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Energy Efficient Smart Street Light System based on Pulse Width Modulation and Arduino

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Abstract—**Across the country, majority of the electric power has been utilized for street lights. These street lights are always ON throughout the night and even in day times due to inefficient street light monitoring systems. An enormous rise in population and waning of natural resources has necessitates the prerequisite of efficient street light system. Therefore, in this work an energy efficient smart street light system based on PWM and Arduino has been proposed. In this work, the power efficiency has been achieved through PWM by switching the brightness of the LED from 100% to 20% based on the vehicle traffic. Based on the vehicle traffic per hour, the duty cycle has been adjusted which inherently changes the width of the pulse. Initially, the lights are in OFF during day time regardless of vehicle movements(LDR is high); during night time or cloudy environment the lights are turn ON based on the vehicle motion detected by PIR. The brightness of the LED is 100% up to a specified time delay, thereafter the brightness has been reduced to 20%. These changes in stats of LED (ON/OFF) have been controlled by PWM duty cycle which is specified by analogWrite(). The performance measures have been evaluated for proposed system by means of power consumption. The experimental results demonstrated that, the proposed system archives a power save (delay of 3 seconds) of 95% with zero vehicle movement, 92% with 30 vehicles per hour, 91% with 50 vehicles per hour and 87% with 100 vehicles per hour when compared to conventional street light systems.**

Keywords- Arduino; duty cycle; electricity; efficiency; light dependent resistor; power consumption; passive infrared sensor; street lighgt system.

I. INTRODUCTION

Over the past century, the population of the world has been quickly growing in urban areas. Therefore, the development of a city and its communities depends greatly on intelligent and sustainable development. Every public street and roads have a street lighting system as a standard service. The street lamp posts become Internet of Things (IoT)-based if they are equipped with sensors and communication technology. The use of lighting systems in streets is one of the major uses of electrical energy [1]. Therefore, it can be concluded that smart energy management in this region can be beneficial to for both aims given the considerable energy consumption in this system and the significance of individual and social security offered by proper lighting system in the city [2-3]. In this work, the power efficiency has been attained by means of PWM by altering the brightness of LED from 100% to 20% by varying duty cycle (see Fig.1) with respect to vehicle traffic.

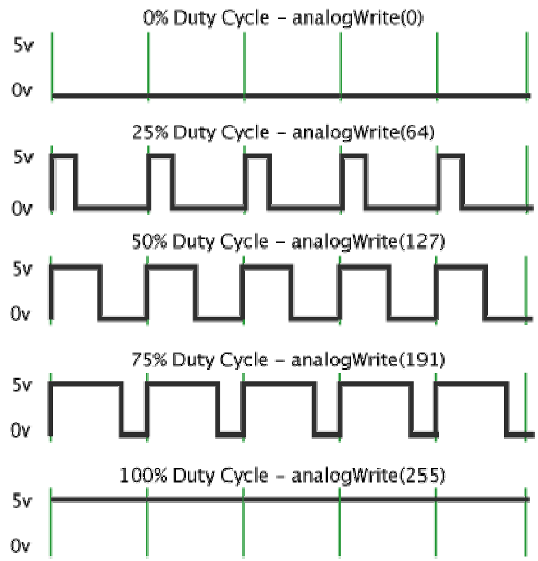

Figure 1. PWM Concept Through Arduino[4]

PWM, often known as pulse width modulation, is a method for producing analogue effects using digital technology [5-6].

A square wave is produced via digital control, which is a signal that is toggled on and off. By altering the ratio of the amount of time the signal spends on compared to the amount of time it spends off, this on-off pattern can imitate voltages between the full Vcc of the board (for example, 5 V on a UNO board), and off (0 Volts). The pulse width is the length of the on time. By modulating the pulse width, can obtain different analogue values. With an LED, for instance, the on-off sequence quickly enough, it appears as though the signal is a constant voltage between 0 and Vcc controlling the LED's brightness.

II. Literature Review

To automate the current street light system, a variety of models, algorithms, and prototypes have been put forth by the researchers. A smart street lighting system should supervise in an effective manner to maximize quality and production. The cost, manpower, and energy requirements should all be considered when implementing a reliable, intelligent, and energy-efficient street lighting system.

The authors in [7], has proposed an effectual shrewd street light supervisory system for smart cities which are built through IoT. A detailed investigation of energy and pecuniary prospects of smart street light system has been presented in [8]. A detailed examination of smart street light system in Nagpur city has been presented for power efficient implementation. A graphical interface tool (GUI) for creating a secure and efficient network for smart streetlights has been developed in [9]. If there is no nighttime traffic on the road, there is no need for street lighting. Since there are less natural energy resources available, it is vital to find ways to conserve energy, especially by lowering the amount of energy used for street lighting.

The authors in [10] has proposed a smart system for energy-efficient street lighting control. Embedded device developments based on smart cities are becoming more and more significant today. It includes efficient public transportation, e-governance, safety and security, intelligent lighting systems, and more. The primary goal of authors in [11] is to offer a street light controller design that will reduce power consumption and enable wireless control, both of which will eventually result in a reduction in the budget needed for electricity for street lights.

A smart street light system has been implemented[12] which has a footstep power generator. In addition, there are numerous inventions for smart street lights based on Zigbee [13], GSM[14], solar panels[15], RFID[16]. The main motive of the available literature on smart street lights systems is to illuminate the environment with less power. Hence this work is focused on reducing the power consumption through PWM.

III. Proposed Hardware Model

A. Block Diagram

The proposed system (see Fig.2) incorporates with light dependent resistor (LDR), a passive infrared sensor, and LED which are interfaced through Arduino. When the street light is glowing based on LDR and PIR answers at any moment, the suggested system is said to be intelligent. When there is sufficient sunlight, the LDR is in the ON state, which means that no current flows through the system because of the high resistance of the LDR. As a result, even if the PIR sensor detects the movement of a vehicle or a person, the LED will not turn on because there is sufficient sunlight present. On the other hand, throughout the night the LED only enters the ON state when the PIR sensor detects movement of the car. In addition, the brightness of the LED has been adjusted in such a way that it depends on time delay and duty cycle (defined through Analog Write()). When the time delay increase, the duty cycle has been adjusted in the program which is noting but the brightness of the LED depends on the width of the pulse. Hence, the brightness of the LED switched from 100% to 20% when there is no vehicle movement after the given time delay. In this way the power consumption has been reduced when compared to existing systems.

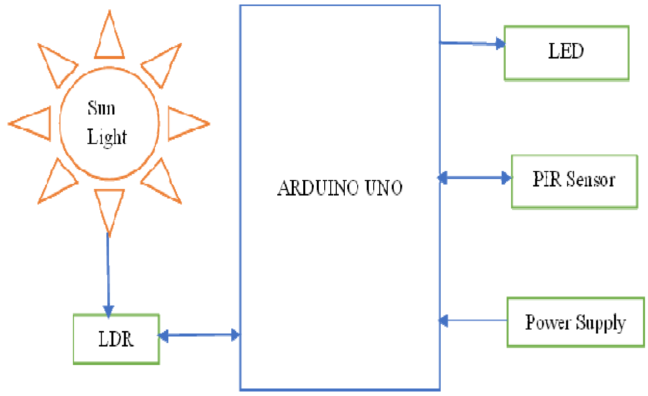

Figure 2. Proposed System Block Illustration

B. Circit Implementation

The circuit connection of the suggested energy efficient smart street light system based on PWM is shown in Fig. 3.

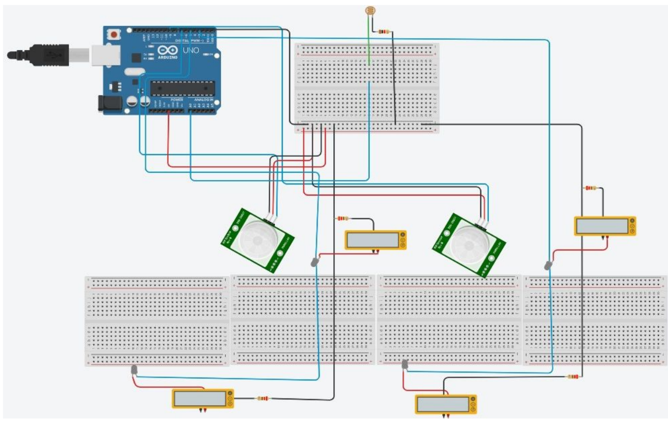

Figure 3. Circiut Implementation of Proposed Model

C. Dveloped Hardware Model

The suggested model includes a PIR sensor for detecting vehicle motion that is place between the street light pole as illustrated in Fig. 3. The LDR has been fixed (see Fig. 4) so that it can detect the sun during the day. For the purpose of creating a 5V smart interface between the LDR and PIR, the Arduino board has been fixed between them.

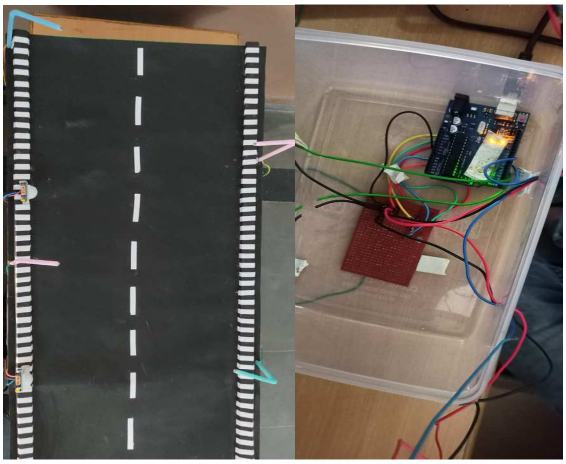

Figure 4. Dveloped Hardware Model

IV. Flow Chart

To understand the proposed model for efficient street light system, a work flow has been created which is depicted in Fig. 5. The sequence of workflow starts with turning on the power supply to the Arduino board.

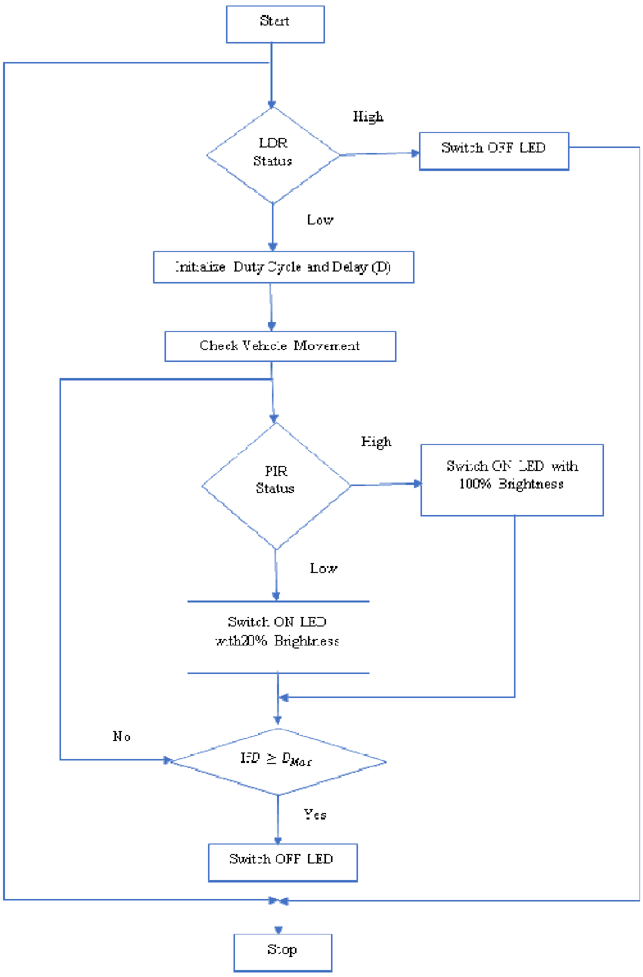

Figure 5. Work Flow for Proposed Model

- Step1: Initially, check the LDR status, if LDR status is high; then switch OFF the LEDs completely.
- Step2: If the LDR status is high, then initialize the duty cycle (pulse width) and delay (*D*).
- Step3: Check for vehicle movement through PIR sensor.
- Step4: Based on the PIR status, the brightness of the light has been altered between 100% to 20%. If the PIR status is high then lights are glowing with 100% brightness until the delay time. Else, the lights are glowing with 20% brightness.
- When there is no vehicle detection through PIR, then the lights are glowing with 20% up to the time delay, thereafter the lights are switched off.
- Again, the process is repeated for night times and cloudy environments.

V. Requirments

The components required for developing a prototype of proposed work and the specifications of each component has been highlighted in Table1.

TABLE I. Component Specifications

Component	Specification
LDR	600 nm, minimum of 1.8 kilo ohms Dark resistance-0.03 mega ohms Maximum resistance-4.5kilo ohms
PIR	3 to 7 meters with horizontal range with 80 degrees
Arduino board	Arduino UNO
LED	5v

VI. Experimental Results

The Arduino programming is done by using Arduino Integrated Development Environment (IDE).

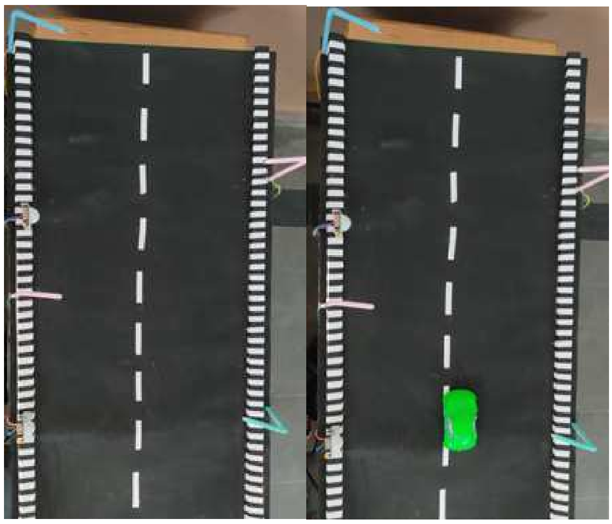

Figure 6. Status of the Proposed System During Day Time

The light dependent resistor is used to detect the daytime and night time automatically based on the resistance of the

LDR. Passive Infrared Sensor (PIR) is used to detect the motion of vehicles and people. It triggers the street light controlled by an Arduino thereby controlling the brightness of Light (i.e., when a vehicle or person movement is detected by the PIR and it triggers the Arduino, which will increase the brightness of the light to 100%). Initially the brightness is maintained 0% but when an object motion is detected the brightness will increase to 100%. Once there is no motion detected by PIR the brightness will fall to 50% from 100%. Further if there is no object motion detected the brightness will fall to 0%.

It is clearly depicted from Fig.6; the system is inactive and all lights are turned off during day time (LDR is exposed to sunlight). Even if there is any object motion, the PIR sensor will not detect the motion as the LDR is exposed to sunlight. Hence, during day time the lights are switched off automatically. Whenever, the sun light condition is not good or during night time, the LDR having low value, then the whole system is active and the brightness of light is initially maintained 0% and the PIR sensors are active.

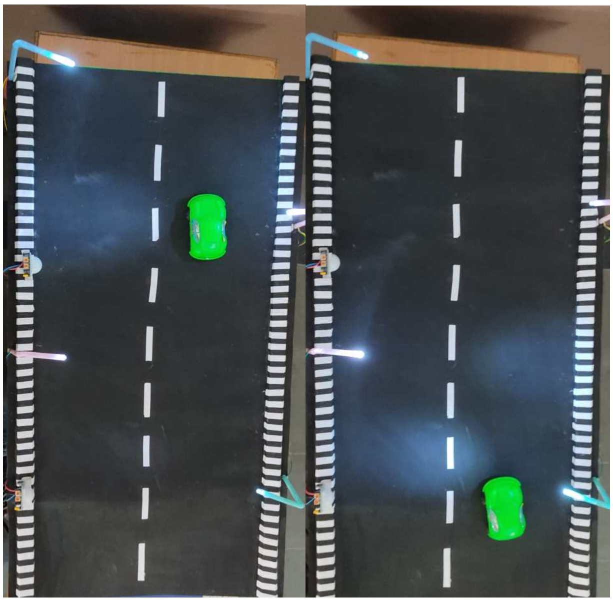

Figure 7. Switching the brightness of lights from 100% to 20% depending upon vehicle movements.

Fig. 7 depicts that the, motion is detected by the PIR sensor and it will increase the brightness from 0% to 100% and stay at 100% till the motion ends. When no more object motion is detected then brightness will fall to its initial state gradually (passing through 50% and 25% to 0% based on duty cycle provided in algorithm)[18].

VII. Performance Evaluation

A. *Without proposed Model*

Power consumption (PC) for one LED Per hour (with voltage of 5V, current of 15mA) can be evaluated using (1). Therefore, the power consumption for one LED per hour will be 75mW according to (1). Similarly for four LEDs the power consumption will be 300mW.

$$PC = V \times I \tag{1}$$

B. *With Proposed Model*

The performance evaluation of proposed model has been conducted with respect to the power consumption. Based on the number of vehicles and time delay between each vehicle appearance, the brightness of the LED is altered which is technically depends on pulse width modulation. The width duration is directly proportional to the brightness status of the LED. Let us consider an example where, the number of vehicles per one hour will be n, and delay is D (seconds). The amount of time (T_1) at which the LED has 100% brightness is represented with (2).

$$T_1 = n \times D \tag{2}$$

Whereas, the time (T_2) at which the LED has 5% brightness is represented with (3).

$$T_2 = 3600 - T_1 \tag{3}$$

Hence, the power consumption in both the cases will be evaluated by using (4) and (5) respectively.

$$PC_{T_1} = \left({}^{PC}/_{3600}\right) \times T_1 \tag{4}$$

$$PC_{T_2} = \frac{(PC \times 0.05 \times T_2)}{3600} \tag{5}$$

The total power consumption of the proposed model is the addition of consumption due to 100% brightness and 5% brightness of LED respectively which is represented using (6).

$$PC_{Total} = PC_{T_1} + PC_{T_2} \tag{6}$$

Finally, the power savage and percentage of power save due to proposed method has been estimated using (7) and (8) respectively.

$$PS = PC - PC_{Total} \tag{7}$$

$$\%PS = \left({}^{PS}/_{PC_{Total}}\right) \times 100 \tag{8}$$

The performance evaluation for proposed method with a delay (D) of 3 seconds have been highlighted in Table 2.

TABLE II. Power Consumption Comparisions for Proposed Model for D=3seconds

n	Power Consumption(mW)		% PS
	PC	PC_{Total}	
0	300	15	95
30		22.12	92.53
50		26.875	91.09
100		38.75	87.09

VIII. Conclusion

In this work, an energy efficient smart street light system has been proposed based on pulse width modulation and Arduino. The power efficiency has been achieved through PWM by switching the brightness of the LED from 100% to 20% based on the vehicle traffic. Based on the vehicle traffic per hour, the duty cycle has been adjusted which inherently changes the width of the pulse. Initially, the lights are in OFF during day time regardless of vehicle movements(LDR is high); during night time or cloudy environment the lights are turn ON based on the vehicle motion detected by PIR. The brightness of the LED is 100% up to a specified time delay, thereafter the brightness has been reduced to 20%. The proposed system attained a power save of 95% when there is no vehicle movement and 87% with 100 vehicles per hour.

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