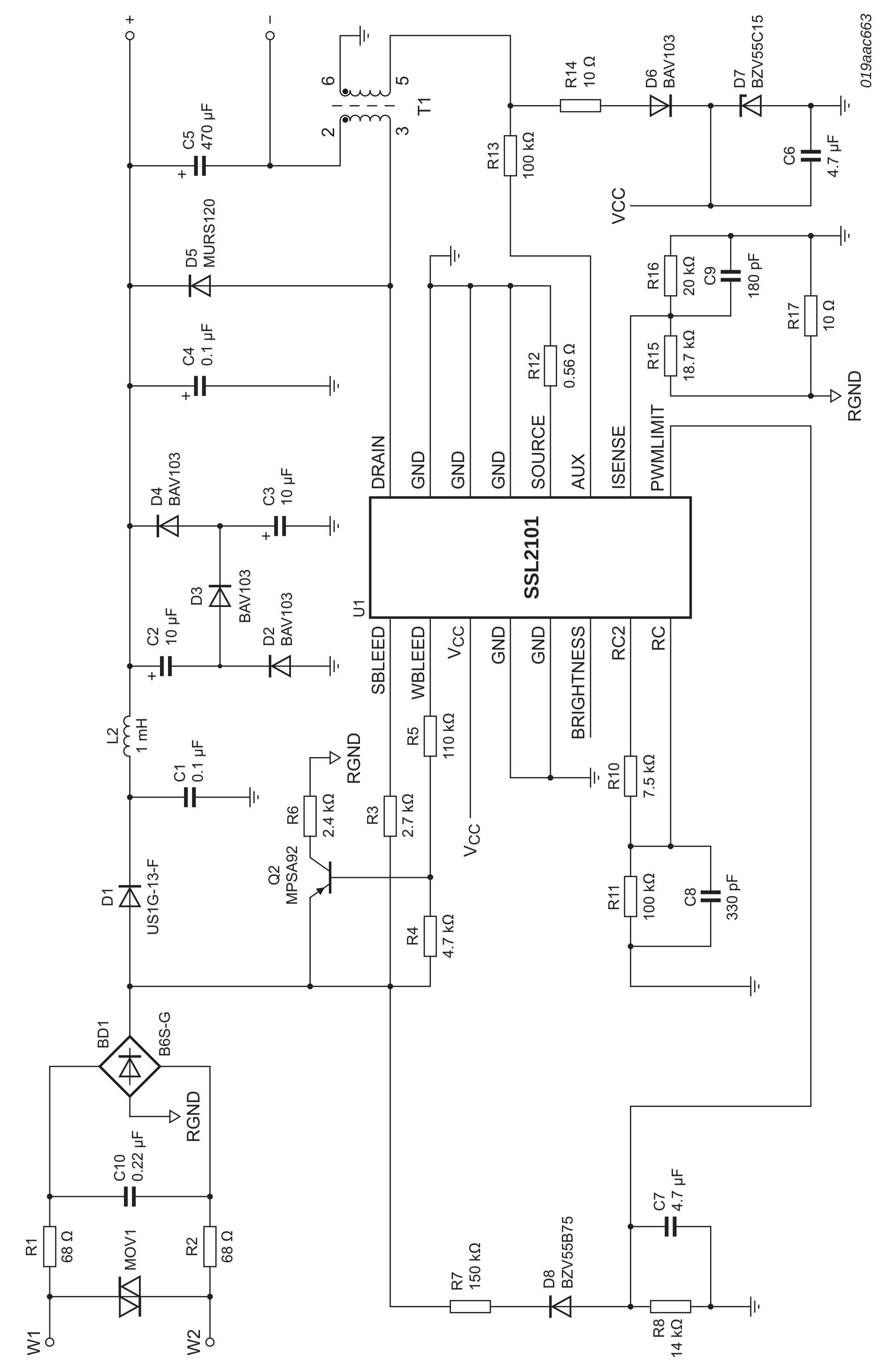


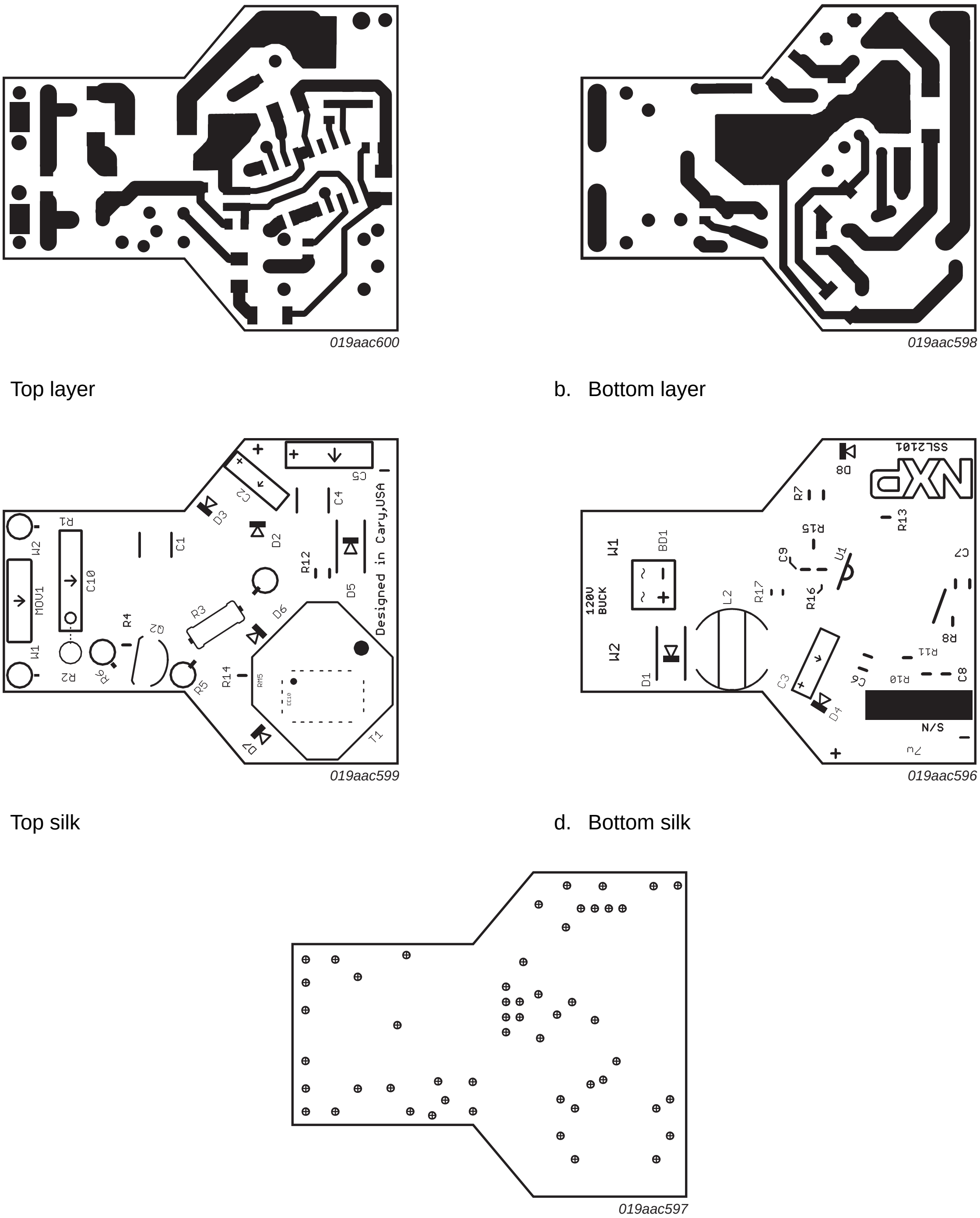

**Fig 10. Schematic diagram**

# 8. Bill of materials

**Table 3. Bill of materials**

| Part reference | Qty | Description/value | Manufacturer/part number |
|---|---|---|---|
| C1; C4 | 2 | 0.1 μF; 630 V; 10 %; 1812 | TDK; C4532X7R2J104K |
| C2;C3 | 2 | 10 μF; 160 V; 20 %; radial | Nichicon; UPW2C100MPD |
| C5 | 1 | 470 μF; 25 V; 20 %; radial | Panasonic-ECG; ECA-1EHG471 |
| C6 | 1 | 4.7 μF; 50 V; 10 %; 1206 | TDK; C3216X5R1H475K |
| C7 | 1 | 4.7 μF; 25 V; 20 %; 1206 | TDK; C3216X7R1E475M |
| C8 | 1 | 330 pF; 25 V; 5 %; 0603 | AVX; 06033A331JAT2A |
| C9 | 1 | 180 pF; 50 V; 5 %; 0603 | TDK; C1608C0G1H181J |
| C10 | 1 | 0.22 μF; 250 V; 10 %; radial | Panasonic-ECG; ECQ-E2224KF |
| BD1 | 1 | bridge rectifier; 600 V; 0.8 A; MBS-1 | ComChip Tech; B6S-G |
| D1 | 1 | fast recovery diode; 400 V; 1 A; DO214AC | Diodes Inc; US1G-13-F |
| D2; D3; D4; D6 | 4 | switching diode; 200 V; 0.25 A; SOD80C | NXP Semiconductors; BAV103,115 |
| D5 | 1 | fast recovery diode; 200 V; 1 A; SMB | Diodes Inc; MURS120-13-F |
| D7 | 1 | Zener diode; 15 V; 2 %; SOD80C | NXP Semiconductors; BZV55C15,115 |
| D8 | 1 | Zener diode; 75 V; 2 %; SOD80C | NXP Semiconductors; BZV55B75,115 |
| L2 | 1 | 1 mH coil; 0.21 A; 10 %; SMD | Bourns; SDR0805-102KL |
| MOV1 | 1 | surge absorber; 240 V; axial | Panasonic-ECG; ERZ-V07D241 |
| R1; R2 | 2 | 68 Ω; 0.25 W; 1 %; axial | Panasonic-ECG; ERO-S2TJ680V |
| R3 | 1 | 2.7 kΩ; 0.25 W; 1 %; axial | Panasonic-ECG; ERO-S2PHF2701 |
| R4 | 1 | 4.7 kΩ; 0.10 W; 1 %; 0603 | Panasonic-ECG; ERJ-3EKF4701V |
| R5 | 1 | 110 kΩ; 0.25 W; 1 %; axial | Panasonic-ECG; ERO-S2PHF1103 |
| R6 | 1 | 2.4 kΩ; 1 W; 5 %; axial | Vishay/BC Components; PR01000102401JR500 |
| R7 | 1 | 150 kΩ; 0.25 W; 5 %; 1206 | Yageo; RC1206JR-07150KL |
| R8 | 1 | 14.7 kΩ; 0.10 W; 1%; 0603 | Panasonic-ECG; ERJ-3EKF1472V |
| R10 | 1 | 7.5 kΩ; 0.10 W; 1 %; 0603 | Rohm; MCR03EZPFX7501 |
| R11; R13 | 2 | 100 kΩ; 0.10 W; 5%; 0603 | Stackpole; RMCF0603JT100K |
| R12 | 1 | 0.56 Ω; 0.25 W; 1 %; 1206 | Panasonic-ECG; ERJ-8RQFR56V |
| R14 | 1 | 10 Ω; 0.10 W; 1 %; 0603 | Panasonic-ECG; ERJ-3EKF10R0V |
| R15 | 1 | 18.7 kΩ; 0.10 W; 1 %; 0603 | Panasonic-ECG; ERJ-3EKF1872V |
| R16 | 1 | 20 kΩ; 0.10 W; 5 %; 0603 | Yageo; RC0603JR-0720KL |
| R17 | 1 | 10 Ω; 0.125 W; 1 %; 0805 | Panasonic-ECG; ERJ-6ENF10R0V |
| T1 | 1 | transformer/Inductor 270 μH; 1 A; RM5 | EPCOS; T6593 |
| Q2 | 1 | PNP; 300 V; 0.5 A; TO-92 | Fairchild; MPSA92 |
| U1 | 1 | Control IC; SO16 | NXP Semiconductors; SSL2101 |

## 9. PCB layout




a. Top layer

b. Bottom layer

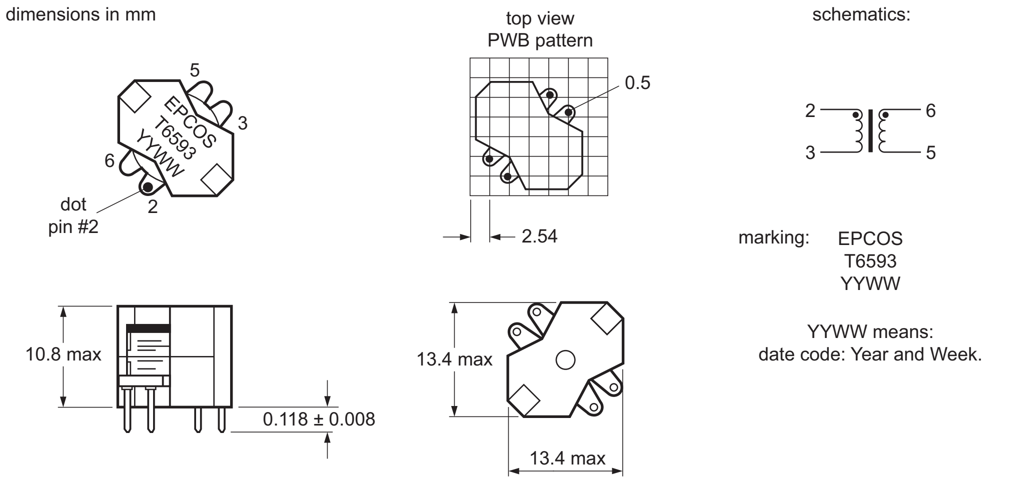
c. Top silk

d. Bottom silk

e. Drill

**Fig 11. Board layout**

## 10. Inductor specification




electrical characteristics: (specified @ 25 °C if not mentioned otherwise) *typical value

all values without tolerances are typical values.

| | | |
|---|---|---|
| inductance: L (2-3) | 270 μH +/- 7 % | 100 mV, 10 kHz |
| inductance: L (2-3) | 205 μH min | 100 mV, 10 kHz, 1 Adc |
| DCR: (2-3) | 290 MΩ max | at 25 °C |
| DCR: (6-5) | 510 MΩ max | at 25 °C |
| turns ratio (2-3:6-5) | 1.338:1 | |
| Hypot (2 to 5) | 500 V AC | 50/60 Hz, 2 mA max, 2 seconds min |
| leakage inductance (2-3 w/5-6 sh) | TBD max | 100 mV, 100 kHz |

packaging:

remarks:
1: ROHS compatible

operating temperature range: -40 °C, 125 °C

*aaa-000467*

**Fig 12. Inductor specification**

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