

Automatic Street Lighting System for Energy Efficiency based on Low Cost Microcontroller

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Abstract — This paper proposes energy efficient of automatic street lighting system based on low cost microcontroller. The main objective is to design energy efficient based controller for controlling the Light Emitting Diode (LED) based street lamp via appropriate lighting levels control. This system is consists of a microcontroller, light sensor, rain sensor, laser sensor and a set of the light emitting diode (LED) module. While, the controlling and managing of the system is based on the number of traffic and five different level of street light brightness has been used for lighting up the street and proportional to the number of traffic. The system was programmed to automatically turn off during the hours of daylight and only operate during the night and heavy raining or bad weather. Several numbers of tests have been conducted to test and validate the proposed prototype in the different environment. As conclusion, around 77%-81% reduction in power consumption can be achieved through this proposed automatic street lighting system for energy efficiency system design.

Keywords - Energy efficient; Street Lighting; Low Power Consumption

I. INTRODUCTION

Basically, street lighting is one of the important parts of a city's infrastructure where the main function is to illuminate the city's streets during dark hours of the day. Previously, the number of streets in the town and city is very small. Therefore, the street lamps are relatively simple but with the development of urbanization, the number of streets increases rapidly with high traffic density which highlighted in [1]. There are several factors need to be considered in order to design a good street lighting system such as night-time safety for community members and road users, provide public lighting at cost effective, the reduction of crime and minimizing it is effect on the environment.

At the beginning, street lamps were controlled by manual control where a control switch is set in each of the street lamps. It is called first generation of the original street light. After that, another method that has been used was optical-control method. This method is using high pressure sodium lamp in their system. It can be seen that this method is widely used in the country nowadays. This method operates by set up an optical control circuit, change the resistance by using of light sensitive device to control street lamps light up

automatically at dusk and turn off automatically after dawn in the morning. Due to the technological development nowadays, road lighting can be categorized according to the installation area, performance and their used, for an example, lighting for traffic routes, lighting for subsidiary roads and lighting for urban center and public amenity areas. While, the wireless sensor network (WSN) helps in improving the network sensing for street lighting as highlighted in [2]-[3].

Meanwhile, street lighting technology can be classified according to the type of lamps used such as incandescent light, mercury vapour light, metal halide light, high pressure sodium light, low pressure sodium light, fluorescent light, compact fluorescent light, induction light and LED light. Different type of light technology used in lighting design with their luminous efficiency, lamp service life and their considerations is given in Table 1.

LED is considered a promising solution to modern street lighting system due to it is behavior and advantages as emphasized in [4]-[6]. A part from that, the advantages of LED are likely to replace the traditional street lamps such as the incandescent lamp, fluorescent lamp and High Pressure Sodium Lamp in future but LED technology is an extremely difficult process that requires a combination of advanced

production lines, top quality materials and high-precision manufacturing process. Therefore, this paper highlights the energy efficient of street lighting design using LED lamps through intelligent sensor interface for controlling and managing.

TABLE I. LIGHT TECHNOLOGY COMPARISON BASED ON LUMINOUS EFFICIENCY, LAMP SERVICE LIFE AND THEIR CONSIDERATION

Light Technology	Average Lamp Life in Hours	Lumens per Watt	Consideration
Incandescent	1000-5000	11-15	Very inefficient and short life time.
Mercury vapour	12000-24000	13-48	Very inefficient, ultraviolet radiation and contains mercury.
Metal halide	10000-15000	60-100	High maintenance UV radiation contains mercury and lead, risk of bursting at the end of life.
High Pressure Sodium	12000-24000	45-130	Contains mercury and lead.
Low Pressure Sodium	10000-18000	80-180	Contains mercury and lead.
Fluorescent	10000-20000	60-100	UV radiation contains mercury, prone to glass breaking and diffused non-directional light.
Compact Fluorescent	12000-20000	50-72	Low life/burn out, dimmer in cold weather and contains mercury.
Induction	60000-100000	70-90	Higher initial cost, limited directionality, contains lead and negatively affected by heat.
LED	50000-100000	70-150	Relatively higher initial cost.

II. METHODOLOGY OF AUTOMATIC STREET LIGHTING SYSTEM

Three parts have been included under this topic for completed this study. Design architecture is the main block function for the proposed design. While, the hardware specification will detail out the components involved in this design from the sensor components until the controller selection. Software development based on the proposed design will be detail out in software part where the flow of the system operation will be detailed out elaborated.

A. Design Architecture

The system development is start with the design architecture of the proposed design. Transparent block diagram has been used to outline the proposed design as shown in Figure 1. Four main components have been identified as the input to the system; clock, power, vector input and water sensor. While, two components have been declared as the output two this system; display and LED module.

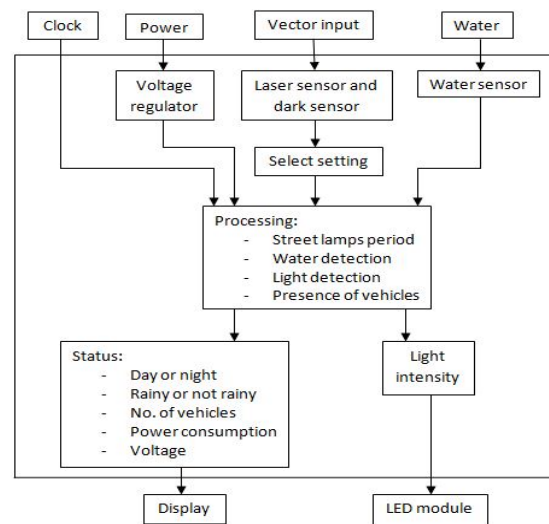


Figure 1. Transparent block diagram of Automatic Street Lighting System.

The street lamp period, water detection, light detection and presence of vehicles are the four processes managed and controller by the microcontroller based on the input from the laser sensor, dark sensor and water sensor. The status of the system operation is display on the LCD and the brightness of the LED module is controlled by the light intensity block based on the input from microcontroller.

B. Hardware Specification

In hardware specification, the components for the proposed system have been classified based on the components group; input, output and controller. Three type of the input have been used in this system; clock, power supply and sensor. The clock has been used to provide clock

oscillation to the microcontroller while the power supply is used to power up the overall system. The supply is controlled by the switch for power switch on and off.

Three type of sensor have been used including vector and non-vector type sensor. The function of dark or light sensor module is to detect the surrounding light level. Light Depends Resistor (LDR) has been used to detect and measured the surrounding light level. All light response or changing is measured in volt. The laser sensor is used to detect the vehicle presence for determine the density of the traffic. Every vehicle crossing the laser beam will be counting and the decision will be making based on the number of vehicles across the sensor. Density of the rain is measured using rain sensor since the rain factor is determined as the influence factor of the road safety. The rain sensor is developed using the array of copper and constructed using printed circuit board (PCB).

Arduino UNO Atmega 328P-PU has been selected as the controller in this system due to the low cost, compatibility, compact size and easy interfacing over several type of other controller including Field Programmable Gate Array (FPGA), Programmable Logic Controller (PLC) and Programmable Integrated Circuit (PIC). The accessible to the Analog to Digital Converter (ADC) without required register location access has making the controller more user friendly for programming and interfacing. On top of that, the complete board running at low power consumption and five six analog port are the other factor for the selection due to the three number of sensor required in this design.

LCD and light intensity are the two outputs used in the proposed system and connected to the microcontroller. The function of LCD is to display the power consumption, voltage, raining status, number of vehicle and day or night. While, the LED module is represent the street light and the brightness of the LED is controlling by intensity module. Five level of the brightest have been included in the intensity module for response the condition and sensor input including the street lamp period, raining density level, surrounding light level and numbers of vehicles. The complete schematic for the proposed design and the components involved is shown in Figure 2.

C. Software Development

The microcontroller required a program to operate and execute the process associated with the proposed design. Arduino programming has been used to construct the program for the proposed design.

In this software development, several stages have been added as the stage of respond for the integrated sensor. The decision for every sensor will determine the process or operation of the system. It starts with analyzing the dark sensor and followed by the rain or water sensor for measuring the raining density level. The laser beam sensor is the last precedence sensor in this system since the function is to identify the density of the traffic or acting as a traffic counter.

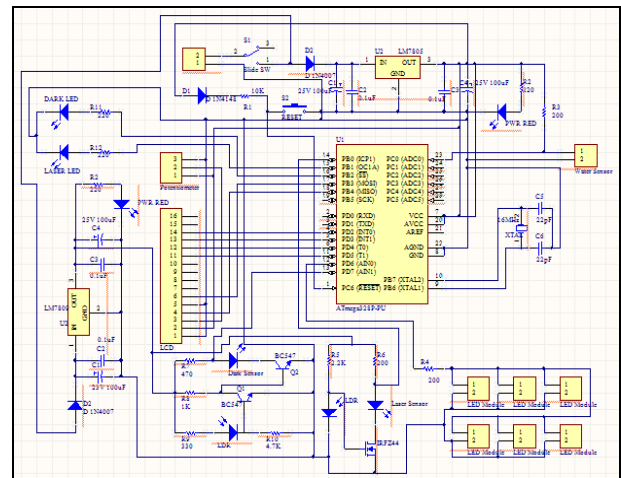


Figure 2. Complete schematic diagram for the proposed design

The system is start by determine the level of surrounding light. Day light and night have been set as two surrounding light level. During the day light, all the lighting system is shut down or switch off. While, during the night time the system is start to operate with several other sub condition to be identified. The raining level status and number of vehicles are the two criteria required before the appropriate energy efficient lighting level can be produced. Five level of street light brightness has been used based on the environment condition. The LCD has been used to indicate the current operation for every system responding. The complete flow operation of energy efficient is shown in Figure 3.

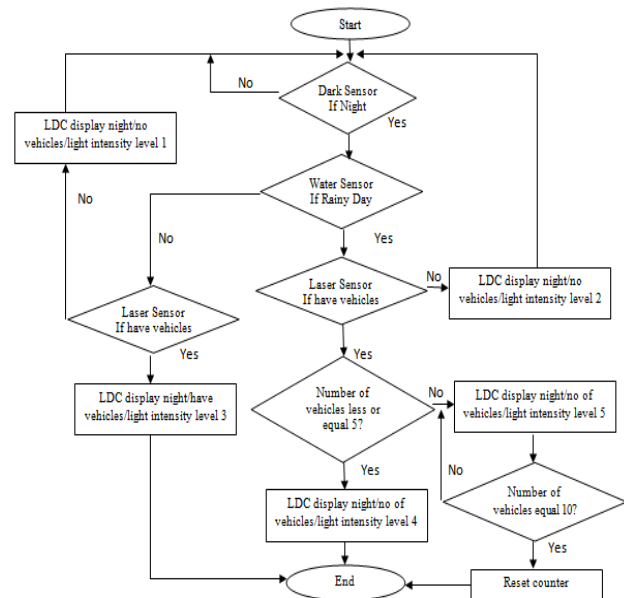


Figure 3. The flow operation of proposed design

D. System Working Principle

System working principle has been used to summarize the principle operation of proposed design. Five levels of light intensity and condition has been summarized in Table 2. The light intensity is switch off or Level 1 when there is no vehicles and not rainy. Whereas, Level 2 has been set when there is rainy and no vehicles used it. Light intensity level 3 can be achieved when there is not rainy and number of vehicles less than 5. While, during the rainy and number of vehicles less than or equal to 5 the light intensity operate at light intensity level 4. The light intensity operates at the maximum level during the rain and number of vehicles greater than 5.

TABLE II. LIGHT INTENSITY AND ENVIROMENT CONDITIONTECHNOLOGY

Light Intensity	Condition	
	Rain	Traffic (No of vehicle)
Level 1	No	No
Level 2	Yes	No
Level 3	No	<5
Level 4	Yes	<=5
Level 5	Yes	>5

III. RESULT AND DISCUSSION

The result and discussion has been divided into three main section; power consumption on different road type, power consumption for different condition type and power consumption for different type of lamps.

A. Power Consumption on Different Road Type

Five level of power consumption for different type of road has been recorded and outlined in Table 3. The result is based on the different type of condition detected by the integrated sensor including dark sensor, water sensor and laser sensor. During the Level 1, the recorded power consumption is 0.00W at 0V. The maximum power consumption recorded at 0.075W for Level 5. While, the remaining recorded power consumption for Level 2, 0.015W; Level 3, 0.045W; and Level 4, 0.060W.

Three type of road at different installation area has been used to measure the power consumption of High Pressure Sodium Lamp for duration of 1 hour and 12 hours showed in Table 4. The most power consuming recorded at Highways with 8400W and follow by Traffic Routes at 5520W. While, the Urban City power consumption is the lowest and recorded at 4775.5W. The type of road has a great influence over power consumption where the power consumption increased proportional to the number of lane.

TABLE III. RESULTS FOR INPUT AND OUTPUT BASED ON FIVE DIFFERENT CONDITIONS

Condition	INPUT			OUTPUT			
	Dark Sensor	Water Sensor	Laser Sensor	LED Lamps	Liquid Crystal Display (LCD)	Voltage (V)	Power Consumption (Watt)
1	Low	Off	High	Level 1	Night/ Not Rainy/ No vehicles	0.0	0.000
2	Low	Off	Low	Level 3	Night/ Not Rainy/ Vehicles	3.0	0.045
3	Low	On	High	Level 2	Night/ Rainy/ No vehicles	1.0	0.015
4	Low	On	Low (if vehicles <= 5)	Level 4	Night/ Rainy/ Number of Vehicles	4.0	0.060
5	Low	On	Low (if vehicles > 5)	Level 5	Night/ Rainy/ Number of Vehicles	5.0	0.075

TABLE IV. NUMBER OF VEHICLES IN 12 HOURS AND 1 HOUR BASED ON ROAD TYPE AT THREE INSTALLATION AREAS

Installation Area	Road Type	Number of Vehicles in 1 Hours	Number of vehicles in 12 Hours	Power Consumption in 12 Hours using High Pressure Sodium Lamp (Watt)
Urban City	Two lanes (both ways)	2000	24000	4775.5
Traffic Routes	Multilane (both ways)	2300	27600	5520.0
Highways	Three lanes (both ways)	3500	42000	8400.0

B. Simulation of Power Consumption on Different Condition

Three different type of road using five different conditions as stated in Table 3 has been simulated from 7.00pm to 7.00am. This simulation is very important to identify the performance of the system running in different type of condition and environment circumstance.

All three type of road recorded at 0.00W power consumption for every hour from 7.00pm to 7.00am during condition 1. The environment circumstance and numbers of traffic is influence this scenario since the condition 1 is set at no vehicles and not rainy. The tabulation of the power consumption for condition 1 is shown in Figure 1.

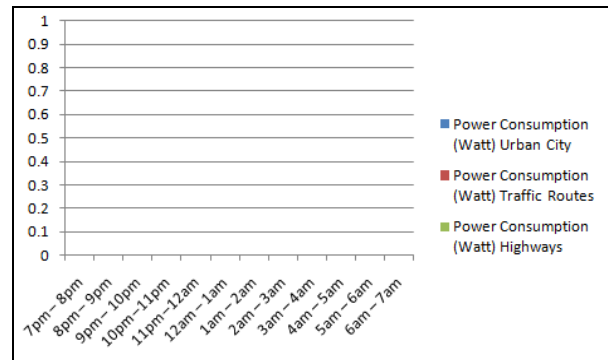


Figure 4. Power consumption for each hour at the urban city, traffic routes and highways according to their road type based on condition 1

The system operated at condition 2 during the rainy condition and no vehicles used the road. Simulation result for this condition is shown in Figure 5. The pattern of recorded value is start to decrease from 7.00pm to 7.00am which the maximum value recorded at 7.00pm and the minimum value recorded at 7.00am. At 7.00pm the power consumption recorded at 297.0W, Highways; 265.5 Traffic Routes; and 247.5, Urban City. While, at 7.00am the power consumption recorded at 39.2W, Highways; 9.9W, Traffic Routes; and 5.9W, Urban City. The power consumption is increase due to the rainy condition.

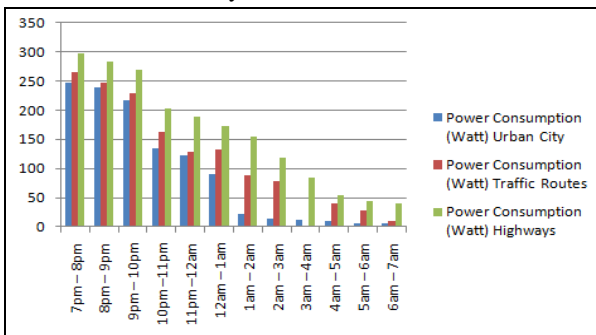


Figure 5. Power consumption for each hour at the urban city, traffic routes and highways according to their road type based on condition 2

During the numbers of vehicles less than 5 for every hour and not rainy; the system operates at condition 3. The laser sensor has been used to count the numbers of vehicles using the road in this condition. The recorded power consumption is slightly lower than condition 2 but maintaining the same pattern since the number of environment circumstance does not required bright light and just enough to overcome the accident and crime. At 7.00pm the power consumption is recorded at 99.0W, Highways; 88.5W, Traffic Routes; and 82.5W, Urban City. While, the recorded data start to decrease and at 7.00am the power consumption is recorded at 13.1W, Highways; 4.8W, Traffic Routes; and 1.9W, Urban City. The complete simulation result for condition 3 is shown in Table 5.

TABLE V. POWER CONSUMPTION FOR EACH HOUR AT THE URBAN CITY, TRAFFIC ROUTES AND HIGHWAYS ACCORDING TO THEIR ROAD TYPE BASED ON CONDITION 3

Hour	Power Consumption (Watt)		
	Urban City	Traffic Routes	Highways
7pm - 8pm	82.5	88.5	99.0
8pm - 9pm	82.5	83.25	94.5
9pm - 10pm	72.0	76.6	90.0
10pm - 11pm	45.0	54.0	67.5
11pm - 12am	40.5	42.8	63.0
12am - 1am	30.0	33.4	57.8
1am - 2am	7.5	26.3	51.3
2am - 3am	4.9	15.0	39.8
3am - 4am	4.1	13.1	28.1
4am - 5am	3.2	9.4	18.0
5am - 6am	2.3	6.7	14.7
6am - 7am	1.9	4.8	13.1

Condition 4 is operated during the rainy and numbers of vehicles less than or equal to 5. The power consumption is slightly higher than condition 2 due to the presence numbers of vehicles using the road. At 7.00pm the power consumption recorded at 396.0W, Highways; 354.0W, Traffic Route; and 330.0W, Urban City. The power consumption start to decrease and the minimum power consumption recorded at 7.00 am with 15.6W, Highways; 13.2W, Traffic Route; and 7.2W, Urban City. Simulation data for condition 4 is shown in Figure 6.

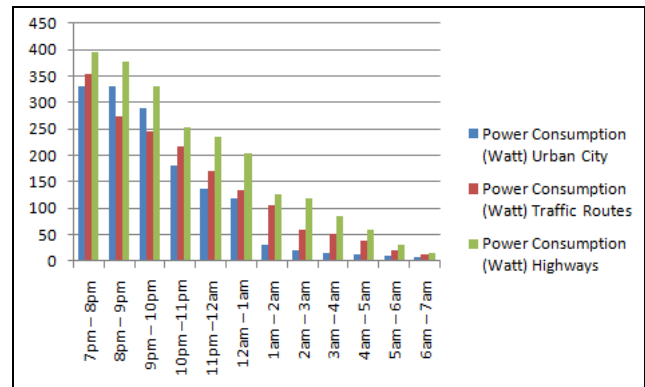


Figure 6. Power consumption for each hour at the urban city, traffic routes and highways according to their road type based on condition 4

The optimum power consumption is obtained at condition 5 when the numbers of vehicles greater than 5 and during rainy weather. The complete simulation for condition 5 from 7.00pm to 7.00am is shown in Figure 7. The maximum power consumption was recorded at 7.00pm with 495.0W, Highways; 442.5W, Traffic Route; and 412.5W, Urban City. The minimum power consumption was recorded at 7.00am with 65.3W, Highways; 16.5W, Traffic Route; and 9.8W, Urban City.

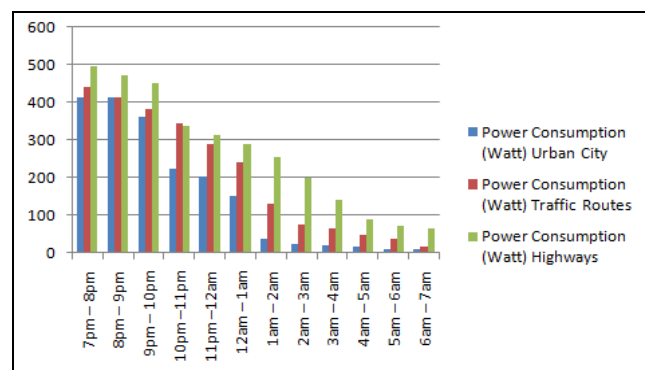


Figure 7. Power consumption for each hour at the urban city, traffic routes and highways according to their road type based on condition 5

C. Comparative of Power Consumption for Different Type of Lamp

The power consumption performance evaluation for High Pressure Sodium and LED Lamp is shown in Table 6. The evaluation was conducted on three different type of road in three different installation areas. LED lamp required less power consumption as compare to Pressure Lamp for all three type of road and Urban City is giving the minimum power consumption at 971.56W.

TABLE VI. THE DIFFERENT OF POWER CONSUMPTION USING HIGH PRESSURE SODIUM LAMP AND LED LAMP

Installation Area	Road Type	Power Consumption in 12 Hours using High Pressure Sodium Lamp (Watt)	Average Power Consumption in 12 Hours using LED Lamps (Watt)
Urban City	Two lanes (both ways)	4775.5	971.56
Traffic Routes	Multilane (both ways)	5520.0	1216.37
Highways	Three lanes (both ways)	8400.0	1592.44

IV. CONCLUSION

In this paper, the automatic street lighting system was presented. As a conclusion, around 77% - 81% of power consumption can be reduced by using this system towards providing a solution for energy saving. Furthermore, the minimal components including the low cost controller and LED module produce the better saving in term of cost. On top of that, the lifetime, better illumination and low power consumption of LED are the other criteria for reducing the operational and maintenance cost after installation compare to high pressure sodium lamp and others. Hence, it helps in

further improves the energy efficiency and quality of lighting level.

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