IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 14, Issue 4 Ser. I (Jul. – Aug. 2019), PP 55-60
www.iosrjournals.org

Solar Powered Street Light Battery Maintenance System Using Arduino Microcontroller

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Abstract : *Street light is simply a device installed on roads, streets and walk-ways to illuminate the environment when the day is dark at night or a dark cloudy day in order improve night vision of users. It has become an essential structural design in every city as it helps to reduce road accidents and increase security. Many designs and construction have been made by researchers and engineers and all has been geared toward the design of a streetlight that is energy conservative, less expensive and automatically operated to eliminate the error associated with manual operation by humans. Most streetlights installed in are powered by batteries charged by a solar panel. Due to inadequate charging of the batteries, they end up being drained and are unable to be charged to power the streetlight. This design provides a system that helps maintain the batteries by keeping them from over-drained condition. A 12V dc battery which is mostly used is fully charged to 12.6V dc and when used, reduces to a useful voltage of 12.1V to 10.5V. Batteries are best maintained if the battery is no allowed to reduce in voltage below 12.3V before recharging it. This design is achieved using Arduino microcontroller which when programed will be able to read the voltage from the battery and use the information to cut off the power supply going to the streetlight by de-energizing a dc relay.*
Keywords: *Arduino Microcontroller, Battery Voltage, DC relay, Over-drained, Streetlight*

Date of Submission: 28-07-2019 Date of acceptance: 13-08-2019

I. Introduction

Finding solution on how to conserve energy, increase security and reduce accidents in Nigeria has become a recurrent decimal. Engineers and researchers trying to solve this problem have placed several designs and facilities in place with the help of the federal government. One of such facilities placed to improve security and reduce accidents is the street light. Street lighting is a particularly critical concern for public authorities in developing countries because of its strategic importance for economic and social stability. It is a device installed on roads and streets to illuminate the environment when the area is dark (at night or a dark cloud) to ensures safe traffic for cars at night, easy movement and save condition for citizens passing by. Providing street lighting is one of the most important and expensive responsibilities of a city but its design has been faced with challenges ranging from the fact that is it manually operated to the level of energy consumed. Better designed has been made to improve its operation from manual to automatic powered by a DC battery that is charged using a solar panel. The solar panel design is made to receive energy from light (Sun) during the day to charge up the battery which is the main source of power to the street light. The battery mostly used is a 12Vdc battery of which when charging could test up to 14+V dc (depending on the type) and sets off at 12.6V at rest but drains down its charge and decreases in voltage when in use at night, therefore needs to be charge regularly by day. Most street lights of this design are in most case found to be faulty or out of used as a result of its battery voltage reducing 10.5V dc or lower which makes it over-drained. When a battery over-drained a limited number of times, it becomes dead [1]. This may be as a result of the battery not fully charged during the day when the light intensity is low or no sun rays to hit the solar panel. This is a big problem to installed streetlight and as well will risk the safety of lives and properties as the street light battery is not maintained. Maintain a battery requires that the battery should not go below 50% of its energy available which if at the range of 12.3V dc and also, not overcharging it [1].

This research is intended to design a system that will advance automated solar powered street light giving it the ability to maintain its battery against over-drainage situation to avoid dead of battery. This can be achieved by applying the automation power of an Arduino microcontroller to cut of battery usage by the street light to stop it from going into over-drainage.

This research will provide solution on how to maintain the battery powering a streetlight to eliminate the problem associated complete battery drainage in order to achieve a more reliable, efficient and energy saving street lighting system that will not fail due to dead in battery.

II. Design Methodology

The research and development of this project consists of the hardware structures and software codes working together to achieve the basic hypothesis.

Hardware Design Methodology

The hardware part of the project is made up of just the structural design and circuit connections as explained by the hardware block diagram shown in figure 1 below.

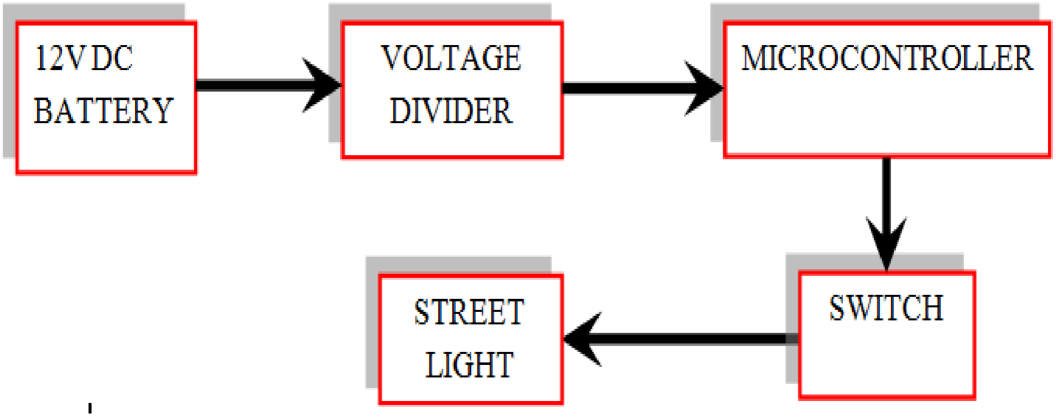

Figure 1: Hardware Block Diagram

The procedure of how this was achieved was carried out as illustrated in the stages below

Stage 1: Voltage Divider

The voltage divider is a device that makes use of the principle of dividing dc voltage into two parts. This is done by using a 10k ohms potentiometer (preset variable resistor shown in figure 2) to divide the 12.6V dc coming from the battery into 5V dc and 7.6V dc.

Figure 2: Preset variable resistor

This is more like reducing (stepping down) the voltage at the output of the potentiometer in order to feed it to the Arduino microcontroller. As the voltage in the battery drops during usage, the voltage across the output of the potentiometer also reduces. The input 12.6V dc from the battery is connected across the two side pins of the preset while the output voltage is obtained from the middle pin and any of the side pins [see figure 3]. The knob of the preset is turned with a screwdriver to set the output voltage to 5V dc.

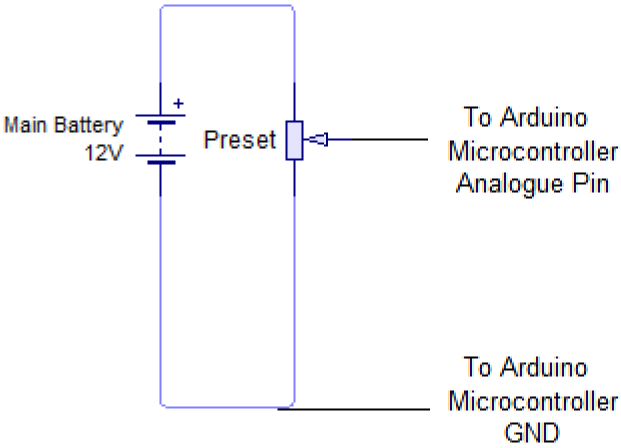

Figure 3: Battery and Preset Circuit Connection

To obtain the values mathematically using resistance, the voltage divider equation can be used [2] which is given as:

$$V_{out} = \frac{y}{x} V_{in} \qquad \text{----------------} \quad (1)$$

Where:
x = the maximum resisatnce of the preset = 10k Ω
y = resitance across the output voltage
V_{in} = input voltage = 12.6V
V_{out} = output voltage = 5V

From equation (1):,

$$y = \frac{V_{out}}{V_{in}} x \qquad \text{----------------} \quad (2)$$

$$y = 3.968\ k\Omega$$

When the battery reduces to 50% (12.3V) of its voltage, using equation (1)

$$V_{out} = 4.881V$$

Stage 2: Microcontroller
Data processing in this automated system was achieved using the Arduino microcontroller board shown in figure 4. Based on a Sketch programming code [3], the Arduino
- Receives the voltage from the preset into its analogue port
- It converts this voltage values to analogue numbers 0 – 1023 to represent 4.0V – 5V respectively
- This converted value is used to properly program the Arduino on how to control the cut-off power switch of the streetlight.

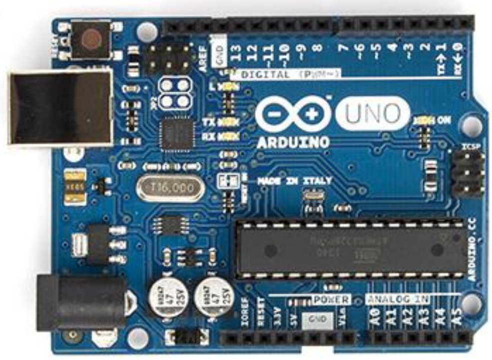

Figure 4: Arduino Microcontroller Board

The Arduino microcontroller is programed such that it produces an output voltage that with switch on/off the power supply going to the streetlight depending on the level of voltage coming from the 12V battery.

Stage 3: Cut-off Power Switch

This stage of the design consists of a DC relays to be actuated by a DC power supply coming from the output of the Arduino microcontroller. It consists of five pins named; Normally Open (N/O), Normally Close (N/C), Common and two DC supply pins to give current to a coil and actuate the device. When the relay is not powered, a connection lies between the N/C and the common but if a DC power is supplied to energize it, the coil becomes magnetic and switches the relay from the N/C to have an electrical connection between the N/O. The pin configuration of a relay is shown in figure 5.

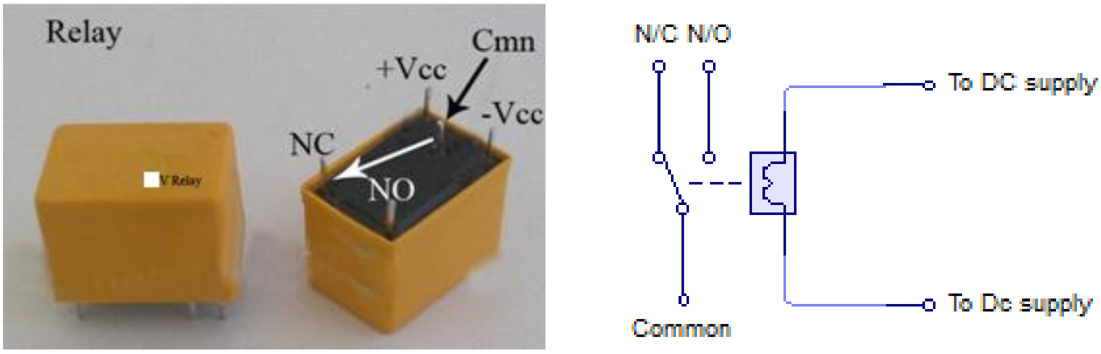

Figure 5: Pin Configuration of a Relay

The power supply to the streetlight is connected between the common and N/O such that when the microcontroller energize the relay, it powers it at vice versa.
The complete circuit diagram of this research design is shown in figure 6 below

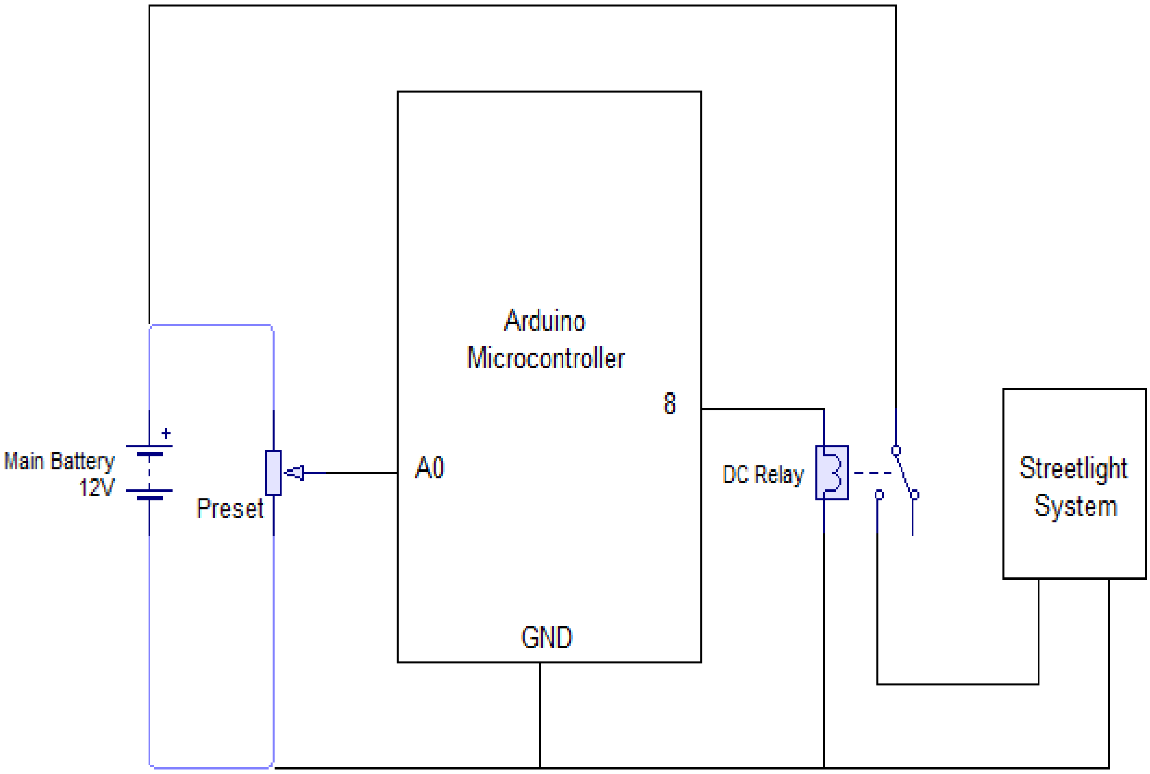

Figure 6: Hardware Circuit Diagram

Software Design Methodology

The figure below shows the software flow chart of this project as controlled by the Arduino microcontroller.

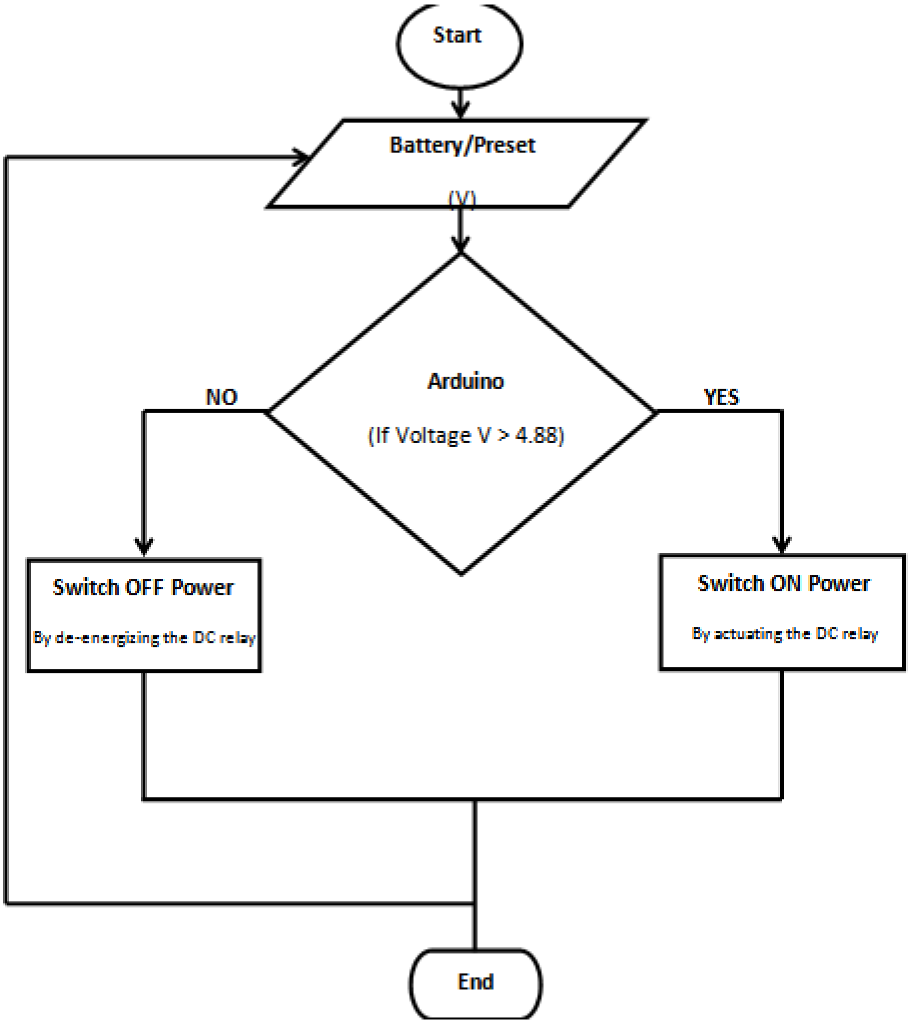

Figure 7: Software Flow Chart

From the START, the Arduino receive the voltage from the battery shown in the data block of the flow chart. These voltage values are read by the Arduino to enable it carryout a decision based on the Arduino sketch program. If the condition of the battery voltage is greater than 4.88V at the output of the preset, [Yes] the streetlight is powered ON. If the condition is not met, [NO] the streetlight is powered OFF.

III. Result Analysis

The data table below shows the relationship between the different voltage levels of the battery and their corresponding Arduino microcontroller analogue conversion including the action of the Arduino output pin 8 and DC relay switching.. The data table shows the relationship obtained from six (6) different battery voltage conditions respectively.

Table1: Result Data

Condition	**Battery Voltage (V)**	**Arduino Input Voltage (V)**	**Arduino Analogue value**	**Arduino Output Pin**	**Power Supply Switch**
1	12.6	5.00	1023	HIGH	ON
2	12.58	4.99	1013	HIGH	ON
3	12.51	4.96	982	HIGH	ON
4	12.40	4.92	941	HIGH	ON
5	12.32	4.89	910	HIGH	ON
6	12.27	4.87	890	LOW	OFF

From condition 1 to condition 5, the battery voltage lies between 12.6V – 12.32V giving a corresponding voltage of 5V – 4.89V to the analogue input of the Arduino microcontroller. Pin 8 (output pin) of the Arduino remains HIGH which energizes the DC relay to keep the streetlight powered.

At condition 6, the battery voltage is at 12.27V giving a corresponding voltage of 4.87V to the analogue input of the Arduino microcontroller. Pin 8 (output pin) of the Arduino goes LOW which de-energizes the DC relay to cut-off the streetlight power.

IV. Conclusion And Recommendation

To The conditions identified in the result analysis shows that the hypothesis this research is achieved, as the research is able to show a design that is able to maintain the battery installed in solar powered streetlight by cutting off the dc power from the streetlight when the voltage drops below a critical voltage. This was achieved using a simple circuit design and with the aid of an Arduino microcontroller.

Other microcontroller board other than Arduino board can also be utilized in the actualization of this design. An engineer/technologist deciding to go into the design and manufacture of this device may decide to improve the system can be improved to maintain battery against overcharging and over-drainage conditions

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Odu Elendu" Solar Powered Street Light Battery Maintenance System Using Arduino Microcontroller" IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) 14.4 (2019): 55-60.