UM10342

SSL2101 3 W mains dimmable buck board

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Document information

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Abstract	This is a user manual for the SSL2101 3 W mains dimmable buck driver demo boards.

founded by Philips

Revision history

Rev	Date	Description
01	20090928	First issue

Contact information

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1. Introduction

The next advance in LED illumination technology requires the optimum use of the maximum potential LED lumen output, enabled at an optimum energy efficiency and form factor.

The NXP AC/DC converter dimmable board supports triac and transistor based dimmers. Deep dimming has been included to increase dimming ratio up to 1:350. Also, a combination of steering methods reduces audible transformer noise and creates a logarithmic dimming curve. The curve approaches the natural dimming curve in brightness as experienced with incandescent lamps.

To provide a cost and size effective thermal design, temperature feedback is incorporated in the boards. This will allow tighter margins in optimization and more effective use of available LED power. 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 board during operation must be avoided at all times. An isolated housing is obligatory when used in uncontrolled, non-laboratory environments, so a galvanic isolation of the mains supply using a variable transformer is always recommended. These devices can be recognized by the symbols shown in Figure 1

a. Isolated

b. Not Isolated

Fig 1. Variac isolation symbols

3. Connecting the board

The board can be optimized for either a 230 V (AC) 50 Hz or a 120 V (AC) 60 Hz mains source. Besides the mains source optimization the board has been designed to work with a several types and configurations of high power LEDs. The dimming performance may decrease if the board is used at a different mains voltage.

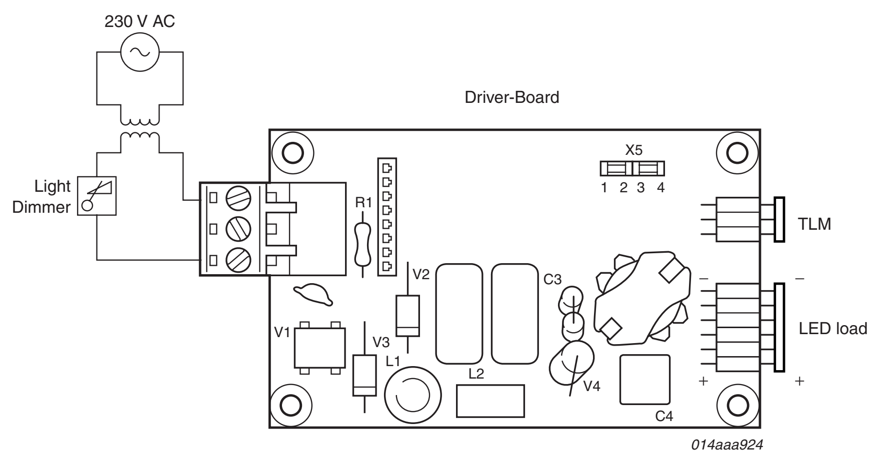

Fig 2. Board connection diagram

- Connect the mains line and the dimmer as shown in Figure 2. The dimmer unit can be placed on either input lead. If a galvanic isolated transformer is used, this should be placed in between the AC source and the dimmer/demo board.
- Connect the load to the right side of the driver board using the side connectors. Attach a jumper on the connector X5, according to load configuration.

Remark: When the board is placed in a metal enclosure, the middle pin of connector K1 can be connected to the metal casing for grounding.

Remark: There should always be one load board with end terminations. At open output, and with power applied, the driver board might be damaged due to an overvoltage on C4. No output overvoltage protection is implemented.

4. Specifications

Table 1 gives the specifications for the SSL2101 3 W LED buck board

Table 1. Specifications

Parameter	Conditions	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)	3.5 V (DC) to 60 V (DC)	Board has been optimized for 19.5 V (DC)
Output current (LED current)	20 mA to 700 mA	Board has been optimized for 250 mA
Output current accuracy	+4 % to –4 % at 230 V (AC) ± 10 %	Based on 250 mA, 6 W
Maximum output power (LED power)	9 W	Using 9 × 1 W LED, 350 mA
Efficiency without dimmer	Typically 66 %	Using 6 × 1 W LED, 250 mA
Power Factor: 230 V (AC)	0.72	At 6 W output power

Table 1. Specifications *...continued*

Parameter	Conditions	Comment
Switching frequency	37 kHz	Can be adjusted, see Section 7.1
Dimming range	0.3 % to 100 %	-
Board dimensions	75 mm × 50 mm × 20 mm	L × B × H
Operating temperature	0° C to 85° C	-

5. Board photos

Fig 3. Driver board (top)

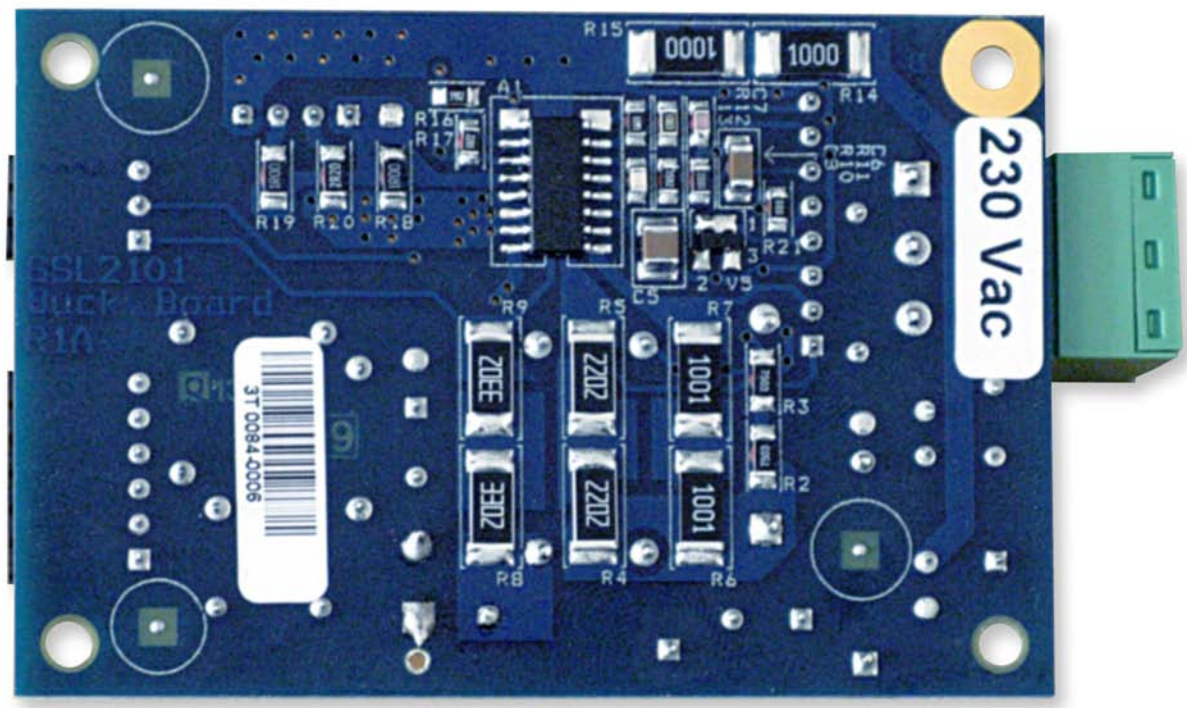

Fig 4. Driver board (bottom)

6. Dimmers

Several triac based dimmers have been tested by NXP Semiconductors. As different dimmers have different specifications the dimming performance of the board might vary. Dimming performance optimization can be achieved by tuning components (see Section 8). Dimmer compatibility is reached through a combination of sensing and control logic in combination with internal switches and external resistors.

7. Functional description

7.1 Converter operation

On the buck demo board, a non-isolated buck converter is used to drive the LEDs. The SSL2101 can be used in two modes, DCM (Discontinuous Conduction Mode) and BCM (Boundary Conduction Mode). It is not suitable for CCM (Continuous Conduction Mode). DCM mode and BCM mode have the advantage over CCM that the switch losses at turn-on are minimal because no current is running. Also, the inductive material is used over the available BH curve because no permanent field is present. Connector X5 pin 1 can be used to monitor inductor and switch current. The peak current is limited using a sense resistor connected to the source pin. The OCP-limit is reached when the voltage at the source pin reaches 0.5 Volt. Three time slots can be distinguished:

- t1 - This is the time required to build up the magnetic field in the inductor.

- t2 - This is the time required to reduce the magnetic field in the inductor.
- t3 - This is the time that no current flows through the inductor.

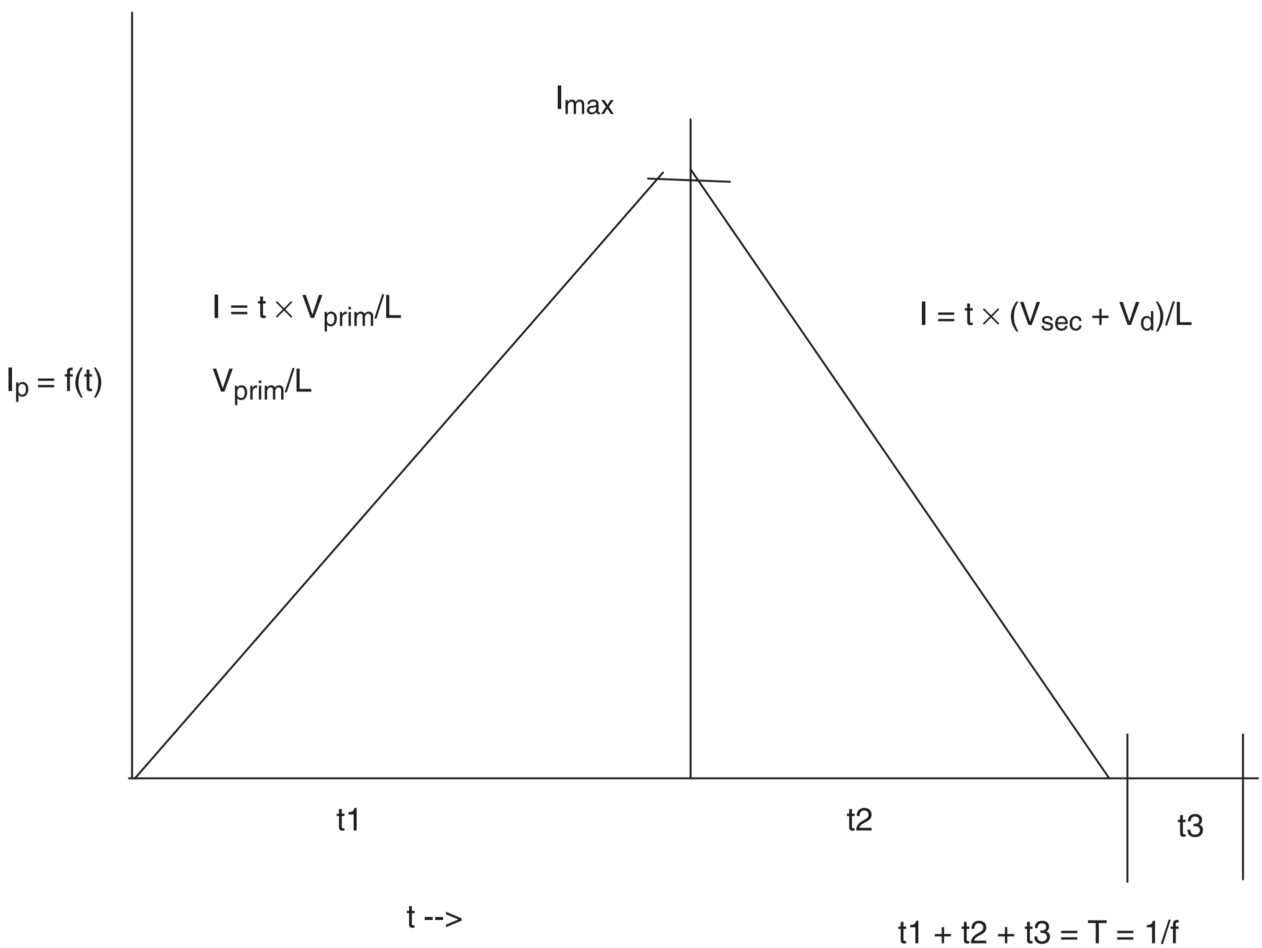

Fig 5. Converter operation

Because t2 depends on LED voltage, t3 will change at fixed frequency and fixed voltage. The demo board is optimized for a load board with 6 LEDs. To achieve maximum power output (at BCM), or to avoid CCM mode (at low V_{LED}) C7 can be tuned up or down leading to a change in base oscillator frequency.

7.2 Dimming curve

Using a resistive divider and low-pass filter, consisting of R2, R3, R10, R11 and R21 and C6, a DC voltage is created from the rectified mains voltage. This DC voltage is used as a reference for the dimming position of the attached dimmer. The voltage is connected with the BRIGHTNESS and PWMLIMIT pin of the SSL2101.

These pins influence output power, by restricting the duty-factor of the converter (PWMLIMIT) and frequency of the converter (brightness). They are sensitive in the range of 0.4 V to 2.5 V. By tuning the divider circuit, dimming steepness and lower threshold can be tuned. Bear in mind that at upper range, both pins should be high enough to obtain full output power, if input voltage independent current stabilization is to be achieved.

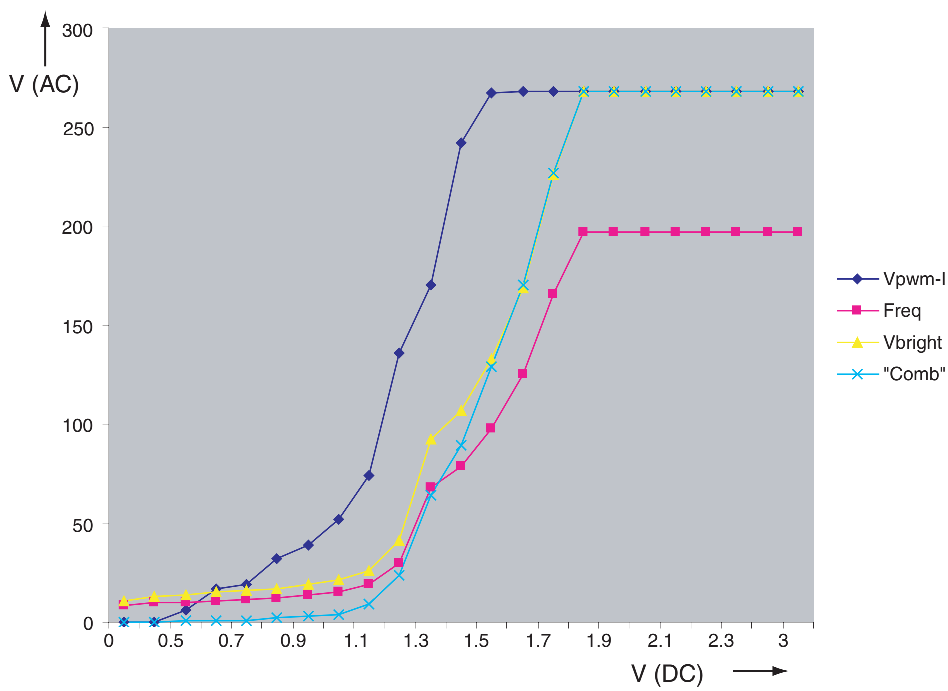

Fig 6. BRIGHTNESS pin and sensitivity

8. Board optimization

You can do the following modifications on the demo board in order to meet specific customer application specifications:

8.1 Change output current

Header X5 on the driver board can be used to tune the output current through the LED's. Table 2 shows measured current versus number of LEDs:

Table 2. LED current configuration

Jumper position	9 × 1 W (mA)	6 × 1 W (mA)	3 × 1 W (mA)
None	85	120	220
1 to 2	150	215	390
2 to 3	125	185	340
3 to 4	250	360	640
1 to 2 and 3 to 4	320[1]	465[1]	810[1]

[1] The coil L4 starts to saturate due to high peak current.

8.2 Changing oscillator frequency

The dimming range of the demo board is partly determined by the oscillation circuit, made up of C7, R12 and R13. The frequency ratio can be calculated with the min and max oscillator frequencies as follows: $f_{min} = \frac{1}{2 \times R12 \times C7}$

$$f_{max} = \frac{1}{2 \times R13 \times C7}$$

$$Frequency\ range = \frac{f_{min}}{f_{max}}$$

f_{max} is limited to 200 kHz. C7 is limited to a maximum of 1 nF.

9. Thermal lumen management

The demo board provides an extra connector for thermal lumen management. For instance, a Negative Temperature Coefficient (NTC) resistor (thermistor) mounted in proximity of the LEDs can be used as sensor. Then, using a current mirror, the value is compared with reference resistor, and at threshold, the PWMLIMIT pin is pulled to GND. By variation of the resister value, the temperature at which stabilization occurs can be set. A lower value will cause higher threshold. Because of thermal resistance versus required galvanic isolation, a temperature difference will occur. If the board is used in free air conditions, this will lead to relative higher LED temperatures. In an enclosed housing, this difference will be smaller.

10. Driver board schematic

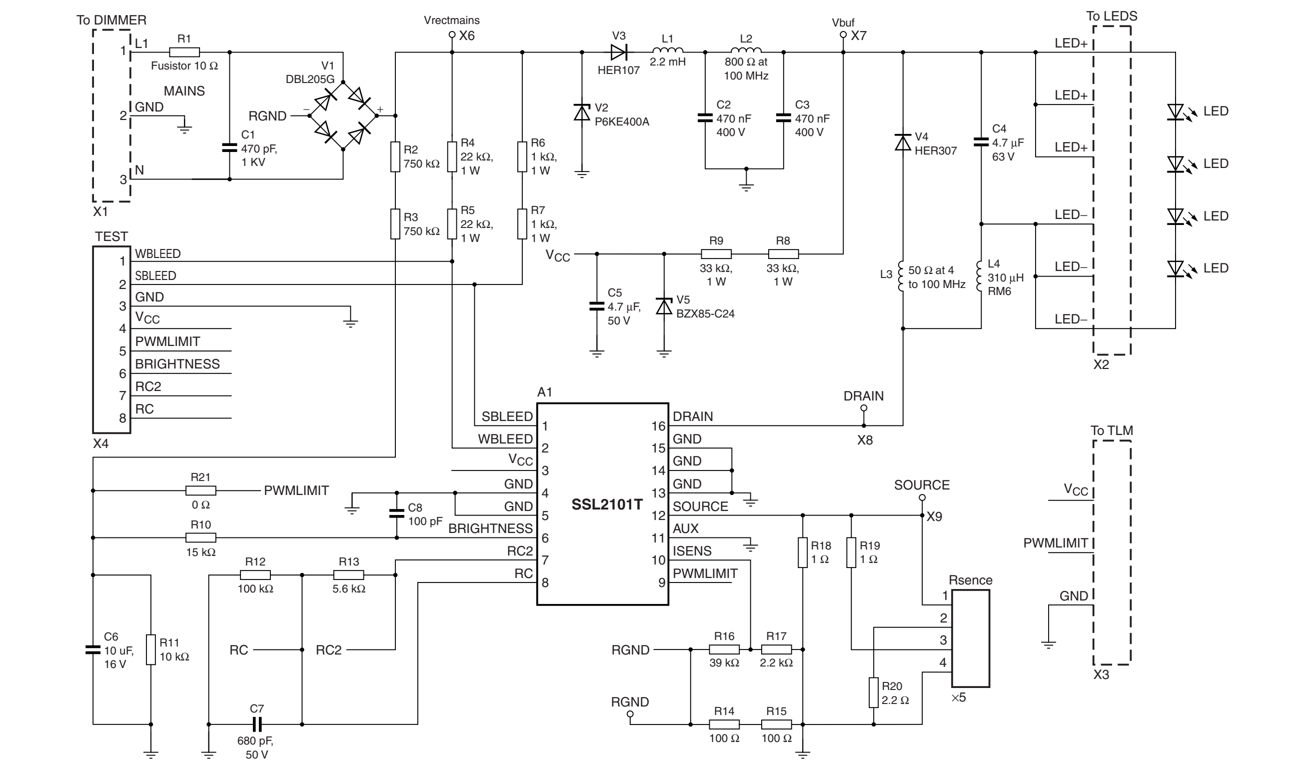

Fig 7. Driver board schematic

11. Bill Of Materials (BOM)

Table 3. Bill of materials 230 V (AC)

Part no	Qty	Ref design	Part	Value	Tol. (%)	Package	Type	Manuf.
1	1	A1	IC	-	-	SO16	SSL2101T	NXP
2	1	C1	Capacitor	470 pF; 1 kV	-	-	DEBB33A471	MUR
3	2	C2, C3	Capacitor	470 nF; 400 V	10	15 mm	2222 468 28474	VIS
4	1	C4	Capacitor	4.7 µF; 63 V	10	7.5 mm	B32560J475K	EPC
5	1	C5	Capacitor	4.7 µF; 50 V	10	1210	GRM32ER71H475KA88L	MUR
6	1	C6	Capacitor	10 µF; 16 V	10	1206	GRM31CR61C106KC31L	MUR
7	1	C7	Capacitor	680 pF; 50 V	10	0805	C0805C681J5GAC	KEM
8	1	C8	Capacitor	100 pF, 100 V	5	0805	B37940K1101J60	EPC
9	1	L1	Inductor	2.2 mH	10	-	RLB9012-222KL	BRN
10	1	L2	Ferrite	800 Ω; 100 MHz	-	-	7427501	SCN
11	1	L3	Ferrite	50 Ω at 4 Mhz to 100 Mhz	-	-	BL02RN2R1M2B	MUR
12	1	L4	Inductor	310 µH	-	-	custom	-
14	1	R1	Resistor	Fusistor 10 Ω	-	-	NFR25H0001009JA100	VIS

Table 3. Bill of materials 230 V (AC) *...continued*

Part no	Qty	Ref design	Part	Value	Tol. (%)	Package	Type	Manuf.
15	2	R2, R3	Resistor	750 kΩ	1	1206	2322 724 67504L	PHY
16	2	R4, R5	Resistor	22 kΩ; 1 W	1	2512	CRCW251222K0FKEG-ND	VIS
17	2	R6, R7	Resistor	1 kΩ; 1 W	1	2512	541-1.00KAFCT-ND	VIS
18	2	R8, R9	Resistor	33 kΩ; 1 W	1	2512	CRCW251233K0FKEG-ND	VIS
19	1	R10	Resistor	15 kΩ	1	0805	2322 734 61503L	PHY
20	1	R11	Resistor	10 kΩ	1	0805	2322 734 61003L	PHY
21	1	R12	Resistor	100 kΩ	1	0805	2322 734 61004L	PHY
22	1	R13	Resistor	5.6 kΩ	1	0805	2322 734 65602L	PHY
23	2	R14, R15	Resistor	100 Ω; 1 W	1	2512	541-100AFTR-ND	VIS
24	1	R16	Resistor	39 kΩ	1	0805	2322 734 63903L	PHY
25	1	R17	Resistor	2.2 kΩ	1	0805	2322 734 62202L	PHY
26	2	R18, R19	Resistor	1 Ω	1	1206	2322 724 61008L	PHY
27	1	R20	Resistor	2.2 Ω	1	1206	2322 724 62208L	PHY
28	1	R21	Resistor	0 Ω	-	0805	2322 730 91002L	PHY
29	1	V1	Bridge Recitfier	-	-	DIP4 Long	DBL205G	TAI
30	1	V2	TVS Diode	400 V; 600 W	-	DO-15	P6KE400A	FAI
31	1	V3	Diode	-	-	DO-41	HER107	MLC
32	1	V4	Diode	-	-	DO201AD	HER307	MLC
33	1	V5	Zener Diode	24 V	-	SOT23	BZX84C24	NXP
34	1	X1	Connector	MSTB 2,5/ 3-G-5,08	-	-	1759020	PHC
35	1	X2	Connector	Socket 6	-	SIL6_2.54 mm	972-8880	-
36	1	X3	Connector	Socket 3	-	SIL3_2.54 mm	972-8880	-
37	1	X4	Connector	header 8	-	SIL8	8280200-08-02	-
38	1	X5	Connector	header 4	-	SIL4	8280200-04-02	-
39	5	X6, X7, X8, X9, X10	Test Point	TP	-	-	-	-

Table 4. Bill of materials 120 V (AC)

Part no	Qty	Ref design	Part	Value	Tol. (%)	Package	Type	Manuf.
1	1	A1	IC	-	-	SO16	SSL2101T/N1,515	NXP
2	1	C1	Capacitor	470 pF; 1 kV	-	-	DEBB33A471	MUR
3	2	C2, C3	Capacitor	470 nF; 400 V	10	15 mm	2222 468 28474	VIS
4	1	C4	Capacitor	4.7 μF; 63 V	10	7.5 mm	B32560J475K	EPC
5	1	C5	Capacitor	4.7 μF; 50 V	10	1210	GRM32ER71H475KA88L	MUR
6	1	C6	Capacitor	10 μF; 16 V	10	1206	GRM31CR61C106KC31L	MUR
7	1	C7	Capacitor	680 pF; 50 V	10	0805	C0805C681J5GAC	KEM
8	1	C8	Capacitor	100 pF; 100 V	5	0805	B37940K1101J60	EPC
9	1	L1	Inductor	2.2 mH	10	-	RLB9012-222KL	BRN

Table 4. Bill of materials 120 V (AC) *…continued*

Part no	Qty	Ref design	Part	Value	Tol. (%)	Package	Type	Manuf.
10	1	L2	Ferrite	800 Ω at 100 MHz	-	-	7427501	SCN
11	1	L3	Ferrite	50 Ω at 4 MHz to 100 Mhz	-	-	BL02RN2R1M2B	MUR
12	1	L4	Inductor	310 μH	-	-	custom	-
14	1	R1	Resistor	Fusistor 10 Ω	-	-	NFR25H0001009JA100	VIS
15	2	R2, R3	Resistor	360 kΩ	1	1206	2322 724 63604L	PHY
16	2	R4, R5	Resistor	22 kΩ; 1 W	1	2512	CRCW251222K0FKEG-ND	VIS
17	2	R6, R7	Resistor	1 kΩ; 1 W	1	2512	541-1.00KAFCT-ND	VIS
18	1	R8	Resistor	33 kΩ; 1 W	1	2512	CRCW251233K0FKEG-ND	VIS
19	1	R9	Resistor	0 Ω	1	2512	-	-
20	1	R10	Resistor	15 kΩ	1	0805	2322 734 61503L	PHY
21	1	R11	Resistor	10 kΩ	1	0805	2322 734 61003L	PHY
22	1	R12	Resistor	100 kΩ	1	0805	2322 734 61004L	PHY
23	1	R13	Resistor	56 kΩ	1	0805	2322 734 65602L	PHY
24	2	R14, R15	Resistor	100 Ω; 1 W	1	2512	541-100AFTR-ND	VIS
25	1	R16	Resistor	39 kΩ	1	0805	2322 734 63903L	PHY
26	1	R17	Resistor	2.2 kΩ	1	0805	2322 734 62202L	PHY
27	2	R18, R19	Resistor	1.0 Ω	1	1206	2322 724 61008L	PHY
28	1	R20	Resistor	2.2 Ω	1	1206	2322 724 62208L	PHY
29	1	R21	Resistor	15 kΩ	1	0805	2322 734 61503L	PHY
30	1	V1	Bridge Recitfier	-	-	DIP4 Long	DBL205G	TAI
31	1	V2	TVS Diode	400 V; 600 W	-	DO-15	P6KE400A	FAI
32	1	V3	Diode	-	-	DO-41	HER107	MLC
33	1	V4	Diode	-	-	DO201AD	HER307	MLC
34	1	V5	Zener Diode	24 V	-	SOT23	BZX84C24	NXP
35	1	X1	Connector	MSTB 2,5/ 3-G-5,08	-	-	1759020	PHC
36	1	X2	Connector	Socket 6	-	SIL6_2.54 mm	972-8880	-
37	1	X3	Connector	Socket 3	-	SIL3_2.54 mm	972-8880	-
38	1	X4	Connector	header 8	-	SIL8	8280200-08-02	-
39	1	X5	Connector	header 4	-	SIL4	8280200-04-02	-
40	5	X6, X7, X8, X9, X10	Test Point	-	-	-	-	-

12. Inductor specification

Figure 8 shows the inductor schematic:

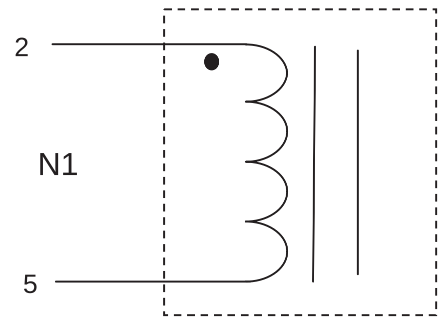

Fig 8. Inductor schematic

12.1 Winding specification

Table 5. Winding specification

No.	Section	Wire	Layers	Turns	Pin	
					Begin	End
1	N1	1 × 0.4	3	30	2	5
2	ISO	0.2	-	-	-	-

12.2 Electrical characteristics

Table 6. Inductance

Section	Inductance
N1	310 μH ± 5 %, at 1 A

12.3 Core and bobbin

- Core: RM6, 4-pin, air gap adjust on value N1 (310 μH) B65807-JR87
- Bobbin: B65808K-N1004-D1
- Clip: B65808A-2203X

12.4 Physical dimensions

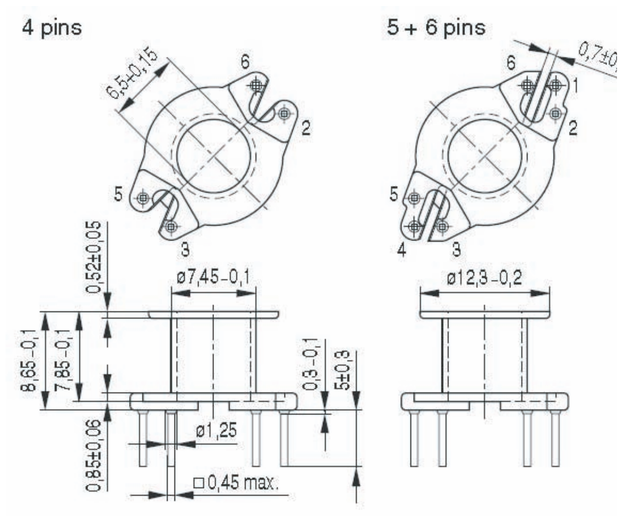

Fig 9. Transformer dimensions

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14. Contents

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