UM10440

UBA2015AT Reference Design 230 V (AC)

Rev. 1.1 — 3 February 2012 **User manual**

Document information

Info	Content
Keywords	UBA2015AT, dimmable, 2x T5 35 W ballast
Abstract	This document describes the UBA2015AT reference design for 230 V (AC). This dimmable design drives two 35 W T5 lamps. This user manual describes the performances, technical data and wiring of the reference design.

Revision history

Rev	Date	Description
v.1.1	20120203	second issue
v.1	20111121	first issue

Contact information

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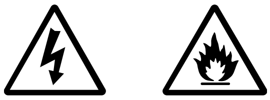
1. Introduction

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 UBA2015AT reference design is intended to serve as a dimmable two lamp ballast example. This document describes the specification and use of the UBA2015AT board. This reference ballast design is intended to drive two T5 35 W lamps.

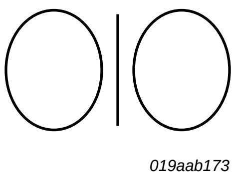
a. top view.

b. bottom view.

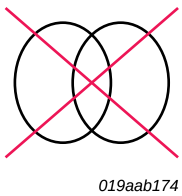
Fig 1. Photograph of the UBA2015AT reference design

2. Safety warning

Connected the board to the mains voltage. Avoid touching the 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. Variac isolation symbols

3. Specifications

Table 1. Specifications for the reference board

Parameter	Comment
ballast type	electronic
starting method	programmed start with preheat
starting time	< 1 s
lamp terminals	7
line voltage	220 V (AC) to 240 V (AC),
line frequency	50 Hz/60 Hz
lamp type	T5 35W
number of lamps	2
dimming interface	1 V to 10 V
transient protection	complies with IEC 61547

Table 2. Ballast performance

Lamp type	Number of lamps	Lamp power (W)	Maximum THD (%)	Power factor	I_{lamp}		
					maximum crest factor	nominal (A)	minimum (mA)
T5 35W	2	35	10	> 0.99	1.7	0.17	5

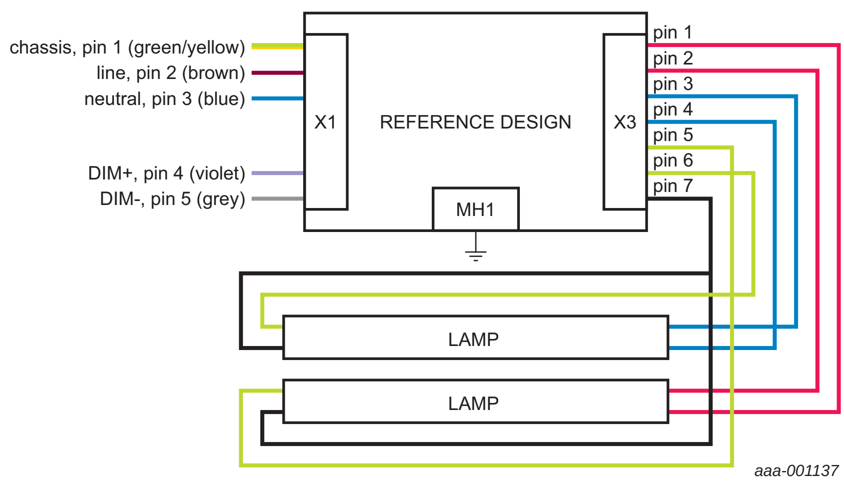


Fig 3. Wiring diagram

Remark: Connected the ballast as shown in Figure 3. When no dimming is needed, do not connect (floating) the dim input.

Remark: The chassis connection must connect to the earth using mounting hole MH1.

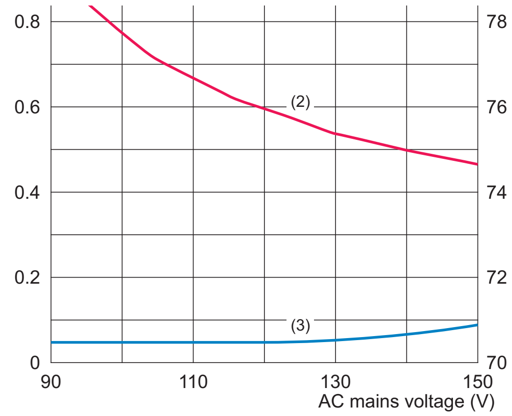
3.1 Dimming without using an external voltage source

The ballast is dimmed with a voltage source of 1 V (DC) to 10 V (DC) connected to connector X1.

It is also possible to dim with an external logarithmic potentiometer of 470 kΩ (for example, no external voltage supply is available). The potentiometer must connect to pin 5 (grey wire, DIM–) and pin 4 (violet wire, DIM+) of connector X1.

4. Performance data

4.1 Efficiency, power factor and THD



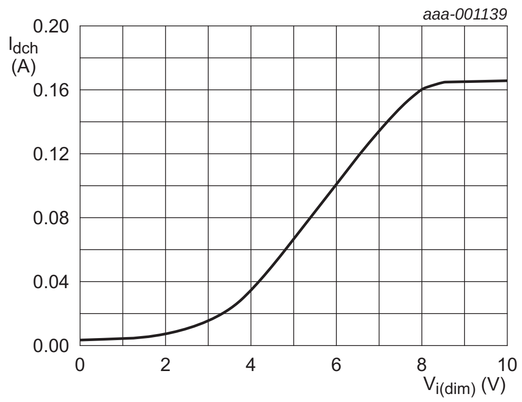
(1) Power factor.

(2) Input power.

(3) Current THD.

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

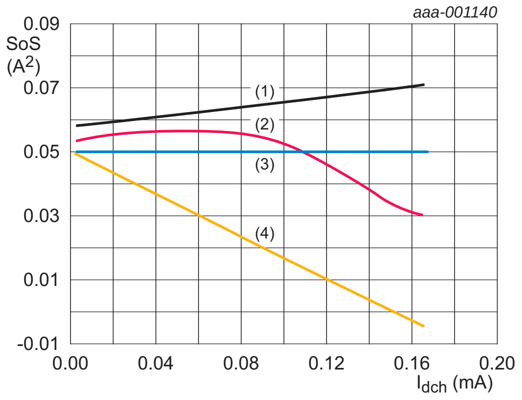
4.2 Dimming curve



(1) Measured with an AC coupled current probe

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

4.3 Sum of Squares (SoS) curve



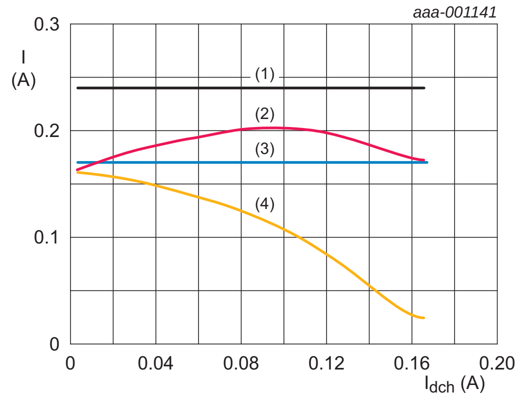
(1) SoS (maximum).

(2) SoS measured.

(3) SoS target.

(4) SoS (minimum).

a. SoS results



(1) I_{LH} (maximum).

(2) I_{L2} measured.

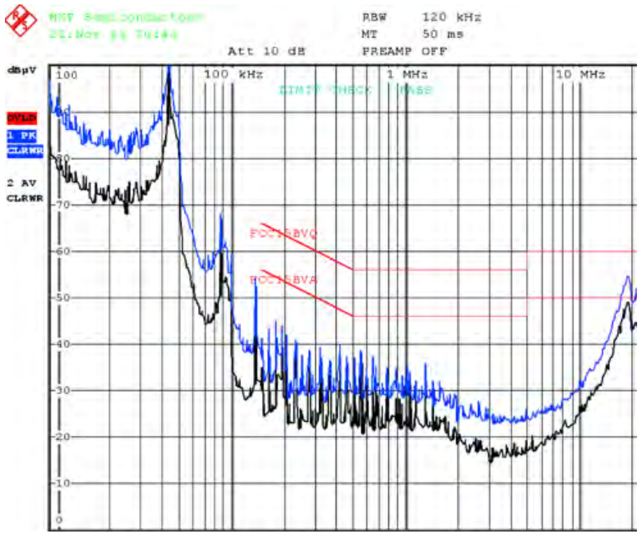
(3) I_{LL} (maximum).

(4) I_{L1} measured.

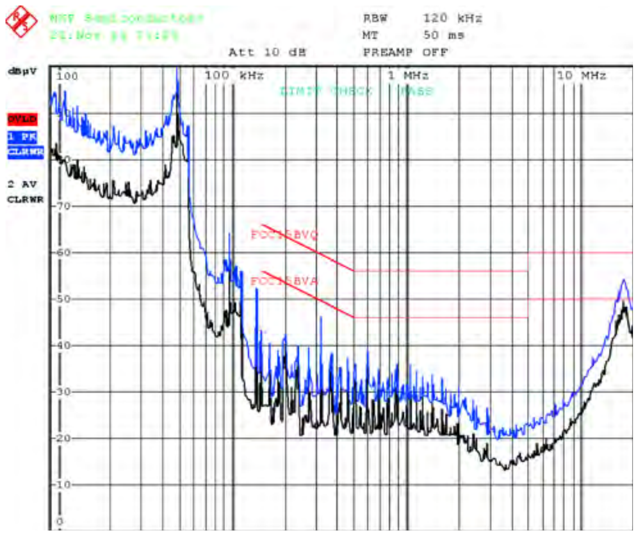
b. Maximum lead current check

Fig 6. Sum of Squares and maximum lead current check

4.4 ElectroMagnetic Interference (EMI) emission tests



a. 230 V (AC) Line



b. 230 V (AC) Neutral

Fig 7. EMI – conducted emission test results

5. Board Information

The input section includes:

- the fuse
- surge protection against fast AC transients
- EMI filter
- full-wave rectifier
- pre-conditioner or power factor correction (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 UBA2015AT 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.

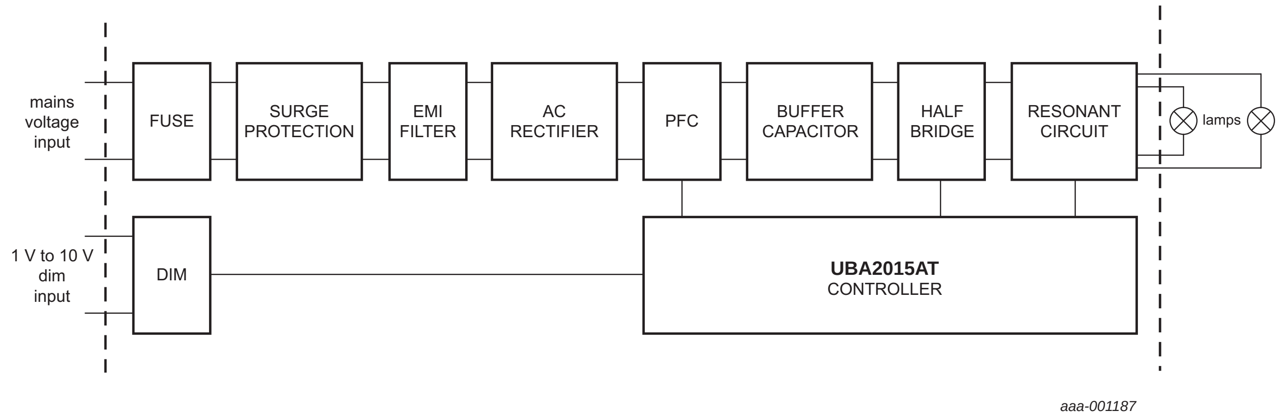


Fig 8. Block diagram

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

5.1 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.

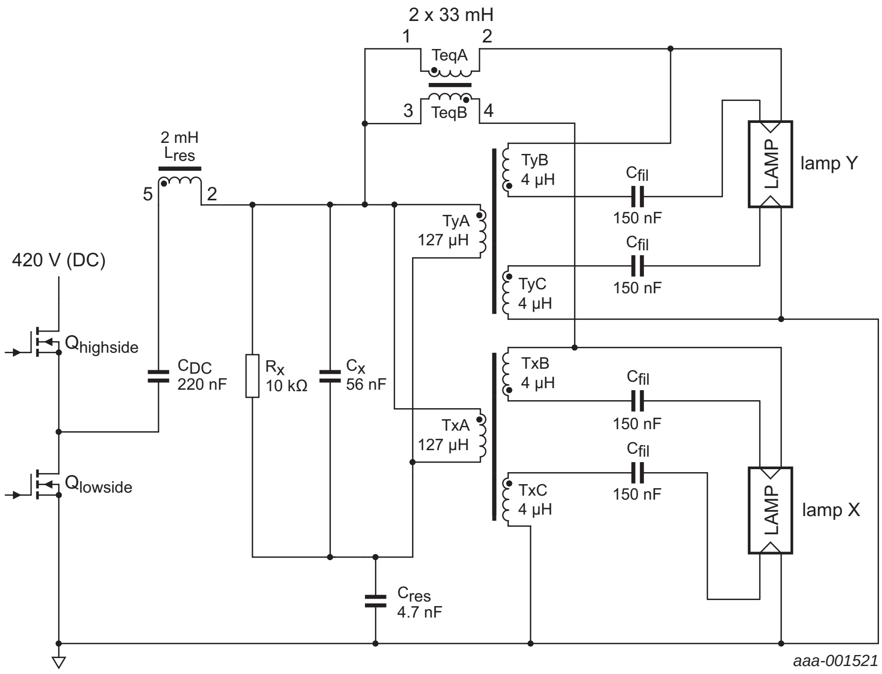


Fig 9. Half-bridge topology

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} ignites the lamp:

$$f_{res} = \frac{1}{2\pi\sqrt{L_{res} \cdot C_{res}}} \rightarrow f_{res} = 51.9\ kHz \quad (1)$$

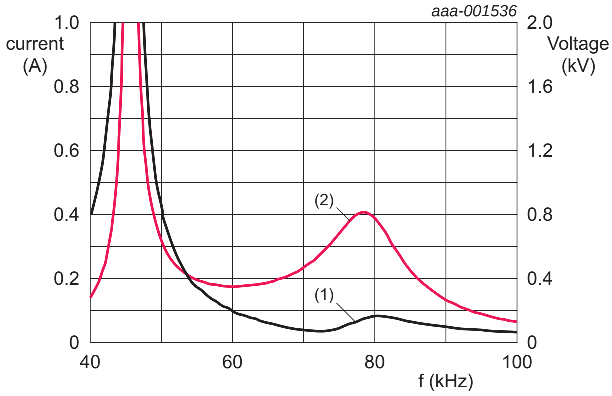
Preheating the electrodes near f_{sec} increases the preheat current without increasing the filament current during normal operation. In dimmable applications, this aids compliance with the lamp sum of squares requirement.

$$f_{sec} = \frac{1}{2\pi\sqrt{\frac{L_{TxA} \cdot L_{TyA}}{L_{TxA} + L_{TyA}} \cdot C_x}} \rightarrow f_{sec} = 84.8\ kHz \quad (2)$$

Rx is used to limit the voltage when both lamps are removed.

An equalizer transformer Teq is used to equalize the lamp currents which is needed in deep dim settings.

The UBA2015AT 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.



(1) LC tank voltage.

(2) I_{fil}.

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

5.2 Schematic diagrams

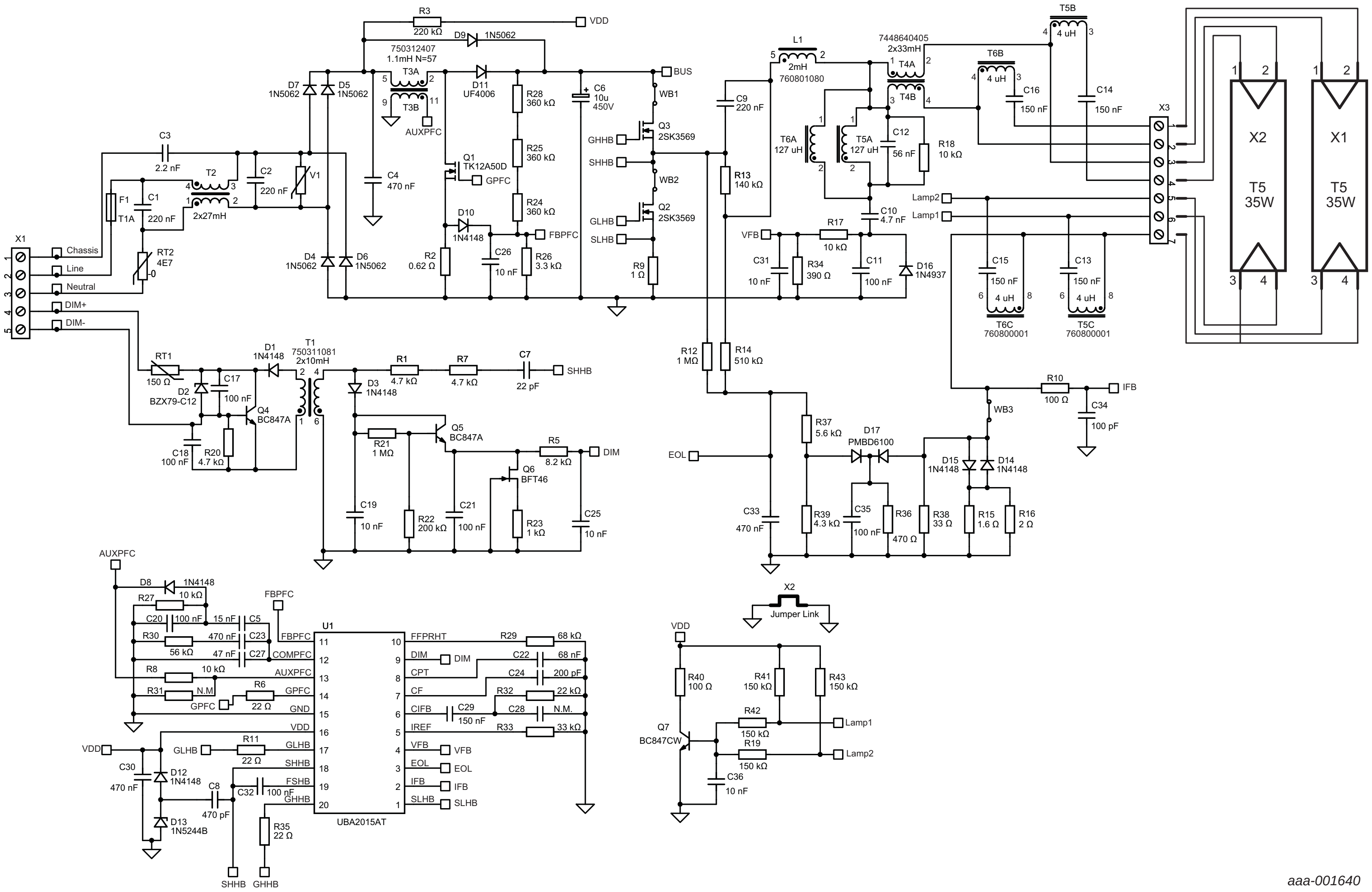


Fig 11. Schematic diagram

5.3 Functional description

The mains voltage is applied to the board and current flows through R3 and R4 to the supply of the controller (VDD pin). When the current through R3 and R4 is higher than 240 μA ($I_{stb(VDD)}$) of 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 C32 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 C8 takes over the VDD supply to supply the IC with enough energy for the gate drivers. The preheat timer starts and the controller sweeps down the frequency 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 the half-bridge switching frequency. The lamp ignites when the LC tank voltage reaches the lamp ignition voltage. The ignition frequency is typically 60 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 protective 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 controlled. It reaches the set point when the average absolute IFB pin voltage equals the DIM pin voltage.

5.3.1 Start-up current and relamp function

The VDD supply of the IC is charged with a start-up current derived from the rectified mains voltage. Resistors R3 and R4 provide the current path and determines the start-up voltage level.

When the lamp is removed while set to deep dimming, the protection must trigger the controller to shut down. In this board, transistor Q7 pulls down the VDD voltage. The signals Lamp1 and Lamp2 sense the filaments of the lamps and control transistor Q7. The pull down by Q7 is released when all lamps are inserted.

6. Board layouts

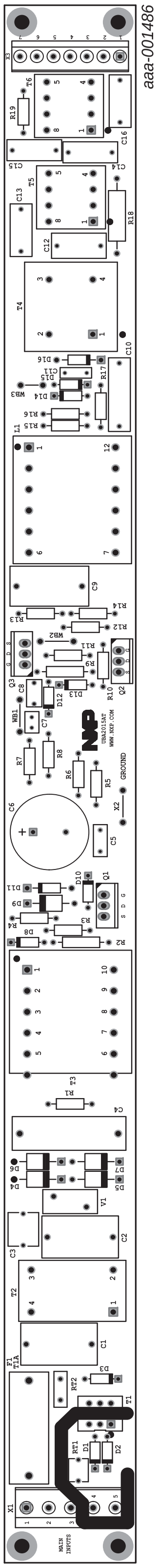


Fig 12. Evaluation board (top view)

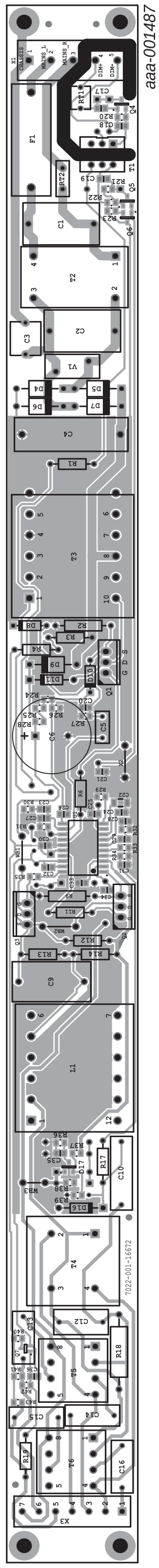


Fig 13. Evaluation board (bottom view)

7. Bill of materials

Table 3. Bill of materials

Part reference	Description/Value	Part number	Manufacturer
0001	PCB UBA2015AT	7022-001-16672	NXP Semiconductors
C1	220 nF; 20 %;275 V	BFC233620224	Vishay
C2	220 nF; 20 %;275 V	BFC233620224	Vishay
C3	2.2 nF; 20 %; 250 V	DE2E3KH222MA3B	Murata
C4	470 nF; 10 %; 400 V	BFC236855474	Vishay
C5	2.2 nF; 10 %; 100 V	MCRR50222X7RK0100	Multicomp
C6	22 μF; 20 %; 450 V	EEU-EB2W220S	Panasonic
C7	22 pF; 5 %; 50 V	1C10C0G220J050B	Vishay
C8	470 pF; 10 %; 1 kV	F471K29Y5RN6UK5R	Vishay
C9	220 nF; 10 %; 400 V	146-MEF2G224K	Xicon
C10	4.7 nF; 5 %; 2 kV	BFC238560472	Vishay
C11	100 nF; 5 %;100 V	R82EC3100DQ70J	KEMET
C12	56 nF; 10 %; 400 V	DME4S56K-F	Cornell Dubilier
C13	150 nF; 5 %;250 V	BFC230342154	Vishay
C14	150 nF; 5 %;250 V	BFC230342154	Vishay
C15	150 nF; 5 %;250 V	BFC230342154	Vishay
C16	150 nF; 5 %;250 V	BFC230342154	Vishay
C17	100 nF; 10 %; 50 V	CC0805KRX7R9BB104	Yageo
C18	100 nF; 10 %; 50 V	CC0805KRX7R9BB104	Yageo
C19	10 nF; 10 %;50 V	2222 580 15636	Philips
C20	100 nF; 10 %; 50 V	CC0805KRX7R9BB104	Yageo
C21	100 nF; 10 %; 50 V	CC0805KRX7R9BB104	Yageo
C22	68 nF; 10 %;50 V	2222 581 15647	Philips
C23	470 nF; 10 %; 25 V	C0805X474K3RACTU	KEMET
C24	200 pF; 1 %; 50 V	GRM2165C1H201FA01D	Murata
C25	10 nF; 10 %;50 V	2222 580 15636	Philips
C26	10 nF; 10 %;50 V	2222 580 15636	Philips
C27	22 nF; 10 %;50 V	2222 580 15641	Philips
C29	150 nF; 10 %; 50 V	C0805C154K5RACTU	KEMET
C30	470 nF; 10 %; 25 V	C0805X474K3RACTU	KEMET
C31	10 nF; 10 %;50 V	2222 580 15636	Philips
C32	100 nF; 10 %; 50 V	CC0805KRX7R9BB104	Yageo
C33	470 nF; 10 %; 25 V	C0805X474K3RACTU	KEMET
C34	100 pF; 2 %;50 V	2222 861 74101	Philips
C35	100 nF; 10 %; 50 V	CC0805KRX7R9BB104	Yageo
C36	10 nF; 5 %; 50 V (DC)	C0805C103J5GAC	KEMET
D1	1N4148	1N4148,133	NXP Semiconductors
D2	BZX79-C12	BZX79-C12, 133	NXP Semiconductors

Table 3. Bill of materials *...continued*

Part reference	Description/Value	Part number	Manufacturer
D3	1N4148	1N4148,133	NXP Semiconductors
D4	1N5062; 800 V; 2 A	1N5062-TR	Vishay
D5	1N5062; 800 V; 2 A	1N5062-TR	Vishay
D6	1N5062; 800 V; 2 A	1N5062-TR	Vishay
D7	1N5062; 800 V; 2 A	1N5062-TR	Vishay
D8	1N4148	1N4148,133	NXP Semiconductors
D9	1N5062; 800 V; 2 A	1N5062-TR	Vishay
D10	1N4148	1N4148,133	NXP Semiconductors
D11	UF4006-E3/73	UF4006-E3;73	Vishay
D12	1N4148	1N4148,133	NXP Semiconductors
D13	1N5244B	1N5244B	Fairchild
D14	1N4148	1N4148,133	NXP Semiconductors
D15	1N4148	1N4148,133	NXP Semiconductors
D16	1N4937/54 600 V; 1 A	1N4937-E3;54	Vishay
D17	PMBD6100; 85 V; 0.2152 A	PMBD6100.215	NXP Semiconductors
F1	fuse ceramic; 1 A	0001.2504	SCHURTER
L1	HB inductor; 2 mH; 2.6 A	760801080	Würth Elektronik
Q1	2SK3767	2SK3767(Q)	Toshiba
Q2	2SK3569	2SK3569	Toshiba
Q3	2SK3569	2SK3569	Toshiba
Q4	BC847A	BC847A	NXP Semiconductors
Q5	BC847A	BC847A	NXP Semiconductors
Q6	BFT46	BFT46	NXP Semiconductors
Q7	BC847CW	BC847CW,115	NXP Semiconductors
R1	4.7 kΩ; 1 %; 350 V; 0.6 W	MRS25000C4701FCT00	Vishay
R2	1.5 Ω; 5 %; 350 V; 1 W	PR01000101508JA100	Vishay
R3	270 kΩ; 1 %; 350 V; 0.6 W	MRS25000C2703FCT00	Vishay
R4	270 kΩ; 1 %; 350 V; 0.6 W	MRS25000C2703FCT00	Vishay
R5	8.2 kΩ; 1 %; 350 V; 0.6 W	MRS25000C8201FCT00	Vishay
R6	22 Ω; 1 %; 350 V; 0.6 W	MRS25000C2209FCT00	Vishay
R7	4.7 kΩ; 1 %; 350 V; 0.6 W	MRS25000C4701FCT00	Vishay
R8	10 kΩ; 1 %; 350 V; 0.6 W	MRS25000C1002FCT00	Vishay
R9	1 Ω; 5 %; 350 V; 1 W	PR01000101008JR500	Vishay
R10	100 Ω; 1 %; 350 V; 0.6 W	MRS25000C1000FCT00	Vishay
R11	22 Ω; 1 %; 350 V; 0.6 W	MRS25000C2209FCT00	Vishay
R12	1 MΩ; 1 %; 350 V; 0.6 W	MRS25000C1004FCT00	Vishay
R13	140 kΩ; 1 %; 350 V; 0.6 W	MRS25000C1403FCT00	Vishay
R14	510 kΩ; 1 %; 350 V; 0.6 W	MRS25000C5103FCT00	Vishay
R15	1.6 Ω; 1 %; 350 V; 0.6 W	MRS25000C1608FCT00	Vishay
R16	2.0 Ω; 1 %; 350 V; 0.6 W	MRS25000C2008FCT00	Vishay

Table 3. Bill of materials *...continued*

Part reference	Description/Value	Part number	Manufacturer
R17	10 Ω; 1 %; 350 V; 0.6 W	MRS25000C1002FCT00	Vishay
R18	10 kΩ; 5 %; 500 V; 2 W	PR02000201002JR500	Vishay
R19	150 kΩ; 1 %; 350 V; 0.6 W	MRS25000C1503FCT00	Vishay
R20	4.7 Ω; 1 %; 150 V; 0.125 W	RC0805FR-074K7L	Yageo
R21	1 MΩ; 1 %; 150 V; 0.125 W	RC0805FR-071ML	Yageo
R22	200 kΩ; 1 %; 150 V; 0.1 W	2322 734 62004	Yageo
R23	1 kΩ; 1 %; 150 V; 0.125 W	RC0805FR-071KL	Yageo
R24	360 kΩ; 1 %; 150 V; 0.1 W	2322 734 63604	Yageo
R25	360 kΩ; 1 %; 150 V; 0.1 W	2322 734 63604	Yageo
R26	3.3 kΩ; 1 %; 150 V; 0.125 W	RC0805FR-073K3L	Yageo
R27	1 kΩ; 1 %; 150 V; 0.125 W	RC0805FR-071KL	Yageo
R28	360 kΩ; 1 %; 150 V; 0.1 W	2322 734 63604	Yageo
R29	68 kΩ; 1 %; 150 V; 0.125 W	RC0805FR-0768KL	Yageo
R30	56 kΩ; 1 %; 150 V; 0.125 W	RC0805FR-0756KL	Yageo
R32	22 kΩ; 1 %; 150 V; 0.125 W	RC0805FR-0722KL	Yageo
R33	33 kΩ; 1 %; 150 V; 0.125 W	RC0805FR-0733KL	Yageo
R34	390 Ω; 1 %; 150 V; 0.125 W	RC0805FR-07330RL	Yageo
R35	22 Ω; 1 %; 150 V; 0.125 W	RC0805FR-0722RL	Yageo
R36	470 Ω; 1 %; 150 V; 0.125 W	RC0805FR-07470RL	Yageo
R37	5.6 kΩ; 1 %; 150 V; 0.125 W	RC0805FR-075K6L	Yageo
R38	33 Ω; 1 %; 150 V; 0.125 W	RC0805FR-0733RL	Yageo
R39	4.3 kΩ; 1 %; 150 V; 0.1 W	MC 0.1W 0805 1% 4K3	Multicomp
R40	100 Ω; 1 %; 150 V; 0.125 W	RC0805FR-07100RL	Yageo
R41	150 kΩ; 1 %; 150 V; 0.125 W	RC0805FR-07150KL	Yageo
R42	150 kΩ; 1 %; 150 V; 0.125 W	RC0805FR-07150KL	Yageo
R43	150 kΩ; 1 %; 150 V; 0.125 W	RC0805FR-07150KL	Yageo
RT1	150 Ω; 25 %; 0;2 A;+85°C	PTGL05AR151H8P52B0	Murata
RT2	4.7 Ω; 20 %; 265 V; 1.4 W	B57153S479M	EPCOS
T1	DIM transformer; Lp = 10 mH; N = 1	750311081	Würth Elektronik
T2	choke; frame core 39 mH; 0.8 A	B82732F2801B001	EPCOS
T3	PFC transformer; Lp = 1.8 mH; 1.43 A; Np : Ns = 60	760801095	Würth Elektronik
T4	equalizer transformer; 2 × 33 mH; 0.3 A	7448640405	Würth Elektronik
T5	heater transformer; Lp = 127 μH; 1.8 A Ls = 4.1 μH	760800001	Würth Elektronik
T6	heater transformer; Lp = 127 μH; 1.8 A; Ls = 4.1 μH	760800001	Würth Elektronik
U1	UBA2015AT	UBA2015AT	NXP Semiconductors
V1	275 V (AC); 85°C; 3.5 kA; 710 V	V10E275P	Littelfuse
WB1	wire-bridge-3E	923345-03-C	3M
WB2	wire-bridge-3E	923345-03-C	3M

Table 3. Bill of materials *…continued*

Part reference	Description/Value	Part number	Manufacturer
WB3	wire-bridge-2E	923345-02-C	3M
X1	screw terminal; MKDSN1;5; 5-5.08	1729157	Phoenix Contact
X2	jumper link	LB 03 G	Fischer Elektronik
X3	screw terminal; MKDS 1; 7-3;81	1727065	Phoenix Contact

8. Inductor appearance and dimensions

8.1 PFC transformer

Wurth Electronics Midcom Inc.; part number: 760801095

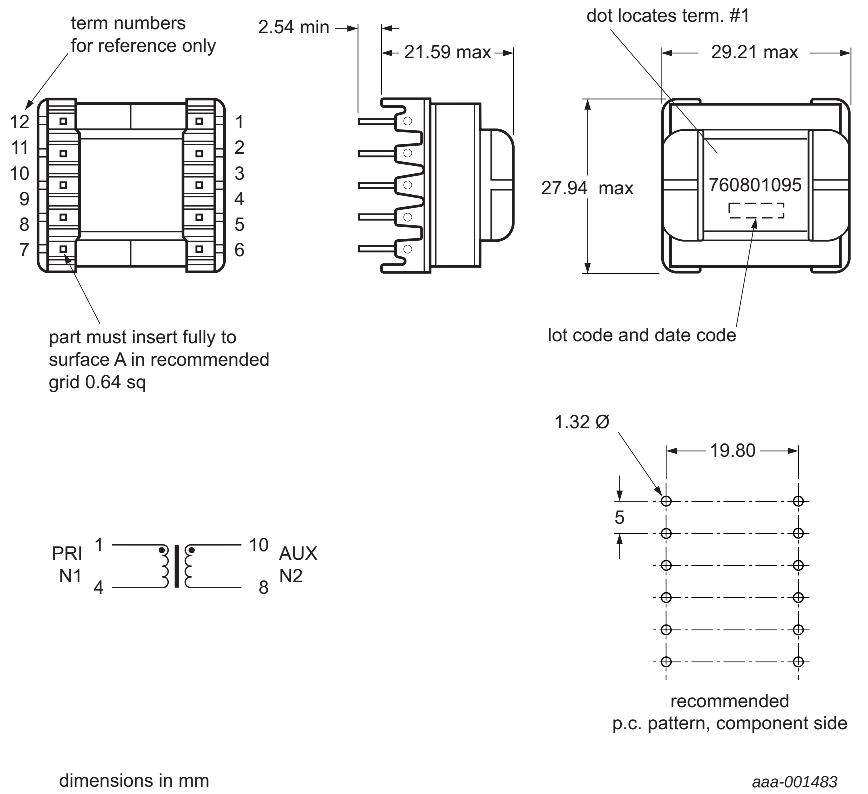


Fig 14. PFC transformer appearance and dimensions

Table 4. PFC transformer electrical specifications

Parameter	Value
Inductance (1 to 4)	1.8 mH
Saturation current (1 to 4)	2 A
Turns ratio (2 to 5) : (8 to 10)	43.33
Leakage inductance	1 µH
Dielectric rating (5 to 9)	1.5 kV (AC)
DC resistance (2 to 5)	1.25 Ω
DC resistance (8 to 10)	120 mΩ
Operating temperature	–40 °C to +125 °C

8.2 Half-bridge inductor

Wurth Electronics Midcom Inc.; part number: 760801080

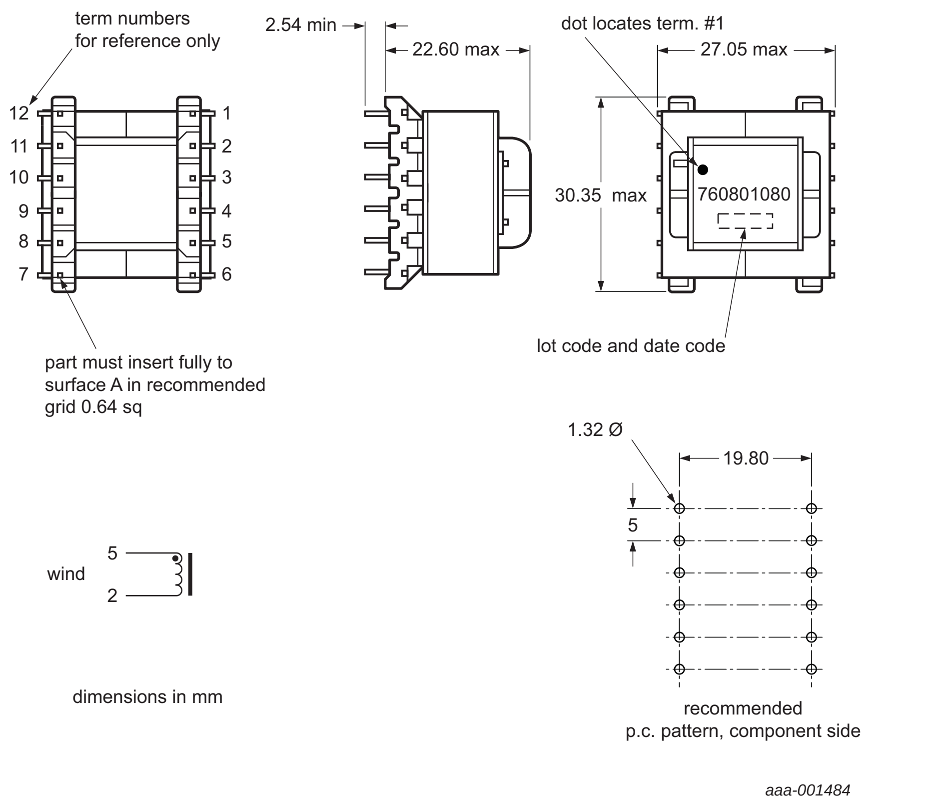


Fig 15. Half-bridge inductor appearance and dimensions

Table 5. Half-bridge inductor electrical specifications

Parameter	Value
Inductance (5 to 2)	2 mH
Saturation current (5 to 2)	2.6 A
DC resistance (5 to 2)	2.15 Ω
Operating temperature	–40 °C to +125 °C

8.3 Heater transformer

Wurth Electronics Midcom Inc.; part number: 760800001

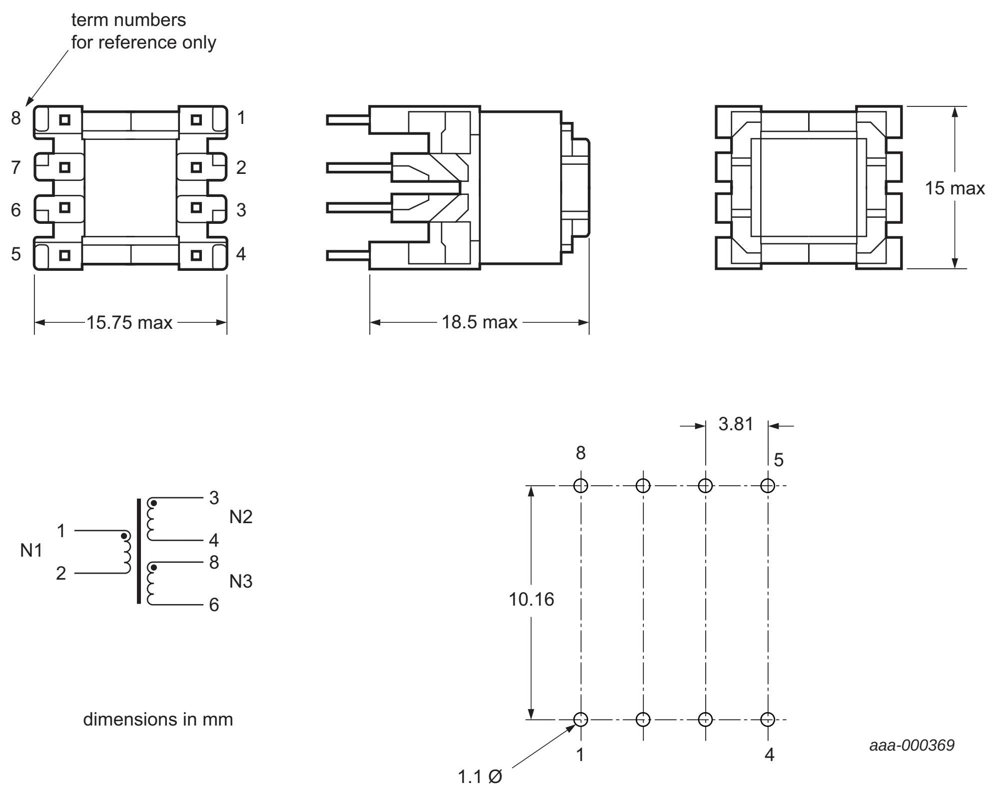


Fig 16. Heater transformer appearance and dimensions

Table 6. Heater transformer electrical specifications

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

8.4 Dim transformer

Wurth Electronics Midcom Inc.; part number: 750311081

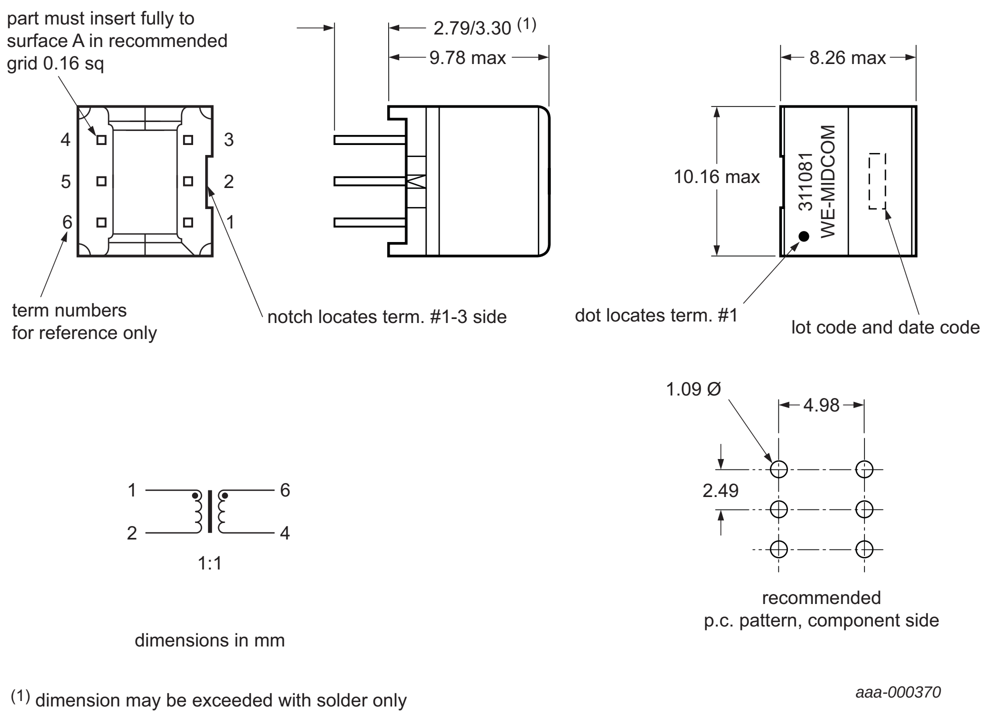


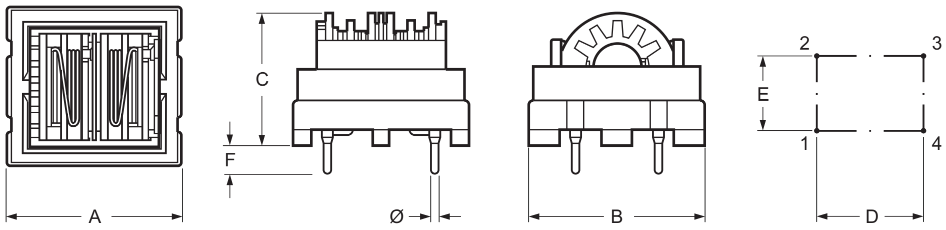
Fig 17. Dim transformer appearance and dimensions

Table 7. Dim transformer electrical specifications

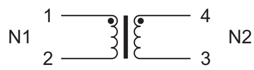
Parameter	Value
Inductance (1 to 2) and (6 to 4)	10 mH
Turns ratio (1 to 2) : (6 to 4)	1
Leakage inductance	10 μH
Dielectric rating (5 to 9)	1.5 kV (AC)
DC resistance (1 to 2)	2.30 Ω
DC resistance (6 to 4)	2.70 Ω
Operating temperature	−40 °C to +125 °C

8.5 Equalizing transformer

Wurth Electronics Midcom Inc.; part number: 7448640405



A	21.2 max	mm
B	21.2 max	mm
C	17.8 max	mm
D	13.0 ± 0,2	mm
E	10.0 ± 0,2	mm
F	4.5 max	mm
Ø	0.8 typ	mm



aaa-001485

Fig 18. Equalizing transformer appearance and dimensions

Table 8. Equalizing transformer electrical specifications

Parameter	Value
Inductance L0	33 mH
Turns ratio (1 to 2) : (6 to 4)	1
Rated current	0.3 A
Dielectric rating	2 kV; 50 Hz
DC resistance	2 Ω
Operating temperature	–25 °C to +125 °C

9. Abbreviations

Table 9. Abbreviations

Acronym	Description
EMI	ElectroMagnetic Interference
MOSFET	Metal-Oxide Semiconductor Field-Effect Transistor
OLP	Open-Loop Protection
PCB	Printed-Circuit Board
PFC	Power Factor Correction
SoS	Sum of Squares
THD	Third order Harmonic Distortion

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11. Contents

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