ME 3113 Measurements and Instrumentation
Laboratory Assignment #6: Arduino Project

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Section	Points
Abstract & Nomenclature	**/ 5**
Abstract: purpose of the project and the main conclusions that resulted from the work.	/ 3
Nomenclature: define any abbreviations or symbols used throughout the report, including units.	/ 2
Introduction	**/ 10**
Detailed statement of scope, purpose, and objectives of the work.	/ 5
Background discussion (e.g., potential practical applications of system developed in this project).	/ 5
Theoretical Background	**/ 15**
Review of relevant theory for the experiment (e.g., basic principles of the sensors/actuators used).	/ 8
Presentation and discussion of relevant equations with explanations of variables (calibration equations for sensors, uncertainty quantification of independent and dependent variables, etc.)	/ 4
Appropriate and properly cited references (using style [x], where x is the number of reference).	/ 3
Instrumentation and Experimental Procedure	**/ 15**
Detailed discussion of components, experimental setup, including circuit diagram, connections and images of the system/apparatus.	/ 7.5
Review of experimental procedure (chronological narrative of the procedure followed when the calibration and experiments were conducted).	/ 7.5
Analysis of Experimental Data	**/ 15**
Extended descriptions of the results of the experiments. Full disclosure of the data collected (e.g., using graphs, charts, or tables of the raw data with units, labels, titles, etc., following the concepts covered in the lectures: regression, graphical analysis and curve fitting).	/ 7.5
Analysis of results and interpretations. Error and uncertainty quantification is required.	/ 7.5
Conclusions	**/ 10**
Summary of the project, main findings, and the most important interpretations of the experiments. It should include recommendations to improve the system and reduce errors/uncertainties.	/ 10
References	**/ 10**
Properly cited references (consistent style, as presented in the template).	/ 10

Grammar	**/ 5**
Spelling/Typos	**/ 5**
Formatting of text (consistent font and style)	**/ 5**
Formatting of figures/tables (appropriate labels, legend names, regression equations with coefficient of determination, etc.)	**/ 5**

TOTAL	/ 100

Using a Photoresistor to Manipulate a Micro Servo Motor
ME 3113 – Measurements and Instrumentation

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ABSTRACT

The objective of this project was to design and test an automated system that controls window blinds based on ambient light conditions using a photoresistor and a micro servo motor. Inspired by a real-life scenario where blinds were often left open at night, the team developed a circuit using an Arduino microcontroller, a calibrated photoresistor, and Potentiometer (for LCD) display to detect light intensity and actuate the blinds accordingly. The photoresistor's voltage output was measured under various lighting conditions, and an exponential relationship between output voltage and light intensity (lux) was identified. Calibration was performed using controlled lighting from an iPhone flashlight and a light meter app. The system successfully demonstrated the ability to translate measured light values into mechanical action, providing an effective low-cost solution for automatic blind control. The experiment proved that the measured lux output of the photoresistor sensor under each controlled light intensity was relatively similar to the reference used in the Light Meter mobile application, and the experiment as a whole proved the possibility of the original concept behind the project of an automatic blind controller using a photoresistor.

NOMENCLATURE

Symbol	Description	Units
A	*Analog input*	*Dimensionless*
R	*Resistance*	*Ω*
S	*Sample standard dev.*	*Ω*
lx	*Lux*	*lm/m2*
V_{in}	*Input voltage*	*Volts*
V_{out}	*Output voltage*	*Volts*
$\bar{x}$	*Mean of R values*	*Ω*
x_i	*Individual R value*	*Ω*
n	*number of data set*	*Dimensionless*
$\sum$	*Summation Symbol*	*Dimensionless*

INTRODUCTION

The purpose of this project was to create a device that measures light intensity values from the window of a bedroom and automatically close the blinds when sufficiently dark outside, conversely opening the blinds when sufficiently bright. This was to support plants placed on the windowsill while still maintaining security within the bedroom as it became night. The goal of this project was to understand the relationship between sensors and actuators that have been covered in class and apply them to a practical real-world application.

To achieve this goal, an Arduino was used that was fitted with a program that would evaluate data from a sensor and control an actuator based on its readings. For this specific project since it relies on light intensity, the ideal sensor to use was a photoresistor, which changes in resistance depending on light intensity. The actuator used was a servo motor, which in theory would turn depending on the light read by the photoresistor to open and close the blinds.

THEORETICAL BACKGROUND

This project is possible through the use of an Arduino that was programmed to be able to read the fluctuating resistance of the photoresistor and convert it into a quantifiable output voltage given its 5-volt input. The photoresistor works by converting photons from a light source that come in contact with its surface into free electrons that allow the flow of electricity. This means that the higher the light intensity is on the surface of the photoresistor, the less the resistance. Inversely, when there is little to no light hitting the photoresistor, the resistance goes up as there are no free electrons to let electricity pass.

Given these properties of a photoresistor, a bridge divider circuit can be made with a 10k ohm resistor as to counteract the photoresistors variability. The fixed value of this resistor in tandem with the photoresistor creates a measurable output voltage value that is proportional to the light reading.

The servo motor is a simple device that turns electrical power into movement, in this case it spins a small shaft into a set position with the assistance of small plastic gears. The servo motor has three connections: power input, data, ground. The power and ground provide the flow of electrons to power the electrical motor and the data wire transmits positional data between the device and the Arduino it is plugged into. With this device the Arduino can read position data of the device and overwrite it, making the motor move the shaft into the desired position. In the case of this experiment, the motor was only made to rotate 180 degrees; up to simulate open blinds, and down for closed.

Because of the 10-bit analog-to-digital converter available in the specific Arduino used for this project, the max analog reading for the photoresistor was an arbitrary value of 1023. With this knowledge, an equation with this number as well as a known input voltage value of 5 volts was able to be derived in order to determine an output voltage that scaled with the reading from the photoresistor. This output voltage formula can be seen in formula 1.

$$V_{out} = \frac{V_{In} \times A}{1023} \quad (1)$$

To analyze variability in the voltage readings, the sample standard deviation was calculated using the formula 2 seen below.

$$s = \frac{\sqrt{(\sum x_i - \bar{x})^2}}{n-1} \quad (2)$$

This method helps quantify the spread of the voltage readings collected under repeated light measurements.

To estimate the uncertainty, a 95% confidence interval was elected in order to determine the range of values that could be estimated for population parameters at each of the controlled light intensities. According to the NSW Teachers Federation source [2], for a sample size n, the uncertainty for a confidence interval at 95% confidence can be seen below in formula 3.

$$\bar{x}_i = \bar{x} \pm ts/\sqrt{n} \quad (3)$$

Here, t is the critical value from the t-distribution table corresponding to $n-1$ degrees of freedom. This allows the final measurement to be reported with a defined confidence range.

INSTRUMENTATION

In this experiment, an Arduino UNO R3 microcontroller from the *LAFVIN Super Learning Kit* was used to develop the circuit. The primary components included a photoresistor, a servo motor, and an LCD display, which together were used to monitor ambient light conditions and control a mechanical response.

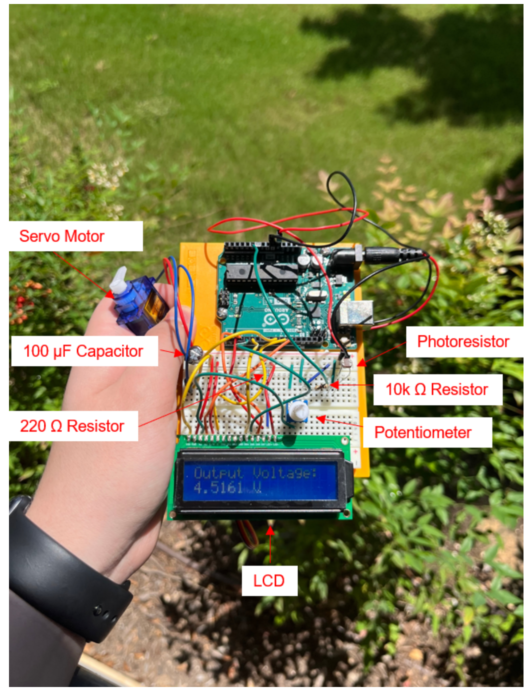

Figure 1: ***Completed Circuit***

Photoresistor

The photo-resistor is used to sense ambient light levels. According to Jeff Christenson [3], the band on the resistor is composed of a photo-conductor material that absorbs radiation and electrons move from the valence band of the semiconductor to a conduction band, allowing for passage of voltage. It is connected in a voltage divider circuit with a 10k Ω resistor, allowing the Arduino Uno R3 to read changes in light as changes in voltage. The photo-resistor was connected to analog input pin A0 on the Arduino. As stated in the theory section, a higher light intensity on the surface of the photoresistor, the lower the resistance, which increases the voltage.

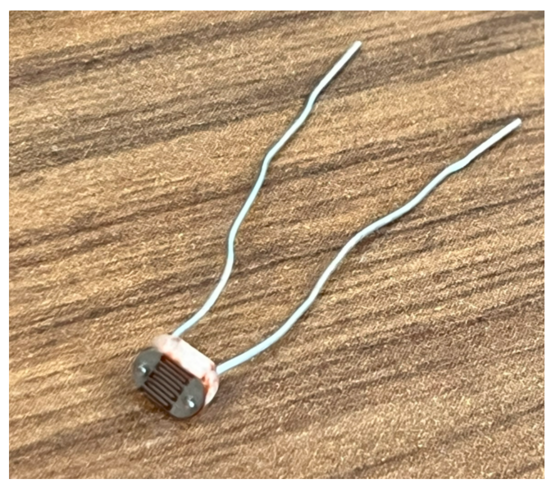

Figure 2: ***Photoresistor***

Servo Motor

A micro servo motor was used to provide a mechanical response to the changes in ambient light levels. The servo was connected to one of the Arduino's digital output pins. When the light level dropped to 1 volt or below, the Arduino rotated the servo to 0°, indicating a "dark" condition. If the light exceeded 1 volt, the servo rotated to 180°, signaling a "light" condition. To smooth the servo's operation and avoid erratic motion due to power fluctuations, a 100 μF capacitor was placed across the servo's power input. This reduced voltage dips when the motor was actuated.

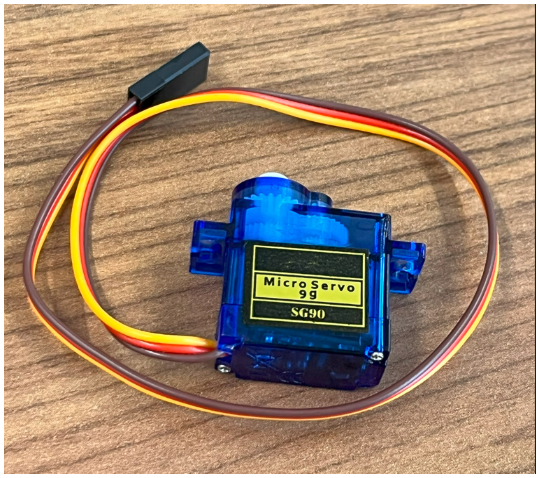

Figure 3: ***Servo Motor***

LCD

The LCD module was used to display real-time voltage values corresponding to the photo-resistor's light reading. This visual feedback helps verify the sensor's response to light change and observe if the servo actuates at the correct threshold. The LCD brightness was controlled using a potentiometer, for easy adjustment based on ambient conditions. Additionally, a 220Ω resistor was connected in series with the LCD's LED+ pin to limit current to the backlight, protecting the component from overcurrent. This LCD was not included in the LAFVIN kit and was chosen due to its 16 pin design with the pins pointing downward as it made it easier to mount to the breadboard as opposed to the 3 pin design included with the kit.

Figure 4: ***Liquid Crystal Display (LCD)***

EXPERIMENTAL PROCEDURE

To ensure a controlled testing environment, the circuit was placed inside a cardboard box to limit ambient light pollution. A small hole was cut into the top of the box to allow light to enter in a directed and measurable way. The LCD screen was covered to prevent its backlight from affecting the photoresistor's readings.

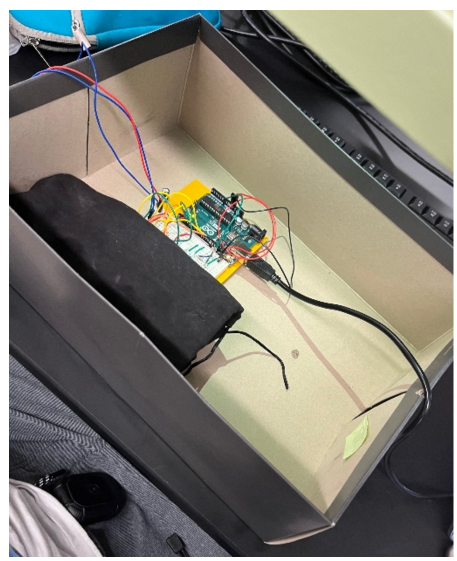

Figure 5: ***Circuit Within Calibration Chamber***

Initial readings were taken in complete darkness by covering the hole, establishing a baseline voltage from the photoresistor. A flashlight from an iPhone SE was then used to introduce light into the box throughout the four brightness settings. For each setting, the output voltage from the photoresistor was observed and recorded for twelve seconds through an Excel data logger.

Figure 6: Shining Light On the Circuit With iPhone SE

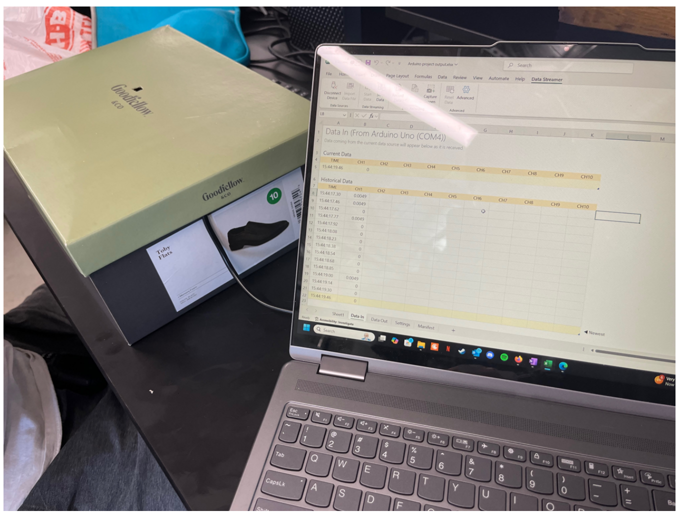

Figure 7: Excel Data Logger

After completing the readings with the circuit, the circuit was removed and replaced with an iPhone 13 running the Light Meter app. A paper diffuser was taped over the phone's camera as recommended by the Light Meter app for better distribution of light over the camera sensor. The phone's screen was recorded during testing, with the flashlight brightness periodically increasing and pausing at each setting for several seconds in order to see the setting's steady state Lux value. These lux readings were later compared with the voltage outputs previously recorded from the Arduino system.

Figure 8: *iPhone13 Running Light Meter Within Calibration Chamber*

ANALYSIS OF EXPERIMENTAL DATA

After voltages were collected from the Arduino circuit the data points recorded over the twelve seconds were averaged to plot them with the steady state lux values.

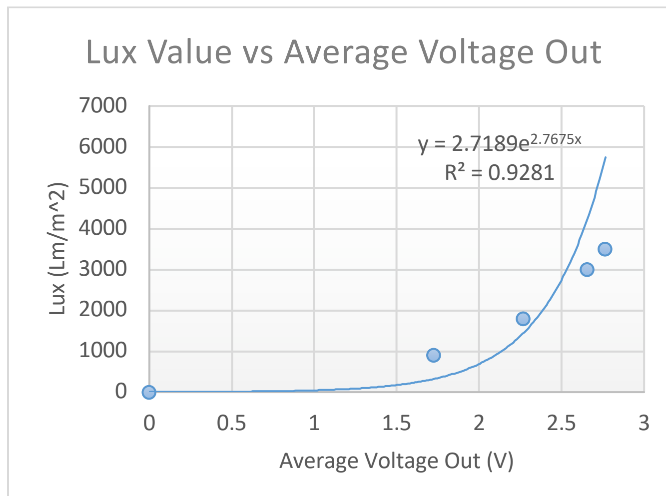

Figure 9: *Phone Lux vs. Average Voltage Output*

Plotting this data gave the trendline equation shown in the top right-hand corner of the graph. This equation was used to convert voltage values into Lux as seen:

$$Lux = 2.7189e^{2.7657*Voltage} \quad (4)$$

All recorded voltage values for each setting were then converted into lux and averaged again. The resulting Lux values were then compared to those from the Light Meter app.

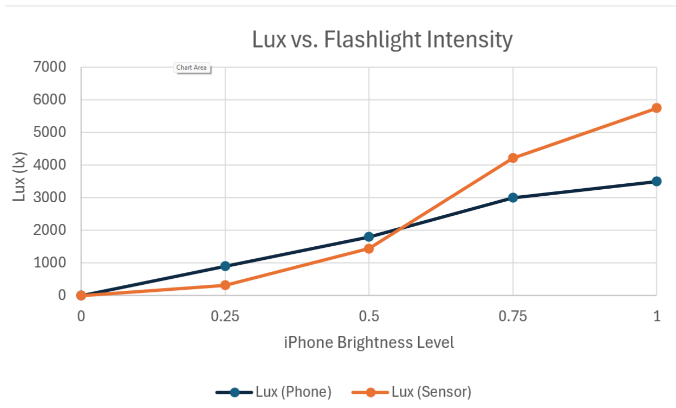

Figure 10: ***Phone Lux vs. Photoresistor Lux Output Error***

Figure 10 depicts the variation between the nominal "true" value (for the purposes of this experiment) measured by the iPhone 13 camera in blue, against the calculated lux output from the photoresistor under the same conditions in orange. The variation remains minimal, especially in conditions of complete darkness, while at higher intensities of light there is more room for error and therefore an increase in the variation. Table 1 below shows the percentage error quantified numerically at each of the light intensity stages.

Table 1: ***Phone Lux vs. Photoresistor Lux % Error***

Intensity	Phone (lx)	Sensor (lx)	%Error
0	1.8	2.7189	51.05
0.25	900	322.4647	64.17059
0.5	1800	1441.999	19.88894
0.75	3000	4218.047	40.60156
1	3500	5743.998	64.11424

Given the sample data collected via a sample size of about 40 readings taken over a period of about 10 seconds for each light intensity, the parameters for a population size can be estimated using the previously student t distribution tables. After using equations 2 and 3 along with the calculated sample means for the lux from the photoresistor, a lux uncertainty and confidence interval was determined in table 2 below.

Table 2: ***Uncertainty of Lux from Photoresistor***

Flashlight Intensity	Uncertainty (lx)	Confidence Interval (lx)
0%	5.68E-16	2.62827-2.62827
25%	0.3660034	311.077 - 311.809
50%	2.41594	1390.28 - 1395.11
75%	6.3583	4063.79 - 4076.51
100%	3.81489	5548.36 - 5555.99

With this data, assuming it can be used as a viable representation of the population parameters, it is clear that in brighter conditions, there will be a lot more fluctuation in the value being received by the photoresistor at any given point while exposed, which may have an impact on the responses from the servo motor. In terms of this specific project, the most issues that can be expected, if any, would be during the day, while there should be relatively no issues to worry about at night in steady state conditions.

CONCLUSIONS

With the voltage shown to increase as the intensity of the light increases, meaning the resistance in the photoresistor decreased. This correlates with prevailing information of photoresistors and highly suggests the theory of this project is correct.

The experiment also shows that the relationship between lux and voltage captured on the device is exponential, suggesting that light on a lux scale is exponential as well. One way to improve upon this experiment and more closely study this would be to use a more powerful flashlight that could support a larger variety of light intensities, allowing for more data to be collected which would lead to a better regression model. Another would be to collect the voltage data from the photoresistor from a higher range, since this experiment was limited to the five volts supplied by the Arduino. The biggest discrepancy also most likely came from the use of an iPhone camera to set the nominal baseline reference point for lux rather than an actual lux meter that would be able to provide more accurate and precise readings.

Overall, the experiment was a success, the servo motor responded to light intensities at a certain custom threshold and could be used to move the blinds.

REFERENCES

1. Fitzgerald, S. & Shiloh, M.. *Arduino Projects Book,* p. 119, 126, and 129, 2015.
2. NSW Teachers Federation. "Uncertainty, Error, and Confidence in Data." Centre for Professional Learning, Semester 1, 2020. Available online: https://cpl.nswtf.org.au/journal/semester-1-2020/uncertainty-error-and-confidence-in-data/

[Accessed: 11-May-2025].

3. Christenson, Jeff. "*Sensors and Transducers," Handbook of Biomechatronics.* 2019. Available online: https://www.sciencedirect.com/topics/engineering/photoresistors#:~:text=A%20photocell%20or%20photoresistor%20is,light%20will%20cause%20higher%20resistance. [Accessed: 11-May-2025].