

UM10341_1

SSL2101/2102 12 W mains dimmable LED driver

Rev. 00.01 — 28 April 2009

User manual

Document information

| Info | Content |
|-----------------|--|
| Keywords | dimmable, SSL2101, SSL2102, SSL1523, driver, Mains supply, AC/DC conversion, LED driver, User manual |
| Abstract | This document is a user manual for the SSL2101/SSL2102 mains dimmable 12 W LED driver demo boards. |

Revision history

| Rev | Date | Description |
|-----|------|-------------|
| 01 | <td> | First draft |

Contact information

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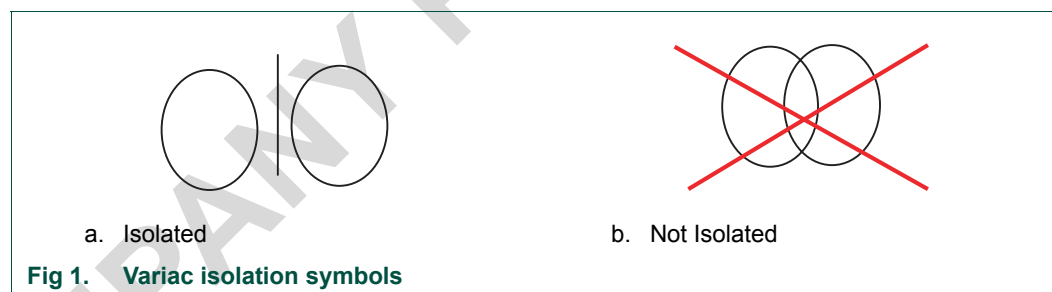
For sales office addresses, please send an email to: salesaddresses@nxp.com

1. Introduction

The SSL2101/2102 12 W LED driver is a solution for a professional application with multiple high power LEDs that requires galvanic isolation and a safe output voltage. It is mains dimmable for both forward phase (TRIAC) dimmers, and reverse phase (Transistor) dimmers. It can generate up to 16 W output power, which is equal to a 100 W incandescent lamp (at 63 Lumen/W). Examples are shelf lighting, down lighting, LED lighting for bathrooms etc. The design gives an example of how to make a drive that is suitable for small form factor applications like retrofit lamps.

2. Safety warning

The board needs to be connected to mains voltage. Touching the reference board during operation must be avoided at all times. An isolated housing is obligatory when used in uncontrolled, non laboratory environments. Even though the secondary circuit with LED connection has a galvanic isolation, this isolation is not according to any regulated norm. Galvanic isolation of the mains phase using a variable transformer is always recommended. These devices can be recognized by the symbols shown in [Figure 1](#):



3. Connecting the board

The board can be optimized for a 230 V (AC) (50 Hz) or for a 120 V (AC) (60 Hz) mains source. Besides the mains voltage optimization, the board is designed to work with multiple high power LEDs with a total working voltage of between 9 V and 23 V. The output current can be limited using trimmer R20. On request, a dedicated LED load can be delivered that is to be connected to K3. Connector K2 can be used to attach other LED loads. The output voltage is limited to 25 V. When attaching a LED load to an operational board (hot plugging) an inrush peak current will occur due to discharge of capacitor C6. After frequent discharges, the LEDs may deteriorate or become damaged.

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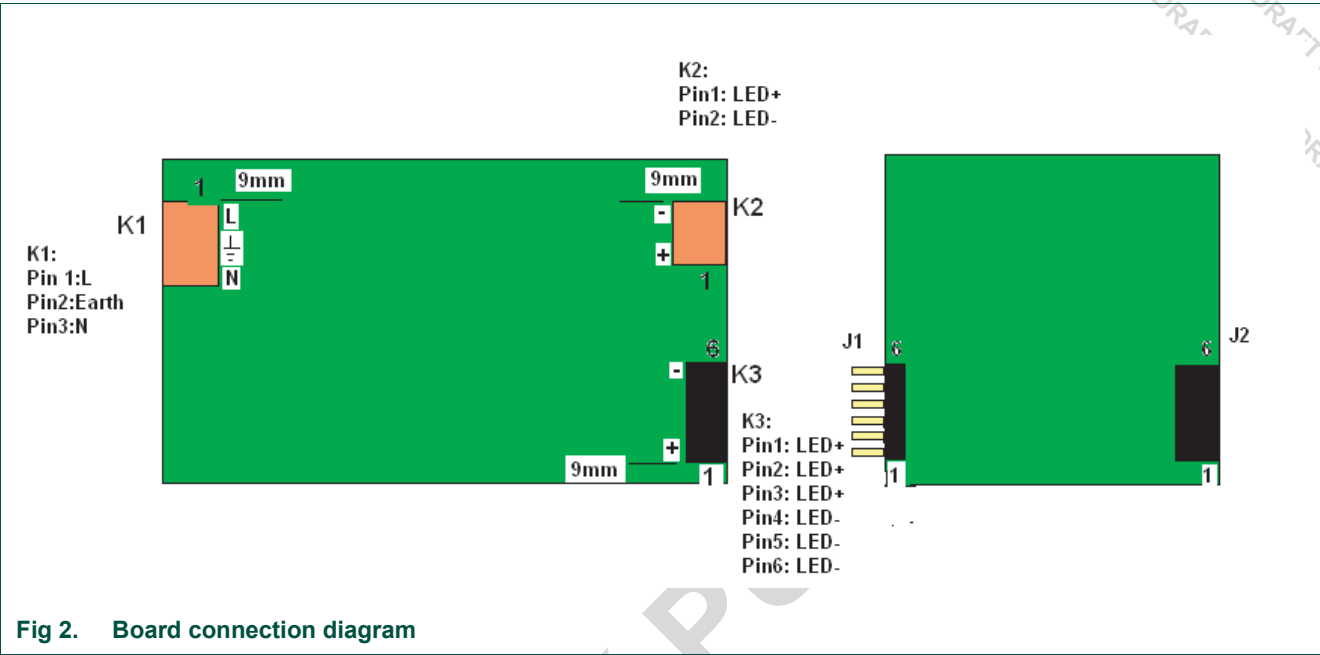


Fig 2. Board connection diagram

If a galvanic isolated transformer is used, it should be placed in between the AC source and the dimmer/demo board. Connect a user defined LED (string) to the connector K2 as shown in [Figure 2](#). Note that the anode of the LED (string) is connected to the bottom side of this connector.

Remark: When the board is placed in a metal enclosure, the middle pin of connector P1 can be connected to the metal casing for grounding.

4. Specifications

[Table 1](#) gives the specifications for the SSL2101/2102 12 W LED driver

Table 1. Specifications

| | | Comment |
|---|------------------------------------|--|
| AC line input voltage | 85 V (AC) to 276 V (AC) | Board has been optimized for 230 V (AC) or 120 V (AC) ± 10 % variation |
| Output voltage (LED voltage) | 9 V (DC) to 23 V (DC) | |
| Output voltage protection | 25 V (DC) | |
| Output current (LED current) | 400 mA to 800 mA | Adjustable with trimmer |
| Output voltage /load current dependency | <+/- 4 % / Volt in regulated range | See attached graphs |
| Current ripple | +/-150 mA | at 500 mA |
| Maximum output power (LED power) | 17 W | At V _{out} + 21 V |
| Efficiency | 70 %-78 % | At t _{amb} = 25°C See attached graphs |

Table 1. Specifications

| | | Comment |
|--|--|---------------------------------------|
| Power Factor: 120 V(AC) 230 V(AC) | 0.99 | at 15 W output power |
| | 0.94 | at 15 W output power |
| | 0.90 | at 11 W output power |
| Switching frequency | 60-75 kHz | |
| Dimming range | 100% – 0% | |
| Board dimensions | 103mm x 50mm x 20mm | L x W x H |
| Operating temperature | 0 to 85 ° Celsius | |
| Isolation voltage | +/-4 KV | Between primary and secondary circuit |
| Input voltage /load current dependency | +5/-6 % in the range of 130 V (AC) to 110 V (AC) +3/-3 % in the range of 250 V (AC) to 210 V (AC) | |

5. Board photos

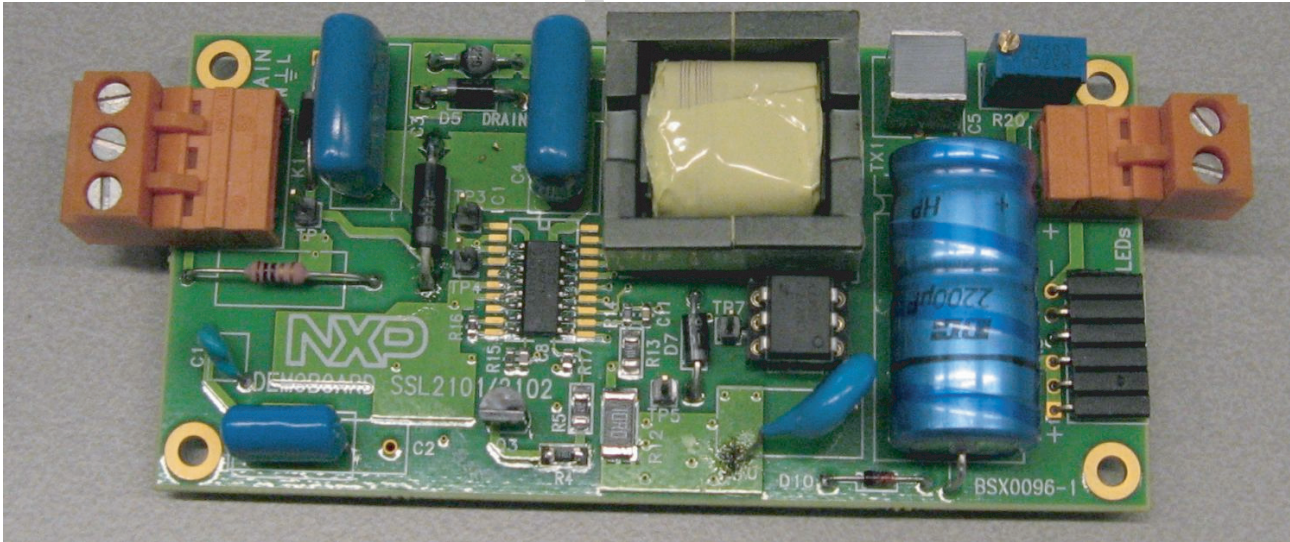


Fig 3. Demo board (top)

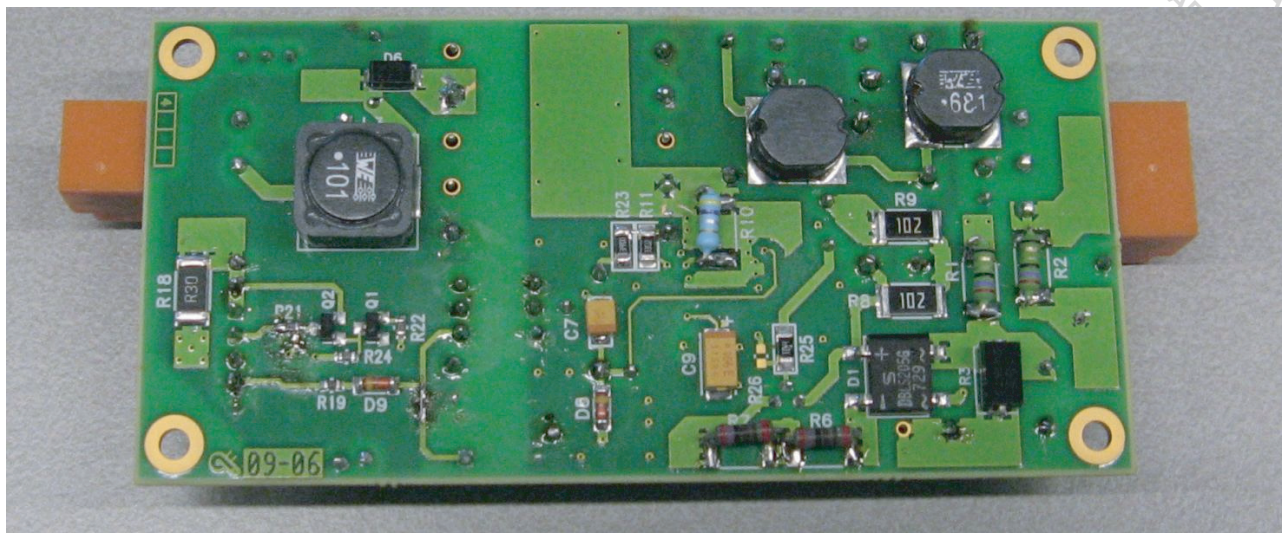


Fig 4. Demo board (bottom)

6. Dimmers

Several TRIAC based dimmers have been tested by NXP Semiconductors. As different dimmers have different specifications, the dimming performance of the board may vary. [Table 2](#) shows the range of dimmers that have been tested with the board:

Table 2. Dimmer selection

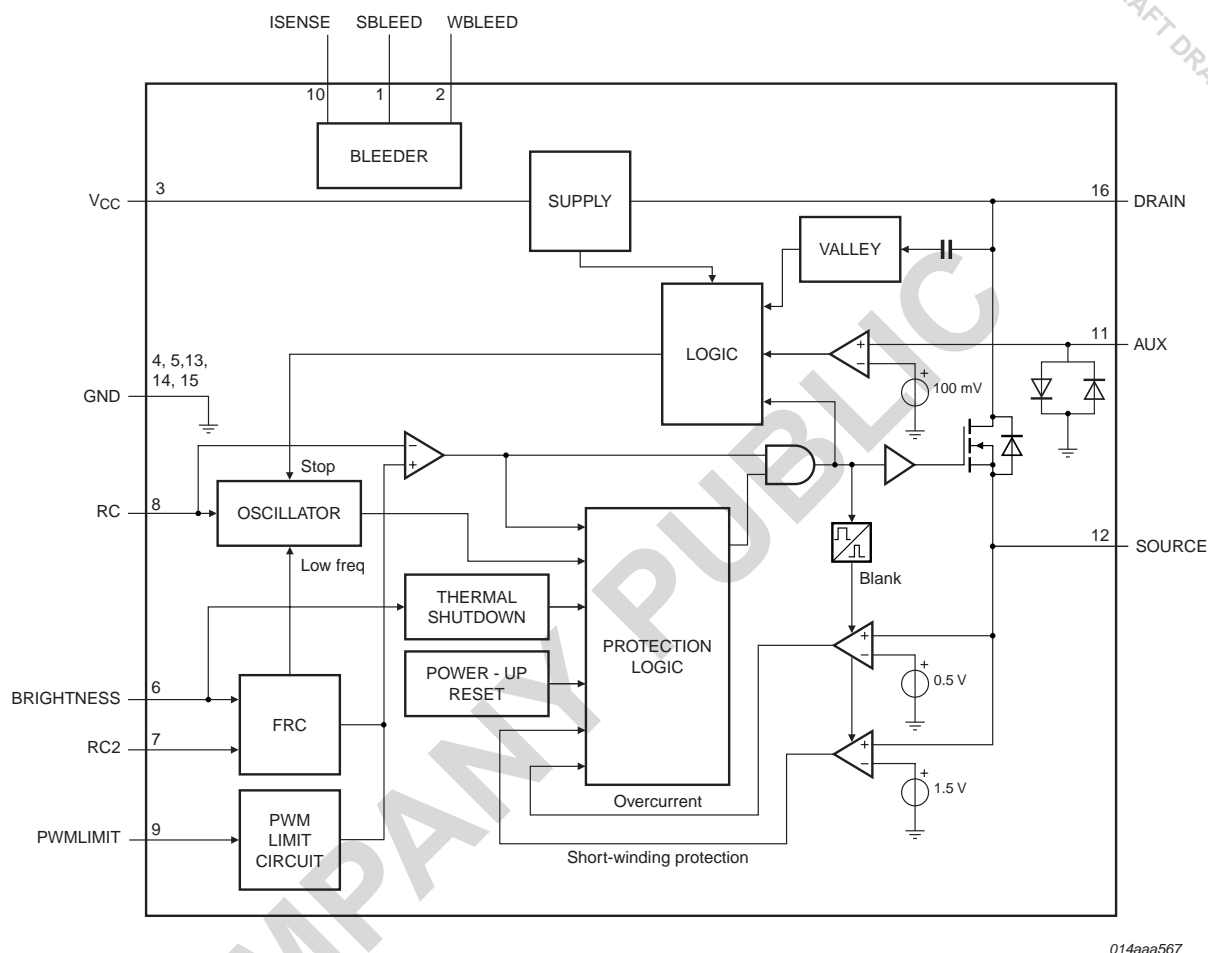
| Manufacturer | Type | Voltage V (AC) | Power range (W) | Load | Min. dimming range |
|--------------|--------------|----------------|-----------------|--------|--------------------|
| Opus | 852.390 | 230 | 60-400 | Ha/Inc | 0.6% |
| Opus | 852.392 | 230 | 20-500 | Inc | 0.05% |
| Bush-Jaeger | 2250U | 230 | 20-600 | Ha/Inc | 0.03% |
| Bush-Jaeger | 2247U | 230 | 20-500 | Ha/Inc | 0.07% |
| Bush-Jaeger | 6519U | 230 | 40-550 | Ha/Inc | 8.4% |
| Gira | 1184 | 230 | 60-400 | Inc | 1% |
| Everflourish | EFO700D | 230 | 50-300 | Ha/Inc | 0.2% |
| Drespa | 0817 | 230 | 20-315 | Ha/Inc | 3.4% |
| Ehmann | 39 Domus | 230 | 20-500 | Ha/Inc | 1% |
| Drespa | 815 | 230 | 20-500 | Inc | 1.1% |
| Lutron | TG-600PH-W H | 120 | 600 | Inc | 0 % (off) |
| Levitron | L12-6641-W | 120 | 600 | Inc | 0 % (off) |
| Levitron | L02-700-W | 120 | 600 | Inc | 0 % (off) |
| Levitron | 6602-IW | 120 | 600 | Inc | 0 % (off) |
| Levitron | 6683-W | 120 | 600 | Inc | 0 % (off) |

Table 2. Dimmer selection

| Manufacturer | Type | Voltage V (AC) | Power range (W) | Load | Min. dimming range |
|--------------|---------------|----------------|-----------------|--------|--------------------|
| Levitron | R12-6631-LW | 120 | 600 | Inc | 0 %(off) |
| Cooper | 6001 | 120 | 600 | Inc | 0 %(off) |
| Lutron | MIR-600THW-WH | 120 | 600 | Ha/Inc | 0.9 % |

7. Functional description

The board can be equipped with either the SSL2101 or SSL2102, depending on the operating conditions and output power. The SSL2102 has lower thermal resistance and is thus more suitable for higher temperatures and higher loads. The IC has several internal functions. It controls and drives the flyback converter part, and it ensures proper dimmer operation. In the IC itself, there are several high voltage switches integrated. One of these switches controls the flyback input power, and it is situated between the Drain pin and Source pin. On closing, a current will start to run, which stores energy in the transformer TX1. This current is interrupted when the duty factor has exceeded the level set by the PWM_{Limit} pin, with a maximum of 75 %, or when the voltage on the Source pin exceeds 0.5 V. At the next cycle, the energy stored in the transformer is discharged to D6 and the output capacitors C5 and C6, and finally absorbed by the load. The converter frequency is set with an internal oscillator, the timing of which is controlled by external RC components on pins RC and RC2. The frequency can be modulated using the brightness pin to an upper and lower value. The ratio between R15 and R16 sets the frequency variation.



014aaa567

Fig 5. Block diagram SSL2101

The two other switches are called the weak-bleeder (pin W_{bleed}), and the strong bleeder (pin S_{bleed}). When the voltage on both these pins is below a certain value (typical 52 V) the S_{bleed} switch closes, providing a current path that loads the dimmer during zero voltage crossing. This resets the dimmer timer. When the voltage on both these pins is above 52 V, and the voltage on the I_{sens} pin is above 100 mV, the weak-bleeder switch closes. Using Q3, this current is boosted and provides a current path that loads the dimmer when the converter draws insufficient current to have the dimmer latching stable. Whilst the strong bleeder is always enabled, the weak-bleeder will activate only when the output power drops below 8 W. This happens when the LEDs are dimmed, or when the maximum LED power is tuned below 8 W. See [Figure 6](#) and [Figure 7](#) that show bleeder voltage versus time in dimmed and un-dimmed position (low voltage = active):

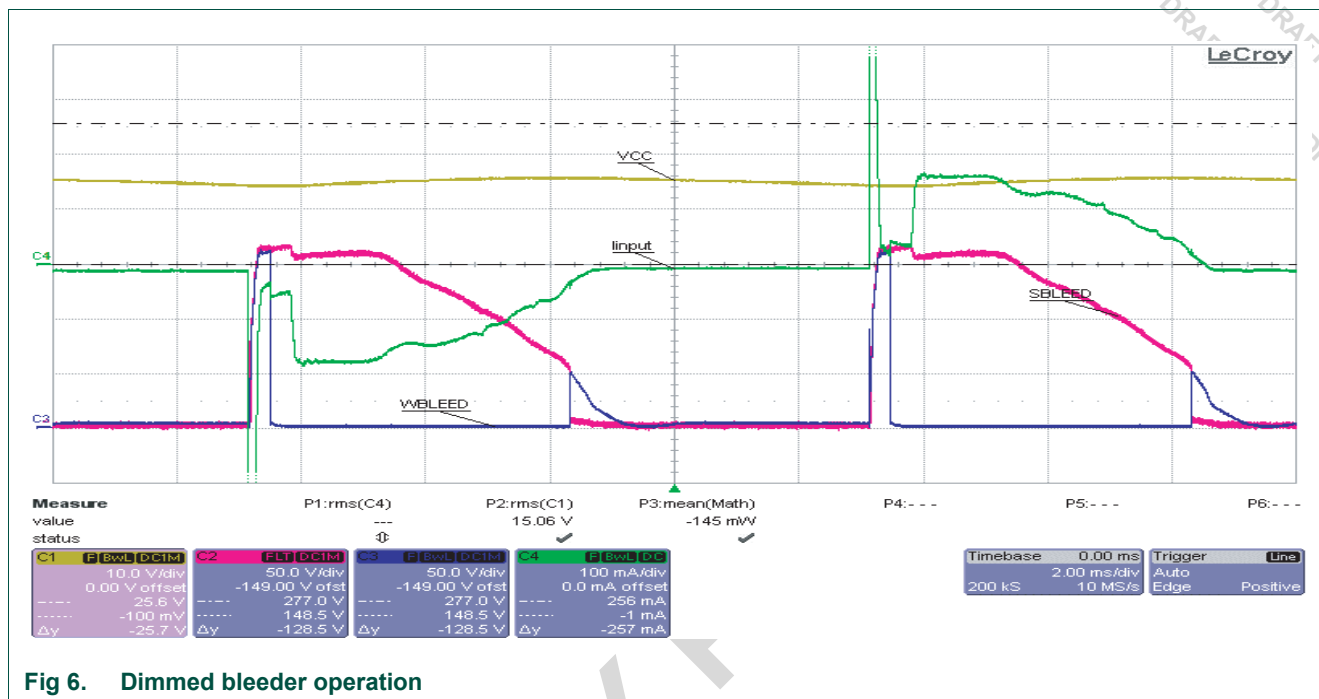


Fig 6. Dimmed bleeder operation

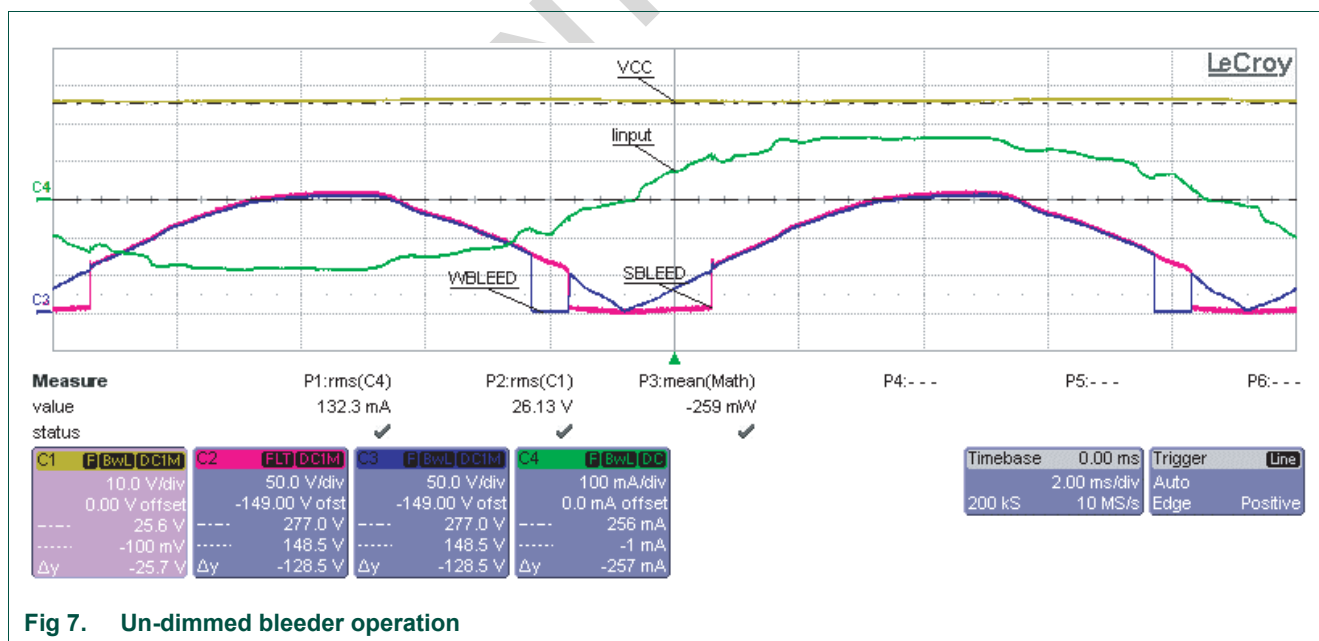


Fig 7. Un-dimmed bleeder operation

This board is optimized to work with a power factor above 0.9. In order to achieve this, the converter operates at constant t_{on} mode. The output power of the converter is buffered by capacitor C6. Due to this configuration, the circuit has a resistive input current behaviour in un-dimmed operation (see Input in Figure 7). In dimmed operation however, not only the dimmer latch and hold current must be maintained, but a damper must be added to dampen the inrush current and to dissipate the electric power that was stored in the LC filter within the dimmer. Though at low power ranges (<10 W) a serial resistor can be used for this, at higher power ranges a single series resistor is not efficient because the converter supply current will cause significant voltage drop and thus dissipation through

this resistor. On the demonstration board, a combination of serial resistance and a parallel damper has been chosen to improve efficiency. The serial resistor is made up of F1, R1, R2 and R12. The parallel damper is made of C2 and R3. See [Figure 8](#).

The input circuit of the converter must be equipped with a filter that is partially capacitive. The combination of C1, L1, L2, C3 and C4 makes a filter that blocks most of the disturbance generated by the converter input current. A drawback of this filter is a reduction of power factor, due to the capacitive load. A lower converter power in relation to the capacitive value of this filter/buffer will cause a lower power factor. At the 230 V (AC) design using 150 nF capacitors, a power factor of 0.9 is reached at 11 W output power.

The board is equipped with a feedback loop that limits the output current. This feedback loop senses the LED current over sense resistor R18, and a current mirror is made of Q1/Q2. Using R20, the current level can be set. The same feedback loop is also used for overvoltage protection. If the LED voltage exceeds 23 V, a current through R19 and D9 will start running. The current through the opto coupler IC2 will pull down the PWM_Limit and brightness pin. At a value below 400 mV, the on time is zero. The feedback loop has proportional action only, and the gain is critical because of phase shift caused by the converter and C6. The relation between PWM_Limit and output current is quadratic in nature. The resulting output current spread will be acceptable for most LED applications.

The dimming range is detected by sensing the average rectified voltage. R4, R5 and R17 make a voltage divider, and C9 filters the resulting signal. The converter sets its duty factor and converter frequency accordingly.

8. Board optimization

The following modifications can be done in order to meet different customer application requirements:

8.1 Changing the output voltage and LED current

One of the major advantages of a flyback converter over other topologies, is that it is suitable for driving other output voltages. Essentially, changing the winding ratio whilst maintaining the value of the primary inductance, will shift the output working voltage accordingly. Part of the efficiency of the driver is linked to the output voltage. A lower output voltage will increase the transformation ratio, and cause higher secondary losses. In practice, a mains dimmable flyback converter will have an efficiency between 80 % for high output voltages (like 60 V) down to 50 % for low output voltages (like 3 V). At low voltages, synchronous rectification might become advisable to reduce losses. The NXP TEA1791 can be applied for this purpose. For exact calculations of transformer properties and peak current, we refer to application note *AN10754_1*, "How to design an LED driver using the SSL2101", and the excel spreadsheet that goes with it.

8.2 Changing the output ripple current

The output current ripple is mostly determined by the LED voltage, the LED dynamic resistance and the output capacitor. Whilst the value of C6 has been chosen to optimize capacitor size with light output. A ripple of ± 25 % will result in an expected deterioration of light output <1 %.

The size for the buffer capacitor can be estimated from the following equation

$$C_6 = \frac{I}{\Delta I} \cdot \frac{I}{6 \cdot f_{net} \cdot R_{dynamic}}$$

As example: For a ripple current of $\pm 5\%$, and a mains frequency of 50 Hz, and a dynamic resistance of 0.6Ω , C_6 becomes $20/(300 \cdot 0.6) = 111 \text{ mF}$. For a ripple current of 25% and a dynamic resistance of 6Ω , $4/(300 \cdot 6) = 2200 \mu\text{F}$. Using a series of LEDs, the dynamic resistance of each LED can be added to the total dynamic resistance.

8.3 Adapting to high power reverse phase (transistor) dimmers.

Reverse phase (transistor) dimmers differ in two ways that can be beneficial but can also cause problems with dimming detection:

- The negative phase causes no inrush current when the dimmer triggers. At TRIAC dimmers, there will be a sudden voltage difference over the input leading to a steep charge of the input capacitors. The resulting peak current will lead to higher damper dissipation. Because this steep charge is missing, the input capacitors will have less stress, and the input circuit is less prone to audible noise.
- Transistor dimmers contain active circuitry that require a load charge during the time that the dimmer is open. The dimensioning of the circuit generating the internal supply voltage inside the dimmer is made critical in order to avoid excessive internal dimmer losses. This means that the remaining voltage drop over the lamp must be low enough to reach this charge. For dimmers like the Busch-Jaeger 6519U, the minimum lamp load is specified at 40 W which is equivalent to a $1.3 \text{ k}\Omega$ resistor load at 230 V(AC). Such a load would result in highly inefficient operation at low output power levels, since most energy is wasted in order to drive the dimmer, and not to produce light.

On the demo board, the weak bleeder value R6/R7 is chosen in such way, that losses are still acceptable (about 2 W to 3 W) and only occur in dimmed position. The voltage drop with some transistor dimmers is however not sufficient to cause full dimming range control (minimum 10 % instead of $<1\%$), because at the SSL2101 the dimming range is sensed by taking the average rectified voltage as input. To compensate for the reduced voltage difference, voltage detection can be made more sensitive by replacing R4 with a Zener diode, like the BZV85-C200 for 230 V(AC), or the BZV85-C68 for 120 V (AC) applications. Because of increased sensitivity, the dimming curve when using TRIAC dimmers, will also be steeper and shifted.

8.4 Changing the load curve

The load curve can be divided into two regions: A part where the control loop limits the duty cycle of the converter, and where the output current is regulated, and a part where the duty factor feedback is not dominant anymore. This last part occurs at output voltages below 13 V. In this area, constant output power becomes the dominant control mechanism. Changing the winding ratio of the transformer to match the output load will also change this load curve.

8.5 Multiple driver support

It is possible to attach multiple converters to a single dimmer. At the use of TRIAC dimmers the inrush current will rise, though not proportionally to the number of converters. Transistor dimmers are more suitable for usage with multiple converters because the dimming range will increase due to the added bleeder action, and there is no inrush current.

9. Board schematic

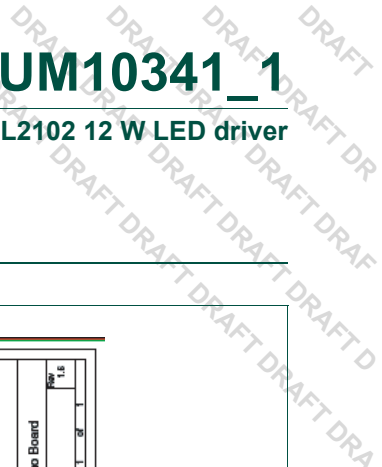


Fig 8. Board schematic diagram

10. Bill of materials (BOM)

Table 3. Bill of materials 230 V (AC)

| Part No. | Ref. Des. | Part | Value | Pwr | Tol. | Volt | Package | Type | Manuf. | Amount |
|----------|-----------|------------------|----------------------|------|------|------|------------|----------------|------------|--------|
| 1 | K1 | Conn 3pin 2u ang | m | | | | | SL 5.08/3/90 | Weidmuller | 1 |
| 2 | K1' | Conn 3pin 2u | f | | | | | BL 5.08/3 | Weidmuller | 1 |
| 3 | K3 | Conn 6pin 1u | f | | | | | BL3.36Z | Fischer | 1 |
| 4 | K2 | Conn 2pin 2u ang | m | | | | | SL 5.08/2/90 | Weidmuller | 1 |
| 5 | K2' | Conn 2pin 2u | f | | | | | BL 5.08/2 | Weidmuller | 1 |
| 6 | F1 | Fusistor | 6.8E | 1 W | 10 % | | Free | | | 1 |
| 7 | R1 | Resistor | 39 Ω | 1 W | 5 % | | Free | | | 1 |
| 8 | R2 | Resistor | 39 Ω | 1 W | 5 % | | Free | | | 1 |
| 9 | R3 | Resistor | 1 K Ω | 2 W | 5 % | | Free | | | 1 |
| 10 | R4 | Resistor | 470 K Ω | 0.25 | 1 % | | Free | | | 1 |
| 11 | R5 | Resistor | 470 K Ω | 0.25 | 1 % | | Free | | | 1 |
| 12 | R6 | Resistor | 10 K Ω | 1 W | 5 % | 200 | Free | | | 1 |
| 13 | R7 | Resistor | 10 K Ω | 1 W | 5 % | 200 | Free | | | 1 |
| 14 | R8 | Resistor | 2.2 K Ω | 1 W | 5 % | 200 | Free | | | 1 |
| 15 | R9 | Resistor | 2.2K Ω 2 | 1 W | 5 % | 200 | Free | | | 1 |
| 16 | R10 | Resistor | 0.4 Ω | 1 W | 1 % | | Free | | | 1 |
| 17 | R11 | Resistor | 33 K Ω | 0.25 | 5 % | 200 | Free | | | 1 |
| 18 | R12 | Resistor | 15 Ω | 1 W | 5 % | 200 | Free | | | 1 |
| 19 | R13 | Resistor | 100 K Ω | 0.1 | 1 % | 200 | Free | | | 1 |
| 20 | R14 | Resistor | 22 K Ω | 0.1 | 1 % | | Free | | | 1 |
| 21 | R15 | Resistor | 470K | 0.1 | 1 % | | Free | | | 1 |
| 22 | R16 | Resistor | 4.7 K Ω | 0.1 | 1 % | | Free | | | 1 |
| 23 | R17 | Resistor | 12 K Ω | 0.1 | 1 % | | Free | | | 1 |
| 24 | R18 | Resistor | 0.3 Ω | 1W | 1 % | | Free | | | 1 |
| 25 | R19 | Resistor | 10 K Ω | 0.1 | 5 % | | Free | | | 1 |
| 26 | R20 | Resistor | 50 K Ω Lin | 0.1 | 5 % | | Horizontal | | Bourns | 1 |
| 27 | R21 | Resistor | 22 K Ω | 0.1 | 1 % | | Free | | | 1 |
| 28 | R22 | Resistor | 330 Ω | 0.1 | 1 % | | Free | | | 1 |
| 29 | R23 | Resistor | 470 Ω | 0.25 | 5 % | | Free | | | 1 |
| 30 | R24 | Resistor | 3.9 K Ω | 0.1 | 5 % | | Free | | | 1 |
| 31 | R25 | Resistor | 470 K Ω | 0.25 | 5 % | | Free | | | 1 |
| 32 | R26 | Resistor | 10 K Ω | 0.1 | 5 % | | Free | | | 1 |
| 33 | C1 | Capacitor | 470 pF | Cer | 10 % | 1 K | | DEBB33A471KC1B | Murata | 1 |
| 34 | C2 | Capacitor | 150 nF | Poly | 10 % | 400 | | NRM-S154K400F | NIC | 1 |
| 35 | C3 | Capacitor | 150 nF | Poly | 10 % | 400 | | NRM-S154K400F | NIC | 1 |
| 36 | C4 | Capacitor | 150 nF | Poly | 10 % | 400 | | NRM-S154K400F | NIC | 1 |
| 37 | C5 | Capacitor | 4.7 μ F | Poly | 10 % | 63 | | B32560J475K | Epcos | 1 |

Table 3. Bill of materials 230 V (AC)

| Part No. | Ref. Des. | Part | Value | Pwr | Tol. | Volt | Package | Type | Manuf. | Amount |
|----------|-----------|-------------|--------------------|------|----------------------|------|---------------------|----------------|-------------|--------|
| 38 | C6 | Capacitor | 2200 μ F | 105° | 10 % | 25 | | 2222 021 16222 | Vishay | 1 |
| 39 | C7 | Capacitor | 4.7 μ F | 105° | 10 % | 25 | Free | | | 1 |
| 40 | C8 | Capacitor | 330 pF | Cer | 5 % | | Free | | | 1 |
| 41 | C9 | Capacitor | 10 μ F | 105° | 10 % | 25 | Free | | | 1 |
| 42 | C10 | Capacitor | 2.2 nF | Cer | 10 % | 4 K | | DECE33J222ZC4B | Murata | 1 |
| 43 | C11 | Capacitor | 10 nF | Cer | 10 % | 25 | Free | | | 1 |
| 44 | L1 | Inductor | 680 μ H | | | | | 744776268 | Würth | 1 |
| 45 | L2 | Inductor | 330 μ H | | | | | 744776233 | Würth | 1 |
| 46 | L3 | Inductor | 100 μ H | | | | | 74477120 | Würth | 1 |
| 47 | TX1 | Transformer | N87/3F3 | | 5 % | | EFD25 | 750340505 | Würth | 1 |
| 48 | D1 | Rect Bridge | 2 A | | | | SO-4 | DBLS205G | Taiwan semi | 1 |
| 49 | D2 | TVS diode | 600 W | | | | | P6KE400A | Fairchild | 1 |
| 50 | D3 | Diode | 1 A 800 V | | | | | HER107 | Taiwan semi | 1 |
| 51 | D4 | Zener | 270 V 3 W | | | | | BZT03-C220 | Vishay | 1 |
| 52 | D5 | Diode | 1 A 800 V | | | | | HER107 | Taiwan semi | 1 |
| 53 | D6 | Diode | 3 A 100 V | | | | | SK310A | Taiwan semi | 1 |
| 54 | D7 | Diode | 1 A 800 V | | | | | HER107 | Taiwan semi | 1 |
| 55 | D8 | Zener | 30 V | | 5 % | | | BZV55-C30 | NXP | 1 |
| 56 | D9 | Zener | 20 V | | 5 % | | | BZV55-C20 | NXP | 1 |
| 57 | D10 | Diode | 75 V | | | | | 1N4148 | NXP | 1 |
| 58 | Q1 | Transistor | NPN | | | | | BC847B | NXP | 1 |
| 59 | Q2 | Transistor | NPN | | | | | BC847B | NXP | 1 |
| 60 | Q3 | Transistor | PNP | | | | | ZTX758 | Zetex | 1 |
| 61 | ISO2 | Optocoupler | | | | | | 4N27 | Vishay | 1 |
| 62 | U1 | IC | SSL2101 SSL2102 | | SO-1 6SO- 20 W | Y | SSL2101/ SSL2102 | | 1 | |

Table 4. Bill of materials 120 V (AC)

| Part No. | Ref. Des. | Part | Value | Pwr | Tol. | Volt | Package | Type | Manuf. | Amount |
|----------|-----------|------------------|-------|-----|------|------|---------|--------------|------------|--------|
| 1 | K1 | Conn 3pin 2u ang | m | | | | | SL 5.08/3/90 | Weidmuller | 1 |
| 2 | K1' | Conn 3pin 2u | f | | | | | BL 5.08/3 | Weidmuller | 1 |
| 3 | K3 | Conn 6pin 1u | f | | | | | BL3.36Z | Fischer | 1 |

Table 4. Bill of materials 120 V (AC)

| Part No. | Ref. Des. | Part | Value | Pwr | Tol. | Volt | Package | Type | Manuf. | Amount |
|----------|-----------|------------------|----------------------|------|------|------|------------|----------------|------------|--------|
| 4 | K2 | Conn 2pin 2u ang | m | | | | | SL 5.08/2/90 | Weidmuller | 1 |
| 5 | K2' | Conn 2pin 2u | f | | | | | BL 5.08/2 | Weidmuller | 1 |
| 6 | F1 | Fusistor | 6.8E | 1 W | 10 % | | Free | | | 1 |
| 7 | R1 | Resistor | 27 Ω | 1 W | 5 % | | Free | | | 1 |
| 8 | R2 | Resistor | 27 Ω | 1 W | 5 % | | Free | | | 1 |
| 9 | R3 | Resistor | 2.7 K Ω | 1 W | 5 % | | Free | | | 1 |
| 10 | R4 | Resistor | 470 K Ω | 0.25 | 1 % | | Free | | | 1 |
| 11 | R5 | Resistor | 0 Ω | 0.25 | 5 % | | Free | | | 1 |
| 12 | R6 | Resistor | 2.7 K Ω | 1 W | 5 % | 200 | Free | | | 1 |
| 13 | R7 | Resistor | 2.7 K Ω | 1 W | 5 % | 200 | Free | | | 1 |
| 14 | R8 | Resistor | 1 K Ω | 1 W | 5 % | 200 | Free | | | 1 |
| 15 | R9 | Resistor | 1 K Ω | 1 W | 5 % | 200 | Free | | | 1 |
| 16 | R10 | Resistor | 0.4 Ω | 1 W | 1 % | | Free | | | 1 |
| 17 | R11 | Resistor | 33 K Ω | 0.25 | 5 % | 200 | Free | | | 1 |
| 18 | R12 | Resistor | 10 Ω | 1 W | 5 % | 200 | Free | | | 1 |
| 19 | R13 | Resistor | 100 K Ω | 0.1 | 1 % | 200 | Free | | | 1 |
| 20 | R14 | Resistor | 15 K Ω | 0.1 | 1 % | | Free | | | 1 |
| 21 | R15 | Resistor | 470 K Ω | 0.1 | 1 % | | Free | | | 1 |
| 22 | R16 | Resistor | 10 K Ω | 0.1 | 1 % | | Free | | | 1 |
| 23 | R17 | Resistor | 12 K Ω | 0.1 | 1 % | | Free | | | 1 |
| 24 | R18 | Resistor | 0.3 Ω | 1W | 1 % | | Free | | | 1 |
| 25 | R19 | Resistor | 10 K Ω | 0.1 | 5 % | | Free | | | 1 |
| 26 | R20 | Resistor | 50 K Ω Lin | 0.1 | 5 % | | Horizontal | | Bourns | 1 |
| 27 | R21 | Resistor | 22 K Ω | 0.1 | 1 % | | Free | | | 1 |
| 28 | R22 | Resistor | 330 Ω | 0.1 | 1% | | Free | | | 1 |
| 29 | R23 | Resistor | 3.9 K Ω | 0.25 | 5 % | | Free | | | 1 |
| 30 | R24 | Resistor | 3.9 K Ω | 0.1 | 5 % | | Free | | | 1 |
| 31 | R25 | Resistor | 100 K Ω | 0.25 | 5 % | | Free | | | 1 |
| 32 | R26 | Resistor | NP | | | | Free | | | 1 |
| 33 | C1 | Capacitor | 470 pF | Cer | 10 % | 1 KV | | DEBB33A471KC1B | Murata | 1 |
| 34 | C2 | Capacitor | 100 nF | Poly | 10 % | 400 | | NRM-S104K400F | NIC | 1 |
| 35 | C3 | Capacitor | 330 nF | Poly | 10 % | 400 | | NRM-S334K400F | NIC | 1 |
| 36 | C4 | Capacitor | 330 nF | Poly | 10 % | 400 | | NRM-S334K400F | NIC | 1 |
| 37 | C5 | Capacitor | 4.7 μ F | Poly | 10 % | 63 | | B32560J475K | Epcos | 1 |
| 38 | C6 | Capacitor | 2200 μ F | 105° | 10 % | 25 | | 2222 021 16222 | Vishay | 1 |
| 39 | C7 | Capacitor | 4.7 μ F | 105° | 10 % | 25 | Free | | | 1 |
| 40 | C8 | Capacitor | 330 pF | Cer | 5 % | | Free | | | 1 |
| 41 | C9 | Capacitor | 10 μ F | 105° | 10 % | 25 | Free | | | 1 |
| 42 | C10 | Capacitor | 2.2 nF | Cer | 10 % | 4 K | | DECE33J222ZC4B | Murata | 1 |

Table 4. Bill of materials 120 V (AC)

| Part No. | Ref. Des. | Part | Value | Pwr | Tol. | Volt | Package | Type | Manuf. | Amount |
|----------|-----------|-------------|--------------------|-----|------|-----------------------|---------|---------------------|-------------|--------|
| 43 | C11 | Capacitor | 10 nF | Cer | 10 % | 25 | Free | | | 1 |
| 44 | L1 | Inductor | 680 μ H | | | | | 744776268 | Wurth | 1 |
| 45 | L2 | Inductor | 330 μ H | | | | | 744776233 | Wurth | 1 |
| 46 | L3 | Inductor | 100 μ H | | | | | 74477120 | Wurth | 1 |
| 47 | TX1 | Transformer | N87/3F3 | | 5 % | | EFD25 | 750340505 | Wurth | 1 |
| 48 | D1 | Rect Bridge | 2 A | | | | SO-4 | DBLS205G | Taiwan semi | 1 |
| 49 | D2 | TVS diode | 600 W | | | | | P6KE270A | Fairchild | 1 |
| 50 | D3 | Diode | 1 A 800 V | | | | | HER107 | Taiwan semi | 1 |
| 51 | D4 | Zener | 270 V 3 W | | | | | BZT03-C220 | Vishay | 1 |
| 52 | D5 | Diode | 1 A 800 V | | | | | HER107 | Taiwan semi | 1 |
| 53 | D6 | Diode | 3 A 100 V | | | | | SK310A | Taiwan semi | 1 |
| 54 | D7 | Diode | 1 A 800 V | | | | | HER107 | Taiwan semi | 1 |
| 55 | D8 | Zener | 30 V | | 5 % | | | BZV55-C30 | NXP | 1 |
| 56 | D9 | Zener | 20 V | | 5 % | | | BZV55-C20 | NXP | 1 |
| 57 | D10 | Diode | 75 V | | | | | 1N4148 | NXP | 1 |
| 58 | Q1 | Transistor | NPN | | | | | BC847B | NXP | 1 |
| 59 | Q2 | Transistor | NPN | | | | | BC847B | NXP | 1 |
| 60 | Q3 | Transistor | PNP | | | | | MPSA92 | NXP | 1 |
| 61 | ISO2 | Optocoupler | | | | | | 4N27 | Vishay | 1 |
| 62 | U1 | IC | SSL2101 SSL2102 | | | SO-16 Y SO-20 W | | SSL2101/ SSL2102 | 1 | |

11. Transformer specification

Figure 9 shows the transformer schematic:

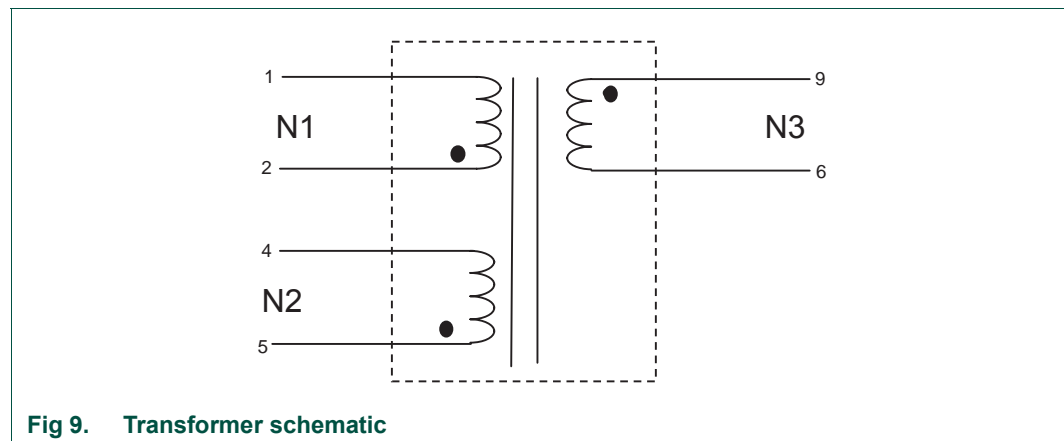


Fig 9. Transformer schematic

11.1 Winding specification

Table 5. Winding specification

| No. | Section | Wire | Layers | Turns | Pin | |
|-----|---------|----------|--------|-------|-------|-----|
| | | | | | Begin | End |
| 1 | N1 | 1X0.315 | 1 | 43 | 2 | |
| 2 | ISO | 0.2 | | | | |
| 3 | N3 | 40X0.071 | 1 | 21 | 9 | 6 |
| 4 | ISO | 0.2 | | | | |
| 5 | N2 | 1X0.2 | 1 | 42 | 5 | 4 |
| 6 | ISO | 0.2 | | | | |
| 7 | N1 | 1X0.315 | 1 | 42 | | 1 |
| 8 | ISO | 0.2 | | | | |

11.2 Electrical characteristics

Table 6. Inductance

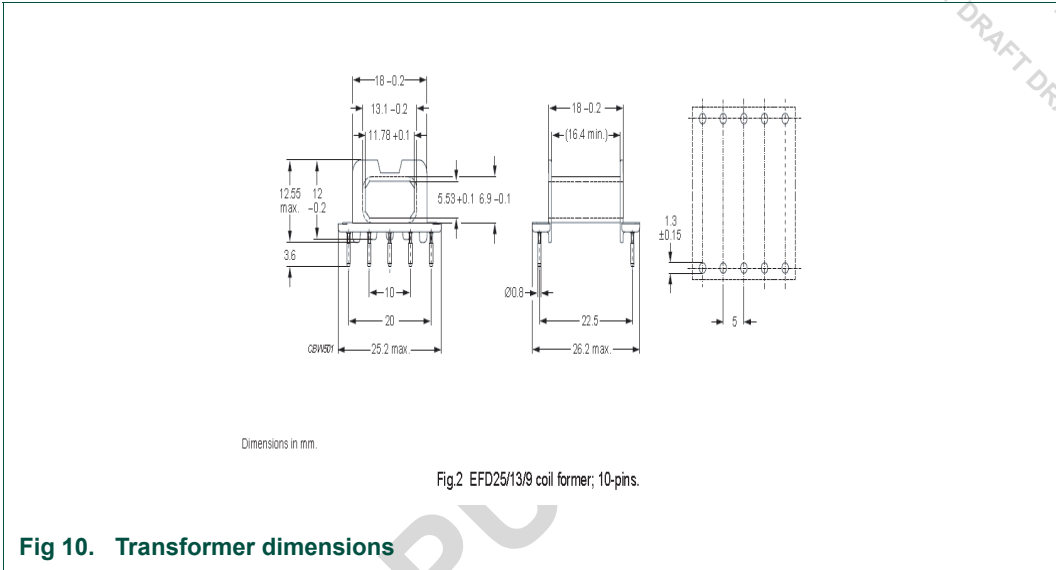
| Section | Inductance |
|---------|---------------------------------|
| N1 | 910 μ H \pm 5 %, at 2.3 A |
| N2 | 70 μ H |
| N3 | 270 μ H |

- Nominal frequency = 100 kHz
- $V_{\text{breakdown N1...N2}}$ = 4 KV

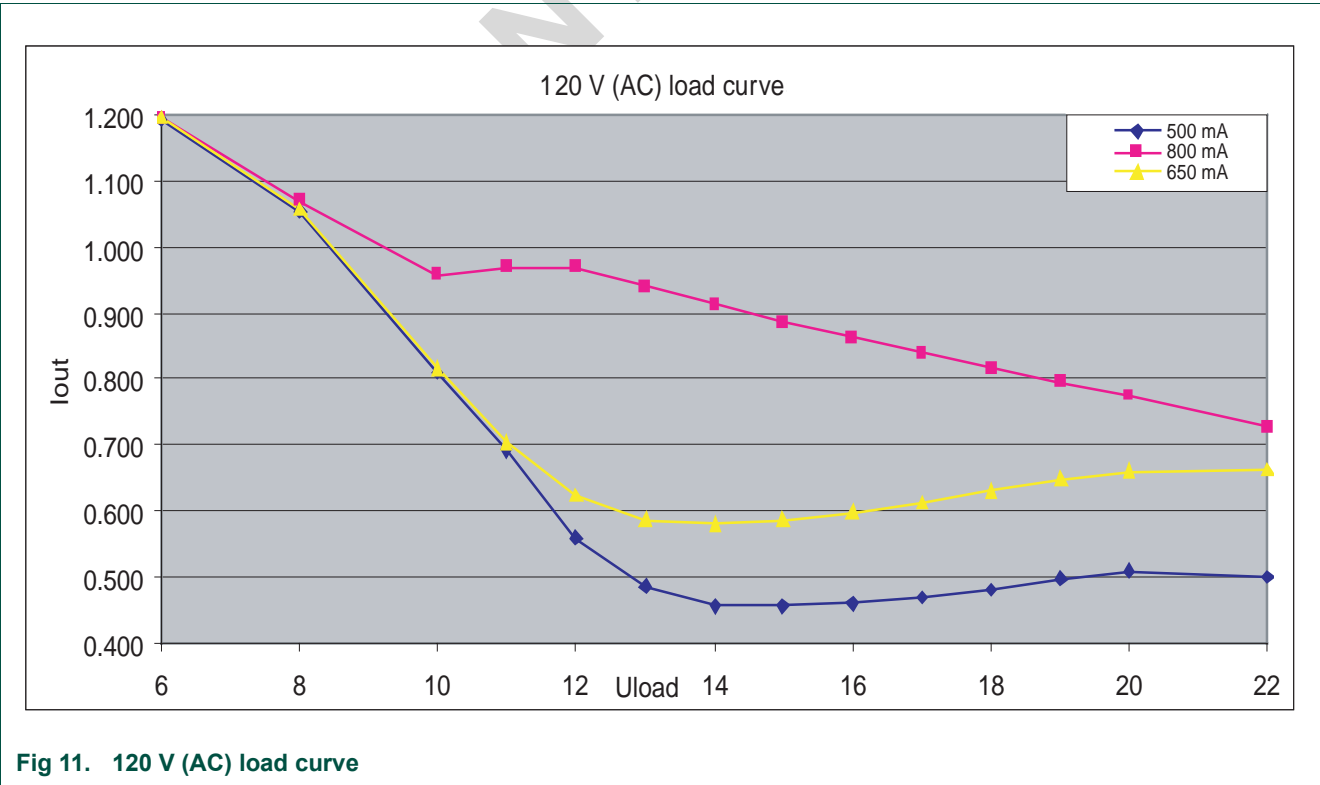
11.3 Core and bobbin

- Core: EFD25, 3F3/N87, airgap center 1100 μ M
- Bobbin: CSH-EFD25-1S-10P

11.4 Physical dimensions



12. Appendix A - Load curves



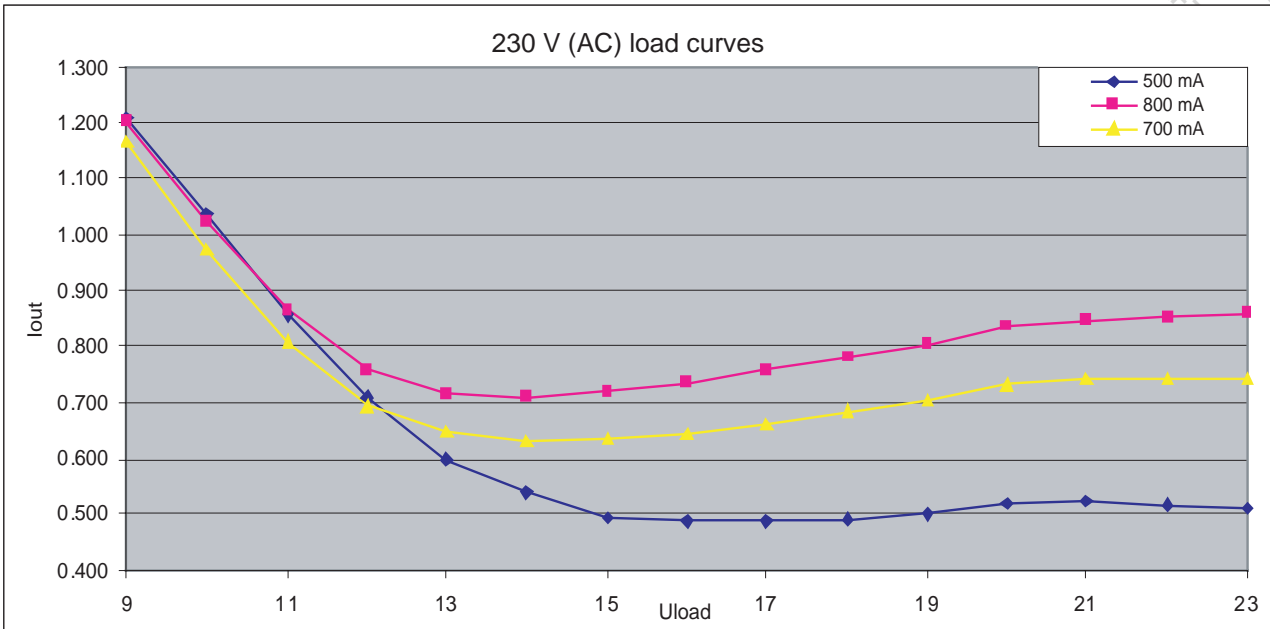


Fig 12. 230 V (AC) load curve

13. Appendix B - Efficiency curves

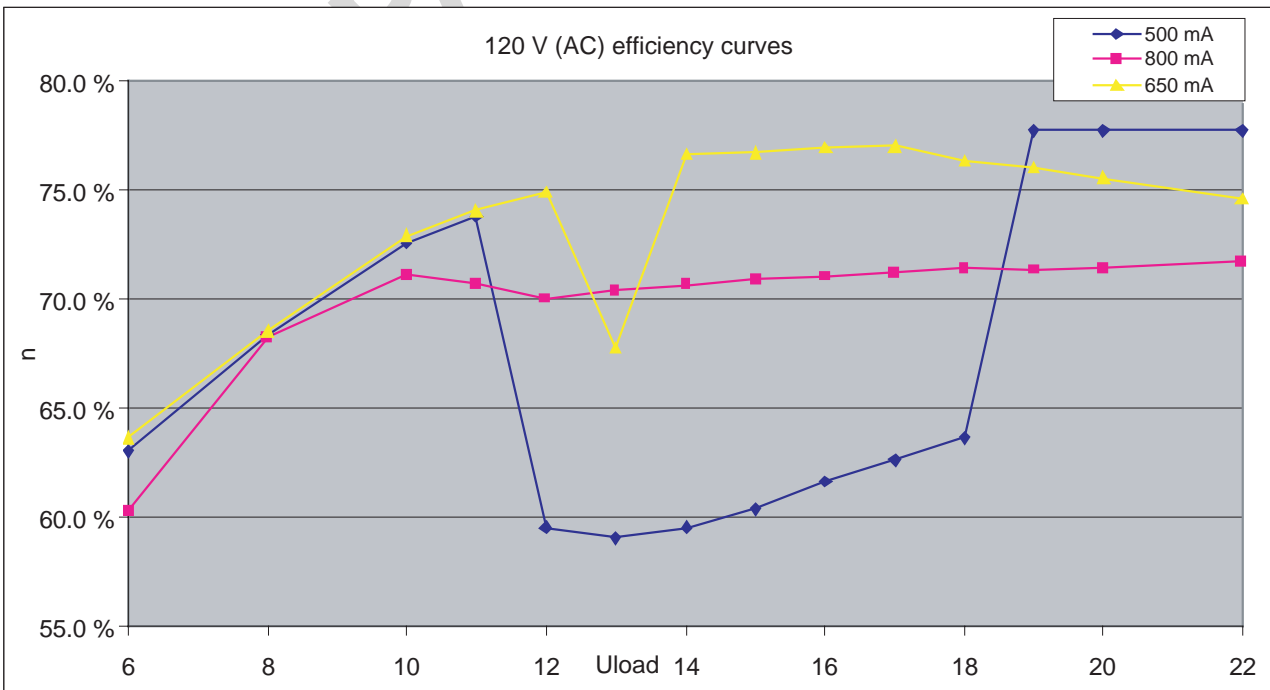


Fig 13. 120 V (AC) efficiency curve

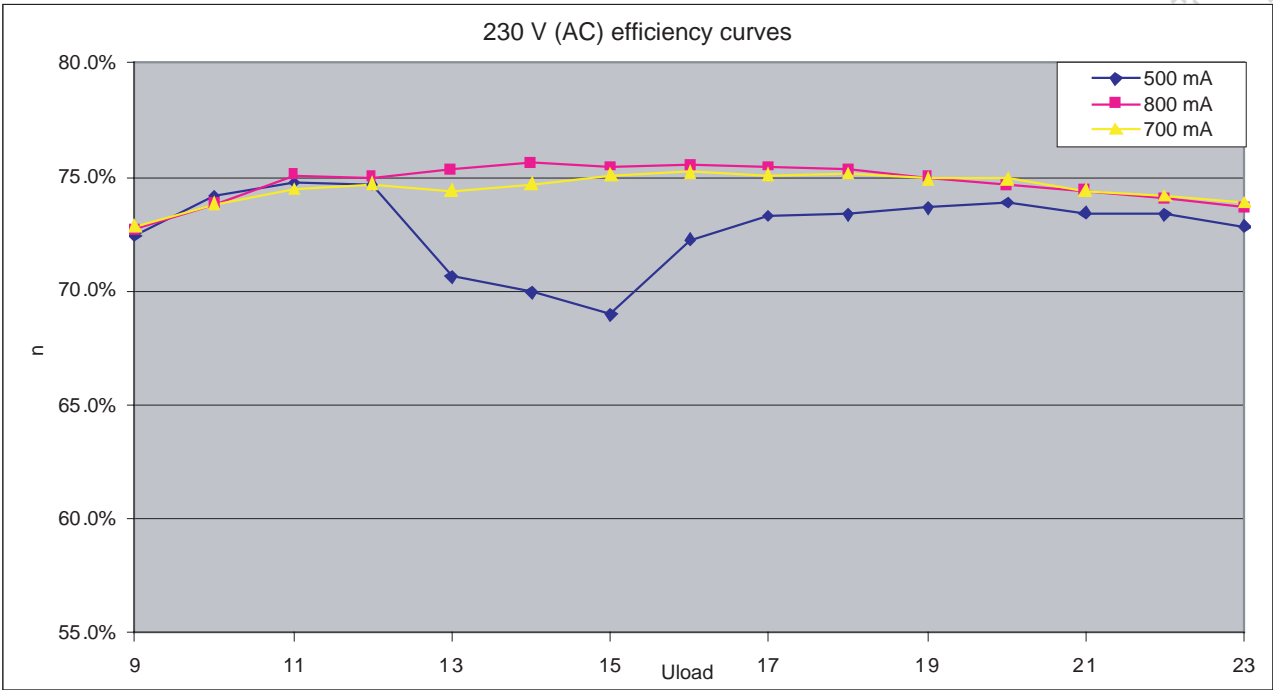


Fig 14. 230 V (AC) efficiency curve

14. Appendix C - Input voltage dependency

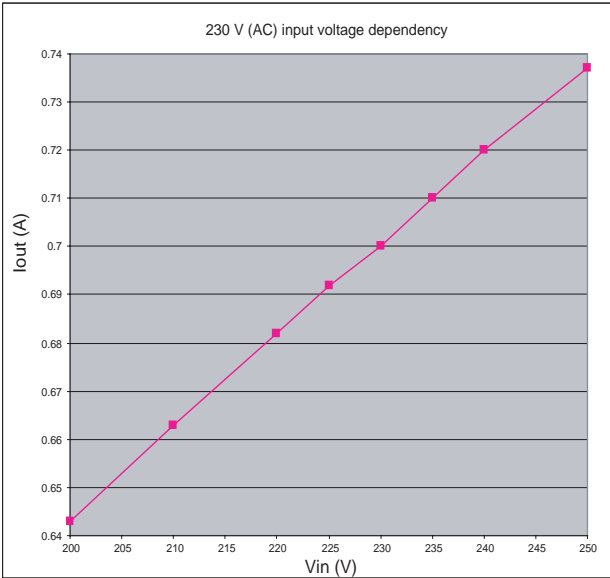
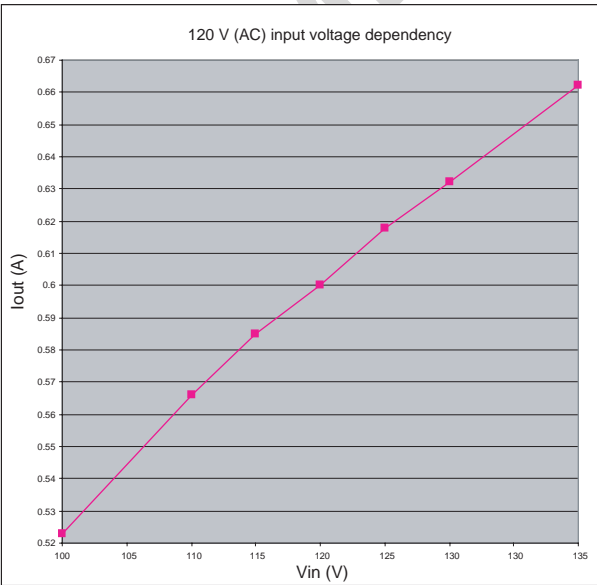


Fig 15. Input voltage/output current dependency

15. Appendix D - Mains conducted harmonics

Table 7. Mains conducted harmonic values

| Harmonic | 230 V (AC) 50 Hz Amplitude (%) | 120 V (AC) 60Hz Amplitude (%) |
|----------|--------------------------------|-------------------------------|
| 1 | 100 | 100 |
| 2 | 0 | 0 |
| 3 | 13.2 | 9 |
| 4 | 0 | 0 |
| 5 | 3.8 | 2.1 |
| 6 | 0 | 0.1 |
| 7 | 1.2 | 1.9 |
| 8 | 0.1 | 0.1 |
| 9 | 3.2 | 2 |
| 10 | 0 | 0.1 |
| 11 | 0.5 | 0 |
| 12 | 0 | 0.1 |
| 13 | 2.5 | 1.3 |
| 14 | 0 | 0.1 |
| 15 | 1.8 | 1.2 |
| 16 | 0 | 0.1 |
| 17 | 2.1 | 0.5 |
| 18 | 0 | 0 |
| 19 | 2.9 | 0.1 |
| 20 | 0 | 0 |
| THD | 15.94 | 10.80 |
| PF | 0.94 | 0.98 |

16. References

- [1] **AN10754_1** — How to design an LED driver using the SSL2101
- [2] **SSL2101** — Datasheet
- [3] **SMPS** — IC for dimmable LED lighting

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