Development and Prototype Production of a Full-spectrum LED Lighting Driver Circuit

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***Abstract*—This paper presents an optimised DC/DC control solutions for full spectrum LED lighting equipment. It also deals with the proposed electronic structure and the key parameters of a lighting system. The research aimed to show various PCB designs for diverse environments, and different converter topologies for dissimilar supply voltages. The article deals with the control and diagnostic possibilities of power light-emitting diodes, with wide spectrum range of an experimental environment.**

Keywords— COB LED driver, light spectrum control, high power LED, full-spectrum LED driver, DC-DC converter topologies, LED DC/DC converter, PCB prototype production

I. INTRODUCTION

Numerous solutions exist to enhance LED driving [1-3], within this the DC to DC conversion based current sources are have got a wide range of solutions [4, 5]. Robust solutions are hardened for external disturbances and also well controllable [6, 7]. Many of these solutions can be realized with different type of converters [8].

The experimental PCBs are based on modular sub-circuits, due to easier modifiability [9, 10], a prototype production line also helped to assemble the diver circuits [11-13]. The optimization of the layout is considered according to the following papers [14-16]. Real time data monitoring and logging is also a significant part of the development [17-20].

One of the effective ways of controlling the system is closed-loops and compensation of disturbance [21-23]. Various optimized solutions and compensating for uncontrolled disturbances is discussed in a series of papers [24-26]. Numerous schemes of control systems architecture are considered [27-31].

II. LIGHT SOURCES

Light Emitting Diodes (LEDs) emit light in a narrow band of the spectrum (Fig. 1), opposed to more traditional methods of lighting such as incandescent light bulbs or fluorescent lamps. LEDs also generally have well defined directional radiation characteristics. such characteristics make it possible to achieve almost any spectral distributions with various areal distributions.

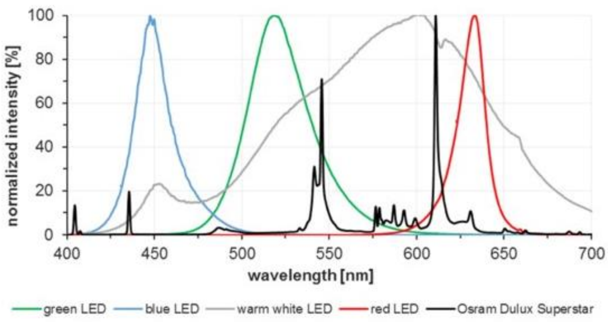

Figure 1. Emission spectra of different LEDs [31]

III. PROTOTYPE PRODUCTION

The purpose of the prototype PCB production is to create a module that can be used to perform various tests during product development. Rapid prototype manufacturing processes significantly accelerate the product development, however, human intervention is required to operate it.

The fast PCB prototyping production line provide a good in-house research and development solution. It contains a PCB milling machine, a stencil printer, an UV exposure box, a pick and place station and a reflow oven, each module is an individual workstation.

EasyEDA is used as the ECAD software, and as an additional software Gerbv is also used for checking gerber files.

The boards are designed with SMD components. The PCB and the stainless steel stencil manufactured by an external company. First step in this type of prototype production process is to paste the PCB with a manual stencil printer (Fig. 2). The stencil should be in perfect alignment with solder pads on the PCB and the squeegee should be at a 45°-60° to the stencil. With a semi-automatic SMT pick and place machine, the electrical SMD components can be placed directly onto the pasted circuit board. After the component placement (see on Fig. 3), the PCB can go to the reflow oven for soldering. Through hole components like connectors are placed and soldered manually to the PCB.

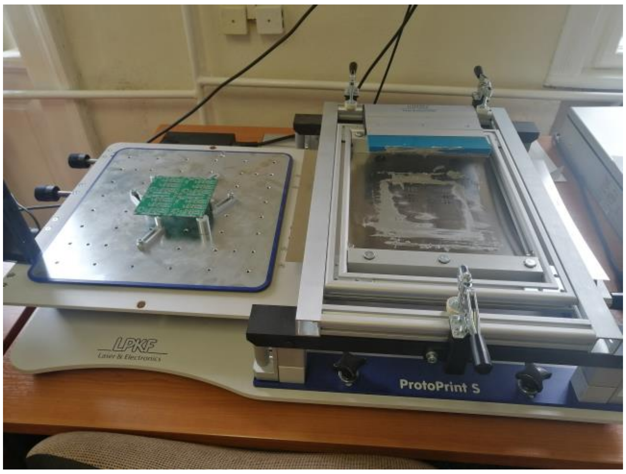

Figure 2. Manual stencil printer station

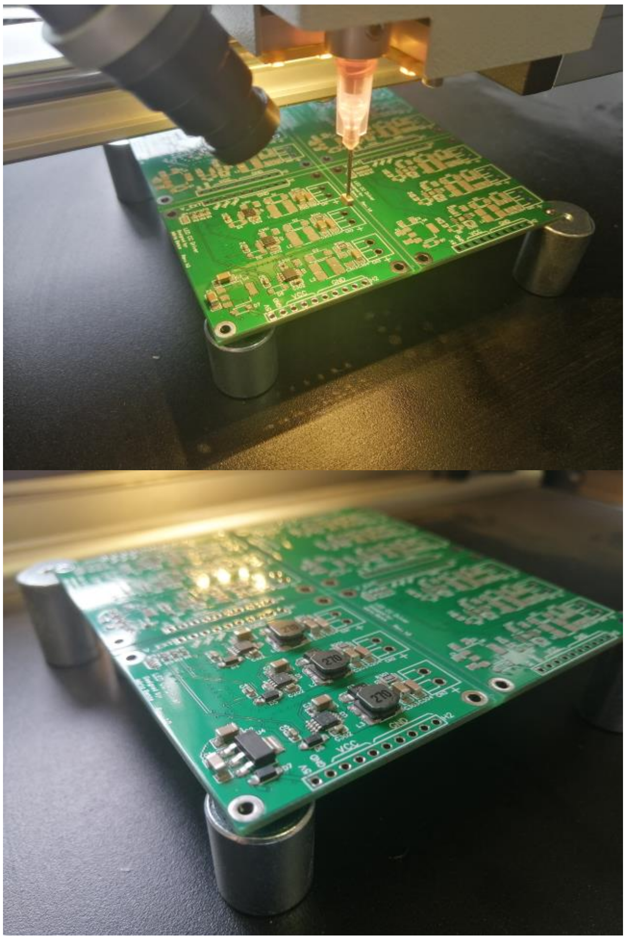

Figure 3. Semi-automated PCB manufacturing

IV. Realization

A. Local lighting

Local lighting solutions are useful in many situations like soldering, handling tiny components, professional photography etc.

The realized circular PCB (see on Fig. 4 and Fig. 5) was made for use with a desktop magnifier. It uses the same driver circuitry as the one presented on Figure 6, with three 1w LEDs connected to its output. for dimming control, it uses an ATTiny85 microcontroller which translates a potentiometer's analog output into a PWM signal. By using 3 of the PCBs, a full circle can be made.

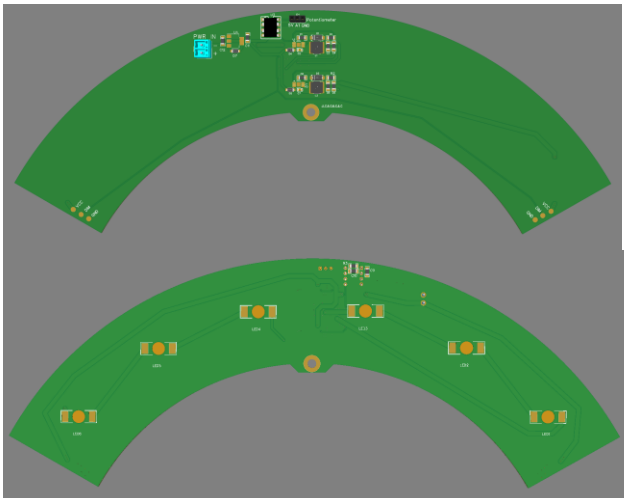

Figure 4. Front side of circular PCBs

Figure 5. Circular PCB

B. Grow power LEDs

As an experimental solution, 900mA buck type driver PCBs were created, see on Fig. 6. These boards are stackable in arrays of two or three. Due to the amount of heat produced by the connectors contact resistance and switching losses, a stack of three boards is only recommended when sufficient airflow and/or temperature sensing is provided.

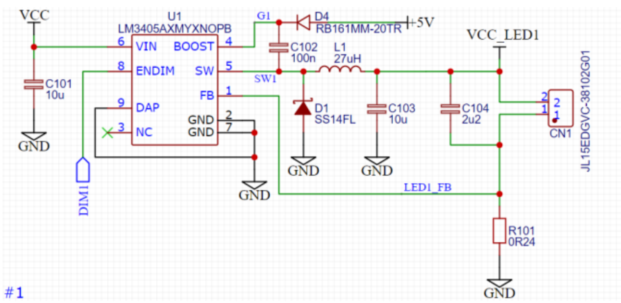

Figure 6. LM3405 LED driver circuit

The power supply of the application area is a 12V high current PSU. The driver board experimental environment can be seen on Fig. 7. The power consumption of the circuit in standby mode is 114mW. The result of the efficiency measurement depending on the control signal duty cycle can be traced in Fig. 8.

Figure 7. LED driver circuit testing environment

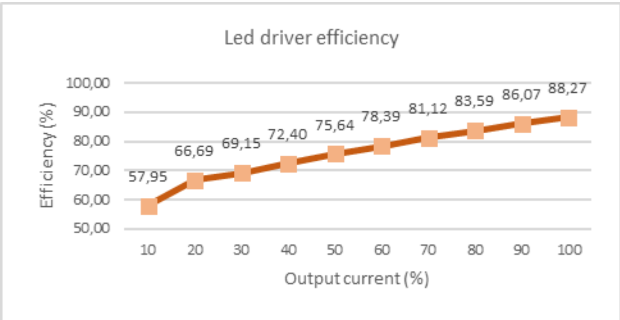

Figure 8. Led driver efficiency graph

C. Control circuit

A boost type 100mA driver board was also realized, this time with 6 channels and a microcontroller socket (ATmega328P or compatible models) for per-channel control capability. The channels can be individually controlled through analog potentiometers or an I2C bus. In I2C mode, all devices must be configured through a UART connection before use. After the successful configuration, any of the devices can be marked as master and control the array trough its UART connection. Additional I2C devices, such as light or temperature sensors can also be added with an appropriate firmware. The schematic diagram can be seen on Fig. 9 and the 3D model is shown in Fig. 10.

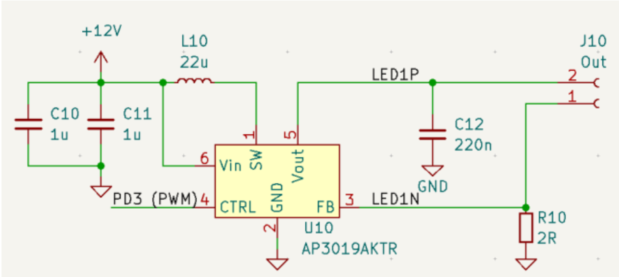

Figure 9. AP3019AKTR LED driver circuit

The array can be configured to work independently from any external devices or subordinate to an external control system shown on Fig. 11. These capabilities can also be combined for fail-safe operation.

In both modes, sensors can be attached to the system, creating a feedback loop for any desired parameter of the system, such as light intensity, spectral distribution or even input/output currents.

The physical realization of the intervening elements of the complex spectrum spatial illumination can be seen in Figure 12.

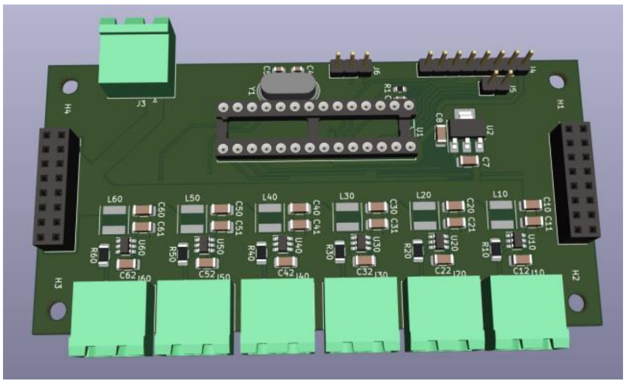

Figure 10. AP3019AKTR LED driver circuit 3D model

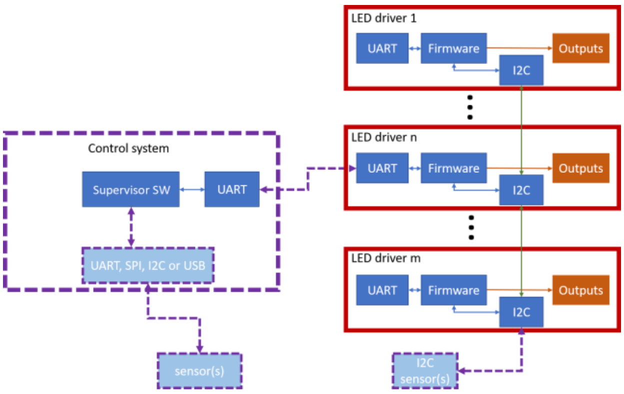

Figure 11. LED driver circuit control system architecture

Figure 12. Grow LED matrix

V. Conclusion

The received results showing the effectiveness of the developed power LED driving circuit concept and the realizations also confirms the functionality of the proposed solution. The results of the development showed that the use of current driver circuits are capable to use for full-spectrum LED lighting, and they can be controlled properly. The shown modular design can also be used for other applications. The proposed architecture is easily scalable, user-friendly, and robust. The article describes the relationship between the system components, also demonstrates the control and measuring options. Eventually conclusions were drawn about the feasibility and requirements of such a system to make it possible to implement.

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