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Cost Effective Automated Street Lighting Control

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ABSTRACT

Roads and their lighting systems are important facilities of local municipals. Most conventional street lighting systems are switched on/off at regular intervals of time. The consequence is that a large portion of electrical energy consumed by the street lighting is wasted meaninglessly if the road traffic is low. With the increasing interest in the global energy consumption and green environment requirement, automated street lighting system raises much interest around the world. In this paper, a cost effective and energy efficient automated street light control based on microcontroller and ZigBee wireless network is proposed. The street lamps are automatically controlled with the ambient light conditions, the road pedestrian and vehicle traffic conditions, and the neighbor traffic conditions.

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1. INTRODUCTION

The origin of the lighting goes as far back as 70,000BC. Manmade pottery held a small fire where a wick was used to control the rate of burning. The times required for people to maintain, sustain and change the lamps periodically. After the early establishment of roads, street lamps were used as lighting after dusk. Fuels to use for lighting were beeswax and an assortment of oils as followed: olive, fish, whale, sesame, and nut oil. By the 19th century, streets became lit by gas [1].

Modern street lights are the product of electricity in the form of incandescent, fluorescent, low pressure sodium (LPS), mercury vapor (MV) and high pressure sodium (HPS) lamps. With the increasing interest in the global energy consumption and green environment requirement, the street lighting systems integrating most recent lighting source, light-emitting diode (LED), were under development [2-4]. However, most conventional street lighting systems are switched on/off at regular intervals of time. The street lights are simply turned on in the evening after dark and switched off after dawn in early morning [5]. The consequence is that a large amount of electrical energy is wasted meaninglessly. As energy consumption is an issue of increasing interest, possible energy savings schematics for street lighting systems are recently studied widely. Various control techniques have been proposed for street lighting controllers. It is common to use relays to make simple logical control decisions. Most smart street lightings are similar to adaptive lightings, which only describes the performance of the light on the road. Streets or roads equipped with such a solution will dynamically adapt the street lighting performance according to the actual needs for the given period/time of the road [6].

Our proposed control project could provide a cheaper and safer tomorrow for its consumers due to the street lamps efficiency and lighting it provides for pedestrians and motorists alike. This project will provide cost effective lighting for the public in an urban and suburban settings. The automated street lamp will be activated primarily by the activities of the local pedestrian, automotive traffic and the ambient light conditions. This design will focus primarily on the modern take of street lamps used around the world. Its setting is very universal, being a valuable asset near city roads, in parking lots, elementary school grounds, college campuses and reservations.

2. SYSTEM DESIGN

This project represents a set of automated street lamps. A microcontroller will receive inputs from a set of two motion sensors that will detect an object 360 degrees around each lamp. Either of the sensors will provide an input condition that will illuminate the lamp if certain other conditions are met. Under normal operation environment, the lamp is then extinguished if the sensors do not detect motion. A photocell in the system will detect the level of the ambient light. If the light level does not require the lighting, a relay will be energized and cut electrical power to the output control circuit thus the lights won't be on.

The system will be fully automated and can be configured to suit various requirements. It can be initiated by the time of day or will be active according to the level of ambient light, and run automatically.

When an object approaches a lamp within a predetermined distance, one of two distance sensors' inputs will be read by the micro-controller. And a relay will be energized and the lamp will illuminate. Once the object is outside a predetermined distance from a sensor, and the microcontroller will de-energize the relay after a period of time passed and the light will extinguish. If the object becomes stationary within the predetermined distance of the sensor, the light will remain illuminated.

The distance monitoredd by each sensor on a lamp will slightly overlap the distance monitored by the sensor of its neighbor lamp. This technique will allow the lamps to be illuminated as each lamp is passed by an object. As the object moves along, and out of range of the first sensor, a period of time will pass, and the lamp will extinguish. This process will be continued until an object is not sensed. The system will remain in a stand-by state.

A photocell can control the initiation of the system. If the photocell detects a high level of ambient light, a relay will be energized to remove power from the lamps. A bypass/test switch is designed to allow the lamps to be illuminated during times of high levels of ambient light.

An emergency switch is also integrated in the system. When the emergency switch is closed, the lamps are turned on unconditionally and the emergency information is transmitted to its neighbor nodes. The neighbor nodes switch on their lamps upon receiving the message.

2.1. System block diagram

Figure 1 shows the system functional block diagram, which mainly consists of a microcontroller block, input/output board, sensors, and output loads (lamps).

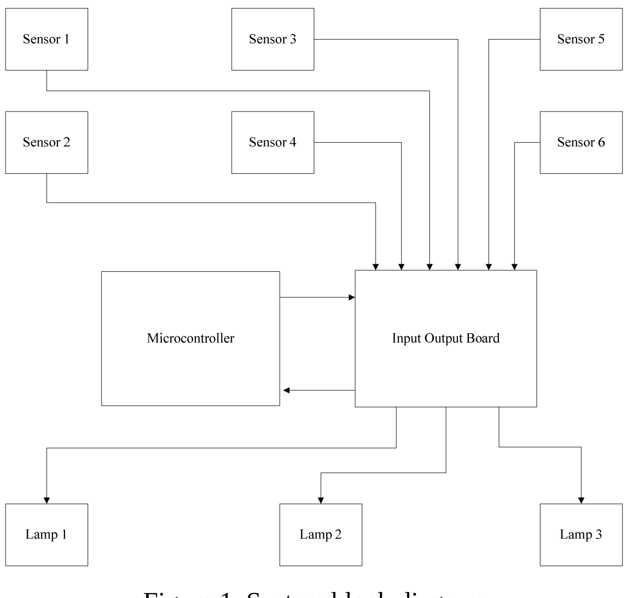

Figure 1. System block diagram

The microcontroller subsystem employs the Arduino Uno that is based on the ATmega328 and the Arduino Wireless SD Shield. The Uno board has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Arduino Wireless SD Shield allows the Arduino Uno board to communicate wirelessly using a wireless module. It is based on the Xbee modules from Digi, which utilizes the ZigBee PRO Feature Set [7]. The Wireless SD Shield is used to implement the wireless communication between neighbor nodes over ZigBee network.

The input/output board provides interface between the microcontroller and sensor inputs and lamp outputs. The Arduino Uno is isolated from its field inputs and outputs so that any overvoltage or overcurrent conditions could not harm the microcontroller subsystem. The inputs and outputs are electrically isolated from the microcontroller by photo-isolation circuitry.

As for input sensors, six Passive Infra-Red (PIR) motion sensors are used. The PIR senses changes in infra-red energy emitted by nearby objects. When an object in motion is detected, the sensor outputs a high signal on its output pin, otherwise it keeps a low signal. Sensors 1 and 2 correspond to lamp 1. Sensors 3 and 4 to lamp 2, and sensors 5 and 6 to lamp 3. Output loads are three light emitting diode (LED) lamps, which offer efficient lighting.

In addition, a photocell is integrated in the board to provide ambient light information, an analog signal, to the microcontroller. A bypass switch and an emergency switch are also included. The bypass switch serves as a by-pass to the photocell circuit. When the switch is open, the system is allowed to remain active regardless of ambient lighting conditions. When the emergency switch is closed, the lamps are turned on unconditionally. These two switches are also incorporated into system test and maintenance.

2.2. Circuit design and simulation

Multisim simulation and circuit design software gives engineers the advanced analysis and design capabilities to optimize performance, reduce design errors, and shorten time to prototype. Intuitive NI tools result in saved printed circuit board (PCB) iterations and significant cost savings [8]. Once the input and output interface circuits are designed, the circuits are simulated and verified by using NI Multisim. Figure 2 shows the input interface circuit and Fig. 3 shows the output circuit. Figures 4, 5, and 6 below illustrate the simulation results under different road and ambient light scenarios.

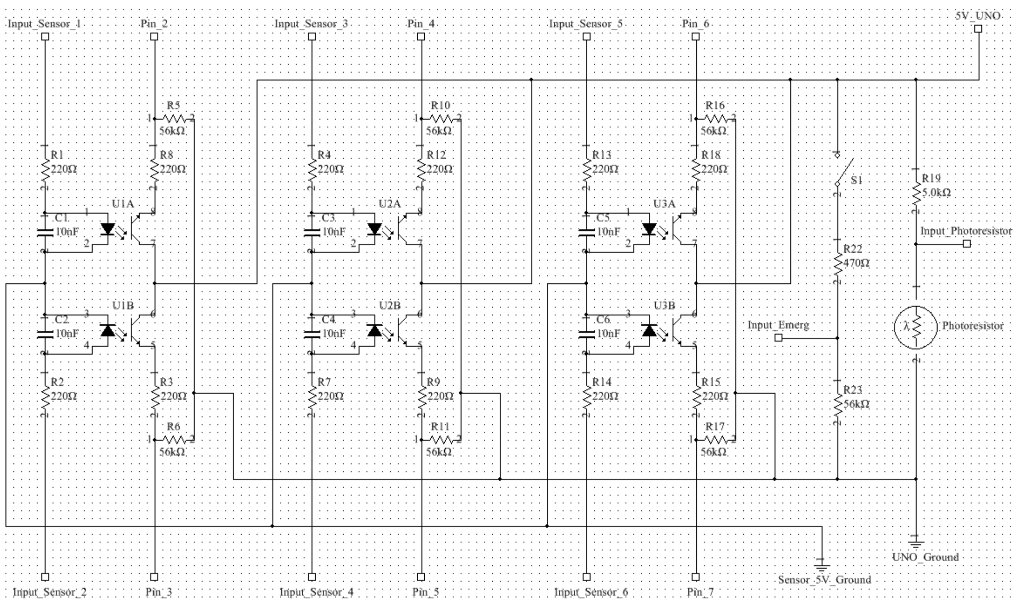

Figure 2. Input circuit

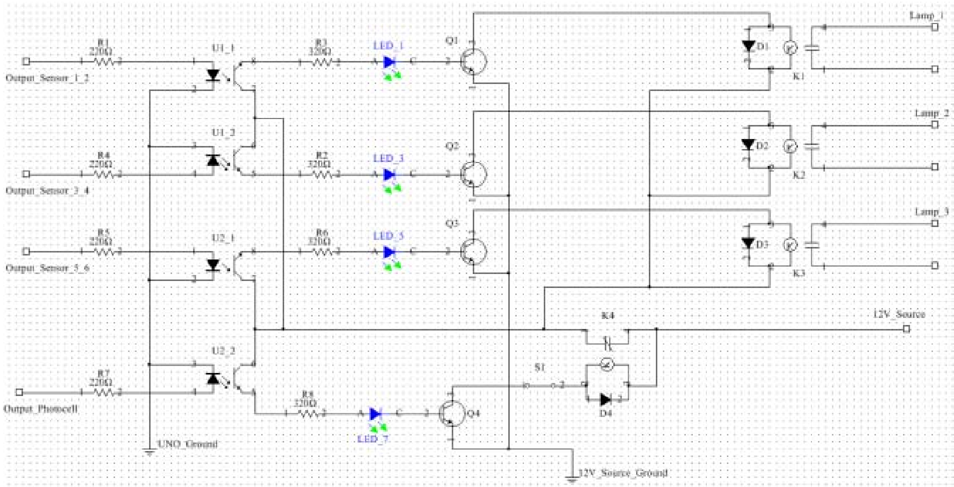

Figure 3. Output circuit

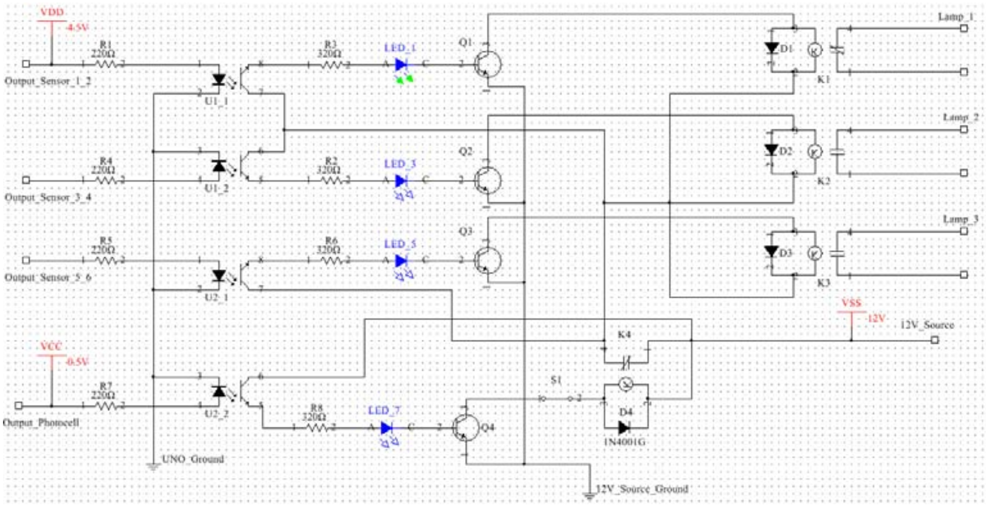

Figure 4. Simulation result under low ambient light condition

Figure 4 above demonstrates the simulation result with active traffic movement under low ambient light condition. In this scenario, the Output_Photocell from the output of Arduino Uno keeps logic 0 which further keeps the relay K4 de-energized and its NC contact closed. Thus, the 12 VDC is supplied to the output interface circuit. With Sensor 1 or Sensor 2 activated, the output from the Arduino Uno sets the Output_Sensor_1_2 to logic 1 that energizes the relay K1 and in turn switches on lamp 1. Under the same road traffic condition but with high ambient light, the Output_Photocell is set to logic 1 which further kills the 12 VDC to the output circuit. The lamp 1 is off though the Output_Sensor_1_2 is logic 1 as shown in Fig. 5. Under the same road and ambient light conditions as for Fig. 5 but in this case the bypass is switched off, the lamp 1 is now turned on though there is a high level of ambient light as illustrated in Fig. 6.

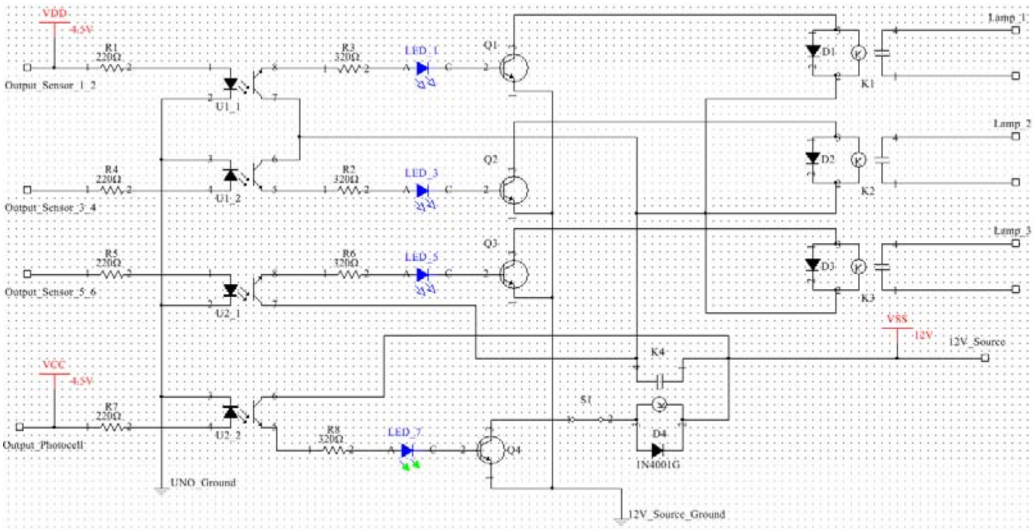

Figure 5. Simulation result under high ambient light condition

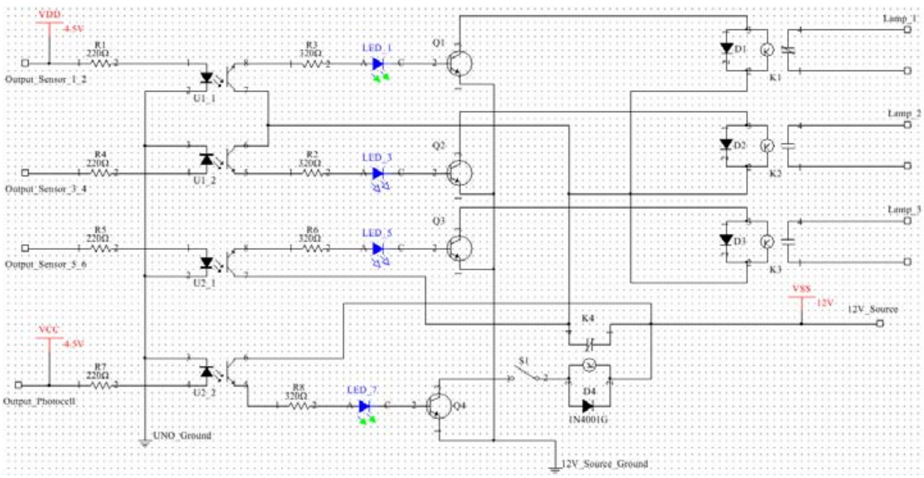

Figure 6. Simulation result with the bypass switch in off state

3. SOFTWARE ARCHITECTURE

The microcontroller on the board is programmed using the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing) [7].

The Arduino integrated development environment (IDE) contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions, and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them. The console displays text output by the Arduino environment including complete error messages and other information [7].

In order to accomplish the functionality of the street lighting control proposed, the software of the controller must be implemented. The application program is developed using Arduino programming language and Arduino IDE. First, the microprocessor initializes all registers and function modules, such as watchdog, timer, interrupt, I/O port, SPI module etc. Second, it continues onto the main cycle to collect the status of all the sensor inputs and control inputs, and check for valid data from its neighbor nodes. And then, the collected and/or received data is processed and analyzed. Last, the corresponding actions are executed. The flow chart of the application program is shown in Fig. 7.

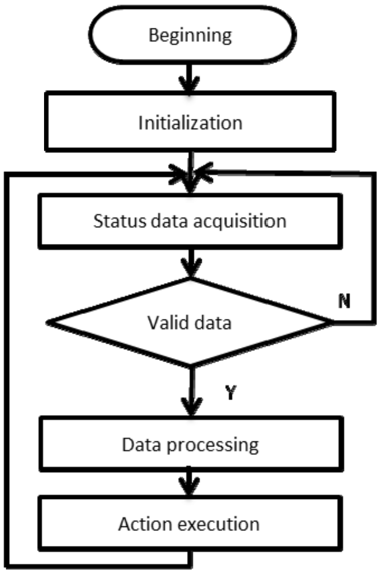

Figure 7. The flow chart of the application program

4. CONCLUSION

In this paper, a cost effective and energy efficient automated street lighting control is described that integrates new technologies, offering energy savings and ease of test and maintenance. This proposed system utilizes the high efficient LED lighting technology and the microcontroller based intelligent management of the lampposts activities of the local pedestrian, automotive traffic and the ambient light conditions. This design focus primarily on the modern take of street lamps used around the world. The proposed control is especially appropriate for street lighting in suburban areas where the traffic is low at times. However, its setting is very universal, being a valuable asset near city roads, in parking lots, elementary school grounds, college campuses and reservations. And it will bring considerable economic benefits.

ACKNOWLEDGEMENTS

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