UM10695

SSL2109ADB1108 - 230 V/18 W high PF isolated T8 LED driver demo board

Rev. 1 — 9 April 2013 **User manual**

Document information

Info	Content
Keywords	SSL2109ADB1108, flyback converter, high power factor, T8 LED
Abstract	This document describes the operation of a 230 V/18 W T8 non-dimmable LED driver demo board featuring SSL2109A and using an isolated flyback topology. The SSL2109ADB1108 demo board is designed for T8 LED lamps used in Solid State Lighting (SSL) applications

Revision history

Rev	Date	Description
v. 1	20130409	first issue

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.

1. Introduction

This user manual describes the operation of the SSL2109ADB1108 demo board featuring the SSL LED driver SSL2109A in a 230 V/18 W isolated application.

The SSL2109ADB1108 demo board is designed for driving a 10-LED string load.

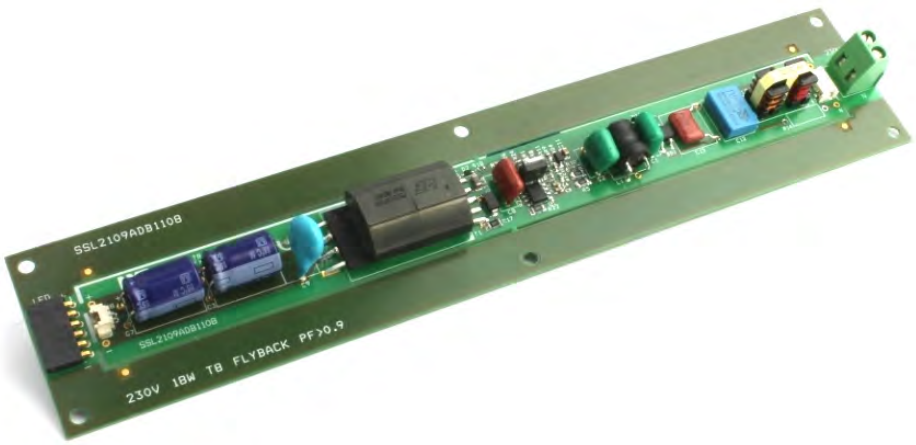
The PCB dimensions are compatible with both T8 LED lamps used in SSL applications.

The demo board provides a simple and effective solution having high power factor, low THD and high efficiency for SSL applications.

1.1 Features of the application

- T8 LED lamp compatibility
- Open LED and short circuit LED string protection
- OverCurrent protection (OCP) and OverTemperature protection (OTP)
- Power factor (PF) greater than 0.9 and THD < 20 %
- Efficiency greater than 85 %
- Minimal changes required in design for a 120 V/18 W SSL application
- Compliant with IEC61000-3-2 harmonics standard

The assembled top and bottom board views are shown in Fig 1 with the board dimensions in Fig 3. The board dimensions allow enough headroom with either T8 LED or PAR30 lamps.



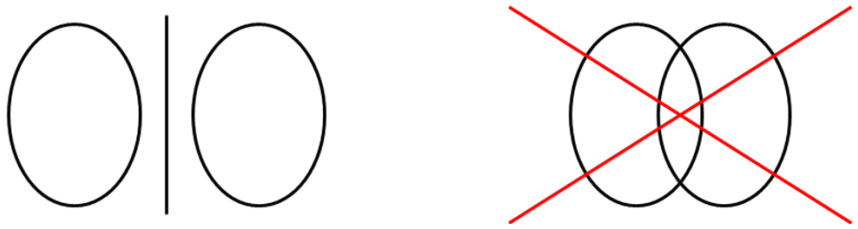
a. Top view

b. Bottom view

Fig 1. SSL2109ADB1108 230 V/18 W T8 LED demo board

2. Safety

The board must be connected to mains voltage. Avoid touching the demo 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 2. Variable transformer isolation symbols

3. Specifications

Table 1. Specifications of the SSL2109ADB1108

Symbol	Parameter	Value
V_{mains}	AC mains supply voltage	230 V; ±10 %
P_{in}	input power	18 W at nominal V_{mains} = 230 V
P_{out}	output power	16.3 W
V_{LED}	output voltage (LED voltage)	25 V to 40 V with nominal V_{LED} = 35V
I_{LED}	output current (LED current)	475 mA
I_{ripple}	output ripple current	165 mA (p-p)
$\Delta I_{LED}/ \Delta V_{mains}$	line regulation	0.5 mA/V (±2.75 % I_{LED} at ±10 % V_{mains} variation)
$\Delta I_{LED}/ \Delta V_{LED}$	load regulation	1 mA/V (±0.8 % I_{LED} at ±10 % V_{LED} variation)
η	efficiency	90 %
PF	power factor	0.94
THD	total harmonic distortion	16 %
f_{sw}	switching frequency	70 kHz

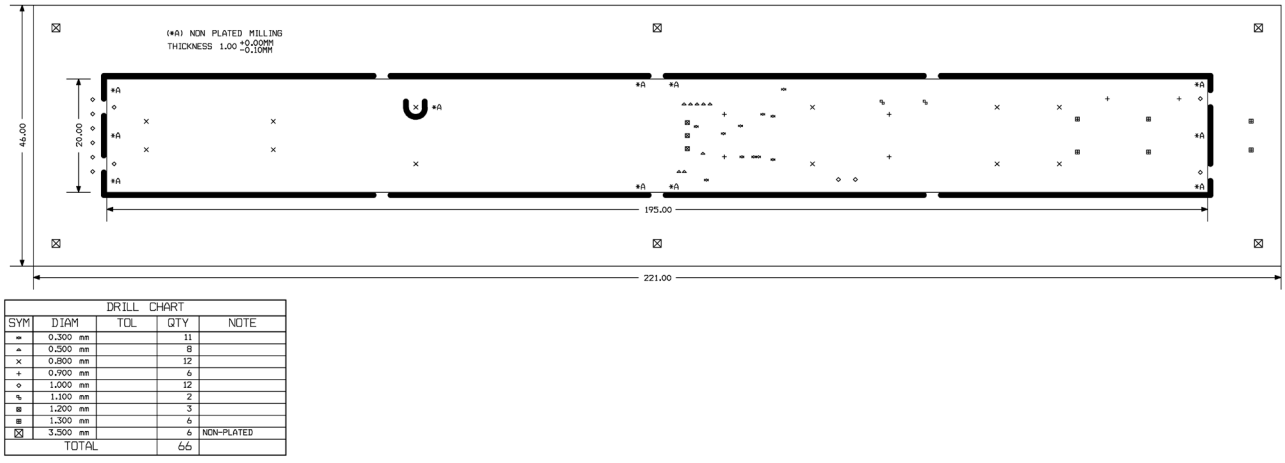


Fig 3. SSL2109ADB1108 demo board dimensions

4. Functional description

4.1 Input filtering

Common-mode and differential mode π filters are implemented to reduce common-mode or differential mode noise originating from the high-frequency (HF) switching currents/voltages in the primary of the converter from returning to the mains. This noise must be kept to a minimum by:

- Small primary current loop (C2 to pin 1 of T1, pin 3 of T1 to drain of external MOSFET Q5, ground return from sense resistors R1, R24, R26 to C2 ground)
- Snubber components D3, R17, C8 closely parallel to pins 1 and 3 of T1
- Track length from pin 3 of T1 to drain of external MOSFET to be small in order to reduce capacitance to surroundings

For this 18 W application, C2 must be chosen sufficiently large to act as a buffer for the HF current flowing in the primary but also small enough to maintain a high PF where a value of 330 nF for C2 is a good compromise.

4.2 PF adjustment

The divider network consisting of R5, R6, R7, R9, R10, D4, C10 and C11 modulates the base of Q7 according to the rectified mains. Consequently, a modulating current set by R11 flows through R8 and the sense current through R1, R24 and R26 is also modulated. Depending on the divider resistor values, the HF current through the primary has a current with a rectified mains modulation resulting in a high PF.

The PF can be increased/decreased by decreasing/increasing R5 and R6 and a compromise can be reached between PF and line regulation.

4.3 RCD clamp

Leakage inductance of the transformer is in series with primary inductance and the drain of MOSFET Q5. This leakage inductance together with the parasitic capacitance across the drain source of Q5 causes HF ringing when Q5 switches off. If the leakage is not minimized the voltage at the drain reaches high voltages levels which can damage Q5 if voltage levels exceed the maximum allowable level.

An RCD clamp (R17, C8 and D3) prevents the voltage on the drain of Q5 exceeding the maximum drain voltage when Q5 switches off.

4.4 Supply voltage

The supply voltage of the SSL2109A is achieved using an auxiliary winding. As further advantages, the auxiliary winding provides, via a resistor R25 on its underwinding, both a simple solution for improved load regulation using R12 and open-circuit protection (OCP) via the NTC pin using R13.

4.4.1 Open circuit protection

If no LED string is connected to the converter output, the voltage can quickly exceed the maximum rating of the output capacitors C3 and C7.

The underwinding of the auxiliary is connected to resistor R25 to prevent this. The voltage across R25 decreases as the output voltage increases. Consequently, the voltage at the NTC pin decreases once the current through R13 exceeds the internal current of the NTC pin. When the NTC voltage drops below 0.35 V then the SSL2109A

switches off.

An external 18 V Zener diode is included at the VCC pin to prevent that the voltage exceeds 20 V at the VCC pin for this no LED string situation

4.4.2 Short circuit

When the LED terminals are shorted, the SSL2109A defaults to its maximum demagnetization time of 36 µs. This prevents that the inductor current ramps up to an excessively large value while the input power is limited and the SSL2109A enters OPS protection (latched) mode.

Remark:

Do not try to short-circuit the LED output while the circuit is powered or without discharging C3. The short-circuit protection is intended for zero-hour short circuit protection (so a short circuit during first assembly before power is applied).

5. Demo board connections

The SSL2109ADB1108 demo board is supplied with a 230 V, 50 Hz mains supply where the board connection is shown in Fig 4.

Table 2. Input and output connections

Connector	Function	Remark
X1	AC MainsL	line wire solder connection on small board
X2	AC MainsN	neutral wire solder connection on small board
X3	LED anode	positive LED wire solder connection on small board
X4	LED cathode	negative LED wire solder connection on small board
X5	AC mains input	AC mains in terminal block
X6	LED load output	LED connector 6-way female for NXP LED load
X7	AC mains input	low profile LEB connector providing board-to-board and wire-to-board capabilities
X8	LED load output	low profile LEB connector providing board-to-board and wire-to-board capabilities

Remarks:

Make all connections with the input mains supply switched off.

Use a protective shield over application and never touch the board when measuring or testing.

Connections and testing:

- Connect a 10-LED string load to the SSL2109ADB1108 together with power meters at both inputs and outputs.
- Connect V_{mains} (230 V (AC)/50 Hz) using an isolating transformer (initially set to 0 V) to the input connection points of the flyback converter. Alternatively, use an AC power supply with limited output current capability (for example 200 mA).
- Increase V_{mains} to 230 V (AC) and measure the different parameters as shown in Table 3.

Table 3. Input / Output parameters SSL2109ADB1108

V_{mains} (V)	I_{in} (mA)	PF	P_{in} (W)	V_{LED} (V)	I_{LED} (mA)	P_{out} (W)	η
230	83	0.94	18	35	475	16.3	0.9

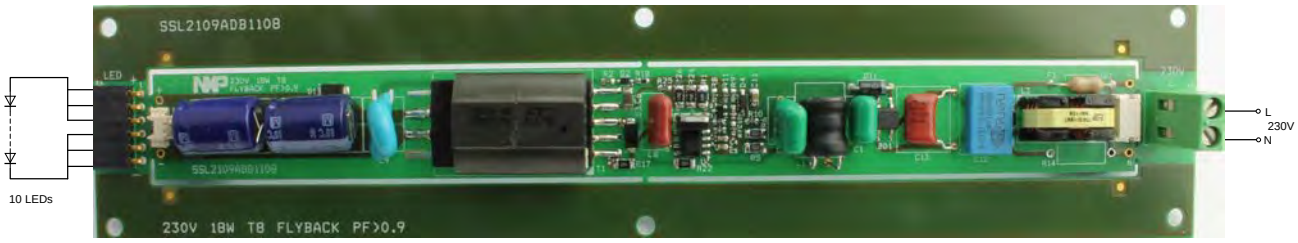


Fig 4. **Board connection for SSL2109ADB1108 with 10-string LED load**

6. Performance data SSL2109ADB1108

6.1 Efficiency

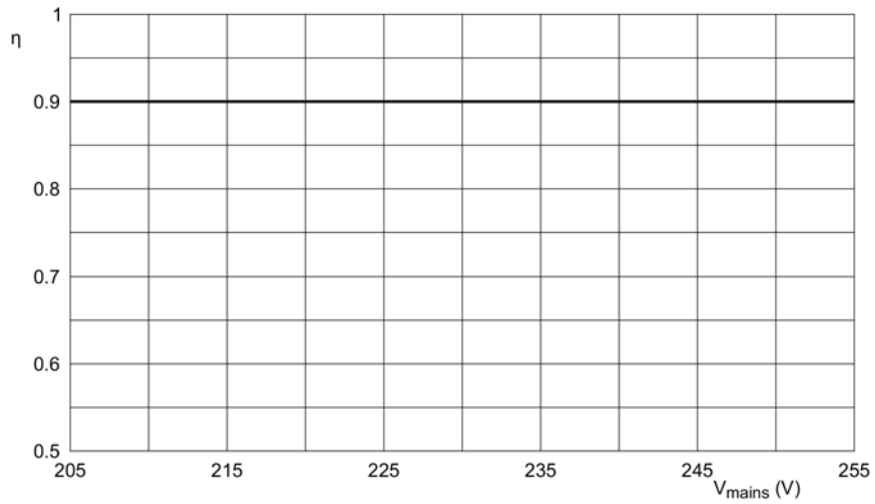


Fig 5. Efficiency as a function of mains voltage

6.2 Power factor

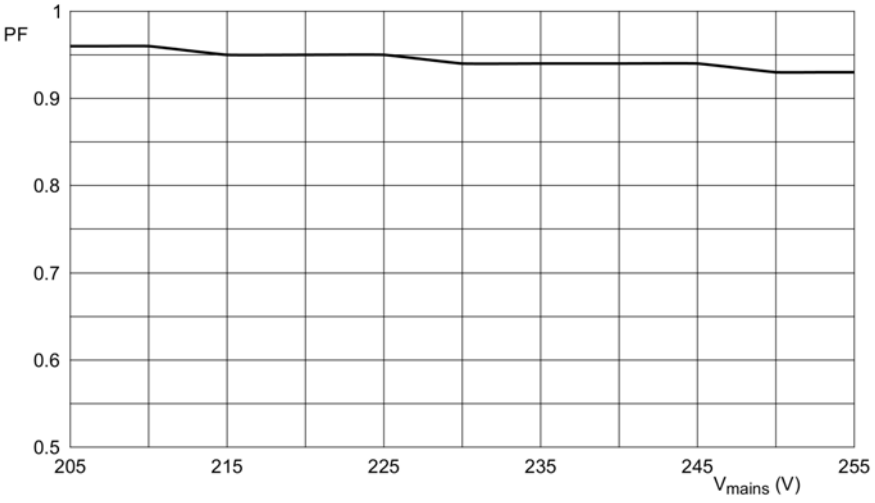


Fig 6. Power factor as a function of mains voltage

6.3 Line regulation

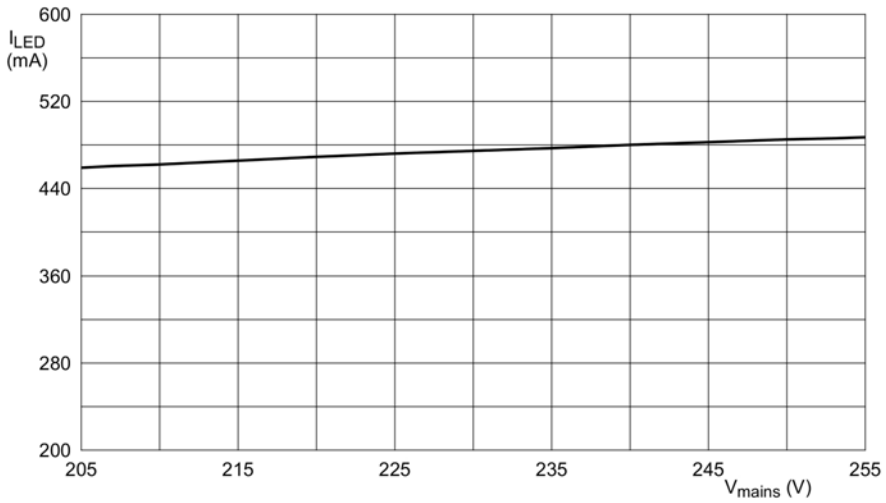


Fig 7. LED current as a function of mains voltage

6.4 Load regulation

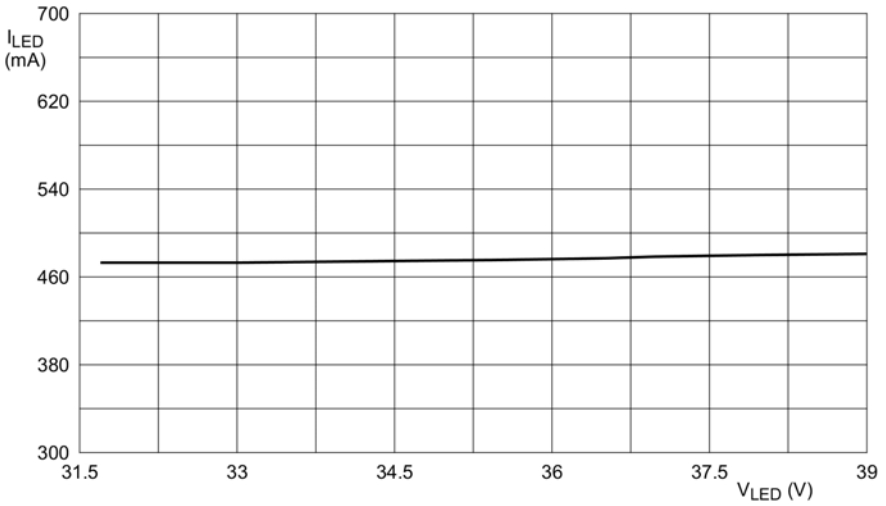


Fig 8. LED current as a function of LED voltage

6.5 ElectroMagnetic Interference (EMI)

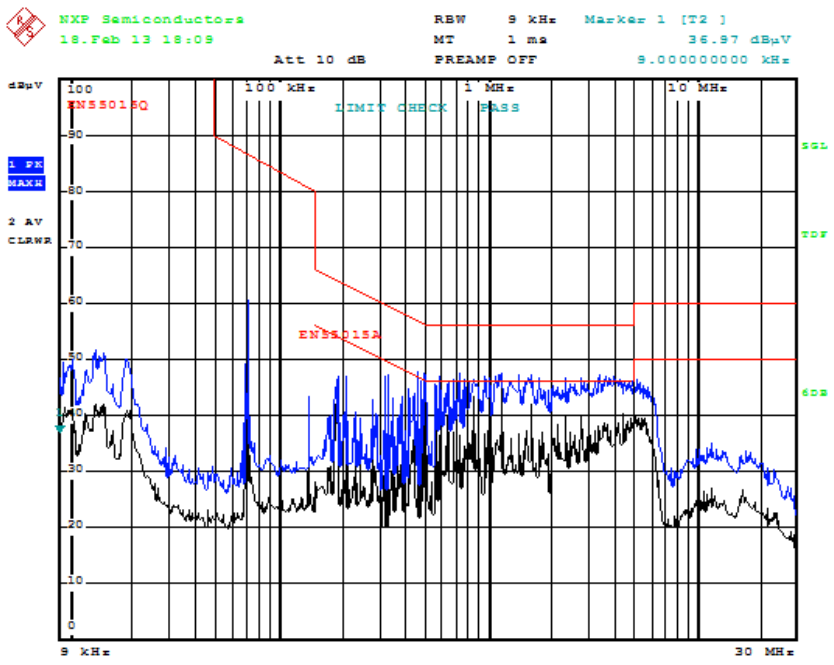


Fig 9. EMI performance

7. Schematic diagram

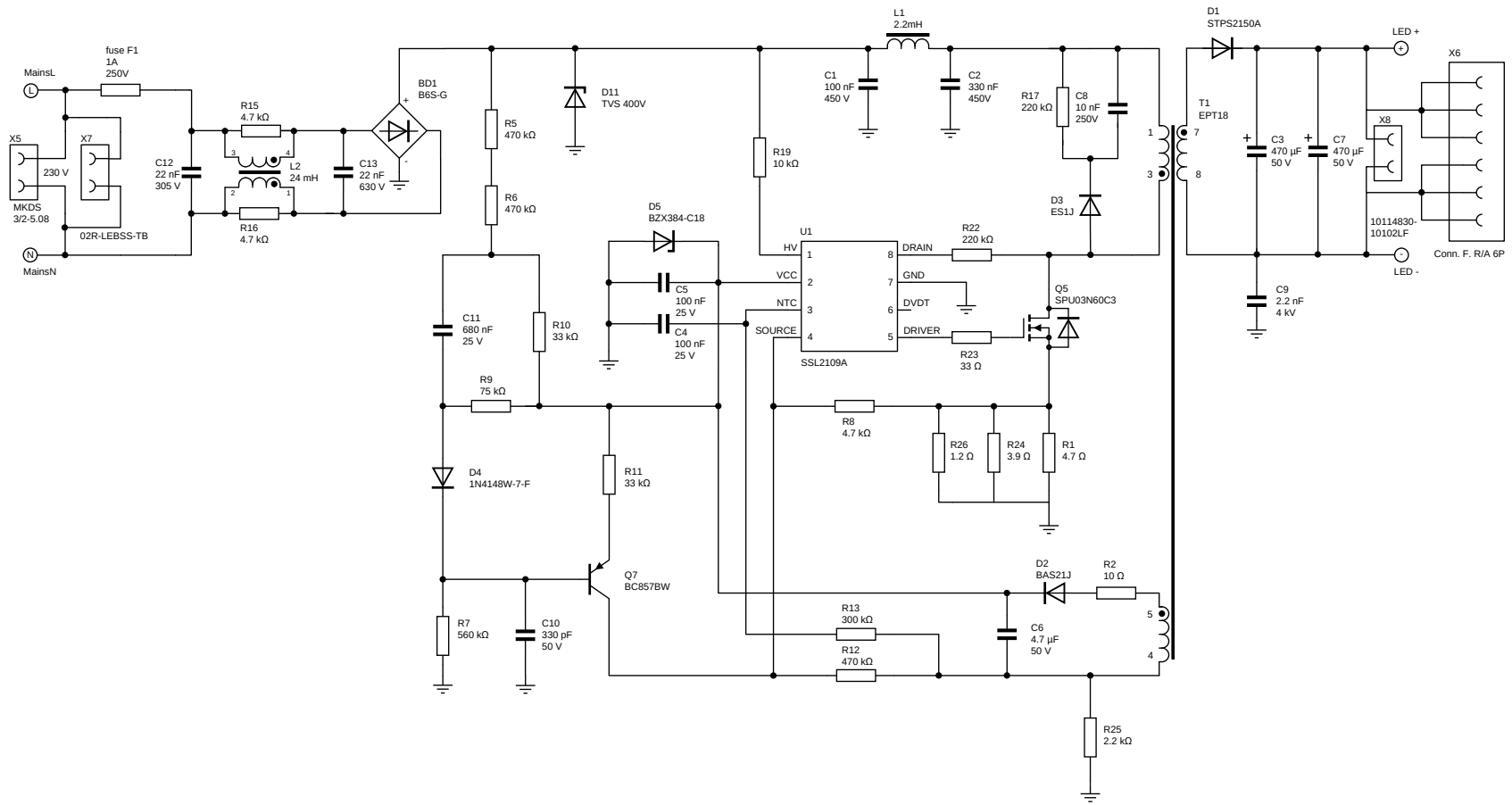


Fig 10. SSL2109ADB1108 schematic

8. PCB component assembly and layout

8.1 PCB component assembly

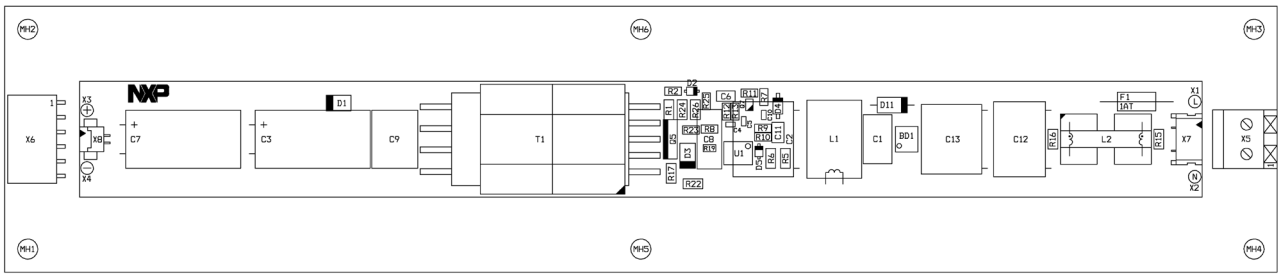
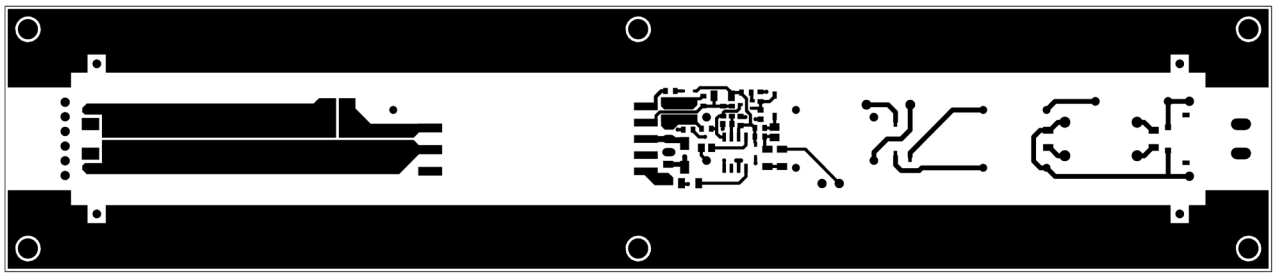
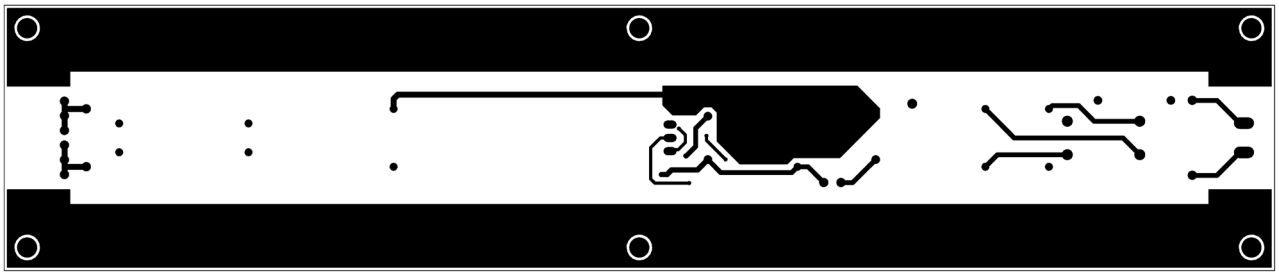


Fig 11. PCB component assembly

8.2 PCB layout



a. Top view



b. Bottom view

Fig 12. PCB Layout

9. Bill Of Material (BOM) SSL2109ADB1108

Table 4.

Reference	Description and values	Part number	Manufacturer
BD1	bridge rectifier; 600 V; 0.8 A	B6S-G	Comchip Technology
C1	capacitor; 100 nF; 450 V; 10 %; metal film; radial	CL21-450V-0.1u F/K	Guang Da
C2	capacitor; 330 nF; 450 V ; 5 %; metal film; radial	ECW-F2W334JAQ	Panasonic
C3	capacitor; 470 µF; 50 V; 20 %; electrolytic; radial	ECA1HM471	Panasonic
C4	capacitor; 100 nF; 25 V; 10 %; X7R ceramic; 0603	GRM188R71E104KA01D	Murata
C5	capacitor; 100 nF; 25 V; 10 %; X7R ceramic; 0603	GRM188R71E104KA01D	Murata
C6	capacitor; 4.7 µF; 50 V; 10 %; 1206	UMK316AB7475KL-T	Taiyo Yuden
C7	capacitor; 470 µF; 50 V; 20 %; electrolytic; radial	ECA1HM471	Panasonic
C8	capacitor; 10 nF; 250 V; 20%; polyester; radial	ECQE2103JF	Panasonic
C9	capacitor; 2.2 nF; 4 kV; 20 %; radial	DE1E3KX222MA5B	Murata
C10	capacitor; 330 pF; 50 V; 20 %; X7R ceramic; 0603	CC0603KRX7R9BB331	Yageo
C11	capacitor; 680 nF; 25 V; 10 %; 0805	C0805C684K3NACTU	Kemet
C12	capacitor; 22 nF; 305 V (AC); radial	B32921C3223M	Epcos
C13	capacitor; 22 nF; 630 V; 5 %; radial	ECQE6223JF	Panasonic
D1	Schottky diode; 150 V, 2 A; DO-214AC; SMA	STPS2150A	ST
D2	switching diode; BAS21J; 300 V; 0.25 A; SOD323F	BAS21J	NXP Semiconductors
D3	fast diode; ES1J; 600 V; 1 A; DO-214AC; SMA	ES1J	Fairchild
D4	high-speed diode; 100 V; 0.4 W; SOD123	1N4148W-7-F	Diodes Inc
D5	Zener diode; 18 V; 200 mA; SOD323F	BZX384-C18	NXP
D11	TVS diode; 400V; DO-41	BZW04-342	Multicomp
F1	fuse slow; 1 A; 250V	MCPMP 1A 250V	Multicomp
L1	inductor; 2.2 mH; 240 mA; 4.5 Ω; radial	13R225C	Murata
L2	inductor; 24 mH; common-mode choke; 250 mA; 6.3 Ω	750311897	Würth
Q5	transistor; N channel MOSFET; 650 V; 1.4 Ω	SPU03N60C3	Infineon
Q7	transistor; BC857BW; PNP; SOT323	BC857BW	NXP Semiconductors
R1	resistor; 4.7 Ω; 0.25 W; 1 %; 1206	RC1206FR-074R7L	Yageo
R2	resistor; 10 Ω; 0.1 W; 5 %; 1206	ERJ3GEYJ100V	Panasonic
R5	resistor; 470 kΩ; 0.25 W; 5 %; 1206	RC1206JR-07470KL	Yageo
R6	resistor; 470 kΩ; 0.25 W; 5 %; 1206	RC1206JR-07470KL	Yageo
R7	resistor; 560 kΩ; 0.1 W; 1 %; 0603	CRCW0603560KFKEA	Vishay
R8	resistor; 4.7 kΩ; 0.1 W; 1 %; 0603	CRCW06034K70FKEA	Vishay
R9	resistor; 75 kΩ, 0.1 W; 1 %; 0603	CRCW060375K0FKEA	Vishay
R10	resistor; 33 kΩ; 0.1 W; 1 %; 0603	CRCW060333K0FKEA	Vishay
R11	resistor; 33 kΩ; 0.1 W; 1 %; 0603	CRCW060333K0FKEA	Vishay
R12	resistor; 470 kΩ; 0.1 W; 1 %; 0603	CRCW0603470KFKEA	Vishay
R13	resistor; 300 kΩ; 0.1 W; 1 %; 0603	CRCW0603300KFKEA	Vishay
R15	resistor; 4.7 kΩ; 0.25 W; 5 %; 1206	RC1206JR-074K7L	Yageo
R16	resistor; 4.7 kΩ; 0.25 W; 5 %; 1206	RC1206JR-074K7L	Yageo
R17	resistor; 220 kΩ; 0.25 W; 5 %; 1206	RC1206JR-07220KL	Yageo

Reference	Description and values	Part number	Manufacturer
R19	resistor; 10 kΩ; 0.125 W; 5 %; 0805	CRCW080510K0FKEA	Vishay
R22	resistor; 220 kΩ; 0.25 W; 5 %; 1206	RC1206JR-07220KL	Yageo
R23	resistor; 33 Ω; 0.1 W; 5 %; 0603	RC0603JR-0733RL	Yageo
R24	resistor; 3.9 Ω; 0.25 W; 1 %; 1206	RC1206FR-073R9L	Yageo
R25	resistor; 2.2 kΩ; 0.1 W; 5 %; 0603	ERJ2GEJ222X	Panasonic
R26	resistor; 1.2 Ω; 0.25 W; 1 %; 1206	RC1206FR-071R2L	Yageo
T1	flyback transformer ; EPT18	750313729 Rev01	Würth
U1	IC; SSL2109A; SO8	SSL2109A	NXP Semiconductors
X1	solder pin for MainsL	-	-
X2	solder pin for MainsN	-	-
X3	solder pin for LED+	-	-
X4	solder pin for LED-	-	-
X5	mains connector terminal block	MKDSN2,5-5.08	Phoenix Contact
X6	LED connector terminal block	BL3.36Z	Fischer Elektronik
X6	LED connector terminal block (alternative)	SSW-106-02-G-S-RA	Samtec
X7	Mains miniature connector	02R-LEBSS-TB	JST
X8	LED miniature connector	10114830-10102LF	FCI

10. Transformer specification

An EPT18 core is used.

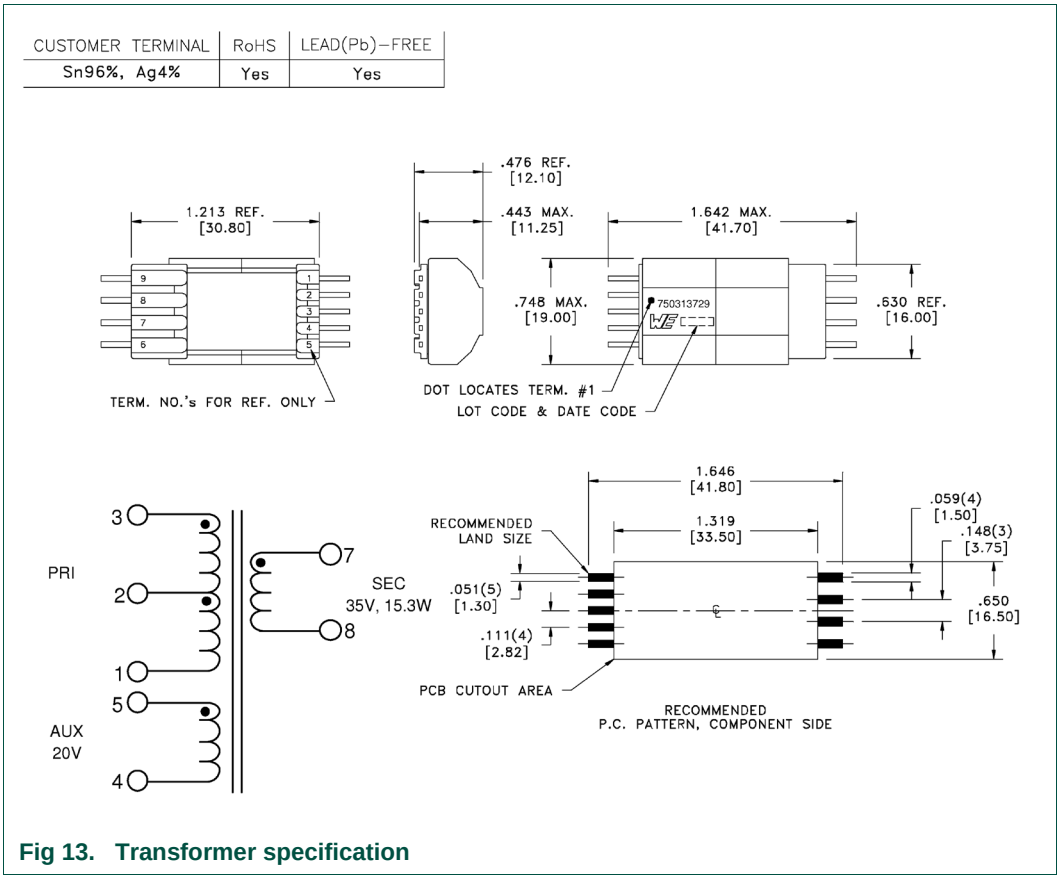


Fig 13. Transformer specification

Table 5. Electrical specification

All values are specified at 25 °C unless otherwise specified. All values without tolerance are typical values. Reinforced insulation for a primary circuit at a working voltage of 250 V (RMS)

Parameter	Value	Comment
DCR (3-1)	1.3 Ω; ±10 %	
DCR (5-4)	340 mΩ; ±10 %	
DCR (7-8)	180 mΩ; ±10 %	
primary Inductance (3-1)	1.2 mH; ±10 %	100 mV; 10 kHz
leakage Inductance (3-1)	maximum 7 µH	100 mV; 100 kHz Short 5-4 and 7-8
primary saturation current	950 mA	
turns ratio (3-1):(7-8)	3:1; ±1 %	
turns ratio (3-1):(5-4)	4.4:1; ±1 %	

11. Derivative board 120 V/18 W T8 LED with PF > 0.9 and η > 85%

To realize a 120 V/18 W T8 LED derivative board from the 230 V/18 W T8 LED demo board with PF > 0.9 and η > 85 % the following changes have to be implemented as shown in Table 6.

Table 6. Changes required for derivative board

Part reference	Description	Remark
C13	capacitor; 22 nF; 400 V; 5 %; radial	voltage rating change from 630 V to 400 V
D11	TVS diode; 400 V; DO-41	delete
R1	resistor; 1.5 Ω; 0.25 W; 1 %; 1206	value change from 4.7 Ω to 1.5 Ω
R6	resistor; 0 Ω; 0.25 W; 5 %; 1206	value change from 470 kΩ to 0 Ω
R24	resistor; 1.5 Ω; 0.25 W; 1 %; 1206	value change from 3.9 Ω to 1.5 Ω
R26	resistor; 2.4 Ω; 0.25 W; 1 %; 1206	value change from 1.2 Ω to 2.4 Ω
RV1	varistor; 300 V (AC); 42 J; radial	add
T1	flyback transformer; EPT18	change Würth 750313729 Rev01 to Würth 750313929 Rev00

Table 7 includes a summary of performance data for the derivative board.

Table 7. Performance data for derivative board

Symbol	Parameter	Value
V_{mains}	AC mains supply voltage	120 V; ±10 %
P_{in}	input power	18.3 W at nominal V_{mains} = 120 V
P_{out}	output power	15.8 W
V_{LED}	output voltage (LED voltage)	25 V to 40 V with nominal V_{LED} = 35 V
I_{LED}	output current (LED current)	465 mA
I_{ripple}	output ripple current	140 mA (p-p)
$\Delta I_{LED}/\Delta V_{mains}$	line regulation	±4.8 % I_{LED} at ±10 % V_{mains} variation
$\Delta I_{LED}/\Delta V_{LED}$	load regulation	±1.6 % I_{LED} at ±10 % V_{LED} variation
η	efficiency	88 %
PF	power factor	0.98
THD	total harmonic distortion	17 %
f_{sw}	switching frequency	65 kHz

11.1 Transformer specification

An EPT18 core is used.

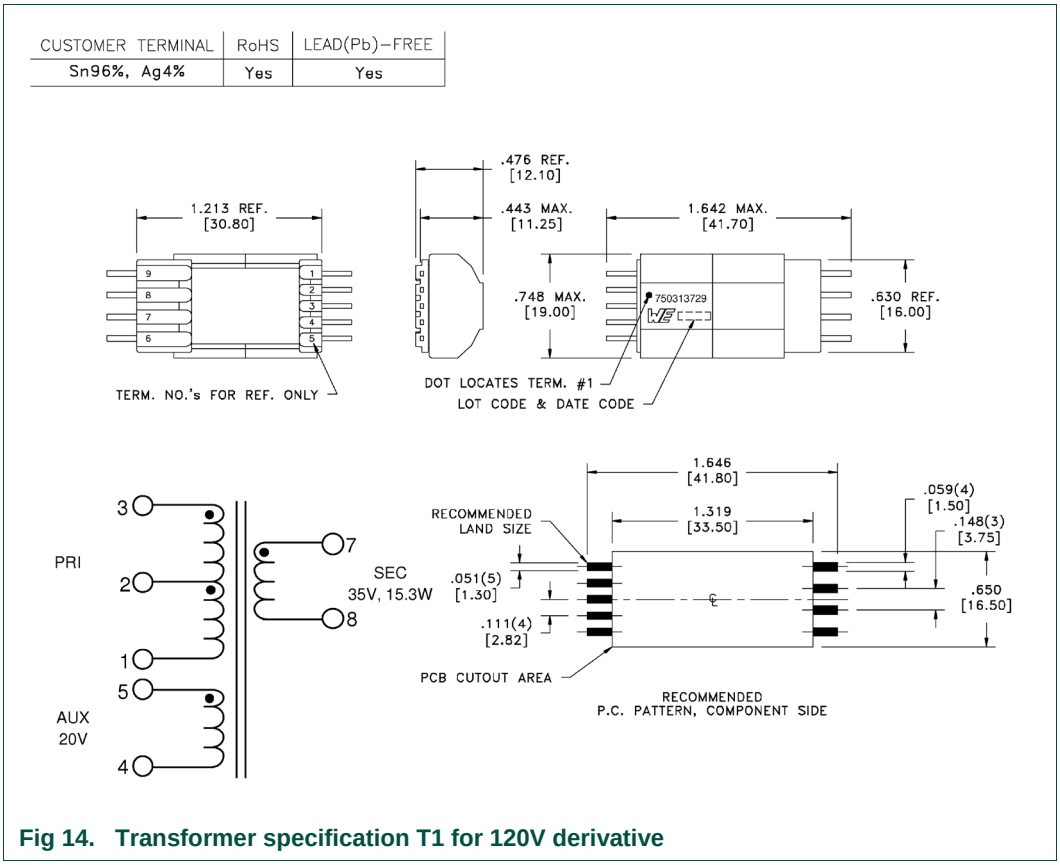


Fig 14. Transformer specification T1 for 120V derivative

Table 8. Electrical specification

All values are specified at 25 °C unless otherwise specified. All values without tolerance are typical values. Reinforced insulation for a primary circuit at a working voltage of 120 V (RMS)

Parameter	Value	Comment
DCR (3-1)	780 mΩ; ±10 %	
DCR (5-4)	200 mΩ; ±10 %	
DCR (7-8)	138 mΩ; ±10 %	
primary Inductance (3-1)	865 µH; ±10 %	100 mV; 10 kHz
leakage Inductance (3-1)	maximum 7 µH	100 mV; 100 kHz Short 5-4 and 7-8
primary saturation current	960 mA	
turns ratio (3-1):(7-8)	3:1; ±1 %	
turns ratio (3-1):(5-4)	4.5:1; ±1 %	

12. Schematic diagram

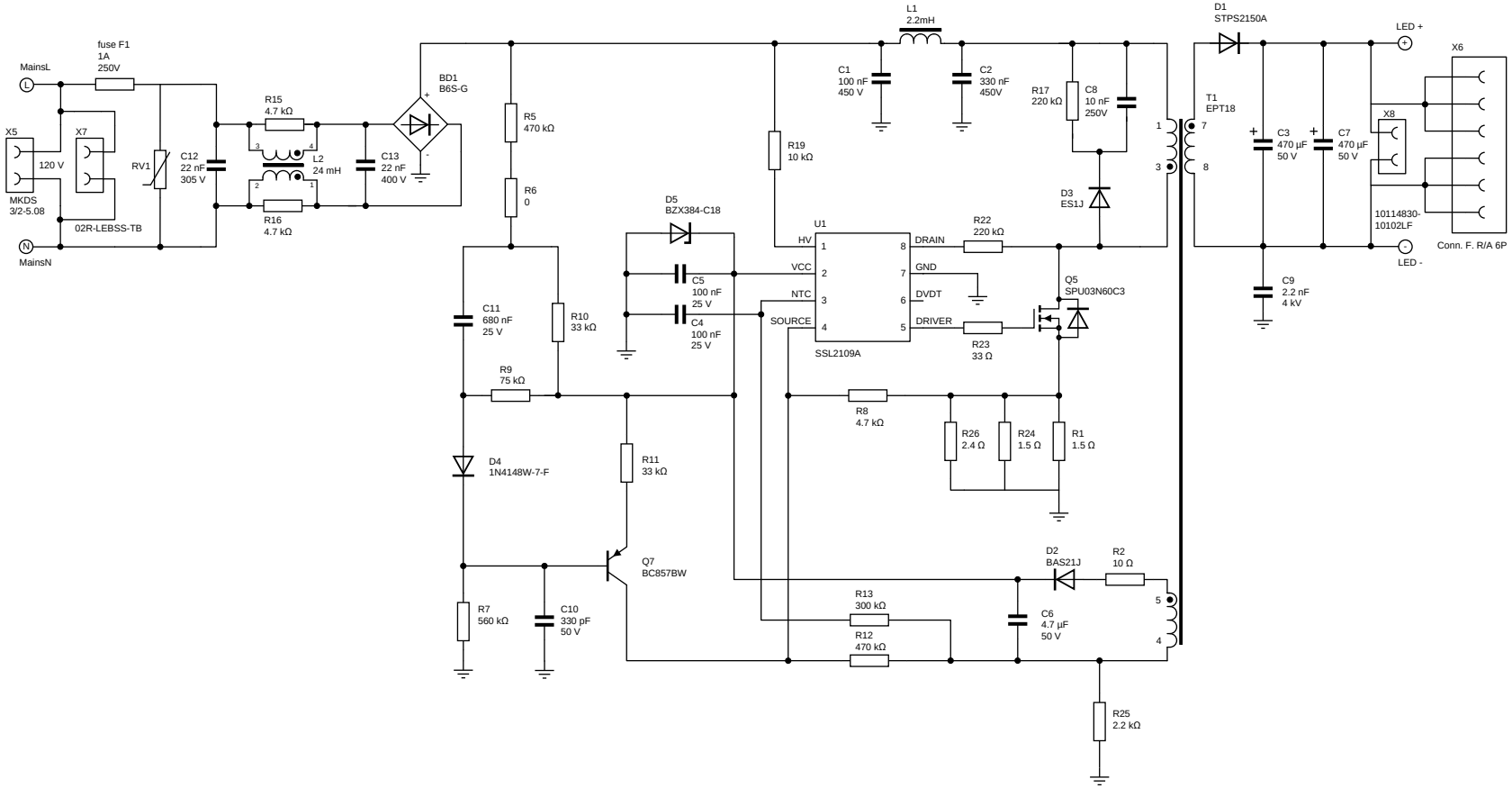


Fig 15. Schematic of 120 V/18 W T8 LED derivative board having PF > 0.9 and η > 85 %

13. Legal information

13.1 Definitions

Draft — The document is a draft version only. The content is still under internal review and subject to formal approval, which may result in modifications or additions. NXP Semiconductors does not give any representations or warranties as to the accuracy or completeness of information included herein and shall have no liability for the consequences of use of such information.

13.2 Disclaimers

Limited warranty and liability — Information in this document is believed to be accurate and reliable. However, NXP Semiconductors does not give any representations or warranties, expressed or implied, as to the accuracy or completeness of such information and shall have no liability for the consequences of use of such information.

In no event shall NXP Semiconductors be liable for any indirect, incidental, punitive, special or consequential damages (including - without limitation - lost profits, lost savings, business interruption, costs related to the removal or replacement of any products or rework charges) whether or not such damages are based on tort (including negligence), warranty, breach of contract or any other legal theory.

Notwithstanding any damages that customer might incur for any reason whatsoever, NXP Semiconductors' aggregate and cumulative liability towards customer for the products described herein shall be limited in accordance with the Terms and conditions of commercial sale of NXP Semiconductors.

Right to make changes — NXP Semiconductors reserves the right to make changes to information published in this document, including without limitation specifications and product descriptions, at any time and without notice. This document supersedes and replaces all information supplied prior to the publication hereof.

Suitability for use — NXP Semiconductors products are not designed, authorized or warranted to be suitable for use in medical, military, aircraft, space or life support equipment, nor in applications where failure or malfunction of a NXP Semiconductors product can reasonably be expected to result in personal injury, death or severe property or environmental damage. NXP Semiconductors accepts no liability for inclusion and/or use of NXP Semiconductors products in such equipment or applications and therefore such inclusion and/or use is at the customer's own risk.

Applications — Applications that are described herein for any of these products are for illustrative purposes only. NXP Semiconductors makes no representation or warranty that such applications will be suitable for the specified use without further testing or modification.

NXP Semiconductors does not accept any liability related to any default, damage, costs or problem which is based on a weakness or default in the customer application/use or the application/use of customer's third party customer(s) (hereinafter both referred to as "Application"). It is customer's sole responsibility to check whether the NXP Semiconductors product is suitable and fit for the Application planned. Customer has to do all necessary testing for the Application in order to avoid a default of the Application and the product. NXP Semiconductors does not accept any liability in this respect.

Export control — This document as well as the item(s) described herein may be subject to export control regulations. Export might require a prior authorization from national authorities.

Evaluation products — This product is provided on an "as is" and "with all faults" basis for evaluation purposes only. NXP Semiconductors, its affiliates and their suppliers expressly disclaim all warranties, whether express, implied or statutory, including but not limited to the implied warranties of non-infringement, merchantability and fitness for a particular purpose. The entire risk as to the quality, or arising out of the use or performance, of this product remains with customer.

In no event shall NXP Semiconductors, its affiliates or their suppliers be liable to customer for any special, indirect, consequential, punitive or incidental damages (including without limitation damages for loss of business, business interruption, loss of use, loss of data or information, and the like) arising out the use of or inability to use the product, whether or not based on tort (including negligence), strict liability, breach of contract, breach of warranty or any other theory, even if advised of the possibility of such damages.

Notwithstanding any damages that customer might incur for any reason whatsoever (including without limitation, all damages referenced above and all direct or general damages), the entire liability of NXP Semiconductors, its affiliates and their suppliers and customer's exclusive remedy for all of the foregoing shall be limited to actual damages incurred by customer based on reasonable reliance up to the greater of the amount actually paid by customer for the product or five dollars (US$5.00). The foregoing limitations, exclusions and disclaimers shall apply to the maximum extent permitted by applicable law, even if any remedy fails of its essential purpose.

Safety of high-voltage evaluation products — 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 that is qualified according to local requirements and labor laws to work with non-insulated mains voltages and high-voltage circuits.

The product does not comply with IEC 60950 based national or regional safety standards. NXP Semiconductors does not accept any liability for damages incurred due to inappropriate use of this product or related to non-insulated high voltages. Any use of this product is at customer's own risk and liability. The customer shall fully indemnify and hold harmless NXP Semiconductors from any liability, damages and claims resulting from the use of the product.

Translations — A non-English (translated) version of a document is for reference only. The English version shall prevail in case of any discrepancy between the translated and English versions.

13.3 Trademarks

Notice: All referenced brands, product names, service names and trademarks are property of their respective owners.

14. Contents

For more information, please visit: http://www.nxp.com
For sales office addresses, please send an email to: salesaddresses@nxp.com

Date of release: 9 April 2013
Document identifier: UM10695