TRUECOLOR REMOTE-CONTROLLED MODULAR SYSTEM FOR LIGHTING AND LIGHTING EFFECTS

Aleksandar Dimitrov Mitev[1], Danail Nikolaev Dimitrov[2], Desislava Angelova Dimcheva[3], Lyubcho Vachkov Haralanov[4], Nina Nikolaeva Paunova[5], Boris Yosifov Ribov[6]

Technical University – Sofia, Branch Plovdiv, P.O. Box 5, 4000 Plovdiv, Bulgaria,
phone: +359 895 587567, e-mail: [1]shondll@yahoo.com, [2]gaddas@mail.bg, [3]miny_des@yahoo.com, [4]lubchoh@yahoo.com, [5]ninkata_13@abv.bg, [6]boris.ribov@bjr-labs.com

Recent developments in the field of LED technology have greatly expanded the scope of LED applications. The advantages of LEDs such as energy efficiency, long life, small size and low-voltage operation, in combination with a suitable control makes it possible for LEDs to completely substitute traditional, out-of-date light sources.

This report introduces a prototype of a truecolor remote-controlled modular system for lighting and lighting effects utilizing ultra bright LEDs. There are effective schematic designs developed, as well as PC based software for direct control by means of visualization plug-ins and user-friendly interface.

Some of the possible applications of the system include home lighting and ambilight behavior, attractive light effects suitable for public places including bars, galleries and even movie theatres.

Keywords: LED, light effects, ambient light

1. INTRODUCTION

The main purpose of the system is emitting ultra bright power-regulated daylight, as well as light covering the entire visible light spectrum. In such a way the system services as a high quality luminary and a means for creating versatile dynamical truecolor light effects. The functionality of the system is controlled by a PC system.

2. DESCRIPTION OF THE COMPONENTS OF THE SYSTEM

2.1 Executive Module (EM)

This is the module that contains the LEDs and that is the physical representation of the luminary. There are two types of light components in the system: twelve 3,2W soft-white LEDs [1] and three 4,4W RGB LEDs [2] produced by Seoul Semiconductor Inc. (the total number of LEDs used may vary depending on the lighting requirements of the room). The first type is used for producing lighting in a room as close to daylight as possible and the second type generates the various color light effects. These RGB LEDs are some of the latest products of the company and their main advantage is integrating the three color components in one physical part important for achieving exclusively homogeneous color. Brightness of the LEDs is controlled by a PIC18F1320 [3] microcontroller, connected to the other elements of the system by means of Infrared Wireless Communication (IRWC). The IRWC makes the module independent of a control cable connection, so the only cable necessary is that of the power supply, thus making it possible for replacing existing luminaries without making major changes to the existing electrical infrastructure.

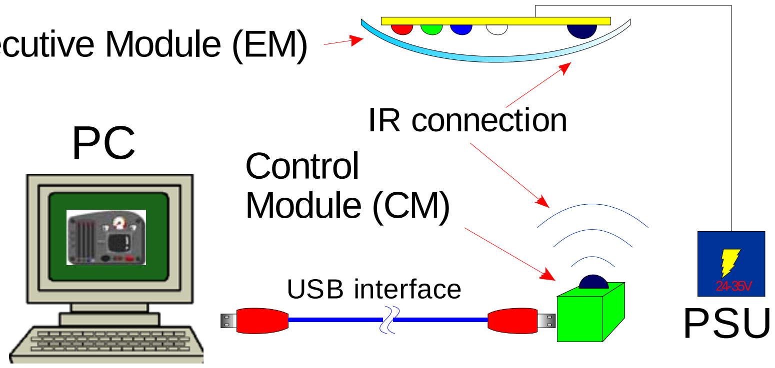

Figure 1 - System overview

2.2 Control Module (CM)

This module serves as an adapter between a PC and the EM. CM connects to the PC via a standard USB interface, and to the EM via IRWC. A PIC18F4620[4] microcontroller is used in the module. The main idea of module comes from the need of recoding and further data processing of the commands, issued by the PC, as well as the possibility for adding functionality to the module, for example adding analogue audio and video inputs for local signal processing, network connectivity and DMX512 interface.

2.3 PC Software

This component of the system generates and sends commands to the CM containing data about the light intensity of the LEDs at any moment. Its functionality is divided into two layers:

2.3.1 Driver layer

It implements a communication protocol between the PC and the CM as well as primitive commands for directly loading the brightness of the LEDs. All the remaining software components are built upon this layer, mainly because it acts as the I/O for the entire software part of the system.

2.3.2 User interface and plug-ins

The layer enables the end-user to configure the system and choose between its modes of operation: manual mode (also used in daylight lighting mode), audio visualization mode and video effects emphasizing mode, all explained in the next section.

2.3.3 Power supply

There must be rectified, non-regulated voltage between 24 – 35V for the system to operate properly. Only the EM uses this power supply. The total consumed power is directly dependant on the number of installed LEDs.

3. MAIN PROBLEMS AND RESULTS

3.1 Energy effective LED control

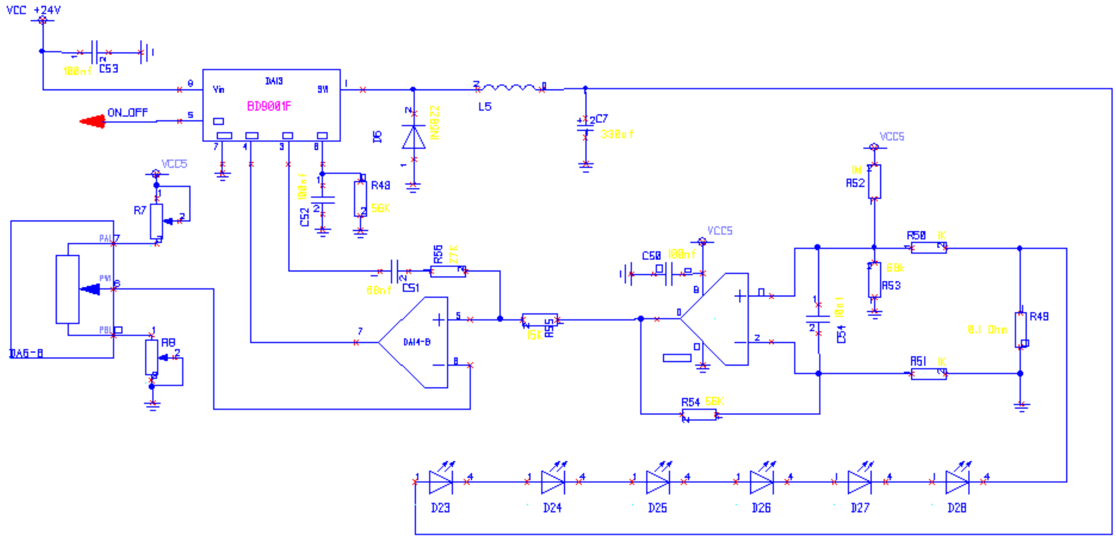

Figure 2 - LED control schematic

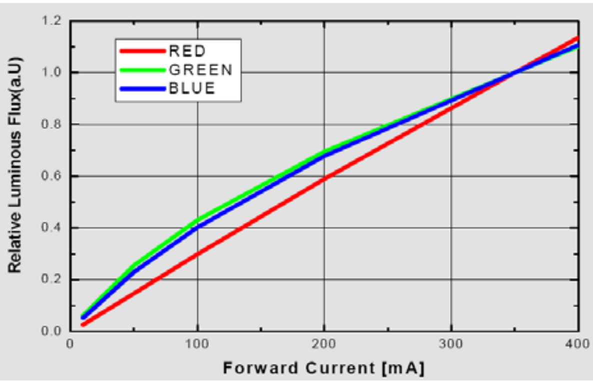

Figure 3 - Forward Current vs. Normalized Relative Luminous Flux, T=25˚

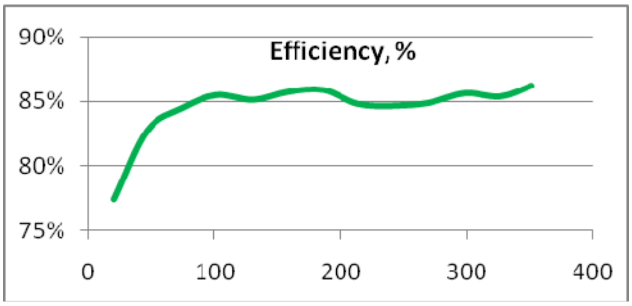

Figure 4 - Forward Current vs. Power Efficiency

The almost linear dependency between the forward current through the LEDs and the relative luminous flux (fig.2) showed that the required gradually regulated brightness of the LEDs may be achieved by means of a regulated current source. It is a common practice to control the average current through an active load using pulse-width modulation of a switching element or an amplifier schematic design. Both methods turned out inapplicable, for the first produced unpleasant flickering when illuminated objects moved fast and the second did not comply with the underlying requirements for low energy losses and could cause further complications because of the limited cooling of the EM. So a special digitally controlled regulated current source was designed, its schematic given in fig. 3. There are 5 such current sources present in the EM, three of which control the R, G, B components and two for the white LEDs. The feedback(FB) of the switching voltage regulator BD9001F is fed not with a function of the output voltage, but with the amplified voltage drop on the shunt resistor of a LED circuit. The design excludes the influence of the built in voltage reference of the BD9001F by means of an external comparator with its inverting input connected to a regulated voltage reference which determines the output current. The external reference is made of a resistor divider, implemented by a digital potentiometer. Fig.4 shows that the switching regulator achieves average 85% efficiency because there are no unnecessary voltage drops producing energy losses. Furthermore, this design offers enough speed for the LEDs' control for the various lighting effects.

3.2 Communication between CM and EM

The IR wireless connection was chosen for the simplicity of its design and the fact that using radio communication could interfere with other radio equipment using the same free frequency bands because of the frequent brightness updates of the LEDs. The MCP2120 [5] IrDA encoder/decoder chips are used with a baud rate of 2400bps, their main purpose being to narrow the width of the IR light impulses in order to avoid interference. Communication is carried out in one direction only (from CM to EM), the CM constantly sending data frames that contain information about the brightness of the LEDs as well as a header key and Frame Check Sequence (FSC) code. The receiving party uses finite state machine algorithm for recognizing a complete frame, which in fact eliminates the possibility of receiving erratic data, even in aggressive environment (passing objects between the transmitter and the receiver, other devices, etc.)

3.3 Communication between PC and CM

The two devices are connected by a universal USB interface, also used for powering the CM. Because of the limited calculating power of the 8-bit microcontrollers and the complexity of software USB implementation a USB to UART convertor is used, namely FT232R, that comes with a prebuilt PC driver developed by the manufacturer. The driver is supplied as a dll file that serves as a base above which the driver part of the custom software is built.

3.4 DSP functionality of the plug-ins and specifics of the user-interface

The software part of the system offers the most versatile possibilities for LED control and effect generating. Up-to-date the following functionality has been developed:

3.4.1 Control panel for direct manual access to the functionality of the system

This is a flash based user interface to control the separate setting of each of the components of the RGB color as well as the intensity of the white light. This functionality is achieved by the communication between ActionScript, which drives the flash file and the custom driver layer software, represented as a dll file written in C++.

3.4.2 Audio plug-in for Winamp

Using Winamp's API functions the sound spectrum of the currently playing file is periodically retrieved. Then the dominant sinusoid is found, which determines the color to display, and its amplitude – the intensity of the color. Thus after processing the signal a command to the CM is issued with the updated values of the LEDs intensity. The procedure is repeated 50 times per second creating smooth dynamic visualization.

3.4.3 Video plug-in for Windows Media Player

The functionality of this component is to some extent identical to that of the audio visualization, the main difference being that in this case the current frame of the playing movie is analyzed. As a result of the analysis the dominant color in the frame is extracted and loaded into the CM. The idea, achieved more than successfully, is to emphasize the special visual effects in the movie and make the overall picture area bigger than it actually is.

4. CONCLUSION AND FUTURE WORK

During the testing period the system demonstrated excellent results in parameters such as energy efficiency, speed, reliability of communication and performance of lighting effects. Generally speaking the dual functionality of the product makes it an able competitor to the existing technology represented by traditional luminaries (fluorescent and incandescent light bulbs) and expensive professional effect lighting systems. Furthermore, the era of LED lighting is just beginning, so the product will remain current in the near future.

Here are some ideas for expanding the functionality of the system:

- Adding a remote control – given the availability of an IR receiver in the EM it is feasible to implement an autonomous mode of operation of the EM, controlled solely by an IR remote control much like a TV set.
- Adding the ability for simultaneous operation of multiple EM – this is a very interesting idea that will enable the CM to control more than one EM at the same time, with each EM having its own address. There may also be EMs sharing the same address thus forming group so that they react the same way on commands sent by the CM. The multitude of EM and the centralized control will provide really impressive lighting effects making the applications of the system far more advanced.
- Adding functionality to the CM – availability of DSP functionality in the CM enables operation of the system without a PC, because the various input signals are processed locally. It is feasible to implement audio inputs, as well as composite, S-video and component video analogue inputs.

5. REFERENCES

[1] Technical Datasheet for F50381, Seoul Semiconductor Co., Ltd, 2006
[2] Technical Datasheet for X4218X, Seoul Semiconductor Co., Ltd, 2007
[3] PIC18F1320 Data Sheet, Microchip Technology Inc., USA, 2004
[4] PIC18F4620 Data Sheet, Microchip Technology Inc., USA, 2004
[5] MCP2120 Encoder/Decoder Data Sheet, Microchip Technology Inc., USA, 2007