How to …?

How to design truly energy saving lighting applications with less reactive power?

by Productivity Engineering GmbH

New power supply solutions for LED lighting and fluorescent energy saving lamps involve PFC !

What is power factor correction (PFC) good for? PFC avoids apparent power being drawn from the power grid. This apparent power becomes larger as the phase shift between current and voltage gets larger due to more capacitive or inductive loads. Such load behavior can be observed with LED light stripes or very often with fluorescent lamps. This topic is generally neglected since the apparent power is not paid for by private utility customers whereas large enterprises already pay for it. This becomes increasingly important with the change towards new lighting sources that require electronic circuitry. Without this power factor correcting circuitry the power grid would be heavily loaded with apparent power. Also, it is not to be forgotten that this power has to be generated in power plants as well. Upon a closer look, this makes the energy saving light sources not so effective any more.

For this reason governmental regulations in some countries have been in place for a couple of years now, but not world wide, e.g. the EN61000-3-2. Common incandescent lamps (with a power factor of one) will disappear from the European Union within 2 years. Instead there will be billions of LED and luminescent lamps. They are much more energy efficient but they require electronic circuitry to operate with an 110V or 220V power supply. This circuitry is typically within the housing of the light sources and so is not visible or noticeable to the user.

All of these electronic circuits have in common a rectifier and reservoir or smoothing capacitor on the power supply side. The capacitor is charged to the peak voltage every half cycle period. The charging current depends on how much the capacitor has been discharged by the load. This causes the current not to follow the voltage and in turn to cause a power factor of less than one. Following the rectification step is the circuitry for the special lighting source. With LEDs it is a DC/DC converter. With fluorescent lamps it is an electronic ballast circuit and a resonant tank circuit to ignite and run the lamp. This circuit as well as the DC/DC converter run at a higher frequency and additionally affect the power factor. For Power LEDs the power factor drops to 0.5 and for fluorescent lights it drops to 0.6. The federal regulations require power factor correction for lighting applications above power levels of 25 watts for a single source. These light sources typically have far less wattage when considered alone (3Watt LED/7Watt Fluorescent light bulb), but who in the world has only one of these in their chandeliers? Now if the whole European Union will replace all lights one can imagine what that means. None of the currently available energy saving light bulbs have power factor correction implemented. So it is to be expected that the federal regulations will have to account for these disharmonies (EN61000-3-2, class C).
Expecting this to happen, PE GmbH has developed very efficient electronic solutions for this problem. PE has developed PFC ICs with incomparable low power consumption. They cover a very wide power application range.

Active PFC is based on the principle to make the input current exactly follow the input voltage in such a way that very few frequency harmonics and phase shifts can be observed. This can be done by charging a capacitor with a voltage above the peak voltage of the input voltage (AC line voltage multiplied by sqrt2). This capacitor has enough energy that can be used to adapt the non linear load to draw linear current from the power line.

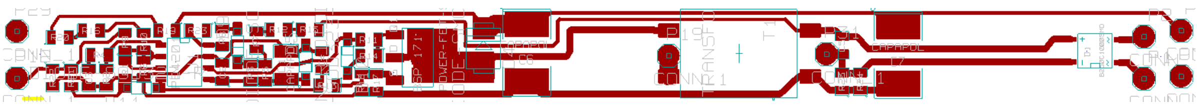
All presented lighting solutions can be used with a standard phase cut-off control for dimming. This standard dimmer is typically used for electronic transformers. Some work also with a phase angel control. This standard dimmer is typically used for light bulbs. Another flexible way to control the brightness of the LEDs is to use a microcontroller with an integrated DAC that drives the VCO input of the PE4201. This way any interface bus can be connected to the PFC circuitry.

If it is not for the PFC, PE GmbH presents very competitive electronic LED lighting solutions. PFC comes as an extra - almost for free.

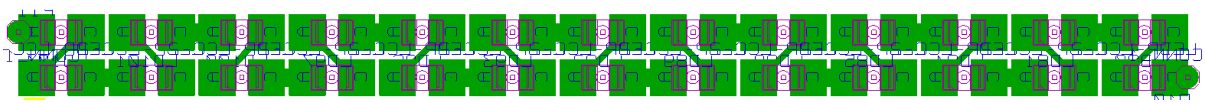
8 Watt 220V LED string with PFC, no galvanic decoupling

Description

A miniaturized PFC board for implementation into a standard light tube (standard 16mm T5 glass tube) using PEs PFC IC PE4201 is described. The advantage of LED based lighting equipment over normal light tubes is the waiving of ballasts or inductors outside the lamp. Also, no mercury needs to be used; though LED based lighting products do not endanger the environment. In addition to the lighter BOM (bill of material), a lot of energy can be saved, since for the same light output, LEDs need half of the power compared to compact fluorescent lamps.



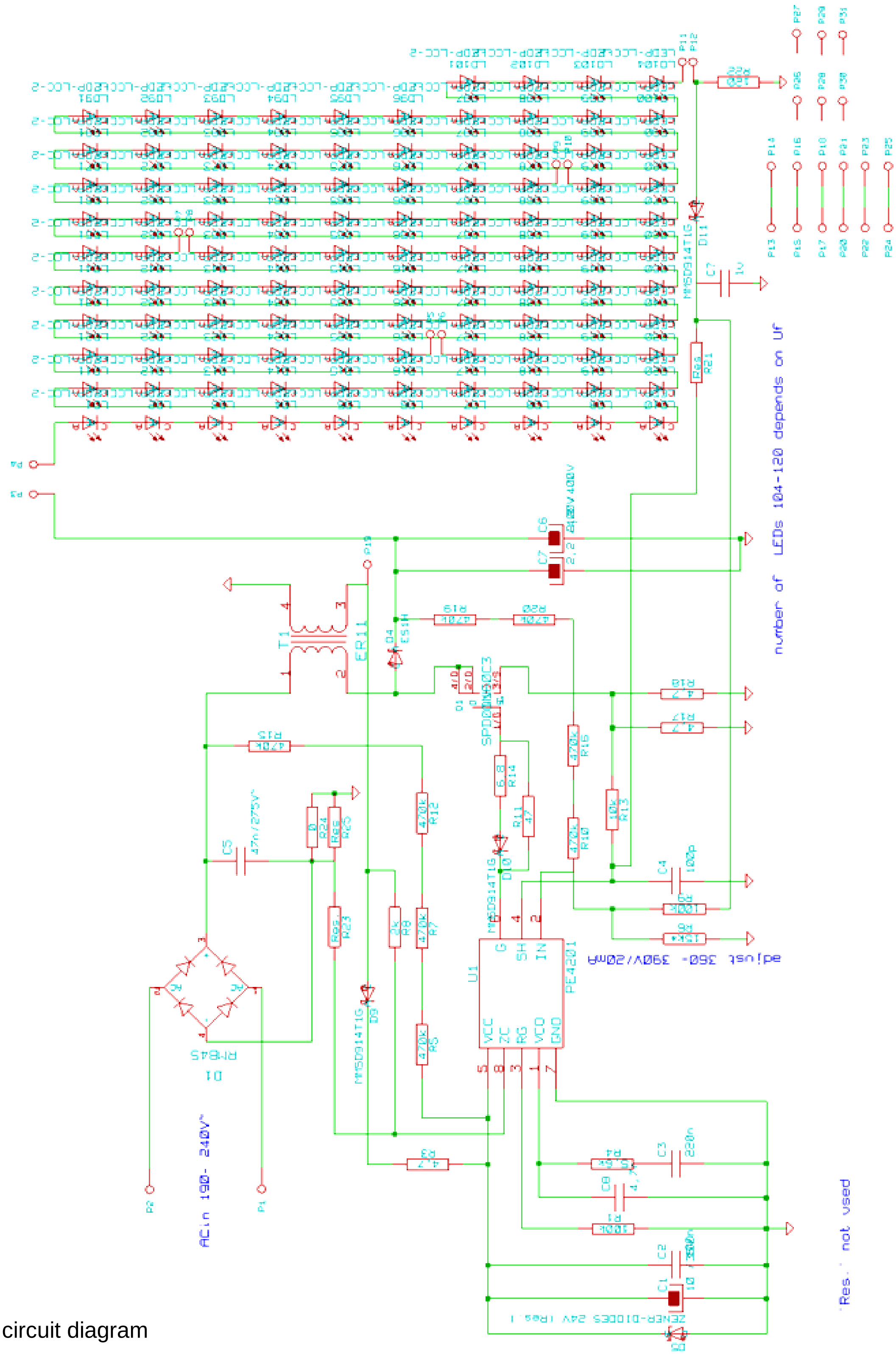
Top view PFC LED tube board (LEDs on the back side of the board, length 540mm)



Bottom view PFC LED tube board (partial view, total amount of LEDs: 104- 120)

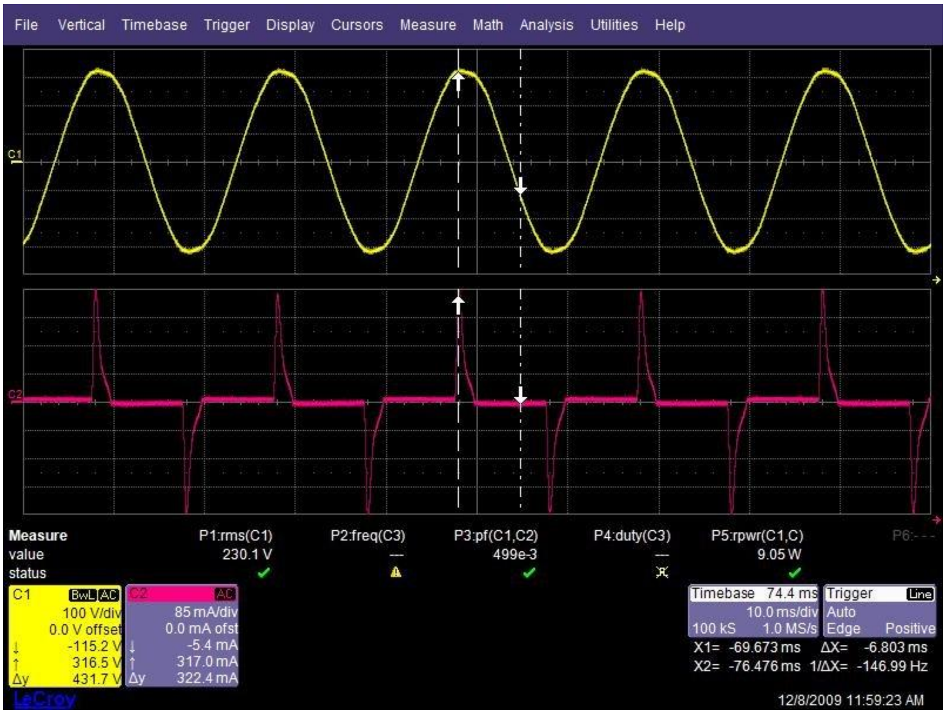
Technical Data

Input voltage ……………………………....	230V (50/60Hz) AC
Output voltage ………………………..….	360- 380V DC (one time to adjust)
Max. input power ……………………..….	8.5 W with PE4201
Efficiency ………………………………..	>90 %
Power factor ..…………………………….	0.90 to 0.98 (depending on power out)
Light output ……………………………...	up to 100lm/W (depending on type of LEDs)
Board dimension ……………………..….	length 540mm, width 10mm, height 10mm

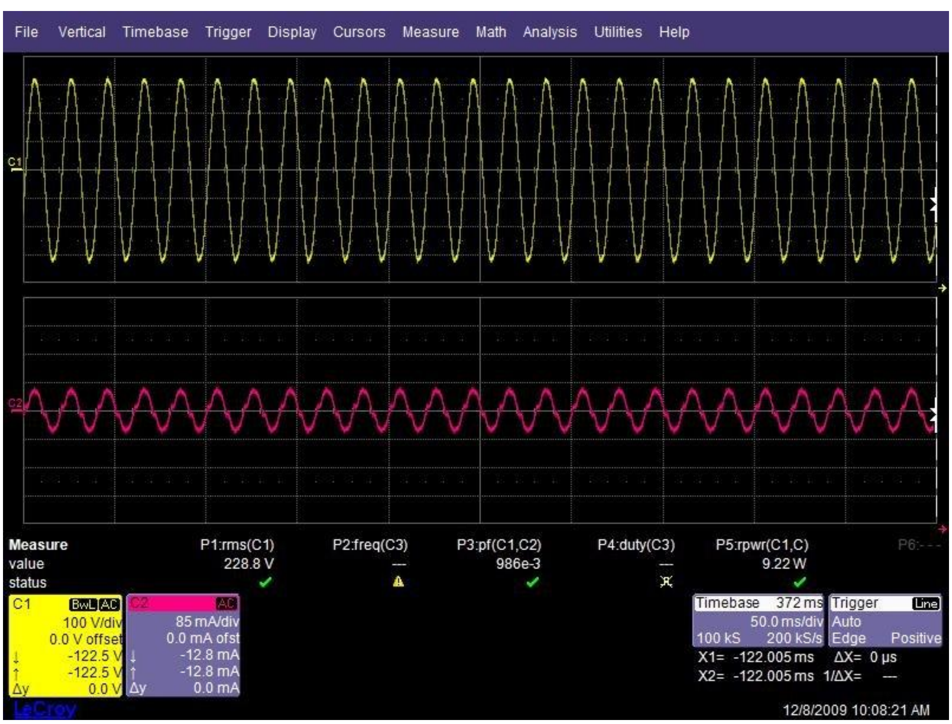


circuit diagram

8 Watt 220V LED string with PFC, no galvanic decoupling



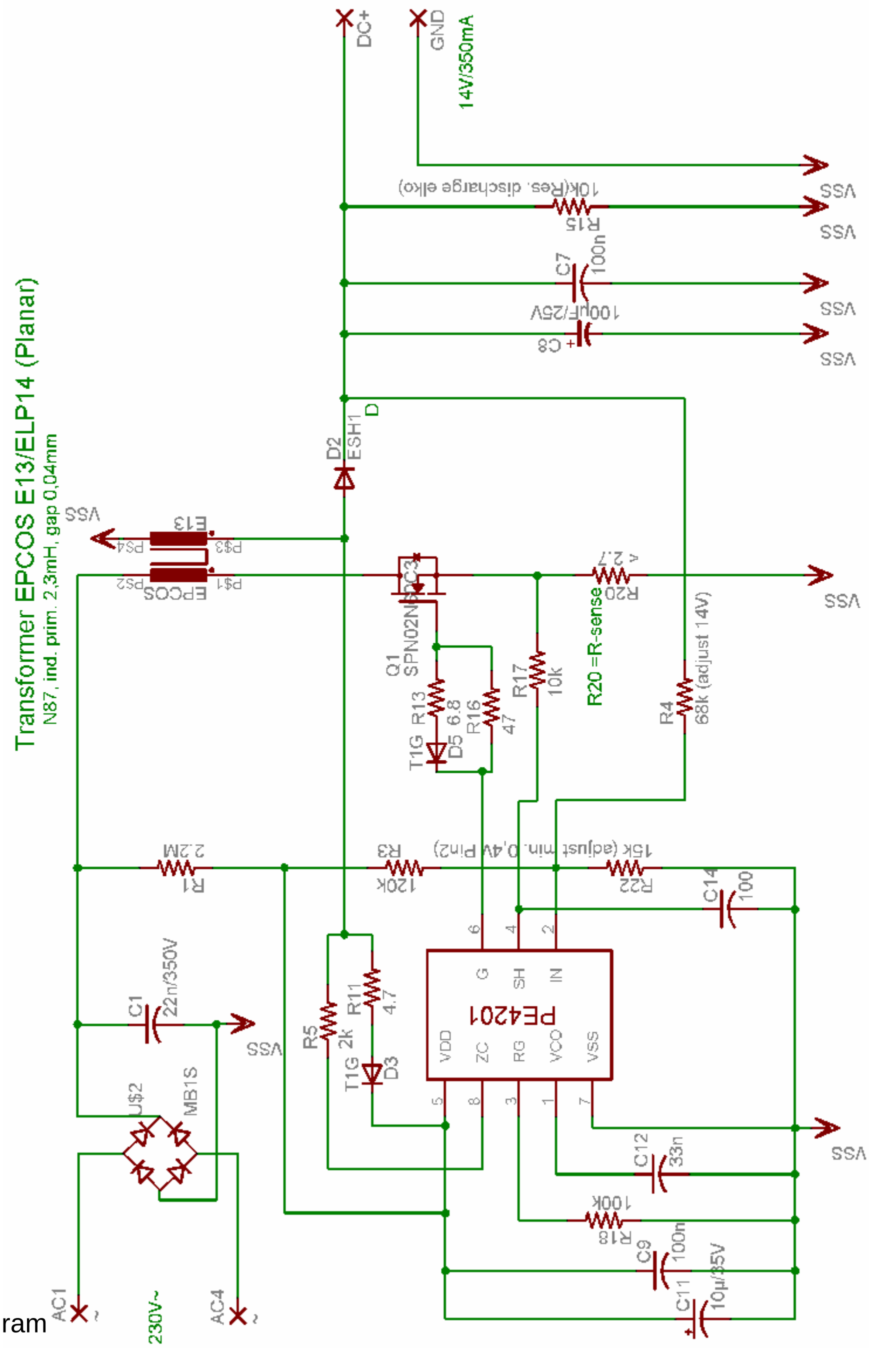
8W LED commercial lamp without PFC, PF=0,499



The same 8W LED lamp with PFC (PE4201), PF=0,986

Technical Data

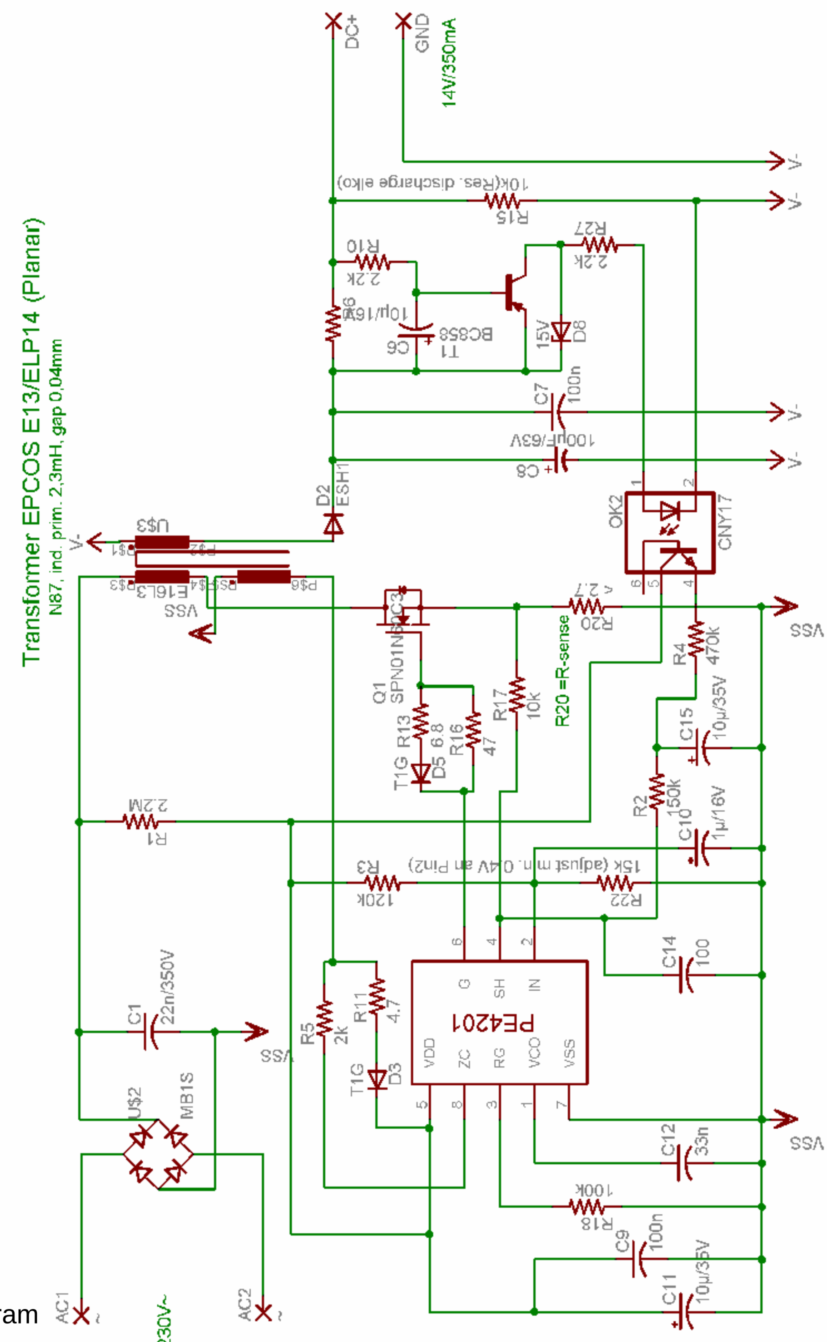
Input voltage …………………190V/240V (50/60Hz) AC
Output voltage ……………… 14V DC (adjustable), 350mA
Max. output ………………… 5 W with PE4201
Efficiency …………………… >82 %
Power factor .……………… 0.90 to 0.98
Output ripple (100Hz)……… 10% (depending on C8)



circuit diagram

Technical Data

Input voltage …………………190V/240V (50/60Hz) AC
Output voltage ……………… 14V DC (adjustable), 350mA
Max. output ………………… 5 W with PE4201
Efficiency …………………… >82 %
Power factor .……………… 0.90 to 0.98
Output ripple (100Hz)……… < 5% (with optocoupler)

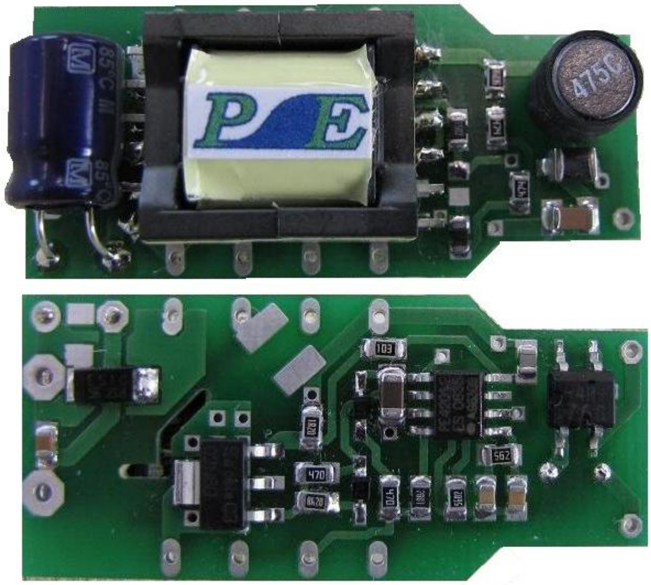


circuit diagram

Technical Data

Input. Voltage ……………	190-240V
Power factor ……………	>= 0,9
Input Power ……………	max. 11VA at 7-8W output power
Isolation ……………	IP20
Output Voltage ……………	21-24V/~330mA
Form factor ……………	fits into E27- Aluminum LED Socket
Operating Temperature…...	0 .. 65°C

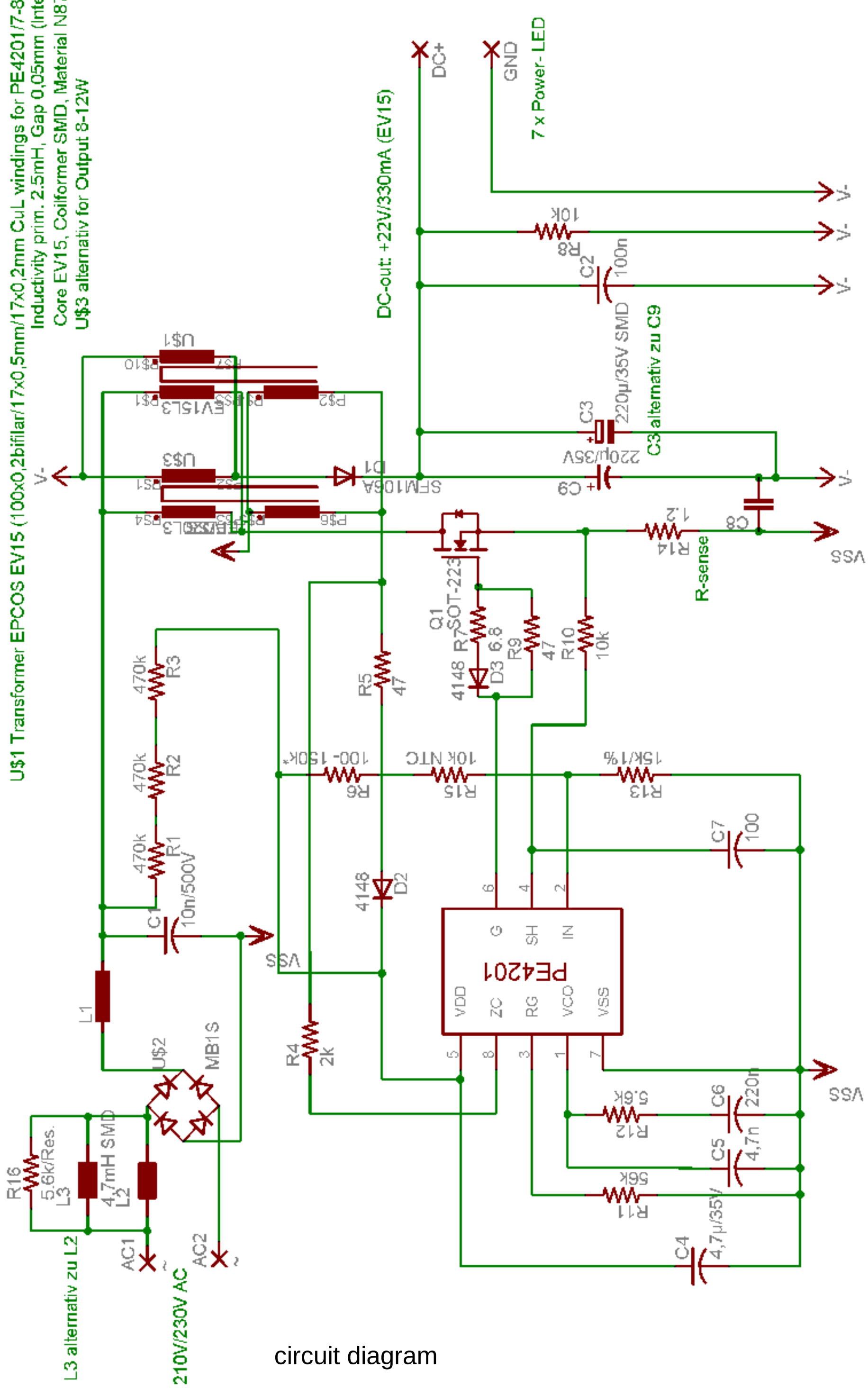
Temperature compensation with NTC



PCB layout

7-11 Watt 220V LED light bulb, galvanic decoupling

*R6 one time adjust max. LED current, to be populated in lamp production
R13 to be optimized for used FET SPN02N60C3 or SPD04N60C3
R13 is to be calculated for max. output current



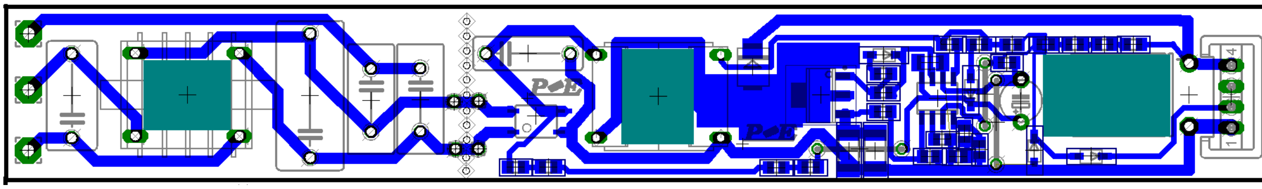
circuit diagram

ISO9001
ISO14001

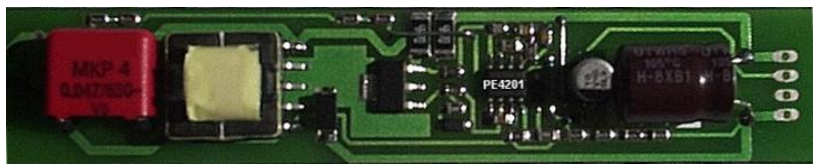
14 Watt 220V LED string with PFC, galvanic decoupling

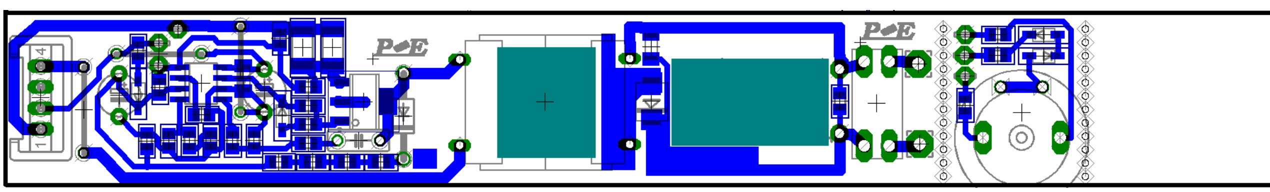
Description

This PFC-DC/DC converter board fits into a standard T8 light tube (28mm aluminium tube) using 2 of PEs PFC IC PE4201. The DC/DC converter is galvanically isolated from mains power, allowing the use of the aluminium profile on the rear side of the tube to effectively cool the LEDs.



PFC board top side





DC/DC board top side

LED tube application, a one-to-one replacement of standard T8 fluorescent lamps by saving about 50% energy (same light output) and longer life cycle of the LED lamp.

Technical Data

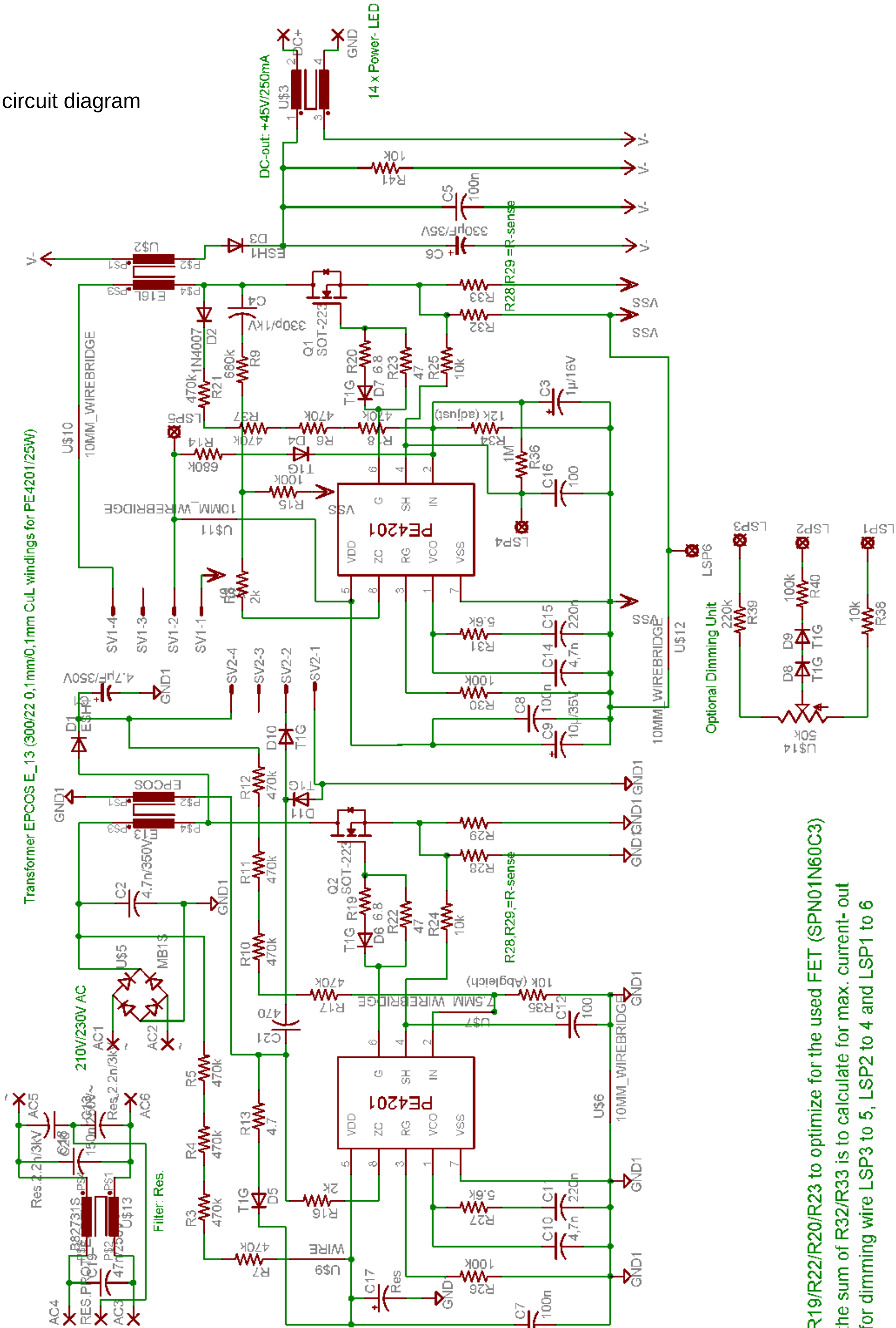
Input voltage …………………………… 230V (50/60Hz) AC
Output voltage ……….………………… 360- 380V DC
Max. input ……………………………..… 14 W with PE4201
Efficiency PFC ………………………… >90 %
Power factor ..………………………..…… 0.95 to 0.98 (depend on power out)
Efficiency DC/DC converter………….... >80 %
DC/DC output …………………..……..… 45V/250mA
Board dimension …………..………….. length 290mm, width 21mm, height ~13mm

The LED board is an aluminium stripe with a length of 120cm (2 stripes 60cm each) with LEDs mounted in a single row (summarizing to 196 LEDs).

Available LED string lights have a power factor of 0.5 only!

14 Watt 220V LED string with PFC, galvanic decoupling

circuit diagram



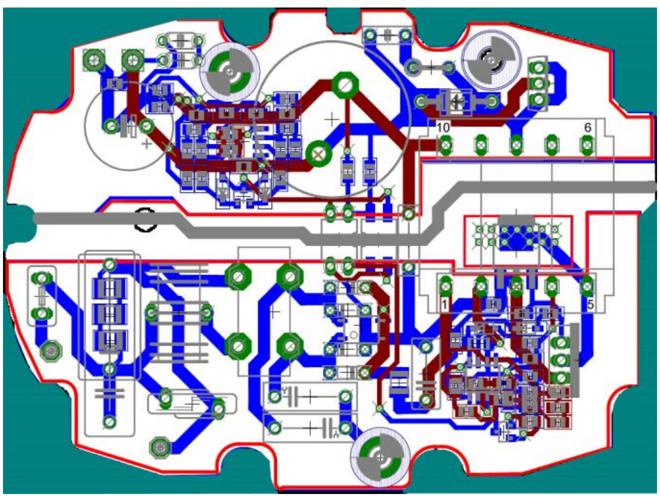
R19/R22/R20/R23 to optimize for the used FET (SPN01N60C3)
the sum of R32/R33 is to calculate for max. current- out
for dimming wire LSP3 to 5, LSP2 to 4 and LSP1 to 6

30 Watt 220V LED Lamp with PFC, galvanic decoupled

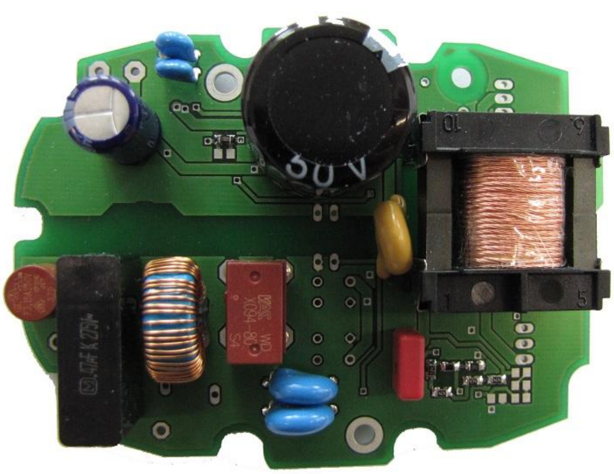
Technical data:

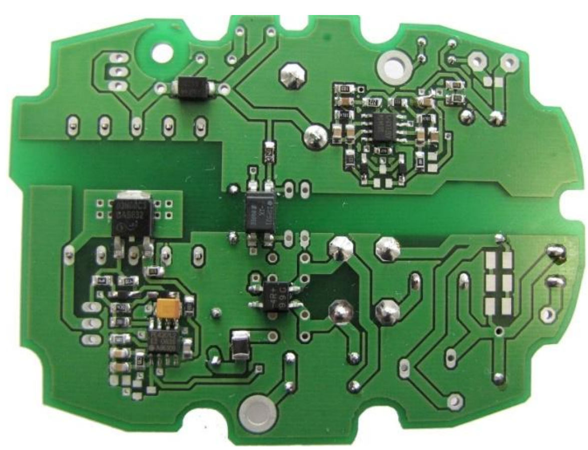
Input voltage ……………....	230VAC
Output voltage ……………	30-34VDC current controlled for 30 LEDs
Output current …………….	ca. 1-1,2A
Input power ……………..…	35-40W
Output ripple ………………	max 20%
Power factor ……………….	> 0,95
Operating temperature …..	-15 .. 65°C
Form factor ………………....	socket E40, LED-lamp on Alu-heatsink for power LEDs (Street light)

Output current control and stabilization, temperature compensation through NTC



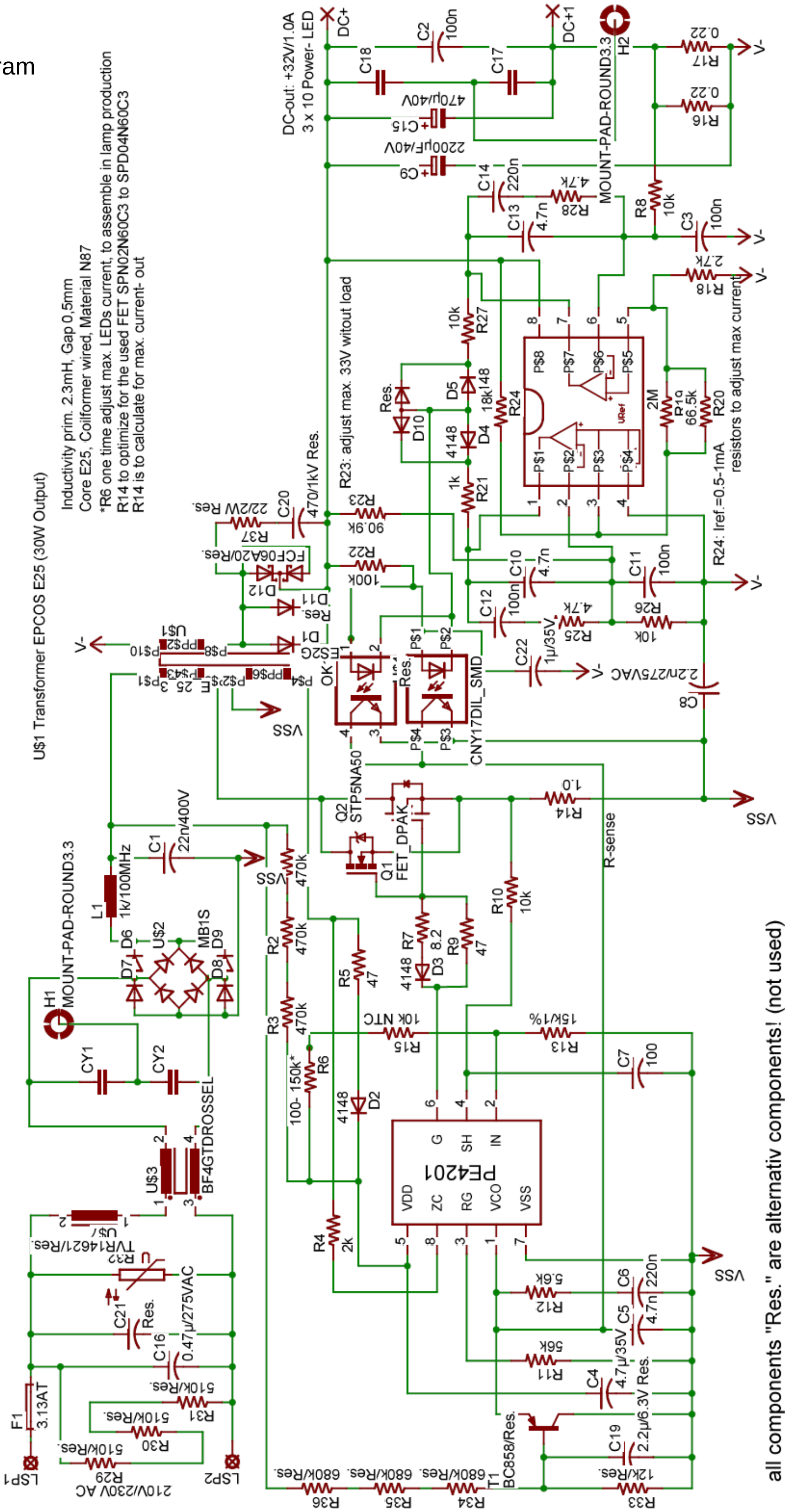
PCB layout for LED street light





30 Watt 220V LED Lamp with PFC, galvanic decoupled

circuit diagram



ISO9001
ISO14001

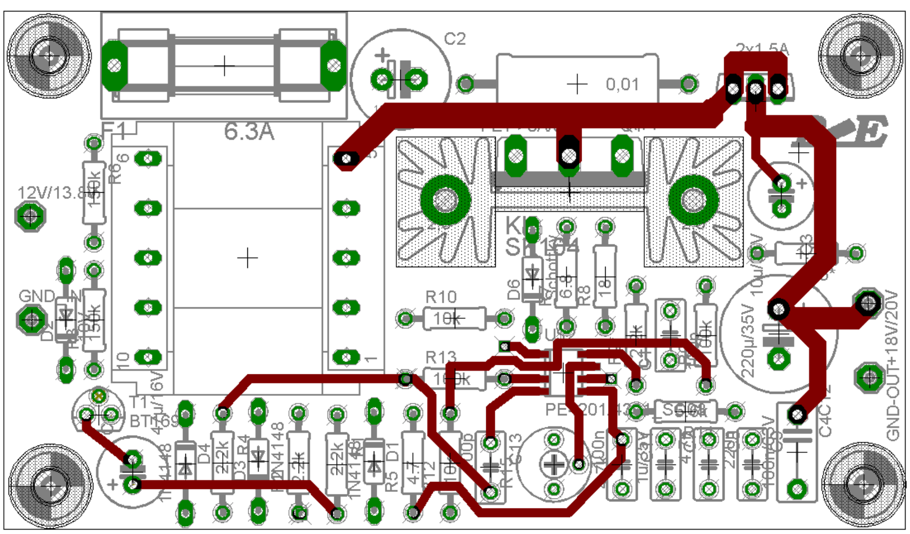
Description

Basis for any LED application is a constant DC source. This application generates a constant output voltage and so current that can be fine tuned from a variable input DC voltage. It can be used for applications where low a DC voltage is available but needs to be stabilized efficiently for LED lighting , e.g. in cars or trailers. Due to the DC character this circuitry does not require a power factor correction unit.

It can also be used with a bridge rectifier and a larger C2 smoothing capacitor on the input to be powered by AC sources (e.g. small wind generator).

Technical Data:

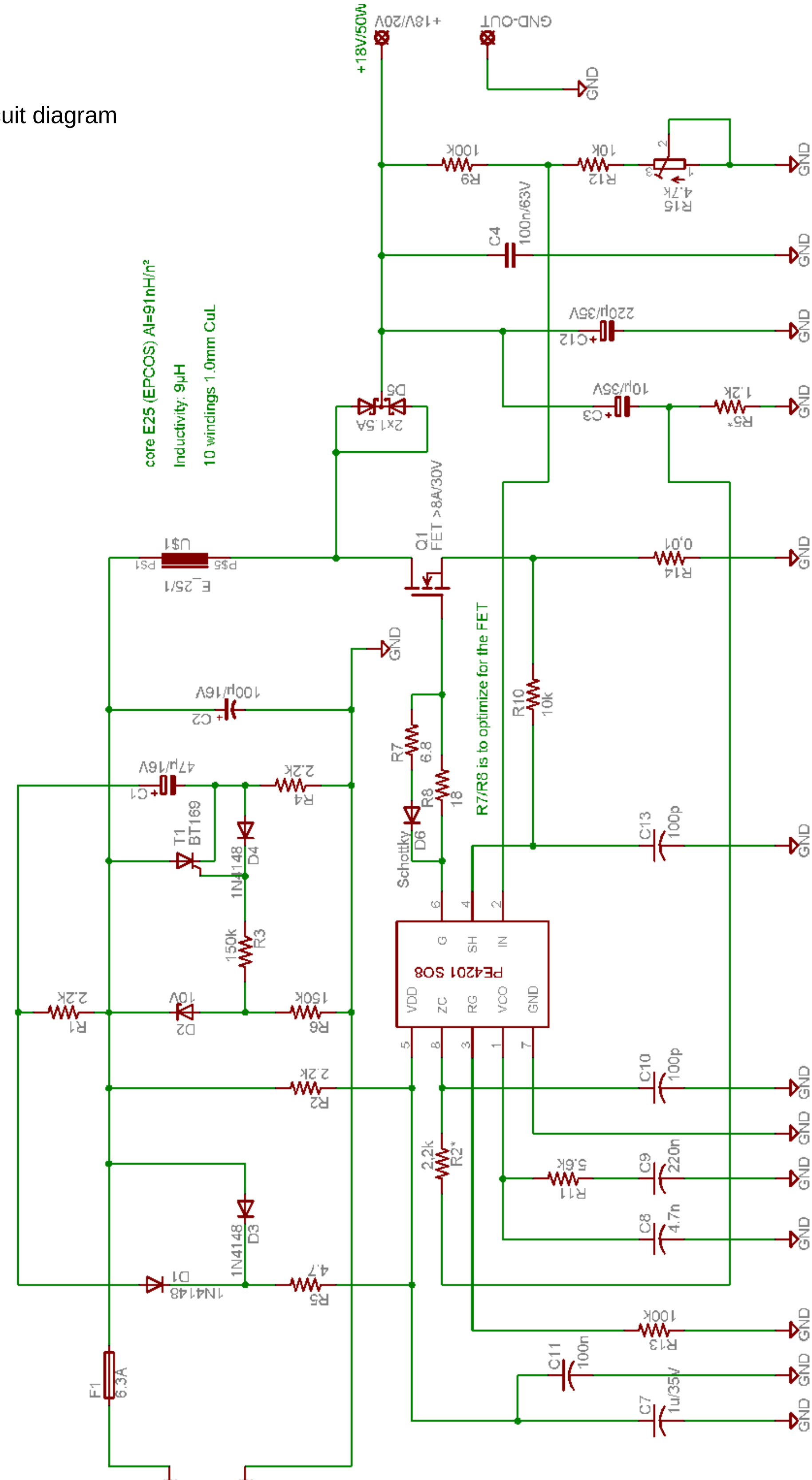
Input voltage ………..	11,5-13,8V DC
Output voltage ………	18-20V DC (adjustable with 1% resistors)
Max. Output …………	50 W
Efficiency ……………	>85 % (25W), >75 %(50W)
Board- Dimension ….	106,5 mm x 55 mm x 25mm (L/B/H)



Board Layout

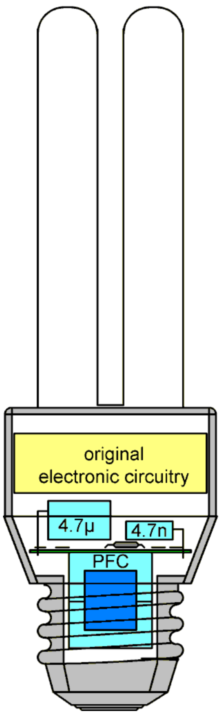
50 Watt (AC)DC/DC converter for LED Lights

circuit diagram



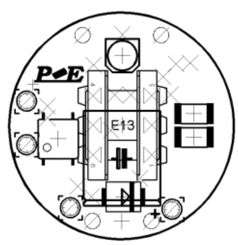
Description

The form factor of energy saving lamps is a challenge since most of the space is occupied by the startup circuitry of the original lamp. A miniaturized PFC board for implementation into a socket of energy saving lamps (E27) using PEs PFC IC PE4201 is described.

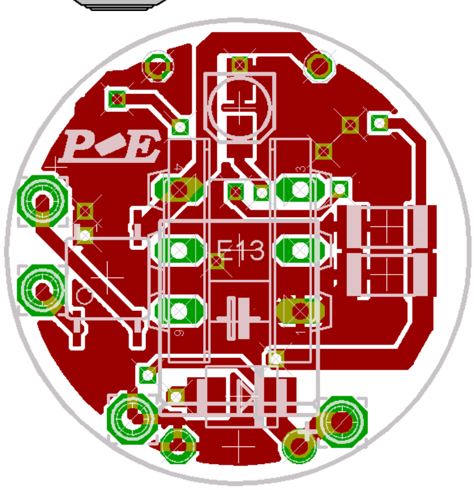


Technical Data

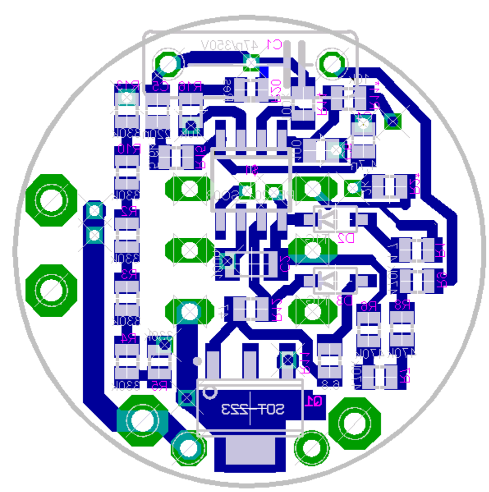
Input voltage	210V/230V (50/60Hz) AC
Output voltage	340- 400V DC (adjustable)
Max. output	25 W with PE4201
Efficiency	>90 %
Power factor	0.90 to 0.98 (depend on power out)
Board dimension	diameter 29mm, height 15mm (assuming usage of existing electrolyte capacitor of the original lamp supply circuitry)



original dimension of the E27 PFC board



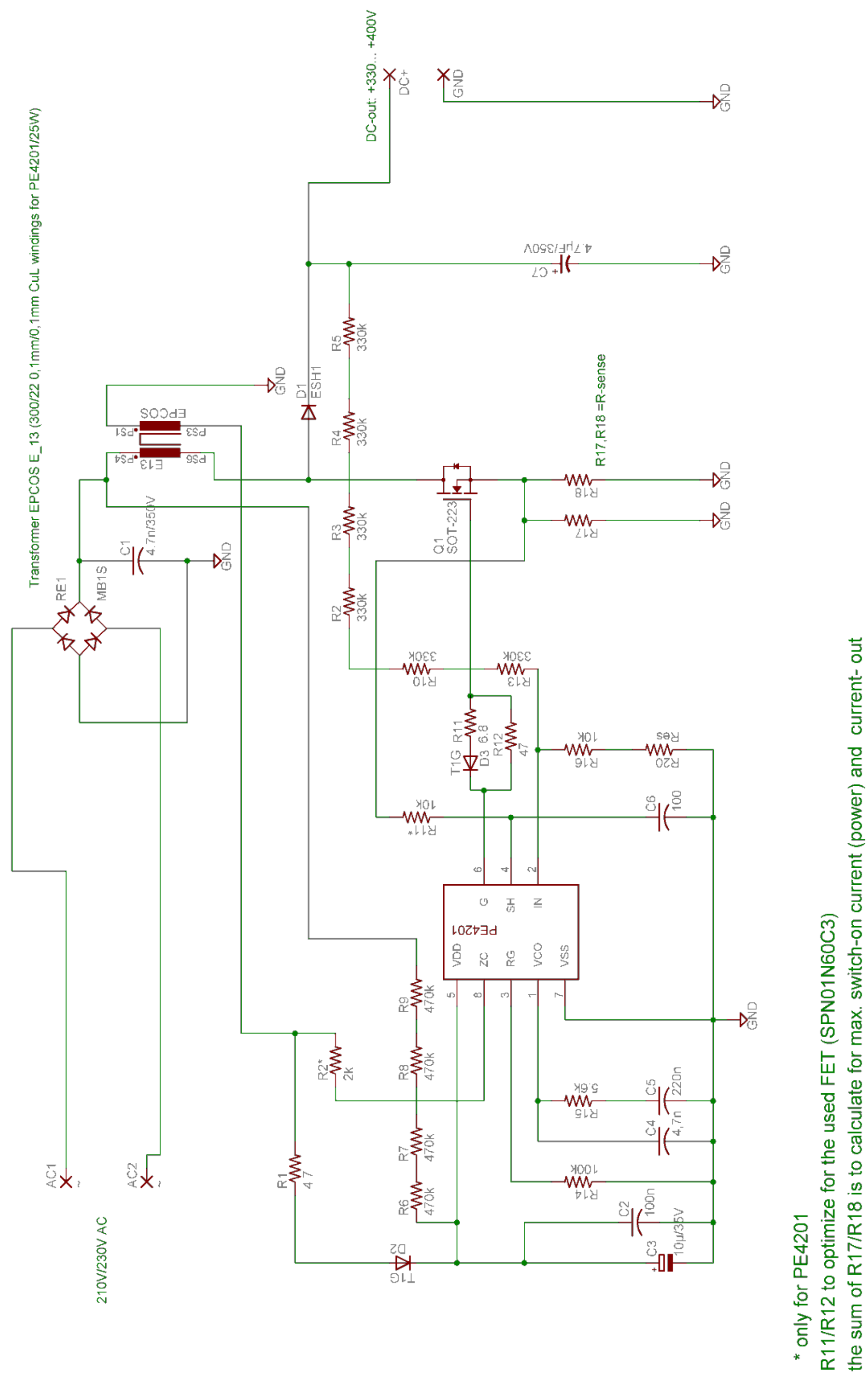
PFC board top side (diameter 29mm, height~15mm)



PFC board bottom side

A standard fluorescent lamp, has a power factor <0,6 at 18 watt only !

25 Watt 220V EnergySavingLamp with PFC, no galvanic decoupling



circuit diagram

Contact Addresses

Germany

Stuttgart

Productivity Engineering GmbH
Behringstrasse 7
D-71083 Herrenberg
Germany
Phone.: +49 (0) 70322798 0
Fax: +49 (0) 70322798 29
Email: info@pe-gmbh.com

Dresden

Productivity Engineering GmbH
Sachsenallee 9
D-01723 Kesselsdorf
Germany
Phone.: +49 (0) 35204777 00
Fax: +49 (0) 35204777 000
Email: info@pe-gmbh.com

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