Intelligent control of LED luminaries

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***Abstract* – The article considers the intelligent control system of LED lighting based on two-circuit regulation of the lighting device: control loop of the temperature crystal LED with using Peltier element and control loop of the luminous flux due to PWM LED driver.**

I. Introduction

Modern LED lighting systems allow to carry out energy savings compared to lighting systems that use halogen and fluorescent lamps 2-3 times. Optimization of work lighting devices significantly increases their reliability and durability of work.

Currently, intelligent light control systems are increasingly used to create optimal lighting modes [1-3]. Such systems are based on self-test of the illumination device in real time with using different types of sensors (temperature, illumination, time, motion). The intelligent system control in the classical case carried out due the controller, which supports the required modes of operation of the LEDs.

The developed control system and lighting control [4] allows us to provide the required level of illumination without losing the reliability of the system. However, this system, as other LED lighting system regulates the operation by means of changes modes operation of the driver of the LEDs. At the same time at operating of lighting systems, especially external lighting, there is a significant change of the ambient temperature, which results to temperature fluctuations of the crystal LED. Changes of luminous flux of the lighting device arising от temperature variations crystal LEDs are usually compensated by the driver.

Passive cooling systems used in the LED lighting devices not allow maintain the temperature modes of LED crystals in recommended by the manufacturers the temperature range. In case of environment temperature between 35^0C-40^0C in passive cooling the temperature of the crystal will be 70^0C-80^0C.

The transition from conventional light sources to LED systems necessitates the use of unique design principles in order to achieve the advantages of LED lighting.

In this article we propose to compensate for changes in temperature of the LED crystal add an extra loop of temperature control, where for the control element are used Peltier's module, allowing carrying out regulation across the temperature range of winter and summer time.

II. Main part of the research

For reliable operation the LED lighting fixture was designed lighting control scheme, which includes two control loops (Fig. 1). This scheme supports through the first control loop the required the crystal's temperature of the LED. The second control loop provides the required illumination by changing the mode of the driver.

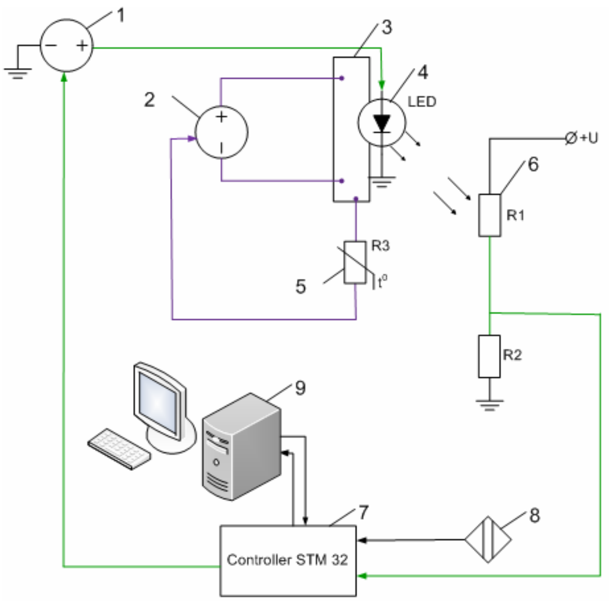

Figure 1. The control circuit of LED lighting system
1 - control driver by LED; 2 - power supply of the Peltier element controlling by the temperature ; 3 - Peltier element; 4 - LED; 5 – thermo resistor; 6 - photoresistor; 7 - microcontroller STM32; 8 - movement sensor; 9 - PC with intelligent control

Consider the work of this scheme.

The first control loop maintains the desired temperature in the range providing a stable operation LED 4, wherein during the time claimed by the manufacturer of the LED is not degraded. Adjustment is carried out automatically by changing the operating voltage of the Peltier element 3 with the developed power supply 2. As the temperature sensor is thermoresistor 5.

The second control loop ensures a constant level of illumination due to power control of LED 4 with a PWM control of driver 1. Microcontroller STM32 controls the operation of the driver. Control signal for controlling goes with photoresistance 6 to controller 7 for executing the program with the necessary scripts the LED operation.

The motion sensor 8 is used for work the lighting system only in the presence of people. The signal from the sensor is fed to the controller STM32 and provides on or off the system, depending on the presence of people.

The personal computer 9 with the necessary software is used for the algorithm recording of intelligent lighting system.

For the designed system as a source of radiation was selected LED high-brightness of Japanese corporation Nichia LED NCSL219B: power - 1W, luminous flux - 126Lm, operating current - 350 mA [5].

The main task of the LED driver is providing a stable constant output current regardless of the change of supply voltage and the number of LEDs in the chain. To ensure a long service life, high reliability and stability characteristics of LED lighting, it is important maintain a high current stability. This raises the question about the choice of the power supply circuit (driver).

The basis for a controlled driver was take chip Supertex HV9910 (company Supertex inc.USA, USA). It is high-performance low-cost PWM current regulator of the LEDs. A distinctive feature is the ability to work as in low-voltage applications (for example in control modules of automobile LED headlights with powered 12V) as well as in applications of decorative street lighting and facilities receiving voltage from electrical networks 220V. HV9910 universal stabilizer current high-brightness LEDs with a supply voltage from 8V to 450V and output current of more than 1A provides maximum flexibility and excellent design parameters.

Distinctive features of the chip are as follows:

– efficiency of more than 90%;
– input voltage range: 8V ... 450V;
– constant current driver for LED;
– provides a constant current from a few mA to 1A;
– chain management LEDs from one to several hundred different embodiments inclusion;
– low frequency PWM regulator output current externally driven [6].

Proprietary technologies Supertex laid down in the design of scheme that are provide a durable isolation of semiconductor structures with input voltages up to 450V.The constancy of the brightness of the LEDs chain is performed by stabilizing of the output current. The current values are easily programmed from zero to maximum with using of the hinged resistor or external low-frequency PWM pulses in the range up to several kHz. Output power of the load is controlled by an external MOSFET transistor at a fixed frequency up to 300 kHz. Using HV9910 provides control flexibility of the LEDs and increases their service life.

The operating temperature range is from -40^{0}C to +85^{0}C.

HV9910 chip makes it very easy to implement a stable power source to power the LED; its standard scheme is shown in Fig. 2. The scheme of inclusion may be different; it can be down-classical (buck), step-up (boost) or inverting (buck-boost). It's not all possible variations of schemes inclusion. The chip is very comfortable presence of its own built-in voltage regulator, which allows her to feed without the use of additional winding (on the throttle or a transformer). It has a pin for programming the switching frequency and outputs to implement dimming function (brightness adjustment).

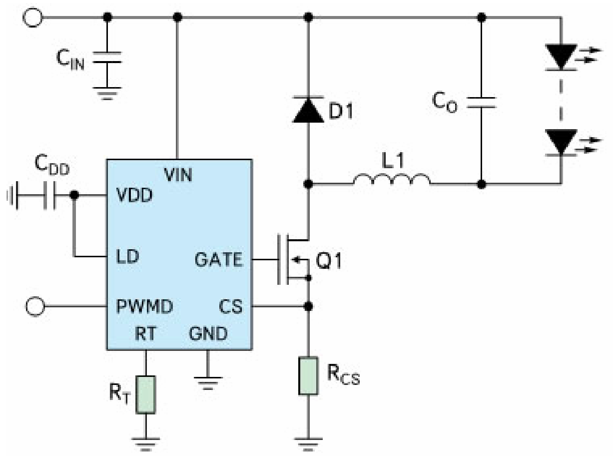

Figure 2. Standard scheme of inclusion chip HV9910

Integrated circuit stabilizes the current per the LEDs by the peak value. The current value is taken directly from the resistor the current sensor (PCA). Current is supplied to the comparator (output circuits CS) and is compared with a reference signal 250mV. If the voltage at RCS exceeds 250mV occurs off key Q1. Average current magnitude can vary by 2 times with an equal pulse width and a peak value. Three possible pulses in different modes of operation (from an intermittent to continuous modes of currents) are shown in Fig. 3.

Load current will vary in a very wide range (up to 2 times) when changing the supply voltage and the number of included LEDs. This introduces some limitations on the use of chip in the systems with wide range of the power supply voltage. This does not allow create the universal stabilizers with any number of series-connected LEDs.

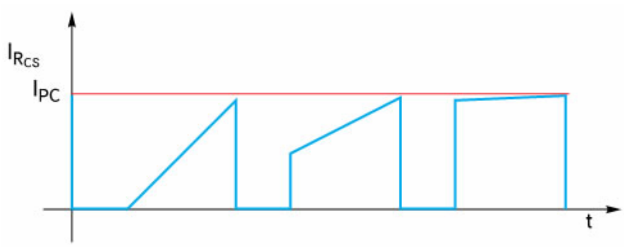

Figure 3. Scheme of possible forms of the current flowing through the resistor Rcs

Controlled driver based on the chip HV9910 was created based on the production complex "Energy" the university with application available the equipments, machines and tools (Fig. 4). Designed printed circuit board is shown in Fig. 5.

Figure 4. Production complex of "Energy"

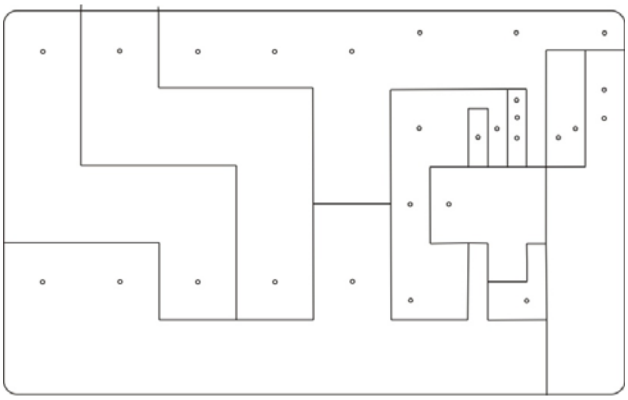

Figure 5. Scheme printed circuit board

Assembling of radio components was carried out in two stages. The first stage involves the solder of the SMD chip in brazing furnace infrared heating. Oven is programmed for a specific time-temperature schedule that is issued by the manufacturer of radio parts. Radio component fixed on his seat with the help of solder paste special chemical composition.

At the second stage performed installation of radio components manually using soldering station with temperature-controlled soldering tip (Fig. 6).

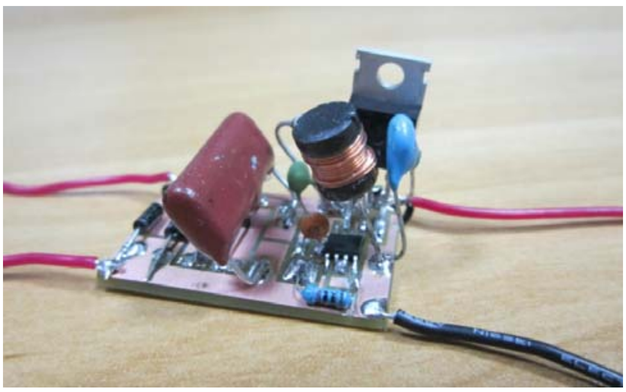

Figure 6. Assembled printed circuit board of controlled driver

Configuring settings assembled electronic device performed using the oscilloscope. Stabilization of current 350 mA is main parameter of settings for a stable and faultless operation of high-brightness LEDs. Further device is tested within 7 days to identify possible failures in its work.

Design controlling the temperature of the LED using a Peltier element (Fig. 7) is shown in Fig. 8.

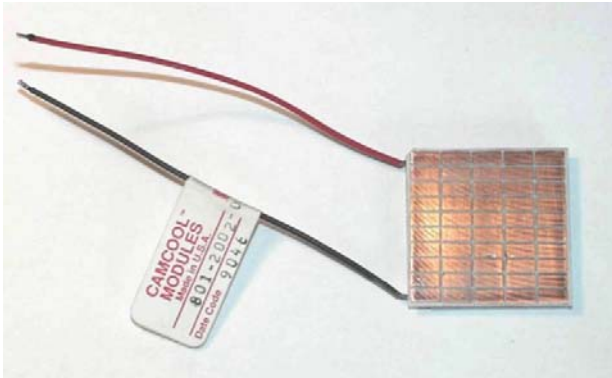

Figure 7. Peltier element

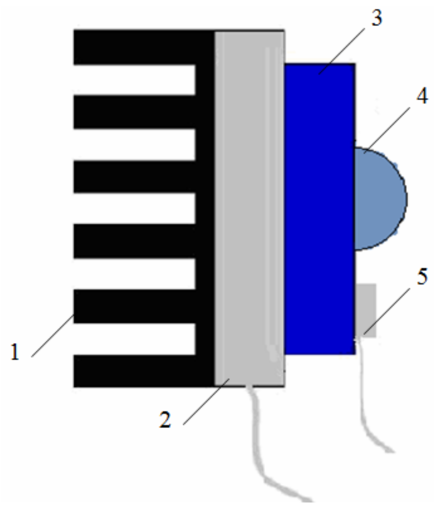

Figure 8. The design for cooling LED using of the Peltier element
1 - radiator of the Peltier element, 2 - plate Peltier, 3 - radiator LED, 4 - LED; 5 - thermoresistor.

To control the Peltier plate allowing regulate the temperature of the LED crystal was made the power supply with feedback. Power supply regulates the output voltage based on the resistance value of the thermoresistor that is measuring the temperature of the radiator LED.

Schematic diagram of the power supply with a Peltier element (Fig. 9) was developed and described in detail by us in the monograph [7].

As Peltier element was chosen model 801-2002-01 having the following characteristics: Pmax 22W, Thmax 60°C, Max 7A, Umax 6V, Weight 28gr, Ncella 49. Chip LM 723 used for the implementation of the required power settings (Current - 5A). Adjust the supply voltage to the Peltier element is performed by changing the adjustable resistance R establishing reference voltage through R1 to the input 6 of the chip. This voltage is a result of the comparison of resistances R8 and R, wherein R8 is a thermoresistor fixed on heat sink of the LED. A detailed description of the chip LM 723 is given in [8].

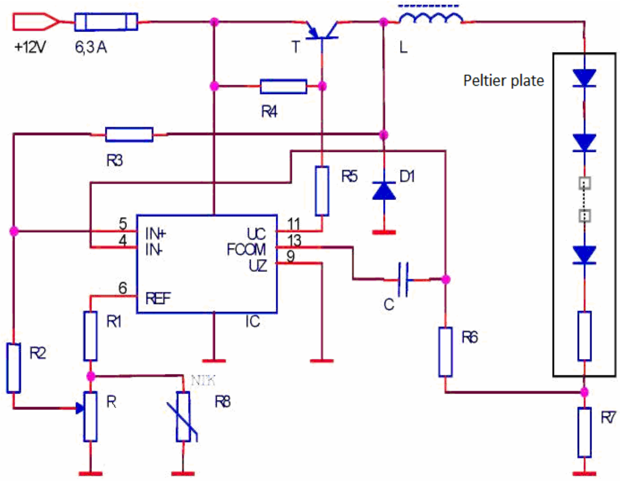

Figure 9. Schematic diagram of the power supply

The appearance designed system of the automatically adjust of the Peltier element temperature is shown in Fig. 10.

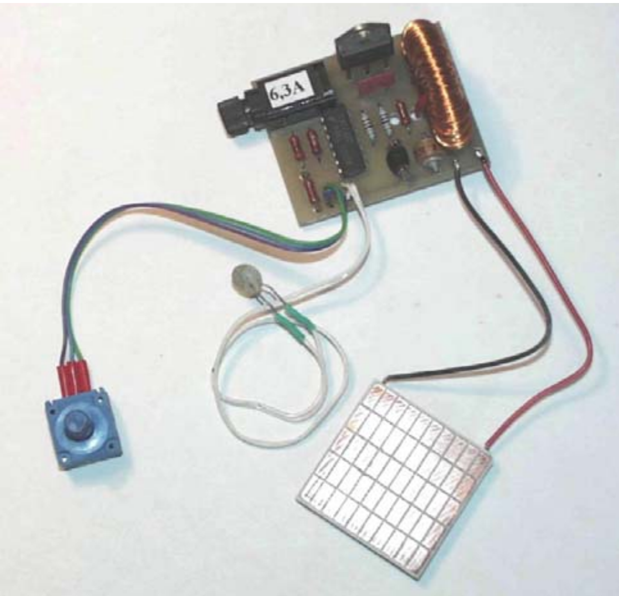

Figure 10. Appearance of the source with elements of monitoring and controlling the temperature of the Peltier element

Since at operation lighting systems during the day there is a change of natural light, depending on the time of year, we developed a program for intelligent lighting control for microcontroller STM32L-Discovery (company STMicroelectronics, Switzerland) [9].

Circuit board STM32L-Discovery (Fig. 11) is based on a series of microcontroller STM32L on core Cortex-M3. It represents complete tool-tories including the evaluation board, the programmer and debugger with support for software development. Underlying STM32L-Discovery laid down 32MHz microcontroller STM32L152RBT6 with 128Kb Flash, 16Kb RAM and 4Kb EEPROM. Also on the board has a built-in LCD controller 8x40 and LCD display 24x8 form factor DIP28. This board has the ability to measure current consumption.

Figure 11. The circuit board module matching based on the microcontroller STM32L-Discovery

III. FIELD STUDY RESULTS

Tests of the developed Intelligent LED lighting systems were carried out on two floors of the academic building of the East Kazakhstan State Technical University (Fig. 12).

Figure 12. LED Lighting of the floor academic building

On one floor used daylight fluorescent lamps, and on another floor LED lamps which operate in two modes: normal mode without a control system and with use intelligent control system. Each segment was equipped with electronic counter associating with the computer for comparison of the economic feasibility (Fig. 13). The first counter shows the power consumption on the floor with fluorescent lighting (counter 1), and the second - with LED illumination (counter 2). Information is displays on a monitor about energy consumption and efficiency of the systems and recorded in the database.

Figure 13. Test bench the electricity consumption over two floors

Experimental data of one lamp "Armstrong» is shown on graph (Fig. 14). In case of use intelligent control system: LED lighting saves energy almost 10-12 times compared to existing lighting based on the fluorescent lamps. Also, the data in-situ measurements have shown that the use of LED saves energy by 2-3 times, even without the use of automation systems.

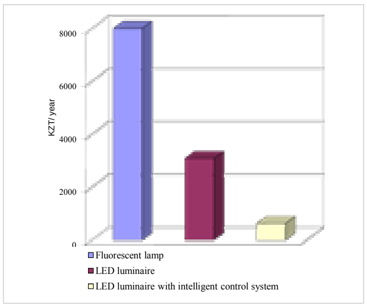

Figure 14. Chart total costs of exploitation of the lighting systems

Real expenditures decrease in LED using and it has visible effect on nature experiment data.

CONCLUSION

The article presents the results of the development and implementation of the intelligent dual-circuit system for the operation control of the LED luminaries that allows maintaining luminous flux and temperature of high-power LEDs in the given values.

Full-scale tests have shown the stability of the developed system, which allowed to create prototype of LED luminary.

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