31015 Introductory Project

Smart Control of LED lighting - ELE3

Group 2
Emil Bruun Krogh - s194008
Emil Løwenstein - s182888
Sune Bruhn - s190746
William Riis - s194019

DTU Electro
March 8, 2021

Contents

1 Project introduction

According to the EPA 93% of an average American life is spent indoors. A lot of that time is spend with the light on. The introduction of wireless smart lighting in homes enables power consumption cuts through automation and brightness control, as well as easing the users control of their lighting to maximise 'hygge'. With our lamp, we furthermore seek to provide entertainment, by providing more advanced and easy-to-use light show-like features than existing smart lighting solutions, at little-to-no extra cost.

To realize all this, the LED's are placed in a matrix formation to enable the user to create their own light patterns as well as load pre-programmed combinations of either flashy light shows or simpler lights for a normal week day. All this will be customizable through a user friendly website made specifically for our lamp. A microprocessor will be the link between LED's and website for optimal communication and response. Finally, to make the lamp usable anywhere, a power converter will make sure the correct amount of power is supplied to the LED's and microprocessor.

The relevant technical terms used throughout this report are described in the following list.

- **Smart lighting** - A term used for bulbs with controllable color, intensity and mood, often changed with an app
- **LED** - Light Emitting Diode, a small light bulb
- **RGB** - Short for "Red Green Blue", the colors used by LED's to make every known color. Describes an LED able to create all colors of light.
- **Multiplexing** - Running LED's in series, and being able to turn on only some in the same row. This is done by switching individual LED's on and off faster than the human eye can follow, making it look like only some of the LED's are on.
- **Constant current driver** - An integrated circuit that ensures that an LED is driven at a constant current
- **LED control circuit** - the circuit controlling the LED's
- **LED circuit** - the circuit consisting of the LED control circuit as well as the actual LED's
- **Microcontroller** - Programmable 'computer' which will control when the LED-matrix gets power through the website hosted on it.
- **Mains power** - the 230 V AC supplied from a wall socket
- **Power converter** - the circuit for converting mains power to the required DC voltages, consisting of a transformer, rectifier and buck converter
- **Transformer** - component that steps AC voltages up or down - in this case, down
- **Rectifier** - circuit that converts AC to DC
- **Buck converter** - circuit that steps down DC, and can keep it well regulated
- **PWM** - Pulse width modulation signal, which is a square wave signal with controllable on- and off-times
- **Duty Cycle** - the percentage on-time of a PWM signal

2 Problem definition

We want our smart lamp to consist of an RGB LED matrix. In order to control this lamp, we will use a microcontroller to host a webpage on a local WiFi network with a user interface for control. Based on the user input, the microcontroller will send instructions to an LED control circuit, which controls the LEDs accordingly. The microcontroller and the LED circuit will be powered by a power converter connected to a wall mains power socket.

Figure 1 explains the basic structure of the above described system. The project can be divided into four main problems as described in the following list.

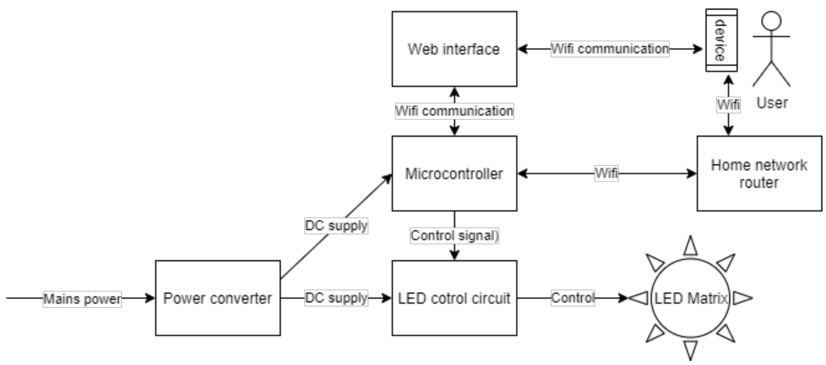

Figure 1: Basic functional block diagram

- How do we control an RGB LED matrix?
  - Each LED needs to be individually controlled in regards to color and brightness.
- How do we design a user friendly interface?
  - We want it to be easy to program moving images, for anyone.
- What voltages and currents do we need to supply to the microcontroller and to the LED circuit, and what kind of power converter is suitable for this?
  - The power converter needs to be able to supply the necessary voltages, and be able to handle the required current, and be efficient as to not waste power.
- How do we use the microcontroller to control and connect the other main components?
  - The microcontroller has to be the bridge between the web interface and the LED control circuit, as well as regulate the power converter.

3 Scope

The product should consist of an LED matrix smart lamp, powered through a wall socket at mains voltage (230 V AC). The lamp should be controllable from a web-based user interface, offering several basic and advanced control features. The control features shall be as listed in the following:

- Simple colour controls:
  - RGB colour
  - Brightness
- On/Off timers
- Artificial sunrise

- Time zone calibration
- Advanced grid control:
  - Control of each LED individually
    - Static pictures
    - Sequences
  - Export/Import of lighting programs

We will not implement control of white colour temperature, as this problem would require a different approach, simply balancing white LED's of different colour temperatures, rather than balancing RGB LED's. To implement these functionalities in parallel in one product doesn't seem resource efficient.

An LED matrix that will be built from scratch using RGB LED strips and probably LED drivers if necessary. Since this involves a lot of soldering, it's crucial that we have properly simulated our design to assure efficiency.

In order to implement the control features, we will need a micro controller with a WiFi connection to host a local web page that works as a user interface. The micro controller will then receive instructions from the web page, and send corresponding instructions to the LED circuit.

A website that will be hosted on the microcontroller and built in standard HTML, combined with Javascript and CSS to make a functional, and visually pleasing, product. We plan on making this using a commercially available text editor such as Atom.

The LED control circuit will be using multiplexing as a way of reducing I/O-ports to the microcontroller. We connect the rows cathodes, and columns anodes and can then turn on a specific LED at any time, as the human eye can't detect fast flickering, to turn on multiple LED's in the same row or column, we switch between the on LED's fast, so to the human eye, it seems as if both LED's are on. As the LED's in series will pull a lot more power, we make use of MOSFET's as switches and connect the gate to the I/O, and the source to the power converter. The source also goes through a constant current LED-driver to regulate the output to match the voltage needs of the LED's, which lowers as the LED's heat up.

The brain of the project, the microcontroller. This will be in charge of fetching the useful information from the website, and converting that information into a simple instruction for the LED matrix.

Finally, the LED circuit and the micro controller will be powered by DC voltages supplied by a mains-connected power converter. The micro controller will regulate the power converter in order to maintain a steady DC voltage. The microcontroller and the LED circuit might need different supply voltages, so 2 buck converters might be necessary.

4 Market segment

This product is meant for private consumers. As the product can both be used as any other lamp and as a more personalized way of lighting, the target group for this product includes people who enjoy quirky gadgets for a low price, while also appealing to consumers with a more basic interest in smart lighting. It allows people with no knowledge of programming to be able to play around with customizing the LED grid in an easy to use interface through a web-browser. The lamps wide functionality enables a wide target group.

5 Procedure

This project consists of 2 hardware tasks, and 2 software tasks, as well as a bonus mechanical task. The hardware tasks are the power converter and the LED circuit, while the software tasks are the microcontroller and the web interface.

The hardware tasks will require research into existing solutions/topologies, adapting these to our own requirements, simulation of our own adaptations in a SPICE simulator (which may re-inform requirements), and prototyping in the lab, until we can finally construct the circuits for the final implementation.

The software tasks will again require research into existing solutions and libraries, adapting these to our own requirements, and testing how our solutions work together, with each others and with the hardware components.

Finally, we will enclose the entire circuitry in a 3d printed enclosure, as our bonus mechanical task. This will require some CAD modelling.

6 Resources

Item	Quant.	price pr. Unit	Total price	
LED	100	0,86	86	kr
ESP32	1	80	80	kr
Transformer	1	50	50	kr
Total			216	kr

As the design of the circuits have yet to be made, some components are missing. We plan to use a lot of the components already available through DTU - Electro, as they have most of the common components readily available.

7 Activity plan

To mitigate time-inefficiency we've decided on a divide-and-conquer approach, splitting up our group to work in parallel on different parts of the project, all while keeping good communication to avoid misunderstandings amongst our group members. This should secure a steady progress throughout the weeks, and a well balanced work distribution. To furthermore ensure the compatibility and cooperation between the hardware part and the software part, every person is assigned one hardware and one software component, with a different person.

In the following, each activity in the time plan is briefly described.

- **Power converter**
  - Circuit design - Research existing solutions and topologies, simulate a circuit in a spice simulator (such as LT-Spice or MultiSim), prototype in lab. This activity is dependant on the LED-circuit design, so that we know what voltage and current the power converter must be able to supply.
  - PCB-design - Design a PCB to realise the prototype on, choosing (and by the associated deadline, ordering) specific components.
  - Construction - Solder components to PCB-board, test and verify with oscilloscope and multimeter.

- **LED-circuit**
  - Circuit design - Research for way to build LED matrix where every LED can be controlled individually by multiplexing and test through spice simulation
  - PCB-design - Design a PCB to realise the prototype on, choosing (and by the associated deadline, ordering) specific components.
  - Construction - Solder components to PCB-board and LED-setup, test and verify with oscilloscope and multimeter.
- **Microprocessor**
  - Regulation of power converter - This activity is closely linked to power converter circuit design. A way to regulate the power converter must be implemented.
  - Communication with web-page - Research how to establish communication protocols between the microcontroller and the web page, and implement it. This can be developed independently of web page and LED circuit design, and then later be tailored to interface demands.
  - Control of LED-circuit - This activity is closely linked to LED circuit design. Using the specifications of the designed LED-circuit, making outputs through the microprocessor to control which LED's should be turned on by the LED control circuit.
- **Web-page**
  - Communication with microprocessor - This is closely linked with the LED circuit design and with microprocessor programming, as these determine what kind of data to send.
  - User interface - Controlling the LED's should be intuitive for the average user. Sliders and switches will be implemented on the website to make sure this is the case.
- **Casing**
  - Design - Depending on LED-circuit, designing a casing using a CAD-model or a drawing.
  - Construction - Printing the casing with a 3d-printer or using wood/other material.

7.1 Plan B

As each component of the system (Power converter, LED circuit, microcontroller and web page) is fairly independant of the others, we can work around any of these failing.

- If the power converter fails, we can use a lab power supply, or even a standard commercial consumer electronics power supply.
- If our own LED circuit fails, we can use the LED circuit supplied by the ELE group, as was originally intended for the project. As this is a circuit consisting of 2 different white LED strips, it will require some changes to the web page interface and the microcontroller instruction protocols, and potentially the power supply too.
- If the web page interface fails, we can hard code some instructions in the microprocessor.
- If the microcontroller power converter regulation fails, we can use another power supply. If the microcontroller communication protocols with the web page fails, we can also hardcode some instructions. If the microcontroller fails to provide instructions for the LED control circuit, we will have a real problem - then hopefully we will at least have a working web interface, power converter and LED circuit, but the system as a whole will fail to perform its purpose.

7.2 Gantt diagram