**UDC: 007.52**

# DESIGN OF DETECTION MODULE FOR SMART LIGTHTING SYSTEM

I.G. Matveev, A.S. Goponenko

Tomsk Polytechnic University, 634050, Russia, Tomsk, Lenin Avenue, 30, office 127
E-mail: Necator94@gmail.com

The paper considers a smart lighting system based on Beaglebone microcomputer. The analysis of existing motion and presence sensors was carried out and then used as a basis for design of a detection system. The detection system and the corresponding connection solution for a smart lighting system were developed. Using the designed smart lighting system, experimental studies were carried out.

**Keywords:**
Smart lighting system, Beaglebone microcomputer, motion sensor, presence sensor, detection system

## Introduction

Modern systems of city lighting have strict requirements connected with energy saving and resource efficiency. It is caused by the increasing level of lighting energy consumption. So, this problem can be solved by using smart lighting systems.

Advantages of smart lighting system in comparison with other systems:

– conventional lighting systems have default lighting time that is independent from time of day and weather.

– switching on and switching off of conventional lighting systems do not depend on presence of pedestrians and moving cars, which leads to excessive energy spending during longer time [1].

Control of smart lighting systems is gained by using of embedded systems, which include lighting level control, processing of signals from detectors, and connection between each other. The type of used detectors defines content and functionality of a system and plays a significant role in the correct functionality of the whole system.

## Structure of a smart lighting system

A lighting system is a combination of central device and streetlights, which are connected to each other (Fig. 1).

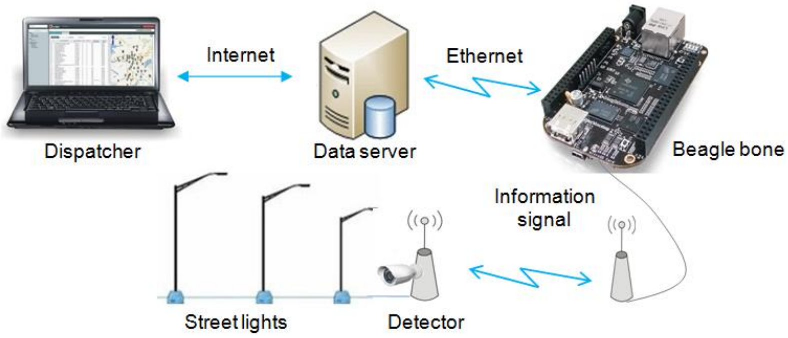



**Fig. 1.** Structure of a smart lighting system

The central control unit is a Beaglebone minicomputer. Each lamp has systems of communication and detection. The first system is used for communication with the Beaglebone, the second one detects a controlled object (a passing-by pedestrian). When a pedestrian enters the control zone, the signal goes to Beaglebone, which will enable lighting close to the pedestrian.

In accordance with the hardware, the corresponding software is used. The developed program is executed by Beaglebone, which supplies appropriate control signals to the lights. The complexity of this is to create a reliable method for detection of a moving or static object. Nowadays, the level of development of motion sensors used in lighting systems challenges to investigate new ways of detection. Sensors currently in use are often falsely triggered and mistakenly stop working when a moving object stops. A solution to this problem can be found using the combination of sensors and improving the data processing algorithms.

After processing, the data arrive at the database server and can be seen and controlled by the operator.

Information is transferred to the data server and the dispatcher after the data is processed.

**Overview of sensors**

*Acoustic (ultrasonic) sensor*

Acoustic sensors work on the principle of active location that is scanning the surrounding space (controlled zone) by sound waves in the ultrasonic range. Parameters of received waves are continuously monitored by the sensor.

A piezoelectric element generates waves with a frequency from 20 to 60 kHz, which are emitted into the controlled zone, reflect from the surrounding objects waves, and come back to the piezoelectric element.

When an object moves in the detection area of the ultrasonic motion sensor, the frequency of the wave reflected from the object is changed (Doppler effect), which is registered by the receiver. The receiver signal is conveyed to the ultrasonic motion sensor to trigger the embedded function [2, 3].

Sometimes, sensitivity of an ultrasonic sensor is not enough to detect the presence of a person, and it has a short distance range for the control area, but, at the same time, it is not influenced by changes of external influences.

*Radio wave (microwave) sensor*

Radio wave sensor contains a microwave unit which consists of a transmitter and a receiver of high-frequency oscillations. Radio wave detectors are active devices because they transmit microwave oscillations (usually 5 to 8 GHz), which are reflected by the surrounding objects and are registered by the sensor. The resulting signal is amplified and filtered to exclude registration of objects, which move too slowly or too quickly, from signal. The only allocated speeds are from 1 to 5 km/h, which are appropriate to the motion of people. Mixer diode adds transmitted and reflected waves [4].

Radio wave sensor, in contrast to the ultrasonic sensor, has a high sensitivity and long-range performance that can cause incorrect work of a detector, for example, by vibrating equipment or small animals. The efficiency of microwave sensors depends on the ambient temperature, and these sensors are much more expensive than other types of detectors.

*Infrared sensor*

The concept of the infrared sensor is based on the registration of change of infrared emission that is caused by movement or presence of a person in the area. The infrared emission is focused by the sensor’s lenses. The more amount of lenses is, the more the sensitivity of the detector is. IR sensors can be divided into motion and presence sensors.

Infrared sensors have high sensitivity, which can be changed, and low cost in comparison with other sensors. However, infrared sensors are highly dependent on the ambient temperature [5].

Given the characteristics of the infrared sensors, the implementation of a lighting system with using infrared sensors for automated control is problematic and is only possible in combination with other types of sensors contributing to the compensation of negative effects of infrared sensors.

As a result of analyzing of the sensor base, their advantages and disadvantages, an optimal combination of infrared and ultrasonic sensor can be identified.

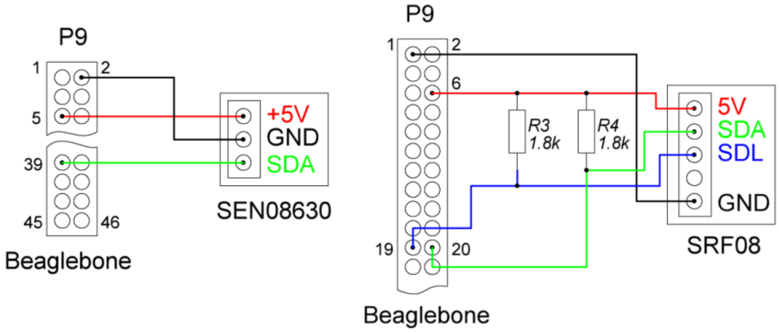


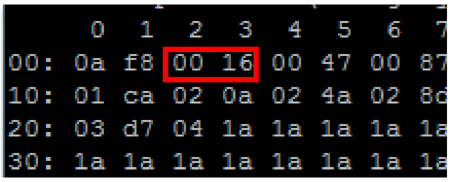

**Fig. 2.** Schemes of connection of SRF08 and SEN08630 sensors to the Beaglebone

High dependence of the infrared sensor on the ambient factors is overcome by using an ultrasonic sensor; the low sensitivity of the ultrasonic sensor can be improved by the infrared sensor.

**Experimental studies**

The sensors that were used in the detection system are the ultrasonic sensor SRF08 and the infrared sensor SEN08630.

The ultrasonic sensor SRF08 connects to the BeagleBone Black microcomputer through serial data bus I2C (fig. 2). At the beginning, the microcomputer initializes the address of the sensor that is connected over the I2C protocol [6]. To scan a control zone by the sensor, the command with specific value is sent to the command register of SRF08. The next step is reading of data from the sensor's register. The data come in hexadecimal format, and include information about the distance to the object in centimeters (Fig. 3).



| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| 00: | 0a | f8 | 00 | 16 | 00 | 47 | 00 | 87 |
| 10: | 01 | ca | 02 | 0a | 02 | 4a | 02 | 8c |
| 20: | 03 | d7 | 04 | 1a | 1a | 1a | 1a | 1a |
| 30: | 1a | 1a | 1a | 1a | 1a | 1a | 1a | 1a |

**Fig.3.** Distance data to the object (cell 0x02 – significant bit and 0x03 – the least significant bit), $0x16_{16}=22_{10}$ cm

Each scan is carried out in 65 ms (minimum time between measurements, which is limited by the sensor's characteristics). The measured value is compared with the previous and when an object appears in the detection zone, the difference between the obtained values arises. It indicates the presence of the object in the control zone.

The connection of the ultrasonic sensor SRF08 is made via ADC pins of BeagleBone Black (Fig. 2).

The signal output of the infrared sensor is connected to the analog input of the microcomputer (maximum voltage is 1.8 V). The amplitude of the output signal of the sensor is approximately 42 mV when the object is absent and 2.7 mV when motion is detected in the control zone (Figure 4). To process the signal from the sensor, a program that indicates the presence of motion for the 2 mV signal level was written.

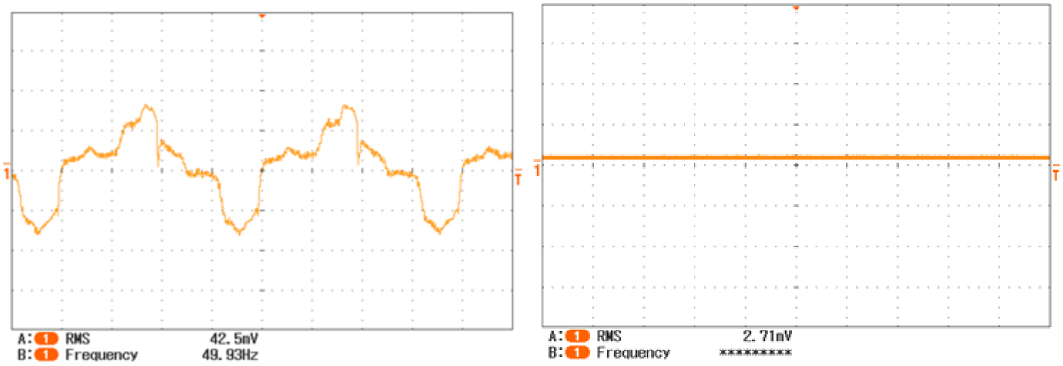



**Fig. 4.** The waveform of the sensor signal with and without motion

Experimental setup of smart lighting system was designed, where the LED has the role of a light source. To increase the detection efficiency in the area of control, ultrasonic and infrared sensors were combined in a system controlled by the BeagleBone Black microcomputer.

LED control program was designed in C ++, which processes the signals from the sensors and switches on the LED if the movement is registered by at least one sensor (Figure 5).

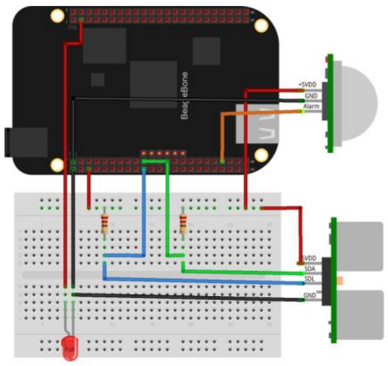


**Fig. 5.** Experimental model of a smart lighting system

**Conclusions**

The main methods of movement and presence detection were analyzed. The best combination of sensors for using in a smart lighting system was defined. Using a combination of methods of detection allows to increase the accuracy and sensitivity of a lighting system.

Schemes and algorithms of sensor connection to the Beaglebone Black microcomputer were designed and, as a result, experimental studies were carried out. A model of a smart lighting system was designed and tested. The designed system successfully solves the problem of motion detection and lighting control.

On the base of the model, design of variations for improving accuracy and sensitivity of the detection system is planned.

## REFERENCES


1. Srivatsa, D.K. ; Preethi, B. ; Parinitha, R. ; Sumana, G. ; Kumar, A. Smart street lights / Proceedings of 2013 Texas Instruments India Educators' Conference (TIIEC), 2013, p. 103-106. DOI: 10.1109/TIIEC.2013.25
2. Technical means of detection. URL: http://www.nicohrana.ru/forum/viewtopic.php?f=18&t=28 (Access date: 20.01.2015)
3. Motion sensors. Main types and features . URL: http://rozetkaonline.ru/poleznie-stati-o-rozetkah-i-vikluchateliah/item/54-datchiki-dvizheniya-osnovnye-vidy-i-ikh-osobennosti-oblasti-primeneniya#ultra (Access date: 23.01.2015)
4. Radio waves and combined detectors. URL: http://library.espec.ws/books/guard/CHAPTER3/3-3.htm (Access date: 29.01.2015)
5. Vlasuk N.P. Passive infrared motion detector / Radiomator. - 2006. - №5. - p. 31-37.
6. Derek Molloy. Tools and Techniques for Building with Embedded Linux, John Wiley & Sons, Inc. 2015.



**Author's information:**

**Matveev I.G.,** master's student at Institute of Non-Destructive Testing, National Research Tomsk Polytechnic University, e-mail: Necator94@gmail.com;

**Goponenko A.S.,** master's student at Institute of Non-Destructive Testing, National Research Tomsk Polytechnic University, e-mail: andreigoponenko@gmail.com;