Application Note
RGB LED-Lamp
Digitally controllable via DALI, IR, DMX

Introduction

This application note describes a digitally controllable RGB-Lamp with an output power of 30 W. It is very efficient and works with a standard TV remote control. It employs active Power Factor Correction (PFC).
To achieve a high efficiency, a single stage design was chosen. This stage is built three times, one channel for each color. Each channel can be controlled independently from each other with the Microcontroller on board. The Microcontroller enables the whole system for multiple digital interfaces, like DALI (Digital Addressable Lighting Interface) or DMX (Digital MultipleX, for stage lighting and effects).

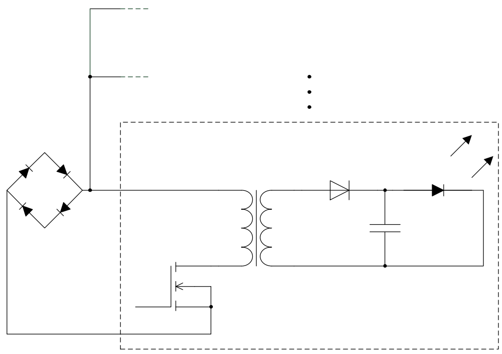
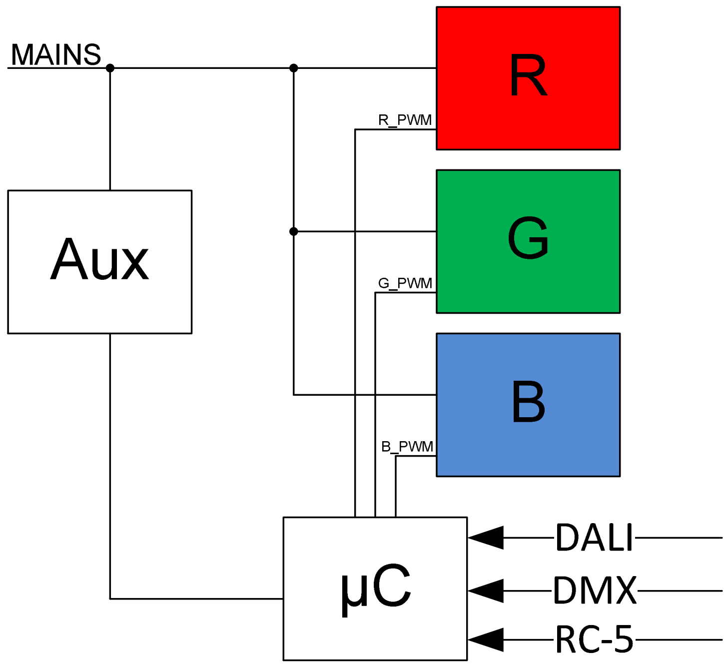


Figure 1: Single Stage Design

The main advantage of the single stage design is the higher efficiency due to lower switching losses.



Single Channel

The Design of a single Channel is shown in the Figure below. It is a single-stage flyback with PFC using the PE4201 Integrated Circuit. A transformer is used for galvanic insulation. The control IC is powered from the auxiliary supply. The tertiary winding is used to detect demagnetization of the transformer core. This allows the circuit to operate in critical conduction mode.

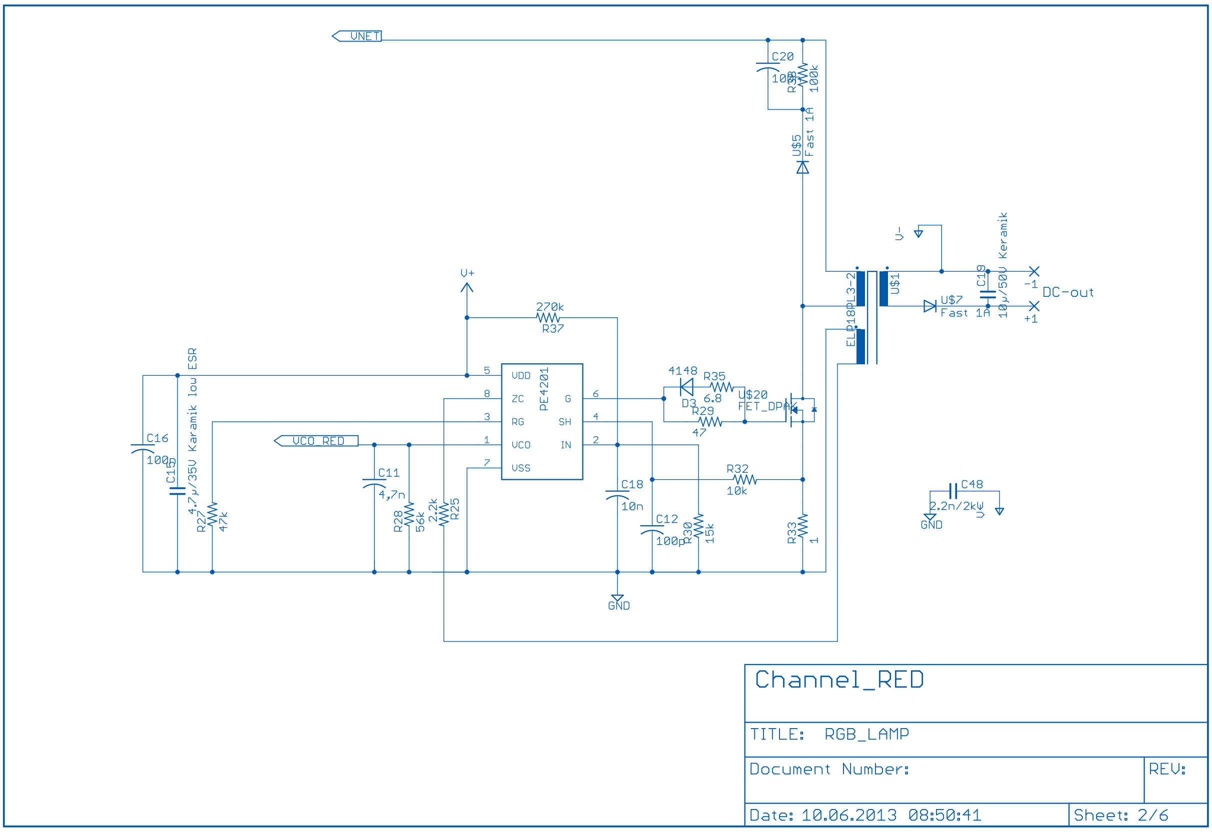


Figure 2: Single Channel

The Output power can be adjusted with the VCO-Pin. The IC regulates the MOSFETs on-time dependent on the voltage at VCO. This voltage is generated by the Microcontroller.

Auxiliary Supply

The Microcontroller is used to decode the signals received by the IR-Sensor and the other busses (DALI/MX). It has to be powered even if the lamp is switched off. Therefore a low-power standby supply is required. This power supply basically uses the same stage design as shown in Figure 2 for the LED channel. Since this supply is only used for standby, it has been optimized for low power output. So it uses a tiny ER11 inductor core instead of the ELP18 core of the color power stages. The output voltage of approximately 18 V is used to power the control-ICs of the power stages. The Microcontroller is operated by 3.3 V which is generated with a MC34063. Alternatively, if the Microcontrollers current consumption is low enough, this voltage could also be generated using a simple Zener-Diode, reducing the overall component count.

Channel Transformers

The form factor for lighting controls is typically a design criteria. Therefore design is very small and flat. The circuit was designed to fit onto a single half euro card PCB. To get rid of the bulky E- or EFD-Cores, is has been decided to use ELP instead (see Figure 3, right corner). This allows to have a maximally flat populated PCB.

Figure 3: PCB side view

LED-Dimming

The PE4201 controls the output power using an analog voltage at the VCO-Pins. Figure 4 shows the basic principle. The analog control voltage is generated by the Microcontroller using PWM and filtering (R79/C40 and C11/R28). The PE4201 must have at least 1 V at VCO to operate and create pulses on the MOSFETs gate. Having at least 1 V on the VCO-pin, the MOSFETs turn-on-time increases with the voltage on that pin. An opamp is used to map the controllers 8-bit PWM-output to a voltage between 1 V (lowest power) and 4 V (full power) via the gain (R34) and offset (R40) trimmers.

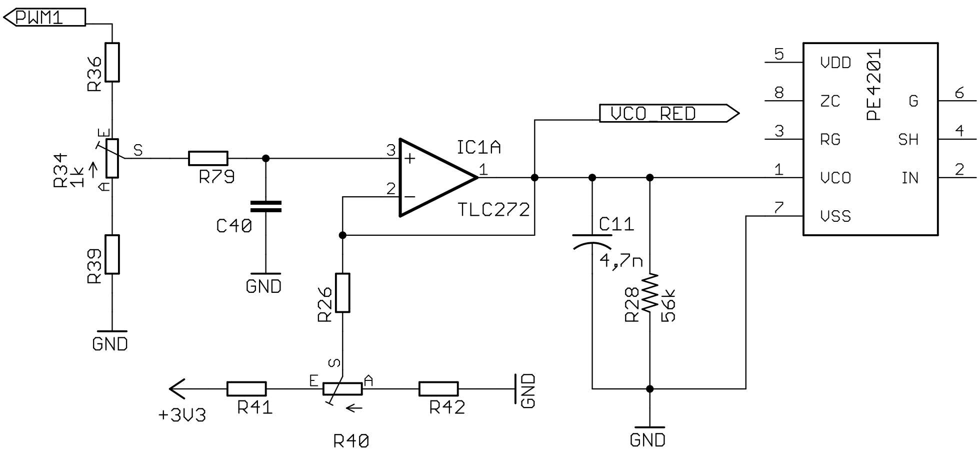


Figure 4: LED-Dimming with PE4201

The following figure shows the duty cycle (yellow) and switching frequency (red) over a full mains periods at full and light load conditions. We observe that the duty-cycle is adjusted permanently to the input voltage, caused by the PFC function.
Especially at low power we can observe two things: the overall switching frequency increases while the duty cycle decreases compared to full load condition. The second thing one can see is the maximum switching frequency. To avoid excessive switching losses, the PE4201 has a minimum off-time, which limits the switching frequency. If the core is demagnetized before this minimum off time has passed, the gate is not switched on until that time has passed. In this case the IC operates in DCM.

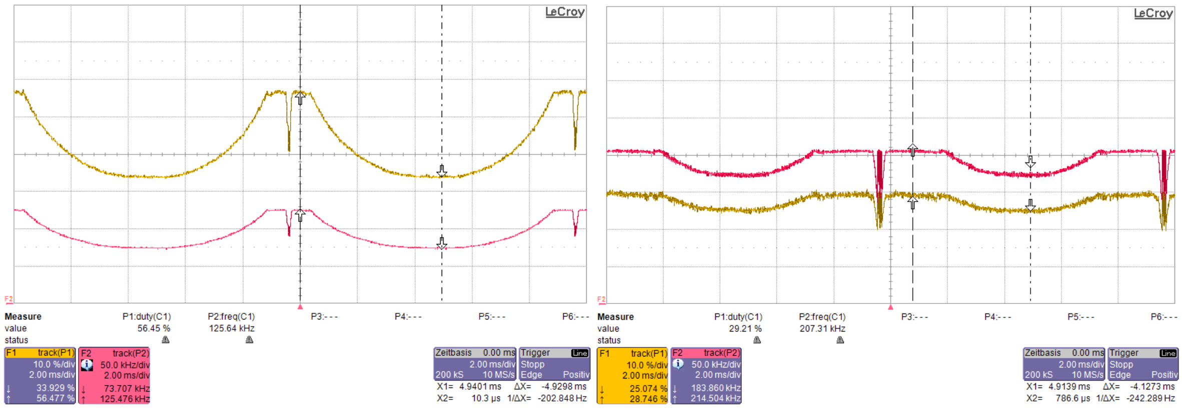


Figure 5: DC (yellow) and frequency (red) at (a) full power and (b) low power

The transition from CRM to DCM occurs around the zero voltage crossings. They may introduce non-linear behavior (e.g. voltage change of 5 % at VCO doesn't equal 5 % change in output voltage). The width of the DCM near the zero crossings can be reduced by using an overall lower switching frequency. However, this implies using a larger core for transferring the same amount of power per time.

Microcontroller

The microcontroller (AVR Mega644V) uses an unsigned 8-Bit variable for each color. These 8-Bit variables feed the PWM directly.
The processor is powered with 3.3 Volts. It handles several infrared protocols (tested with Phillips RC-5 and Sony SIRC) as well as the DALI Protocol and is prepared to support DMX-512.
To support an easy way of programming for a new remote control, the microcontroller can be started in a programming mode. Just two pins have to be connected during startup to enter this mode. This can be done using a special connector. The processor then waits for 8 different codes which are mapped to the functions shown in Table 1.

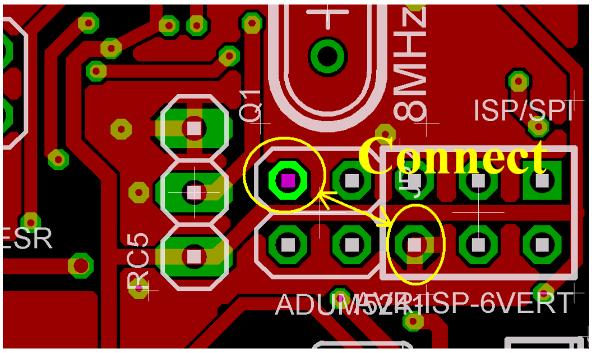
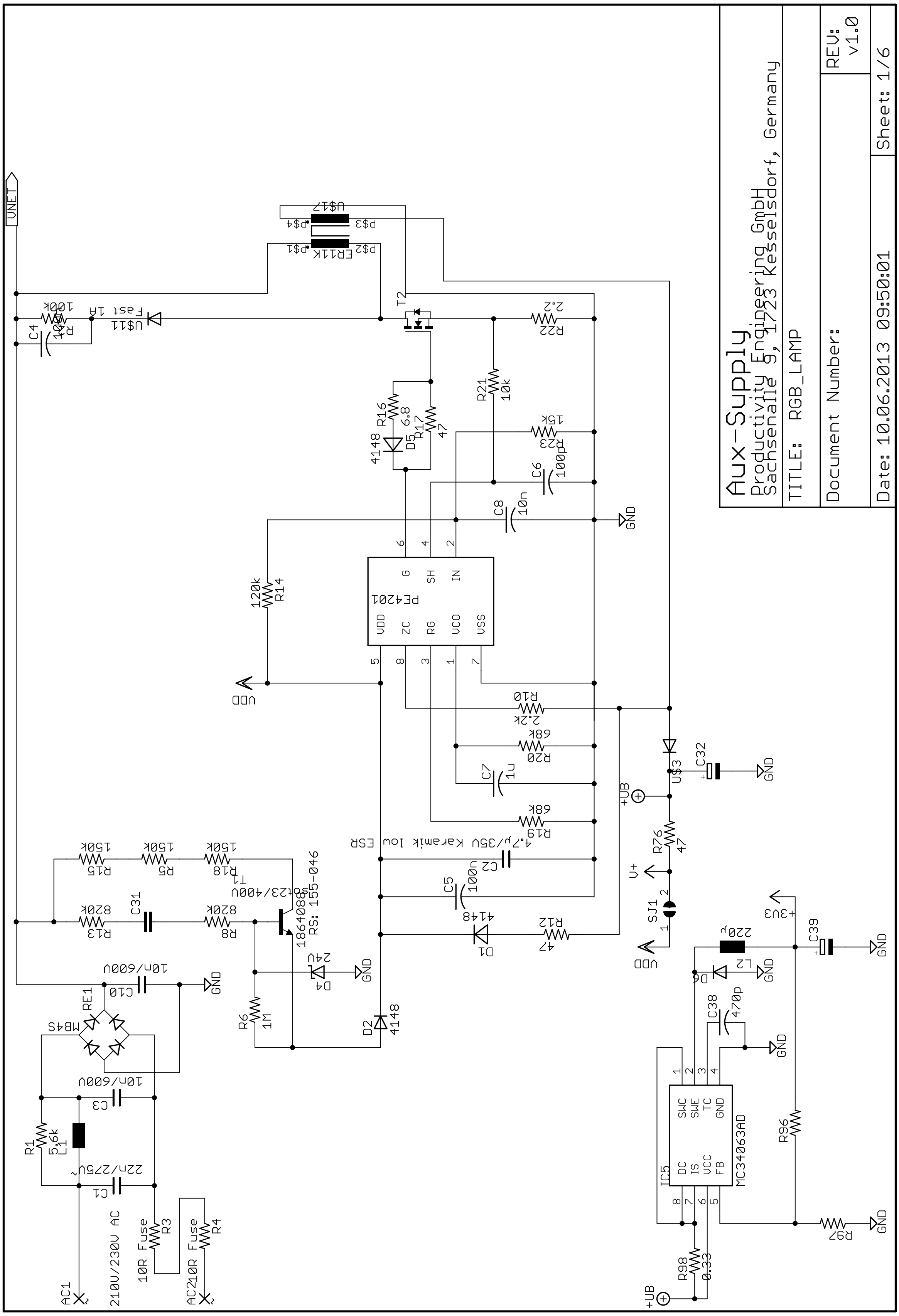


Figure 6: Enter Programming mode

1	switch to red
2	switch to green
3	switch to blue
4	switch to white
5	increase brightness
6	decrease brightness
7	toggle on/off
8	r.f.u.

Table 1: IR commands

Schematics



Aux-Supply
Productivity Engineering GmbH
Sachsenallee 9, 17723 Kesselsdorf, Germany
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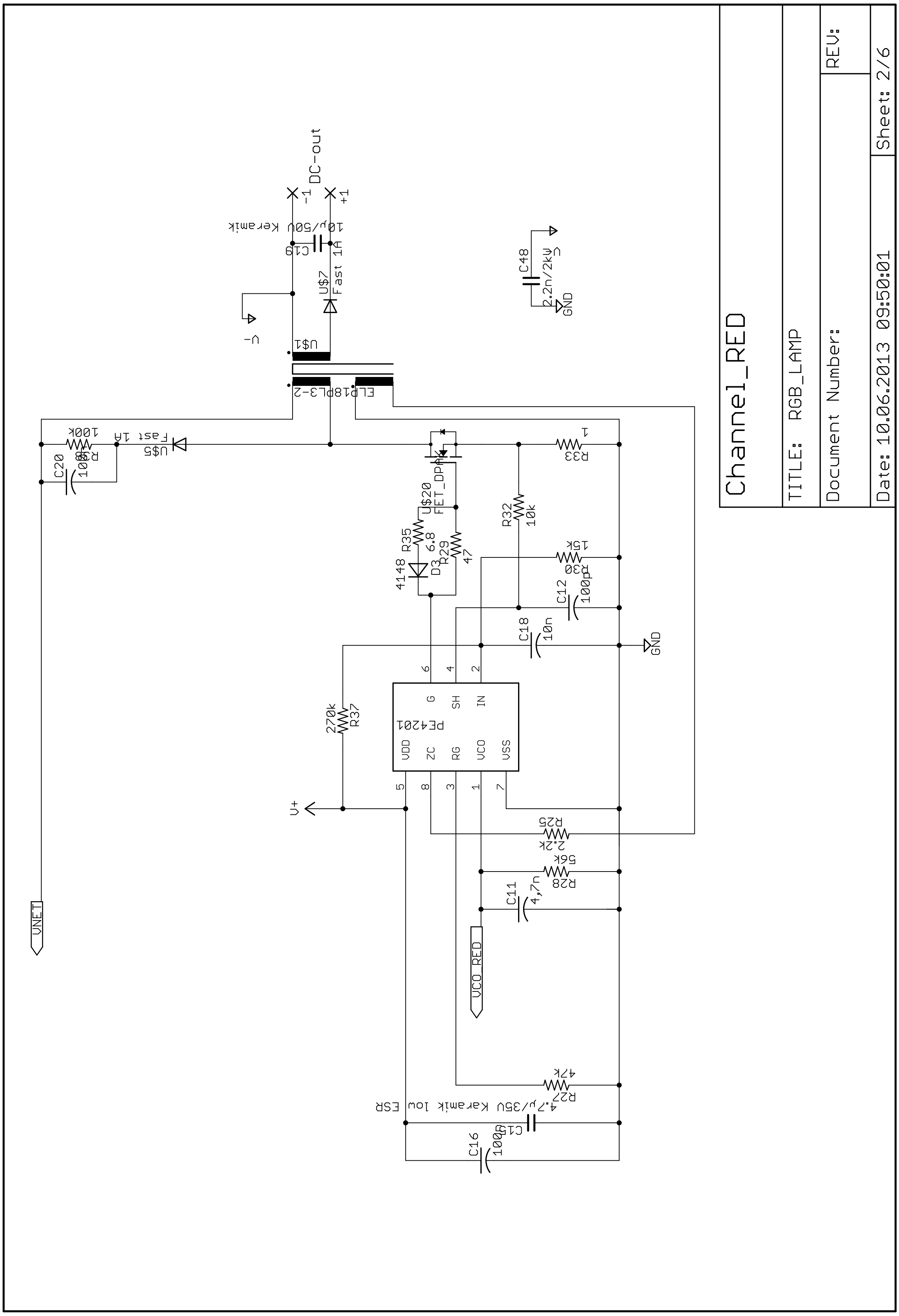

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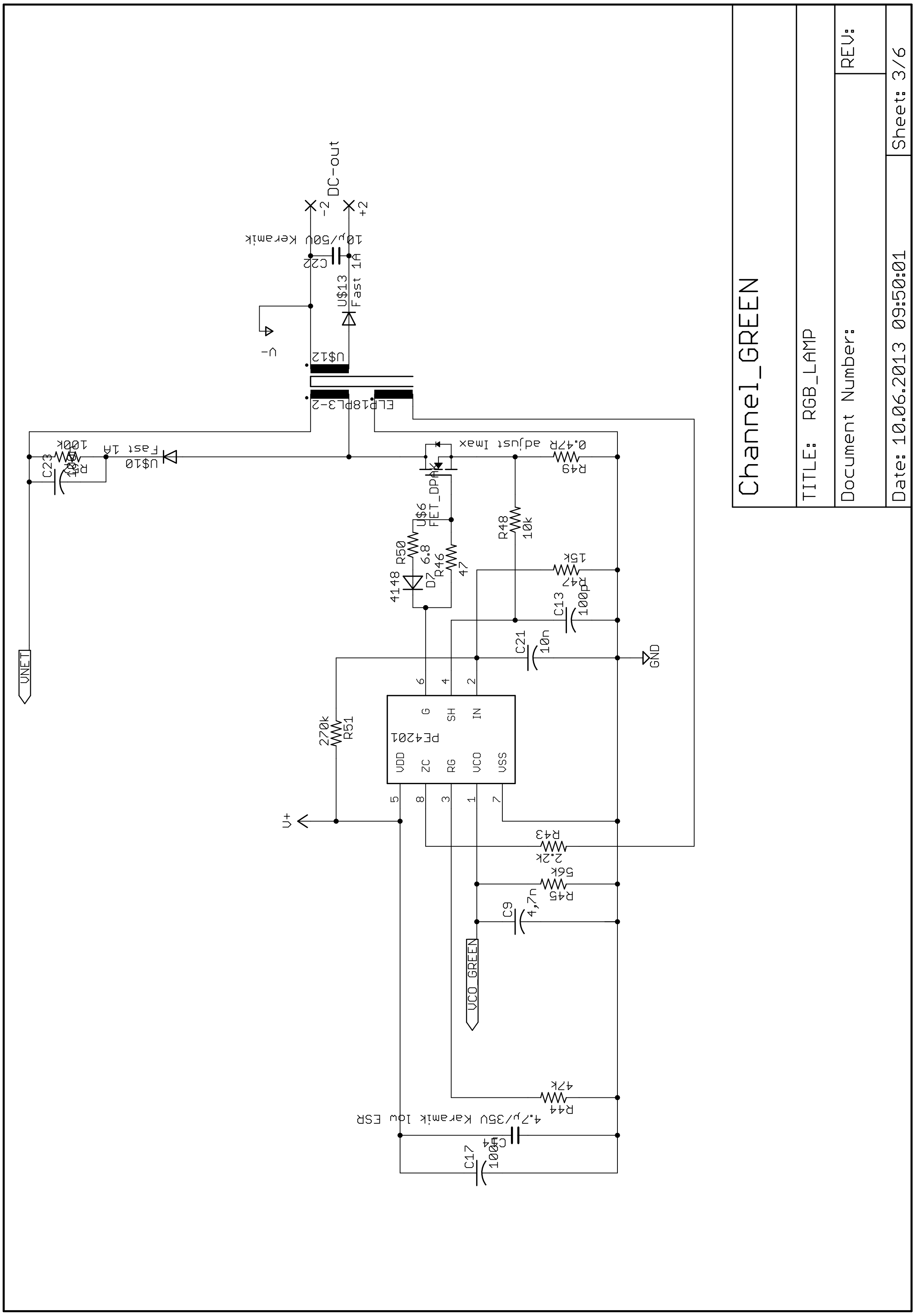
DC-out
-1
+1
C19
10µ/50V Keramik
U$7
Fast 1A
U-
U$1
ELP18PL3-2
U$5
Fast 1A
R38
100k
C20
100n
U$20
FET_DPAK
R33
1
R32
10k
R35
6.8
R29
47
D3
4148
R30
15k
C12
100p
C18
10n
GND
C48
2.2n/2kV
PE4201
VDD
ZC
RG
VCO
VSS
G
SH
IN
R37
270k
V+
R25
2.2k
R28
56k
C11
4,7n
VCO_RED
VNET
R27
47k
C15
4.7µ/35V Karamik low ESR
C16
100n



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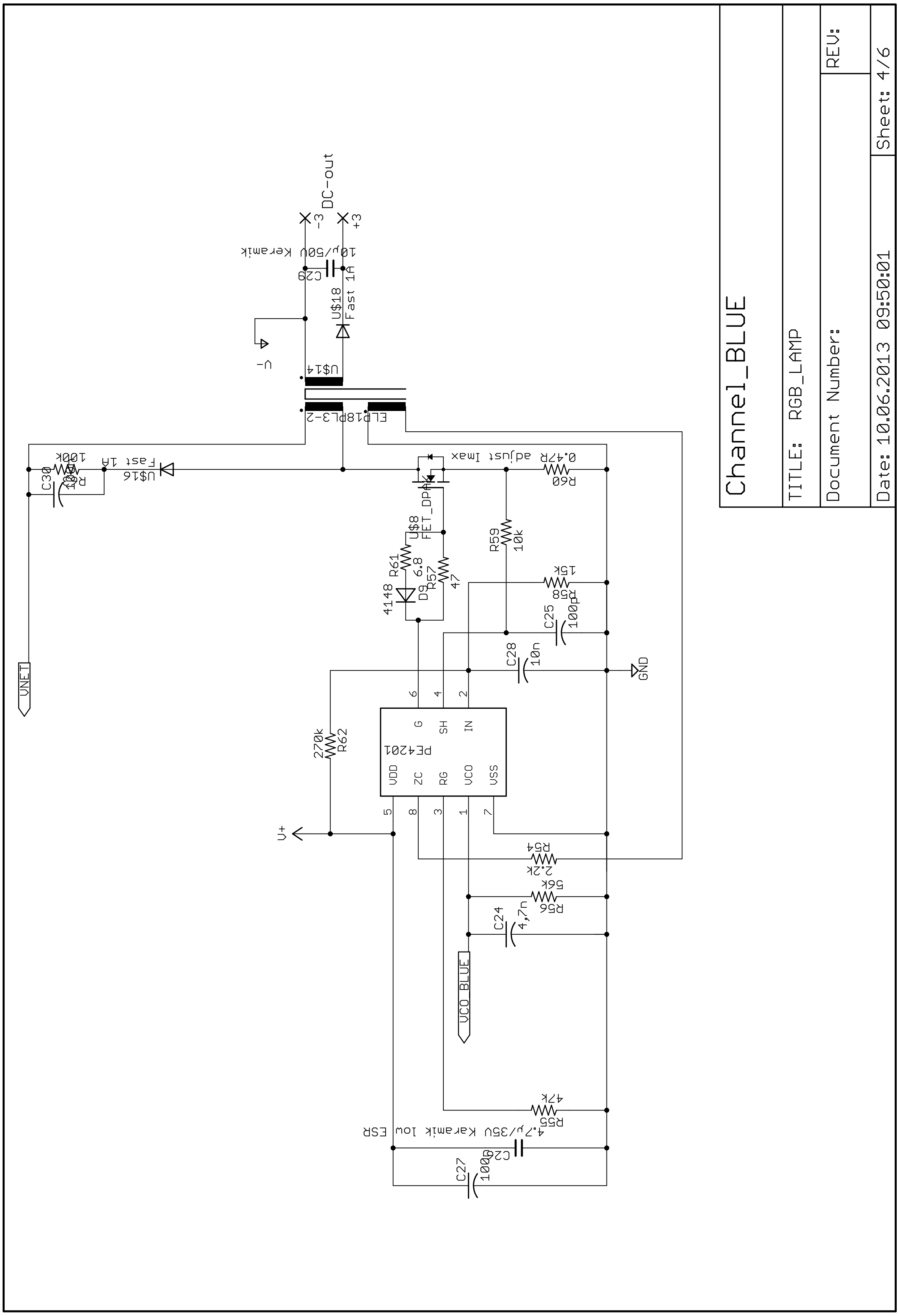
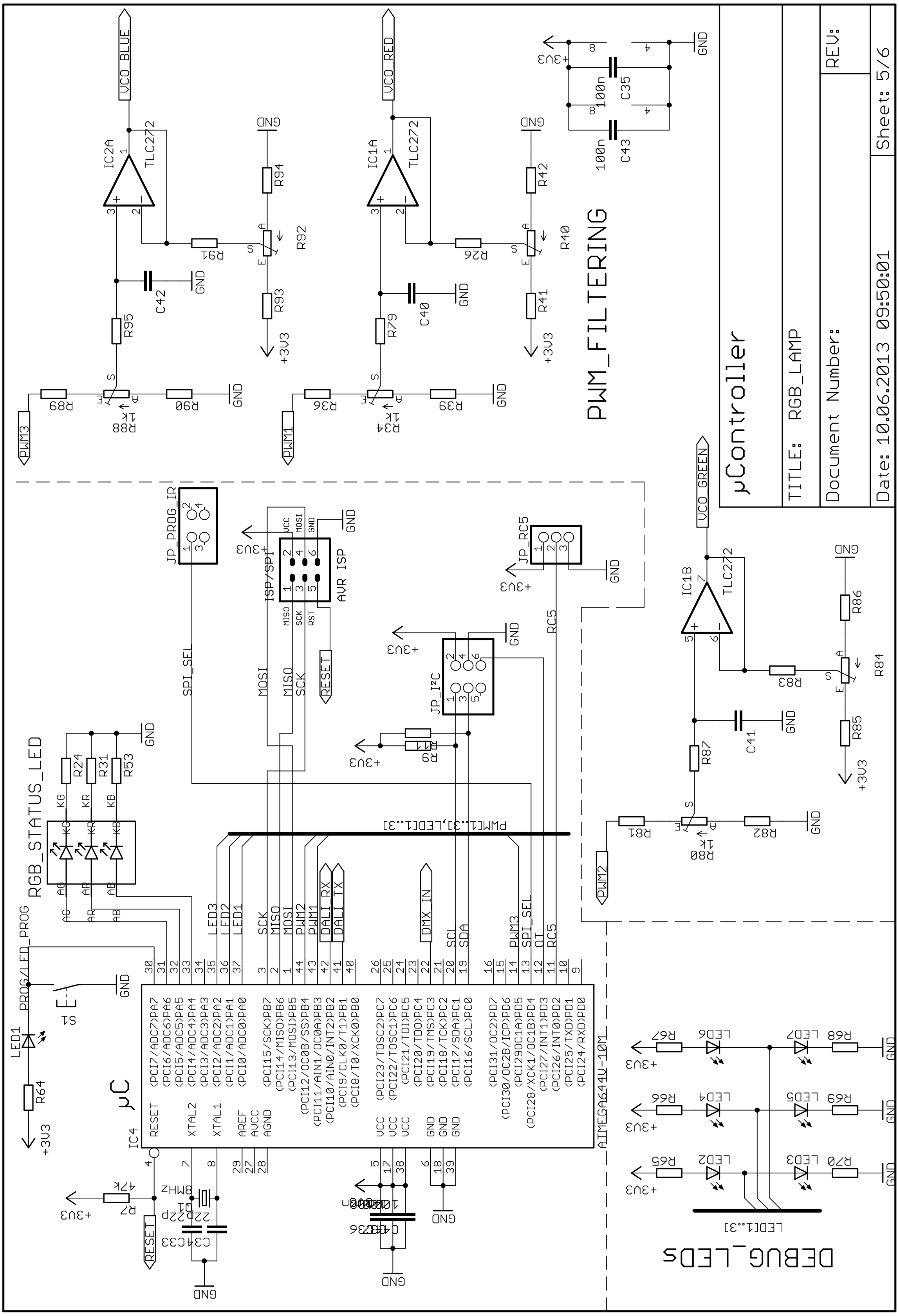
DC-out
PE4201
VDD
ZC
RG
VCO
VSS
G
SH
IN
UNET
VCO_GREEN
GND

SERMA PRODUCTIVITY ENGINEERING

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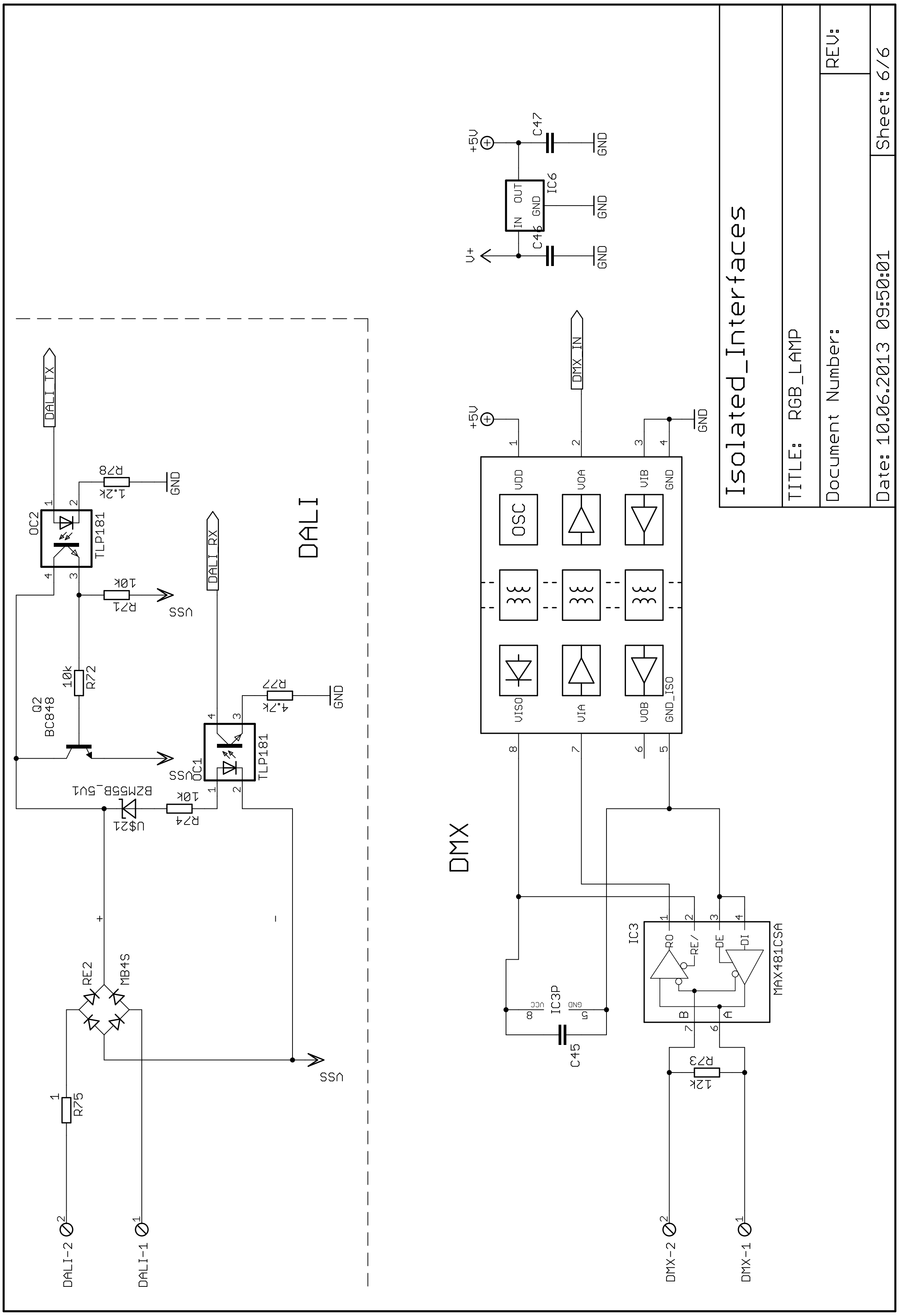

Isolated_Interfaces
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DALI
DMX
DALI_TX
DALI_RX
DMX_IN
OC2
TLP181
OC1
Q2
BC848
R78
1.2K
R71
10K
R72
10k
R77
4.7K
R74
BZM55B_5V1
U$21
RE2
MB4S
R75
DALI-1
DALI-2
IC6
IN OUT GND
C47
C46
+5V
V+
GND
VSS
OSC
VDD
VOA
VIB
VISO
VIA
VOB
GND_ISO
IC3
MAX481CSA
RO
RE/
DE
DI
B
A
IC3P
C45
R73
12K
DMX-1
DMX-2

Contact

Germany

Stuttgart

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

Dresden

Productivity Engineering GmbH
Branch
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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