Extra Feature

Moodlight

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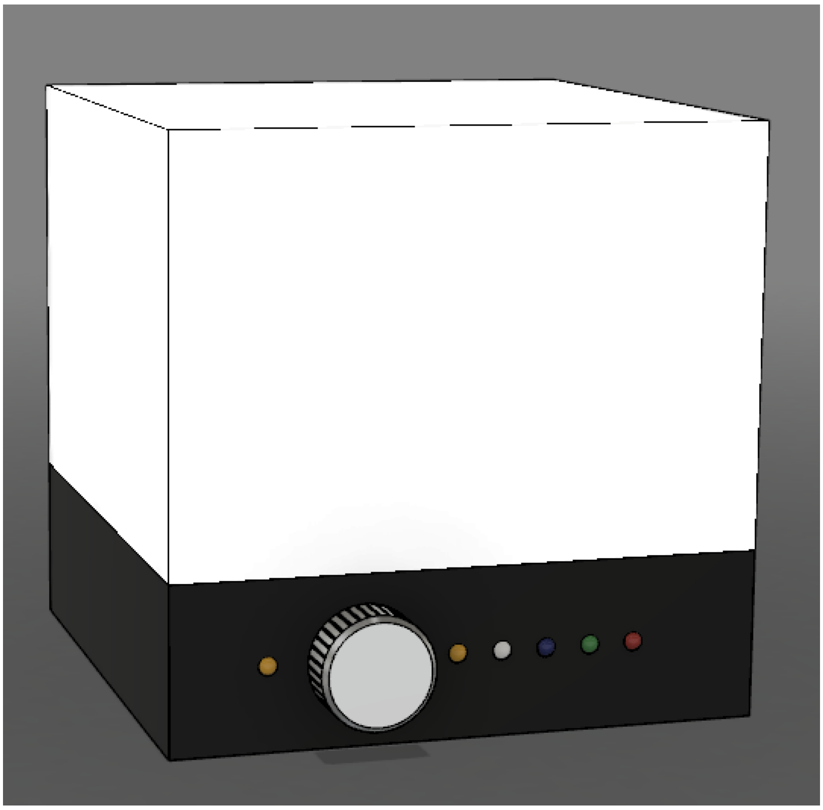

1 Overview

In this documentation the specifications of the Moodlight's extra features are described and the test results are shown. It includes the hardware and software report of the *local user interface* and of the *bass pulsing feature*.

The Moodlight has additionally to the standard function a *local user interface*, where the user can handle the whole Moodlight with a rotary encoder and integrated button. With the help of the *on/off circuit* the button of the rotary encoder can be used to turn the Moodlight on and off.

With the *bass pulsing feature* the Moodlight has the possibility to adapt the light to the ambient sound. The implemented microphone and lowpass-filter detect the bass and send an analog signal to the uC where the signal is further processed.

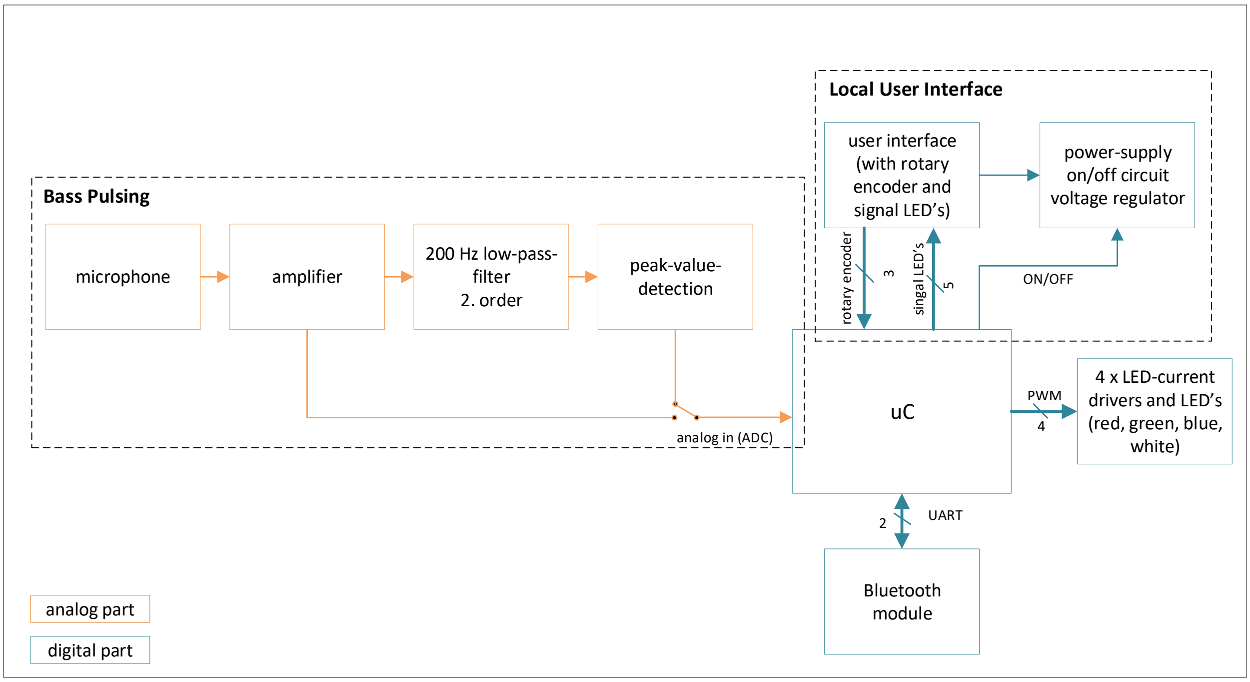

Figure 1: Block diagram over the whole Moodlight

2 Specification

2.1 Local User Interface

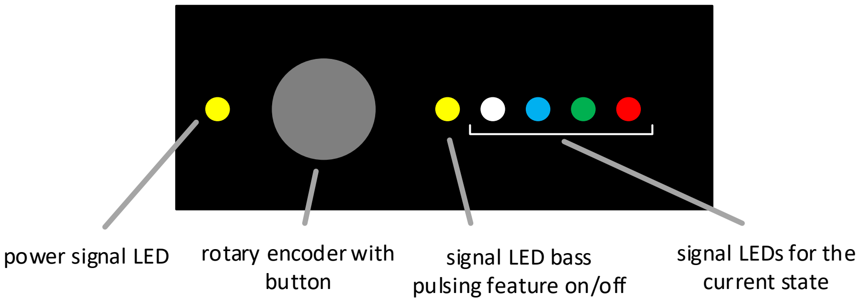

Figure 2: Example of the local user interface

The block diagram of the *local user interface* (Figure 1) can be seen. To switch the Moodlight on, the user has to press the rotary encoder. The *power on / off* signal LED (Figure 2) turns on and signals that the Moodlight is powered.
When the Moodlight is turned on, a single short press on the rotary encoder, switches between the different colour states. The colour that can be adjusted is shown via the signal LEDs for the current state (Figure 2).
When the rotary encoder is rotated clockwise, the brightness of the colour will be increased. If the rotary encoder is rotated counter-clockwise, the brightness will be decreased. With a double tab on the rotary encoder, the Moodlight will turn the *bass pulsing feature* on, or in case, that the *bass pulsing feature* is already on, it will turn it off. The signal LED *bass pulsing feature on / off* (Figure 2) is on if the *bass pulsing feature* is activated, otherwise it will be off. To switch the Moodlight off, the rotary encoder must be pressed for at least 2 seconds. As soon as all signal LEDs except the *power signal* LED turn off the rotary encoder can be released and the Moodlight will shut down. This will then turn the *power signal* LED off as well.

2.2 Bass Pulsing Feature

To make the Moodlight pulsate to the bass of the music it has an integrated microphone. The signal from the microphone will be amplified. The amplified sound signal goes through a lowpass-filter to get the bass frequencies. Afterwards the signal will be processed by the uC. The Moodlight will adjust the brightness to the volume of the bass from the music.

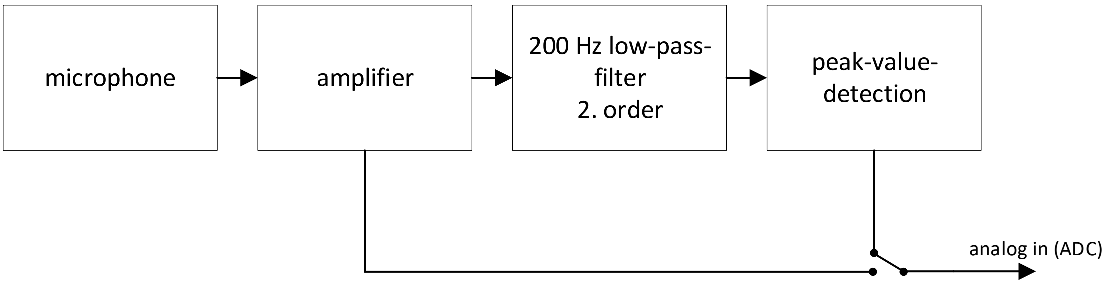

Figure 3: Block-diagram of the Hardware for the bass pulsing feature

In the first step, the amplified signal is filtered with a low-pass filter with cut off frequency $200\ Hz$. In the second step, the peak-value-detection will convert the signal to a DC voltage. This voltage will be converted into a digital signal by the ADC of the uC and then processed. For the possibility of a different application in the future, the amplified microphone signal can be connected directly to the ADC of the uC and gives the possibility to process it completely in software.

3 Hardware

3.1 Local User Interface

3.1.1 Rotary Encoder

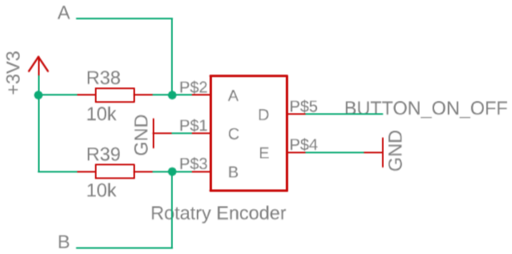

Figure 4: Schematic Rotary Encoder

The rotary encoder phases A and B are driven with a pull-up resistor. The button of the rotary encoder is on the pins D and E. It is also driven by a pullup resistor from the *on / off circuit.*

3.1.2 On / Off Circuit

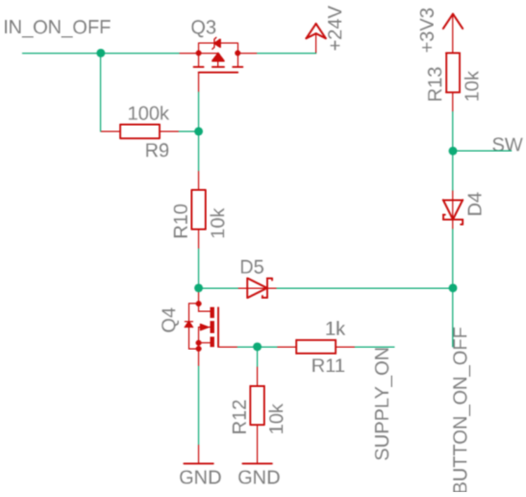

Figure 5: Schematic of the on / off circuit

When the button from the rotary encoder is pressed, the FET Q3 conducts. The uC will be supplied and will first set the pin SUPPLY_ON high. With this pin set high, the FET Q4 begins to conduct as well. The supply is on as long as the uC sets the pin SUPPLY_ON to high. When the uC pulls the pin SUPPLY_ON down, the FET Q4 does not conduct anymore, then the FET Q3 will also stop to conduct and the whole supply of the Moodlight will be turned off. Because of the two diodes D4 and D5, the button from the rotary encoder can still be read by the uC.

3.1.3 Test

To test the *local user interface*, a test-program was developed. With a press of the button from the rotary encoder, the uC switches the Moodlight on. If the Moodlight is turned on the presses of the button can be evaluated by the uC. If the SUPPLY_ON pin is pulled down by the test-program the Moodlight turns off. By rotating the rotary encoder, the uC receives the signals from the phases A and B. The test-program evaluates the phases and adjusts the white colour LED.

The rotary encoder and the *on / off circuit* fulfil all the requirements and thus pass the test.

3.2 Bass Pulsing Feature

The microphone will be first amplified and then filtered. The amplification can be adjusted with a potentiometer. Because the signal from the microphone will be converted by the ADC of the uC, the maximum output voltage of the filter should correspond be the supply voltage of the uC ($V_{cc} = 3.3\ V$). The amplifier should be a rail-to-rail op-amp and is use with a single supply.

3.2.1 $V_{cc}/2$ supply

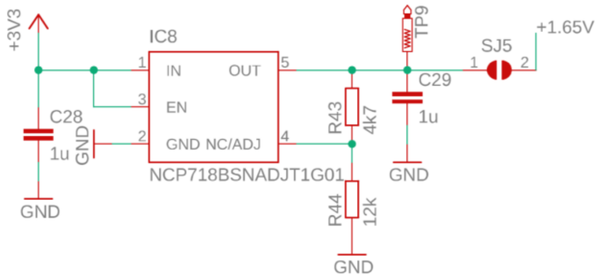

Figure 6: Schematic of the 1.65 V supply

Because of the single supply, the circuit with the op-amp needs $V_{CC}/2$ as reference voltage. The $V_{CC}/2$ supply should not have an influence on the filter. This is realised with a low-dropout regulator (LDO). The chosen LDO is the NPC718LDO.

3.2.1.1 Calculations

$V_{CC}/2 = 1.65\ V$

$V_{adj} = 1.2\ V$

$$\frac{R_{43}}{R_{44}} = \frac{V_{CC}/2 - V_{adj}}{V_{adj}}$$

The Resistor R_2 will be chosen as $\boldsymbol{R_2 = 12\ k\Omega}$

$$R_{43} = R_{44}\frac{V_{CC}/2 - V_{adj}}{V_{adj}} = 4.5\ k\Omega, \qquad in\ the\ E24-row: \boldsymbol{R_{43} = 4.7\ k\Omega}$$

3.2.2 Filter

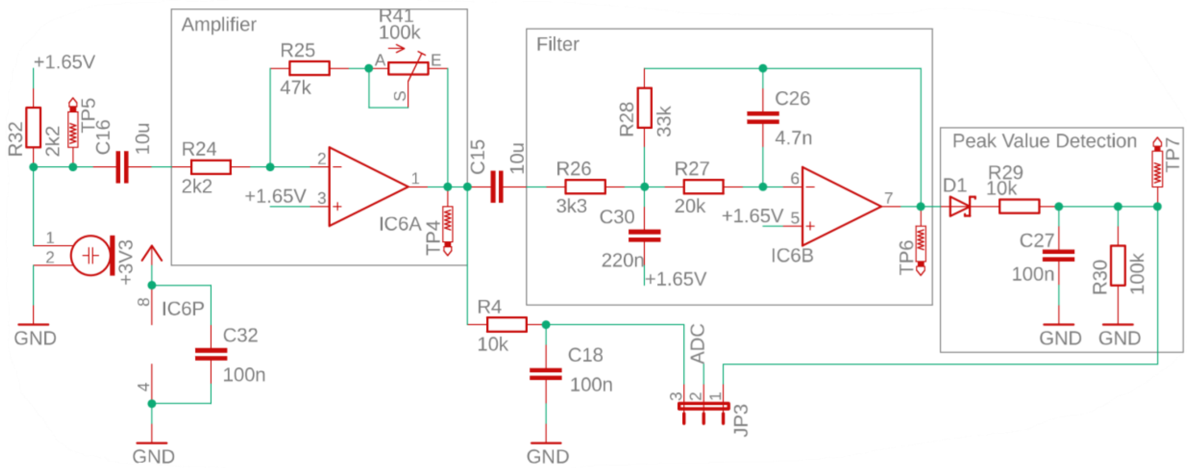

Figure 7: Schematic of the filter and amplifier circuit

The chosen filter is a Butterworth-filter, because the frequency response of the Butterworth-filter is one of the steepest and comes without a ripple. It will be a second order filter, because this will be steep enough. The chosen circuit is a multiple negative feedback filter (MNF). This part of the filter circuit also amplifies the signal with $|A_0| = 10$. The chosen cut-off frequency is $f_0 = 200\ Hz$. Because of the low cut off frequency, the Gain-Bandwidth-Product and the slew-rate of the chosen op-amp do not have an influence. With the jumper JP3 the amplified signal can be put directly on the ADC of the uC. With the potentiometer $R41$ the gain can be adjusted in a range of $|A_1| = 21$ down to $|A_1| = 66$.

3.2.2.1 Calculations

$$\omega_0 = f_0 2\pi, \qquad f_0 = 200\ Hz, \qquad A_0 = -10$$
$$a_1 = 1.4142, \qquad b_1 = 1$$

$$H_{MNF}(s) = \frac{-\frac{R_{28}}{R_{26}}}{1 + C_{26}\left(R_{28} + R_{27} + \frac{R_{28}R_{27}}{R_{26}}\right)s + C_{26}C_{30}R_{28}R_{27}s^2}, \qquad H_{LP}(s) = \frac{A_0}{1 + a_1\frac{s}{\omega_g} + b_1\left(\frac{s}{\omega_g}\right)^2}$$

With coefficient comparison there are these formulas:

$$A_0 = -\frac{R_{28}}{R_{26}}, \qquad a_1/\omega_g = C_{26}\left(R_{28} + R_{27} + \frac{R_{28}R_{27}}{R_{26}}\right), \qquad b_1/\omega_g^2 = C_{26}C_{30}R_{28}R_{27}$$

The capacitors C_{26}, C_{30} will be chosen as $C_{26} = 4.7\ nF,\ C_{30} = 220\ nF$

$$R_{28} = \frac{a_1C_{30} - \sqrt{(a_1C_{30})^2 - 4C_{26}C_{30}b_1(1 - A_0)}}{2\omega_g C_{30}C_{26}} = 32.6\ k\Omega\ \ in\ the\ E24-row\colon \boldsymbol{R_{28} = 33\ k\Omega}$$

$$\boldsymbol{R_{26}} = -\frac{R_{28}}{A_0} = \boldsymbol{3.3\ \Omega}$$

$$R_{27} = \frac{b_1}{\omega_g^2 C_{30}C_{26}R_{28}} = 18.6\ k\Omega, \qquad in\ the\ E24-row\colon \boldsymbol{R_{27} = 20\ k\Omega}\,,$$

3.2.2.2 Simulation

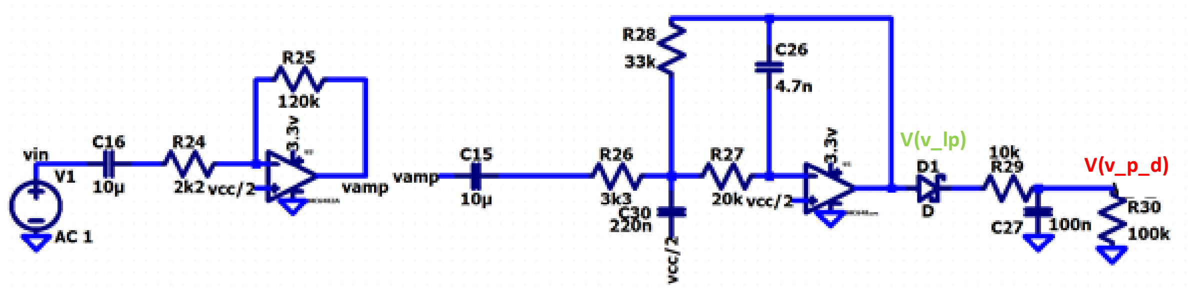

Figure 8: Schematic of the simulation

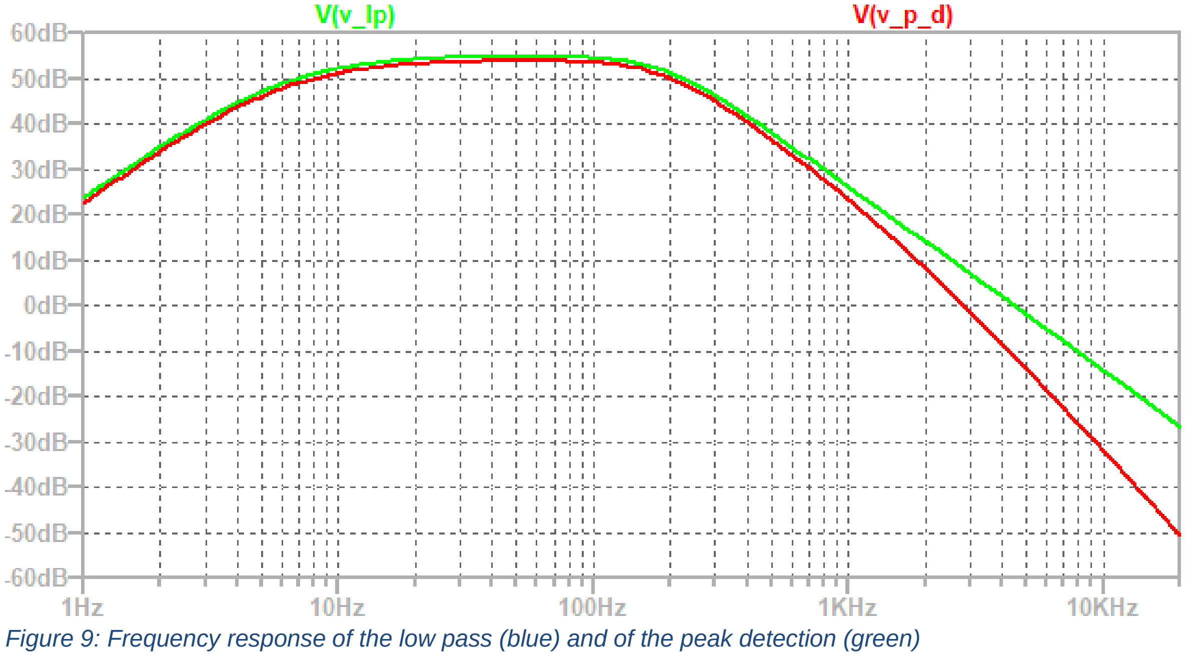

Figure 9: Frequency response of the low pass (blue) and of the peak detection (green)

The frequency response of the lowpass is as calculated. With the peak detection, the attenuation in the cut-off region is steeper than without the peak detection.

3.2.2.3 Test

To test the circuit, the $V_{CC}/2$ voltage will be measured first. To measure the frequency response a $2.2\ k\Omega$ resistor should be in series to the function generator to simulate the microphone which has an impedance of $2.2\ k\Omega$. The amplitude of the function generator should be $V_{in_{pp}} = 0.04\ V$. First, the gain of the amplifier has to be adjusted with the potentiometer $R41$. The adjustment will be done at an input frequency of $100\ Hz$ and with an input voltage of $V_{in_{pp}} = 0.04\ V$. The voltage $V_{out_{pp}} filter$ should be $3.0\ V$.

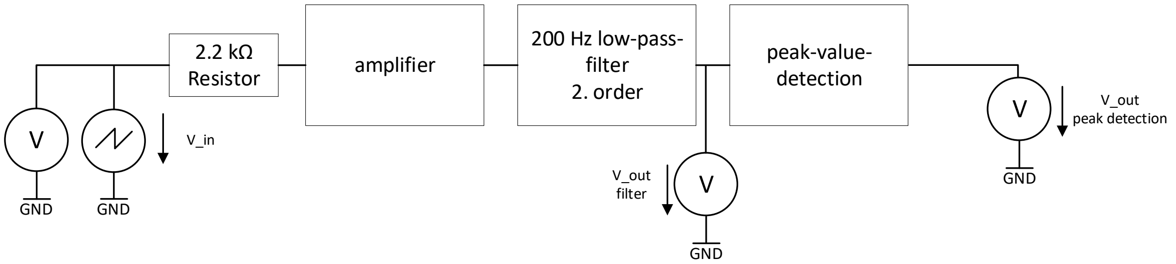

Figure 10: Measurement schematic of the filter

Measurements: $V_{CC}/2$=$1.67\ V$

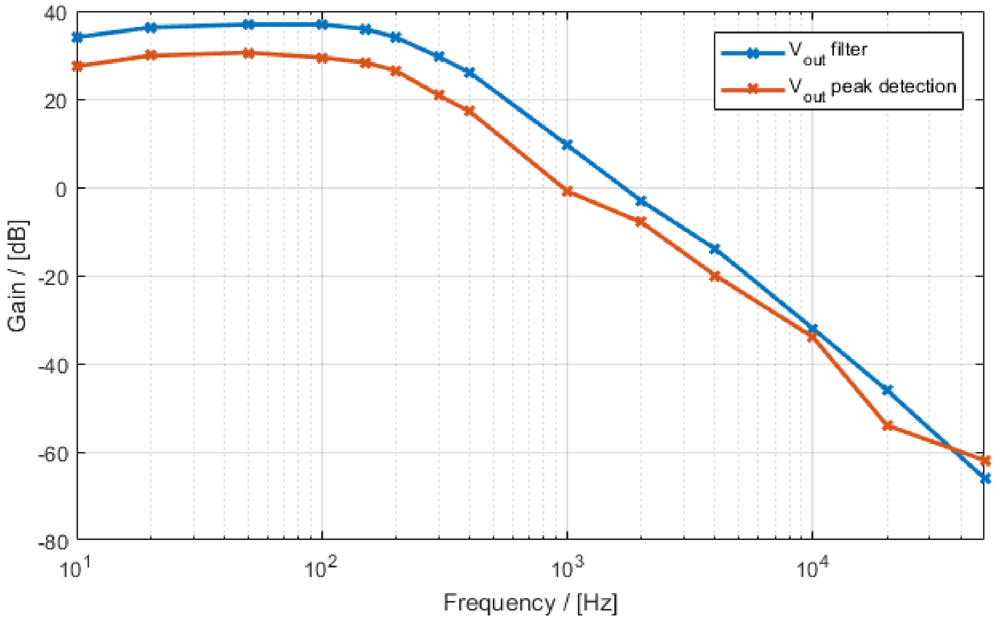

Figure 11: Frequency response measurement

The measured frequency response (Figure 11) looks like the frequency response (Figure 9) of the simulation. The cut-off frequency is as calculated by about $200\ Hz$. The gain is not as high as in the simulation, this is because in the simulation the voltage of the microphone was not known. The gain will be adjusted after the assembly, because the case of the Moodlight will attenuate the volume of the sound.

4 Software

4.1 Local User Interface

4.1.1 Float Diagram

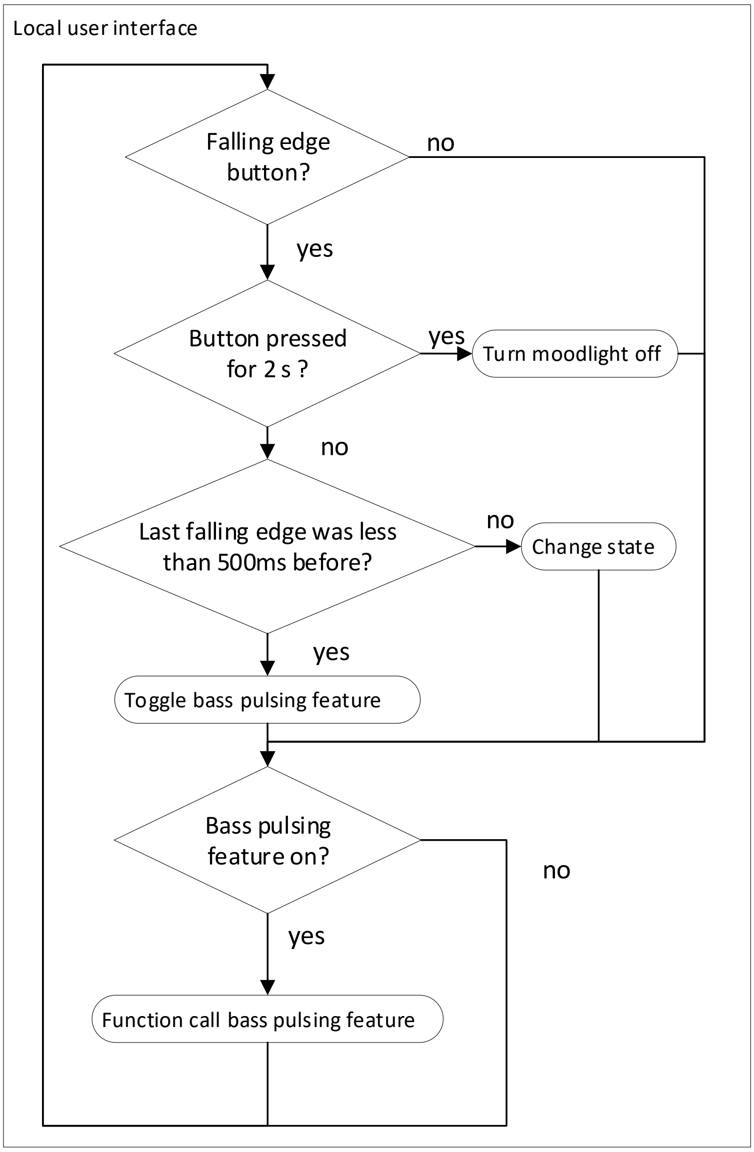

Figure 12: float diagram for the local user interface

The *local user interface* will run in the main loop. It will handle the adjustment of the colour intensity and the state of the *bass pulsing feature*. The adjustment of the intensity will be done with the rotary encoder. This will be done via an interrupt service routine to the rising edge of the phase A. With a single tab on the button of the rotary encoder, the state will be changed and another colour can be adjusted. This will happen with the sequence shown on Figure 13. With a double tab on the button from the rotary encoder, the *bass pulsing feature* will be switched on and off. If the button is pressed longer than two seconds, the Moodlight will switch off via the *on / off circuit*

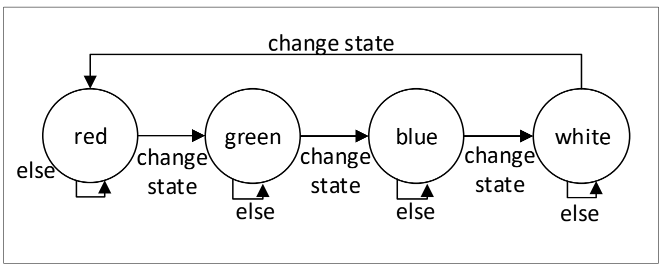

Figure 13: State diagram of the local user interface

4.1.2 Test

To test the *local user interface* the signal LEDs in the front are used. With a single tab, the LED's change as shown in Figure 13. With a double tab to the button of the rotary encoder, the LED for the *bass pulsing feature* should toggle. By turning the rotary encoder clockwise, the intensity of the power LEDs should increase, by turning it counter-clockwise, the intensity should decrease. To test the switching off the Moodlight, the button of the rotary encoder must be pressed for 2 seconds. After that all signal LEDs except for the power signal LED should be turned off by Software. If you release the button, also the power signal LED will turn off. The Moodlight passes this test.

4.2 Bass Pulsing Feature

4.2.1 Float Diagram

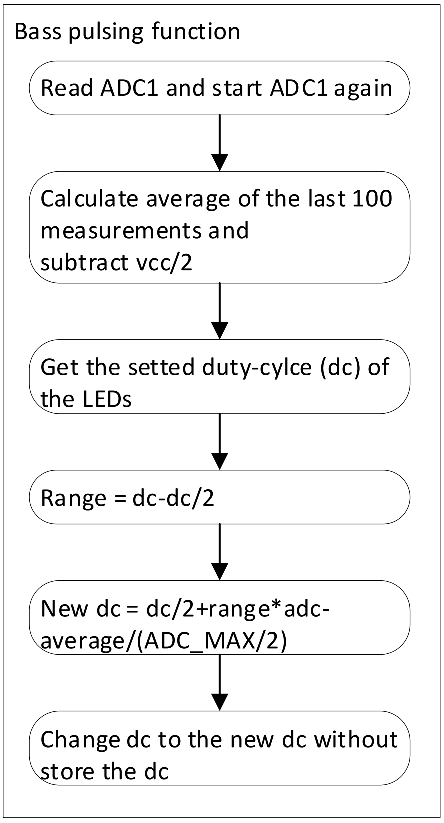

Figure 14: Float diagram for the bass pulsing feature

The ADC will be used in single mode. Because of that the program is less complex than in interrupt or continuous mode. The program in single mode is fast enough for this application. The *bass pulsing feature* adjusts the intensity of the active LEDs to the bass of the music. The maximum intensity is the intensity which the user selects. If there is no bass, the intensity of the LEDs is set to the half of the selected intensity. With the bass, the intensity can go up to the initial value.

4.2.2 Test

To test the *bass pulsing feature*, the Moodlight should be in the *bass pulsing feature* mode. The intensity of the LED is set to the maximum. After that music with a clear bass is turned on to detect visually if the intensity changes when there is the bass or not. The Moodlight passes this test.

5 Conclusion

The *local user interface* with the rotary encoder and the *on / off circuit* worked like expected. The design of the filter was without any incidents. The simulation and the measurements are as calculated. The peak detection in analog and the light pulsing to the bass work as planned. The pulsing of the light to the bass could be optimised with further range than the current 50% of the adjusted intensity to increase the effect. The gain from the microphone signal should be adjusted after the PCB and uC are built in the case. In further steps, there is the possibility to do the processing the microphone signal in software. For that the jumper can be used. With that there are more possibilities to adapt the light to the ambient sound.