

UM10710

UBA20270DB1122 - 35 W/46 V/690 mA LED driver demo board

Rev. 2 — 25 September 2013

User manual

Document information

Info	Content
Keywords	UBA20270DB1122, demo board, LED, non-dimmable, PFC
Abstract	The UBA20270DB1122 is a non-dimmable 230 V mains 35 W LED driver demo board. It uses a passive PFC topology driving a 46 V/690 mA LED string. Key features: 35 W, isolated, low ripple, small output Electrolytic capacitors



Revision history

Rev	Date	Description
v.2	20130925	new, updated issue
Modifications:		• Text and graphics updated throughout this user manual.
v.1	20130612	first issue

Contact information

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1. Introduction

WARNING

Lethal voltage and fire ignition hazard



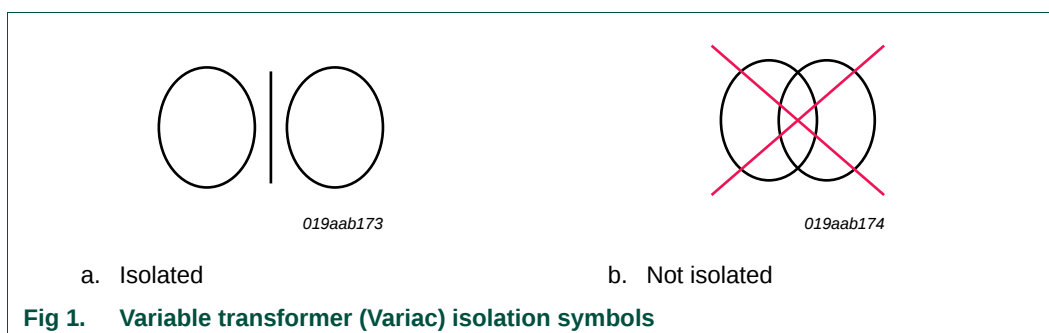
The non-insulated high voltages that are present when operating this product, constitute a risk of electric shock, personal injury, death and/or ignition of fire.

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 UBA20270DB1122 demo board is a non-dimmable LED driver using a passive Power Factor Correction (PFC) topology. This manual describes the specification and use of the UBA20270DB1122 board.

2. Safety warnings

The board must be connected to the 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.

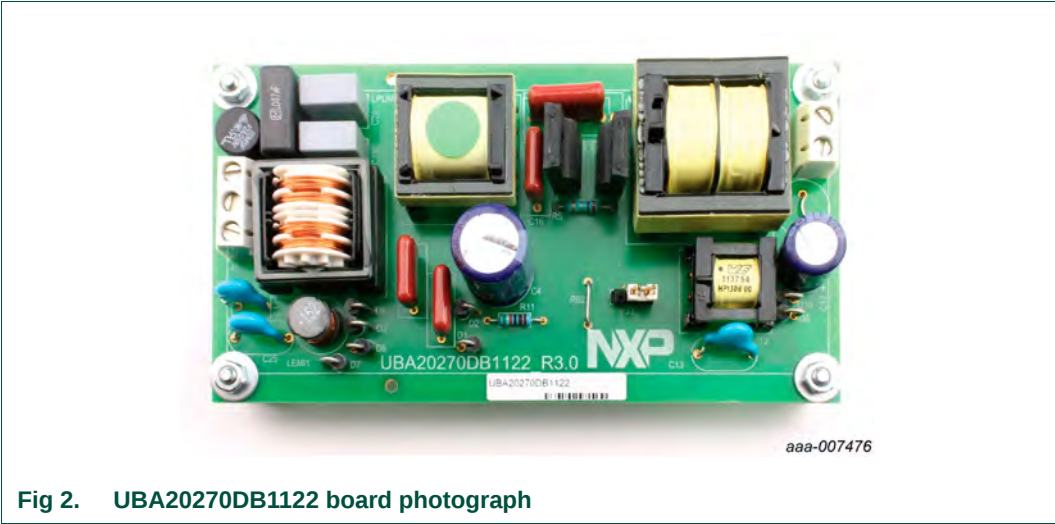


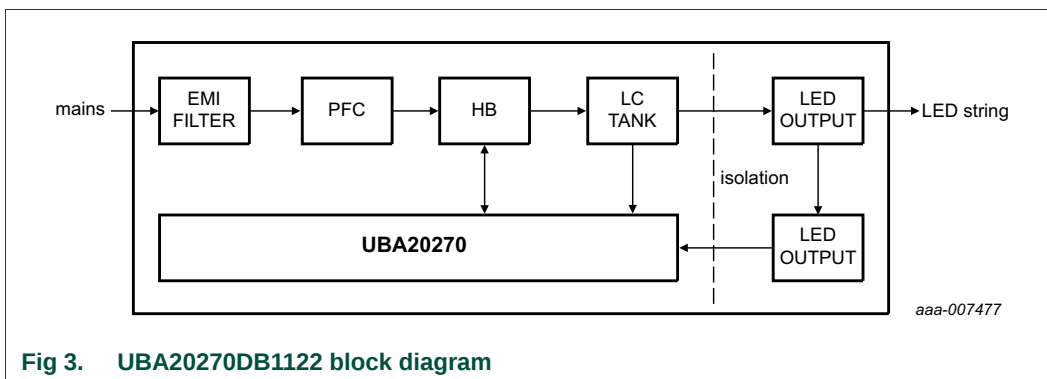
3. Specification

Table 1. Specification for the demo board

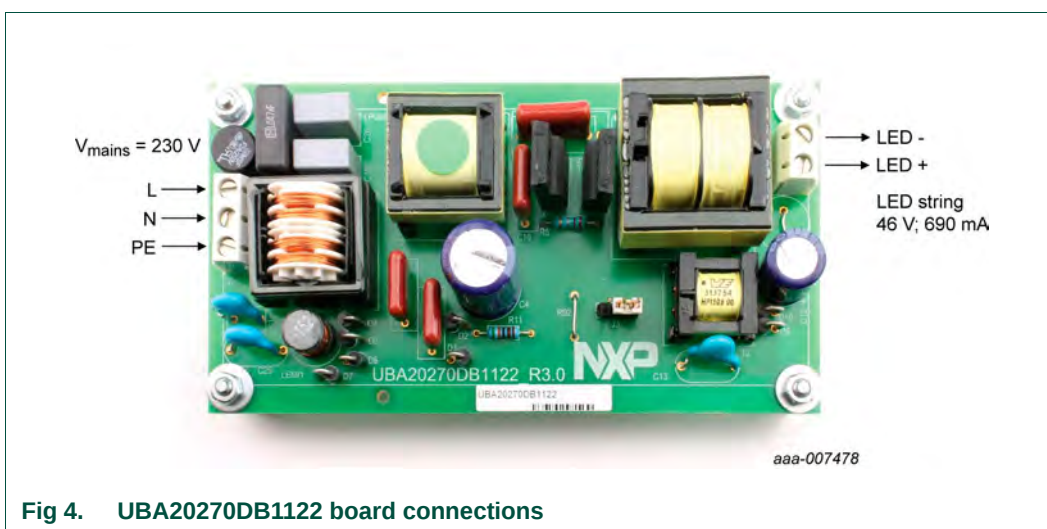
Symbol	Parameter	Values	Description
V_{mains}	mains voltage	200 V to 260 V (AC)	
I_{inrush}	inrush current	12 A	230 V (AC)
$t_{\text{d(on)}}$	turn-on delay time	30 ms	230 V (AC)
$P_{\text{o(max)}}$	maximum output power	50 W	
V_{o}	output voltage	40 V to 50 V (AC)	
I_{o}	output current	0.690 A	230 V (AC)
$\Delta I_{\text{o}}/\Delta V_{\text{mains}}$	line regulation	< 3 %	
$\Delta I_{\text{o}}/\Delta V_{\text{o}}$	load regulation	< 2 %	
η	efficiency	86 %	230 V (AC)
PF	power factor	0.96	230 V (AC)
THD	total harmonic distortion	22 %	230 V (AC)
P_{i}	input power	35 W	230 V (AC)
T	temperature	−20 °C to +85 °C	operating range; 230 V (AC)

4. Board photograph and block diagram





5. Board connections



6. Functional description

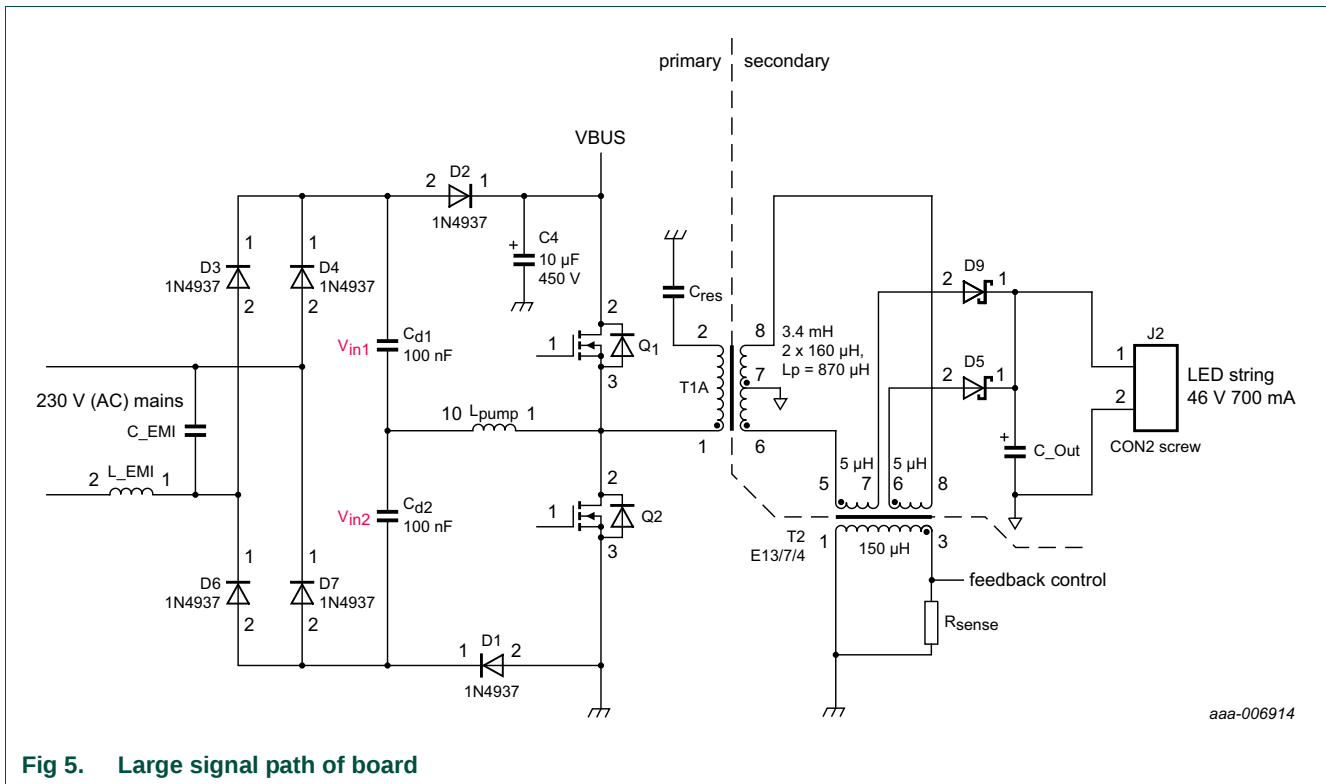
6.1 Output stage component values

The LED current can be modified easily to a desired value by changing the value of resistor R6. The board has a $\pm 20\%$ margin to deal with an LED string voltage.

If a large variation to the existing LED voltage/current values is required, then modify transformers T1 and T2.

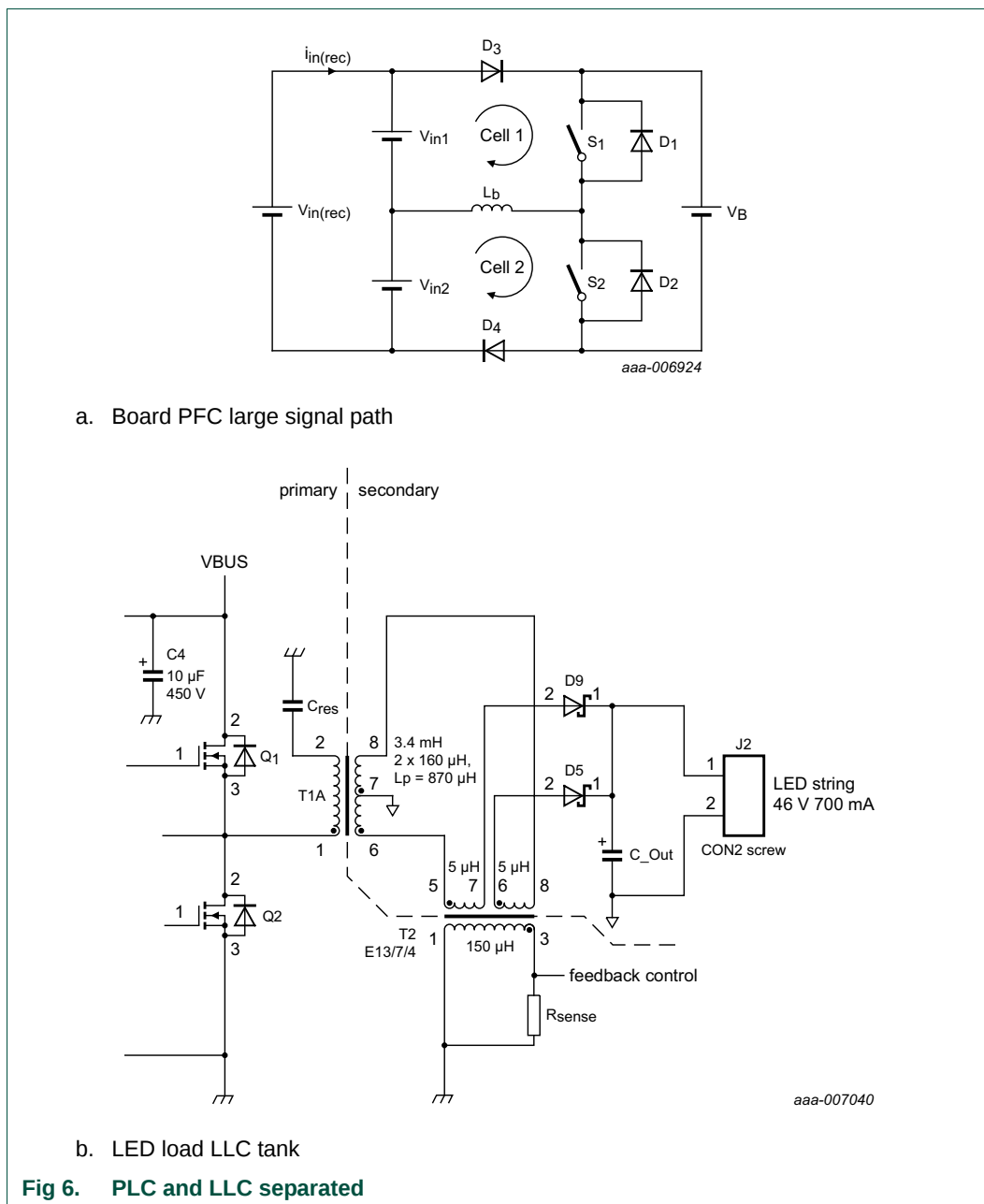
6.2 Board topology

The board operates with the passive PFC DCM topology described in detail in *Advanced High-Frequency Electronic Ballasting Techniques for Gas Discharge Lamps* by Fengfeng Tao ([Ref. 1](#)).



The voltages V_{in1} , V_{in2} are each half the value of the momentary rectified mains input voltage.

The circuit can be seen as split into two separate circuits, one circuit that acts as PFC and one that drives the LED string. They run on the same frequency because they share the half-bridge. In a conventional two stage solution, the PFC and the load each have their own separate operating frequency.

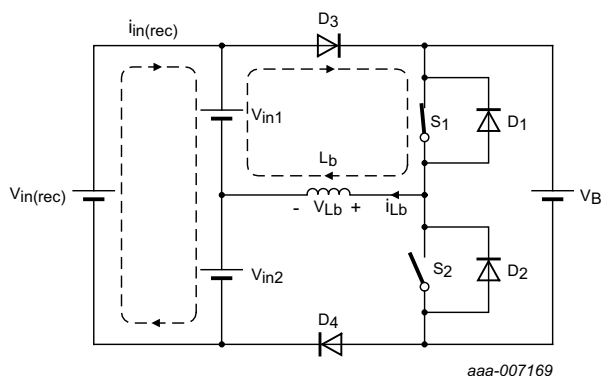


6.3 Passive PFC boost

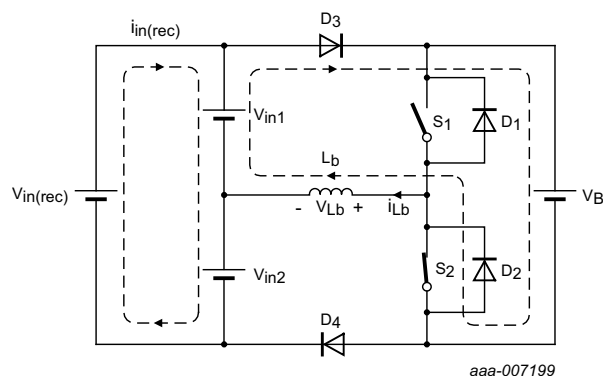
The PFC stage can be considered as two DCM boost converters operated 180° out of phase and sharing the boost inductor. For the PFC stage, there are four topological stages over one switching cycle as shown in [Figure 7](#).

- Mode 1 $[t_0, t_1]$ V_{in1} is applied to L_b and i_{Lb} linearly increases
- Mode 2 $[t_1, t_2]$ The negative voltage ($V_b - V_{in1}$) is applied to L_b and i_{Lb} linearly decreases, this mode ends when i_{Lb} reaches zero
- Mode 3 $[t_2, t_3]$ V_{in2} is applied to L_b and i_{Lb} linearly decreases

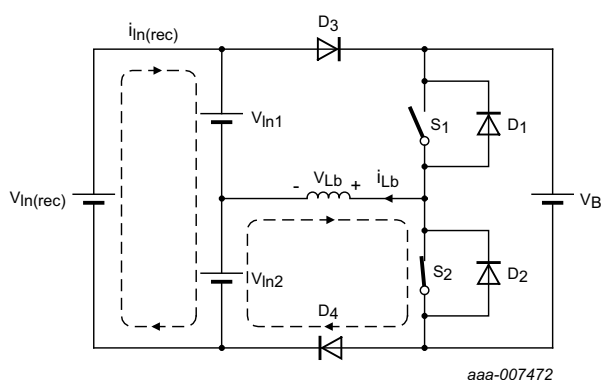
- Mode 4 [t_3, t_4] The voltage ($V_b - V_{in2}$) is applied to L_b and i_{Lb} linearly increases, this mode ends when i_{Lb} reaches zero



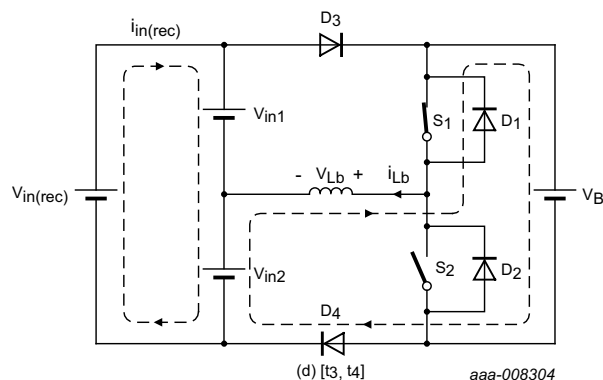
a. Mode 1: t_0, t_1



b. Mode 2: t_1, t_2



c. Mode 3: t_2, t_3



d. Mode 4: t_3, t_4

Fig 7. Topological stages of the PFC

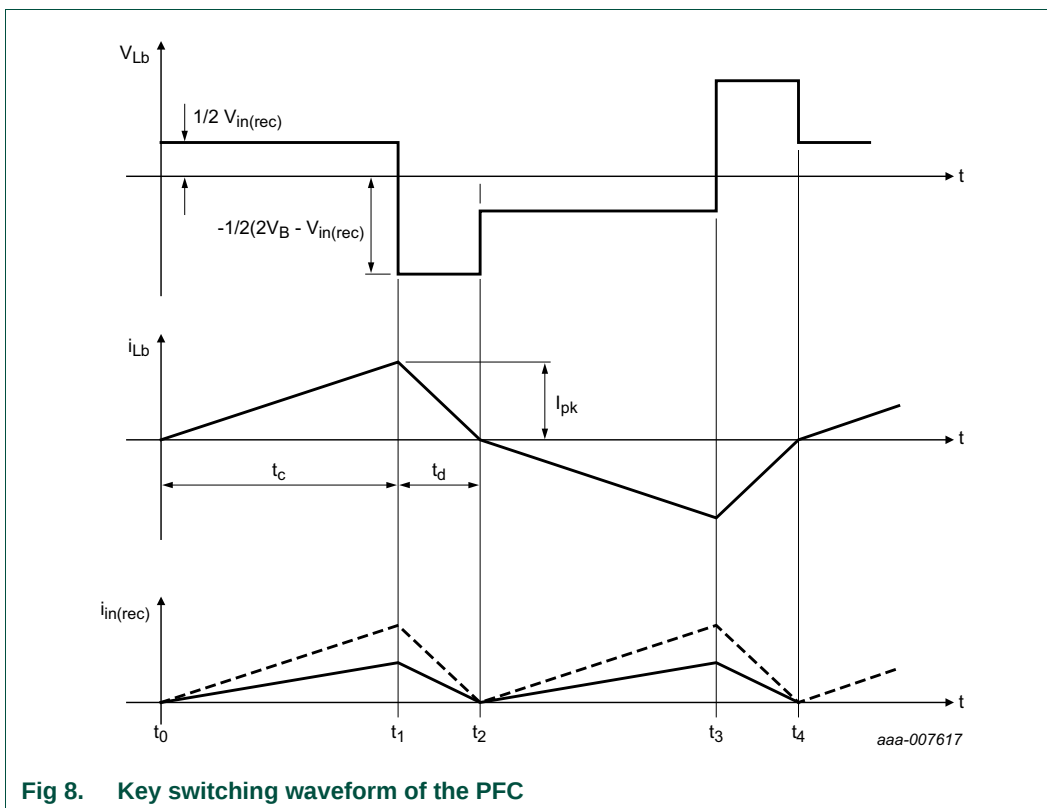


Fig 8. Key switching waveform of the PFC

The exact equations for the input power versus V_{mains} , V_b , frequency and the value of L_b can be found in *Advanced High-Frequency Electronic Ballasting Techniques for Gas Discharge Lamps* by Fengfeng Tao ([Ref. 1](#)).

For 35 W input power, 230 V and 45 kHz the inductor must have a value of 1.2 mH as on the board. If a higher power is required, the inductor must be lowered in value. If less power is given to the LED load, the inductor value must be increased.

In the passive PFC topology, the bus voltage and frequency stabilize at a point where the input power equals the output power + losses. Changing the pump inductor value for $\pm 20\%$ of the nominal power is not required. The UBA20270 feedback control system can increase or decrease the operating frequency to compensate for the different load.

6.4 LLC resonant tank

The LED string is driven with a so called LLC half-bridge resonant tank topology.

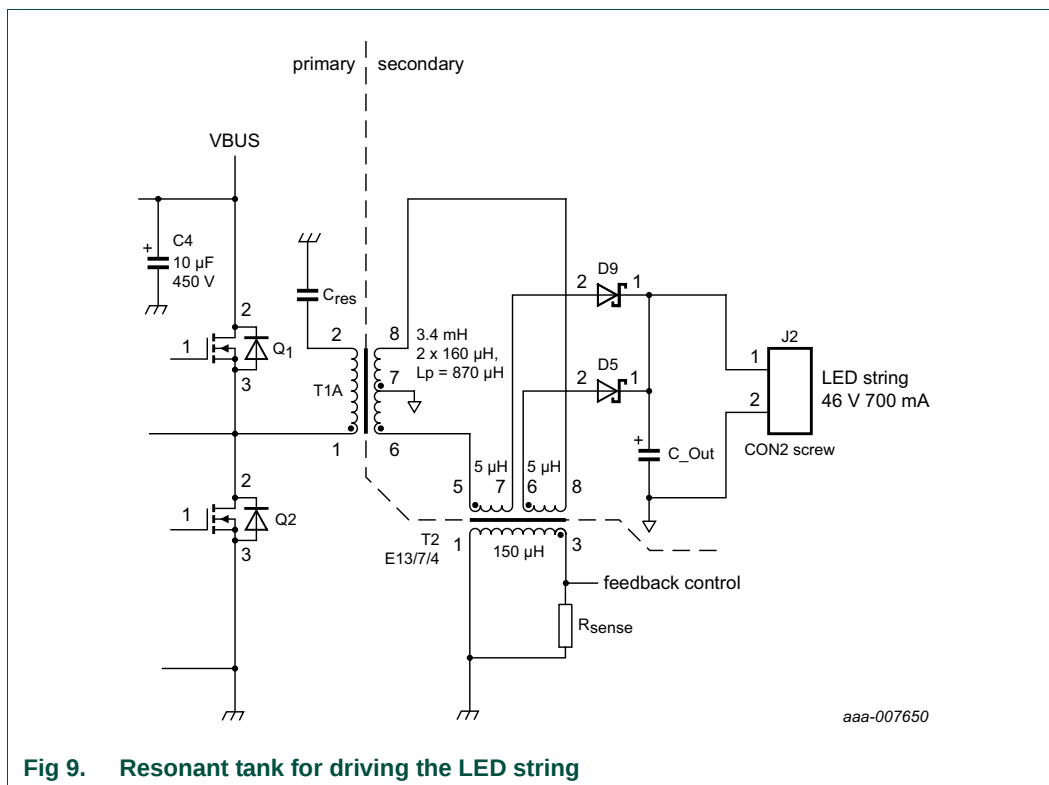


Fig 9. Resonant tank for driving the LED string

The resonant tank consists of transformer T1 and capacitor C2. More primary current flowing through T1 means more secondary (LED) current is flowing. The resonant tank current depends on the bus voltage and the frequency. Transformer T1 has a relatively large leakage inductance dominating the current.

What is unique in this design compared to other LED drivers is the feedback control. Instead of a secondary circuit with operational amplifiers and an optocoupler, a current transformer (T2) is used to generate a feedback signal of the actual LED current. Using resistor R6, the LED current is transformed into a voltage for the current sense input (CSI) of the UBA20270.

The equations for the LED current versus bus voltage, transformer leakage inductance and transfer ratio, frequency and resonant capacitor value can be found in *Multi-Channel Constant Current (MC³) LED Driver for Indoor LED Luminaries* by Haoran Wu ([Ref. 2](#)).

6.5 Protection circuits

The UBA20270 IC has two inputs that can be used for protection. One is pulling down the CP pin causing a latched standby. The other option is pulling down the DCI pin causing a reset.

There are two protection circuits on the board:

- LED overvoltage protection
- Bus (electrolytic capacitor) overvoltage protection

With the board component values as mounted, the bus overvoltage protection is triggered if the input mains is too high (> 270 V). It resets the UBA20270. The protection is also triggered if an LED output short circuit event occurs, because the pumped up input power is far higher than the used output power then. If an overvoltage situation occurs, the board continuously resets.

If going to standby in this overvoltage situation is required, the CP pin can be pulled low instead of the DCI pin. The LED overvoltage can also be configured via jumper 3 to cause a reset rather than a latched standby. For this purpose, the board contains diode D21 and resistor R21. Otherwise every restart slightly increases the output level damaging the diodes or the electrolytic capacitor in the output circuit.

For LED output short circuit protection, mount diodes D19 and D20. The diodes avoid a voltage spike on the CSI pin of the UBA20270 at start-up which is too high.

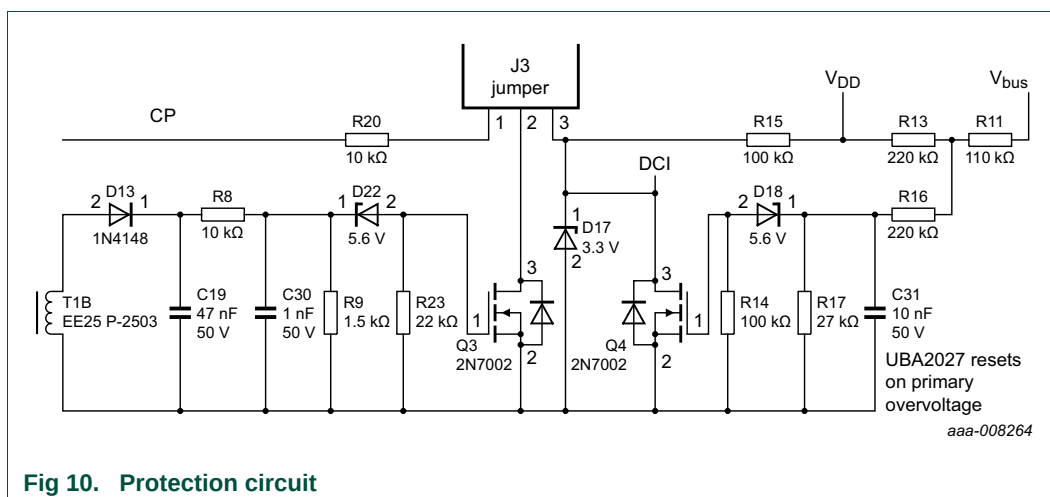
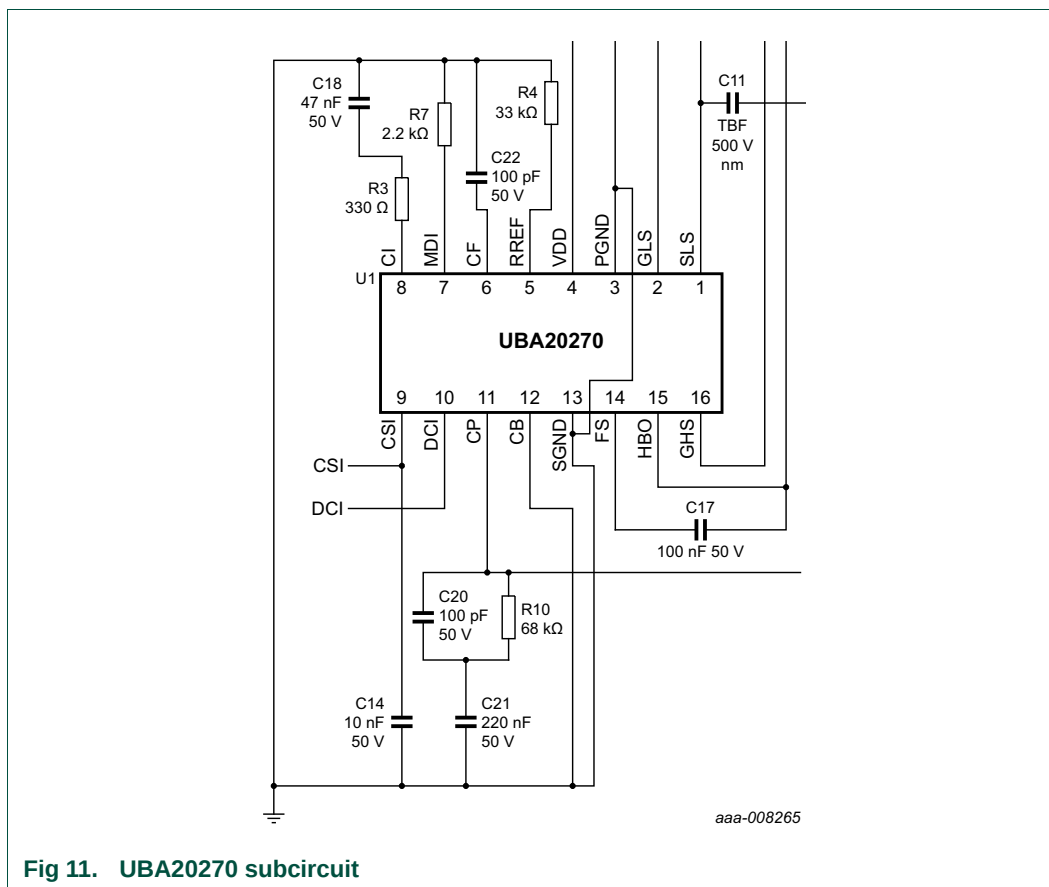


Fig 10. Protection circuit

6.6 UBA20270 circuit

The low-voltage V_{DD} of the UBA20270 is generated with a charge pump via capacitor C5 and diode D15 requiring the half-bridge output to run. The V_{DD} supply starts up using resistors R11 and R13.

The UBA20270 is designed as a CFL controller IC. Therefore it has a preheat timer. This preheat time is shortened to just a few ms using the R10/C20 circuit. For more information, see the *UBA20270 data sheet* ([Ref. 3](#)).



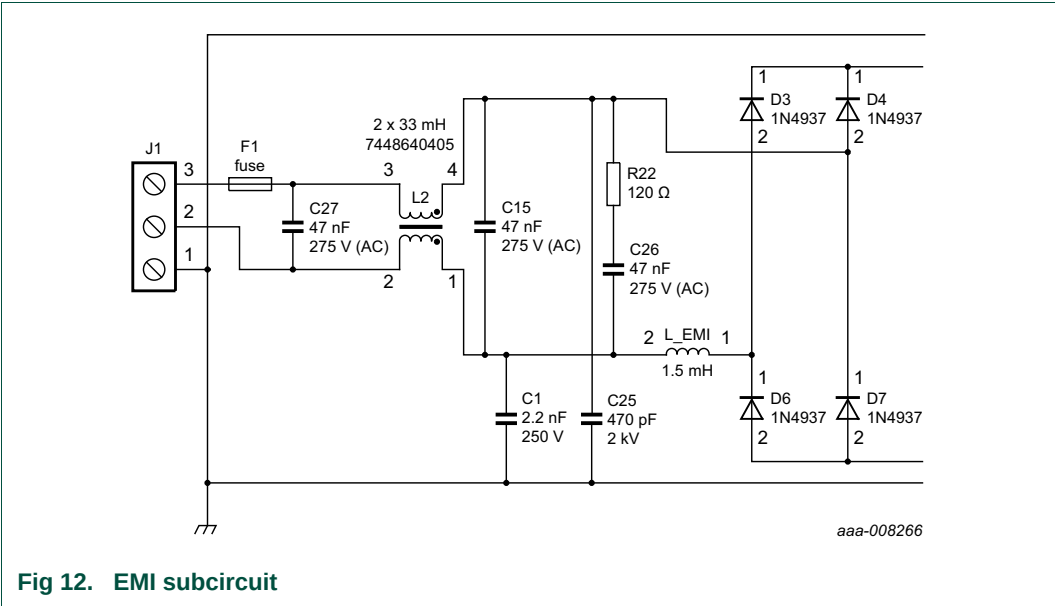
6.7 ElectroMagnetic Interference (EMI) filter

6.7.1 EMI circuit

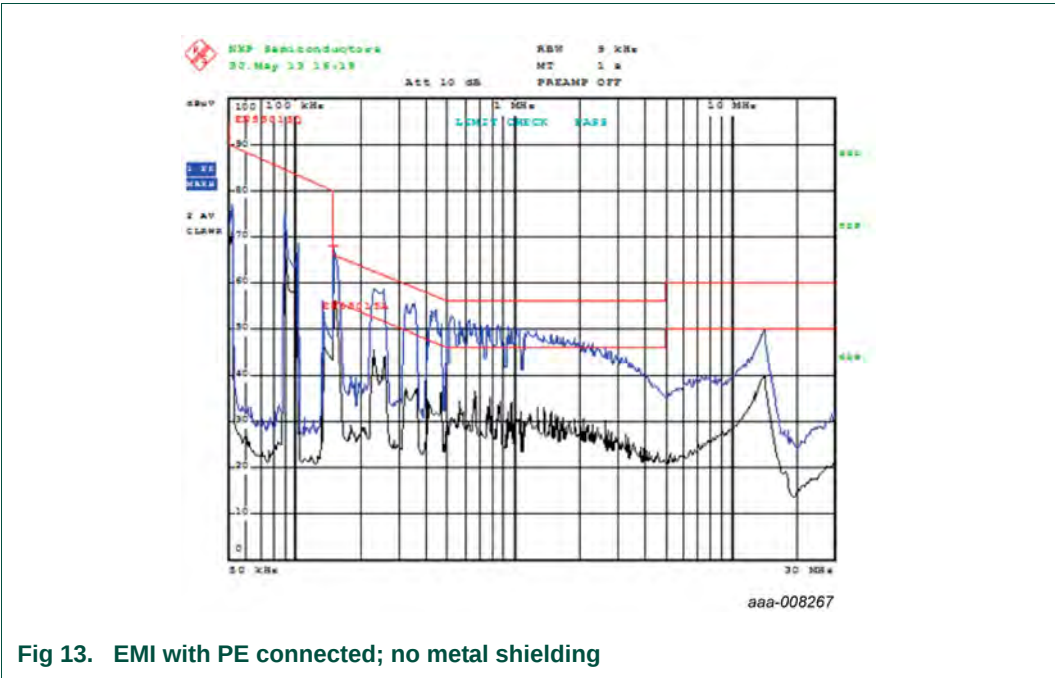
The ground of the bridge rectifier is not the ground of the circuit. A common-mode filter with more suppression is required for this passive PFC circuit compared to a conventional active PFC + half-bridge circuit. The combination of resistor R22 and capacitor C26 is used to dissipate some of the differential EMI noise that passes L_EMI.

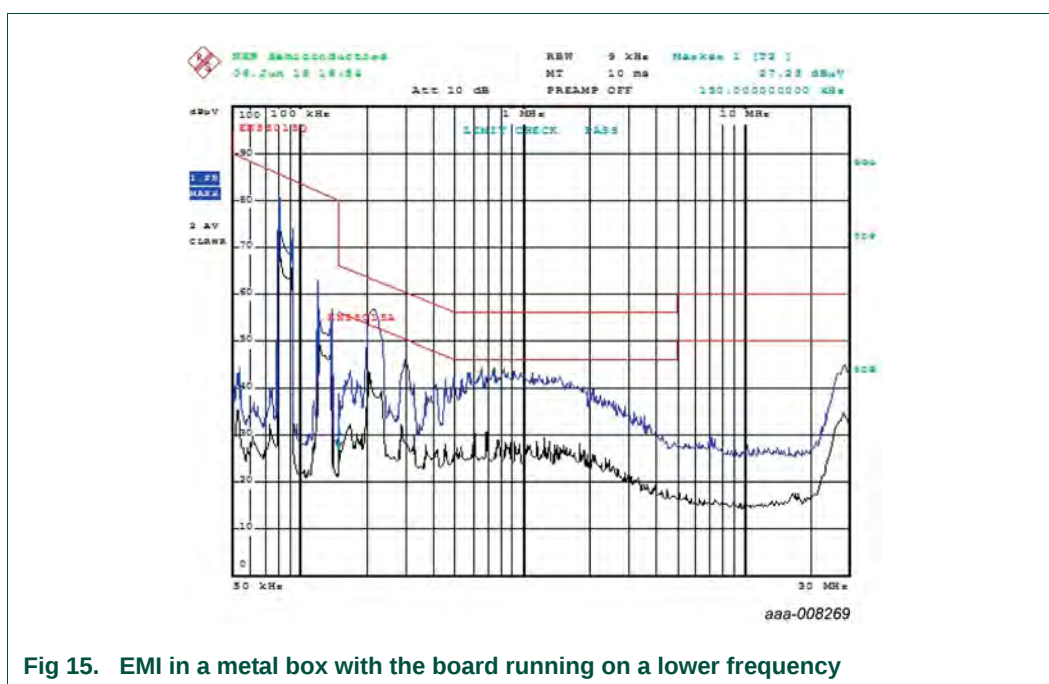
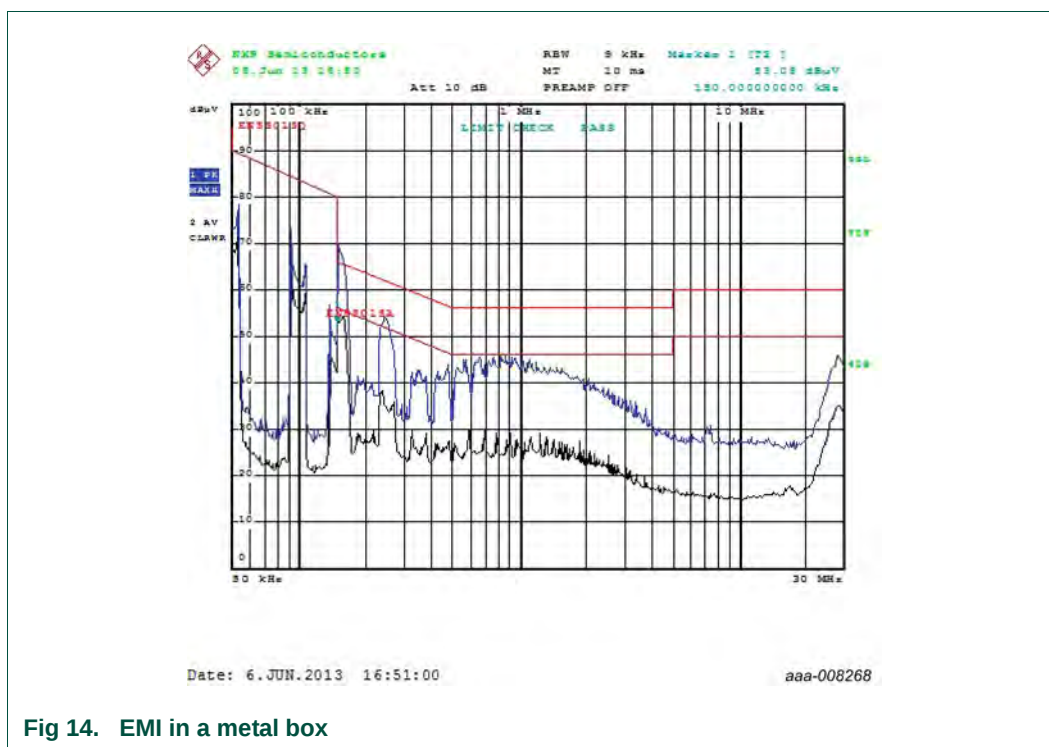
L2 suppresses the common-mode noise using capacitors C1 and C25.

The board requires either the protective earth to be connected, to be used on top of a conducting plate or inside a metal box. One of the corners has a track that ensures easy connection to such a metal plate at 1 cm to 3 cm from the PCB.



6.7.2 Conducted EMI results





As can be seen in the EMI plot, the third harmonic of the operating frequency is crossing the limit line. For this purpose, the operating frequency must be lowered.

Small capacitors over diodes D1 and D2 at the input stage avoid ringing of inductor LBoost which causes EMI. A small resistor/capacitor combination over the output Schottky diodes D8 and D10 stops ringing in the LLC secondary stage.

6.8 Mains harmonic distortion

The board is compliant to Class C. However, it must be made to operate at 35 kHz to 45 kHz instead of 45 kHz to 55 kHz as it is now (see [Section 11](#)).

Table 2. Harmonic distortion at 35 kHz to 45 kHz

Harmonic distortion (%)	Class C limit (%)	Measured value (%)
3	$30 * \lambda = 28.8$	19.9
5	10	7.6
7	7	4.5
9	5	3.7
11	3	2.7
13	3	2.7
15 to 39	< 3	< 2.3

The 11/13 harmonics are marginal. They can be further improved by reducing the capacitance in the EMI filter.

6.9 Measuring on the board

Use fully mains isolated measurement equipment (battery operated or differential mode) when evaluating/modifying the board. The ground connection of a normal oscilloscope to the ground connection of the UBA20270 circuit adds a charge pump to the circuit modifying its properties. The addition of a charge pump is related to the Y-cap (1 nF to 2.2 nF) present in every oscilloscope.

7. Schematic

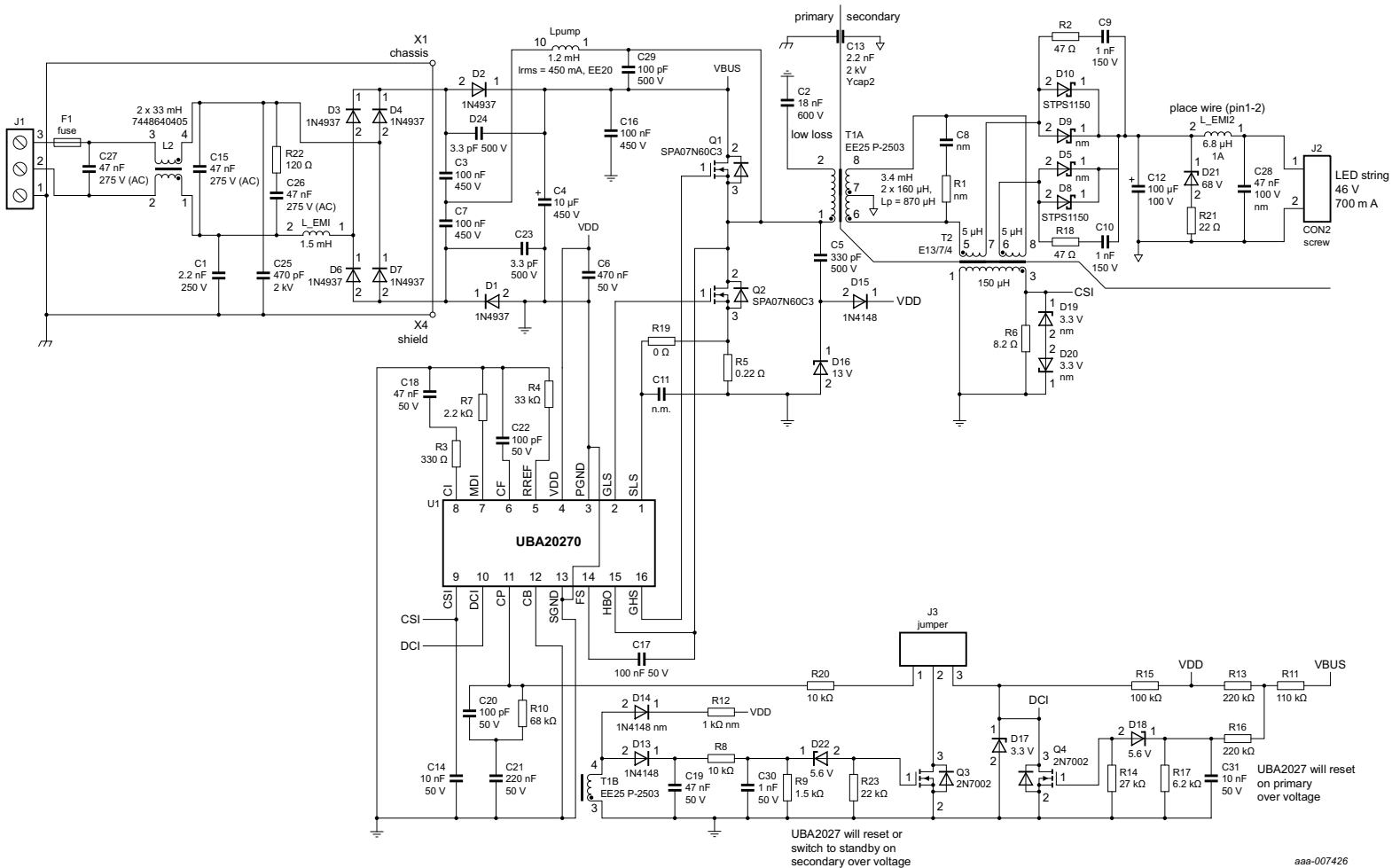


Fig 16. UBA20270DB1122 schematic diagram

8. Bill Of Material (BOM)

Table 3. Bill of material

Reference	Description and values	Part number	Manufacturer
C1; C13	capacitor; 2.2 nF; 20 %; 250 V; X1/Y2	DE2E3KY222MA3BM02	Murata
C2	capacitor; 18 nF; 10 %; 600 V	B32672L1183K	EPCOS
C3; C7; C16	capacitor; 100 nF; 5 %; 450 V	ECWF2W104JAQ	Panasonic
C4	capacitor; 10 µF; 10 %; 450 V	ECA2WM100	Panasonic
C5	capacitor; 330 pF; 10 %; 630 V; 1206; X7R	MCCA000760	Multicomp
C6	capacitor; 470 nF; 10 %; 50 V; 1206; X7R	ESD55C474K4T2A-26	AVX
C8	capacitor; not mounted	-	-
C9; C10	capacitor; 1 nF; 10 %; 200 V; 0603; X7R	06032C102KAT2A	AVX
C12	capacitor; 100 µF; 100 V; 10 %	ECA-2AM101	Panasonic
C14	capacitor; 10 nF; 10 %; 16 V; 0603; X7R	MC0603B103M160CT	Multicomp
C15; C26	capacitor; 47 nF; 10 %; 275 V	BFC233820473	Vishay
C17	capacitor; 100 nF; +80 %/-20 %; 50 V; 0603; Y5V	MC0603F104Z500CT	Multicomp
C18	capacitor; 22 nF; 10 %; 25 V; 0603; X7R	MCCA000169	Multicomp
C19	capacitor; 47 nF; 10 %; 50 V; 0603; X7R	MC0603B473K500CT	Multicomp
C20; C22	capacitor; 100 pF; 5 %; 50 V; 0603; NP0	MCCA000204	Multicomp
C21	capacitor; 47 nF; 10 %; 25 V; 0603; X7R	06033C473JAT2A	AVX
C23; C24	capacitor; 3.3 pF; 10 %; 500 V; 0805; C0G	MC0805N3R3C501CT	Multicomp
C25	capacitor; 470 pF; 10 %; 2 kV	DEHR33D471KA3B	Murata
C27	capacitor; 47 nF; 20 %; 275 V (AC)	ECQ-U2A473ML	Panasonic
C30	capacitor; 1 nF; 20 %; 50 V; 0603	MC0603B102M500CT	Multicomp
C31	capacitor; 10 nF; 50 V	06031C103JAT2A	AVX
D1; D2; D3; D4; D6; D7	fast diode; 1 A; 600 V	1N4937G	Multicomp
D8; D10	Schottky diode; 150 V; 1 A	STPS1150	ST
D13; D15	high-speed diode; SOD-80C	PMLL4148L	NXP Semiconductors
D16	Zener diode; 0.5 W; 13 V	BZV55-C13	NXP Semiconductors
D17	Zener diode; 0.5 W; 3.3 V	PDZ3.3B,115	NXP Semiconductors
D18; D22	Zener diode; 0.5 W; 5.6 V	BZV55-C5V6	NXP Semiconductors
D21	Zener diode; 68 V; 1 W	1SMA4760	Multicomp
F1	fast fuse; 2 A	0034.6017	SCHURTER
J1	connector; mains inlet	CTB5000/3	Camdenboss
J2	connector; LED output	CTB5000/2	Camdenboss
J3	header	SL 11/190/ 20/G	Fischer Elektronik
L2	choke; common-mode; 2 × 33 mH	7448640405	Würth Elektronik
L_EMI	choke; 1.5 mH	744772152	Würth Elektronik
L _{pump}	choke; 1.2 mH	750313755	Würth Elektronik
Q1; Q2	MOSFET-N; 600 V; 7.3 A	SPA07N60C3	Infineon
Q3; Q4	MOSFET-N; 60 V; 0.19 A; SOT23	NX7002AK	NXP Semiconductors

Table 3. Bill of material ...continued

Reference	Description and values	Part number	Manufacturer
R01; R02	wire		
R1	resistor; not mounted	-	-
R2; R18	resistor; 47 Ω ; SMD	-	-
R3	resistor; 330 Ω ; SMD	-	-
R4	resistor; 33 k Ω ; SMD	-	-
R5	resistor; 0.22 Ω film; 5 %; 500 mW	1622600-1	TE Connectivity
R6	resistor; 8.2 Ω ; 1 %; 250 mW; SMD	-	-
R7	resistor; 2.2 k Ω ; SMD	-	-
R8; R20	resistor; 10 k Ω ; SMD	-	-
R9	resistor; 1.8 k Ω ; SMD	-	-
R10	resistor; 68 k Ω ; SMD	-	-
R11	resistor; 110 k Ω	-	-
R13; R16	resistor; 220 k Ω ; SMD	-	-
R14	resistor; 27 k Ω ; SMD	-	-
R15	resistor; 100 k Ω ; SMD	-	-
R17	resistor; 6.2 k Ω ; SMD	-	-
R19	resistor; 0 Ω ; SMD	-	-
R21	resistor; 22 Ω ; SMD	-	-
R22	resistor; 120 Ω ; SMD	-	-
R23	resistor; 22 k Ω ; SMD	-	-
T1	LLC transformer	750313753_01	Würth Elektronik
T2	sense transformer	750313754	Würth Elektronik
U1	IC half-bridge controller	UBA20270T	NXP Semiconductors

9. Transformer information

9.1 Integrated LLC transformer

Wurth Electronics Midcom Inc.; part number: 750313753_01.

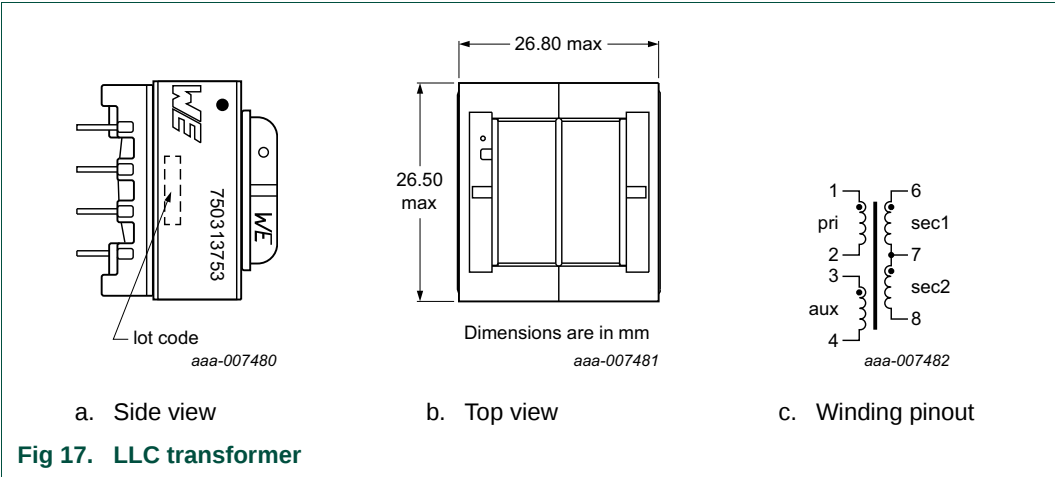


Table 4. LLC transformer electrical specifications

Symbol	Parameter	Value	Condition
L_p	inductance	3400 μ H	pins 1 to 2
I_{sat}	saturation current	1.27 A	
N	turns ratio	4.25	(1-2):(6-7) (1-2):(6-7)
		6.18	(1-2):(3-4)
L_{lk}	leakage inductance	870 μ H	tie 6 + 7 + 8
V_e	dielectric rating	1250 V (AC)	pins 1 to 8
R_{DC}	DC resistance	1590 m Ω	pins 1 to 2
		238 m Ω	pins 6 to 7 and 7 to 8
		720 m Ω	pins 3 to 4
	dielectric rating	1250 V (AC)	between primary and secondary side

9.2 Sense transformer

Würth Electronics Midcom Inc.; part number 750313754

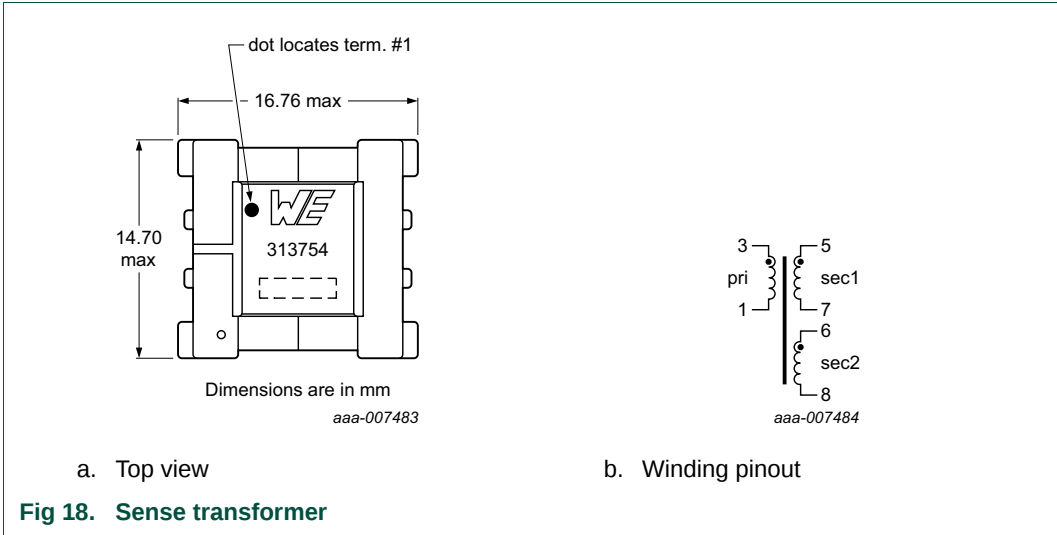


Table 5. Sense transformer electrical specifications

Symbol	Parameter	Value	Condition
L _p	inductance	150 μH	pins 1 to 3
L _{lk}	leakage inductance	< 4 μH	tie pins (5 + 6 + 7 + 8)
N	turns ratio	6.666	(1-3):(5-7); (1-3):(6-8)
R _{DC}	DC resistance	470 mΩ	pins 1 to 3
		15 mΩ	pins 5 to 7
		15 mΩ	pins 6 to 8

9.3 Pump inductor

Würth Electronics Midcom Inc.; part number 750313755

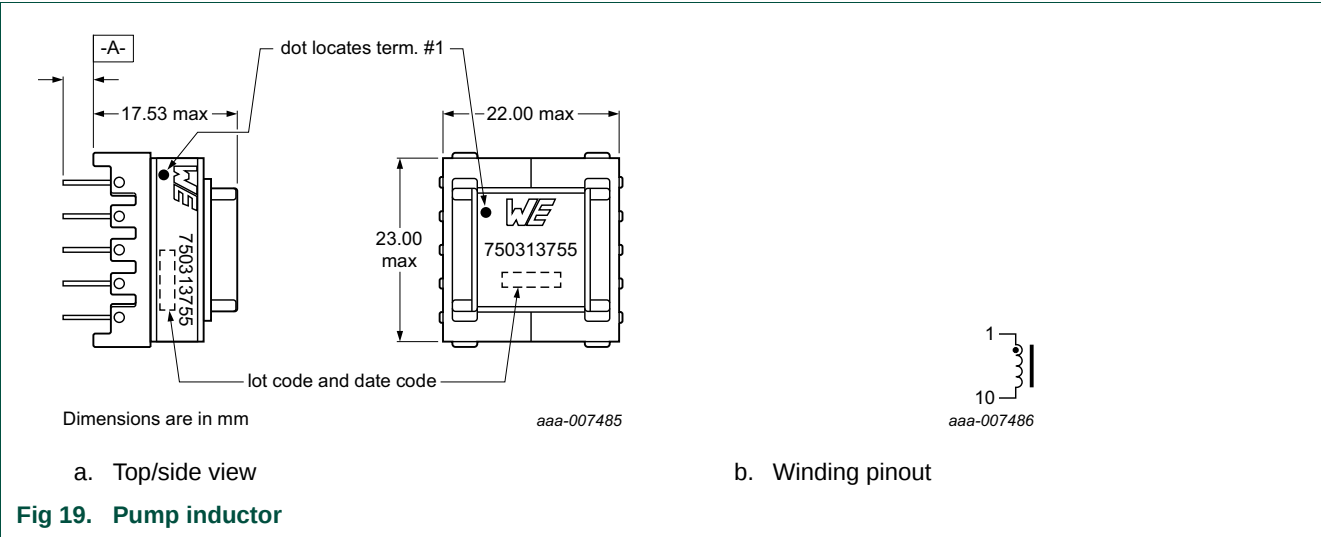


Table 6. Sense transformer electrical specifications

Symbol	Parameter	Value	Condition
L_p	inductance	1200 μ H	pins 1 to 10
I_{sat}	saturation current	1 A	
R_{DC}	DC resistance	510 m Ω	pins 1 to 10

10. PCB layout

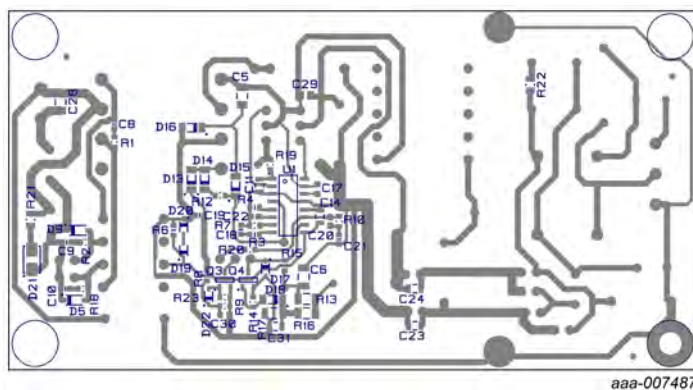


Fig 20. UBA20270DB1122 PCB layout: top side components

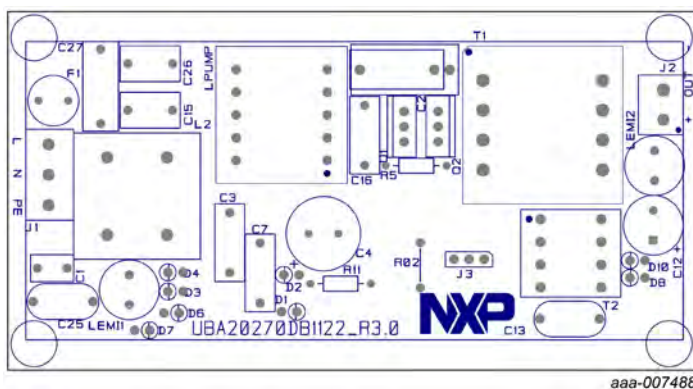


Fig 21. UBA20270DB1122 PCB layout bottom side copper and components

11. Errata

With the current PCB, it can happen that the ballast does not start at a quick on/off/on cycle. To fix this issue, connect the V_{DD} start-up resistor R13 to the anode of D2. At the same time increase resistor R11 to 220 k Ω .

The board EMI spectrum shows a peak at 150 kHz which is on the edge of the limit (depending on the exact load and mains voltage). Its 11th and 13th harmonic are also on the limit. Both problems can be solved by running the board on a lower frequency. To run the board on a lower frequency, increase the LBoost to 1.4 mH. At the same time increase capacitor C22 (CF pin UBA20270) from 100 pF to 120 pF.

12. References

- [1] **Advanced High-Frequency Electronic Ballasting Techniques for Gas Discharge Lamps** — Fengfeng Tao, 19 December 2001
- [2] **Multi-Channel Constant Current (MC3) LED Driver for Indoor LED Luminaries** — Haoran Wu, 14 November 2011
- [3] **UBA20270** — 600 V Driver IC for dimmable compact fluorescent lamps; 8 September 2011; Copyright: NXP Semiconductors

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Date of release: 25 September 2013

Document identifier: UM10710