BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY
DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

EEE 400

Optoelectronics Laboratory

Final Project Report

Section: B2 Group: 04

Experimental Setup to Measure L-I characteristics of a LED

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Signature of Instructor: ______________________________

Academic Honesty Statement:

IMPORTANT! Please carefully read and sign the Academic Honesty Statement, below. Type the student ID and name, and put your signature. *You will not receive credit for this project experiment unless this statement is signed in the presence of your lab instructor.*

"In signing this statement, We hereby certify that the work on this project is our own and that we have not copied the work of any other students (past or present), and cited all relevant sources while completing this project. We understand that if we fail to honor this agreement, We will each receive a score of ZERO for this project and be subject to failure of this course."

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1 Abstract

This experiment aims to characterize the relationship between the forward bias voltage applied to an LED and the resulting current that flows through it. This relationship, known as the L-I characteristic, is crucial for understanding the operating conditions and limitations of the LED.

The setup will involve a regulated power supply capable of providing a variable voltage input (Arduino), power MOSFET, a current-limiting resistor to protect the LED from excessive current, a voltmeter to measure the current flowing through the LED. By systematically varying the voltage output of the power supply and recording the corresponding current readings, a comprehensive picture of the L-I characteristic will be obtained.

The experiment will also explore the limitations of the LED, such as the forward voltage required for significant light emission and the maximum current the device can safely handle without damage. The data collected will be used to plot the L-I curve, enabling further analysis and interpretation of the LED's behaviour.

2 Introduction

Light emitting diodes (LEDs) have become ubiquitous in modern technology due to their energy efficiency, long lifespan, and versatility. However, for optimal performance and safe operation, understanding the relationship between the current flowing through an LED and the voltage applied to it is crucial. This relationship is captured in the L-I characteristic, which serves as a vital fingerprint for each unique LED.

This experiment delves into the practical setup for measuring the L-I characteristic of an LED. We will construct a circuit utilizing readily available electronic components such as a power supply, current-limiting resistor, ammeter, and voltmeter. By systematically varying the voltage output and measuring the corresponding current, we will systematically map the L-I curve, revealing valuable insights into the LED's behavior.

Furthermore, this experiment will explore the forward voltage drop, the minimum voltage required for the LED to emit significant light, and the maximum current rating, the highest current the LED can safely handle without compromising its performance or lifespan.

Through this hands-on experience, we aim to gain a deeper understanding of LED operation and the vital role the L-I characteristic plays in their effective application.

3 Methodology

3.1 Problem Formulation (PO(b))

3.1.1 Identification of Scope

The experiment focuses on designing an automated prototype that takes a LED as input and gives the (I,V) and (L,I) points for generating the I-V and the L-I curves without using an optcal power meter. For this, calibration is needed with the experimental data and the actual output power from the optical power meter.

3.1.2 Literature Review

The threshold voltage refers to the minimum voltage required for an LED to turn on and emit a noticeable amount of light. This voltage varies depending on the color of the LED due to the different materials used in their construction. Here's a breakdown of the typical threshold voltages for red, green, and blue LEDs:

Red LED: Threshold voltage typically falls between 1.7 volts and 2.0 volts.
Green LED: Threshold voltage is generally in the range of 2.9 volts to 3.1 volts.
Blue LED: Due to the higher energy required to produce blue light, the threshold voltage for blue LEDs is higher, typically between 3.0 volts and 3.3 volts.

It's important to note that these are general ranges, and the specific threshold voltage for a particular LED can vary depending on the manufacturer and the specific model.

3.1.3 Formulation of Problem

The main obstacle was how to design a circuit that can generate an output parameter that can be used to measure the current and output power of the LED that is taken for test by the circuit prototype. So, we focused on designing an automated system.

3.2 Design Method (PO(a))

3.3Circuit Diagram

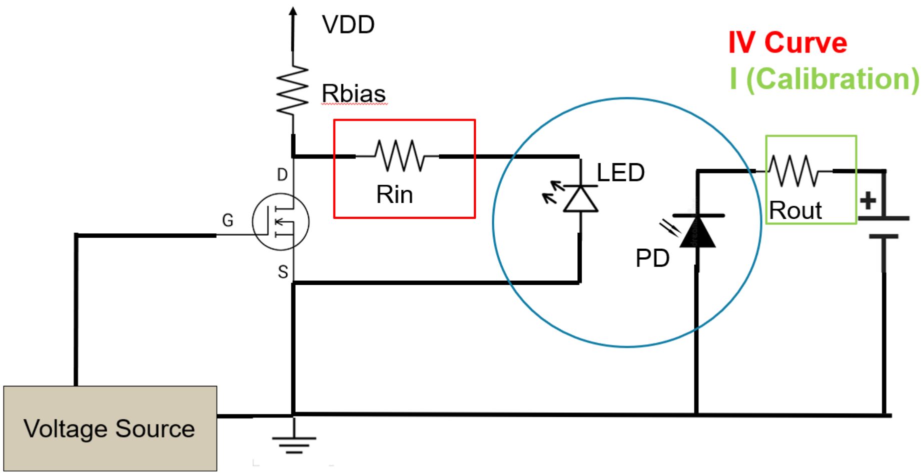


Figure 1: Experimental Setup

3.4 Simulation Model

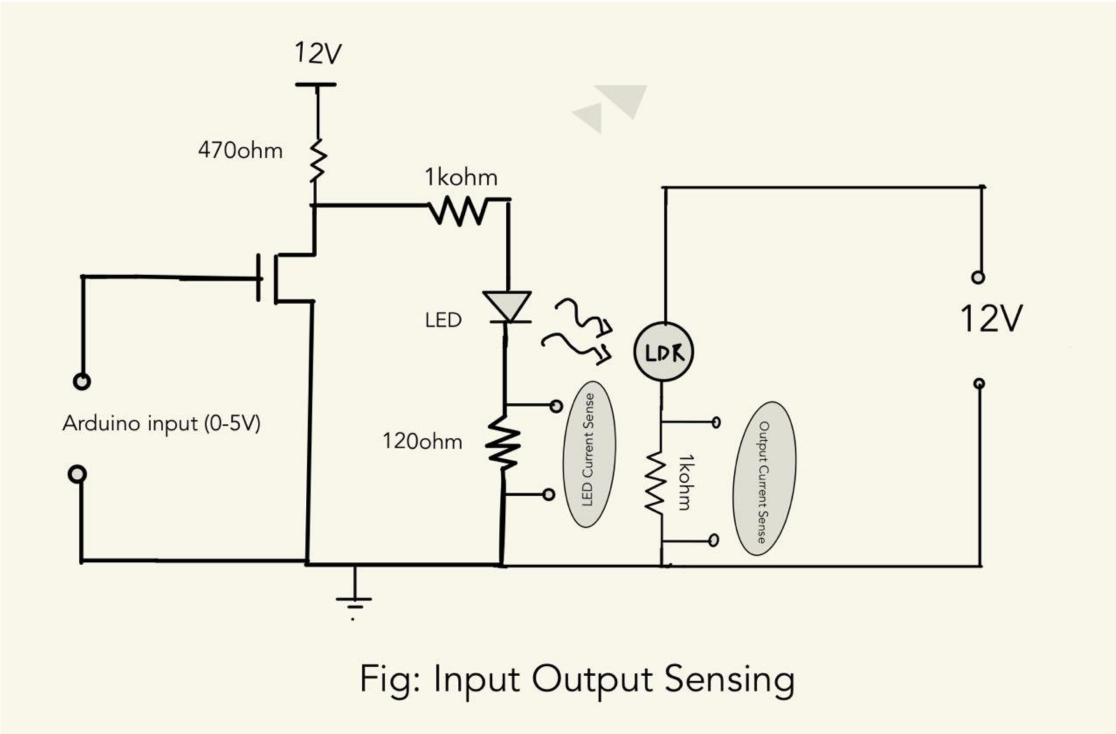


Figure 2: Simulation Design

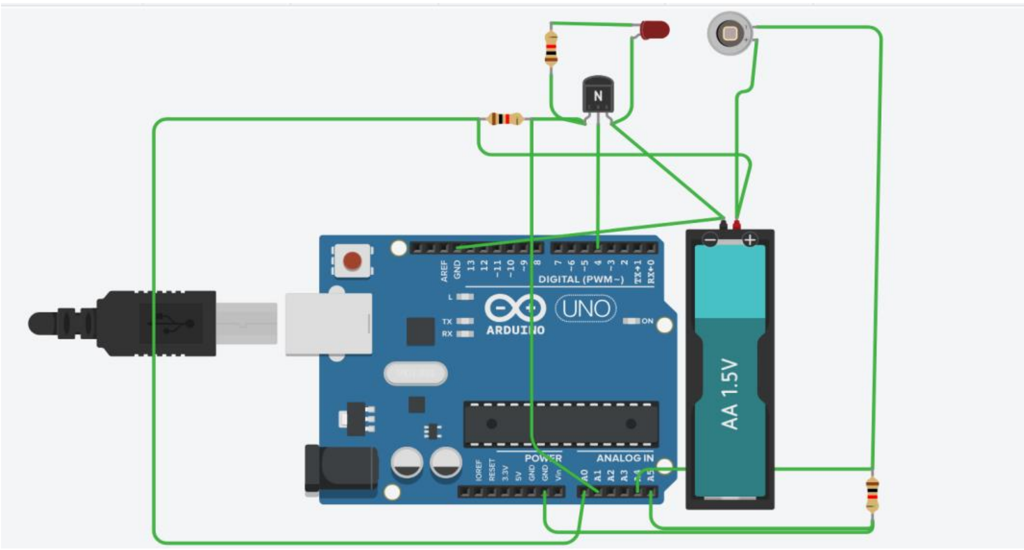
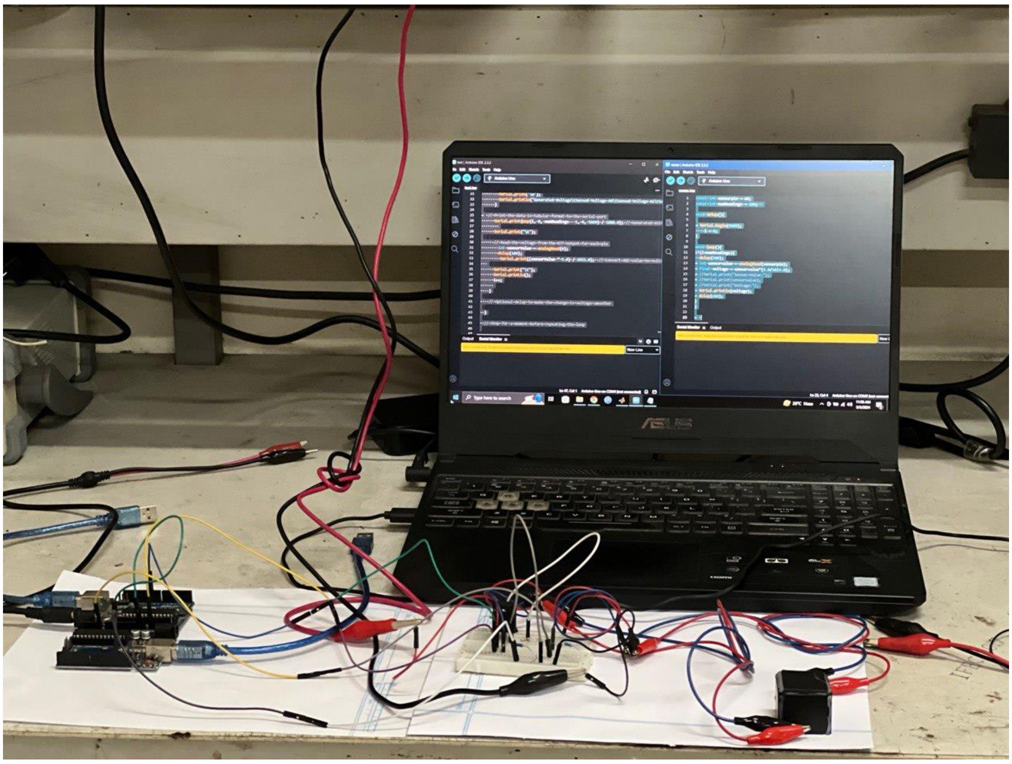
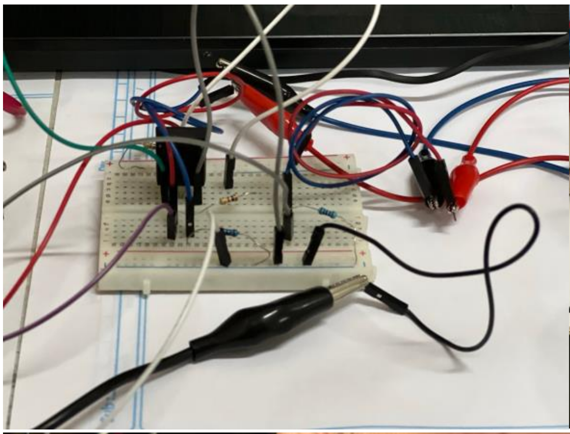
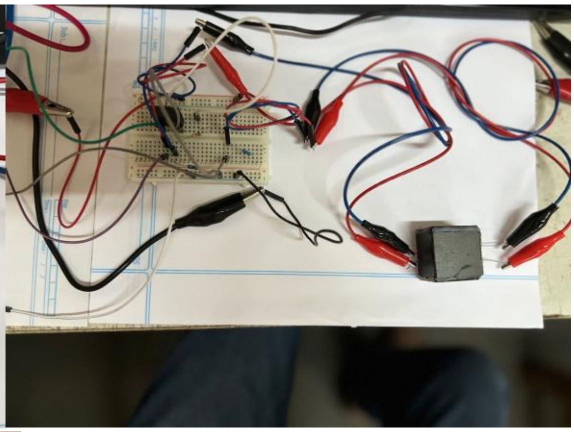


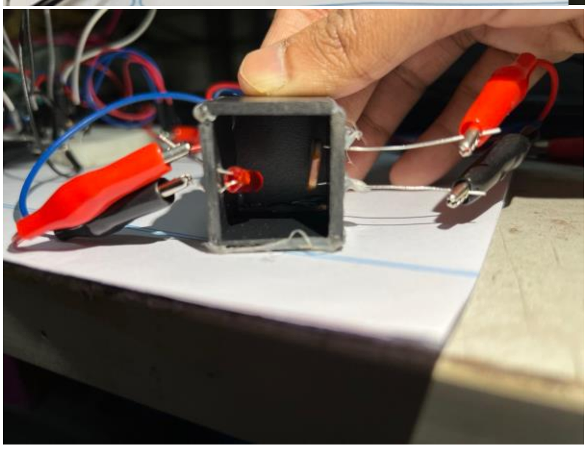
Figure 2: Simulated CIrcuitt

3.5 Hardware Design









3.6 Full Source Code

sense code

```
const int sensorpin = A0;
const int numReadings = 100;

void setup(){

         Serial.begin(9600);
    i = 0;
}

void loop(){
if(i<numReadings){
  delay(500);
         int sensorvalue = analogRead(sensorpin);
         float voltage = sensorvalue*(5.0/1023.0);
         //Serial.print("Sensor Value:");
         //Serial.print(sensorvalue);
         //Serial.print("Voltage:");
         Serial.println(voltage);
         delay(600);
}
}
```

Voltage generator code

```
const int pwmPin = 10;                           // PWM pin connected to generate voltage
const int analogInPins = { A0};  // Analog input pin connected to BJT output
const int numReadings = 100;                     // Adjust this based on how many readings you want to store
volatile int i;

void setup() {
  Serial.begin(9600);  // Initialize serial communication at 9600 bps
  i = 0;

}


void loop() {
    // Generate and sense voltage from 0 to 5V
    if(i<numReadings){
      analogWrite(pwmPin, map(i, 0, numReadings - 1, 0, 255));
      delay(1000);

      // Print header row
      if (i == 0) {
        Serial.print("\n");
        Serial.println("Generated Voltage\tSensed Voltage A0\tSensed Voltage A1\tSensed Voltage A2\tSensed Voltage A3");
      }

          // Print the data in tabular format to the serial port
      Serial.print(map(i, 0, numReadings - 1, 0, 5000) / 1000.0); // Generated Voltage

      Serial.print("\t");

      // Read the voltage from the BJT output for each pin
        int sensorValue = analogRead(0);
        delay(100);
         Serial.print((sensorValue * 5.0) / 1023.0);  // Convert ADC value to voltage

      Serial.print("\t");
      Serial.println();
      i++;

    }

    // Optional delay to make the change in voltage smoother

  }

  // Stop for a moment before repeating the loop
```

Table-1: Source Code for the main program

4 Implementation

4.1 Description

This is the description for the design to detect the LED from the L-I characteristics.

Input Side: On the input side, we have written an Arduino code to generate and change input voltage slowly from 0 to 5V. This voltage will be connected to the gate of the power MOSFET (IRFP 450). The threshold voltage of the transistor is approximately 2V. In this way, current across the LED light will start to change accordingly. We have used 2kohm resistor to limit the current through the LED and taken voltage across 120ohm to measure the current flowing through the LED. LED will start to turn on.

Output Side: Sensing the optical power from the LED, resistance of the LDR will start to reduce. This will increase the current flowing through the circuit. To measure the current, we have taken voltage across the 1kohm resistor. Then we have multiplied it with the calibration factor to get the output.

5 Design Analysis and Evaluation

5.1 Novelty

The experimental setup gives the optical power output and the current output of three different color of LED without the use of an optical power meter. The use of MOSFET to isolate the LED from the voltage source can be identified as a new approach.
As the microcontroller doesn't give enough driving current to light up the LED, we used the microcontroller generated voltage in the gate of the MOSFET and the drain current of the MOSFET powered by the voltage source drives the LED to its full brightness. The MOSFET also isolated the microcontroller from the input LED.

5.2 Design Considerations (PO(c), (PO(f)), (PO(f)))

5.2.1 Considerations to environment

The L-I characteristic measurement project itself has minimal direct environmental impact. Energy Consumption during measurement the main consideration we need to focus on.

While minimal compared to the LED's regular use, the experiment itself consumes some energy. Consider using energy-efficient power supplies and conducting the experiment for the shortest necessary duration to minimize the overall energy footprint.

5.2.2 Considerations to cultural and societal needs

The experiment directly doesn't have any cultural impact, but it can increase our scientific curiosity to investigate more and find alternative and better solutions of a problem.

5.2.3 Assessment of Safety Issues

Eye Safety: Proper safety precautions are crucial to prevent eye damage. Safety must be followed during experimentation.
Voltage source: Voltage source must be used carefully.

5.2.4 Assessment of Legal/Ethical Issues

Considering the experimental setup for studying the L-I (light-current) characteristics of Light Emitting Diodes (LEDs), several legal and regulatory aspects come into play:

Product Liability: Manufacturers and researchers must ensure that LEDs meet quality standards. Any defects or failures could lead to product liability claims.
Consumer Safety: LEDs used in commercial products (lighting, displays, etc.) must comply with safety regulations to prevent harm to consumers.

5.3 Investigations (PO(d))

5.3.1 Design of Experiment

1. **470ohm:** we have used a 470ohm resistor across the supply and the drain of the power mosfet. This resistor has a impact on the voltage swing of the output drain voltage. When the mosfet fully turns on, it works like a short circuit and can have a very large current that can damage the components of the circuit. Our resistor will prevent that.

2. **120 ohm:** We have used a small resistor (120ohm) between the LED light and the ground. Small resistor will have a small voltage drop. Also, Arduino can detect between 0 to 5V. Basically it will have a nonexistent effect on the current value and fix the suitable range for the Arduino.

3. **1kohm:** We have used 1kohm between LDR and ground of the circuit. From the testing, we have observed that the resistance of the red LED fluctuated between 5k and 60kohm. It is 2k-35k and 1.5-30k for the green and blue LED respectively. So, we have chosen a 1kohm in such a way that voltage drop across it remains always between 0 to 5V. Basically, so that our Arduino UNO can sense the voltage drop range.

4. **LDR:** We have our LDR model name such that in the dark setup, it shows a few Mohm resistance. And when we give light to it, it drops down to even 1kohm in our findings. Our choice is because of the wide resistance of the LDR to detect all the LED.

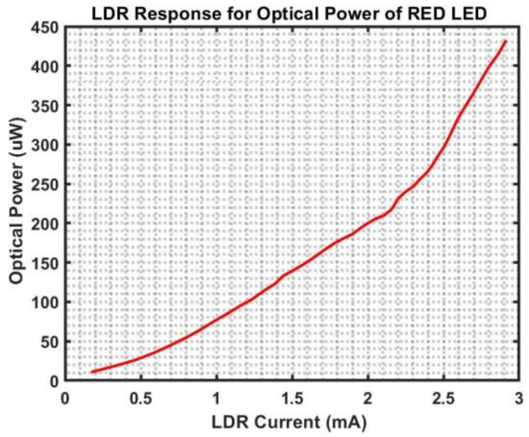
5.3.2 Data Collection

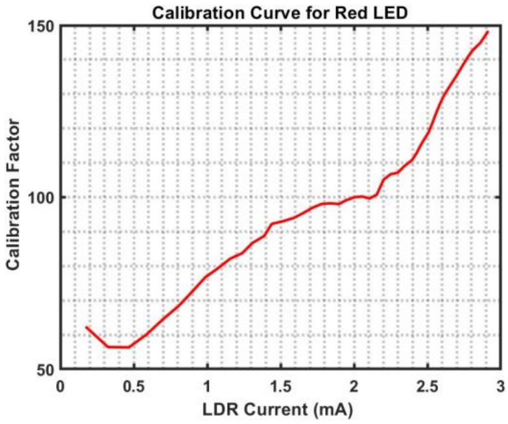
Data from Optical Power Meter: The PM100D optical power meter from the PV lab (ECE 11th floor) was used to collect the actual power output of the Red, Green and Blue LED's beforehand for the need of calibration.

Data from the e xperimental setup: Red, Blue and Green LED are used in our experimental setup to collect the output current of the LED and the current of the LDR to find the output curves.

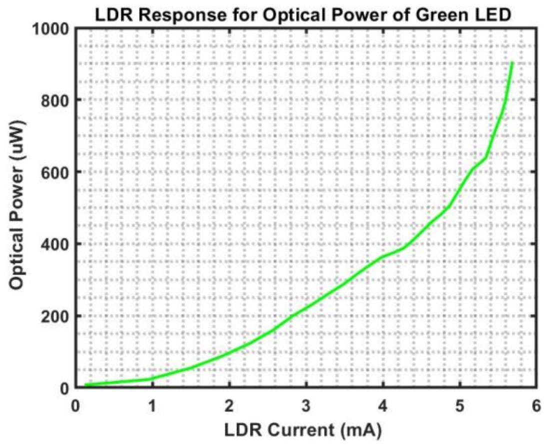
5.3.3 Output Curves

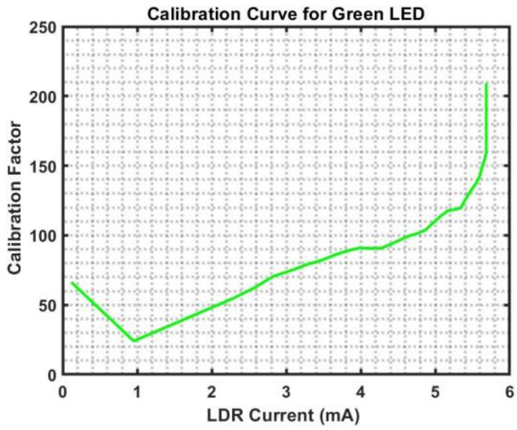
1. RED LED



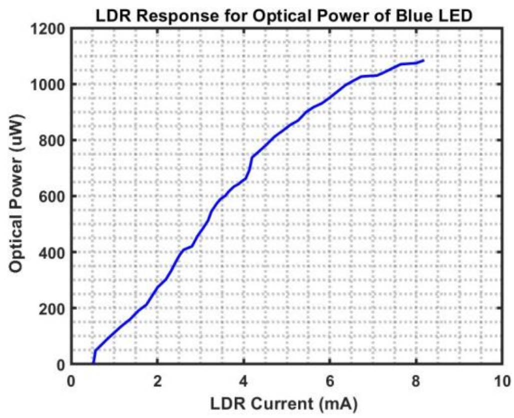


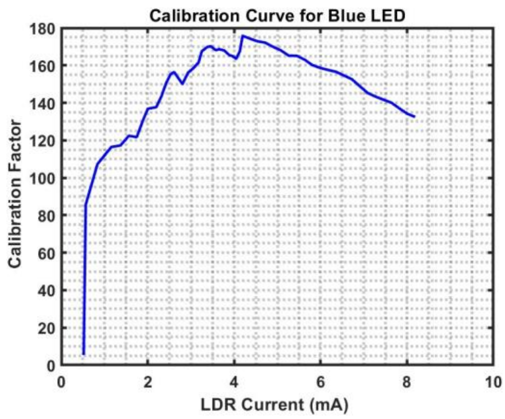
2. GREEN LED



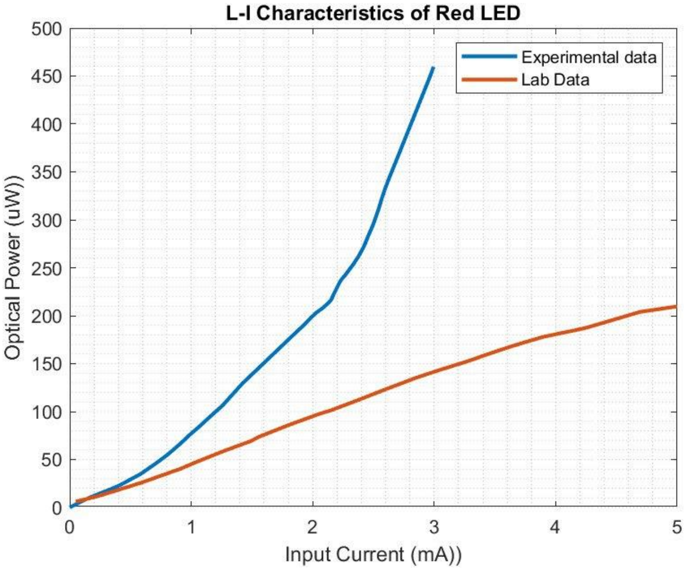


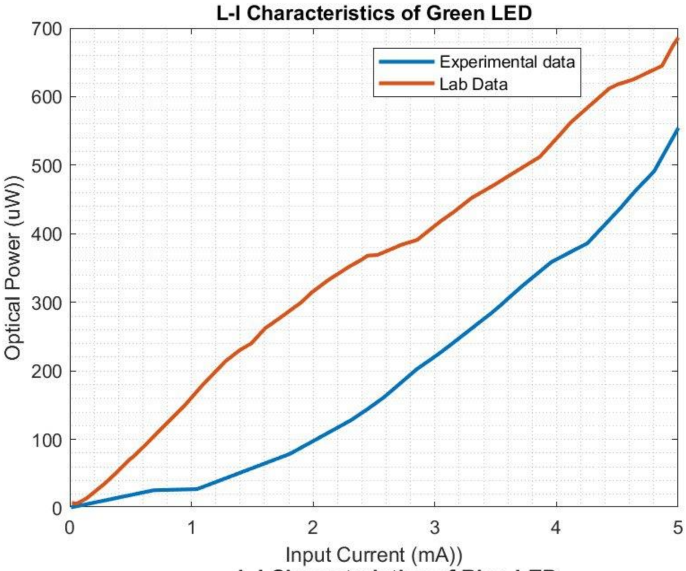
3. BLUE LED

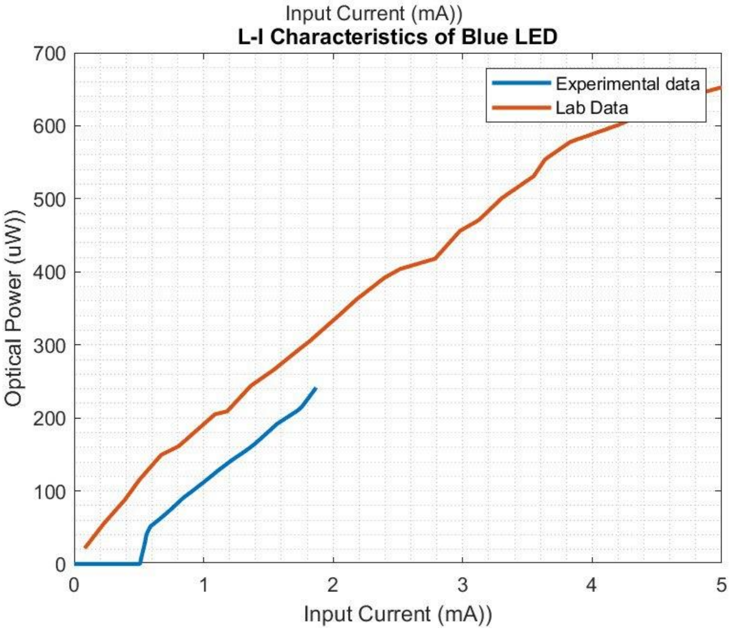




4. Tested L-I


L-I Characteristics of Red LED
Experimental data
Lab Data
Optical Power (uW))
Input Current (mA))
0
50
100
150
200
250
300
350
400
450
500
0
1
2
3
4
5


L-I Characteristics of Green LED
Experimental data
Lab Data
Optical Power (uW))
Input Current (mA))
0
100
200
300
400
500
600
700
0
1
2
3
4
5


L-I Characteristics of Blue LED
Experimental data
Lab Data
Optical Power (uW))
Input Current (mA))
0
100
200
300
400
500
600
700
0
1
2
3
4
5

5.3.4 Interpretation and Conclusions on Data

1. RED LED L-I: The LDR resistance is a nonlinear function of the light intensity. Upto 1.5 mA of current, the trend is followed. But After 1.5mA, the resistance of the LDR changes drasticallty and the curve deviated.

2. GREEN LED L-I : The Green LED almost follows the PM100D data quite well.

3. BLUE LED L-I: This LED follows the trend upto 2mA of input current of the LDR and further input current was not measured due to the limitations of the drain voltage swing of the MOSFEt. The the maximum swing of the MOSFET is (0 to 8) V.

The built in potential of the Blue LED is around 3V. So, further input current could not tested.

5.4 Limitations of Tools (PO(e))

1. There was a problem encountered in Arduino analog sensing. So, 2 Arduino was needed.
2. LDR responsivity was an issue to handle.
3. Orientation of LED and LDR.

6 Reflection on Individual and Team work (PO(i))

6.1 Log Book of Project Implementation

Month	Milestone achieved	Individual Role
2nd Week, February	Data collected from PM100D	1806092, 1806097
3rd week, February	Experimental setup ready	1806089, 1806192
4th week, February	Data collection and analysis.	All Group Members
1st week, March	Report, video, project presentation.	All Group Members

7 Communication to External Stakeholders (PO(j))

7.1 User Manual

Connect RED/BLUE/GREEN LED in the setup ->
supply voltage Vdc ->
Upload the Miconcoltroller code ->
Take readings ->
Calibrate the data.

7.2 YouTube Link

8 Project Management and Cost Analysis (PO(k))

8.1 Bill of Materials

1.12V DC Power Supply-	200
LDR-	60
Transistor (IRFP 450)-	30
Resistor (1k, 2k, 120)-	40
Jumper wire -	50

8.2 Calculation of Per Unit Cost of Prototype

Total Cost – 2000 Tk by rounding

9 Future Work (PO(l))

1. The setup can be made into a PCB.
2. Better Microcontroller can be used for better result.
3. Higher output power needs to be calibrated properly.

10 References

1. https://link.springer.com/article/10.1007/s12633-020-00553-8
2. https://ieeexplore.ieee.org/abstract/document/9862375/
3. https://link.springer.com/chapter/10.1007/978-94-007-2169-2_105