ELEKTRONICA-ICT

Project Ontwerpen

Led controller

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Content

Introduction

The emergence of indoor vertical agriculture with LEDs is stimulating new technological developments to operate the LEDs efficiently. The LED controller discussed in this application note is used in vertical farming for controlling and automating the LED infrastructure. The schematic used for the LED controller, is found in the Elektor magazine [1]. The design consists of several segments, each with different functions. With the LED drivers and the integrated ESP32 module, a solution is created to control the intensity and light cycles through a convenient web interface. Four different LED chains can be individually controlled with this model. Each chain can contain LEDs with a specific light spectrum. Combining the LED chains and controlling them individually, creates an optimal light spectrum for a specific plant and its growing stage. In this application note, the process of designing the PCB and associated research is described.

Materials and methods

2.1 Materials

2.1.1 Hardware

The LED controller consists of about a hundred components, most of which are common such as resistors, capacitors, inductors and semiconductors. There are three different modules used in the design, the LM2576HVS, MagI³C-LDHM and the ESP-32-WROVER-B. [1]

The LM2576HVS is a step-down converter that converts an input between 4V and 60V to an adjustable constant voltage between 1.23V and 57V. This is determined by its arrangement. [2]

The MagI³C-LDHM is an LED driver module that provides an adjustable constant current. The current is determined by connecting a certain resistance value to its Iset pin. It needs a minimum of 4.5V and tolerates a maximum of 60V at its input. This module provides up to 450mA. [3] With this module, LEDs can be dimmed with the use of PWM signals.

ESP32-WROVER-B is a powerful, generic WiFi-BT-BLE MCU module that targets a wide variety of applications. [4] In this design, the ESP32-WROVER-B generates four PWM signals, 1 for each LED driver. The module is programmed to connect to the web and be controlled through a web interface.

A specific led must be chosen for a particular application. After research, the LUXEON Sunplus 35 LEDs are preferred for vertical farming applications, instead of the LED series from Würth Elektronik recommended by the Elektor magazine [1]. The LUXEON Sunplus 35 LEDs are suitable for vertical farming because they produce little heat. [5] Therefore they can be placed closer to the plant and thus save space, which is critical in vertical farming. The LEDs from Würth Elektronik emit more photons per electric usage and thus are more efficient. But they are meant to be placed in greenhouses at a long distance from the plant and thus produce more heat. Therefore they are not suitable for our application.

2.1.2 Software

The Arduino IDE is used to program the ESP-32-WROVER-B. This requires the ESP32 library for Arduino to be installed. The Arduino IDE is preferred over other IDEs because the associated code is written for the Arduino IDE. [1]

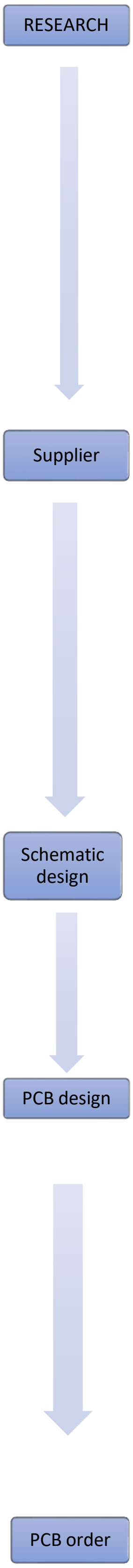
To draw the schematics and design the PCBs, Altium designer is used. Altium Designer, compared to other software such as Aegle, has more features and is more often used in the professional field. Altium also offers many easy-to-reference instructions.

2.1.3 Bill of materials

Bill of materials					
Description	**Manufacturer**	**Qnt**	**Price p/u**	**Digikey Part Number**	**Est. Delivery Date**
Resistor		*12*			
10 kΩ, thick film, 5%, 0.1W, 150V	Multicomp	1	€0.09	541-CRCW120610K0JNEBCT-ND	6/04/2021
1 kΩ, thick film, 5%, 0.1W, 150V	Multicomp	1	€0.09	2019-RK73B2ATTD102JCT-ND	6/04/2021
2.7 kΩ, thick film, 5%, 0.1W, 150V	Multicomp	1	€0.09	P2.7KACT-ND	6/04/2021
1.6 kΩ, thick film, 1%, 0.125W,150V	Multicomp	1	€0.09	P1.60KCCT-ND	6/04/2021
Inductor		*6*			
EMI suppression ferrite, 1500Ohm	Würth Elektronik	1	€0.19	732-4649-1-ND	6/04/2021
SMD common mode line filter 10uH	Würth Elektronik	1	€2.10	732-1476-1-ND	6/04/2021
SMD power inductor, 10uH, 800mA	Würth Elektronik	1	€0.84	732-11499-1-ND	6/04/2021
SMD power inductor 2.2uH, 2.5A	Würth Elektronik	1	€1.44	732-1250-1-ND	6/04/2021
Power Inductor (SMD), 470 µH, 600 mA	Würth Elektronik	1	€1.81	732-4039-1-ND	6/04/2021
Ferrite bead, 31 Ohm, 3A, size 1206	Würth Elektronik	1	€0.20	732-1626-1-ND	6/04/2021
Capacitor		*8*			
4.7 µF, 100 V, 7.7 x 6.3mm	Würth Elektronik	1	€1.53	732-11980-1-ND	6/04/2021
100 nF, 100 V, X7R, 0805	Würth Elektronik	1	€0.09	732-12244-1-ND	6/04/2021
27 µF, 100 V, 20%, 8mm, radial	Würth Elektronik	1	€0.36	732-9253-1-ND	6/04/2021
47 µF, 10 V, 2312	Vishay	1	€0.53	718-1087-1-ND	6/04/2021
4.7 µf, 50V, X7R, 1210	Murata Electronics	1	€0.49	490-1864-1-ND	6/04/2021
100 µF, 10 V, 5.5 x 5.5mm	Würth Elektronik	1	€0.48	732-6410-1-ND	6/04/2021
2.2 µF, 100V, X7R, 1210	Kemet	1	€0.64	399-5511-1-ND	6/04/2021
1 nF, 16V, X7R, 0603	Würth Elektronik	1	€0.09	732-7953-1-ND	6/04/2021
Semiconductor		*9*			
MBRS540, 40 V, 5 A, Vf=550 mV @ If=5 A	ON Semiconductor	1	€0.47	MBRS540T3GOSCT-ND	6/04/2021
LED, green, 3 mm	Würth Elektronik	1	€0.21	732-5012-ND	6/04/2021
LED, red, 3 mm	Würth Elektronik	1	€0.21	732-5013-ND	6/04/2021
LED, yellow, 3 mm	ürth Elektronik	1	€0.21	732-5014-ND	6/04/2021
LED, blue, 3 mm	Würth Elektronik	1	€0.21	732-5011-ND	6/04/2021

BC847C, 45 V, 100 mA, 250 mW, hfe=400	NXP	1	€0.10	1727-2924-1-ND	6/04/2021
MagI3C LED	Würth Elektronik	1	€6.67	732-6218-1-ND	6/04/2021
LM2576HVS-ADJ	Texas Instruments	1	€5.93	LM2576HVS-ADJ/NOPB-ND	6/04/2021
ESP-32-WROVER-B	Espressif	1	€4.22	1904-1034-1-ND	6/04/2021
Other		*13*			
Switch, tactile, 12 V, 50 mA, 6x6 mm	Würth Elektronik	1	€0.09	450-1650-ND	6/04/2021
Terminal block 5.08 mm, 2-way, 630 V	Würth Elektronik	9	€1.41	277-1273-ND	6/04/2021
header male 5 pin, 0.1" pitch vertical	Fisher Elektronik	1	€0.21	732-5318-ND	6/04/2021
header male 6 pin, 0.1" pitch vertical	Fisher Elektronik	1	€0.28	732-5319-ND	6/04/2021
header male 4 pin, 0.1" pitch vertical	Fisher Elektronik	1	€0.15	732-5317-ND	6/04/2021
Jumper, 1x2, vertical	TE Connectivity	1	€0.11	732-5315-ND	6/04/2021
4 x Jumper, 2 way, 2.54 mm	FCI	4	€0.09	S9341-ND	6/04/2021

2.2 Methods



2.2.1 Research

2.2.1.1 Schematic design research

Schematic design research has been done by examining the schematic of the LED controller published by Elektor [1]. The complete schematic and all the components needed are found in this magazine.

2.2.1.2 Individual component research

All the individual components were examined according to their datasheets. In addition to the datasheet, research has been done on the MagI3C module through the given webinar from Würth Elektronik [6]. A video from Würth Elektronik demonstrating the module and giving a short explanation of its function was also examined [7].

2.2.2 Supplier

2.2.2.1 Requirements

Because there are more than 100 components it is recommended to order the components from one supplier. This way an organized overview of the order is kept. Delivery time and delivery costs are also important to take into account.

2.2.2.2 DigiKey

Digikey has been chosen as a supplier because it meets these requirements. It has one of the largest assortments and has all the required components in stock.

2.2.3 Altium schematic design

The next step is drawing the schematic in Altium designer. Elektor's schematic is divided into three smaller schematics for each module and its associated components. This way the project is more manageable. The LED driver, ESP-32-WROVER-B and the LM2576HVS have their schematic inside Altium. Because the PCB will split up, the diagram is modified with suitable connectors to provide a connection between each other.

2.2.4 Altium PCB design

After drawing the schematics, the PCB can be created.

2.2.4.1 LED driver

The schematics of the LED driver and its associated components have their PCB. This way it is possible to upgrade to more than four LED drivers or replace a defective one. The schematics are modified so that the necessary connections between the ESP32-WROVER-B and the LED driver can be made.

2.2.4.2 ESP32-WROVER-B

The second PCB is a merge between the ESP32 and the LM2576HVS schematic. The LM2576HVS provides the voltage for the ESP32 and is therefore chosen to be placed on the same PCB for convenience. The tracks connected to the LM2576HVS module should withstand more current. Therefore the width of associated tracks is increased.

Results

3.1 LED drivers

3.1.1 Operation

The led drivers deliver the controlled current for each chain of LEDs. For this project, 4 LED drivers are used to control 4 different LED chains individually.

3.1.1.1 MagI3C

Each LED driver has its own MagI3C module. The MagI3C is the core of the LED driver and is responsible for the current controlling functionality. The module can also process PWM signals easily and thereby adjust the brightness of the LED chain. [3]

3.1.1.2 Determine current

The amount of current is determined by connecting a resistor to one of the pins on the magI3C. The resistance value determines the amount of current the module will provide to the LED chain. The magI3C datasheet consists of a formula to calculate the amount of current a certain resistance value will generate. [3] The PCB consists of a potentiometer and two through-hole resistor pads to solder a fixed resistor value to. One of three options can be selected using jumpers.

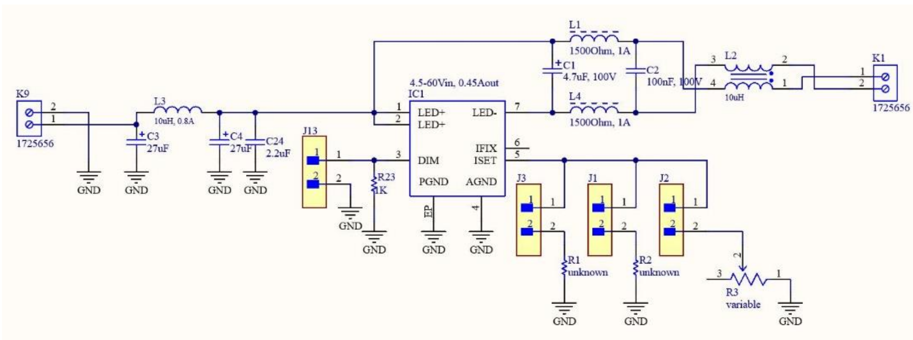
3.1.1.3 PWM

A PWM signal can be applied to the jumper tied to a pin of the magI3C module. To use the module without PWM, a constant voltage above 1.25V must be connected to the jumper. All signals below 1.25V will disable the module. [3]

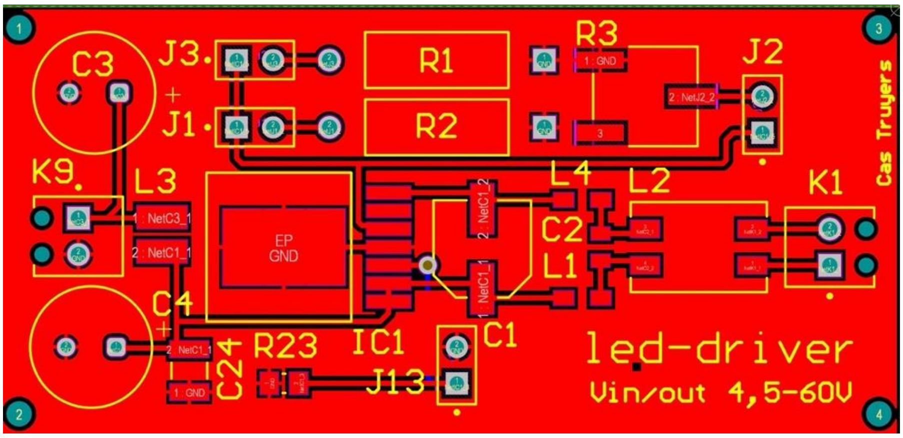
3.1.1.4 Noise reduction.

In addition, there are 4 capacitors and 3 coils per LED driver. The capacitors and coils have noise reducing properties. A signal with less noise improves the lifetime of the LEDs and is therefore recommended.

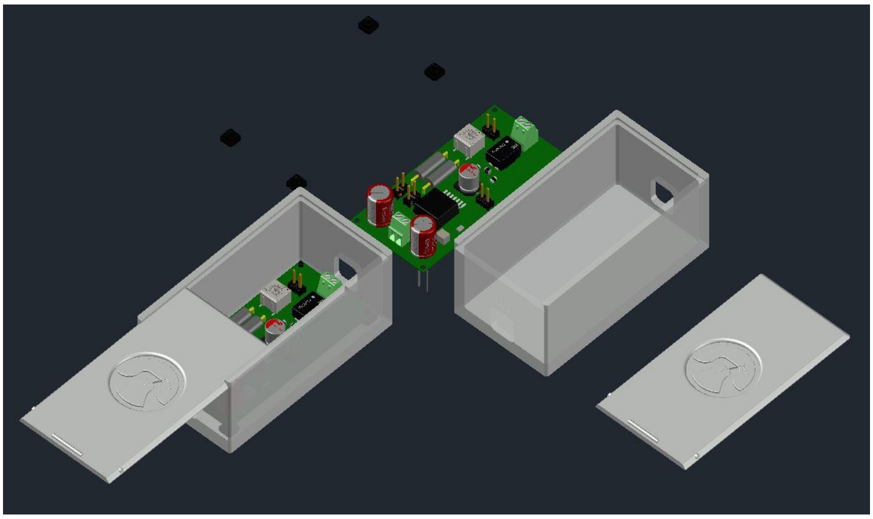
3.1.2 Schematic



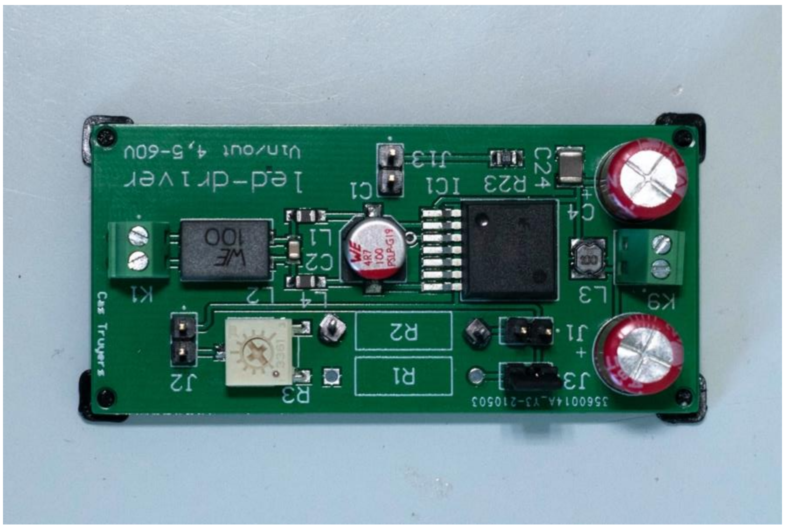
3.1.3 PCB design



3.1.4 Mechanical design



3.1.5 Finalized product



3.2 Voltage regulator

3.2.1 Operation

The LM2576 step-down module and its associated components such as capacitors, inductors and resistors take power from an external power supply and converts it to 3.3V. This is used to power the esp32 module.

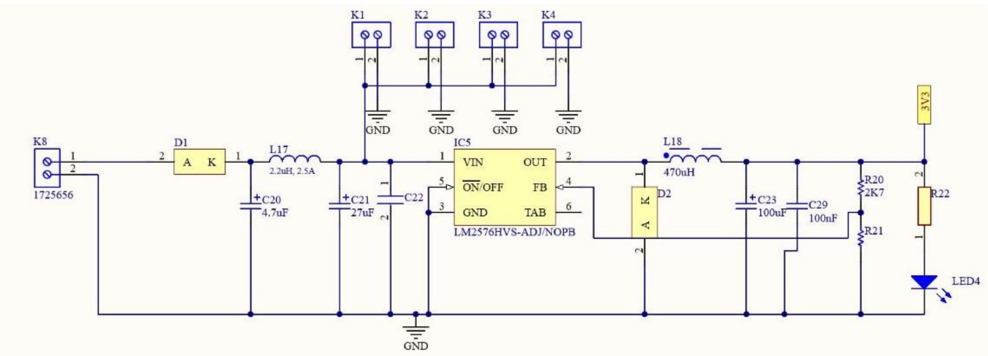
3.2.1.1 ESP32

The voltage divider connected to one of the LM2576 pins determines the voltage output. [2] The voltage divider resistor values are selected to provide the ESP32 with its recommended 3.3V. Capacitors and inductors reduce the noise on the signal and thus increasing the lifetime of the ESP32.

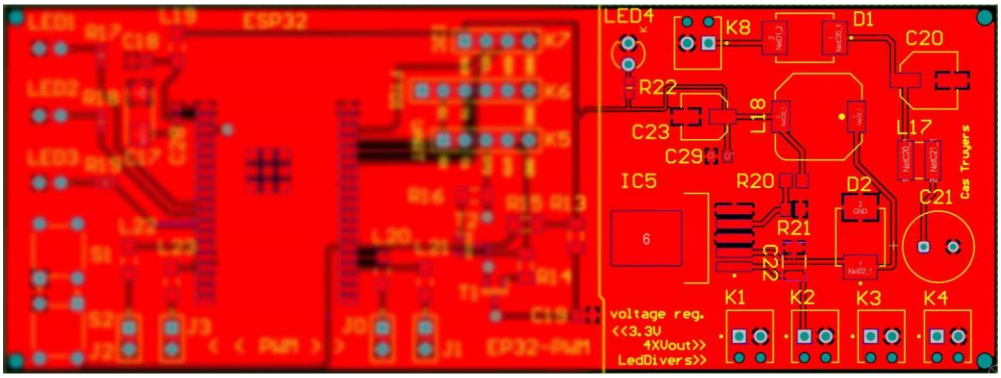
3.2.1.2 LED drivers

The voltage driving the LED drivers is not regulated by the LM2576. The led drivers are, in addition to a coil and 3 capacitors, connected to the output voltage of the external power supply. The coil and capacitors counteracts pollution to the grid caused by the use of LEDs.

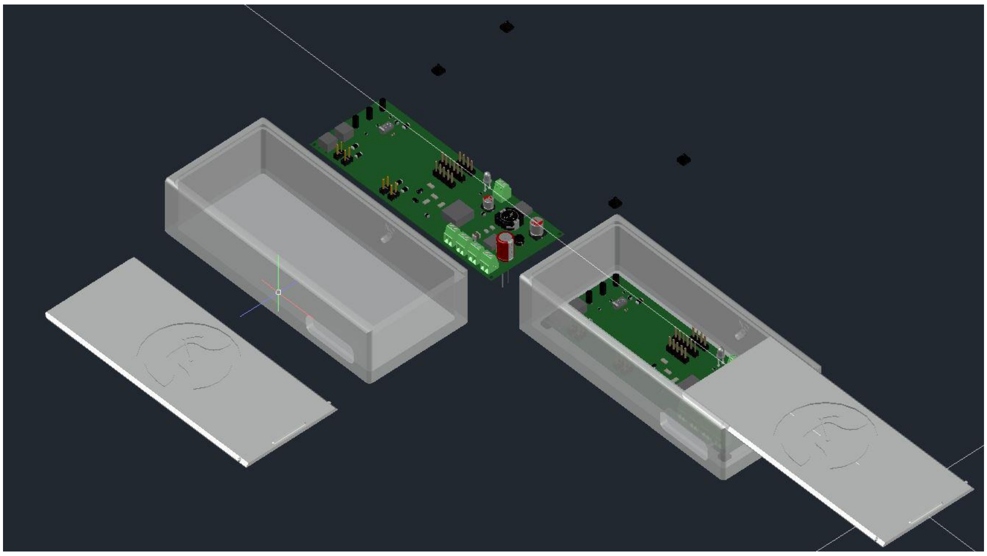
3.2.2 Schematic



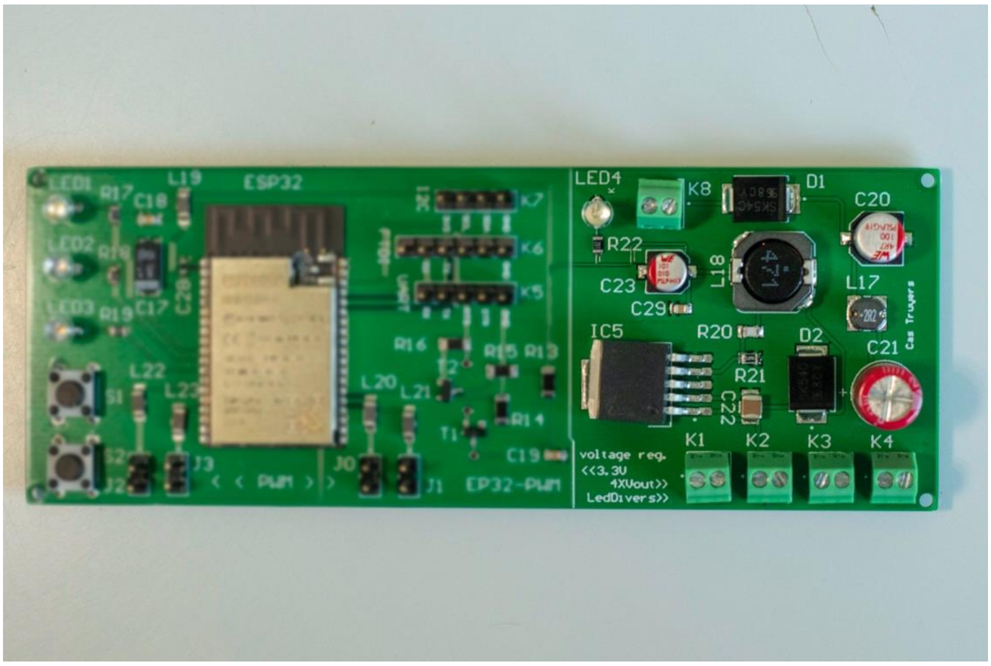
3.2.3 PCB design



3.2.4 Mechanical design



3.2.5 Finalized product



3.3 ESP32

3.3.1 Operation

The ESP32 module is the brain of this project. It generates PWM signals, day/night cycles and allows for wireless control. [1]

3.3.1.1 User interface

The ESP32 creates a web interface. This allows for easy controlling and programming of the ESP32. [4]

3.3.1.2 PWM

The most important feature of the ESP32 is generating 4 individual PWM signals. These PWM signals connected to the LED drivers dim the LED chains accordingly. [1] Controlling each LED chain with an individual PWM signal allows for mixing different light spectrums and thus providing control over the total light spectrum. Because each phase of plant growth prefers a specific light spectrum, crop yield can be improved when controlling it accordingly.

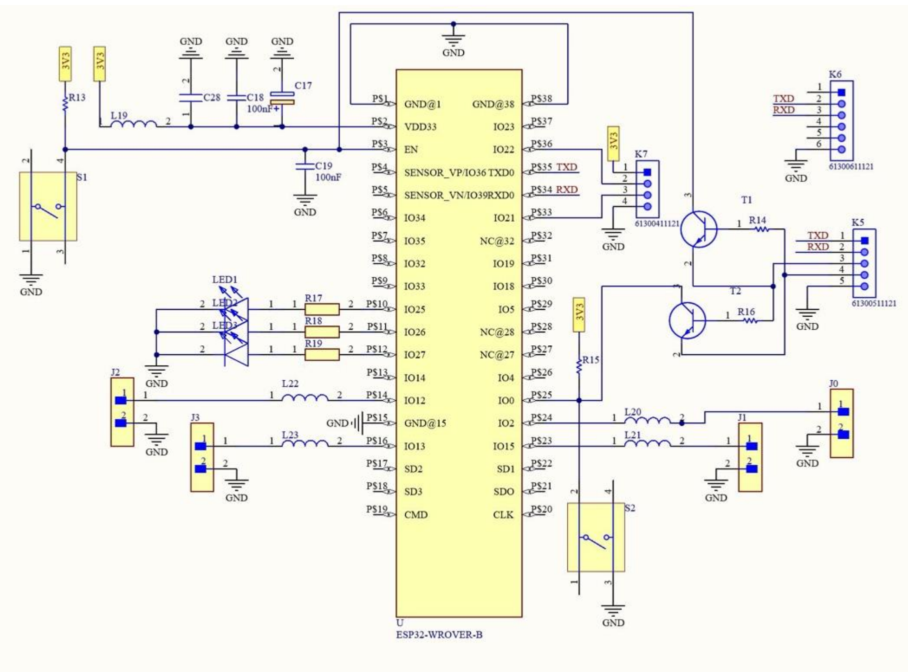
3.3.1.3 Day/night cycles

Day and night cycles determine the on and off time of the LEDs. Through the web interface you can automate this or switch it on and off manually.

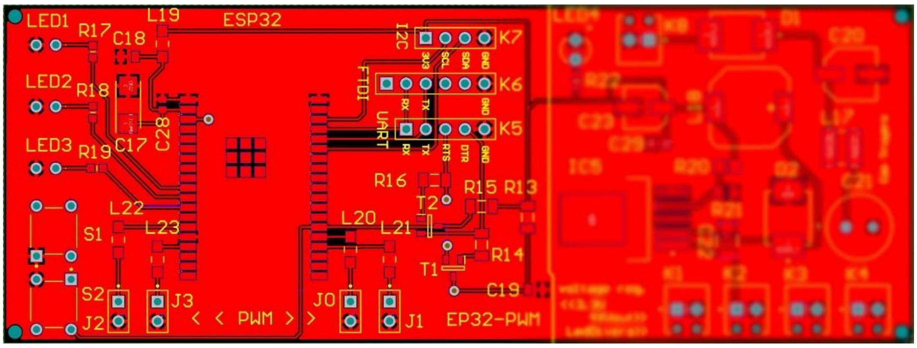
3.3.1.4 Programming

The ESP32's UART is available on K5 for serial communication or for programming the ESP32 in bootloader mode. The terminals DTR and RTS on K5 are connected to transistors T1 and T2 which automatically puts the ESP32 into bootloader mode. Bootloader mode can also be activated manually using button S1 and S2 and can then be programmed through K6. It can also be programmed with I²C using K7. [1]

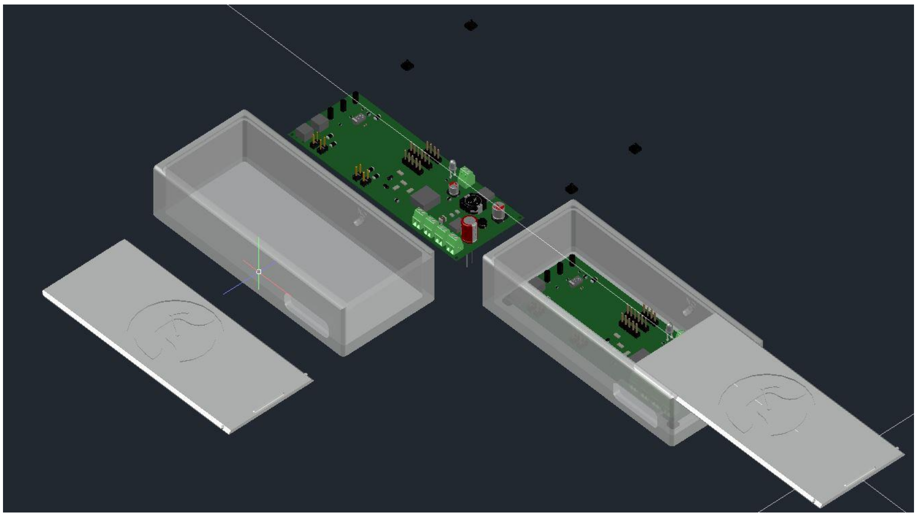
3.3.2 Schematic



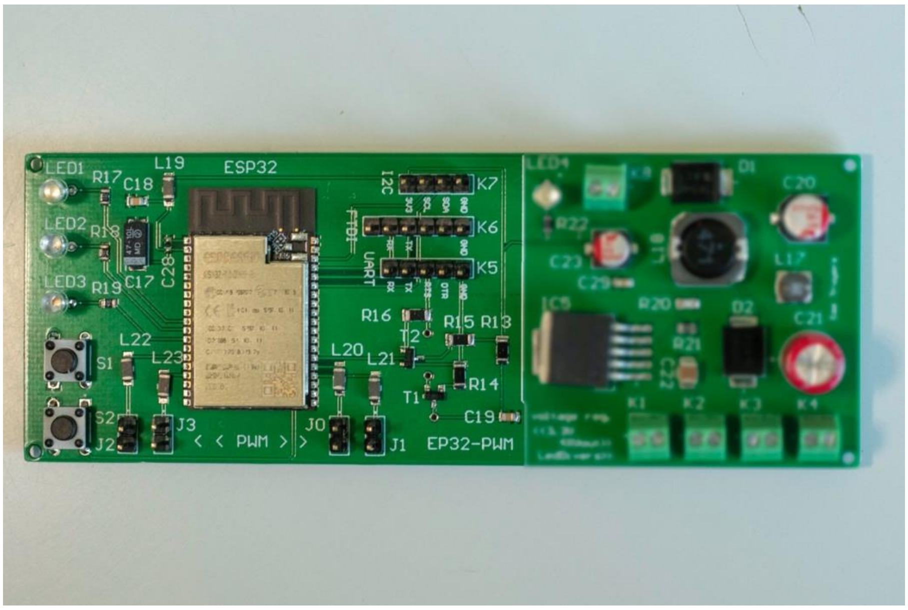
3.3.3 PCB design



3.3.4 Mechanical design



3.3.5 Finalized product



Discussion

4.1 Difficulties

4.1.1 LEDS

There are so many different LEDs and finding the appropriate one for a particular application is not easy. So is finding a supplier for these LEDs not easy either. Researching the different LEDs is time consuming but is the most important part of the project and therefore cannot be dismissed.

4.1.2 Backorder

During the ordering process a component went temporarily out of stock. In this case the schottky diode was only available through backorder. However, the schottky diode became available through another supplier and was therefore ordered from there.

4.1.3 Enabling LED driver

Testing of the LED drivers didn't show voltage on the output. After several hours of investigation, it was noticed that the jumper connected to the PWM DIM pin of the MagI3C module was always grounded through a trace on the PCB. A connection to the ground on this pin caused the module to be switched off.

To activate the module, a voltage above 1.25V is required on the jumper. [3] The PCB is designed so that the jumper is always connected to a PWM signal. This is not a design flaw but something that was not anticipated.

4.2 Reflection

4.2.1 PCB silkscreen

The polarity was forgotten to be marked next to the input and output connectors. This required the use of a multimeter to determine the polarity.

4.2.2 Programming

Programming the ESP32 is being done using the Ardiuno IDE and the associated code published by Elektor [1]. The code is no longer up to date and some of the associated libraries are no longer supported. This could be the reason why errors are occuring during compalition of the associated code.

4.3 Conclusion

In a future project, more attention should be spent on the markings next to the components. The LED driver is completely functional and a similar designing approach will be applied in the future.

Reference list

[1] L. Lemmens, „LED-kweekbox,” Elektor, 8 9 2019. [Online]. Available: https://www.elektormagazine.nl/magazine/elektor-112/51089. [Geopend 2020].

[2] T. Instruments, „LM2576xx datasheet,” 6 1999. [Online]. Available: https://www.ti.com/lit/ds/symlink/lm2576.pdf?ts=1622049672580&ref_url=https%253A%252F%252F www.google.com%252F. [Geopend 2021].

[3] W. Elektronik, „MagI3C Power Module,” 5 2016. [Online]. Available: https://www.we-online.com/catalog/en/MAGIC-LDHM-TOP263-7EP. [Geopend 2021].

[4] Espressif, „ESP32-Wrover-B Datasheet,” 1 2021. [Online]. Available: https://www.espressif.com/sites/default/files/documentation/esp32-wrover-b_datasheet_en.pdf. [Geopend 2021].

[5] Lumileds, „Luxeon Sunplus 35,” 2019. [Online]. Available: https://www.lumileds.com/products/horticulture-leds/luxeon-sunplus-35-line/. [Geopend 2021].

[6] W. E. Group, „YouTube,” Würth Elektronik Group, 19 3 2020. [Online]. Available: https://www.youtube.com/watch?v=2nH48m71nWI&t=732s. [Geopend 2020].

[7] W. E. Group, „YouTube,” Würth Elektronik Group, 24 9 2018. [Online]. Available: https://www.youtube.com/watch?v=OU1vD2DDwic. [Geopend 2020].