Modular LED Lamp

Andra Aedma, Nils Petersen, Piotr Rzeznik, David González Alen, Norbert Ritter

***Abstract*—** The aim of this project is to analyse issues that are related to energy-saving LED lighting and to develop an innovative product meeting the defined objectives. LED lamp should change colours, fit to the universal socket, has low cost and innovative design. In particular, the analysis included the currently used technologies and similar products placed on the market. The result is a Modular LED lamp prototype which is able to change colours and brightness. Besides this, the project contains the topics that are necessary for launching the final product into the market, e.g. schemes, branding and other problems connected with sales. The new LED lamp allows potential customers to run their business complying with sustainability policy requirements related to energy consumption, environmental and ethical issues, as well as with people's well-being.

***Keywords*—** Brightness, Colors, Energy-efficient, Lamp, LED

I. Introduction

In the past and even at present incandescent lamps are very popular. The positive aspect of these lamps is that they are cheap, but there are more disadvantages than advantages. For example incandescent lamps have low efficiency. For an incandescent light bulb to work, electrical energy has to pass through a filament for it to be converted to heat. It is when the filament becomes hot enough that light is produced. Since this process generates more heat, about 90 percent of its output, than light, a great deal of electrical energy is wasted [1]. Also incandescent lamps have short lifespan and they are not environment friendly. It means that we need some kind of alternative to replace incandescent lamp. LED lamp seems to be good solution of that problem. This issue motivated us to develop Modular LED lamp. Main objectives for the lamp were: possibility to change only one LED at the time, it should change colours and it should fit to the universal socket. Also LED lamp should be compatible with other similar products and should have sustainable production.

We designed a branch-shape light bulb, which changes colours using a remote control, it fits to the E27 socket and includes automatic brightness control system. Product is targeted to the business market and in design we have thought about sustainability as well.

The paper is organized in seven sections. Firstly, the "LED Lighting solutions" section describes related products and technologies. Then, an overview of used materials technologies is provided. Thirdly, the Project development is presented, the design of the product and the steps of building a prototype are introduced. Next, the Test chapter describes the tests and results. According to the studies and tests we are presenting our achievements and in the end we refer to future developments.

II. LED Lighting Solutions

At the beginning the modular system and method for providing power for LED lighting systems are described to get to know more about LED system details. The power source unit comprises a power supply that converts alternate current voltage to regulated direct current (D/C) voltage, a configurable intelligent gateway module that receives the regulated D/C voltage and places it on a power bus to which one or more power node modules and any accessories in need of power, such as motion detectors or cooling units, are coupled, and an intelligent power node module that converts the regulated D/C voltage to a regulated D/C current and provides it to the particular LED Light Module (LLM), and which also receives data from the LLM, such as temperature data, and adjusts the regulated current accordingly. The gateway module also may receive control data from control devices, such as dimmers or wireless controllers, and instruct the power node module to regulate its output current accordingly [2].
In this chapter we are introducing similar products to developed project, studying specifications of lighting system.

A. Related products

There are a lot of similar products in the market. Table 1 and Table 2 include different kind of LED lighting solutions which are currently in the market.

Table 1: Related products

Product	Features	Price [EUR]	Picture
TurnRound [6]	Available in fixed and adjustable versions; dimmable; 25 and 40° beam angles; high-Power LED technology.	111	
iColor Flex MX [7]	Strand consists of 50 individually addressable LED nodes; each node produces full-colour light output of up to 1.44 candela. Flexible form factor. Multiple lens options: clear dome and translucent dome lenses as standard; clear flat and translucent flat lenses also available. Standard and custom lengths and node spacing.	352	
eW Flex SLX [8]	Strand consists of 50 individually addressable LED nodes; each node produces full-colour light output of up to 1.44 candela. Flexible form factor. Works with complete Philips line of controllers, as well as third-party DMX controllers. Multiple lens options: clear dome and translucent dome lenses as standard; clear flat and translucent flat lenses also available. Standard and custom lengths and node spacing.	300	

Table 2: Related products 2

HDE® Remote Control Colour Changing 16 LED Light Bulb with RC [10]	Operates in standard light sockets.5 watt 16 colour LED; colour: red, green, blue and white; adjustable shades and brightness; batteries: CR2025; size: 2.5"/ 6.35 cm; package contents: 1 x LED Light Bulb; 1 x remote.	7,2	
LivingColours Bloom White [11]	Choose among 16.000.000 colours, dimmable, light output 120 lumen, easy-to-use remote control, adjustable colour intensity, automatic colour changing mode, nice diffused light effect, 2 buttons to store your favourite colours.	72	
The ColourFuse Powercore [12]	Advanced colour mixing and superior colour consistency. Light output of 380 lumens per fixture. Rotation in 10° increments through full 180° for precise aiming and colour mixing.	214	
ColourBlast Powercore [13]	Medium beam angle 36°. Colour: white, dimmable.	431	
The C-Splash 2 [14]	Long-life LEDs delivering RGB colours and light output of over 500 lumens. IP68-rated: also able to withstand water treated with bromine or chlorine. 10° clear glass lens for extended light projection and 22° frosted tempered glass lens for a soft-edge beam.	924	
LED A Shape [15]	Provides light similar to natural daylight, lasts 22.8 years, instant on, reduces energy costs, similar shape and size as standard incandescent, dimmable.	17	
Reflector - Flood [16]	Provides Bright Crisp Light, lasts 22.8 years, instant on, reduces energy costs, similar shape and size as standard incandescent, dimmable.	17	

As tables of related products show there are many different LED light bulbs and lamps. There are still room for developing mood lighting market, existing products are very expensive and variety of Europe products is not very big. Our team concentrates to mood lighting lamp and takes challenge to make mood lighting more affordable.

III. Methods and Technologies

In order to build working prototype which meets the requirements different technologies have to be used. This chapter gives overview of main technology issues which rose developing the Modular LED Lamp.

1. Which LED to use?
2. What kind of brightness sensor to use?
3. What kind of remote control type to use?

A. LED

As we are developing LED lamp it is necessary to choose right LED for our project. Requirements for LED are that they must be small and it is possible to change colors. RGB LED is the best solution for our project. They are small and include red, green, and blue emitters, which allow for it to combine the three primary colours in different amounts to produce new colours with incredible precision. There are literally millions of possibilities of colour combinations with today's increasingly sophisticated controllers [3].

B. Brightness sensors

Modular LED Lamp contains automatic brightness system for detect movements, therefore brightness sensor has to be used. We were considering using laser or ultrasonic sensor. As laser sensor is too big and expensive, ultrasonic sensor was chose. Ultrasonic sensors work on a principle similar to radar or sonar which evaluates attributes of a target by interpreting the echoes from radio or sound waves respectively. Ultrasonic sensors generate high frequency sound waves and evaluate the echo which is received back by the sensor [4].

C. Remote control

The most common remote control types are WIFI, Bluetooth and Infrared. For WIFI it is necessary to have internet connection and for Bluetooth it is necessary to open some application in your phone. Infrared seemed to be easiest and cheapest way to control the lamp. The signal between a remote control handset and the device it controls consists of pulses of infrared light, which is invisible to the human eye, but can be seen through a digital camera, video camera or a phone camera. The transmitter in the remote control handset sends out a stream of pulses of infrared light when the user presses a button on the handset [5].

IV. Project Development

In this chapter Modular LED Lamp electrical schematics and also design of light bulb are introduced.

A. Architecture

In order to start building prototype, electrical schematics for the lamp and remote control has to be done. Figure 1 shows electrical scheme for the light bulb and Figure 2 introduces electrical scheme of remote control.

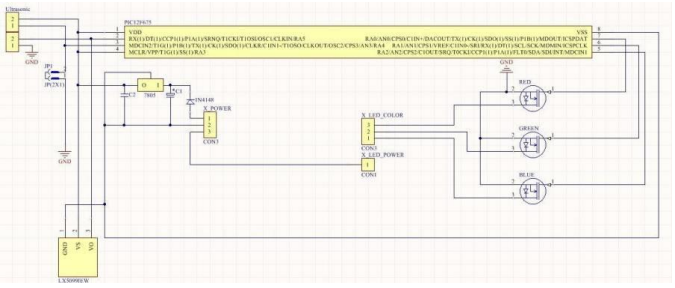

Figure 1: LED Lamp electrical scheme

In our Modular LED lamp we are using 12V power supply, because it will give enough tension to the system to drive 4 red, 3 blue and 3 green LEDs.

We have to include a regulator guarder by a diode to get the right amount of voltage to drive the PIC microcontroller. To

the PIC output 3 MOSFETs are connected, one for each colour of LEDs. It is necessary to control the colour and intensity of the LEDs with PWM modulation. IR receiver is connected to the PIC microcontroller for the communication between the remote control. Ultrasonic sensor is also connected to the PIC for distance detection.

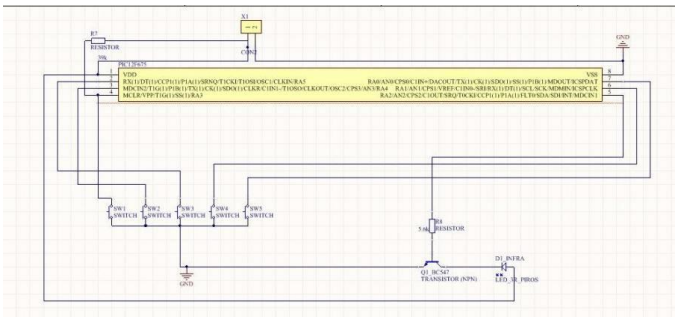

Figure 2: Remote control electrical scheme

As it was necessary to do schematics to LED panel and driver, it is necessary to do circuit design to the remote control as well, so it would work like required. Main idea in remote control schematics is to have 5 buttons for different functions.

We have 12V for the circuit, but for the microcontroller it is necessary to regulate voltage to the optimum level. Therefore it is important to use regulators. We don´t need any calculations, because datasheet gives us exact information about size of the condensators.

B. Functionalities

Comparing to the other similar products, our developed LED Lamp has more features. Modular LED lamp contains features, like:

- Fits to E27 lamp socket;
- Changes colours with remote control (radius 10 m);
- Easy construction to change the LED;
- Includes an automatic brightness control system (maximum radius 4 m).

Remote control functionalities:
Our developed remote control has several functionalities. It offers different operating modes and can be configured by the user. Remote control allows to choose and change colours like red, orange, yellow, green, blue, cyan, white. And has 5 different button for different application.

1) Increase brightness
It is possible to increase brightness manually.
2) Decrease brightness
It is possible to decrease brightness manually.
3) Static mode
It is possible adjust fixed colour manually.
4) Lamp On / off button
Turns off and turns on the lamp.
5) Brightness sensor on/ off button
Turns off and on the brightness sensor.

C. Design

As our team wanted to create something unique, special light bulb design was made. Light bulb is inspired from nature and has similarity with wood branch.
In the design, there is one main tube where three other tubes are coming out. Three tubes are meant for LEDs and one for Ultrasonic sensor to sense movements. Also near to the socket, where goes power supply, there are cuts inside material for cooling. For fixing the electronic parts certain inner design was made as well. Two kinds of hallows were cut into the walls to slide there different PCB-s, we are wiring power supply to the lattice which is in the leg where goes also ultrasonic sensor. For ultrasonic sensor there are 2 round holes, we are placing sensor into the holes and screw it to the tube wall. Tubes have removable covers to make LED changing more easier. LEDs are pressed into the removable covers where LED-shape holes are.
Prototype is made of plastic with 3D printer. Figure 3 presents design of developed Modular LED Lamp. It is possible to see shape of the bulb as well as inner design.

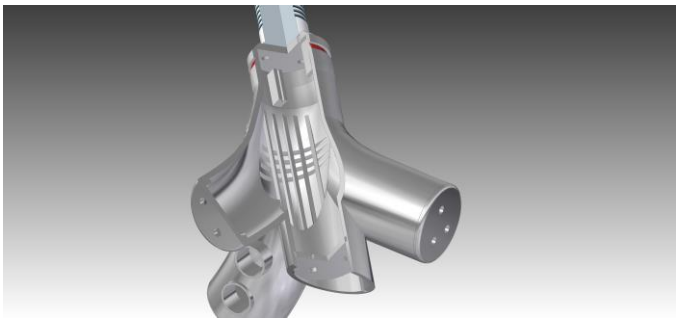

Figure 3: Design

D. Tests and results

Certain tests have to carry out to be sure if lamp works properly. Tests which are necessary to make are described in the following:

1. Have to try if LED light bulb fits to E27 lamp socket

2. Have to try remote control. For that it is necessary to connect light bulb with a grid and when turning the button of remote control light bulb should change colours (in 10 m)

3. Have to try take out some LED or only one LED and replace them by another LED. For changing the LED it is necessary to push LED in order to have clear cover, then turn the tube cover and remove it. For every LED there are connectors, in every connector there is white plastic part which has to pull open in order to remove old LED. Then replace old LED to new one, close the plastic cover, push LED back to tube covers and turn cover back. Also have to

connect light bulb to the grid to see if changed LED is working.

4. Have to connect light bulb to the grid, then move towards to the light bulb, when being at the distance of maximum 4 m it should reduce the brightness. Also when moving further than maximum 4 m from lamp, it should increase the brightness again

In development process occurred some difficulties, for example there was material delay and not much time for improvements for all these functionalities. It means that initial objectives are not fully developed. In this state Modular LED Lamp fits to the E27 socket and has colour changing function, but without remote control, therefore there is a button in lamp surface. Colour changing function have several variations:

1. Fade through full colour spectrum;
2. Fade through full colour spectrum, 75% intensity, slow;
3. Pastel colours fade, fast;
4. Pastel colour fade, slow;
5. Slow fade Red + Green, 50% to 100%;
6. Slow fade Red + Blue, 50% to 100%;
7. Slow fade Green + Blue, 50% to 100%;
8. Red full intensity, slow fade to off; Green full intensity, slow fade to off; Blue full intensity, slow fade to off;
9. Slow fade of Red to full intensity, slow fade to off; slow fade of Green to full intensity, slow fade to off; slow fade of Blue to full intensity, slow fade to off;
10. Slow fade of Red on, slow fade of Green on, slow fade of Red off, slow fade of Blue on, slow fade of Green off, slow fade of Red on, slow fade of Green off;
11. Slow cycle of fade between rainbow of colour, various combinations of Red, Green and Blue on/off at various intensities;
12. Bright White: Red, Green and Blue combination;
13. Half White: Red, Green and Blue combination;
14. Low White: Red, Green and Blue combination;
15. Full colour spectrum fade;
16. Slower full colour spectrum fade;
17. Slow warm colour spectrum fade;
18. Cool colour spectrum fade;
19. Purple colour fades;
20. Red, Green, Blue cycle at 50mS rate;
21. Red, Green, Blue cycle at 100mS rate;
22. Red, Green, Blue cycle at 200mS rate;
23. Red, Green, Blue cycle at 300mS rate;
24. Red, Green, Blue cycle at 400mS rate;
25. Red, Green, Blue cycle at 0.5S rate;
26. Red, Green, Blue cycle at 1S rate;
27. Triple flash of Green and Blue with delay between flashes.

When the PIC is first powered on after programming, it should start running the first RGB sequence found. It will run a sequence of red-fade out, green-fade out, blue-fade out repeatedly.
Press the Switch to step through all available sequences. When the last sequence has been reached it will go back to the first available sequence. Each time the switch is pressed the RGB LED PWM values are set back to 0 (LED off).
Press and hold switch for about 2 seconds to put the PIC into sleep mode. Once in sleep mode, press the switch for about 2 seconds then release it to wake the PIC from sleep. If the switch button isn't held for two seconds the PIC returns to sleep - this prevents the circuit from being accidentally turned on.
Anytime the PIC is put into sleep mode by holding SW1 switch down, the currently selected sequence is also saved to EEPROM.

For this new solution we also created new electrical scheme which is presented in Figure 4.

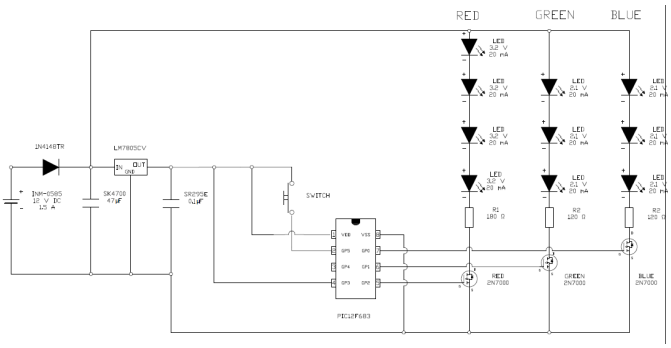

Figure 4: Final LED Lamp scheme

V. ACHIEVEMENTS

At this stage we have managed to produce 3D printed bulb as well as package. According to the test failure, we drawn new scheme for LED Lamp and changed the features into easy ones. In this case it was the best solution, because we had limited time resource and that way we were able to make lamp at least working. Lamp changes colours and fits to the E27 socket. All the working functions are described in paragraph Project Development in Tests and Results part.

VI. FUTURE DEVELOPMENT

As prototype of Modular LED Lamp was not fully successful in testing, new prototype needs to be developed. New PCB and programming improvements has to be done. Nowadays, people want to control everything from their computer and phone. It means an instant access to their devices. Therefore, development considering the remote control could be an option. Instead of using infrared communication between lamp and remote control, we could use Bluetooth or Wi-Fi connection between device and Web application or also design a mobile application for that purpose.

We would like to decrease the size of the lamp. It is necessary to reduce PCB boards and use, for example, other movement detecting sensor in order to achieve smaller bulb dimensions. There are some opportunities for light bulb design development as well. For example, it would be better if there is possibility to move/turn movement detecting sensor. As ultrasound sensor was so big it was very difficult to place it the way that it would move. What is more, different material could be considered, because already used material is sensitive to heat and in high temperatures it could melt. In future design we can use a flexible material.

CONCLUSION

We chose Modular LED Lamp project, because it sounded interesting and we had two electrical engineer students in our group. Although, they had knowledge about electricity, there have been still appearing some complications. As there was delay of materials we had to work very fast and effective. Sadly some problems occurred and firstly designed prototype did not work. Reason was wrong PCB. To solve this situation and present working prototype, we changed the electrical schematics and PCB into easier ones. This change allowed us to see improvements. In current state LED Lamp is able to change colours, there are several colour variations. For changing colours there is button in the lamp, remote control is not necessary in that kind of solution. Lamp also fits to the E27 socket. As we did not meet entirely with initial guidelines additional improvements has to be done in future.

In order to have unique product, special design for the light bulb was made. Our light bulb is inspired by nature and resemble a bit wood branch. 3D drawings were made and converted to the suitable version to use a 3D printing option what was provided by school. The bulb prototype is made of plastic.

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