Lux Measurement System Design

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Abstract—**This study is carried out to design a lux measurement system. The lux measurement system is a design to measure brightness of street light in lux. Brightness is an attribute of visual perception. It is a source appears to be radiating or reflecting light. In other words, brightness is the perception elicited by the luminance of a visual target. This is a subjective attribute or property of an object being observed. It can be measured while in moving situation. In this study, the lux measurement system was designed using a voltage divider circuit. By connecting light dependent resistor (LDR) to another resistor in series, it became a voltage divider where the voltage drop across it acts as a function of the light intensity. A voltage divider is useful in determining the voltage drop across the resistance within a series circuit. This Lux Measurement System Design has memory to store the measured values and software to analyze readings.**

Keywords—Light dependent resistor (LDR), Light emittance diode (LED), Arduino Uno Board, Arduino LCD keypad shield, SD card board, SD card

I. INTRODUCTION

Lux is the SI unit of illuminance and luminous emittance. It is used as a measurement of light intensity as perceived by human eye. Luminance is the density of luminous intensity in a given direction and falls within a given solid angle [1]. It measures in lux or lumens/m^2. Illuminance can be measured with a lux meter. For a given light source, the closer the light source to the illuminated area, the higher the illuminance value.

Street lighting can cause accidents if misused, and cause light pollution. The major advantages of street lighting include prevention of accidents and increase in safety [2]. The loss of night vision because of the accommodation reflex of drivers' eyes is the greatest danger. As drivers emerge from an unlighted area into a pool of light from a street light their pupils quickly constrict to adjust to the brighter light, but as they leave the pool of light the dilation of their pupils to adjust to the dimmer light is much slower, so they are driving with impaired vision. As a person gets older the eye's recovery speed gets slower, so driving time and distance under impaired vision increases. Other than loss of night vision, the oncoming headlights are more visible against a black background than a grey one. The contrast creates greater awareness of the oncoming vehicle.

The malfunction of the street light and its inappropriate brightness will increase the number of accidents. It is thus important to ensure an appropriate brightness is supplied by the street light to accommodate drivers at nights. This study is therefore carried out to design a lux measurement system to measure the intensity of street light. The designed system allows the intensity to be measured while on the move. It has the capability to collect data and analyze them whether the street light is well functioning or otherwise. The system also offers everyday lighting harvesting solutions. Since it can measure the intensity while on the move, it can thus be incorporated in a car.

Theoretically, light dependent resistor (LDR) is an electronic component whose resistance decreases with increasing incident light intensity. In other word, the more light it gets the less resistive it becomes. It can also be referred to as a photoconductor, or photocell. A light dependent resistor is made of a high-resistance semiconductor. If light falling on the device, photons are absorbed by the semiconductor and releases electrons to the conduction band. The resulting free electron conducts electricity, thereby lowering resistance. A light dependent resistor device can be either intrinsic or extrinsic. An intrinsic semiconductor has its own charge carriers and is not an efficient semiconductor [3].

In this study, the lux measurement system was developed and designed using Arduino Uno board. The variation of the voltage drop across the resistor was measured depending on the light intensity. This voltage drop (V_o) will then be converted to light intensity which is in lux unit.

II. METHODOLOGY

The overall work involved in designing this lux measurement system is summarized in the flow chart shown in Fig. 1. The implementation of hardware and software were only carried out after the study on LED, illuminance, luminance and street lighting has already done. The hardware in this system includes the sensor circuit, Arduino Uno board, LCD keypad shield, SD card board and of course SD card itself to create file and store data on it.

In Arduino, it also has its own software which is easy to understand. When talk about Arduino, it includes hardware and software. The implementation between hardware and software can be compiled easily [4]. After the design was simulated, data will be collected and analyzed.

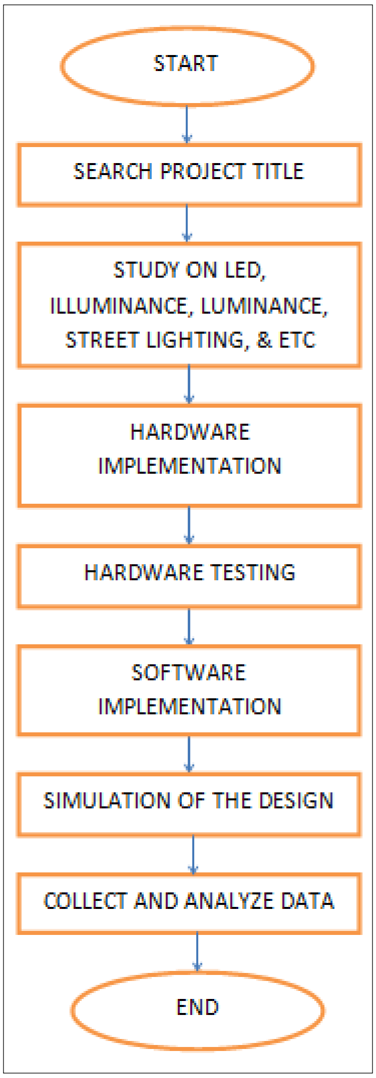

Figure 1. Overall flow chart of hardware and software design.

III. HARDWARE IMPLEMENTATION

The hardware part of this lux measurement system consisted of input and output. Fig. 2 shows the block diagram of the hardware design. In this design, LDR circuit acted as the input sensor while LCD keypad shield and SD card as the output. The LCD keypad shield will display the measured values as luminance and write all the values to the SD card.

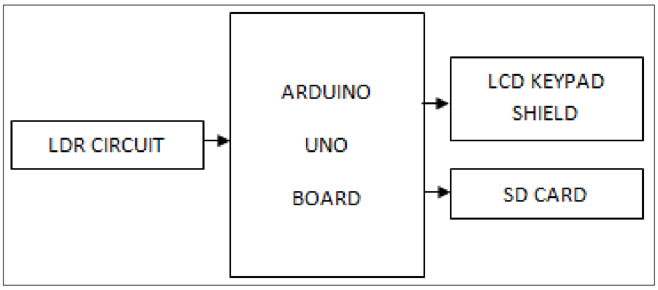

Figure 2. Block diagram for hardware design.

Light dependent resistor is a useful sensor. It is the key component in measuring light intensity. Light dependent resistor has a resistance that varies according to the amount of visible light that falls on it. Its resistance changes according to the light intensity exposed to it. High light intensity results in low resistance. The output voltage produced will be displayed by LCD keypad shield and stored in SD card. The light dependent circuit is shown in Fig. 3. This circuit acts exactly the same as voltage divider circuit.

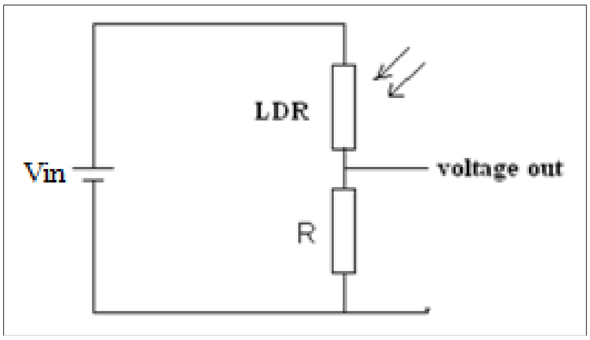

Figure 3. Sensor circuit.

The voltage divider rule (VDR) is useful in determining the voltage drop across a resistance within a series circuit [5]. The equation 1 and 2 as shown below is the basic equation for voltage divider circuit.

$$Vo = \frac{\mathrm{R}}{\mathrm{LDR+R}}.\mathrm{Vin} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

$$LDR = \mathrm{R}(\frac{\mathrm{Vin}}{\mathrm{Vo}} - 1) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

The voltage drop across the resistance (V_o) in this circuit connected to analog input at Arduino Uno board. This voltage drop (V_o) will then be converted to light intensity which is in lux unit.

IV. SOFTWARE IMPLEMENTATION

Arduino software is much easier to understand. The software is written using C language [6]. The whole software of the light intensity system consists of digital inputs and analog inputs. The digital input which can read two states, '0' or 'LOW' or no voltage and '1' or 'HIGH' or high voltage. The analog input can read up to 1024 different states which are 0 until 1023. These are voltage equivalent when 5V divided to 1023. Therefore, 1 equals to 0.00488V. So basically the input is a scale of 0 to 5V in 1024 states.

The input on Arduino can only read from 0 to 1023 states. However, it can change to voltage by multiplying it to 0.00488V. By writing an appropriate program the voltage can then be converted into light intensity. The command as shown in Fig. 4 is the example of the written program.

```
Vo=analogRead(A1);
Vo=Vo*0.00488;
delay(1000);
lcd.begin(16,2);
lcd.clear();
lcd.setCursor(0,0);
lcd.print("ILLUMINANCE");
lcd.setCursor(0,1);
lcd.print(Vo);
```

Figure 4. An example of simple program.

Fig. 5 shows the flow chart for software design. The program initializes port whether the SD card is inserted or not. If not it will wait until SD card is inserted. If inserted it means 'a' is equal to '1'. If not LCD displays 'initialization insert SDcard'. When SD card inserted, the LCD will display "Initialization Done". Analog input (A5) reads value from light dependent resistor circuit and writes to LCD and in SD card file after the input has been converted to lux unit. The result will be taken every few second.

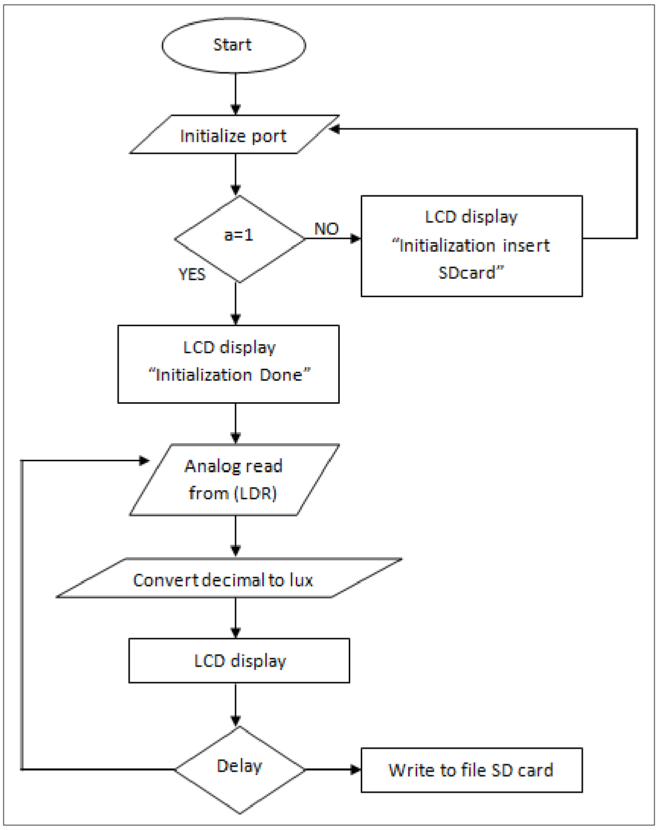

Figure 5. Flow chart for software design.

Fig. 6 shows the program for looping command to repeat commands. Here, the program writes the command as required such as to print the light intensity values to LCD keypad shield every two seconds.

```
Vo=analogRead(A5); // read the value from the sensor:
t2=millis();
t3=t2-t1;
    lcd.clear();
    lcd.setCursor(0,0); // set the cursor position:
    lcd.print("light intensity"); // print the letter:
    lcd.setCursor(0,1); // set the cursor position:
    Vo=Vo*0.00488;
    LDR=Vo/0.005;
    lcd.print(LDR); // print the value of LDR:
    lcd.setCursor(7,1); // set the cursor position:
    lcd.print("lux"); // print the letter:
    delay(2000);
```

Figure 6. Analog input reads value from sensor and writes to LCD and SD card.

Fig. 7 shows a program to create a file in SD card to print the output voltage (V_o) and light intensity values into it and also to serial monitor.

```
myFile = SD.open("test.txt", FILE_WRITE);
if (myFile){
myFile.print("Vo=");
myFile.print(Vo); // print the value of Vo in SDcard file:
myFile.print("\t");
myFile.print("\t");
myFile.print("ILLUMINANCE=");
myFile.println(LDR);
Serial.print("Vo=");
Serial.print(Vo); // print the value of Vo in serial monitor:
Serial.print("\t");
Serial.print("\t");
Serial.print("ILLUMINANCE=");
Serial.println(LDR); // print to serial monitor:
myFile.close(); // close the file:
t1=t2;
```

Figure 7. A program to create file in SD card.

V. RESULTS AND DISCUSSION

a. Data collection

In this work, the lux measurement system was analyzed by measuring the intensity of light emitting diode (LED). The LED was put 8 cm away from the ground to act as a model of a street light. The output voltage produced by the sensor circuit was measured by using multimeter. The intensity of the light was also measured using actual lux meter. All the recorded data is summarized in Table 1. As expected, the voltage increases as the light intensity increases.

TABLE I. DATA OF OUTPUT VOLTAGE FOR VARIOUS INTENSITY OF LIGHT

Light intensity (lux)	Vo (V)
16	1.94
33	2.29
48	2.54
64	2.76
79	2.90
94	3.03
109	3.13
124	3.17
139	3.24
154	3.37
169	3.41
184	3.46
198	3.43
212	3.57
225	3.61

The plotted data is shown in Fig. 8. As can be seen the output voltage is proportional to the light intensity.

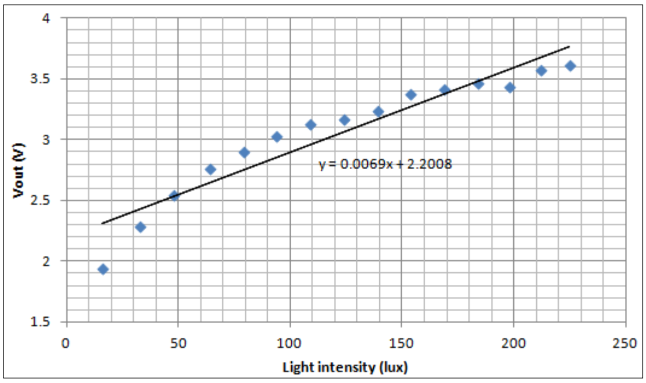

Figure 8. Graph of output voltage as a function of light intensity.

The resistance of LDR was also measured by using multimeter. The LDR resistance can be measured by disconnecting it from source and ground. The recorded data is shown in Table 2. From the recorded data it shows that the light intensity increases its resistance decreases.

TABLE II. DATA OF OUTPUT VOLTAGE FOR VARIOUS INTENSITY OF LIGHT

Light intensity (lux)	Resistance (kOhm)	Log 10 Light intensity	Log 10 Resistance
16	14.10	1.2041	4.1492
33	8.29	1.5185	3.9186
48	6.16	1.6812	3.7900
64	5.00	1.8062	3.7000
79	4.24	1.8976	3.6274
94	3.71	1.9731	3.5694
109	3.32	2.0374	3.5211
124	3.01	2.0934	3.4786
139	2.77	2.1430	3.4425
154	2.56	2.1875	3.4082
169	2.38	2.2279	3.3766
184	2.25	2.2648	3.3522
198	2.17	2.2967	3.3263
212	2.01	2.3263	3.3032
225	1.91	2.3522	3.2800

The data has been plotted using log 10 resistance and light intensity. The logarithm scales means that there is no direct relationship between resistance and light intensity as shown in Fig. 9 [7].

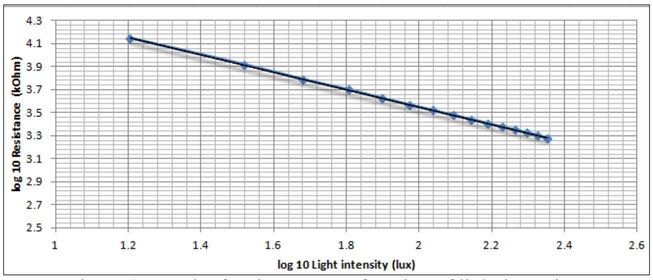

Figure 9. Graph of resistance as a function of light intensity.

b. Simulation

This simulation can work after developing both hardware and software. Fig. 10 shows the LCD keypad shield displayed “initialization insert Sdcard” indicating that no SD card was detected.

Figure 10. No SD card detection.

The "initialization done" will be displayed once SD card has been inserted as shown in Fig. 11. However, it depends on how the program was written.

Figure 11. SD card inserted.

Fig. 12 shows an example of light intensity value in lux unit. The display changes every two seconds if the sensor receives various values of light intensity.

Figure 12. Display the light intensity.

The executed program will print the results in SD card file. This design was set in a range of 0 to 1000 lux. All results were already converted to lux unit. When there is no light applied to the LDR sensor, the light intensity and output voltage become zero. The increases in the light intensity resulted in the increases of output voltage. Fig. 13 shows the output result measured using the designed lux measurement system.

Vo = 0.00	ILLUMINANCE = 0.00
Vo = 0.00	ILLUMINANCE = 0.00
Vo = 0.03	ILLUMINANCE = 6.83
Vo = 0.17	ILLUMINANCE = 33.18
Vo = 0.18	ILLUMINANCE = 35.14
Vo = 0.29	ILLUMINANCE = 58.56
Vo = 0.46	ILLUMINANCE = 92.72
Vo = 0.75	ILLUMINANCE = 149.33
Vo = 1.17	ILLUMINANCE = 234.24
Vo = 1.25	ILLUMINANCE = 250.83
Vo = 1.32	ILLUMINANCE = 263.52
Vo = 1.42	ILLUMINANCE = 284.02
Vo = 1.48	ILLUMINANCE = 296.70
Vo = 1.56	ILLUMINANCE = 312.32
Vo = 1.66	ILLUMINANCE = 332.82
Vo = 1.95	ILLUMINANCE = 390.40
Vo = 2.90	ILLUMINANCE = 580.72
Vo = 3.31	ILLUMINANCE = 662.70
Vo = 3.94	ILLUMINANCE = 788.61
Vo = 4.40	ILLUMINANCE = 879.38
Vo = 4.54	ILLUMINANCE = 908.66
Vo = 4.64	ILLUMINANCE = 927.20
Vo = 4.81	ILLUMINANCE = 961.36
Vo = 4.88	ILLUMINANCE = 976.00

Figure 13. In SD card file when a light from low to high applied to sensor.

VI. CONCLUSION AND RECOMMENDATION

The program written was successfully done when tested using Arduino software and the results were identical to the expected ones. Light dependent resistor (LDR) come in many different types. Inexpensive cadmium sulphide cells can be found in many consumer items.

There are several recommendations for this lux measurement system design. It can be modified to lighting system where it can measure light intensity and control the light when there is changing of weather. Furthermore, it also can be implemented in car. This design can be implemented for maintenance highway. In addition, this system can be installed on new highway construction.

Lux Measurement System Design is important to make better life of mankind especially in term of safety. Therefore, the measurement of light intensity with this Lux Measurement System Design is important to apply on the street. The design will measure the lux and collect the correct data along the road. This project may reduce electrical uses of power consumption for illuminance and minimize the danger as well.

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