Documentation

EVA4201_LED

Evaluation and Development Board

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Version	Date	Changes	Page
Initial Version V1.0	05/2010		

2. Safety Instruction

Please take caution - the board operates at high voltage and shall not be directly plugged into the power network. Operating this Board requires an isolating separation transformer!
When operating with integrated circuits always take precautions regarding ESD protection. These devices are sensitive to electrostatic discharges and can be damaged.

3. General

The EVA4201_LED Development and Evaluation Kit is a complete LED application. LEDs are known to be very efficient light sources and become more and more popular. The only remaining burden to bring an LED application into a product is the constant current power supply. This power supply mainly defines the total efficiency of the end product and also the life time is greatly defined by the used devices within this supply. Investigations on available power supply sources for LEDs in the market have shown poor performance with power factors of down to 0.5 and heat dissipation in transformers and power FETs.
The EVA4201_LED features a complete power supply for LED applications for lighting. The board has four areas. The main area, the development section is populated with all devices that make up for power factor correction. The second area is populated with 16 Power LEDs attached to a cooling fan. The fan can be left out if an aluminum convector will be used that can dissipate the heat of the LEDs. Two not populated sectors on the board can be populated for an E27 socket and a T5 tube lamp. The circuitry used here is the same as for the development section.
This kit takes weeks if not months off from the development time engineers will need to develop such a low cost high performance LED power supply on their own.

4. Parameters

Electrical and mechanical parameters of the power supply:

Input. Voltage	:	190 ... 240V
Power factor	:	>= 0,9
Input Power	:	max. 10VA at 7 … 8 W output power
Isolation	:	1 KV tested (**power only through an isolating separation transformer**)
Output Voltage	:	variable (switch board) 12V, 24V, 36V, 48V
Form factor	:	LED configuration with 16 LEDs (changing when output voltage will be switched) and active cooling (external supply voltage 5 ...12V for fan, not provided!)

5. Not populated section

The EVA4201_LED contains not populated areas. They are available for retro-design-LED-lamps. The form factor of the PCBs in these areas is very small to fit the requirements of an E27 socket and a T5 tube lamp. These two areas can be populated by the user equivalent to the development area. Application notes for these two form factors can be downloaded at:
http://www.pe-gmbh.com/.

Features of the PFC-IC PE4201:

- low total harmonic distortion (THD)
- low start-up current (<5µA)
- low operating current (<450µA)
- disable function (<170µA)
- under-voltage Lockout with >8V hysteresis
- many protection features
- decreased operating frequency at low output power
- high efficiency at high and low output power
- integrated clamp resistor on G
- fast driver switch 'off'
- very fast Driver 'off' at over current
- drives loads up to 5nF

Applications

- Active power factor correction
- Switch mode power supplies

6. Circuit description

The primary circuit part consists of an active power factor correction and employs the PE4201 IC.
The input filter consists of L3, R16 and C10 and suppresses the switching pulses toward the power grid. The bridge rectifier in conjunction with C1 and C2 provides a pulse shaped DC voltage twice the input frequency. L1 suppresses HF EM interferer toward the power grid.

The rectified DC voltage is connected to the primary winding of the transformer through L1.
The resistor string of R2 ... R4 provides the starting voltage for the PFC controller, PE4201. The combination of C2 ... C4 charges up to 20 ... 22V. The IC starts operation at this voltage level. By changing R2 ... R4 the startup time can be influenced. By reducing the resistance the startup occurs earlier. The series connection of three resistors is necessary since the maximum voltage here can be 340 volt to ground.

A second precondition has to be fulfilled in order to start the IC. Pin2 (IN) has to see at least 0,4 volt, otherwise the internal protection (OLP) will hold it from operation. This voltage is being provided by the voltage divider on IN from VDD. If both preconditions are valid, G will provide 8,5V and the power FET Q1 will be turned on. TP2 can be observed to see the gate voltage on Q1. The primary winding of the transformer drives current now. The current drives through R17, the source resistor to ground. The turn-off condition on SH is defined by the resistor value and the maximum source current. This may. Value will only be reached if the turn-off condition through “IN” will not be valid earlier. The PE4201 compares the voltage on “IN” (ca. 2,5V) to the internal reference. If this value is reached “G” will be turned to ground again. (Alternatively with higher priority when “SH” will see 0,25V) The FET will become high resistive and the transformer will induce an opposite voltage. The hot end (P$2) of the help winding between P$2 and P$4 will be positive and C2, C3, C4 will be charged through R9 and D2. From now on power supply between 20 and 22V for the PE4201 will be provided by this self powering mechanism. The IC itself works stable between 8 … 28V on VDD.

At the same time the secondary winding provides positive voltage to D2 and charges C14. The output voltage is from now on available.
After the current trough the transformer has gone down, meaning the energy in the transformer core has been used up, conditions on the windings change to the opposite. P$2 of the help winding now becomes negative. Pin8 recognizes through R6 zero-crossing of the voltage and a few millivolt below zero Q1 will be turned on again. This cycle repeats itself. After a few cycles the secondary DC voltage has reached the LED operating voltage. Now the charging process has to stop. In order to avoid the expensive opto coupler the voltage on C2/C3 (VDD) is used to give the circuit the required information for the voltage regulation. “IN” is being used to provide the voltage information as a representation of the output secondary voltage. Turn on time of Q1 will be reduced if the voltage on “IN” has reached 2,5V. This way also the maximum output voltage will be limited when no output load (LED) will be present. This is to protect the capacitors on the secondary side against over voltage damage.
This regulation can be observed on Pin1 “VCO”. The voltage at this point is between 1 and 4 volts.

Due to the fact that the input voltage consists of positive sinus-oidal half waves there is no voltage present during zero crossing. The circuit strives to transform as much energy as possible in the first third of the half wave. The switching frequency is low then and the pulse width is high. This changes when coming closer to the peak point of the half wave. Switching frequency raises and pulse width becomes smaller.

After the peak point this changes again. Consequently a 100Hz ripple can be observed on C14. This is reduced to less than 20% with 200µF and is not visible in the LED light.

LEDs heat up. As common with semiconductors the flow voltage decreases when temperature rises. A current control, as commonly used with LEDs, is not applied here and so a good trimming between the voltage divider on “IN” and the transformer to the maximum output power is required to compensate for this temperature behavior. The NTC (R8||R20) reduces the output power when temperature rises. This way temperature overload of the LEDs will be avoided. As with any Power LED it is required to be familiar with and to stick to the temperature specification of the LED manufacturer. Power LEDs have to be cooled! When used in a retro lamp where cooling space is limited this circuit topology is of great advantage compared to commonly used current controlled supplies since this application circuit does not cause lifetime reduction for the LEDs. The transformer will never transform more energy than required for the LEDs normal operation. R1 can adjust the max power (depending on LED type) in the range of ±1W. The value of R1 and R7 has to be chosen once for an LED type before series production of the final lamp configuration. The NTC can be taken off the board and can be replaced by a wired version to be placed close to the LED head sink.

Output voltage on C14 can be chosen by the switch plug/socket combination between 12V, 24V, 36V or 48V.

Note: Changing the plug can only be done when the EVA4201_LED is not powered!
Depending on the load current the output voltage can change in the range of ± 15%. This depends on the flow voltage of the LEDs and the value on R1. In case there will be larger variations with some LEDs they can be accounted for by adding/leaving an LED or changing the winding of the transformer.
A mismatch can easily be recognized by a poor power factor. At 36 volt only 12 LEDs will be on.
R10 on Pin3 (RG) adjusts the internal timing of the IC. This value has been chosen for optimal performance with the small transformer. The frequency shall be higher for more powerful applications with larger transformers. The frequency range of the PFC within each half wave can be between 60kHz and 180kHz. It varies with input voltage and load. R15 is to discharge C5/C14 when no load is present. It can be left out when in a closed housing where there will always be an LED connected.

Use of other transformers:

In order to be able to use other transformers the layout has been captured very flexible to also hold an EE16 or an EFD20. The EE16 can be used for lower output power (5 ... 6W) and the EFD20 can be used for higher output power (10 … 12W). Only one of them can be populated. Jumper R18 and R19 have to be left open. This separates EV15 from the rest of the circuit. Jumper JP9 has to be set from 2-3 to 1-2. Voltage switching with the EE16 and EFD20 only works for the LED board itself since there are no separated output windings for different voltages on the transformer layouts. Accordingly the right LED combination has to be chosen in order to not destroy the LEDs with over voltage. If LEDs are being combined in a way that they will not match the voltage, combination of LEDs can also be connected on AUX1 or AUX2. The LED block has to be disconnected in this case.

Using a different Power FET

A small FET in SOT223 can be used instead of the DPAK and should be soldered to the PCB cooling plate. When using a FET in D²PAK a small head sink can be mounted to the PCB (mind isolation).

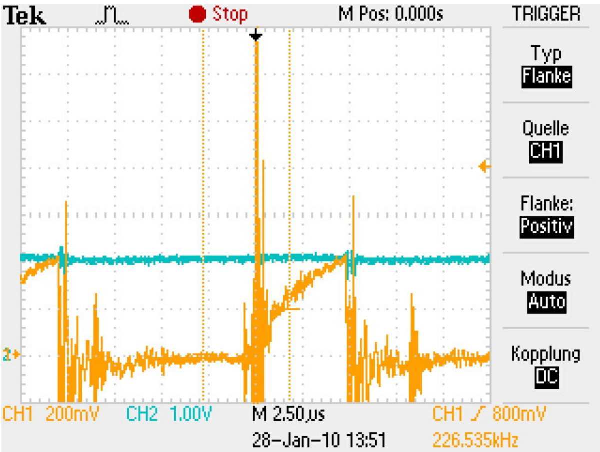


Figure1
Oscillation on shunt (yel), example for too small dimensioned FET – Current curve is steady.

Remarks for transformer dimensioning

Due to the fact that a naturally PFC has no input capacitor after the rectifier the transformer serves an energy storing element. It serves to store and transport the energy to the storage capacitor, that is on the secondary side of the transformer. To fulfill this task effectively the transformer must not go into saturation (small core hysteresis). For that reason an air gap with isolation has to be in the core. At small power below 20 watt and small cores this gap is in the range of 0,04mm (5-8W) and 0,15mm (8-12W). Best results for PF and efficiency can be achieved if the operating point at maximum power is slightly below saturation. This can be observed on the shunt resistor, see figure 2 and 3.
Best results in terms of PF and efficiency can be achieved if the operating point at maximum output power is close below the saturation (which can be detected on the oscillogram of the shunt voltage, see figure).

Figure 2
Shunt current o.k. -> gap o.k.

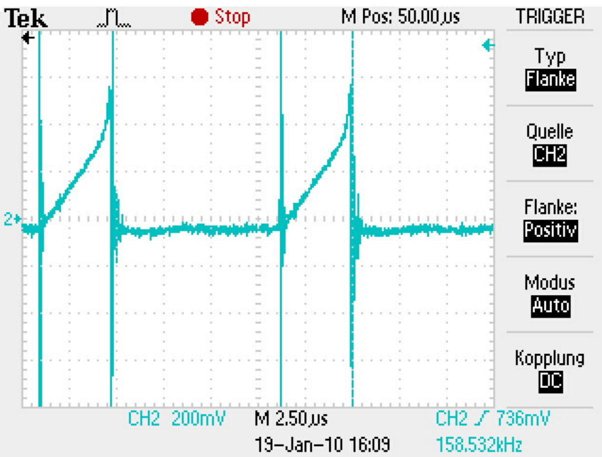


Figure 3
Core in saturation -> gap to small

Best results in terms of PF and efficiency can be achieved if the operating almost at maximum output power is below the saturation (which can be detected on the oscillogram of shunt, see figure).

Transformer Core material is standard SMPS compliant (resonance frequency 100- 500kHz, e.g. EPCOS N87). Primary inductance shall be 1- 2,5mH, less inductance for higher power. Calculation can roughly be done by support of the MS Excel calculation at
http://www.pe-gmbh.com.
The table also provides shunt resistance and resulting currents. Relation between primary winding and help winding (P$2 – P$4) 6/1 to 5/1. VDD of the PE4201 shall be at ca. 22V (Note: higher gate capacity of a different power FET requires possibly more). Windings of the secondary coil results from the relation secondary voltage/22V = Wdg-sec/Wdg-help + coupling loss, meaning higher output voltage than 22V results in higher number of windings and opposite. Winding area between primary and secondary windings shall be shared equally for 90%. Help winding has to provide 2mA only (0,2mm wire). Isolation between primary and secondary cold has to be provided for proof voltage. To account for leakage path wire end of the secondary coil might have to be soldered some distance from the transformer itself. All necessary precautions according to standard power supply rules have to be obeyed.

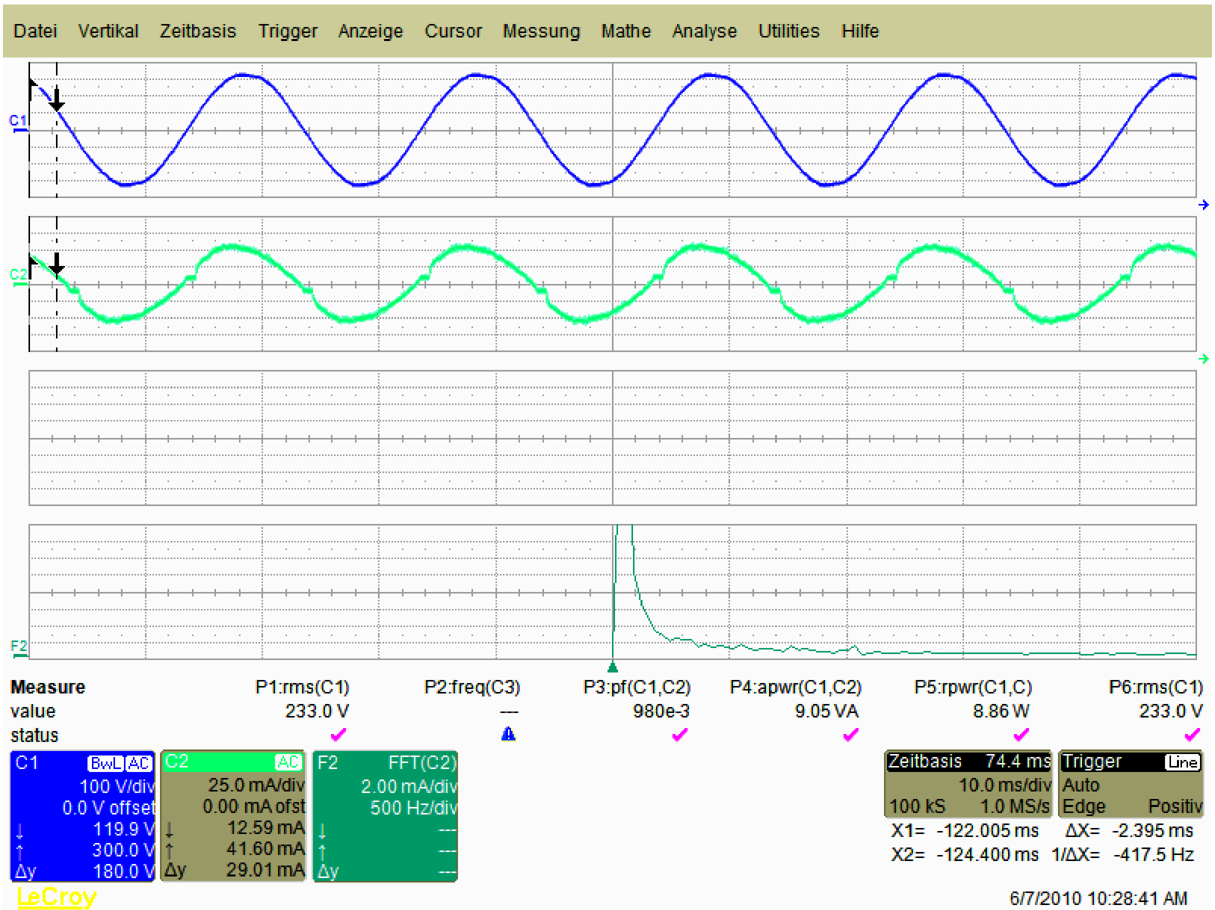
7. LED temperature management

Light Efficiency of high power LEDs used for lighting applications is in the range of 20 ... 25% today. This is remarkably more than for light bulbs but still 75 … 80% of power comes as heat. Additionally, an LED reduces light power above chip temperatures of 75 ... 80℃ and they start aging drastically. This means light efficiency reduces over time when the LED will be powered at such temperatures. For that reason chip temperature has to stay below these temperatures.
Cooling can be conducted in two ways typically.
On opportunity is to use passive heat sinks. The other opportunity is to use active cooling with a fan.
The EVA4201_LED employs the latter. This is for area and space reasons.

It is extremely important to use the fan, especially if the board will be powered for more than a couple of minutes. At full power the cooling fan should be running at all times. Power supply of the cooling fan can be external. When running at 12V the fan can also be connected to the board itself.
Keep in mind that the fan also consumes power in the range of one watt, when starting up potentially more. When analyzing the efficiency of the LED power supply itself the fan should not be powered from the EVA4201_LED board.

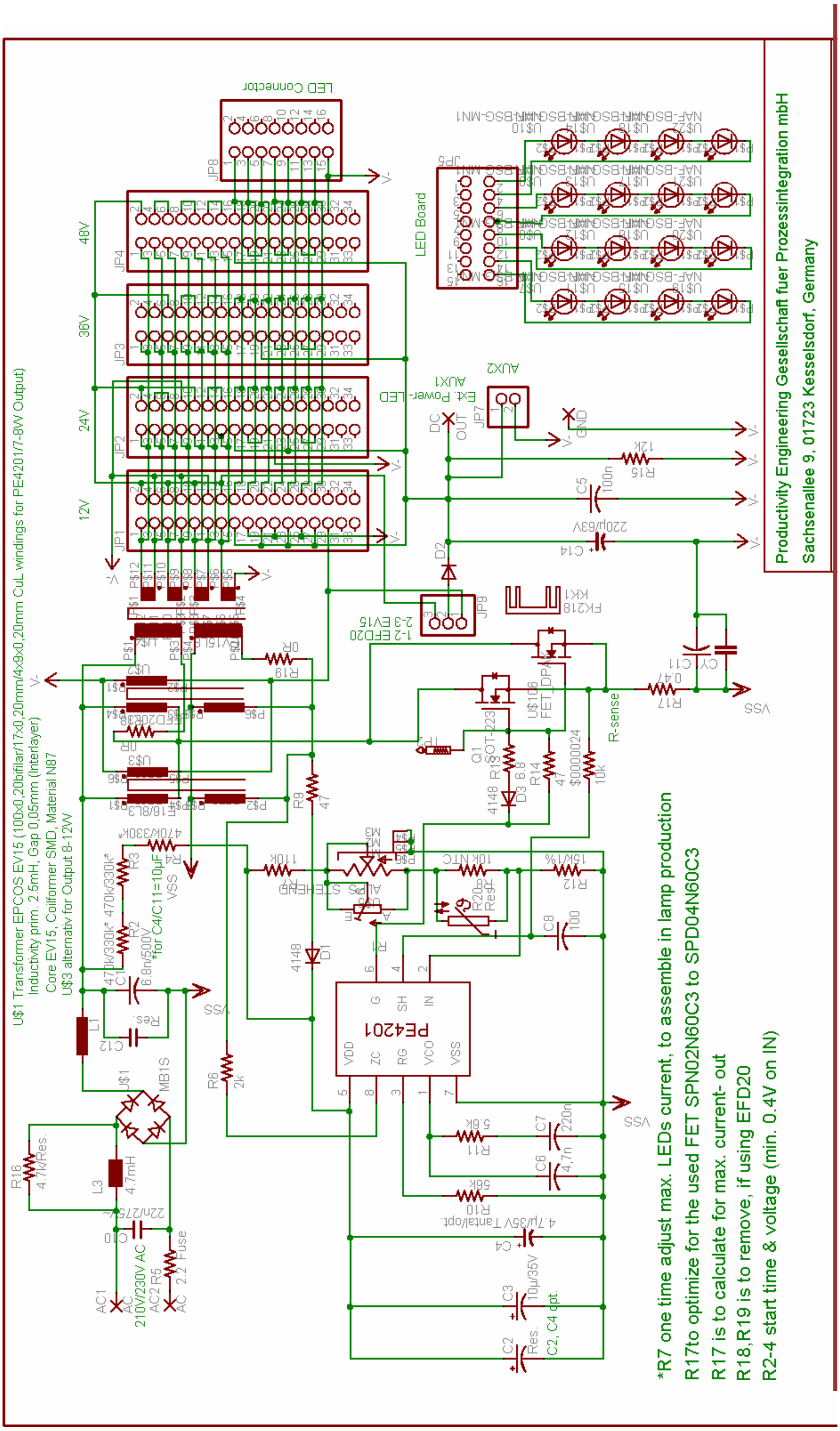
Note: PE recommends to always use an external power supply to run the fan for the LEDs.

8. Board Performance



C1= voltage on power grid
C2= current from power grid
P1= input voltage
P3= power factor = **0,98**
P4= total power
P5= effective power
F2= harmonics (current) up to 2,5kHz

9. Circuit diagramm



10. Layout

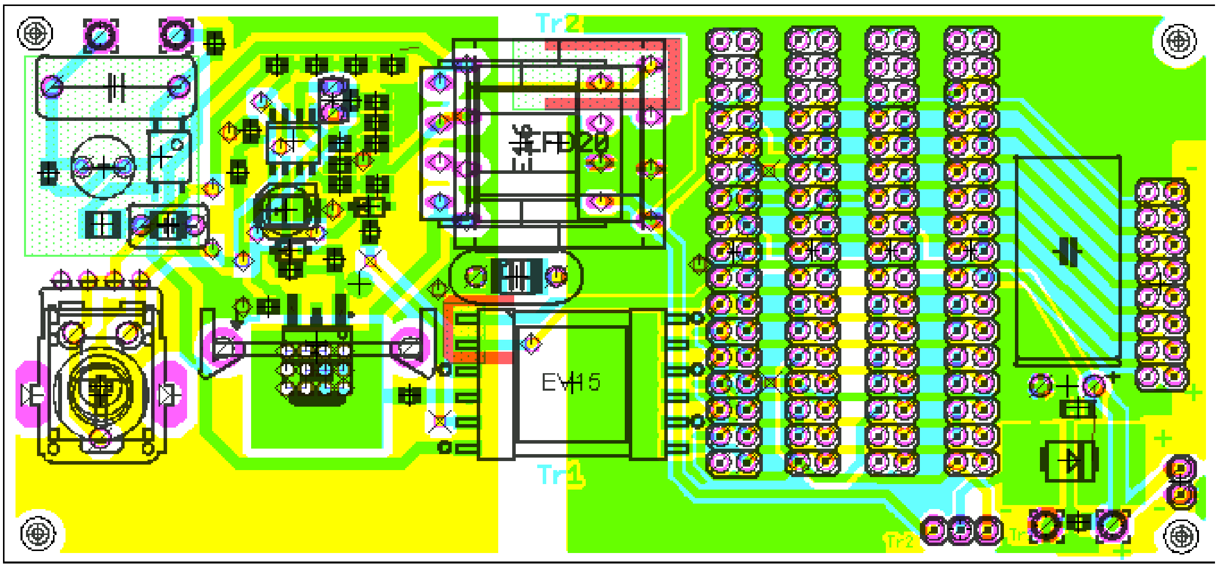


Figure 4: EVA4201_LED main board

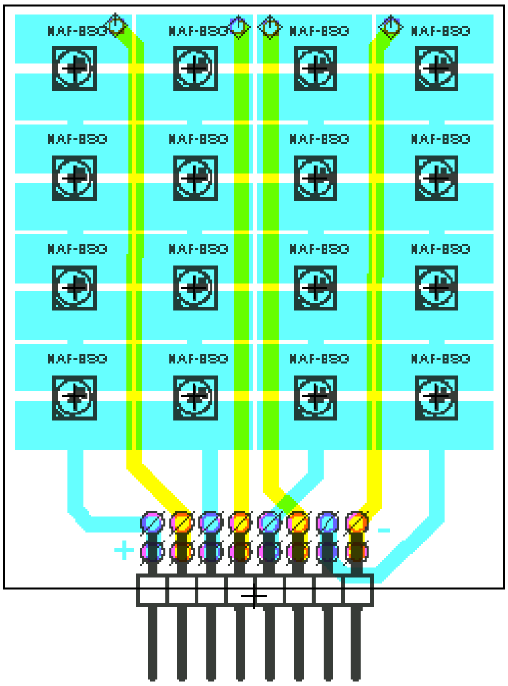
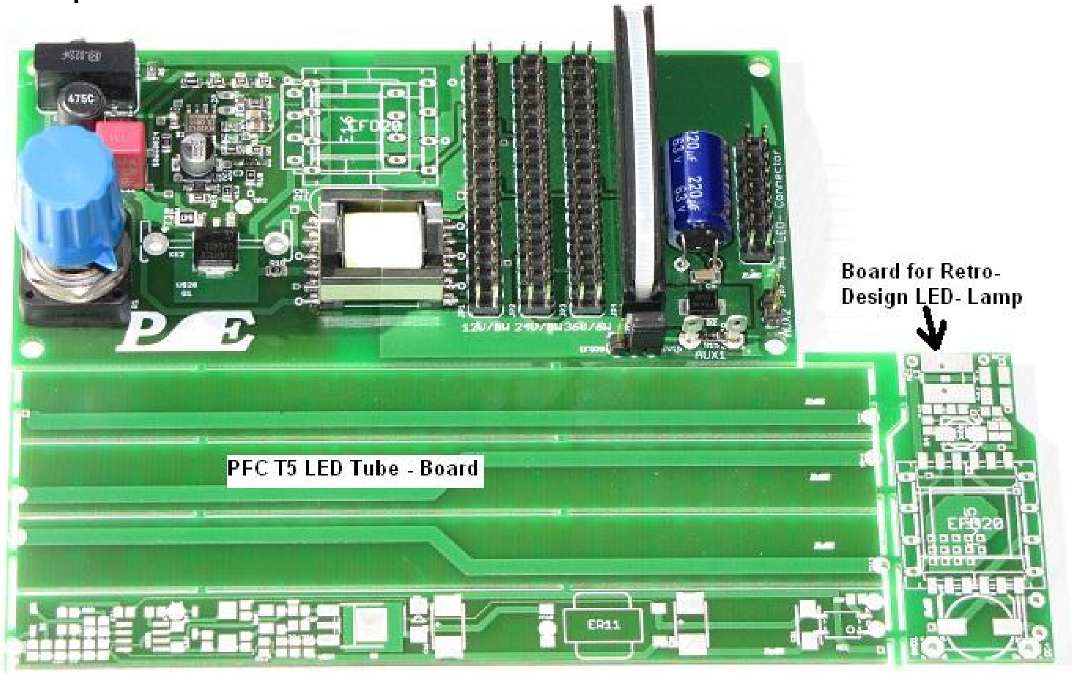
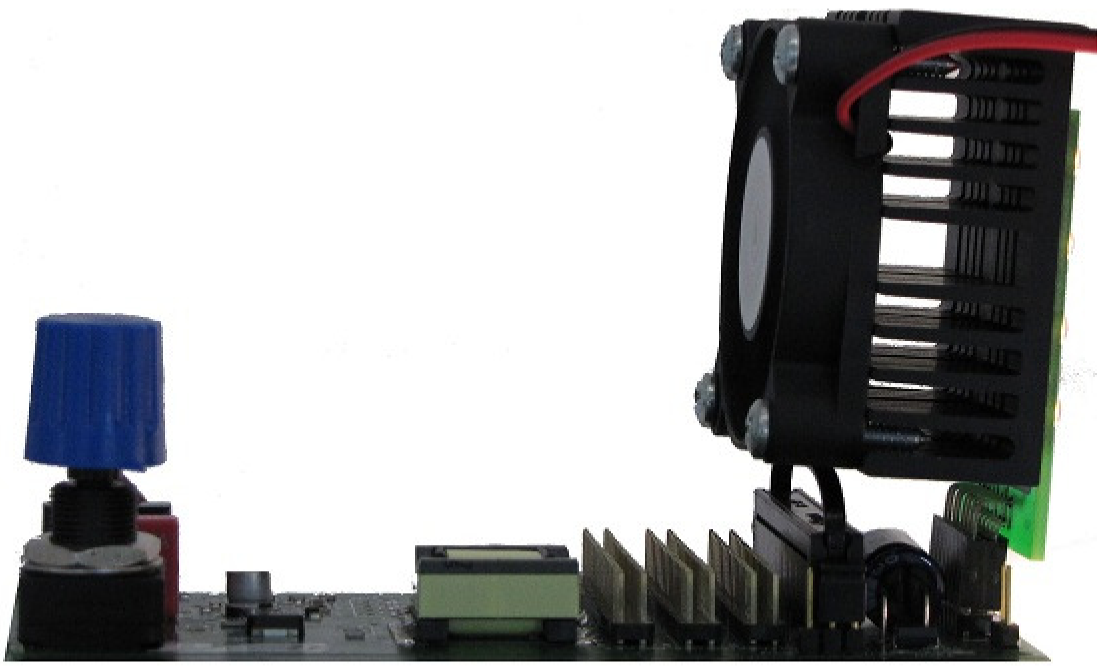


Figure 5: LED-Board

11. Board pictures



Board in usage position (socket/switch at 48V):



12. BOM

Part	Value	Package	Distributor	Manu-facturer	amount
$1	PE4201_SO08	PE4201_SO08	PE-GmbH	PE-GmbH	1
$0000024	10k	R0805	Farnell		1
C1	6.8n/500V	C1210	Farnell		1
C2	Res.	CT6032	Farnell		1
C3	10µ/35V Res.	153CLV-0505	Farnell		1
C4	4.7µ/35V Tantal bottom	3528/T	Farnell		1
C5	100n	C1206K	Farnell		1
C6	4,7n	C0805	Farnell		1
C7	220n	C0805	Farnell		1
C8	100	C0805	Farnell		1
C10	22n/275V~	C120-150X060	Farnell		1
C11	Res.	C4532	Farnell		1
C12	47p/1kV	C050-075X040	Farnell		1
C14	220µ/63V	CEH-050-100X200	Farnell		1
CY1	Res.	YC7B5	Farnell		1
D1	4148	SOD123	Farnell		1
D2	ultrafast 1A/200V	SMB	Farnell		1
D3	4148	SOD123	Farnell		1
JP1	Connector strip	2X17	Conrad- El.		1
JP2	Connector strip	2X17	Conrad		1
JP3	Connector strip	2X17	Conrad		1
JP4	Connector strip	2X17	Conrad		1
JP5	connector 90°	2X08/90	Conrad		1
JP7	Connector strip	1X02	Conrad		1
JP8	Connector strip	2X08	Conrad		1
JP9	Connector strip	1X03	Conrad		1
L1	Ferrit >300Ω/100MHz	L1210	Farnell		1
L3	4.7mH	WE-TI_S/M	Farnell	Würth-El.	1
Q1	SOT-223 Res.	SPN02N60C3	Farnell	Infineon	1
R1	10k	ECP10S	Conrad- El.		1
R2	470k/330k*	R0805	Farnell		1
R3	470k/330k*	R0805	Farnell		1
R4	470k/330k*	R0805	Farnell		1
R5	2.2 Fuse	R0805	Farnell		1
R6	2k	R0805	Farnell		1
R7	100- 150k*	R0805	Farnell		1
R8	10k NTC	R0805	Farnell		1
R9	47	R0805	Farnell		1
R10	56k	R0805	Farnell		1
R11	5.6k	R0805	Farnell		1
R12	15k/1%	R0805	Farnell		1

Part	Value	Package	Distributor	Manu-factorer	Order Code/Mindermengen
R13	6.8	R0805	Farnell		1
R14	47	R0805	Farnell		1
R15	10k	R0805	Farnell		1
R16	5.6k/Res.	R0805	Farnell		1
R17	0.68	R0805	Farnell		1
R18	0R	R0805	Farnell		1
R19	0R	R0805	Farnell		1
R20	Res.	N640	Farnell		1
U$1	MB1S	SOIC4	Farnell		1
U$2	EFD20L3	EFD20LR3	EPCOS	EPCOS	1
U$3	EV15L8	EV15_SMD	EPCOS	EPCOS	1
U$4- 19	NAF-BSG-MN1	NAF-BSG	Conrad- El.		16
U$20	SPD04N60C3	DPAK	Farnell	Infineon	1
U$21	10k Res.	ALPSSTEH	Conrad- El.		1
U$22	E16/8L3 Res.	E16/8L3	EPCOS	EPCOS	1

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