UM10438

UBA2015AP 120 V (AC) evaluation board

Rev. 2.1 — 9 March 2012 **User manual**

Document information

Info	Content
Keywords	UBA2015AP, evaluation board, dimming, boost
Abstract	This document describes the performance, technical data and wiring of the UBA2015AP 120 V (AC) evaluation board.

Revision history

Rev	Date	Description
v.2.1	20120309	fourth issue
v.2	20111117	third issue
v.1.1	20110912	second issue
v.1	20110826	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.

This evaluation board is intended to build applications with the UBA2016A, UBA2015A and UBA2015 ballast controller family. This document describes the specification and use of the board. This ballast design is intended to drive one 35W T5 lamp with the UBA2015AP. However, several options are provided on the board to use it with the UBA2016AP and UBA2015P.

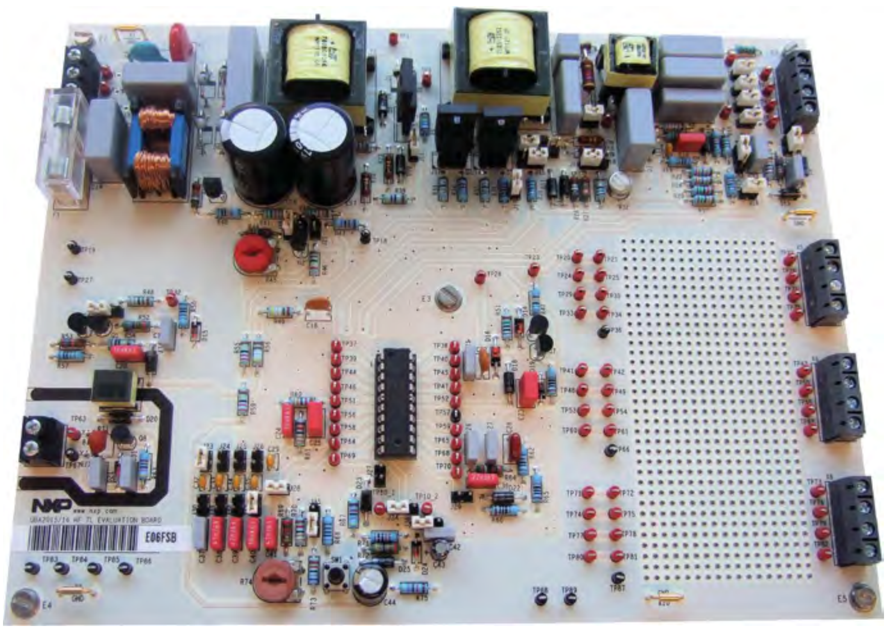

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Fig 1. Photograph of the UBA2015AP evaluation board

2. Safety warning

This evaluation board is connected to a high AC voltage (up to 200 V). Avoid touching the reference board during operation. An isolated housing is mandatory when used in uncontrolled, non-laboratory environments. Galvanic isolation of the mains phase using a fixed or variable transformer (Variac) is always recommended. The symbols shown in Figure 2 indicate these devices.

a. Isolated

b. Not isolated

Fig 2. Variac isolation symbols

3. Specification

Table 1. Specifications for the evaluation board

Parameter	Description
Ballast type	electronic
Starting method	programmed start with preheat
Lamp terminals	4
Line voltage	100 V to 140 V
Line frequency	50 Hz or 60 Hz
Number of lamps	1
Dimming interface	1 V to 10 V
Transient protection	IEC61547

Table 2. Supported lamps

Lamp type	Description
T5 35W	35 W T5 high-efficiency fluorescent lamp

Table 3. Ballast performance

Lamp type	Lamps	P_o (W)	Maximum THD	Maximum lamp current crest factor	Power factor	Nominal lamp current (A)	Minimum lamp current (mA)
T5 35W	1	35	10 %	1.7	>0.95	0.170	5

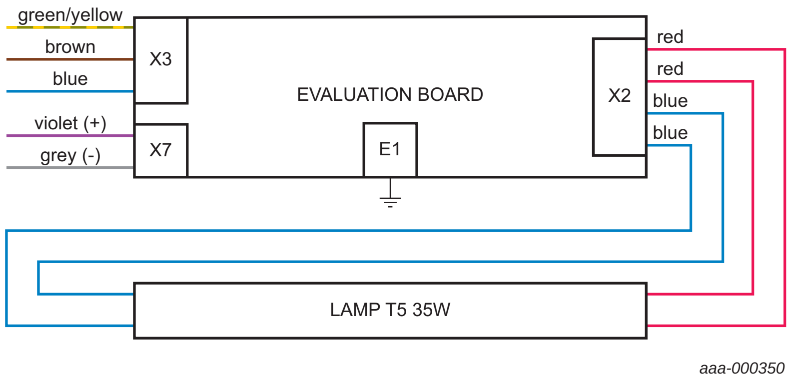


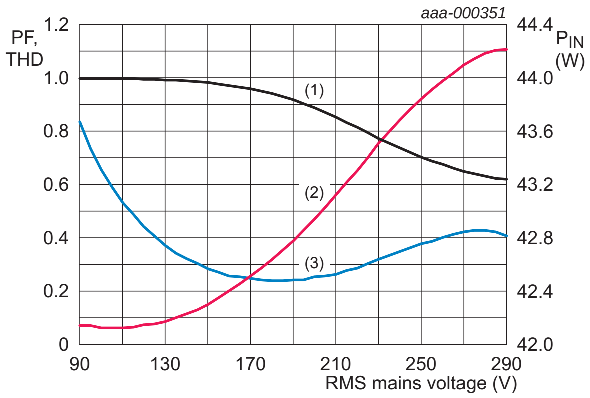
Fig 3. Wiring diagram

Remark: The chassis (if any) must connect to the earth which is available on mounting hole E1.

Remark: Before powering up the board, check if the three MOSFETs are correctly mounted. During transport, the MOSFETs can become detached.

4. Performance data

4.1 Power factor, THD and input power



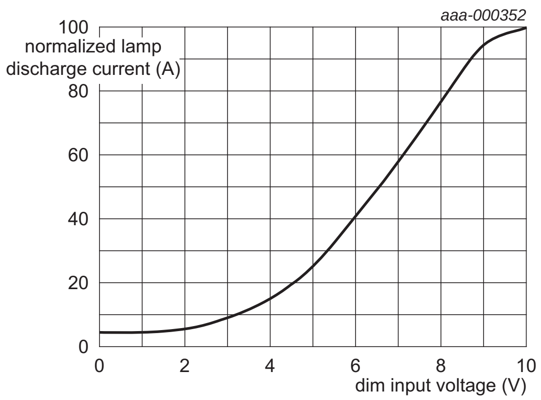
(1) PF.

(2) Current THD.

(3) input power.

Fig 4. Power factor, THD and input power as function of the mains input voltage

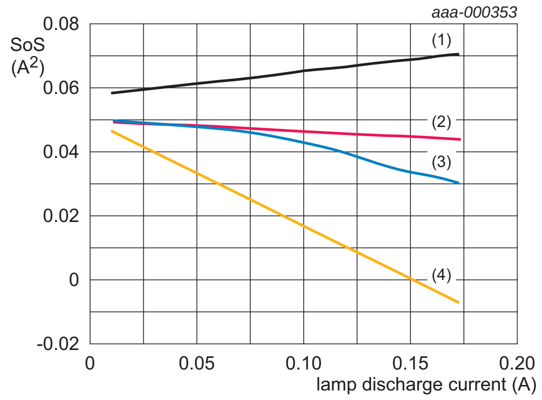
4.2 Dimming curve



(1) Measured with an AC coupled current probe

Fig 5. Normalized lamp discharge current as function of the DIM input voltage

4.3 Sum of Squares (SoS) curve



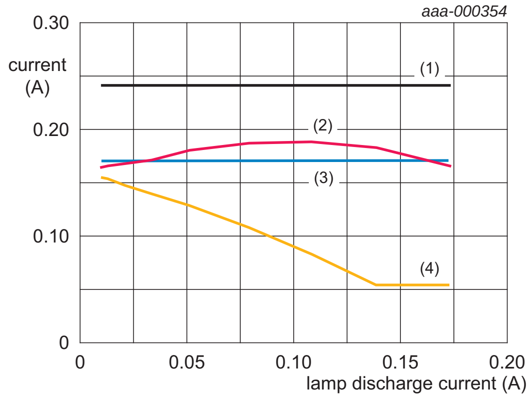
(1) SoS (maximum).

(2) SoS target.

(3) SoS measured.

(4) SoS (minimum).

a. SoS results



(1) I_{LH} (maximum).

(2) I_{L1} measured.

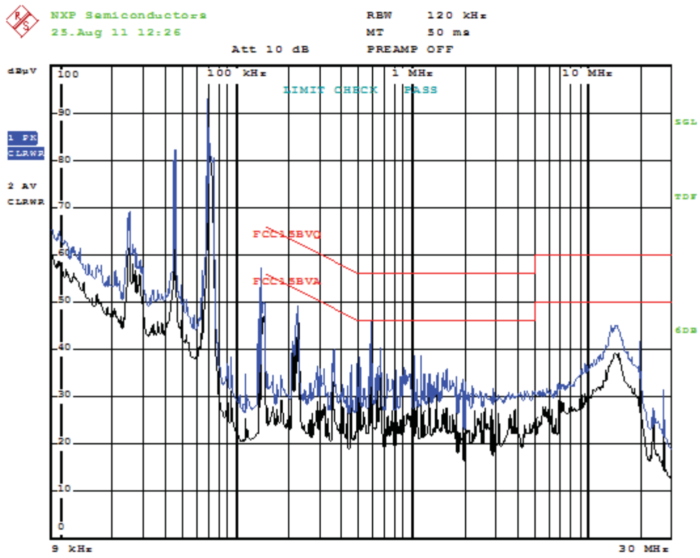
(3) I_{LL} (maximum).

(4) I_{L2} measured.

b. Maximum lead current check

Fig 6. Sum of Squares and maximum lead current check

4.4 ElectroMagnetic Interference (EMI) emission tests



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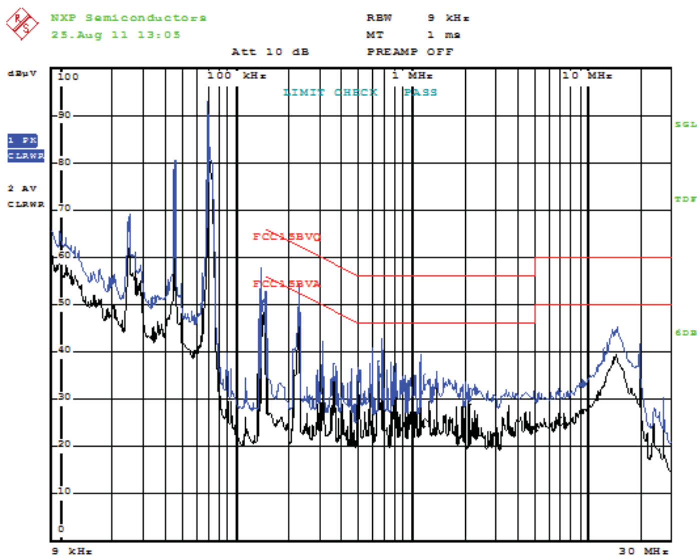
a. 115 V (AC) L



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b. 115 V (AC) N

Fig 7. EMI – conducted emission test results

5. Board Information

The input section includes the fuse; surge protection against fast AC transients; EMI filter; double side rectifier and pre-conditioner or power factor correct (PFC). The output of the PFC connects to a buffer electrolytic capacitor to supply the half-bridge circuit. The lamp connects to the half-bridge circuit. The UBA2015AP controller IC controls the PFC and the half-bridge circuit. A low-voltage control input is present to control the dimming of the lamp light output.

The PFC is implemented as an up-converter in boundary conduction mode. The resonant circuit is voltage fed by the half-bridge which consists of two NMOST transistors. The resonant circuit includes a transformer for electrode preheating and heating.

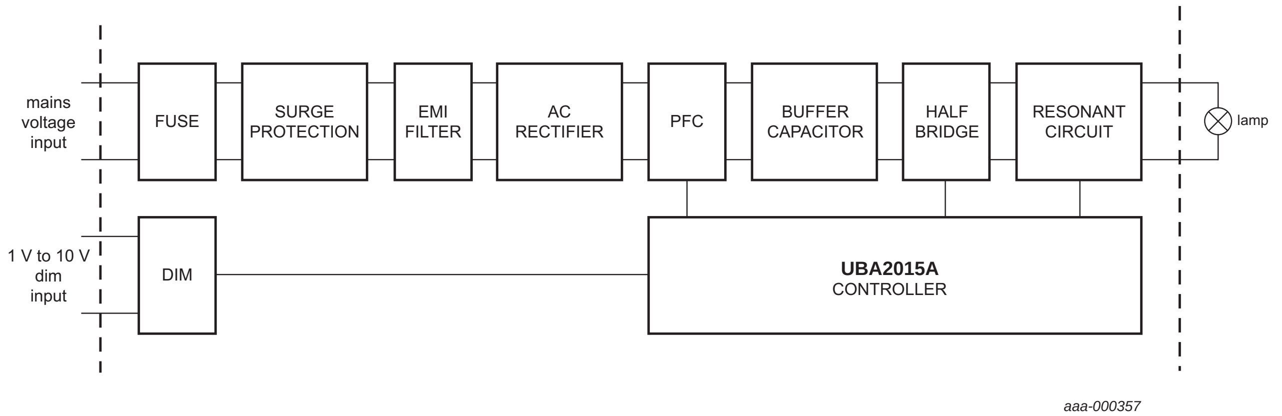


Fig 8. Block diagram

The type of ballast presented here is used for most ballast for lamp powers above 25 W. It has proven to be a cost effective application.

Remark: Some of the components are overrated for this **evaluation board**. When designing a final application, some component ratings can be lowered and some circuits can be simplified or combined to reduce component count and costs.

5.1 Dimming without using an external voltage source

The ballast is dimmed with a voltage source of 1 V (DC) to 10 V (DC) connected to connector X7.

It is also possible to dim with an external potentiometer of 470 kΩ (for example, no external voltage supply is available). The potentiometer must connect to pin 1 (black wire, DIM–) and pin 2 (red wire, DIM+) of connector X7.

5.2 Half-bridge operating principle

This topology supports dimming and preheat times below 1 s for T5 lamps. It uses an additional transformer for preheating/heating the filaments.

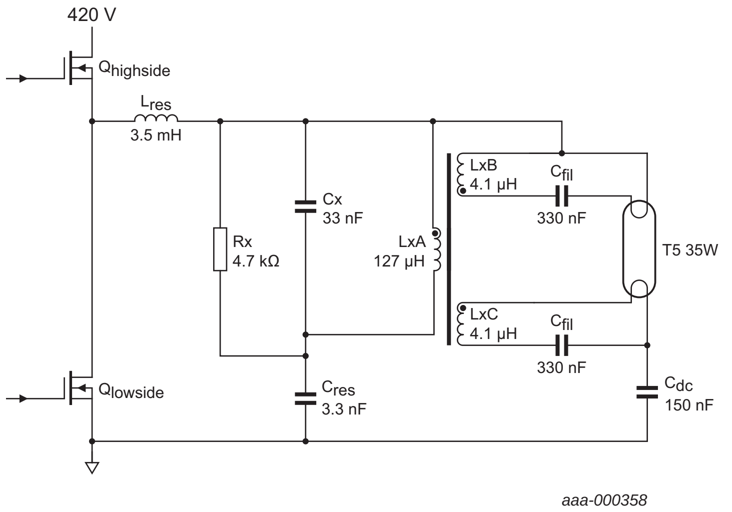


Fig 9. Half-bridge topology

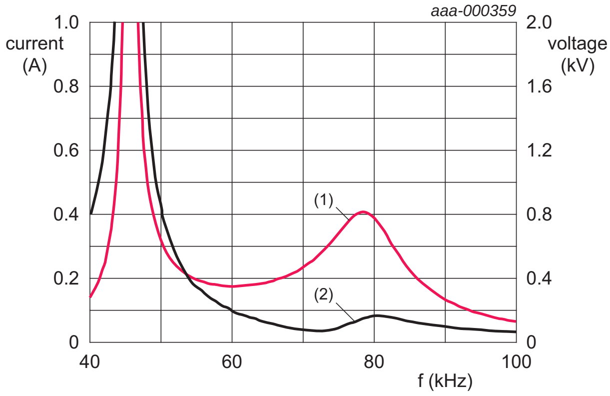
When the lamp is off, two resonant frequencies can be distinguished. A main resonant frequency f_{res} and a second frequency f_{sec}. Approaching f_{res} will ignite the lamp:

$$f_{res} = \frac{1}{2\pi\sqrt{L_{res} \cdot C_{res}}} \rightarrow f_{res} = 46.8\ kHz \quad (1)$$

Preheating the electrodes near f_{sec} increases the preheat current without increasing the filament current during normal operation. In dimmable applications, this aids compliance with the lamp sum of squares requirement.

$$f_{sec} = \frac{1}{2\pi\sqrt{LxA \cdot Cx}} \rightarrow f_{sec} = 77.7\ kHz \quad (2)$$

Rx is used to limit the voltage across Cx and LxA when the lamp is removed during preheat or ignition.



(1) I_{fil}.

(2) LC tank voltage.

Fig 10. Half-bridge frequency response with lamp not ignited

The UBA2015AP controller starts at 100 kHz and sweeps down until the preheat frequency is reached. The resistor on pin PH/EN sets the preheat frequency. During preheat, the LC tank voltage remains below 200 V to prevent early ignition and glow.

5.3 Schematic diagrams

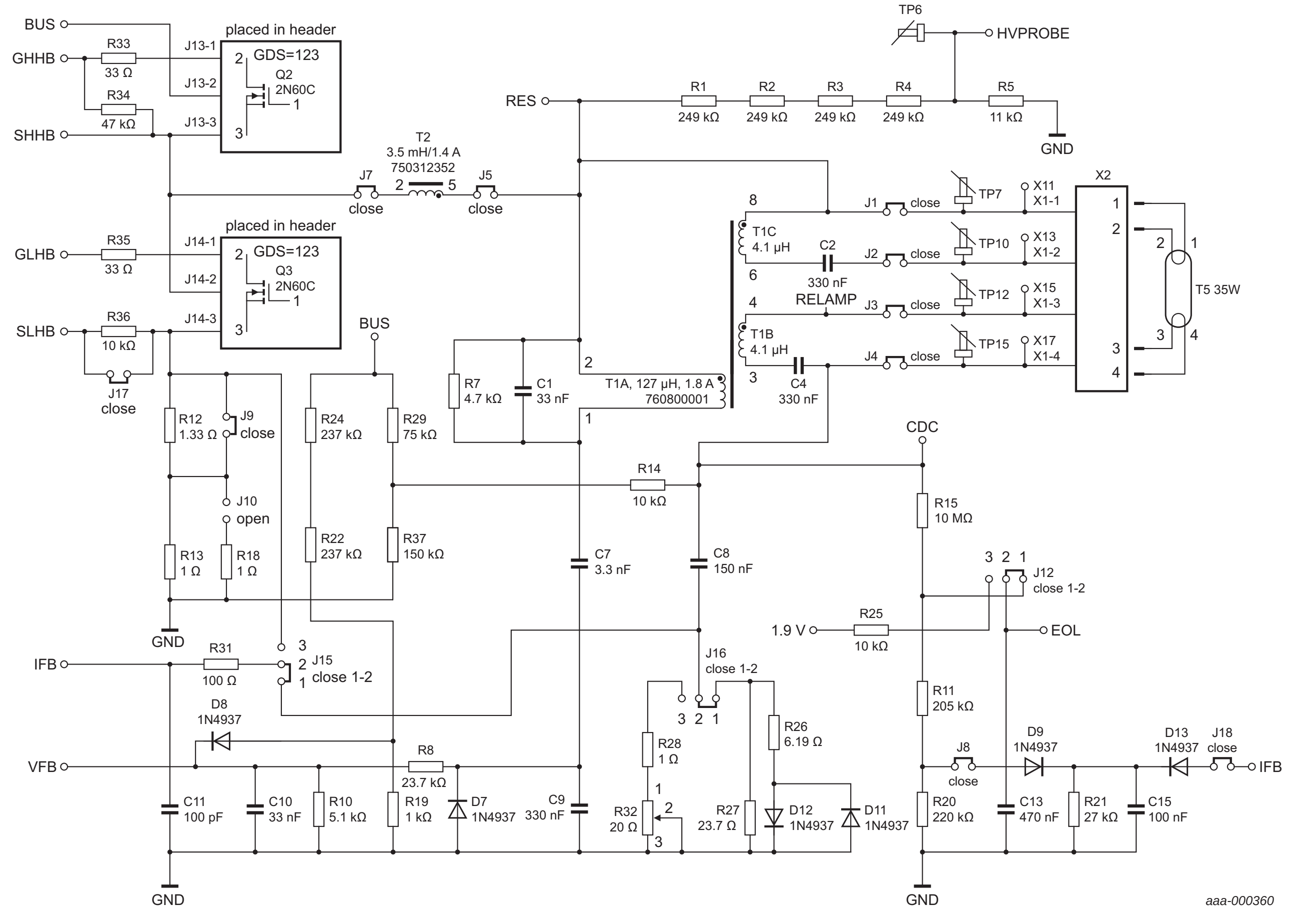


Fig 11. Schematic diagram: Half-bridge circuit

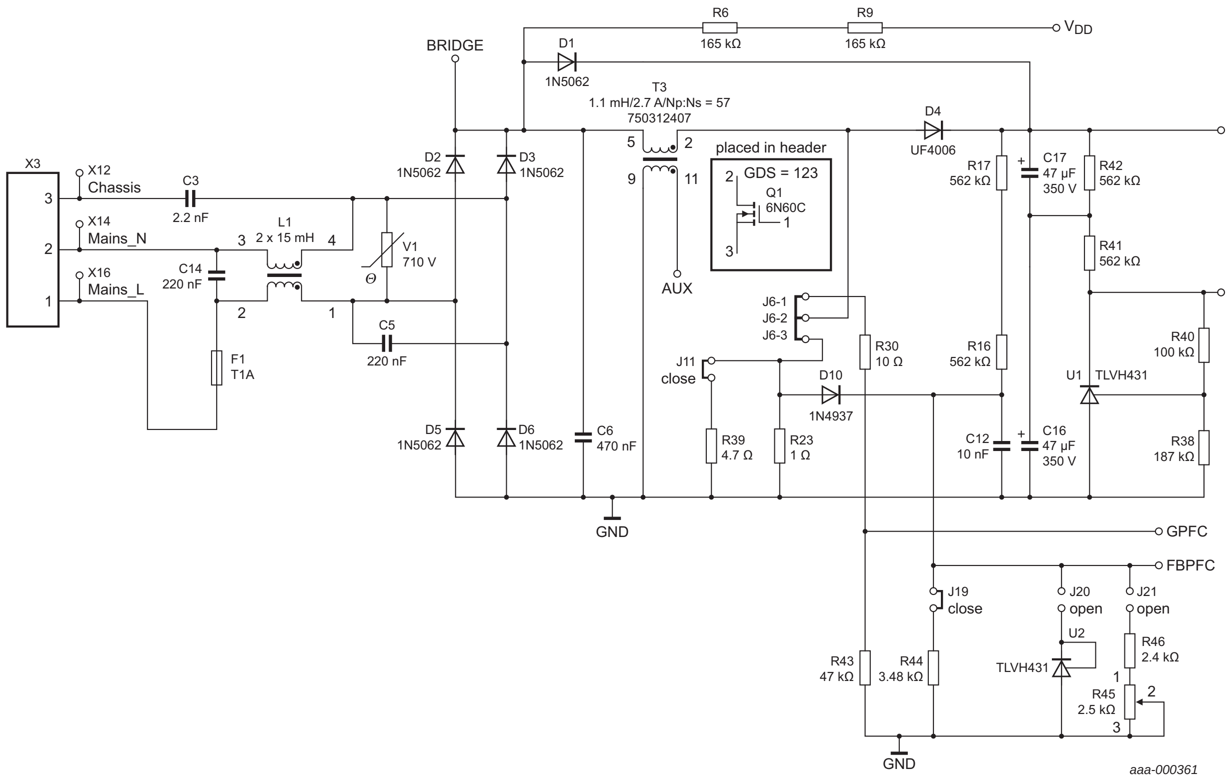


Fig 12. Schematic diagram: PFC circuit

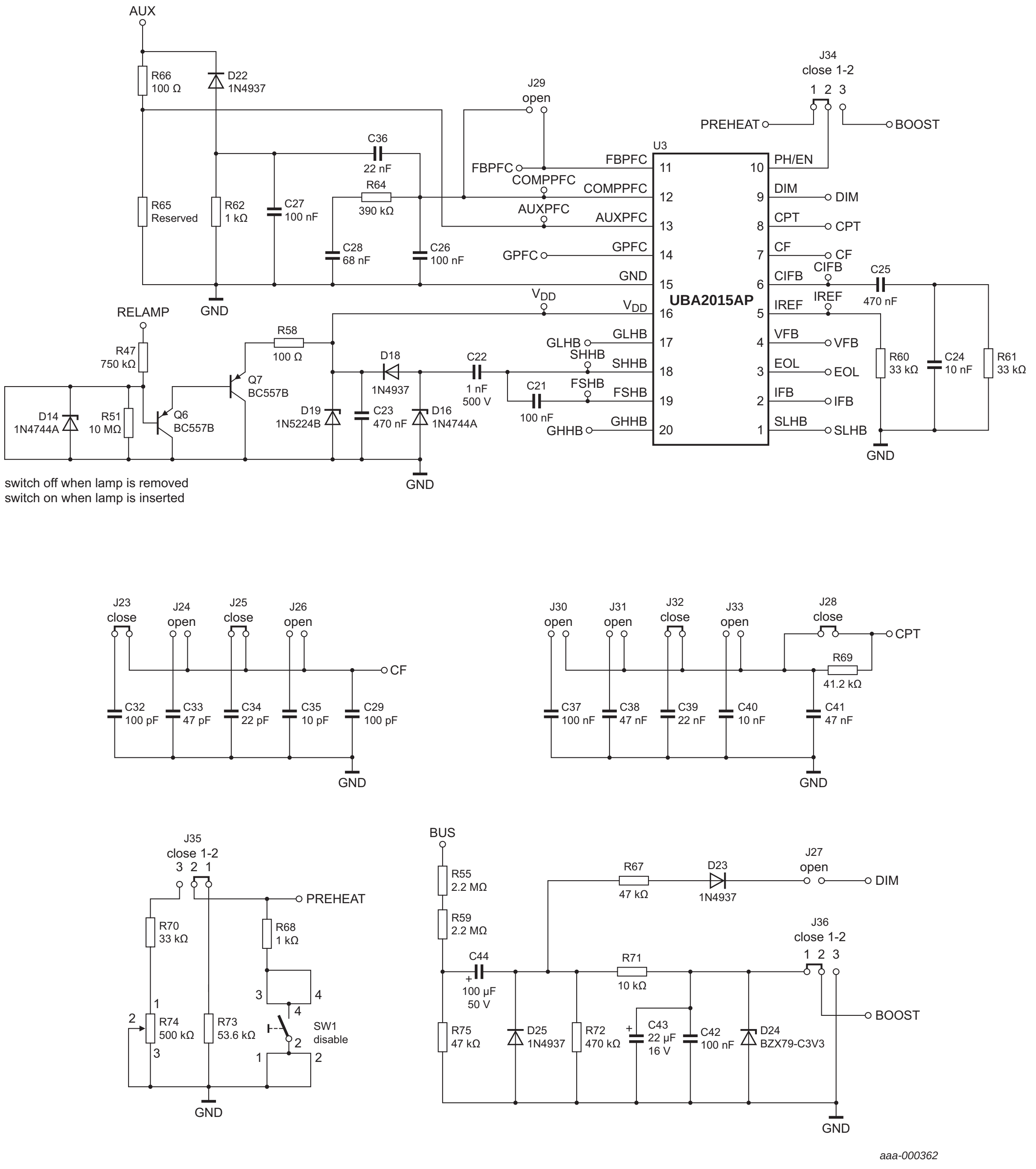


Fig 13. Schematic diagram: controller circuit

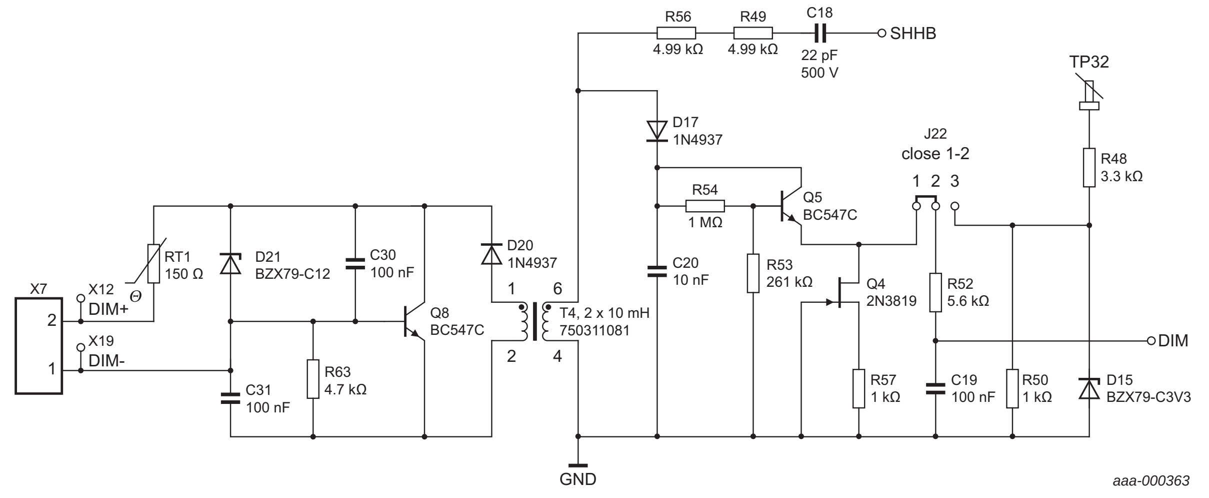


Fig 14. Schematic diagram: dim input circuit

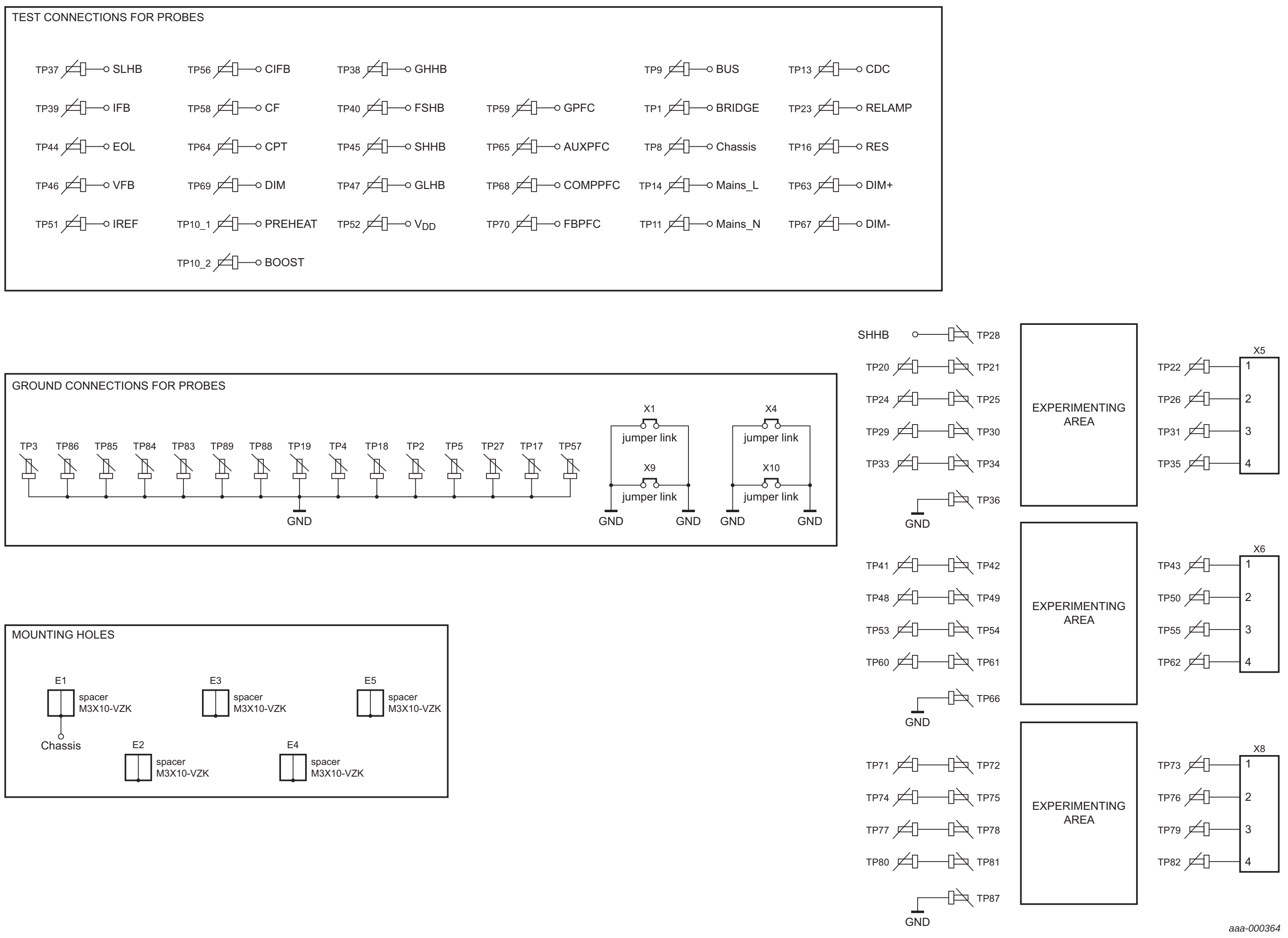


Fig 15. Schematic diagram: test points

5.4 Functional description

The mains voltage is applied to the board and current flows through R6 and R9 to the supply of the controller (VDD pin). When the current through R6 and R9 is higher than 240 μA ($I_{stb(VDD)}$), the controller the VDD voltage rises. When the VDD voltage is above 4.2 V ($V_{rst(VDD)}$), the half-bridge circuit low-side MOSFET switches on and the floating supply capacitor C1 is pre-charged.

The controller starts oscillating when the VDD voltage is above the 12.4 V ($V_{startup(VDD)}$). The PFC gate driver starts and the HB gate drivers start oscillating at 100 kHz ($f_{sw(high)}$). The dV/dt supply with capacitor C22 takes over the VDD supply to supply the IC with enough energy for the gate drivers. The preheat timer starts and the controller sweeps the frequency down from 100 kHz to the preheat frequency set by the PH/EN pin. The oscillator remains at the preheat frequency until the preheat timer has ended.

When the preheat ends, the controller sweeps down to the half-bridge switching frequency. The lamp ignites when the LC tank voltage reaches the lamp ignition voltage. The ignition frequency is typically 50 kHz. The lamp current increases and the LC tank voltage decreases. The controller senses the lamp current and LC tank voltage. When the lamp current is high enough and the LC tank voltage is low enough for 3 ms ($V_{IFB} > V_{th(lod)IFB}$ and $V_{VFB} < V_{th(lod)VFB}$ for $t_{d(lod)}$), the controller assumes that the lamp is on. The controller enters burn state.

In burn state, all the protection features are activated. The controller closes the lamp current control loop and the oscillator regulates the half-bridge switching frequency. The half-bridge frequency is regulated and reaches its set point when the average absolute IFB pin voltage equals the DIM– pin voltage.

5.4.1 Start-up current, relamp and antistriation

The VDD supply of the IC is charged with a start-up current derived from the rectified mains voltage. Resistor R2 provides the current path and determines the start-up voltage level.

When the lamp is removed while the IC is set to deep dimming, a protection is triggered and the controller is shut down. In this board, transistor Q7 pulls down the VDD voltage. The signal RELAMP indicates the filament of the lamp and controls transistor Q7. The pull-down by Q7 is released when the lamp is inserted.

UBA2015P and UBA2015AP can also be disabled by pulling down the voltage on the PH/EN pin.

The RELAMP signal is generated with a DC current injection on the DC blocking capacitor C8. This DC current also takes care of the antistriation function.

5.5 Evaluation board features

This board is equipped with evaluation functionality. This section described the additional functionality and how to use the jumpers.

5.5.1 Default jumper settings

Table 4 shows the default (factory) configuration jumper settings with the UBA2015AP mounted.

Table 4. Default jumper setting

Jumper	Function	Type	UBA2015AP
J1	Lamp connection	2-pin	closed
J2	Lamp connection	2-pin	closed
J3	Lamp connection	2-pin	closed
J4	Lamp connection	2-pin	closed
J5	HB inductor	2-pin	closed
J6	PFC MOSFET socket	socket	6N60C
J7	HB inductor	2-pin	closed
J8	EOL circuit	2-pin	closed
J9	HB current sense	2-pin	closed
J10	HB current sense	2-pin	open
J11	PFC over current sense	2-pin	closed
J12	EOL disable	3-pin	closed 1-2
J13	HB MOSFET socket high-side	socket	2N60C
J14	HB MOSFET socket low-side	socket	2N60C
J15	IFB input select	3-pin	closed 1-2
J16	Lamp current sense circuit select	3-pin	closed 1-2
J17	HB current sense	2-pin	closed
J18	EOL circuit	2-pin	closed
J19	Bus voltage setting	2-pin	closed
J20	FBPFC fixed voltage	2-pin	open
J21	Bus voltage adjustable	2-pin	open
J22	DIM input setting	3-pin	closed 1-2
J23	CF capacitor bank 100 pF	2-pin	closed
J24	CF capacitor bank 47 pF	2-pin	open
J25	CF capacitor bank 22 pF	2-pin	closed
J26	CF capacitor bank 10 pF	2-pin	open
J27	Start-up dim level	2-pin	open
J28	CPT test	2-pin	closed
J29	PFC disable	2-pin	open
J30	CPT capacitor bank 100 nF	2-pin	open
J31	CPT capacitor bank 47 nF	2-pin	open
J32	CPT capacitor bank 22 nF	2-pin	closed
J33	CPT capacitor bank 10 nF	2-pin	open
J34	Boost/ fixed freq preheat select	3-pin	closed 1-2
J35	Preheat frequency setting	3-pin	closed 1-2
J36	Boost select	3-pin	closed 1-2

5.5.2 Supporting other IC versions

The board supports all DIP versions of the ballast controller family. Make sure that the BUS capacitor is discharged when replacing ICs.

5.5.2.1 UBA2015P

The UBA2015P IC is a non-dimmable version with fixed frequency preheat option. The UBA2015P does not support boost.

The default jumper settings are suited. The DIM input pin of the UBA2015P is internally not connected.

5.5.2.2 UBA2016AP

The UBA2016AP IC is a dimmable version with no fixed frequency preheat option. The UBA2015AP supports boost.

Table 5. UBA2016AP jumper setting

Jumper	Function	Type	UBA2016AP
J9	HB current sense	2-pin	open
J34	Boost/fixed freq preheat select	3-pin	closed 2-3

5.5.3 Evaluation features and alternative jumper settings

5.5.3.1 PFC overcurrent adjustment

Table 6. Jumper settings: PFC overcurrent sense resistor

Jumper	Function	Setting	R_{SENSE}
J11	PFC over current sense	closed	0.82 Ω[1]
J11		open	1 Ω

[1] Default setting.

5.5.3.2 External supply for the half-bridge circuit with PFC disabled

Experimenting with an external voltage (laboratory supply or separate PFC controller) for the BUS is possible. Fix the PFC feedback signal FBPFC and the COMPFC to 1.24 V.

The default bus voltage is 420 V (DC). When adjusting the bus voltage it is advised to disable the EOL protection with jumper J12.

The external laboratory supply must connect to the BRIDGE (TP1) because the start-up current supplies the VDD pin.

Table 7. Jumper settings: PFC disable for external half-bridge supply

Jumper	Function	Setting
J6	PFC MOSFET socket	remove MOSFET
J19	Bus voltage setting	open
J20	FBPFC fixed voltage 1.24 V	closed
J21	Bus voltage adjustable	open
J29	PFC disable	closed

5.5.3.3 Bus voltage adjustment with PFC enabled

The default bus voltage is 420 V (DC). With the alternative jumper settings shown in this paragraph, it is possible to adjust the bus voltage. When adjusting the bus voltage, it is advised the EOL protection is disabled using jumper J12.

The bus voltage V_{bus} is adjustable with resistor R45:

- R45 turned clockwise: V_{bus} = 300 V (DC)
- R45 turned counter clockwise: V_{bus} = 600 V (DC)

Table 8. Jumper settings: PFC output voltage (VBUS) adjustment

Jumper	Function	Setting
J19	Bus voltage setting	open
J20	FBPFC fixed voltage	open
J21	Bus voltage adjustable	closed

5.5.3.4 Half-bridge frequency control loop options

The default setting is lamp current control. The controller can regulate any other signal such as the HB current. The controller increases the half-bridge switching frequency when the feedback signal is too high. The controller decreases the half-bridge switching frequency when the feedback signal is too low.

Table 9. Half-bridge frequency control loop jumper setting

Jumper	Function	Setting	IFB input
J15	IFB input select	closed 1-2[1]	Lamp current
J15		closed 2-3	HB current
J15		open	Disabled

[1] Default setting.

HB current sense (J15 closed 2-3): Some LC tank topologies allow dimming to 10 % via the HB current sense. The HB current is fed back to the IFB pin and the controller regulates the HB current.

Remark: The LC tank topology on this board is not suited for dimming via the HB current sense. A dedicated LC circuit could be placed in the experiment area, see NXP Semiconductors AN10872 for suitable series resonant type of circuits.

Disabled (J15 open): The IFB pin is internally pulled down to ground level when the IFB pin is left open. The controller then operates at the minimum operating frequency set by the CF capacitor. The default minimum operating frequency is default 43 kHz.

Remark: It is recommended to connect the IFB pin to ground instead of leaving J15 open to avoid interference on the PCB track.

5.5.3.5 Lamp current sense

There are two lamp current sense circuits on the evaluation board; by default the non-linear sense circuit is selected.

The IC contains a double-sided rectifier. This setup means that no rectification is required in the sense circuit.

Table 10. Half-bridge frequency control loop jumper setting

Jumper	Function	Setting	Remarks
J16	Lamp current sense circuit select	closed 1-2[1]	non-linear
J16		closed 2-3	adjustable resistor

[1] Default setting.

Non-linear sense: Compared to a normal (linear) sense resistor, this circuit has the advantage that:

- The control is less sensitive and the light output can be regulated more accurately
- The lamp current feedback signal is larger and therefore less sensitive to disturbances

Adjustable resistor: The lamp current can be adjusted with resistor R32:

- R45 turned clockwise: R_{SENSE} = 21 Ω
- R45 turned counter clockwise: R_{SENSE} = 1 Ω

5.5.3.6 Half-bridge current sense resistor

Several values can be programmed with the jumpers J9 and J10.

Table 11. Half-bridge frequency control loop jumper setting

Jumper Setting		Function	R_{SENSE} (Ω)
J9	J10		
closed	closed	HB current sense	0.5
closed	open		1[1]
open	closed		1.88
open	open		2.33

[1] Default setting.

During the leading edge (300 ns) of the GLHB, the SLHB voltage is blanked inside the IC. In case fixed frequency preheat is required, the SLHB voltage must remain below $V_{ctrl(ph)SLHB}$ minimum level (0.44 V) during start-up and preheat.

In case current controlled preheat is required, the SLHB voltage peak must be the $V_{ctrl(ph)SLHB}$ typical level (0.48 V) during preheat.

5.5.3.7 Preheat frequency adjustment

The resistor on pin PH/EN sets the preheat frequency. Using a jumper option, adjustable resistor R74 is used to set the preheat frequency.

Table 12. Fixed frequency preheat

Jumper Setting		Preheat frequency
J34	J35	
closed 1-2	closed 1-2	76 kH[1]
closed 1-2	closed 2-3	adjustable between $f_{sw(high)}$ and current controlled preheat function on pin SLHB

[1] Default setting.

- R74 turned clockwise: RPH/EN = 500 kΩ
- R74 turned counter clockwise: RPH/EN = 33 kΩ (preheat at $f_{sw(high)}$)

5.5.3.8 Enable disable function

To evaluate the disable/enable function on the PH/EN pin, a switch SW1 is placed on the board to pull down the PH/EN voltage. In normal ballast circuits, a transistor replaces the switch. The transistor pulls down the PH/EN pin, in a similar way to the open-drain of a microcontroller.

- Enable: Press SW1 before power-on and release after power is applied
- Disable: Press SW1 after power is applied and the lamp is on

5.5.3.9 PFC THD waveshaper circuit disable

To measure the THD performance without waveshaping circuit: the THD waveshaping feature can be disabled by removing capacitor C36.

5.5.3.10 Boost mode

The boost function is only in the UBA2016A IC. The UBA2015 and UBA2015A have instead of the boost function the fixed frequency preheat with enable/disable option and burn state indicator.

The boost circuit is designed to boost only at power-on of the ballast.

Table 13. Fixed frequency preheat

Jumper Setting			IC	Boost mode
J27	J34	J36		
-	closed 1-2	closed 1-2	UBA2015	disabled
-	closed1-2	closed 1-2	UBA2015A[1]	
-	closed 2-3	closed 2-3	UBA2016A	
open	closed 2-3	closed 1-2	UBA2016A	enable

[1] Default setting.

5.5.4 Half-bridge operating frequency

The operating frequency is set using the CF capacitor bank. $f_{sw(high)}$ is always 2.4 times $f_{sw(low)}$. Table 14 shows frequency values while I_{BOOST} = 0 μA.

Table 14. Jumpers: operating frequency settings

Jumpers headers				CF (pF)	$f_{sw(low)}$ (kHz)	$f_{sw(high)}$ (kHz)
J23 (100 pF)	J24 (47 pF)	J25 (22 pF)	J26 (10 pF)			
open	open	-	-	100 ~ 132[1]	> 60	> 144
open	closed	open	open	147	59	140
open	closed	open	closed	157	55	131
open	closed	closed	open	169	51	122
open	closed	closed	closed	179	48	115
closed	open	open	open	200	43	103
closed	open	open	closed	210	43	98
closed	open	closed	open	222[2]	41	93
closed	open	closed	closed	232	37	89
closed	closed	open	open	247	35	84
closed	closed	open	closed	257	33	80
closed	closed	closed	open	269	32	77
closed	closed	closed	closed	279	31	74

[1] Outside the specification.

[2] Default setting.

5.5.5 Preheat timer and slow fault timer capacitor bank

The preheat time is set using the CPT capacitor bank. The default fault time is 20 % of the preheat time. This ratio can be modified using series or parallel resistors as explained in the relevant IC data sheet.

Table 15. Jumpers: preheat timer and slow fault timer settings

Jumpers headers				CF (nF)	t_{ph} (s)	Fault time (s)
J30 (100 nF)	J31 (47 nF)	J32 (22 nF)	J33 (10 nF)			
open	open	open	open	47	0.44	0.088
open	open	open	closed	57	0.54	0.107
open	open	closed	open	69[1]	0.65	0.130
open	open	closed	closed	79	0.74	0.149
open	closed	open	open	94	0.88	0.177
open	closed	open	closed	104	0.98	0.196
open	closed	closed	open	116	1.09	0.218
open	closed	closed	closed	126	1.18	0.237
closed	open	open	open	147	1.38	0.276
closed	open	open	closed	157	1.48	0.295
closed	open	closed	open	169	1.59	0.318
closed	open	closed	closed	179	1.68	0.337
closed	closed	open	open	194	1.82	0.365
closed	closed	open	closed	204	1.92	0.384
closed	closed	closed	open	216	2.03	0.406
closed	closed	closed	closed	226	2.12	0.425

[1] Default setting.

5.5.5.1 EOL protection disable

When varying the bus voltage, the EOL protection could be triggered because the EOL pin voltage moves out of the windows comparator. The EOL protection can be disabled by fixing the EOL pin voltage to 1.9 V with jumper J12 for use in experiments.

Table 16. Jumper settings: EOL functions

Jumper	Function	Setting
J12	enabled	closed 1-2[1]
	disabled (fixed to 1.9 V)	closed 2-3

[1] Default setting.

5.5.5.2 Minimum dim level adjustment

An accurate current source $I_{bias(DIM)}$ (26 μA) inside the controller generates a voltage across the external resistor R52. The easiest way to adjust the minimum dim level is to modified resistor R52.

- A reduced R52 lowers the minimum dim level (less light)
- An increased R52 increases the minimum dim level

6. Board layouts

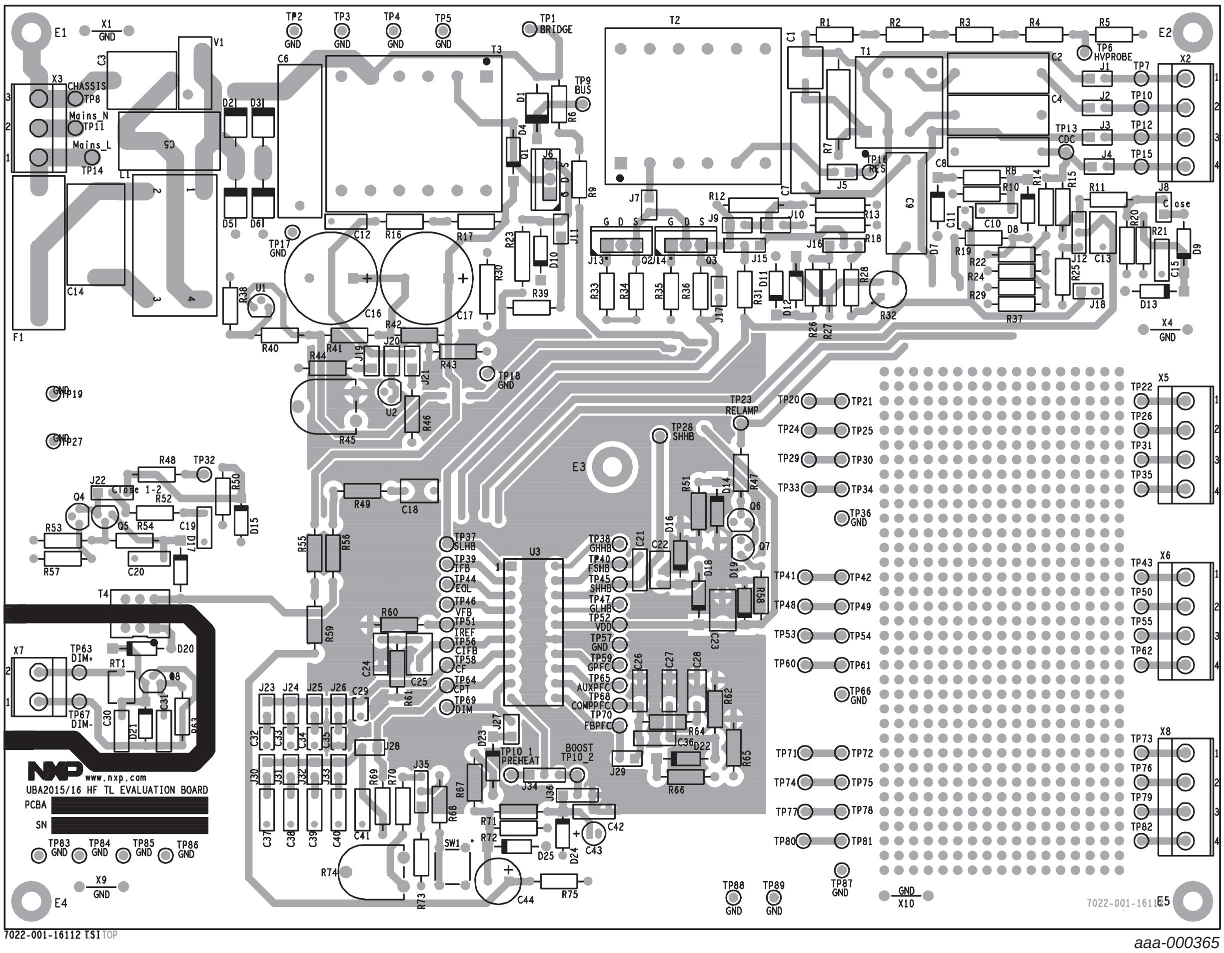


Fig 16. Evaluation board (top view)

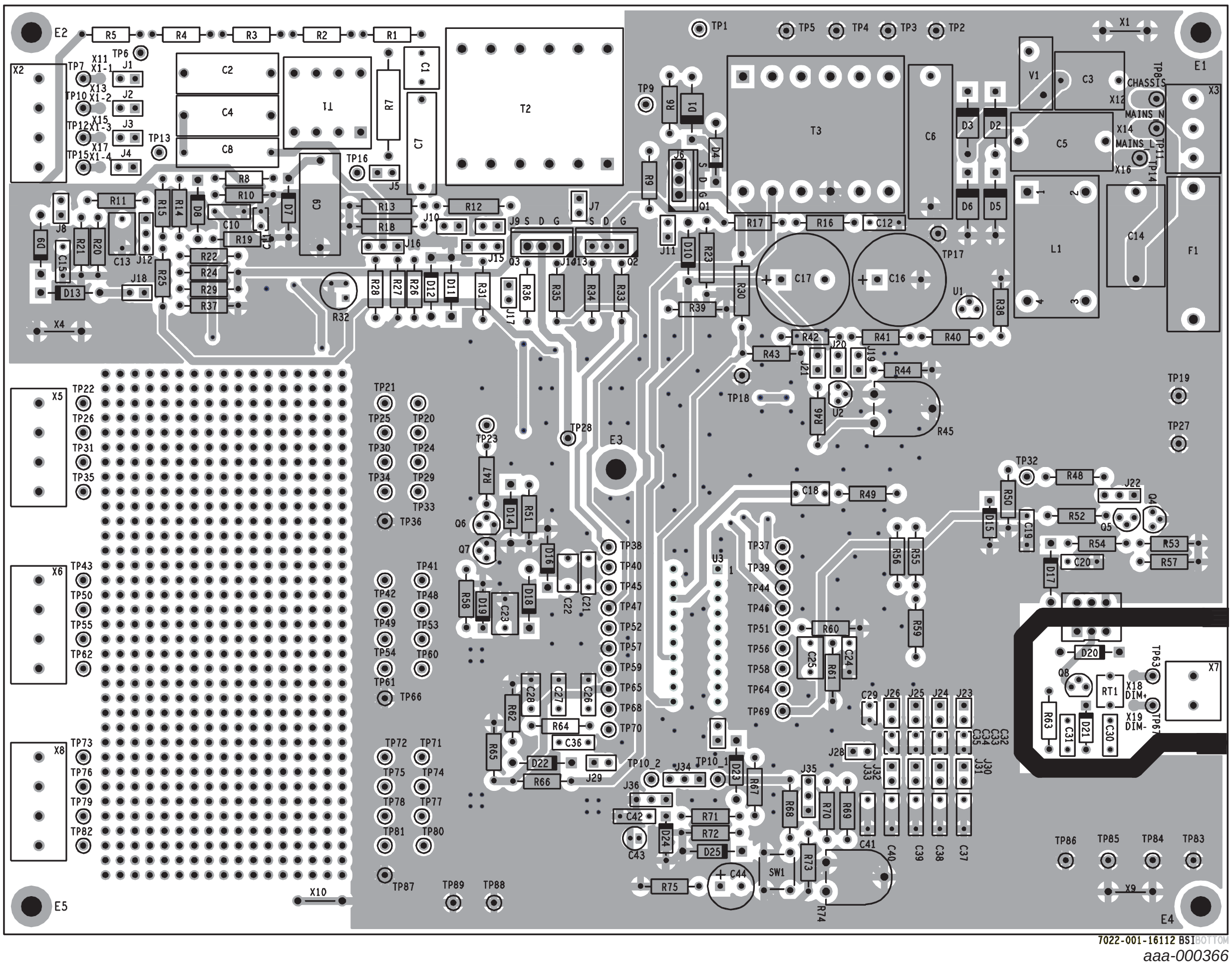


Fig 17. Evaluation board (bottom view)

7. Bill of materials

Table 17. Bill of materials

Part reference	Description/Value	Part number	Manufacturer
C1	33 nF; 5 %; 400 V	BFC247066333	Vishay
C2	330 nF; 10 %; 400 V	BFC237353334	Vishay
C3	2.2 nF; 20 %; 250 V	DE1E3KX222MA4BL01	Murata
C4	330 n; 10 %; 400 V	BFC237353334	Vishay
C5	220 nF; 20 %; 275 V	BFC233620224	Vishay
C6	470 nF; 5 %; 400 V	MKP1840447404M	Vishay
C7	3.3 nF; 5 %; 2 kV	BFC238580332	Vishay
C8	150 nF; 10 %; 400 V	BFC237353154	Vishay
C9	330 nF; 10 %; 400 V	BFC237353334	Vishay
C10	33 nF; 5 %; 63 V	MKS2C023301A00JSSD	WIMA
C11	100 pF; 1 %; 50 V	C315C101F5G5TA	KEMET
C12	10 nF; 5 %; 63 V	MKS2-.01/63/5	WIMA
C13	470 nF; 10 %; 63 V	BFC237011474	Vishay
C14	220 nF; 20 %; 275 V	BFC233620224	Vishay
C15	100 nF; 10 %; 63 V	BFC237011104	Vishay
C16	47 µF; 20 %; 350 V	EEU-ED2V470	Panasonic
C17	47 µF; 20 %; 350 V	EEU-ED2V470	Panasonic
C18	22 pF; 5 %; 500 V	D220J25C0GL63L6R	Vishay
C19	100 nF; 10 %; 63 V	BFC237011104	Vishay
C20	10 nF; 5 %; 63 V	MKS2-.01/63/5	WIMA
C21	100 nF; 10 %; 63 V	BFC237011104	Vishay
C22	1 nF; 10 %; 500 V	H102K25X7RL63J5R	Vishay
C23	470 nF; 5 %; 63 V	MKS20.47/63/5	WIMA
C24	10 nF; 5 %; 63 V	MKS2-.01/63/5	WIMA
C25	470 nF; 5 %; 63 V	MKS20.47/63/5	WIMA
C26	100 n; 10 %; 63 V	BFC237011104	Vishay
C27	100 nF; 10 %; 63 V	BFC237011104	Vishay
C28	68 nF; 5 %; 50 V	ECQV1H683JL	Panasonic
C29	100 pF; 1 %; 50 V	C315C101F5G5TA	KEMET
C30	100 nF; 10 %; 63 V	BFC237011104	Vishay
C31	100 nF; 10 %; 63 V	BFC237011104	Vishay
C32	100 pF; 1 %; 50 V	C315C101F5G5TA	KEMET
C33	47 pF; 5 %; 50 V	C315C470J5G5CA7303	KEMET
C34	22 pF; 5 %; 50 V	C315C220J5G5TA	KEMET
C35	10 pF; 5 %; 50 V	C315C100J5G5TA	KEMET
C36	22 nF; 5 %; 63 V	MKS2C022201A00JSSD	WIMA
C37	100 nF; 10 %; 63 V	BFC237011104	Vishay
C38	47 nF; 5 %; 63 V	MKS2-.047/63/5	WIMA

Table 17. Bill of materials *...continued*

Part reference	Description/Value	Part number	Manufacturer
C39	22 nF; 5 %; 63 V	MKS2C022201A00JSSD	WIMA
C40	10 nF; 5 %; 63 V	MKS2-.01/63/5	WIMA
C41	47 nF; 5 %; 63 V	MKS2-.047/63/5	WIMA
C42	100 nF; 10 %; 63 V	BFC237011104	Vishay
C43	22 μF; 20 %; 16 V	16ML22MEFC4X7	Rubycon
C44	1002 μF; 20 %; 50 V	EEU-FM1H101	Panasonic
D1	1N5062; 800 V; 2 A	1N5062-TR	Vishay
D2	1N5062; 800 V; 2 A	1N5062-TR	Vishay
D3	1N5062; 800 V; 2 A	1N5062-TR	Vishay
D4	UF4006	UF4006-E3/73	Vishay
D5	1N5062; 800 V; 2 A	1N5062-TR	Vishay
D6	1N5062; 800 V; 2 A	1N5062-TR	Vishay
D7	1N4937; 600 V; 1 A	1N4937-E3/54	Vishay
D8	1N4937; 600 V; 1 A	1N4937-E3/54	Vishay
D9	1N4937; 600 V; 1 A	1N4937-E3/54	Vishay
D10	1N4937; 600 V; 1 A	1N4937-E3/54	Vishay
D11	1N4937; 600 V; 1 A	1N4937-E3/54	Vishay
D12	1N4937; 600 V; 1 A	1N4937-E3/54	Vishay
D13	1N4937; 600 V; 1 A	1N4937-E3/54	Vishay
D14	1N4744A	1N4744A	Vishay
D15	BZX79-C3V3	BZX79-C3V3.133	NXP Semiconductors
D16	1N4744A	1N4744A	Vishay
D17	1N4937; 600 V; 1 A	1N4937-E3/54	Vishay
D18	1N4937; 600 V; 1 A	1N4937-E3/54	Vishay
D19	1N5244B	1N5244B	Fairchild
D20	1N4937; 600 V; 1 A	1N4937-E3/54	Vishay
D21	BZX79-C12	BZX79-C12.133	NXP Semiconductors
D22	1N4937/54; 600 V; 1 A	1N4937-E3/54	Vishay
D23	1N4937/54; 600 V; 1A	1N4937-E3/54	Vishay
D24	BZX79-C3V3	BZX79-C3V3.133	NXP Semiconductors
D25	1N4937/54 600 V; 1 A	1N4937-E3/54	Vishay
F1	Fuse T1A	34.3117	SCHURTER
N1	PCB	7022-001-16112	Custom
Q1	6N60C	FQPF6N60C	Fairchild
Q2	2N60C	FQPF2N60C	Fairchild
Q3	2N60C	FQPF2N60C	Fairchild
Q4	2N3819	2N3819-E3	Vishay
Q5	BC547C	BC547C	Fairchild
Q6	BC557B	BC557BZL1G	On-Semi
Q7	BC557B	BC557BZL1G	On-Semi

Table 17. Bill of materials *...continued*

Part reference	Description/Value	Part number	Manufacturer
Q8	BC547C	BC547C	Fairchild
R1	249 kΩ; 1 %; 0.6 W	MRS25000C2493FCT00	Vishay
R2	249 kΩ; 1 %; 0.6 W	MRS25000C2493FCT00	Vishay
R3	249 kΩ; 1 %; 0.6 W	MRS25000C2493FCT00	Vishay
R4	249 kΩ; 1 %; 0.6 W	MRS25000C2493FCT00	Vishay
R5	11 kΩ; 1 %; 0.6 W	MRS25000C1102FCT00	Vishay
R6	165 kΩ; 1 %; 0.6 W	MRS25000C1653FCT00	Vishay
R7	4.7 kΩ; 5 %; 2 W	PR02000204701JR500	Vishay
R8	23.7 kΩ; 1 %; 0.6 W	MRS25000C2372FCT00	Vishay
R9	165 kΩ; 1 %; 0.6 W	MRS25000C1653FCT00	Vishay
R10	5.1 kΩ; 1 %; 0.6 W	MRS25000C5101FCT00	Vishay
R11	205 kΩ; 1 %; 0.6 W	MRS25000C2053FCT00	Vishay
R12	1.33 Ω; 5 %; 1 W	PR01000101008JR500	Vishay
R13	1 Ω; 5 %; 1 W	MRS25000C1338FCT00	Vishay
R14	10 kΩ; 1 %; 0.6 W	MRS25000C1002FCT00	Vishay
R15	10 MΩ; 1 %; 0.6 W	MRS25000C1005FRP00	Vishay
R16	562 kΩ; 1 %; 0.6 W	MRS25000C5623FCT00	Vishay
R17	562 kΩ; 1 %; 0.6 W	MRS25000C5623FCT00	Vishay
R18	1 Ω; 5 %; 1 W	PR01000101008JR500	Vishay
R19	1 kΩ; 1 %; 0.6 W	MRS25000C1001FCT00	Vishay
R20	220 kΩ; 1 %; 0.6 W	MRS25000C2203FCT00	Vishay
R21	27 kΩ; 1 %; 0.6 W	MRS25000C2702FCT00	Vishay
R22	237 kΩ; 1 %; 0.6 W	MRS25000C2373FCT00	Vishay
R23	1 Ω; 5 %; 1 W	PR01000101008JR500	Vishay
R24	237 kΩ; 1 %; 0.6 W	MRS25000C2373FCT00	Vishay
R25	10 kΩ; 1 %; 0.6 W	MRS25000C1002FCT00	Vishay
R26	6.19 Ω; 1 %; 0.6 W	MRS25000C6198FCT00	Vishay
R27	23.7 Ω; 1 %; 0.6 W	MRS25000C2379FCT00	Vishay
R28	1 Ω; 1 %; 0.6 W	MRS25000C1008FCT00	Vishay
R29	75 kΩ; 1 %; 0.6 W	MRS25000C7502FCT00	Vishay
R30	10 Ω; 1 %; 0.6 W	MRS25000C1009FCT00	Vishay
R31	1 kΩ; 1 %; 0.6 W	MRS25000C1001FCT00	Vishay
R32	20 Ω; 10 %; 0.5 W	3329H-1-200LF	Bourns
R33	33 Ω; 1 %; 0.6 W	MRS25000C3309FCT00	Vishay
R34	47 kΩ; 1 %; 0.6 W	MRS25000C4702FCT00	Vishay
R35	33 Ω; 1 %; 0.6 W	MRS25000C3309FCT00	Vishay
R36	10 kΩ; 1 %; 0.6 W	MRS25000C1002FCT00	Vishay
R37	150 kΩ; 1 %; 0.6 W	MRS25000C1503FCT00	Vishay
R38	187 kΩ; 1 %; 0.6 W	MRS25000C1873FCT00	Vishay
R39	4.7 Ω; 1 %; 0.6 W	MRS25000C4708FCT00	Vishay

Table 17. Bill of materials *...continued*

Part reference	Description/Value	Part number	Manufacturer
R40	100 kΩ; 1 %; 0.6 W	MRS25000C1003FCT00	Vishay
R41	562 kΩ; 1 %; 0.6 W	MRS25000C5623FCT00	Vishay
R42	562 kΩ; 1 %; 0.6 W	MRS25000C5623FCT00	Vishay
R43	47 kΩ; 1 %; 0.6 W	MRS25000C4702FCT00	Vishay
R44	3.48 kΩ; 1 %; 0.6 W	MRS25000C3481FCT00	Vishay
R45	2.5 kΩ; 20 %; 0.15 W	262UR252B	CTS
R46	2.4 kΩ; 1 %; 0.6 W	MRS25000C2401FCT00	Vishay
R47	750 kΩ; 1 %; 0.6 W	MRS25000C7503FCT00	Vishay
R48	3.3 kΩ; 1 %; 0.6 W	MRS25000C3301FCT00	Vishay
R49	4.99 kΩ; 1 %; 0.6 W	MRS25000C4991FCT00	Vishay
R50	1 kΩ; 1 %; 0.6 W	MRS25000C1001FCT00	Vishay
R51	10 MΩ; 1 %; 0.6 W	MRS25000C1005FRP00	Vishay
R52	5.6 kΩ; 1 %; 0.6 W	MRS25000C5601FCT00	Vishay
R53	261 kΩ; 1 %; 0.6 W	MRS25000C2613FCT00	Vishay
R54	1 MΩ; 1 %; 0.6 W	MRS25000C1004FCT00	Vishay
R55	2.2 MΩ; 1 %; 0.6 W	MRS25000C2204FCT00	Vishay
R56	4.99 kΩ; 1 %; 0.6 W	MRS25000C4991FCT00	Vishay
R57	1 kΩ; 1 %; 0.6 W	MRS25000C1001FCT00	Vishay
R58	100 Ω; 1 %; 0.6 W	MRS25000C1000FCT00	Vishay
R59	2.2 MΩ; 1 %; 0.6 W	MRS25000C2204FCT00	Vishay
R60	33 kΩ; 1 %; 0.6 W	MRS25000C3302FCT00	Vishay
R61	33 kΩ; 1 %; 0.6 W	MRS25000C3302FCT00	Vishay
R62	1 kΩ; 1 %; 0.6 W	MRS25000C1001FCT00	Vishay
R63	4.7 kΩ; 1 %; 0.6 W	MRS25000C4701FCT00	Vishay
R64	390 kΩ; 1 %; 0.6 W	MRS25000C3903FCT00	Vishay
R66	100 Ω; 1 %; 0.6 W	MRS25000C1000FCT00	Vishay
R67	47 kΩ; 1 %; 0.6 W	MRS25000C4702FCT00	Vishay
R68	1 kΩ; 1 %; 0.6 W	MRS25000C1001FCT00	Vishay
R69	41.2 kΩ; 1 %; 0.6 W	MRS25000C4122FCT00	Vishay
R70	33 kΩ; 1 %; 0.6 W	MRS25000C3302FCT00	Vishay
R71	10 kΩ; 1 %; 0.6 W	MRS25000C1002FCT00	Vishay
R72	470 kΩ; 1 %; 0.6 W	MRS25000C4703FCT00	Vishay
R73	53.6 kΩ; 1 %; 0.6 W	MRS25000C5362FCT00	Vishay
R74	500 kΩ; 20 %; 0.15 W	262UR504B	CTS
R75	47 kΩ; 1 %; 0.6 W	MRS25000C4702FCT00	Vishay
RT1	150 Ω; 25 %; 0.2 A; +85 °C	PTGL05AR151H8P52B0	Murata
SW1	switch	PTS645SL95LFS	C&K Components
T1	transformer	760800001	Würth Elektronik
T2	transformer	750312352	Würth Elektronik
T3	transformer	750312407	Würth Elektronik

Table 17. Bill of materials *…continued*

Part reference	Description/Value	Part number	Manufacturer
T4	transformer	750311081	Würth Elektronik
U1	TLVH431BQLPR	TLVH431BQLPR	Texas Instruments
U2	TLVH431BQLPR	TLVH431BQLPR	Texas Instruments
U3	UBA2015AP	UBA2015AP	NXP Semiconductors
V1	275 V (AC); 3.5 kA; 710 V	V10E275P	Littelfuse
X2	PCB screw terminal	MKDSN2.5/4-5.08	Phoenix Contact
X3	PCB screw terminal	MKDSN2.5/3-5.08	Phoenix Contact
X5	PCB screw terminal	MKDSN2.5/4-5.08	Phoenix Contact
X6	PCB screw terminal	MKDSN2.5/4-5.08	Phoenix Contact
X7	PCB screw terminal	MKDSN2.5/2-5.08	Phoenix Contact
X8	PCB screw terminal	MKDSN2.5/4-5.08	Phoenix Contact

8. Inductor appearance and dimensions

8.1 PFC transformer

Wurth Electronics Midcom Inc., part number: 750312407

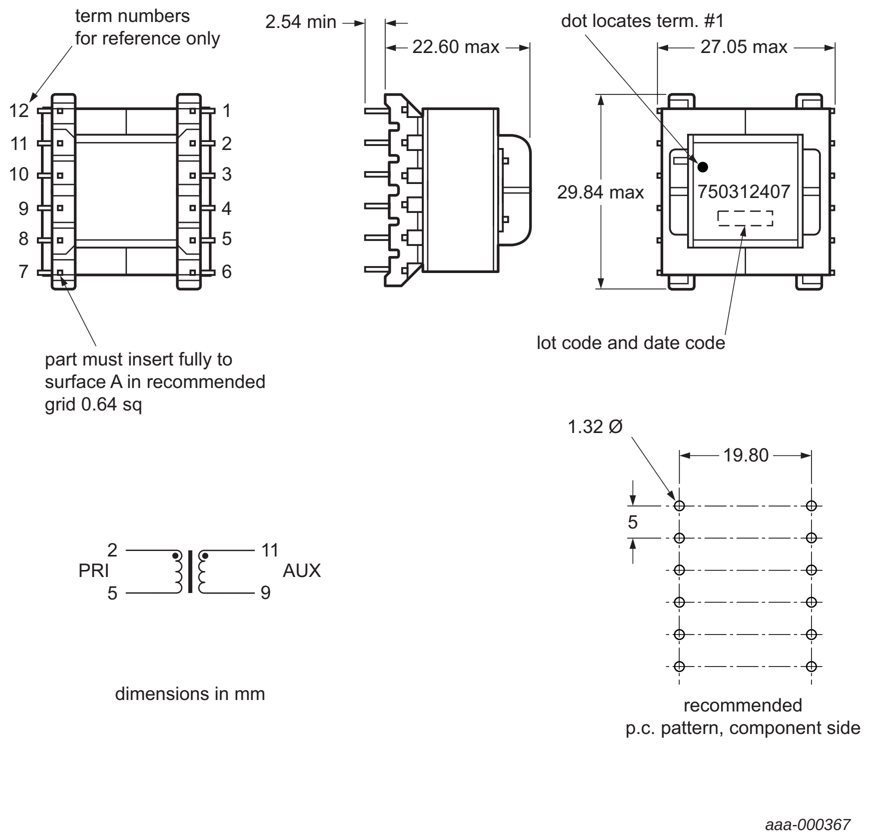


Fig 18. PFC transformer appearance and dimensions

Table 18. PFC transformer electrical specifications

Parameter	Value
Inductance (2-5)	1.1 mH
Saturation current (2-5)	2.7 A
Turns ratio (2-5) : (11-9)	60
Leakage inductance	465 µH
Dielectric rating (5-9)	1.5 kV (AC)
DC resistance (2-5)	1.35 Ω
DC resistance (9-11)	0.11 Ω
Operating temperature	–40 °C to +125 °C

8.2 Half-bridge inductor

Wurth Electronics Midcom Inc., part number: 750312352

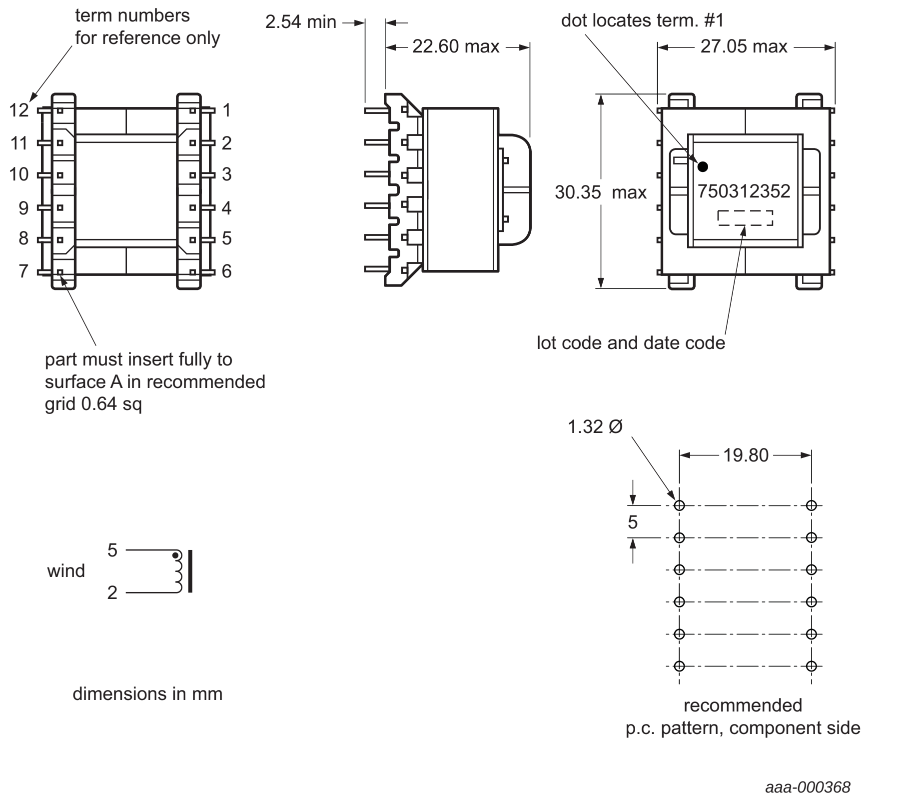


Fig 19. Half-bridge inductor appearance and dimensions

Table 19. Half-bridge inductor electrical specifications

Parameter	Value
Inductance (2-5)	3.5 mH
Saturation current (2-5)	2 A
DC resistance (2-5)	2.15 Ω
Operating temperature	−40 °C to +125 °C

8.3 Heater transformer

Wurth Electronics Midcom Inc., part number: 760800001

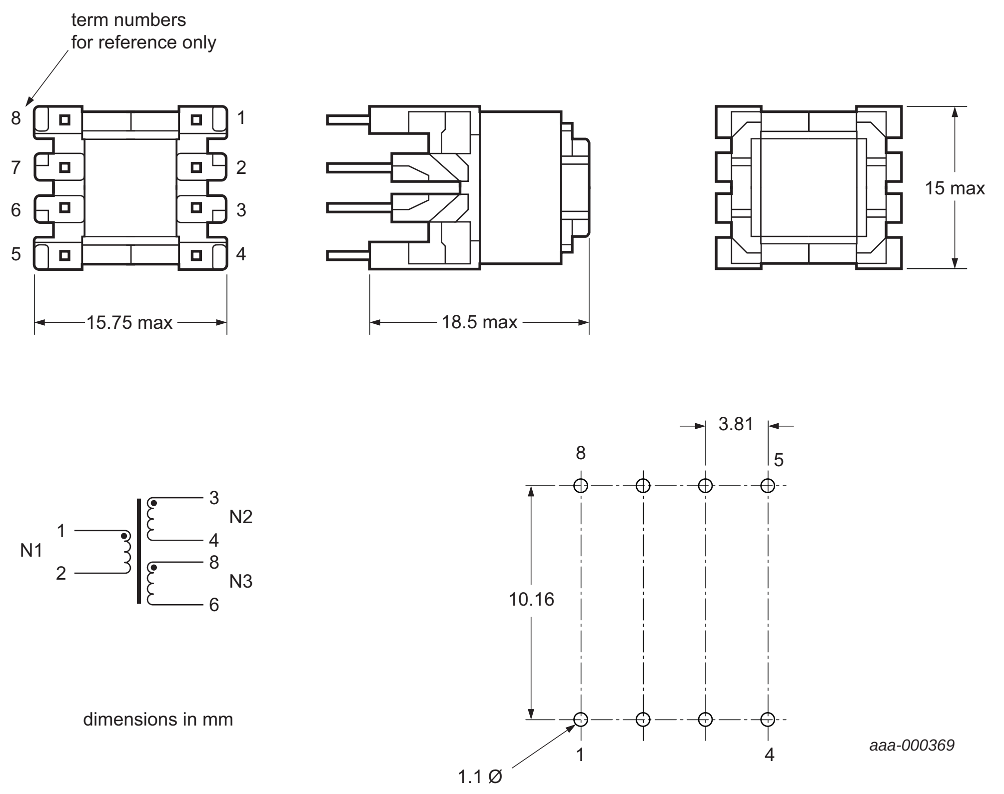


Fig 20. Heater transformer appearance and dimensions

Table 20. Heater transformer electrical specifications

Parameter	Value
Inductance (1-2)	127 µH
Inductance (3-4) and (8-6)	4.1 µH
Saturation current (1-2)	2.5 A
Rated current (1-2)	0.7 A
Dielectric rating (5-9)	2 kV (AC)
DC resistance (1-2)	0.30 Ω
DC resistance (3-4) and (8-6)	0.11 Ω
Operating temperature	–40 °C to +125 °C

8.4 Dim transformer

Wurth Electronics Midcom Inc., part number: 750311081

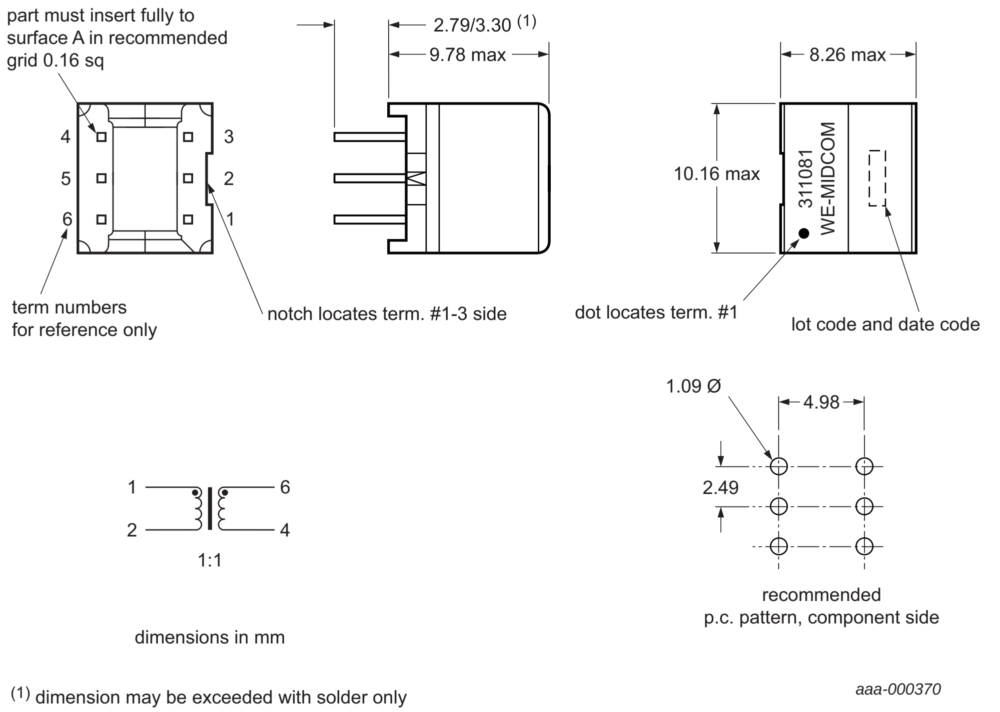


Fig 21. Heater transformer appearance and dimensions

Table 21. Dim transformer electrical specifications

Parameter	Value
Inductance (1-2) and (6-4)	10 mH
Turns ratio (1-2) : (6-4)	1
Leakage inductance	10 µH
Dielectric rating (5-9)	1.5 kV (AC)
DC resistance (1-2)	2.30 Ω
DC resistance (6-4)	2.70 Ω
Operating temperature	–40 °C to +125 °C

9. Abbreviations

Table 22. Abbreviations

Acronym	Description
CMP	Capacitive Mode Protection
EMC	ElectroMagnetic Compatibility
EMI	ElectroMagnetic Interference
HBC	Half-Bridge resonant Converter
MOSFET	Metal-Oxide Semiconductor Field-Effect Transistor
OCP	OverCurrent Protection
OPP	OverPower Protection
OVP	OverVoltage Protection
OLP	Open-Loop Protection
PCB	Printed-Circuit Board
PFC	Power Factor Correction
RMS	Root Mean Square
SoS	Sum of Squares
ZVS	Zero Voltage Switching

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