Swakeup

PROJECT REPORT

within the lecture of
Microcontroller Programming

at Uppsala University
in the Departement of Information Technology

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1 Introduction

Idea

It is a well-known fact, that it is quite dark in Sweden in the winter. In a strong winter every source of light is a source of happiness. This wakeup light, which is based on a strong light source (10 W RGB LED), is able to give one the optimal start into a dark winter day. The *Swakeup* (from engl. "Swedish Wakeup Light") is communicating to the user through the light. It does not simply wake one up, but also gives one information about Facebook, latest mails, calendar and weather. The user interface consits besides of a big LED of an OLED screen. *Swakeup* is also part of the *IoT* as it has the ability to communicate via *IEEE 802.11*. This of course enables a lot of possibilities e.g. connecting your phone to the wakeup light. A lot of effort has been put into the designing maxim, that everything should be as small as possible. The whole electronics fit on an base area of 5 cm x 4 cm. So the *Swakeup* fits smoothly on the bedside table. And honestly: What is the last thing you are doing before you go to sleep? Right! You look on your phone. That is why *Swakeup* comes with a USB charger for your e.g. phone as well.

Sytem Overview

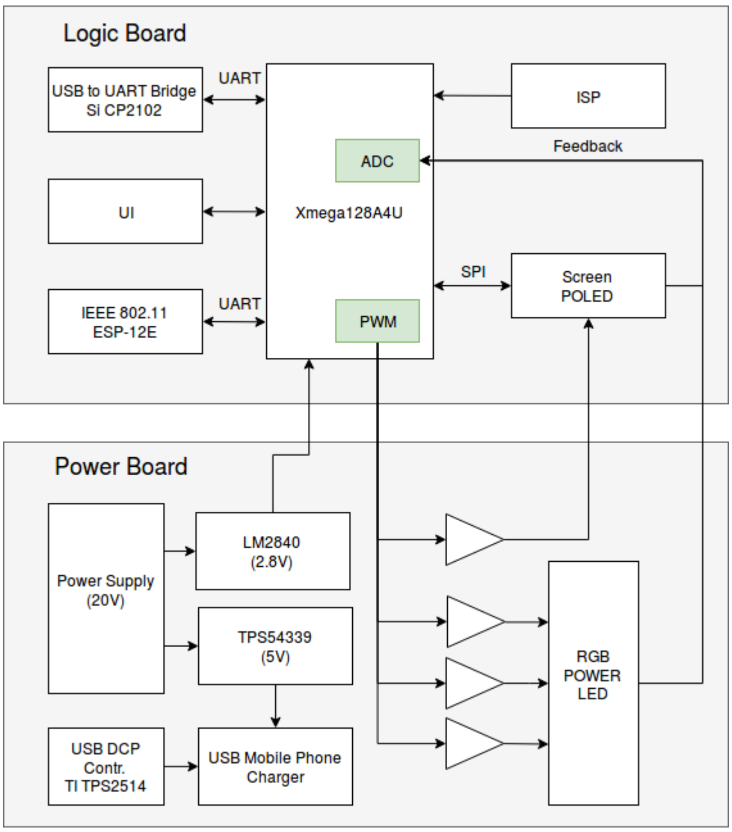


Figure 1.1: Blockdiagram of the Swakeup wakeup light.

In fig. 1.2 the actual system architecture from an abstract point of view is displayed. One can clearly see, that the system is divided into two physical boards. The logic board consists of the μC, a serial connection infrastructure, an OLED screen, an *IEEE 802.11* module, a ISP programming infrastructure and some LEDs/a button (UI).

The power board takes the 20 V input of a low-cost power supply and breaks it down to 2.8 V (Vcc), 5 V for phone charging and the power which is needed for the RGB LED.

The partitioning of the system functionalities on two boards has a bunch of advatages: Two people worked on this project, so each could develop a PCB; It is quite common to seperate signals from power lines out of EMI reasons; There was simply not eanough space on one two-layer board for the whole system keeping a base area of 5 cm x 4 cm.

The two boards are connected together through four headers. By these headers an electrical and mechanical connection is maintained. The headers allow a feedback from the LED driver on the power board to the logic board (ADC). Also the control variable (PWM) comes via the headers from the μC to the LED driver. The 2.8 V Vcc is produced and regulated on the power board and is also availabe at one header. Another voltage available from one header is the OLED driver voltage.

2 Hardware

Logic Board

Power Board

The board design has been made in *KiCAD*. *Git* was used for version control. In the schematics (Appendix A) one can see that the whole board consists of three main building blocks: Connectors, a LED driver with feedback and two step-down converters. A part of the LED driver is also "abused" to drive the OLED.

Microcontroller Power Supply

There are two step-down converter ICs on the power board. It is the LM2840 which in combination with a simple voltage divider ensures the 2.8 V for Vcc. All step-down converters use the same inductor with a value of 33 uH. It is a low-cost, quite small, shielded inductor which is ment to be used for switching power supplies. Moreover all step-down converters are enhanced with a SMD schottky diode and a of course SMD capacitor for smoothing the output signal. As it is good practice to do so all ICs are making use of decoupling capacitors.

Designated USB Charging Port

For charging ones phone the TS30012, another step-down converter IC, is used. The feedback voltage divider of this IC is already integrated and does not need to be provided externally as the IC provides fixed 5 V output. The output is connected to a USB connector type A. This IC can deliver up to 2 A. An interesting feature of the phone charging circuitry on the power board is the "Dedicated Charging Port" (DCP) functionality. The TPS2514 is a small, easy-to-use, 6-pin component, which complies to the USB standard and a majority of the minefield of propriatary standards to signal a DCP. What does that mean? Well this means, that if you connect your IPhone, it will know, that it can draw more than 100 mA, which is the minimum current provided by a normal USB 2.0 port. Otherwise the current drawn by the phone will be limited. The charging functionality can be turned on and off via a GPIO pin. The TS30012 comes in a QFN16 package (pad pitch of 0.5 mm) to save space.

HW Debugging

For testing purposes a lot of test points have been included into the design. Futhermore there are LEDs for different voltages (e.g. Vcc).

RGB LED Driver

The LED driver consists of an actual power electronics part and a feedback part. The idea is, that the voltage driven through the three color channels of the RGB LED can be controlled by software (PID controller). In the power electronics part there are three analog circuits. Each circuit mainly consists of a p-channel MOSFET, which is switched by a NPN bipolar transistor. This bipolar transistor gets its intput signal from the μProcessor (PWM). By pulling the 20 V to GND the PMOS "sees" a negative gate-to-source voltage and opens. The additional bipolar transistor ensures, that the gate-source capacity is charged fastly as soon as the PWM NPN blocks. In this case the base is pulled up via $10\,\mathrm{k}\Omega$ to 20 V and as long as the collector (which has the same potential as the gate of the PMOS) does not also have 20 V the NPN keeps pumping charge into the gate-source capacity. The simple silicon diode ensures that the gate-charging NPN has no effect as soon as the PWM NPN opens. The rest of the circuit is again a standard step-down converter. At the output of every single color channel power circuit one can see a shunt resistor of $0.1\,\Omega$. This shunt resistor is combined with a simple low-pass filter. The feedback signal is amplified by a differential amplifier which comes after the filter. The signal is supposed to be between 0 V and 1 V (if the internal reference voltage is used). By doing so one can use all bits of the ADC and therefore supress quantization noise.

So as there are three color channels (red, green and blue) one needs three operational amplifiers. Hence the LM324QT, which provides four operational amplifiers, has been chosen. Of course QFN16 was selected as the package once more to save even more space. An additional operational amplifier was now ready to be used as a digital-analog converter to drive the OLED screen (this was referred to earlier as "abuse"). For this reason a low-pass filter is attached to the input of the fourth opamp. Apart from that the opamp is configured just like a standard non-inverting amplifier. By software the OLED screen brightness is steerable. The feedback from the OLED is generated by a voltage divider.

3 Software

Code Structure

Operating System

Realization

4 Status Quo and Outlook

What works? What does not work?

The hardware right now is in revision 2.0. There has been one revision before the current one. This revision has been fabricated in january 2017 and the design process began in november 2016. There were some mistakes on the first hardware revision, which were not fixable so easily, especially because of the fact, that everything is quite small. Table 4.1 gives an overview of the current satus of the hardware.

HW Block	**Working**	**Problem**
USB Charging	✓	
OLED Driver	✓	
Vcc for μC	✓	
IEEE 802.11	✓	
USB2UART	✓	
LED Driver		Wrong footprint assignment
Crystal		Wrong pin assignment
USB DCP		Further tests necessary

Table 4.1: Hardware Overview: What works? What does not?

Table 4.2 deals with an overview about the status of the software.

SW Block	**Working**	**Problem**
UART	✓	
SPI	✓	
EPROM	✓	
Timer	✓	
ADC		
PWM		
ESP8266	✓	
Terminal	✓	
SEP525F	✓	
Wifi		
Command	✓	
Log	✓	
Screen	✓	
Timekeeper	✓	
Controller		
Core	✓	
Weather	✓	
Clock	✓	
Social		

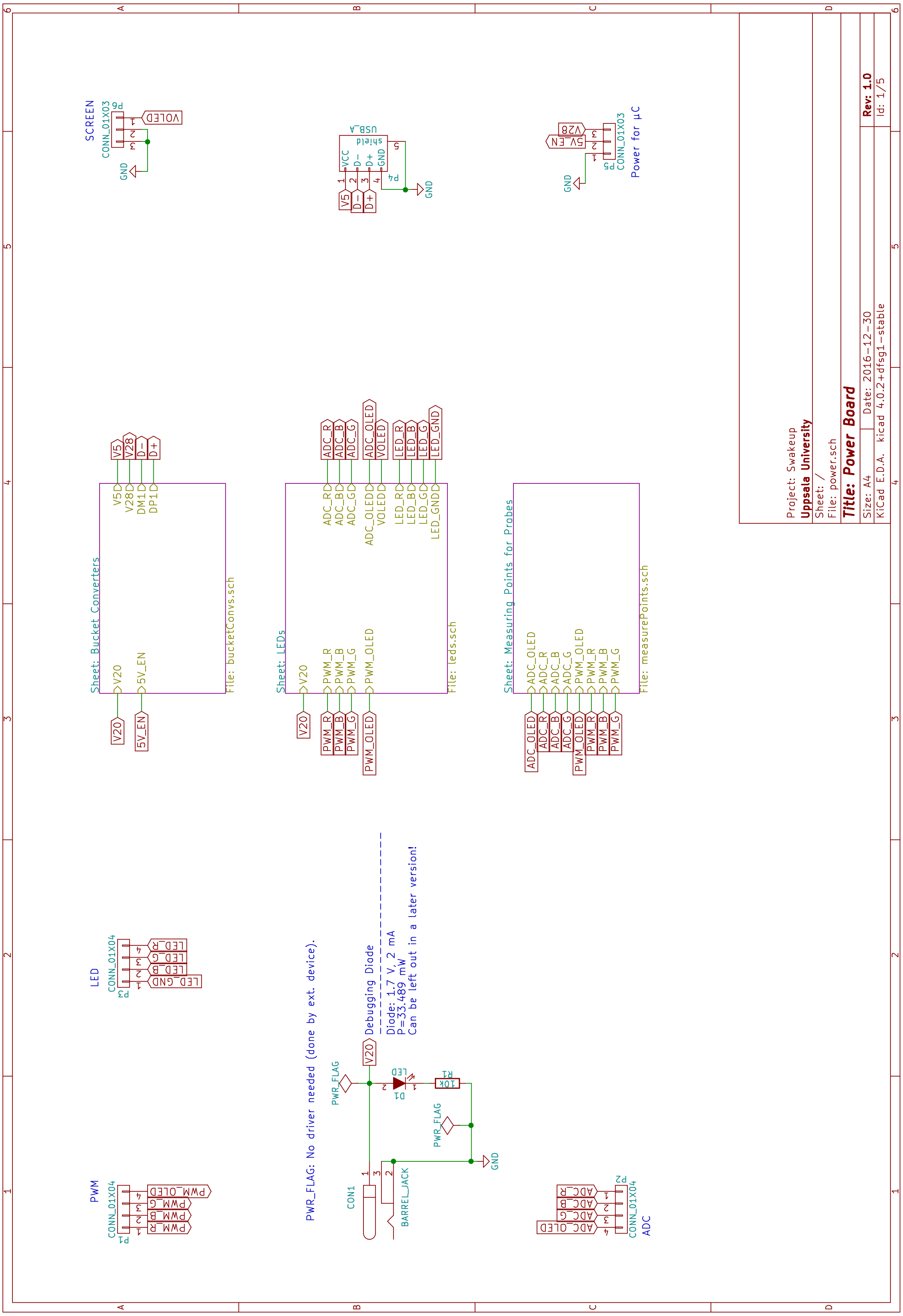
Table 4.2: Software Overview: What works? What does not?

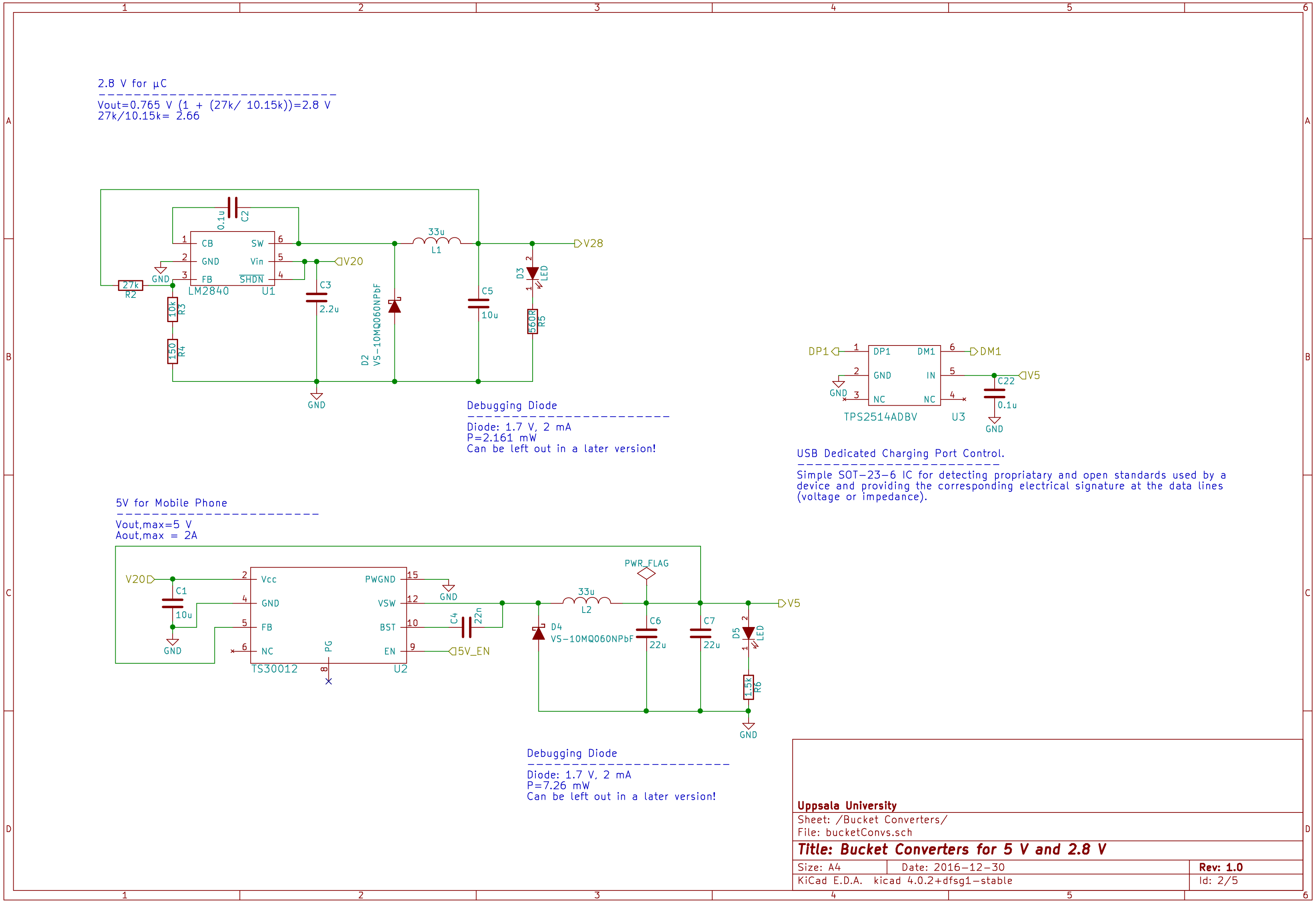
Outlook

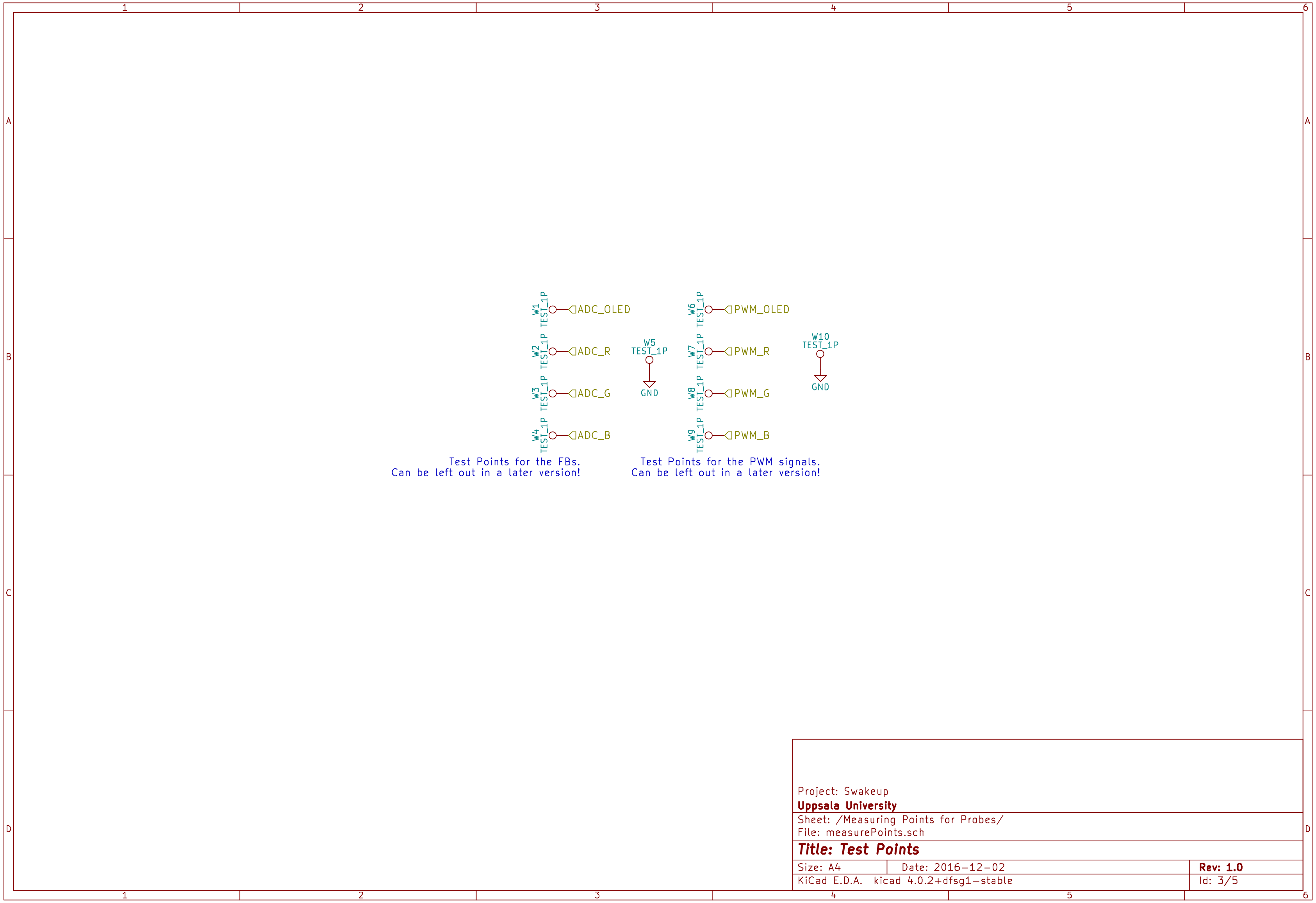
Hopefully the LED driver will work with the next revision. The new boards have not arrived until the deadline. As soon as the hardware is working, the controllers will be implemented in software.

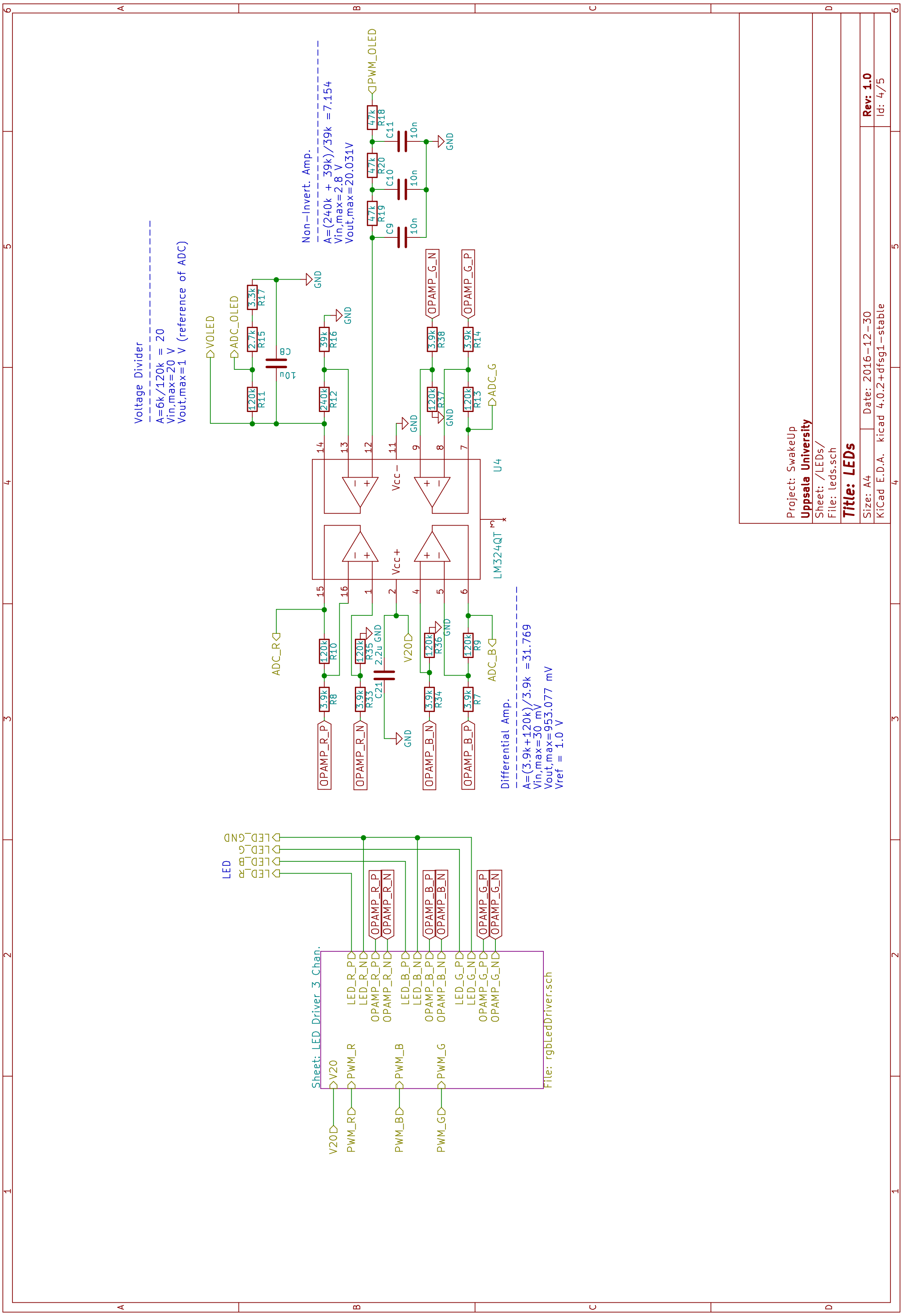
Aditional funtionality will be implemented e.g. connecting you calendar to the device and seing your daily agenda when you wake up. Also there is no housing yet.

A Schematics Power Board




2.8 V for µC
Vout=0.765 V (1 + (27k/ 10.15k))=2.8 V
27k/10.15k= 2.66
CB
GND
FB
SW
Vin
SHDN
LM2840
U1
C2
0.1u
C3
2.2u
V20
33u
L1
V28
D2
VS-10MQ060NPbF
C5
10u
D3
LED
R5
560k
27k
R2
10k
R3
150
R4
GND
Debugging Diode
Diode: 1.7 V, 2 mA
P=2.161 mW
Can be left out in a later version!
DP1
DM1
GND
IN
NC
TPS2514ADBV
U3
C22
0.1u
V5
USB Dedicated Charging Port Control.
Simple SOT-23-6 IC for detecting propriatary and open standards used by a
device and providing the corresponding electrical signature at the data lines
(voltage or impedance).
5V for Mobile Phone
Vout,max=5 V
Aout,max = 2A
V20
C1
10u
Vcc
GND
FB
NC
PG
PWGND
VSW
BST
EN
TS30012
U2
C4
22n
5V_EN
PWR_FLAG
33u
L2
D4
VS-10MQ060NPbF
C6
22u
C7
22u
D5
LED
1.5k
R6
V5
Debugging Diode
Diode: 1.7 V, 2 mA
P=7.26 mW
Can be left out in a later version!
Uppsala University
Sheet: /Bucket Converters/
File: bucketConvs.sch
Title: Bucket Converters for 5 V and 2.8 V
Size: A4
Date: 2016-12-30
Rev: 1.0
KiCad E.D.A. kicad 4.0.2+dfsg1-stable
Id: 2/5


W1 TEST_1P
ADC_OLED
W2 TEST_1P
ADC_R
W3 TEST_1P
ADC_G
W4 TEST_1P
ADC_B
W5 TEST_1P
GND
W6 TEST_1P
PWM_OLED
W7 TEST_1P
PWM_R
W8 TEST_1P
PWM_G
W9 TEST_1P
PWM_B
W10 TEST_1P
GND
Test Points for the FBs.
Can be left out in a later version!
Test Points for the PWM signals.
Can be left out in a later version!
Project: Swakeup
Uppsala University
Sheet: /Measuring Points for Probes/
File: measurePoints.sch
Title: Test Points
Size: A4
Date: 2016-12-02
Rev: 1.0
KiCad E.D.A. kicad 4.0.2+dfsg1-stable
Id: 3/5


Voltage Divider
A=6k/120k = 20
Vin,max=20 V
Vout,max=1 V (reference of ADC)
Non-Invert. Amp.
A=(240k + 39k)/39k =7.154
Vin,max=2.8 V
Vout,max=20.031V
Differential Amp.
A=(3.9k+120k)/3.9k =31.769
Vin,max=30 mV
Vout,max=953.077 mV
Vref = 1.0 V
VOLED
ADC_OLED
PWM_OLED
ADC_R
ADC_G
ADC_B
V20
GND
U4
LM324QT
Vcc+
Vcc-
OPAMP_R_P
OPAMP_R_N
OPAMP_B_N
OPAMP_B_P
OPAMP_G_N
OPAMP_G_P
LED
LED_GND
LED_G
LED_B
LED_R
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File: rgbLedDriver.sch
V20
PWM_R
PWM_B
PWM_G
LED_R_P
LED_R_N
LED_B_P
LED_B_N
LED_G_P
LED_G_N
Project: SwakeUp
Uppsala University
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File: leds.sch
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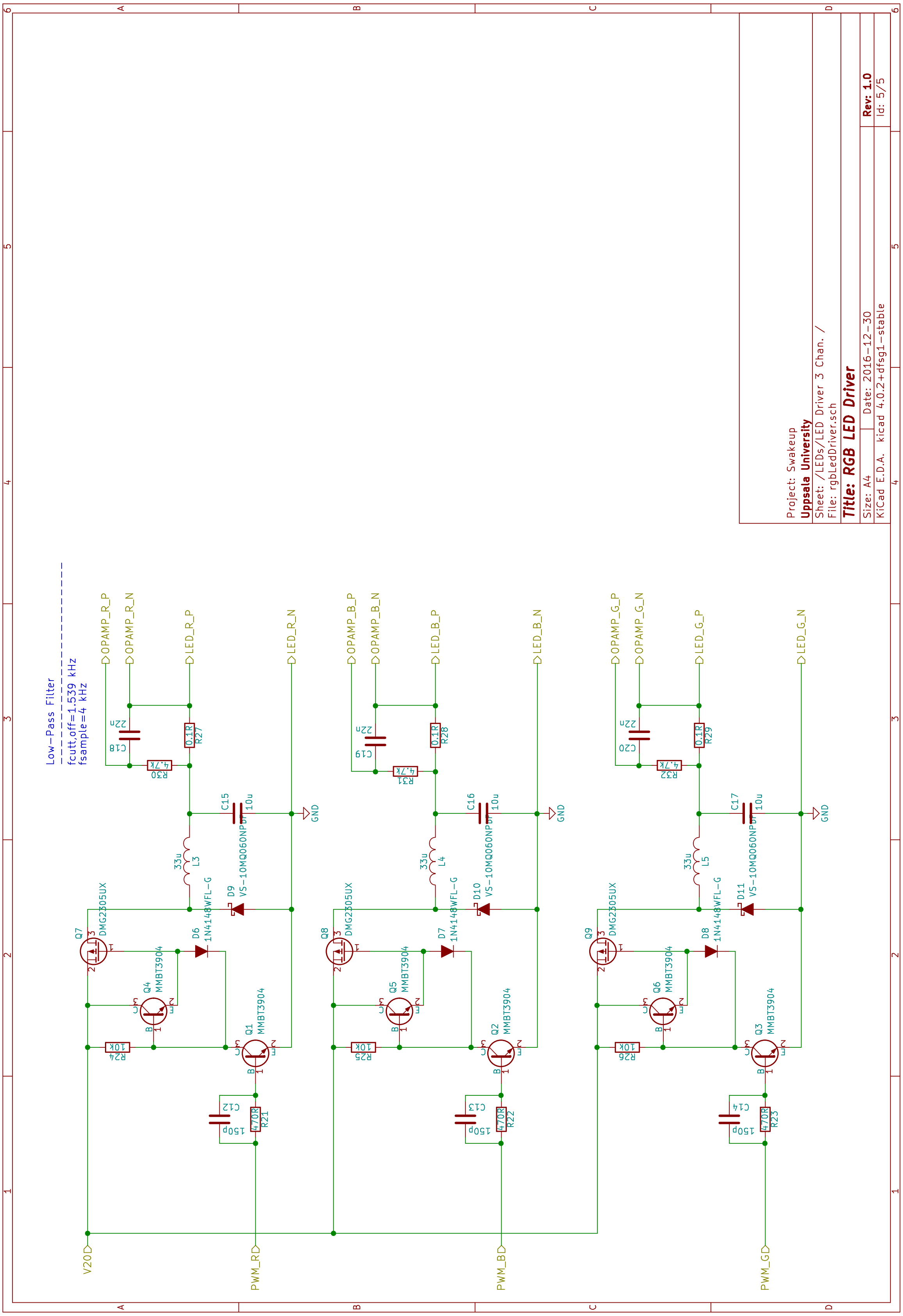
Size: A4
Date: 2016-12-30
Rev: 1.0
KiCad E.D.A. kicad 4.0.2+dfsg1-stable
Id: 4/5



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Uppsala University
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Title: RGB LED Driver
Size: A4
Date: 2016-12-30
Rev: 1.0
KiCad E.D.A. kicad 4.0.2+dfsg1-stable
Id: 5/5
Low-Pass Filter
fcutt,off=1.539 kHz
fsample=4 kHz
OPAMP_R_P
OPAMP_R_N
LED_R_P
LED_R_N
OPAMP_B_P
OPAMP_B_N
LED_B_P
LED_B_N
OPAMP_G_P
OPAMP_G_N
LED_G_P
LED_G_N
V20
PWM_R
PWM_B
PWM_G
GND
DMG2305UX
MMBT3904
1N4148WFL-G
VS-10MQ060NPbF