Ambient Lux Monitor

Group 27

Muhammad Aiman Hakim Bin Mahazir[#1], Muhammad Aiman Syamiel Bin Abdul Muiz[#2] Muhammad Muhaimin Bin Mohamad Azman[#3], Wan Muhammad Hakim Bin Noruddin[#4] Chong Hui Zhi[#5]

#Bachelor of Computer Engineering with Honours, Faculty of Intelligent Computing, Universiti Malaysia Perlis, 02600 Arau, Perlis, Malaysia

[1]s231021358@studentmail.unimap.edu.my

[2]s241022423@studentmail.unimap.edu.my

[3]s241021389@studentmail.unimap.edu.my

[4]s231021437@studentmail.unimap.edu.my

[5]s231021318@studentmail.unimap.edu.my

***Abstract*— This paper presents the design and implementation of an Ambient Lux Monitor system utilising a Light Dependent Resistor (LDR) as the primary transducer. The system is calibrated to operate within the illumination range of 100–500 lux, corresponding to typical indoor lighting conditions. The analogue signal from the LDR is conditioned and acquired using NI myRIO, processed in LabVIEW, and transmitted to an ESP8266 microcontroller for wireless actuator control. The system provides real-time lux monitoring, threshold detection, data logging, and adaptive lighting control. Results confirm accurate lux estimation, fast response, and reliable wireless operation, making the system suitable for smart lighting applications.**

Keywords:Keywords
Ambient light monitoring, LDR, NI myRIO, ESP8266, LabVIEW, signal conditioning, smart lighting.

1.0 Introduction

Lighting conditions directly influence human comfort, productivity, and energy efficiency. In modern smart environments, adaptive lighting systems are increasingly deployed to maintain optimal illumination while reducing unnecessary energy consumption. Lux monitoring, which quantifies illuminance in units of lux, is a fundamental requirement in such systems.

This project introduces an Ambient Lux Monitor designed to operate within the range of 100–500 lux, corresponding to typical indoor lighting conditions. The system integrates an LDR sensor for transduction, NI myRIO for data acquisition and processing, and ESP8266 for wireless actuator control. The objective is to provide a reliable, real-time monitoring and control solution that enhances ergonomic lighting standards.

2.0 Design of Electronic Instrumentation

The electronic instrumentation of the Ambient Lux Monitor was designed to measure and control indoor light levels within the range of **100–500 lux**. The system consists of an LDR sensor, a signal conditioning circuit, a processing unit, and a wireless control module.

The LDR is used as the main transducer to sense ambient light. Changes in light intensity cause variations in the LDR resistance, which are converted into an analogue voltage using a voltage divider circuit. This voltage represents the illumination level in the surrounding environment.

To ensure accurate measurement, the sensor output is passed through a signal conditioning circuit that improves sensitivity and reduces noise. The conditioned signal is then acquired by the NI myRIO and processed using LabVIEW. Calibration and filtering are applied to convert the voltage signal into lux values.

The processed data is transmitted wirelessly to an ESP8266, which controls external indicators and lighting devices. This design enables real-time monitoring, reliable control, and easy integration with smart lighting systems.

2.1 Flow Chart and Block Diagram

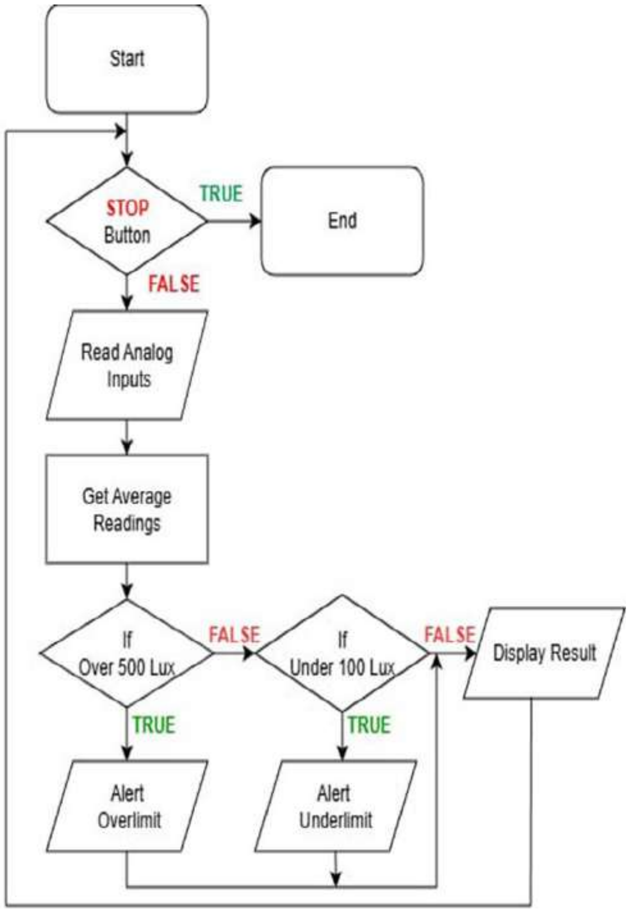


Figure 1: Flowchart

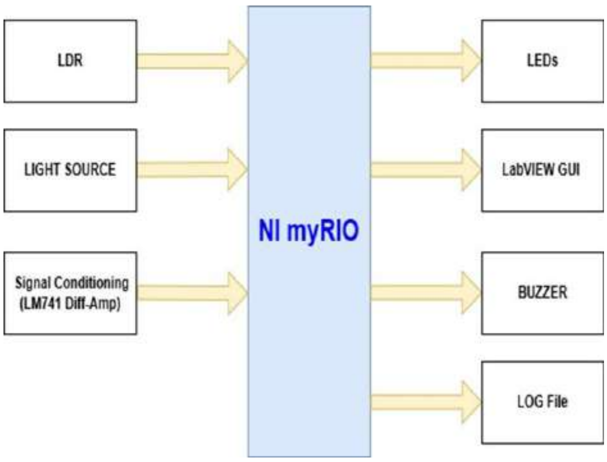


Figure 2: Block Diagram

2.2 Design of transducer

This design utilises a NORP12 Cadmium Sulphide (CdS) Light Dependent Resistor (LDR) as the primary sensing element, selected for its spectral response that closely approximates that of the human eye. The transducer operates on the principle of photoconductivity, where the cell's resistance decreases significantly as light intensity increases, dropping from a high dark resistance of typically 1.0MΩ to much lower values in bright conditions. By configuring the LDR within a voltage divider circuit, this variable resistance is translated into a measurable analogue voltage (Vout), allowing for precise detection of illumination levels for applications such as automatic lighting control or light interruption detectors.

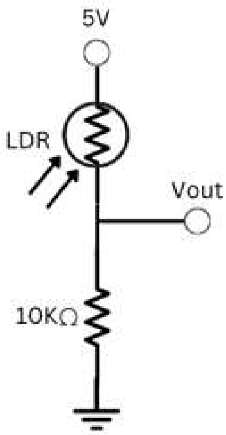


Figure 3: Transducer Circuit Diagram

Circuit Parameters:

V(in): 5V

R_2 (Fixed Resistor): 10kΩ

Sensor: Light Dependent Resistor (LDR)

The general voltage divider formula used is:

$$V_{out} = V_{in}\left(\frac{R_2}{R_2 + R_{LDR}}\right)$$

Case 1: At 100 Lux
Given:
$R_{LDR} = 5\text{k}\Omega$
Calculation:

$$V_{out} = 5\text{V}\left(\frac{10\text{k}\Omega}{10\text{k}\Omega + 5\text{k}\Omega}\right)$$

$$V_{out} = 5\left(\frac{10}{15}\right)$$

$$V_{out} = 3.33\text{V}$$

Case 2: At 500 Lux
Given:
$R_{LDR} = 1\text{k}\Omega$
Calculation:

$$V_{out} = 5\text{V}\left(\frac{10\text{k}\Omega}{10\text{k}\Omega + 1\text{k}\Omega}\right)$$

$$V_{out} = 5\left(\frac{10}{11}\right)$$

$$V_{out} = 4.55\text{V}$$

Light Condition	LDR Resistance	Voltage "Share" by LDR	Output Voltage (Vout)
Darker (100 Lux)	High (5kΩ)	Takes more	Lower (3.33V)
Brighter (500 Lux)	Low (1kΩ)	Takes less	Higher (4.55V)

Table 1: Transducer Circuit Design

2.3 Design of Signal Conditioning Circuit

The signal conditioning stage utilises a Texas Instruments LM741 general-purpose operational amplifier configured as a differential amplifier. This stage is required to scale the transducer output voltage to a standard 0–5 V analogue range suitable for digital interfacing.

The design requirements are derived from the transducer characterisation and the electrical specifications of the LM741 operational amplifier.

Transducer Input Low ($V_{in\ low}$): 3.33 V (at 100 Lux)
Transducer Input High ($V_{in\ high}$): 4.55 V (at 500 Lux)
Target Output Span: 0 V to 5.0 V

According to the datasheet, the LM741 is designed for dual supply operation, with recommended supply voltages between ±10V and ±15V. Furthermore, the output voltage swing is typically limited to ±13V when using a ±15V supply. Therefore, to achieve a strictly linear output down to 0 V and up to 5 V, the circuit must be powered by split rails (e.g., ±12V or ±15V) rather than a single 5 V supply.

The required closed-loop voltage gain (A_{v}) is calculated from the ratio of the target output span to the input differential:

$$A_v = \frac{V_{out\_max} - V_{out\_min}}{V_{in\_high} - V_{in\_low}}$$

Substituting the values:

$$A_v = \frac{5.0\text{ V} - 0\text{ V}}{4.55\text{ V} - 3.33\text{ V}} = \frac{5.0}{1.22} \approx 4.098$$

The gain of a differential amplifier is set by the resistor network R_f (feedback) and R_i (input), as governed by:

$$\frac{R_f}{R_i} = A_v \approx 4.1$$

The theoretical output voltage (V_{out}) is validated against the device's permissible output swing.

Condition 1: High Illumination (500 Lux)

$$V_{out} = (4.55\ \mathrm{V} - 3.33\ \mathrm{V}) \times 4 = 1.22\ \mathrm{V} \times 4 = 4.88\ \mathrm{V}$$

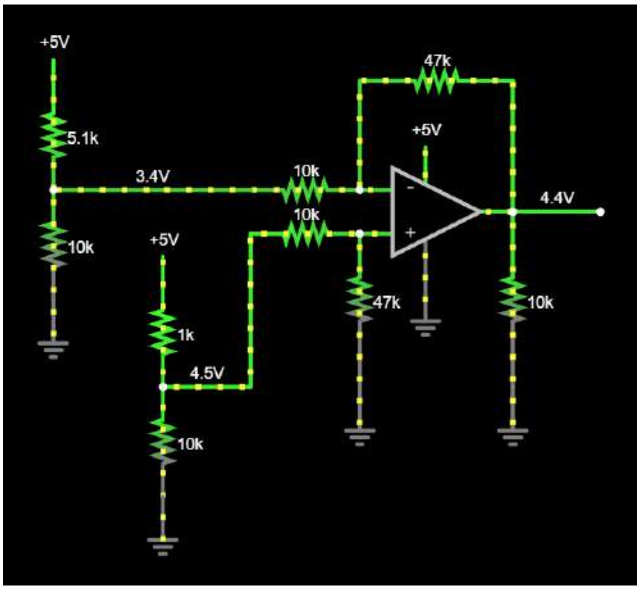


Figure 4: Signal Conditioning Circuit Diagram (500 Lux)

Condition 2: Low Illumination (100 Lux)

$$V_{out} = (V_{in} - V_{ref}) \times \frac{R_f}{R_i} = (3.33\ \mathrm{V} - 3.33\ \mathrm{V}) \times 4 = 0\ \mathrm{V}$$

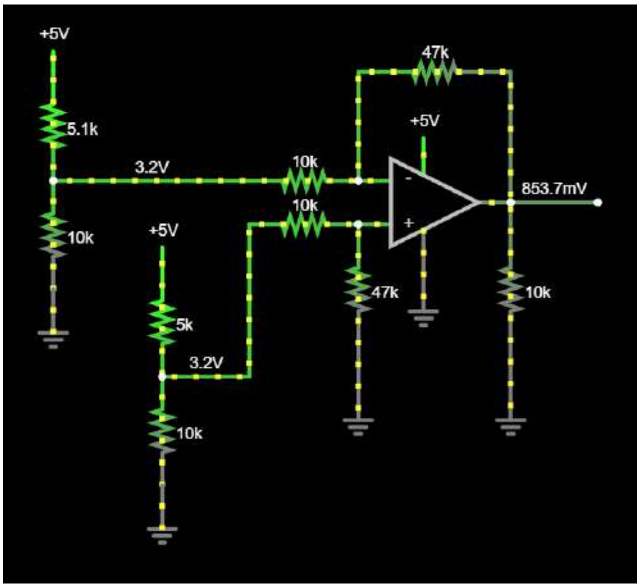


Figure 5: Signal Conditioning Circuit Diagram (100 Lux)

3.0 Virtual Instrument Design Using LabVIEW and NI ELVIS II Board

The virtual instrument (VI) was developed using LabVIEW in conjunction with the NI ELVIS II platform. This configuration enables efficient data acquisition, real-time processing, visualisation, storage, and control within a unified graphical programming environment. The VI was designed to interface with the LDR-based sensing circuit, providing accurate ambient light monitoring within the specified range of 100–500 lux.

3.1 Data Acquisition

The NI myRIO platform was employed as the primary data acquisition (DAQ) device, interfaced with the LDR-based voltage divider circuit. The analogue output from the transducer was connected to the myRIO analogue input channels (AI0 and AI1). LabVIEW was programmed to continuously sample these signals at 100 ms intervals, ensuring real-time responsiveness. The acquired voltages were scaled to lux values using calibration constants derived from experimental measurements (3.33 V ≈ 100 lux, 4.55 V ≈ 500 lux).

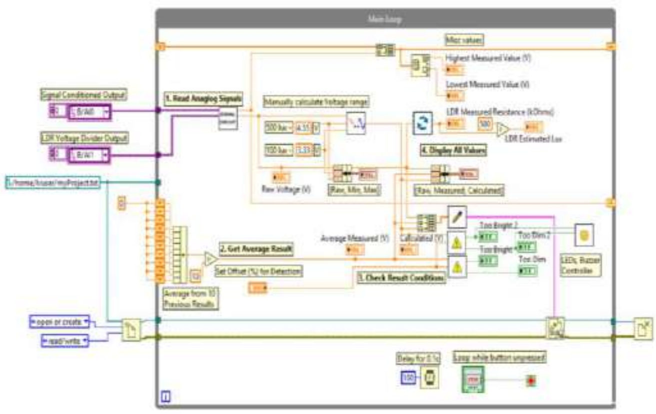


Figure 6: Main Loop (Block Diagram)

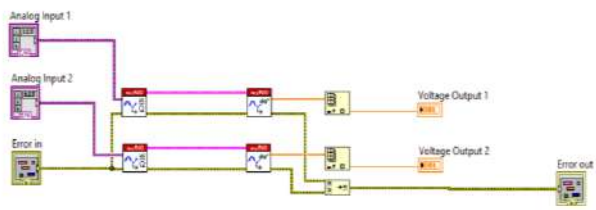


Figure 7: Analog Signal (Block Diagram)

3.2 Data Processing (Calibration & Error Correction)

Raw voltage signals were subject to calibration and error correction routines within LabVIEW. A moving average filter (10-sample window) was implemented to reduce noise and stabilise readings. Offset correction was applied to compensate for systematic deviations observed during testing. The lux estimation algorithm mapped voltage values to lux using a linear interpolation model, ensuring accurate conversion across the 100–500 lux range.

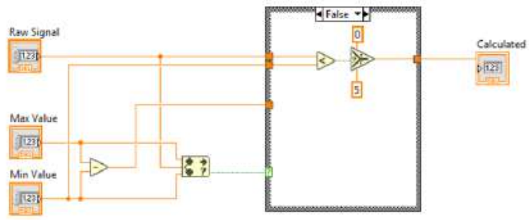


Figure 8: Voltage Range (Block Diagram)

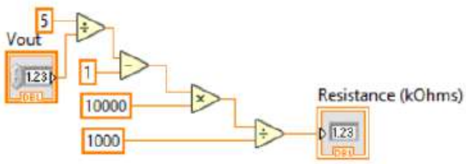


Figure 9: LDR Measured Resistance (kOhms) (Block Diagram)

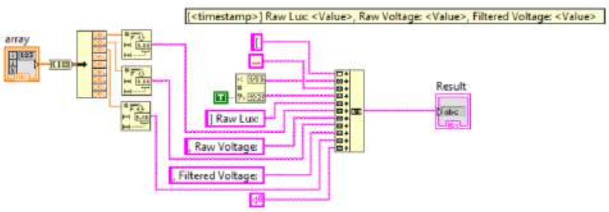


Figure 10: File I/O (Block Diagram)

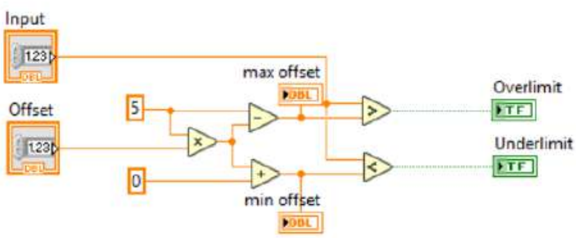


Figure 11: Result Conditions (Block Diagram)

3.3 Data Display/Presentation

The LabVIEW front panel provided a graphical interface for real-time monitoring. Key features included:

1) Waveform Graphs: Displaying raw, filtered, and calculated signals simultaneously.

2) Numeric Indicators: Showing highest and lowest measured voltages, LDR resistance, and estimated lux.

3) Threshold Alerts: Colour-coded indicators labelled "Too Dim" (<100 lux) and "Too Bright" (>500 lux).

4) Status LEDs: Virtual LEDs representing system states, synchronised with physical LEDs on the NI ELVIS II board.

This interface allowed users to visually interpret system behaviour and verify lux conditions at a glance.

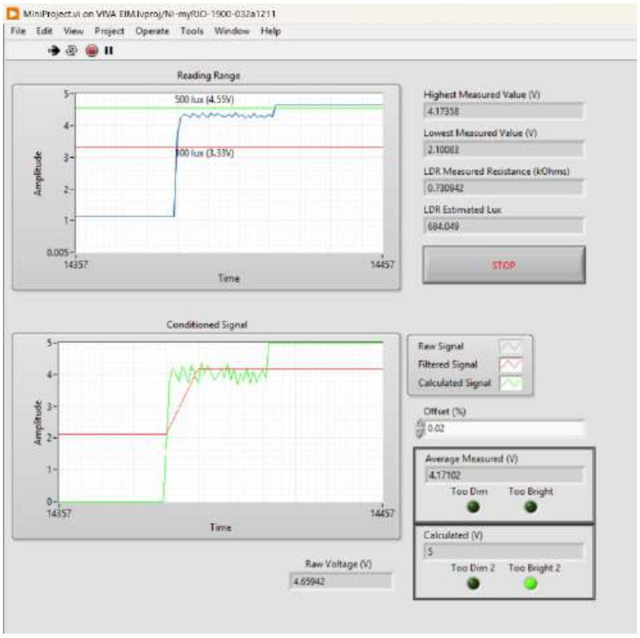


Figure 12: Main Loop (Front Panel)

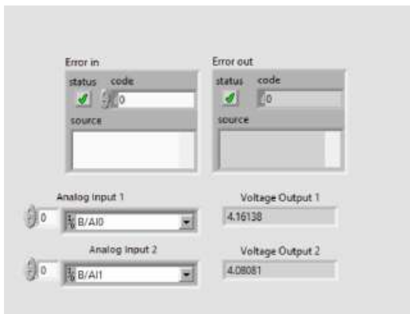


Figure 13: Analog Signal (Front Panel)

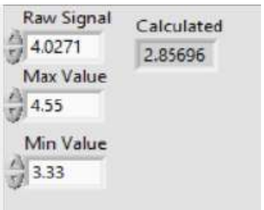


Figure 14: Voltage Range (Front Panel)

Figure 15: LDR Measured Resistance (kOhms) (Front Panel)

Figure 16: File I/O (Front Panel)

Figure 16: Result Conditions (Front Panel)

3.4 Datalogging

A dedicated LabVIEW VI was developed for data logging. Voltage and lux readings were written to a text file (`myProject.txt`) in real time, with timestamps included for traceability. The log file contained raw voltage, filtered voltage, and calculated lux values, enabling post-experiment analysis and validation. The use of LabVIEW's "Write to Measurement File" function ensured structured data storage compatible with external analysis tools.

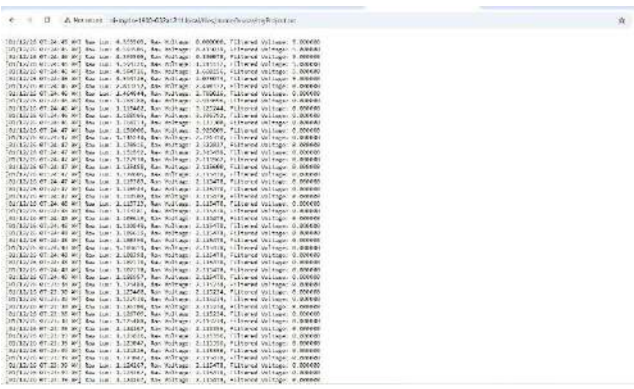


Figure 17: Data Logging NI MAX

3.5 Actuator Control

The processed lux data was used to drive actuators via digital output pins on the NI ELVIS II board and ESP8266 microcontroller. Control logic implemented in LabVIEW triggered:

1) LED Indicators: Green LED for normal range (100–500 lux), Red LED for over-bright (>500 lux), and Blue LED for under-dim (<100 lux).

2) Buzzer: Activated when lux exceeded thresholds, providing audible alerts.

3) Wireless Control: Lux values were transmitted to ESP8266, which adjusted external lighting modules through IoT-based commands.

This closed-loop control ensured that ambient illumination was maintained within the desired ergonomic range, combining hardware actuation with wireless scalability.

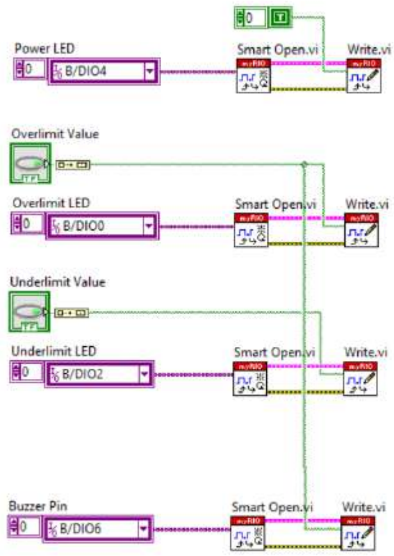


Figure 18: LEDs and Buzzer Controller (Block Diagram)

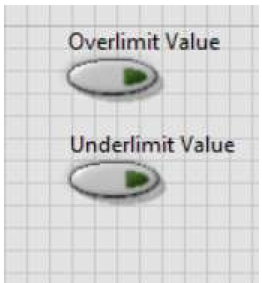


Figure 19: LEDs and Buzzer Controller (Front Panel)

4.0 Result and Discussion

The Ambient Lux Monitor system was tested under controlled indoor lighting conditions to

evaluate its performance within the specified illumination range of 100–500 lux. The results demonstrate that the integration of the LDR transducer, signal conditioning circuit, NI

myRIO, and wireless control module operates reliably and consistently.

Experimental results show that the system successfully converts variations in ambient light into corresponding voltage changes, which are accurately mapped to lux values using the calibration model implemented in LabVIEW. At low illumination levels (approximately 100 lux), the system generated stable voltage readings near the lower calibration threshold, while higher illumination levels (approximately 500 lux) produced voltages close to the upper limit. The linear interpolation approach ensured smooth and accurate lux estimation across the operating range.

The moving average filtering technique effectively reduced noise and short-term fluctuations caused by ambient disturbances, resulting in stable real-time readings. Threshold detection logic performed as intended, correctly identifying under-illuminated and over-illuminated conditions. Visual indicators and actuator responses, including LEDs and buzzer alerts, were triggered promptly when lux levels exceeded predefined limits, confirming correct control logic implementation.

Wireless communication using the ESP8266 module enabled remote monitoring and control. Lux data transmitted from the processing unit was received reliably, with minimal latency. To enhance system usability, the implementation can be extended by integrating Telegram as a notification medium. By using Telegram bots, real-time lux alerts, threshold warnings, and system status updates can be sent directly to users' mobile devices. This feature would significantly improve accessibility, remote supervision, and practical deployment in smart building and office environments.

Overall, the results validate that the proposed system achieves accurate lux monitoring, responsive actuation, and reliable wireless communication, making it suitable for smart lighting and energy-efficient applications.

5.0 Conclusion

This project successfully designed and implemented an Ambient Lux Monitor capable of accurately measuring and controlling indoor illumination within the range of 100–500 lux. By utilising an LDR as the primary transducer, combined with signal conditioning, NI MyRIO based data acquisition, and LabVIEW processing, the system delivers reliable real-time lux monitoring and threshold-based decision making.

The integration of wireless communication via the ESP8266 enhances system flexibility and scalability. The proposed extension of Telegram-based notifications provides a practical and user-friendly solution for remote monitoring and alert delivery, aligning with modern Internet of Things (IoT) applications.

In conclusion, the developed system demonstrates strong potential for deployment in smart offices, classrooms, and residential environments where ergonomic lighting and energy efficiency are critical. Future work may include cloud-based data storage, advanced calibration techniques, and adaptive control algorithms to further improve accuracy and system intelligence.

Data Sheet

Light dependent resistors

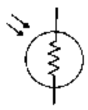
NORP12 RS stock number 651-507
NSL19-M51 RS stock number 596-141

Two cadmium sulphide (cdS) photoconductive cells with spectral responses similar to that of the human eye. The cell resistance falls with increasing light intensity. Applications include smoke detection, automatic lighting control, batch counting and burglar alarm systems.

Guide to source illuminations

Light source	Illumination (Lux)
Moonlight	0.1
60W bulb at 1m	50
1W MES bulb at 0.1m	100
Fluorescent lighting	500
Bright sunlight	30,000

Circuit symbol



Light memory characteristics

Light dependent resistors have a particular property in that they remember the lighting conditions in which they have been stored. This memory effect can be minimised by storing the LDRs in light prior to use. Light storage reduces equilibrium time to reach steady resistance values.

NORP12 (**RS** stock no. 651-507)

Absolute maximum ratings

Voltage, ac or dc peak	320V
Current	75mA
Power dissipation at 30°C	250mW
Operating temperature range	-60°C to +75°C

Electrical characteristics

T_A = 25°C. 2854°K tungsten light source

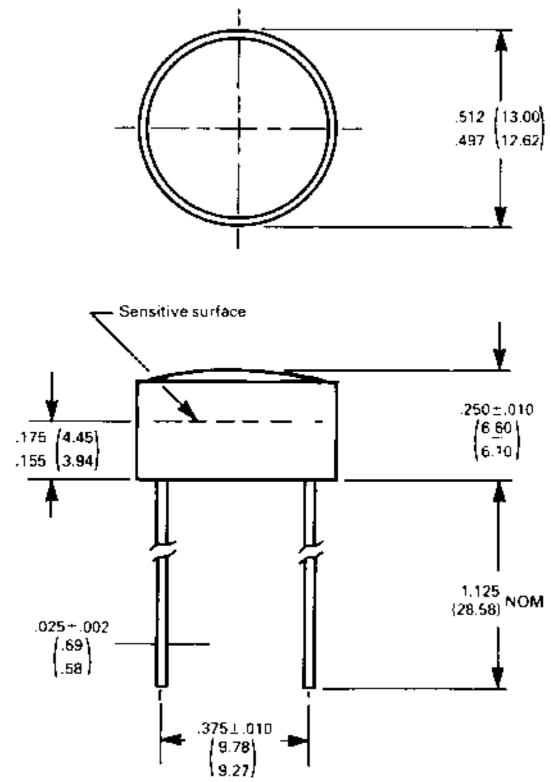
Parameter	Conditions	Min.	Typ.	Max.	Units
Cell resistance	1000 lux 10 lux	- -	400 9	- -	Ω kΩ
Dark resistance	-	1.0	-	-	MΩ
Dark capacitance	-	-	3.5	-	pF
Rise time 1	1000 lux 10 lux	- -	2.8 18	- -	ms ms
Fall time 2	1000 lux 10 lux	- -	48 120	- -	ms ms

1. Dark to 110% R_L
2. To 10 × R_L
R_L = photocell resistance under given illumination.

Features

- Wide spectral response
- Low cost
- Wide ambient temperature range.

Dimensions



Units in inches (millimetres)

Figure 1 Power dissipation derating

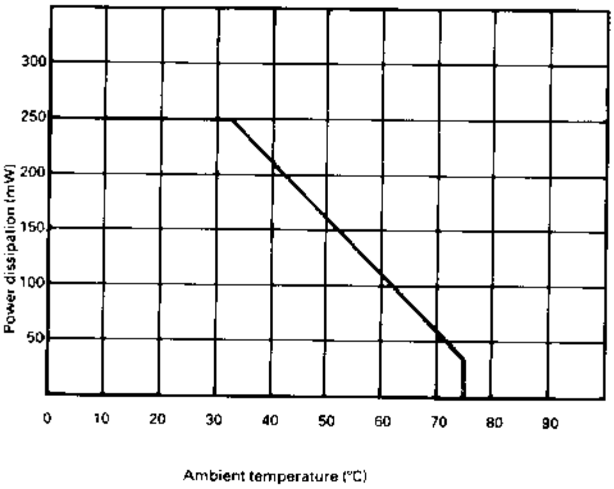
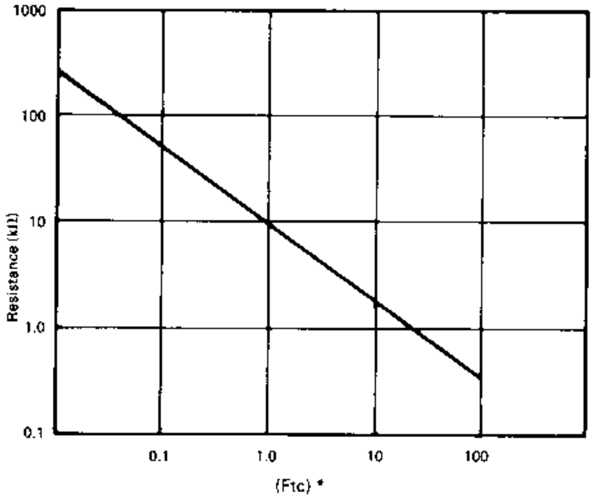
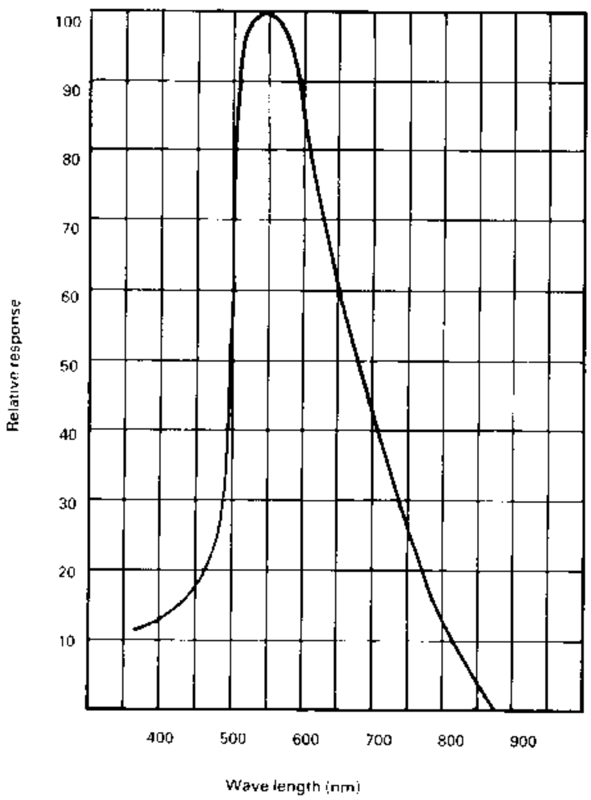


Figure 3 Resistance as a function of illumination



*1Ftc=10.764 lumens

Figure 2 Spectral response



Absolute maximum ratings

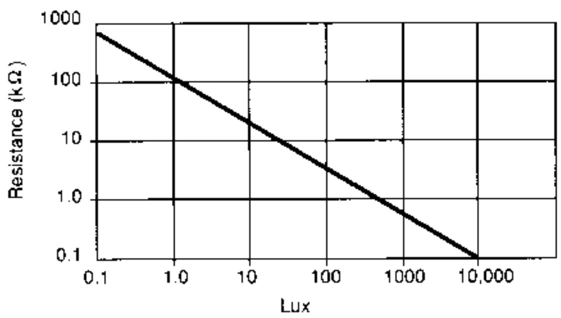
Voltage, ac or dc peak ______ 100V
Current ______ 5mA
Power dissipation at 25°C ______ 50mW*
Operating temperature range ______ -25°C +75°C

*Derate linearly from 50mW at 25°C to 0W at 75°C.

Electrical characteristics

Parameter	Conditions	Min.	Typ.	Max.	Units
Cell resistance	10 lux 100 lux	20 -	- 5	100 -	kΩ kΩ
Dark resistance	10 lux after 10 sec	20	-	-	MΩ
Spectral response	-	-	550	-	nm
Rise time	10ftc	-	45	-	ms
Fall time	10ftc	-	55	-	ms

Figure 4 Resistance as a function illumination



Dimensions

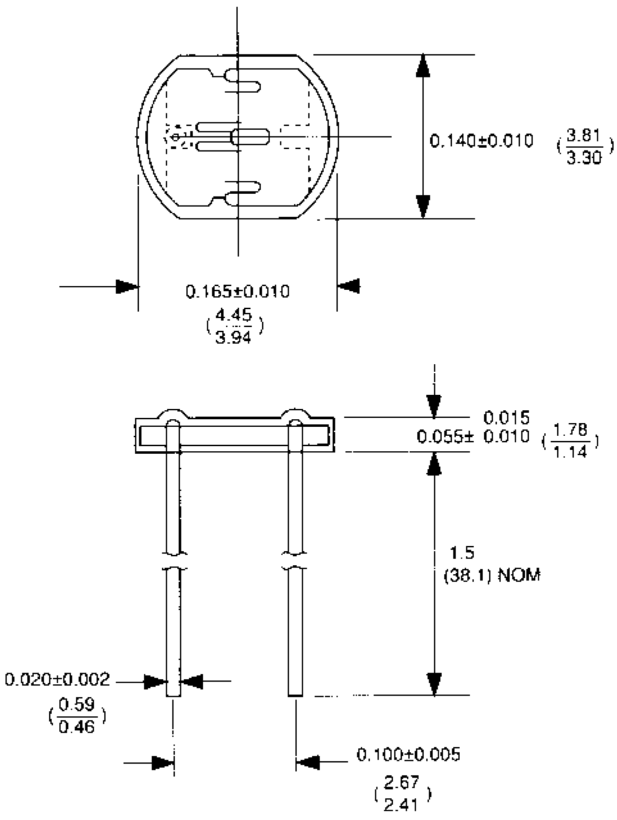
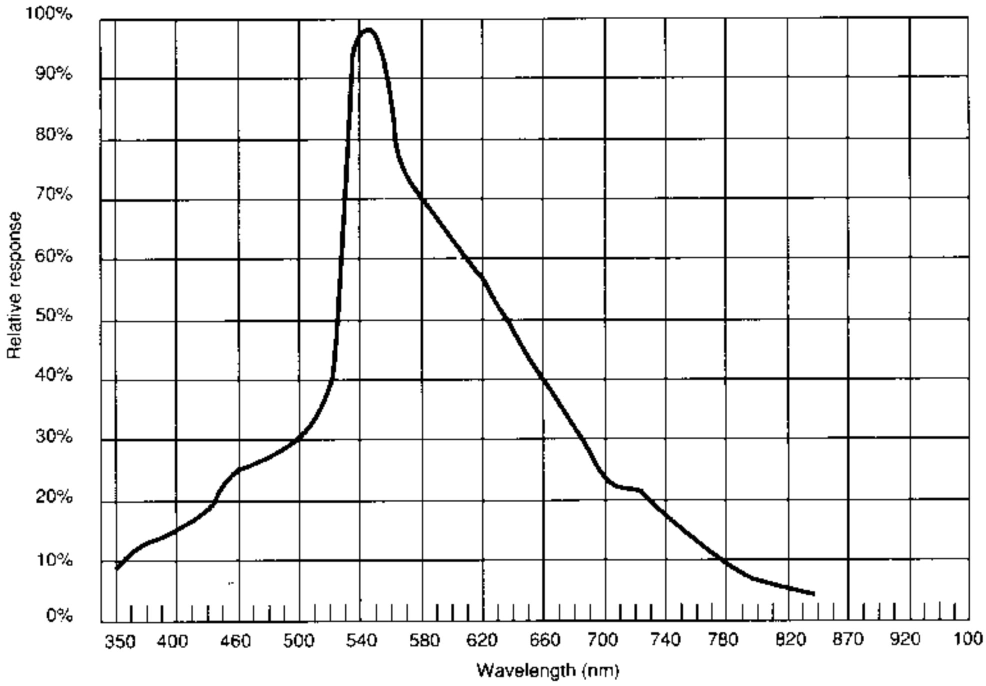
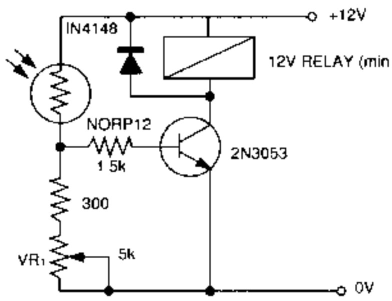


Figure 5 Spectral response



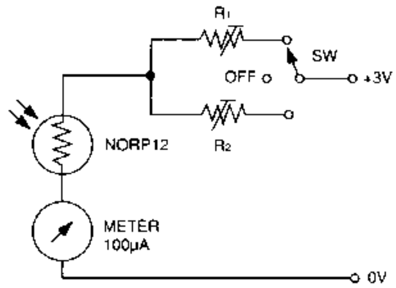
Typical application circuits

Figure 6 Sensitive light operated relay



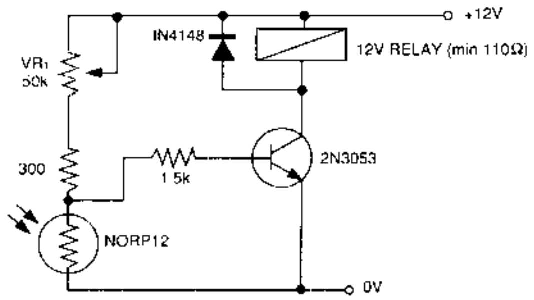
Relay energised when light level increases above the level set by VR_1

Figure 9 Logarithmic law photographic light meter



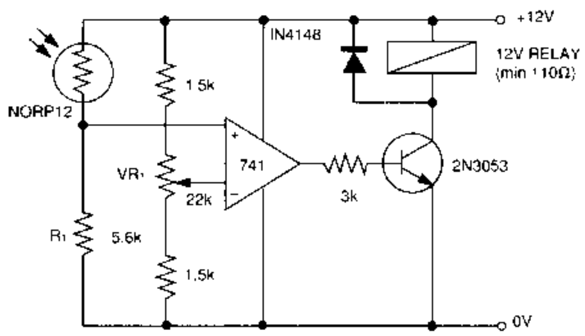
Typical value $R^1 = 100k\Omega$
$R^2 = 200k\Omega$ preset to give two overlapping ranges.
(Calibration should be made against an accurate meter.)

Figure 7 Light interruption detector



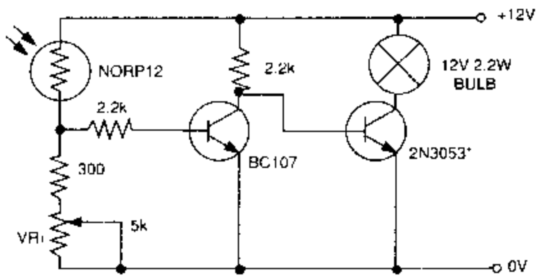
As Figure 6 relay energised when light level drops below the level set by VR_1

Figure 10 Extremely sensitive light operated relay



(Relay energised when light exceeds preset level.) Incorporates a balancing bridge and op-amp. R_1 and NORP12 may be interchanged for the reverse function.

Figure 8 Automatic light circuit



*Fit with RS 50°C/W heatsink

Adjust turn-on point with VR_1

RS Components, PO Box 99, Corby, Northants, NN17 9RS
An Electrocomponents Company
Telephone: 01536 201234

LM741 Operational Amplifier

1 Features

- Overload Protection on the Input and Output
- No Latch-Up When the Common-Mode Range is Exceeded

2 Applications

- Comparators
- Multivibrators
- DC Amplifiers
- Summing Amplifiers
- Integrator or Differentiators
- Active Filters

3 Description

The LM741 series are general-purpose operational amplifiers which feature improved performance over industry standards like the LM709. They are direct, plug-in replacements for the 709C, LM201, MC1439, and 748 in most applications.

The amplifiers offer many features which make their application nearly foolproof: overload protection on the input and output, no latch-up when the common-mode range is exceeded, as well as freedom from oscillations.

The LM741C is identical to the LM741 and LM741A except that the LM741C has their performance ensured over a 0°C to +70°C temperature range, instead of −55°C to +125°C.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM741	TO-99 (8)	9.08 mm × 9.08 mm
	CDIP (8)	10.16 mm × 6.502 mm
	PDIP (8)	9.81 mm × 6.35 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Typical Application

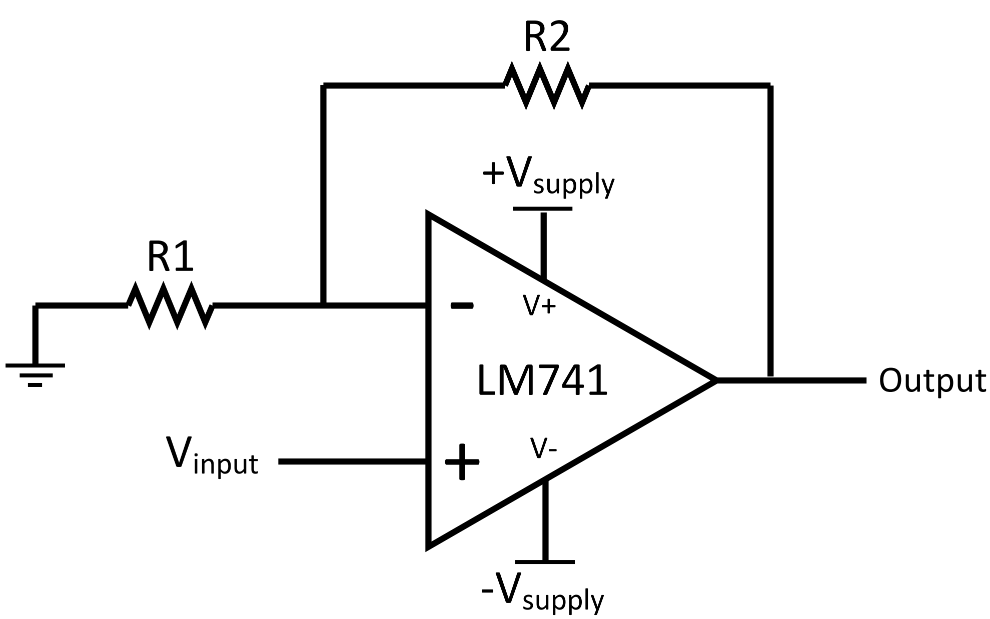


Table of Contents

4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision C (October 2004) to Revision D **Page**

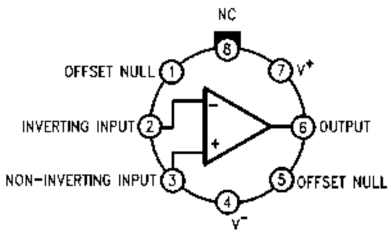
- Added *Applications* section, *Pin Configuration and Functions* section, *ESD Ratings* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section 1
- Removed NAD 10-Pin CLGA pinout 3
- Removed obselete M (S0-8) package from the data sheet 4
- Added recommended operating supply voltage spec 4
- Added recommended operating temperature spec 4

Changes from Revision C (March 2013) to Revision D **Page**

- Added *Applications* section, *Pin Configuration and Functions* section, *ESD Ratings* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section 1
- Removed NAD 10-Pin CLGA pinout 3
- Removed obselete M (S0-8) package from the data sheet 4
- Added recommended operating supply voltage spec 4
- Added recommended operating temperature spec 4

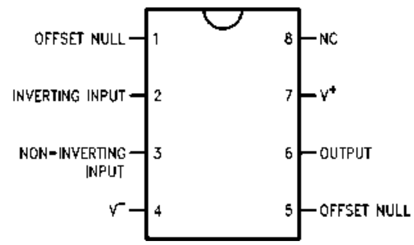
5 Pin Configuration and Functions

LMC Package
8-Pin TO-99
Top View



LM741H is available per JM38510/10101

NAB Package
8-Pin CDIP or PDIP
Top View



Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
INVERTING INPUT	2	I	Inverting signal input
NC	8	N/A	No Connect, should be left floating
NONINVERTING INPUT	3	I	Noninverting signal input
OFFSET NULL	1, 5	I	Offset null pin used to eliminate the offset voltage and balance the input voltages.
OFFSET NULL			
OUTPUT	6	O	Amplified signal output
V+	7	I	Positive supply voltage
V–	4	I	Negative supply voltage

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)[(1)(2)(3)]

		MIN	MAX	UNIT
Supply voltage	LM741, LM741A		±22	V
	LM741C		±18	
Power dissipation [(4)]			500	mW
Differential input voltage			±30	V
Input voltage [(5)]			±15	V
Output short circuit duration		Continuous		
Operating temperature	LM741, LM741A	–50	125	°C
	LM741C	0	70	
Junction temperature	LM741, LM741A		150	°C
	LM741C		100	
Soldering information	PDIP package (10 seconds)		260	°C
	CDIP or TO-99 package (10 seconds)		300	°C
Storage temperature, T_{stg}		–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) For military specifications see RETS741X for LM741 and RETS741AX for LM741A.
(3) If Military/Aerospace specified devices are required, please contact the TI Sales Office/Distributors for availability and specifications.
(4) For operation at elevated temperatures, these devices must be derated based on thermal resistance, and T_j max. (listed under “Absolute Maximum Ratings”). $T_j = T_A + (\theta_{jA} P_D)$.
(5) For supply voltages less than ±15 V, the absolute maximum input voltage is equal to the supply voltage.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001[(1)]	±400	V

(1) Level listed above is the passing level per ANSI, ESDA, and JEDEC JS-001. JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	NOM	MAX	UNIT
Supply voltage (VDD-GND)	LM741, LM741A	±10	±15	±22	V
	LM741C	±10	±15	±18	
Temperature	LM741, LM741A	–55		125	°C
	LM741C	0		70	

6.4 Thermal Information

THERMAL METRIC[(1)]		LM741			UNIT
		LMC (TO-99)	NAB (CDIP)	P (PDIP)	
		8 PINS	8 PINS	8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	170	100	100	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	25	—	—	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, SPRA953.

6.5 Electrical Characteristics, LM741[(1)]

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
Input offset voltage		$R_S \le 10\ k\Omega$	$T_A = 25°C$		1	5	mV
			$T_{AMIN} \le T_A \le T_{AMAX}$			6	mV
Input offset voltage adjustment range		$T_A = 25°C$, $V_S = \pm 20\ V$			±15		mV
Input offset current		$T_A = 25°C$			20	200	nA
		$T_{AMIN} \le T_A \le T_{AMAX}$			85	500	
Input bias current		$T_A = 25°C$			80	500	nA
		$T_{AMIN} \le T_A \le T_{AMAX}$				1.5	μA
Input resistance		$T_A = 25°C$, $V_S = \pm 20\ V$		0.3	2		MΩ
Input voltage range		$T_{AMIN} \le T_A \le T_{AMAX}$		±12	±13		V
Large signal voltage gain		$V_S = \pm 15\ V$, $V_O = \pm 10\ V$, $R_L \ge 2\ k\Omega$	$T_A = 25°C$	50	200		V/mV
			$T_{AMIN} \le T_A \le T_{AMAX}$	25			
Output voltage swing		$V_S = \pm 15\ V$	$R_L \ge 10\ k\Omega$	±12	±14		V
			$R_L \ge 2\ k\Omega$	±10	±13		
Output short circuit current		$T_A = 25°C$			25		mA
Common-mode rejection ratio		$R_S \le 10\ \Omega$, $V_{CM} = \pm 12\ V$, $T_{AMIN} \le T_A \le T_{AMAX}$		80	95		dB
Supply voltage rejection ratio		$V_S = \pm 20\ V$ to $V_S = \pm 5\ V$, $R_S \le 10\ \Omega$, $T_{AMIN} \le T_A \le T_{AMAX}$		86	96		dB
Transient response	Rise time	$T_A = 25°C$, unity gain			0.3		μs
	Overshoot				5%		
Slew rate		$T_A = 25°C$, unity gain			0.5		V/μs
Supply current		$T_A = 25°C$			1.7	2.8	mA
Power consumption		$V_S = \pm 15\ V$	$T_A = 25°C$		50	85	mW
			$T_A = T_{AMIN}$		60	100	
			$T_A = T_{AMAX}$		45	75	

(1) Unless otherwise specified, these specifications apply for $V_S = \pm 15\ V$, $-55°C \le T_A \le +125°C$ (LM741/LM741A). For the LM741C/LM741E, these specifications are limited to $0°C \le T_A \le +70°C$.

6.6 Electrical Characteristics, LM741A[(1)]

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Input offset voltage	$R_S \le 50\ \Omega$	$T_A = 25°C$		0.8	3	mV
		$T_{AMIN} \le T_A \le T_{AMAX}$			4	mV
Average input offset voltage drift					15	μV/°C
Input offset voltage adjustment range	$T_A = 25°C$, $V_S = \pm 20\ V$		±10			mV
Input offset current	$T_A = 25°C$			3	30	nA
	$T_{AMIN} \le T_A \le T_{AMAX}$				70	
Average input offset current drift					0.5	nA/°C
Input bias current	$T_A = 25°C$			30	80	nA
	$T_{AMIN} \le T_A \le T_{AMAX}$				0.21	μA
Input resistance	$T_A = 25°C$, $V_S = \pm 20\ V$		1	6		MΩ
	$T_{AMIN} \le T_A \le T_{AMAX}$, $V_S = \pm 20\ V$		0.5			
Large signal voltage gain	$V_S = \pm 20\ V$, $V_O = \pm 15\ V$, $R_L \ge 2\ k\Omega$	$T_A = 25°C$	50			V/mV
		$T_{AMIN} \le T_A \le T_{AMAX}$	32			
	$V_S = \pm 5\ V$, $V_O = \pm 2\ V$, $R_L \ge 2\ k\Omega$, $T_{AMIN} \le T_A \le T_{AMAX}$		10			

(1) Unless otherwise specified, these specifications apply for $V_S = \pm 15\ V$, $-55°C \le T_A \le +125°C$ (LM741/LM741A). For the LM741C/LM741E, these specifications are limited to $0°C \le T_A \le +70°C$.

Electrical Characteristics, LM741A(1) (continued)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
Output voltage swing		V_S = ±20 V	R_L ≥ 10 kΩ	±16			V
			R_L ≥ 2 kΩ	±15			
Output short circuit current		T_A = 25°C		10	25	35	mA
		T_{AMIN} ≤ T_A ≤ T_{AMAX}		10		40	
Common-mode rejection ratio		R_S ≤ 50 Ω, V_{CM} = ±12 V, T_{AMIN} ≤ T_A ≤ T_{AMAX}		80	95		dB
Supply voltage rejection ratio		V_S = ±20 V to V_S = ±5 V, R_S ≤ 50 Ω, T_{AMIN} ≤ T_A ≤ T_{AMAX}		86	96		dB
Transient response	Rise time	T_A = 25°C, unity gain			0.25	0.8	µs
	Overshoot				6%	20%	
Bandwidth (2)		T_A = 25°C		0.437	1.5		MHz
Slew rate		T_A = 25°C, unity gain		0.3	0.7		V/µs
Power consumption		V_S = ±20 V	T_A = 25°C		80	150	mW
			T_A = T_{AMIN}			165	
			T_A = T_{AMAX}			135	

(2) Calculated value from: BW (MHz) = 0.35/Rise Time (µs).

6.7 Electrical Characteristics, LM741C(1)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
Input offset voltage		R_S ≤ 10 kΩ	T_A = 25°C		2	6	mV
			T_{AMIN} ≤ T_A ≤ T_{AMAX}			7.5	mV
Input offset voltage adjustment range		T_A = 25°C, V_S = ±20 V			±15		mV
Input offset current		T_A = 25°C			20	200	nA
		T_{AMIN} ≤ T_A ≤ T_{AMAX}				300	
Input bias current		T_A = 25°C			80	500	nA
		T_{AMIN} ≤ T_A ≤ T_{AMAX}				0.8	µA
Input resistance		T_A = 25°C, V_S = ±20 V		0.3	2		MΩ
Input voltage range		T_A = 25°C		±12	±13		V
Large signal voltage gain		V_S = ±15 V, V_O = ±10 V, R_L ≥ 2 kΩ	T_A = 25°C	20	200		V/mV
			T_{AMIN} ≤ T_A ≤ T_{AMAX}	15			
Output voltage swing		V_S = ±15 V	R_L ≥ 10 kΩ	±12	±14		V
			R_L ≥ 2 kΩ	±10	±13		
Output short circuit current		T_A = 25°C			25		mA
Common-mode rejection ratio		R_S ≤ 10 kΩ, V_{CM} = ±12 V, T_{AMIN} ≤ T_A ≤ T_{AMAX}		70	90		dB
Supply voltage rejection ratio		V_S = ±20 V to V_S = ±5 V, R_S ≤ 10 Ω, T_{AMIN} ≤ T_A ≤ T_{AMAX}		77	96		dB
Transient response	Rise time	T_A = 25°C, Unity Gain			0.3		µs
	Overshoot				5%		
Slew rate		T_A = 25°C, Unity Gain			0.5		V/µs
Supply current		T_A = 25°C			1.7	2.8	mA
Power consumption		V_S = ±15 V, T_A = 25°C			50	85	mW

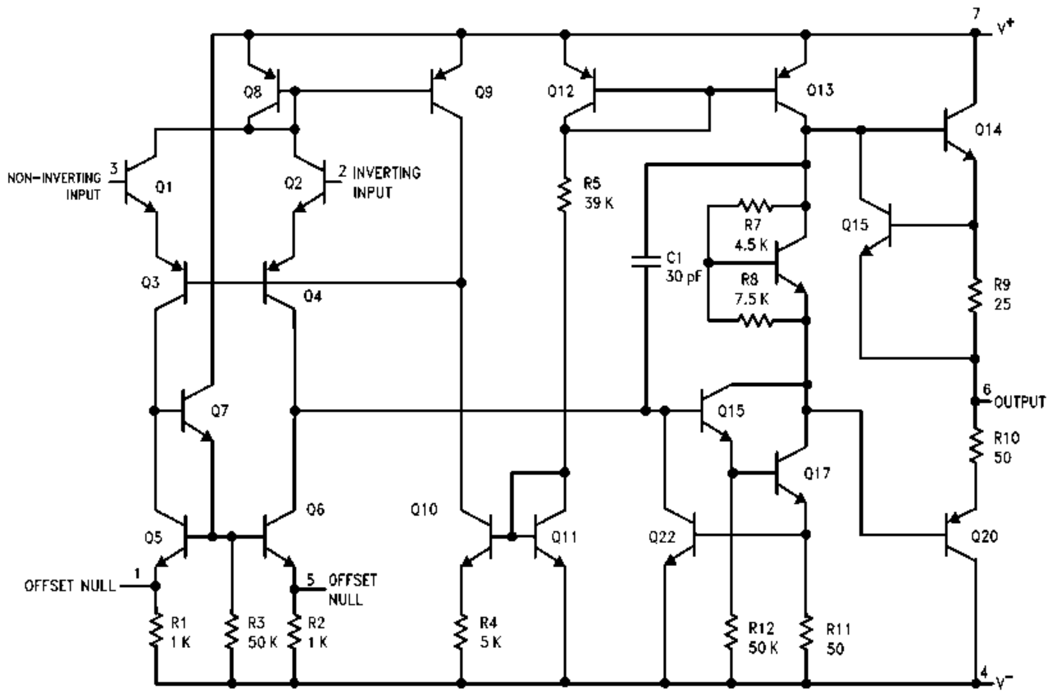
(1) Unless otherwise specified, these specifications apply for V_S = ±15 V, −55°C ≤ T_A ≤ +125°C (LM741/LM741A). For the LM741C/LM741E, these specifications are limited to 0°C ≤ T_A ≤ +70°C.

7 Detailed Description

7.1 Overview

The LM74 devices are general-purpose operational amplifiers which feature improved performance over industry standards like the LM709. It is intended for a wide range of analog applications. The high gain and wide range of operating voltage provide superior performance in integrator, summing amplifier, and general feedback applications. The LM741 can operate with a single or dual power supply voltage. The LM741 devices are direct, plug-in replacements for the 709C, LM201, MC1439, and 748 in most applications.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 Overload Protection

The LM741 features overload protection circuitry on the input and output. This prevents possible circuit damage to the device.

7.3.2 Latch-up Prevention

The LM741 is designed so that there is no latch-up occurrence when the common-mode range is exceeded. This allows the device to function properly without having to power cycle the device.

7.3.3 Pin-to-Pin Capability

The LM741 is pin-to-pin direct replacements for the LM709C, LM201, MC1439, and LM748 in most applications. Direct replacement capabilities allows flexibility in design for replacing obsolete parts.

7.4 Device Functional Modes

7.4.1 Open-Loop Amplifier

The LM741 can be operated in an open-loop configuration. The magnitude of the open-loop gain is typically large thus for a small difference between the noninverting and inverting input terminals, the amplifier output will be driven near the supply voltage. Without negative feedback, the LM741 can act as a comparator. If the inverting input is held at 0 V, and the input voltage applied to the noninverting input is positive, the output will be positive. If the input voltage applied to the noninverting input is negative, the output will be negative.

7.4.2 Closed-Loop Amplifier

In a closed-loop configuration, negative feedback is used by applying a portion of the output voltage to the inverting input. Unlike the open-loop configuration, closed loop feedback reduces the gain of the circuit. The overall gain and response of the circuit is determined by the feedback network rather than the operational amplifier characteristics. The response of the operational amplifier circuit is characterized by the transfer function.

8 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

The LM741 is a general-purpose amplifier than can be used in a variety of applications and configurations. One common configuration is in a noninverting amplifier configuration. In this configuration, the output signal is in phase with the input (not inverted as in the inverting amplifier configuration), the input impedance of the amplifier is high, and the output impedance is low. The characteristics of the input and output impedance is beneficial for applications that require isolation between the input and output. No significant loading will occur from the previous stage before the amplifier. The gain of the system is set accordingly so the output signal is a factor larger than the input signal.

8.2 Typical Application

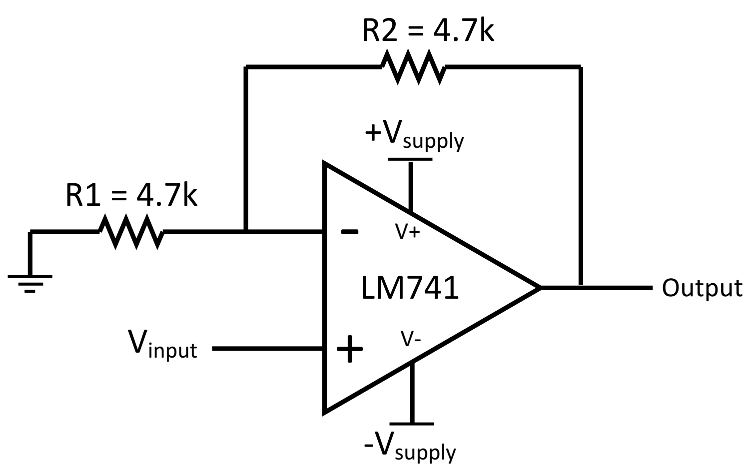


Figure 1. LM741 Noninverting Amplifier Circuit

8.2.1 Design Requirements

As shown in Figure 1, the signal is applied to the noninverting input of the LM741. The gain of the system is determined by the feedback resistor and input resistor connected to the inverting input. The gain can be calculated by Equation 1:

$$\text{Gain} = 1 + (R2/R1) \tag{1}$$

The gain is set to 2 for this application. R1 and R2 are 4.7-k resistors with 5% tolerance.

8.2.2 Detailed Design Procedure

The LM741 can be operated in either single supply or dual supply. This application is configured for dual supply with the supply rails at ±15 V. The input signal is connected to a function generator. A 1-Vpp, 10-kHz sine wave was used as the signal input. 5% tolerance resistors were used, but if the application requires an accurate gain response, use 1% tolerance resistors.

Typical Application (continued)

8.2.3 Application Curve

The waveforms in Figure 2 show the input and output signals of the LM741 non-inverting amplifier circuit. The blue waveform (top) shows the input signal, while the red waveform (bottom) shows the output signal. The input signal is 1.06 Vpp and the output signal is 1.94 Vpp. With the 4.7-kΩ resistors, the theoretical gain of the system is 2. Due to the 5% tolerance, the gain of the system including the tolerance is 1.992. The gain of the system when measured from the mean amplitude values on the oscilloscope was 1.83.

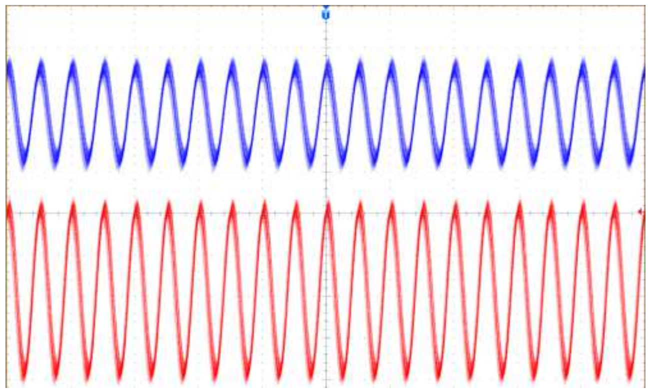


Figure 2. Waveforms for LM741 Noninverting Amplifier Circuit

9 Power Supply Recommendations

For proper operation, the power supplies must be properly decoupled. For decoupling the supply lines, a 0.1-µF capacitor is recommended and should be placed as close as possible to the LM741 power supply pins.

10 Layout

10.1 Layout Guidelines

As with most amplifiers, take care with lead dress, component placement, and supply decoupling in order to ensure stability. For example, resistors from the output to an input should be placed with the body close to the input to minimize pick-up and maximize the frequency of the feedback pole by minimizing the capacitance from the input to ground. As shown in Figure 3, the feedback resistors and the decoupling capacitors are located close to the device to ensure maximum stability and noise performance of the system.

10.2 Layout Example

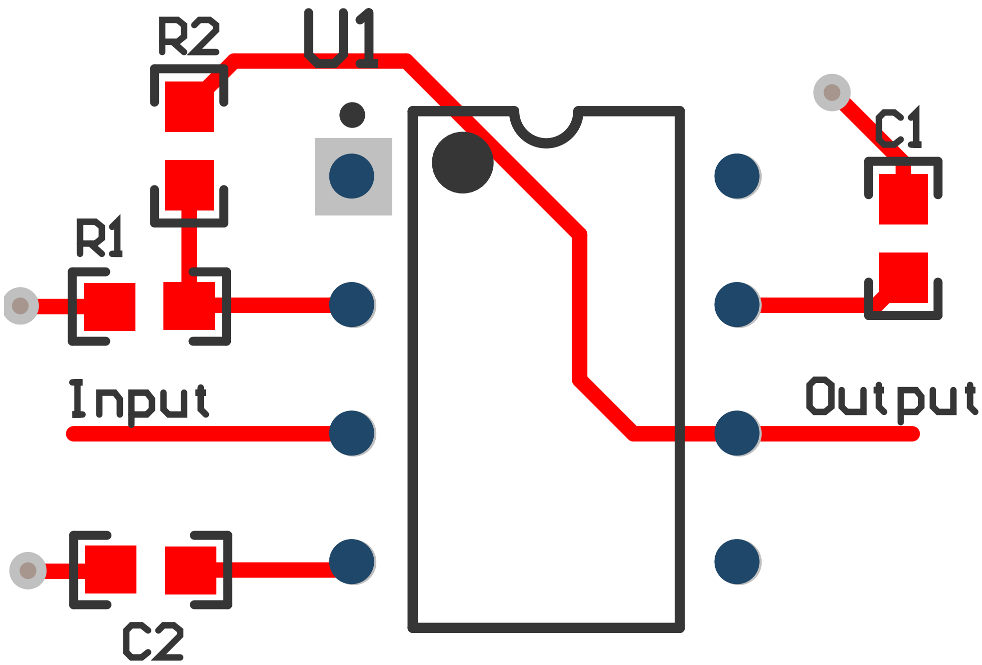


Figure 3. LM741 Layout

11 Device and Documentation Support

11.1 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

TI E2E™ Online Community ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

11.2 Trademarks

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

11.3 Electrostatic Discharge Caution

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

11.4 Glossary

SLYZ022 — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
LM741C-MWC	Active	Production	WAFERSALE (YS) | 0	1 | null	Yes	Call TI	Level-1-NA-UNLIM	-40 to 85	
LM741C-MWC.B	Active	Production	WAFERSALE (YS) | 0	1 | null	-	Call TI	Level-1-NA-UNLIM	-40 to 85	
LM741CN/NOPB	Active	Production	PDIP (P) | 8	40 | TUBE	Yes	NIPDAU	Level-1-NA-UNLIM	0 to 70	LM 741CN
LM741CN/NOPB.B	Active	Production	PDIP (P) | 8	40 | TUBE	Yes	NIPDAU	Level-1-NA-UNLIM	0 to 70	LM 741CN
LM741CN/NOPBG4	Active	Production	PDIP (P) | 8	40 | TUBE	Yes	NIPDAU	Level-1-NA-UNLIM	-40 to 85	LM 741CN
LM741CN/NOPBG4.B	Active	Production	PDIP (P) | 8	40 | TUBE	Yes	NIPDAU	Level-1-NA-UNLIM	-40 to 85	LM 741CN

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

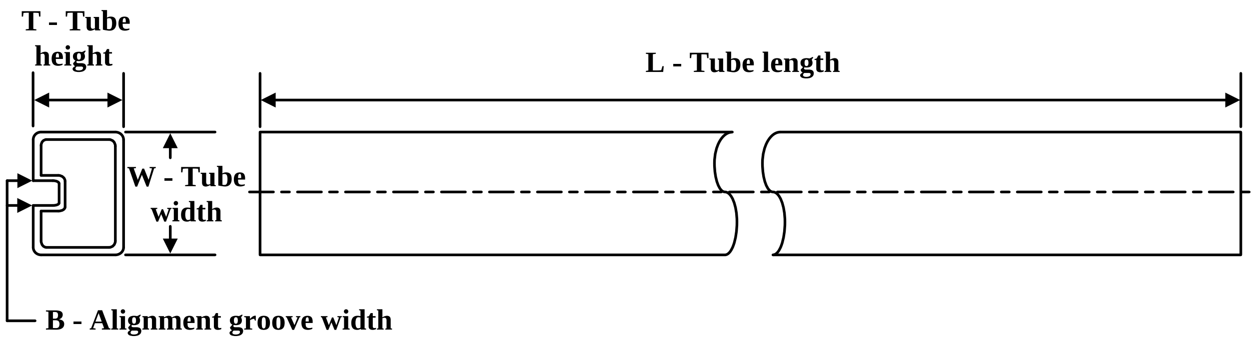
(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

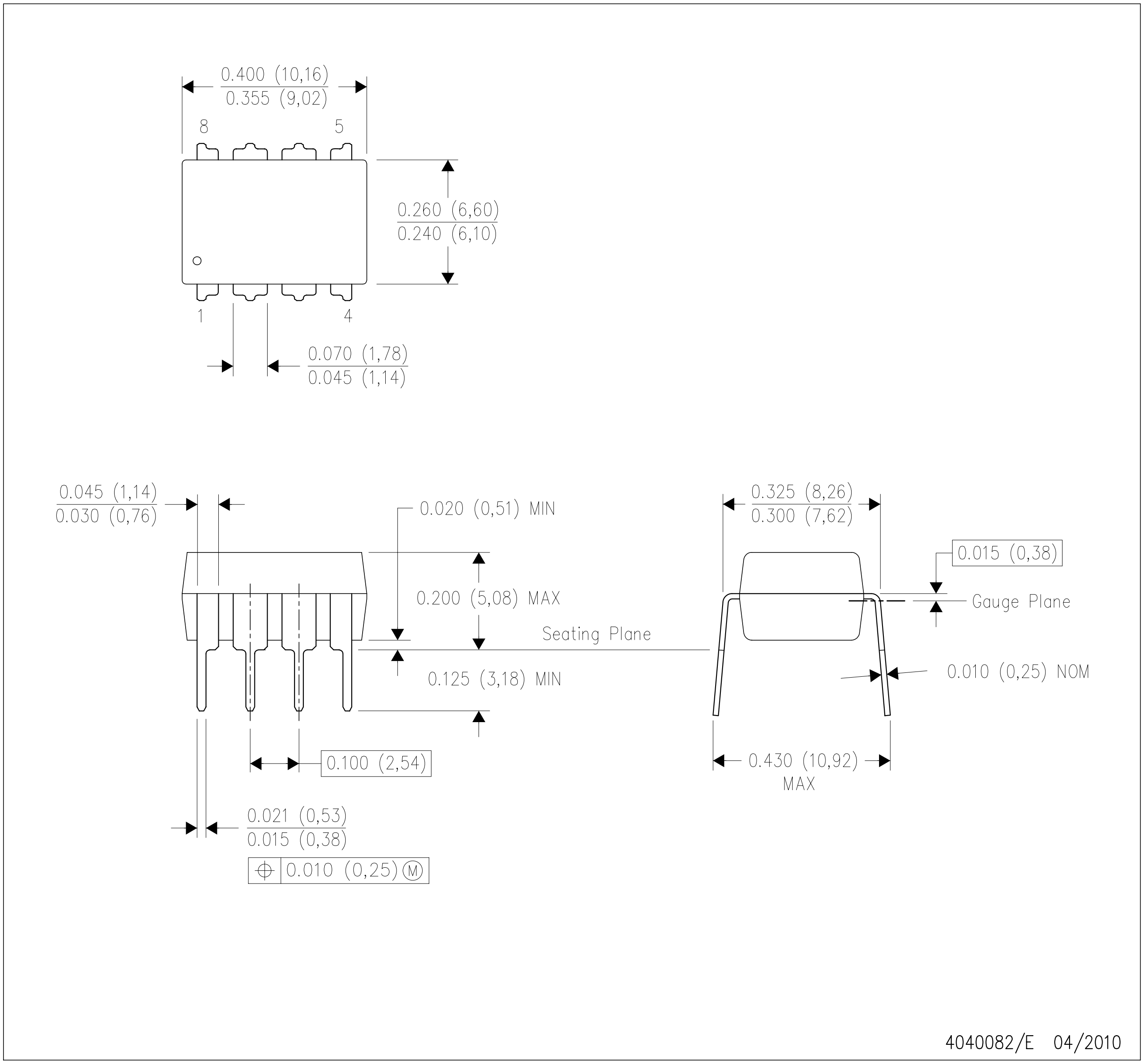
TUBE



*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (µm)	B (mm)
LM741CN/NOPB	P	PDIP	8	40	502	14	11938	4.32
LM741CN/NOPB.B	P	PDIP	8	40	502	14	11938	4.32
LM741CN/NOPBG4	P	PDIP	8	40	502	14	11938	4.32
LM741CN/NOPBG4.B	P	PDIP	8	40	502	14	11938	4.32

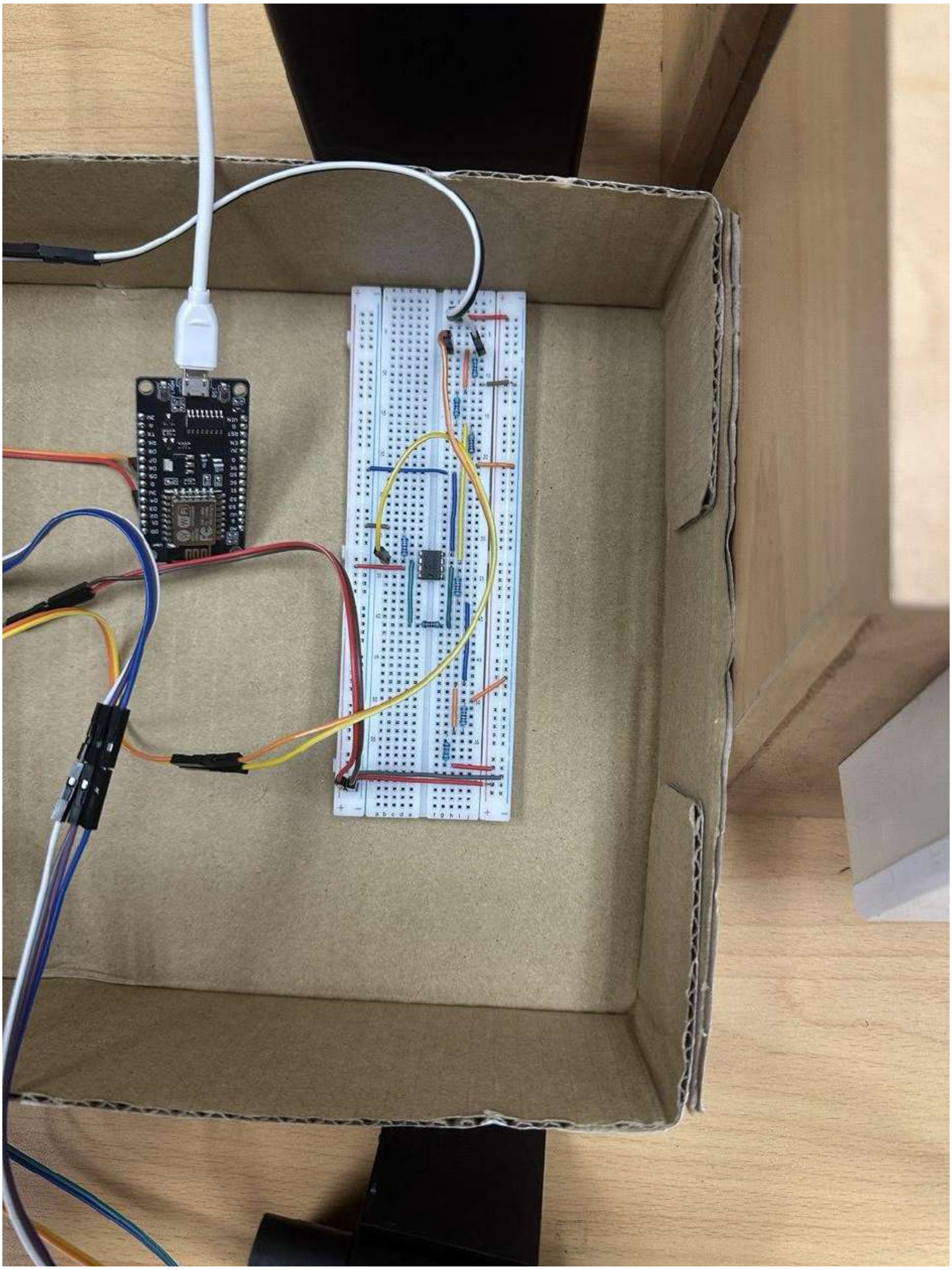
P (R-PDIP-T8) PLASTIC DUAL-IN-LINE PACKAGE

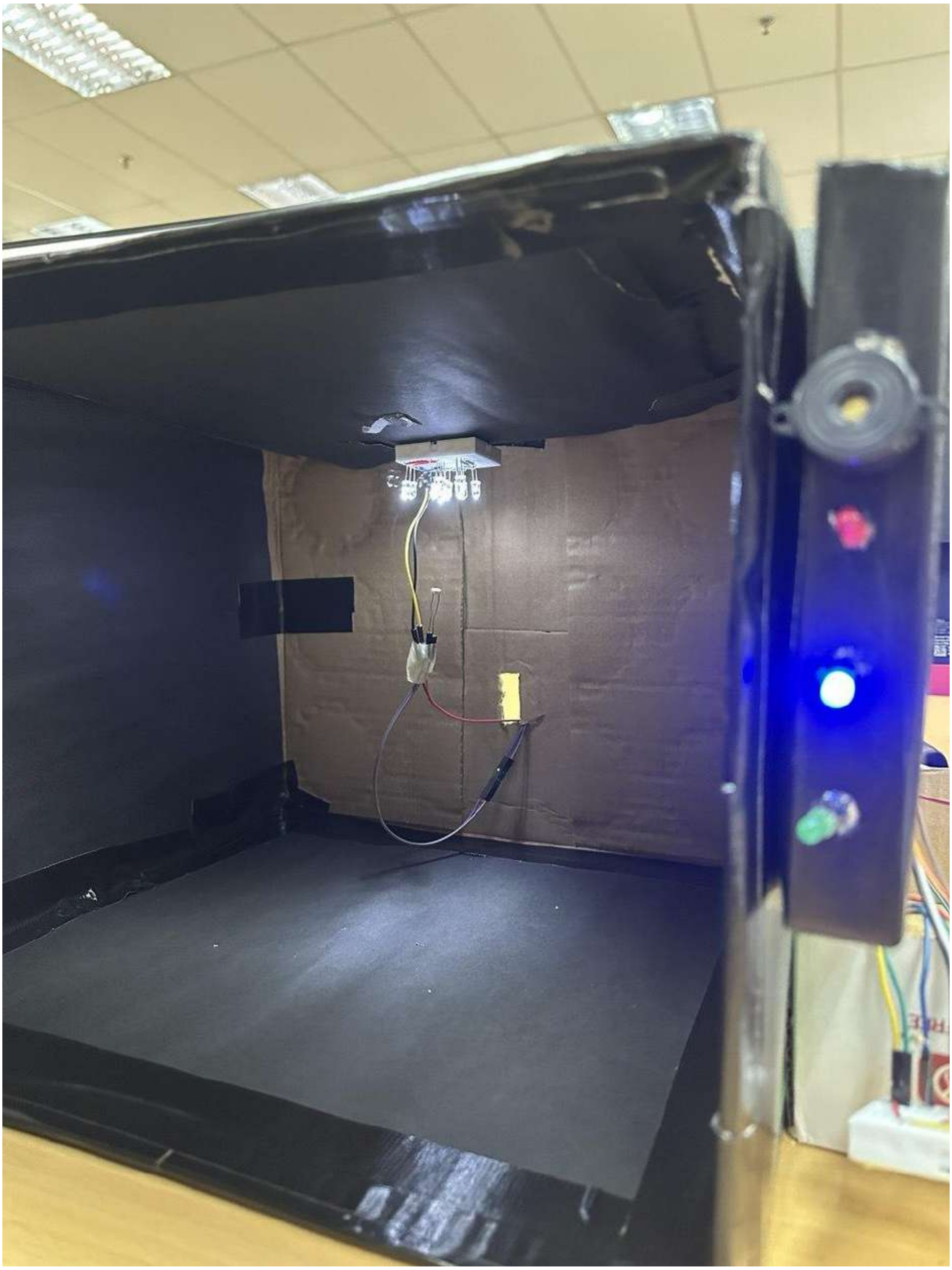


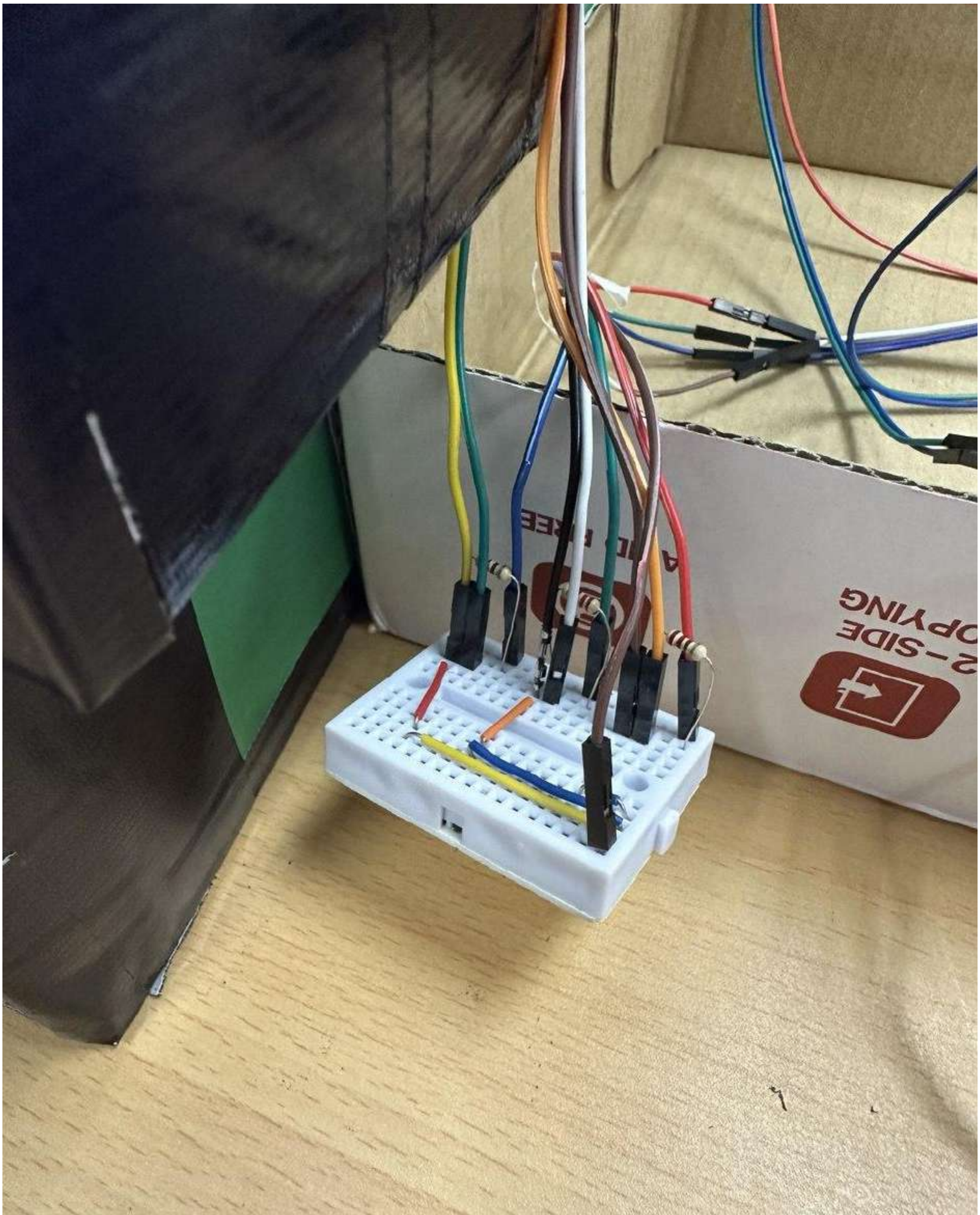
NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS-001 variation BA.

8.0 Appendix

85
2-SIDE
COPYING
INKJET
LASER
COPY
Buzzer
Blue
DGND
UGREEN





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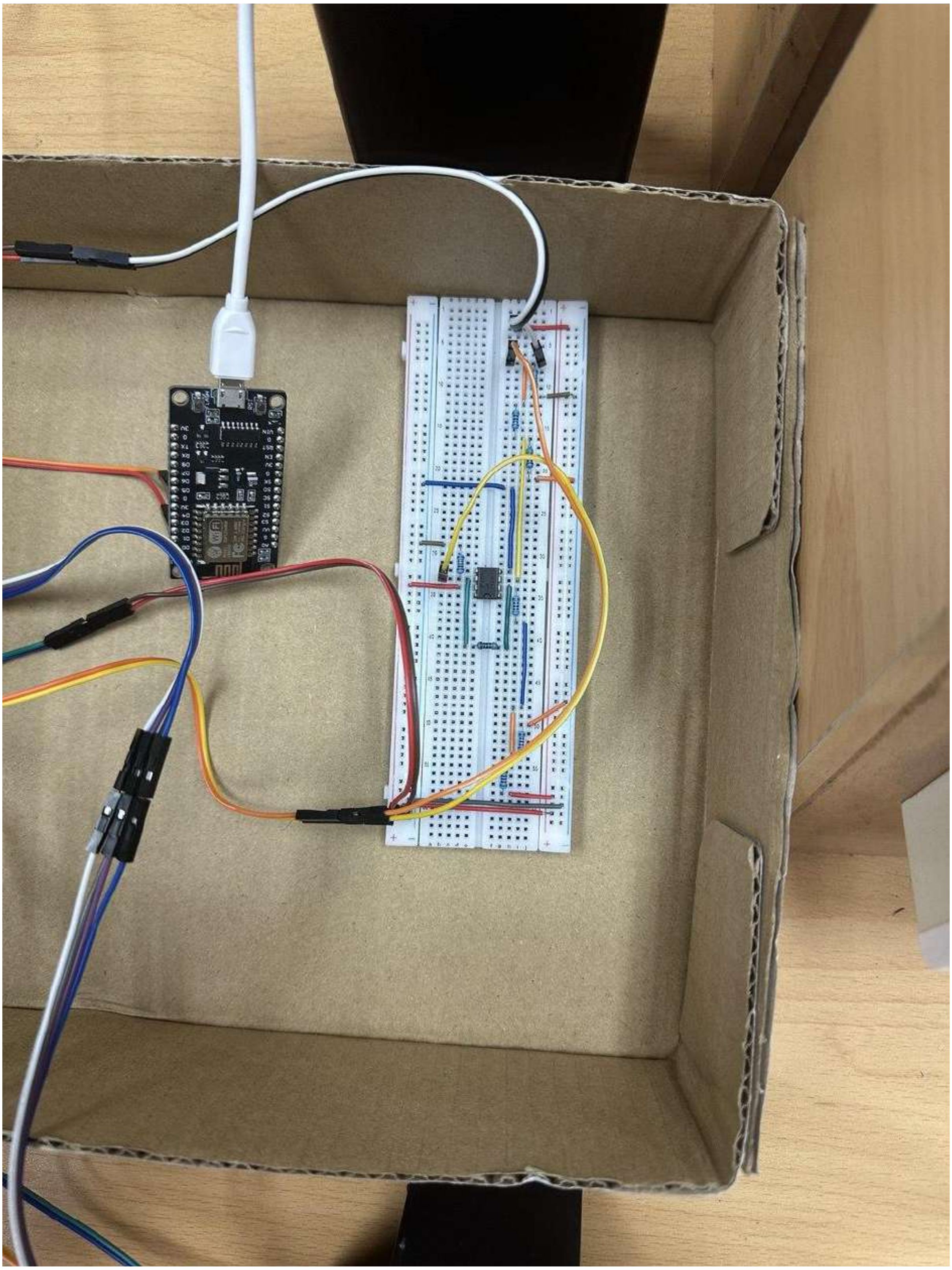

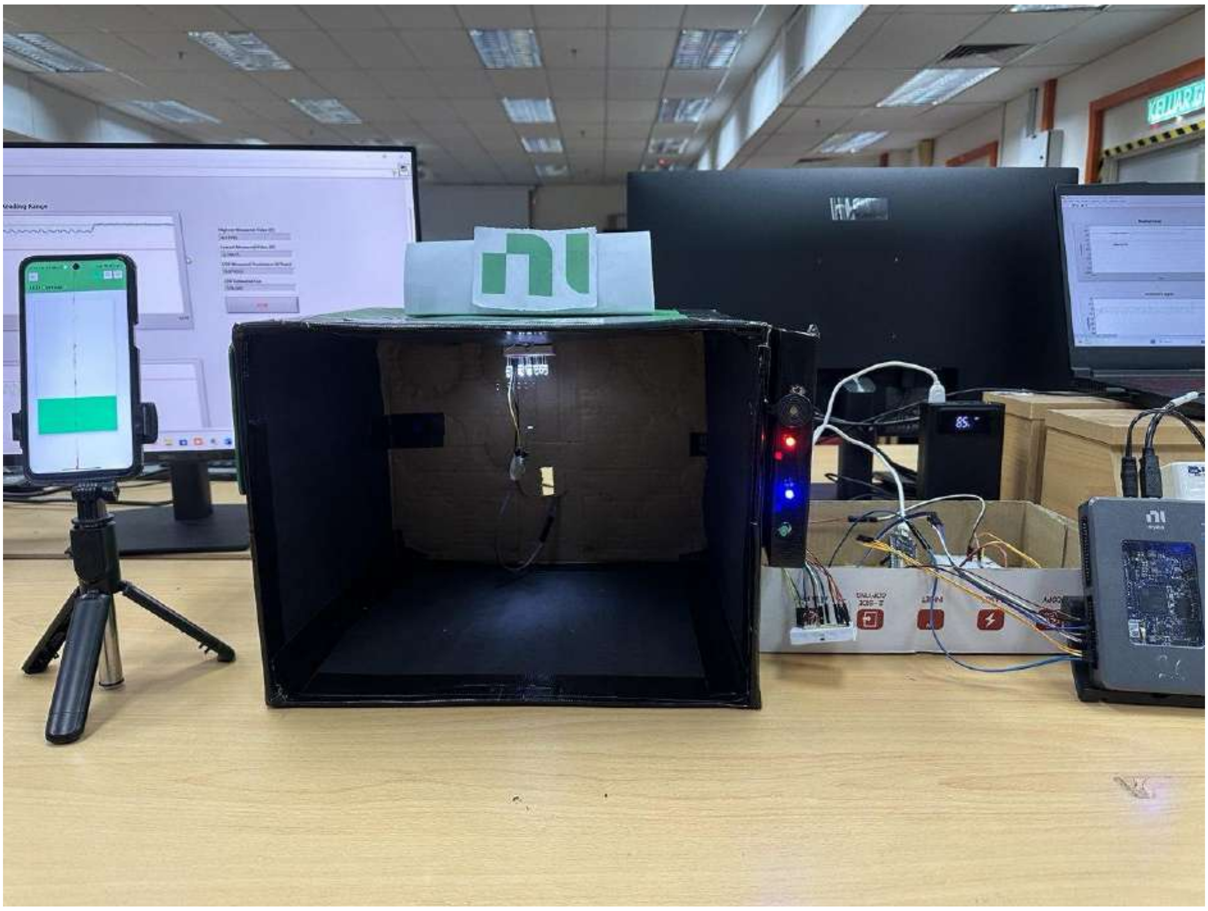

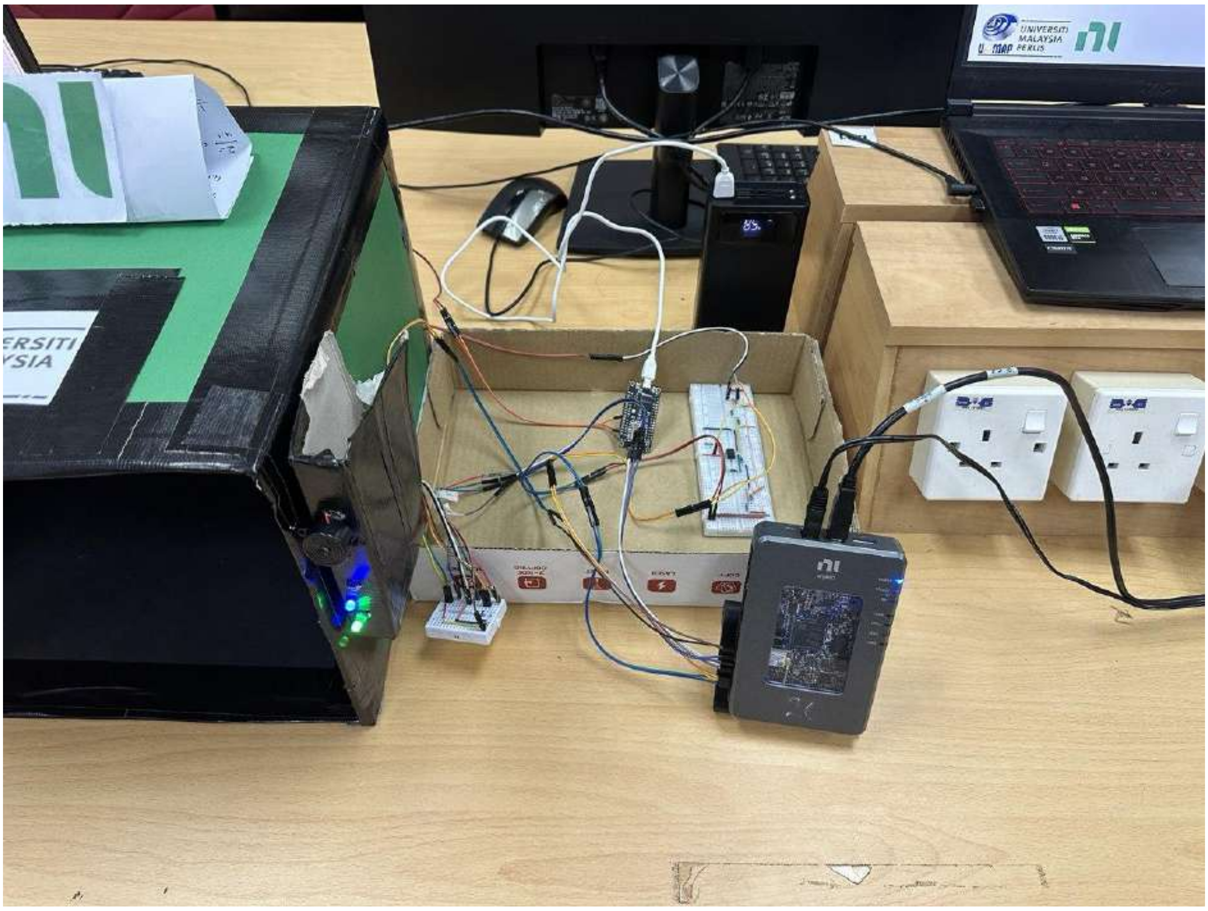
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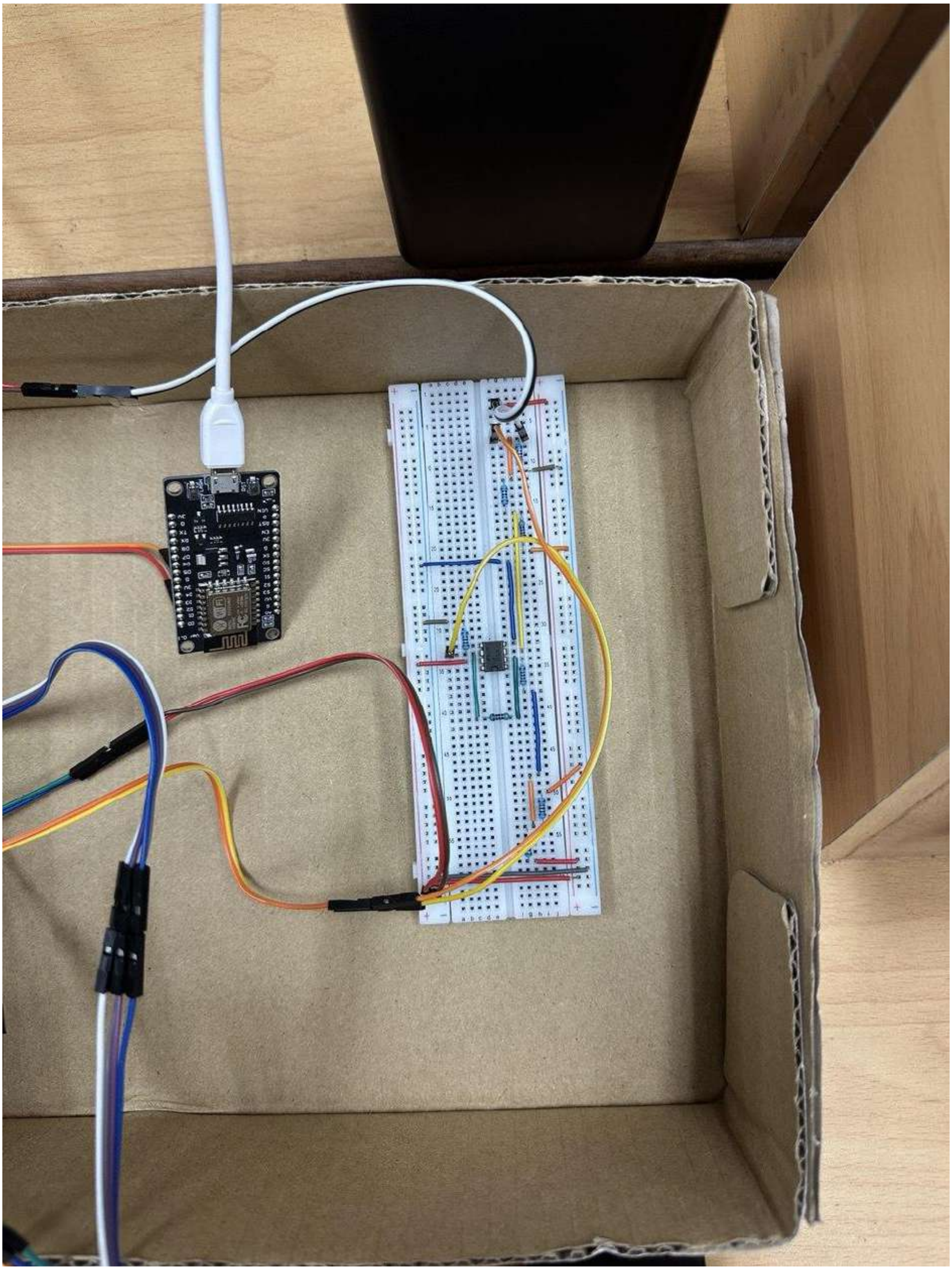

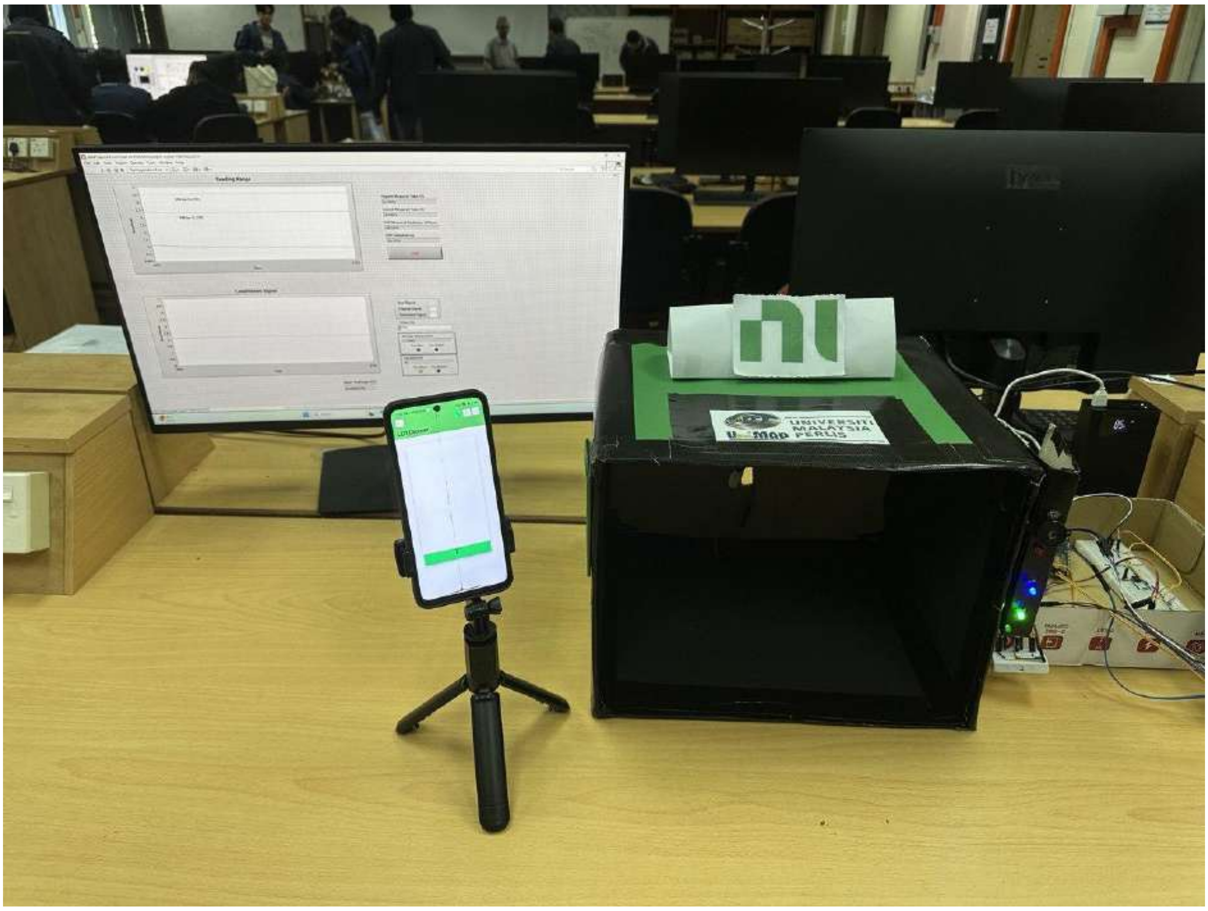
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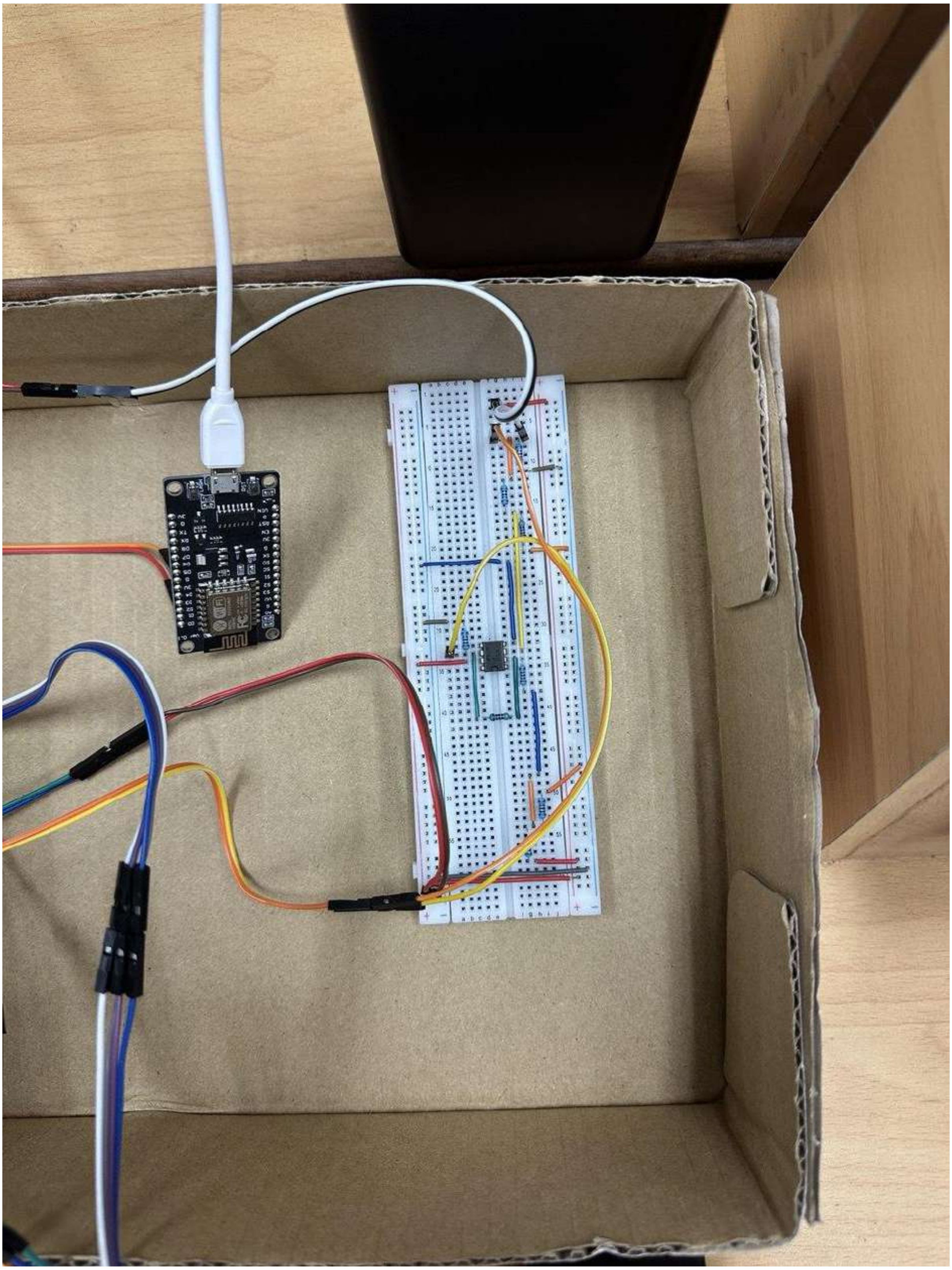

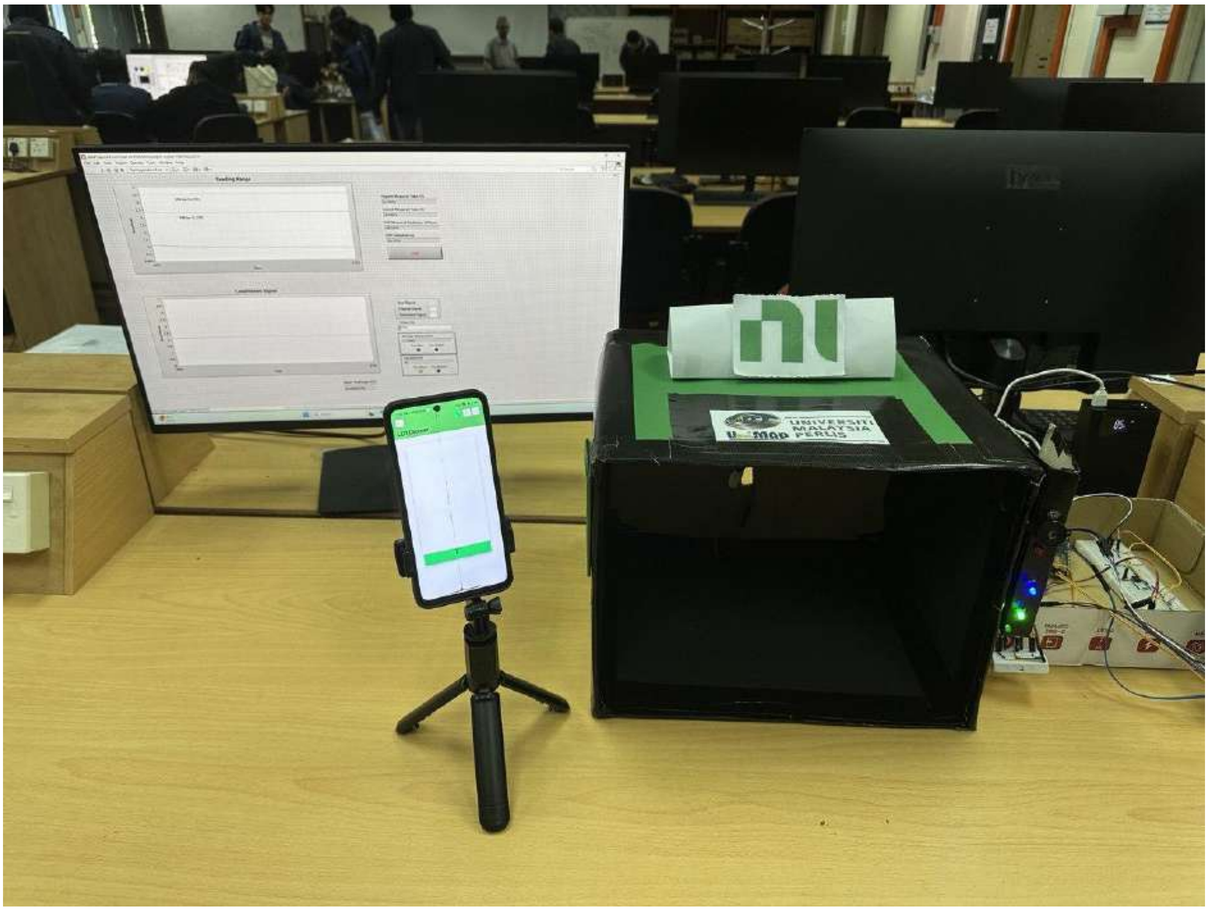
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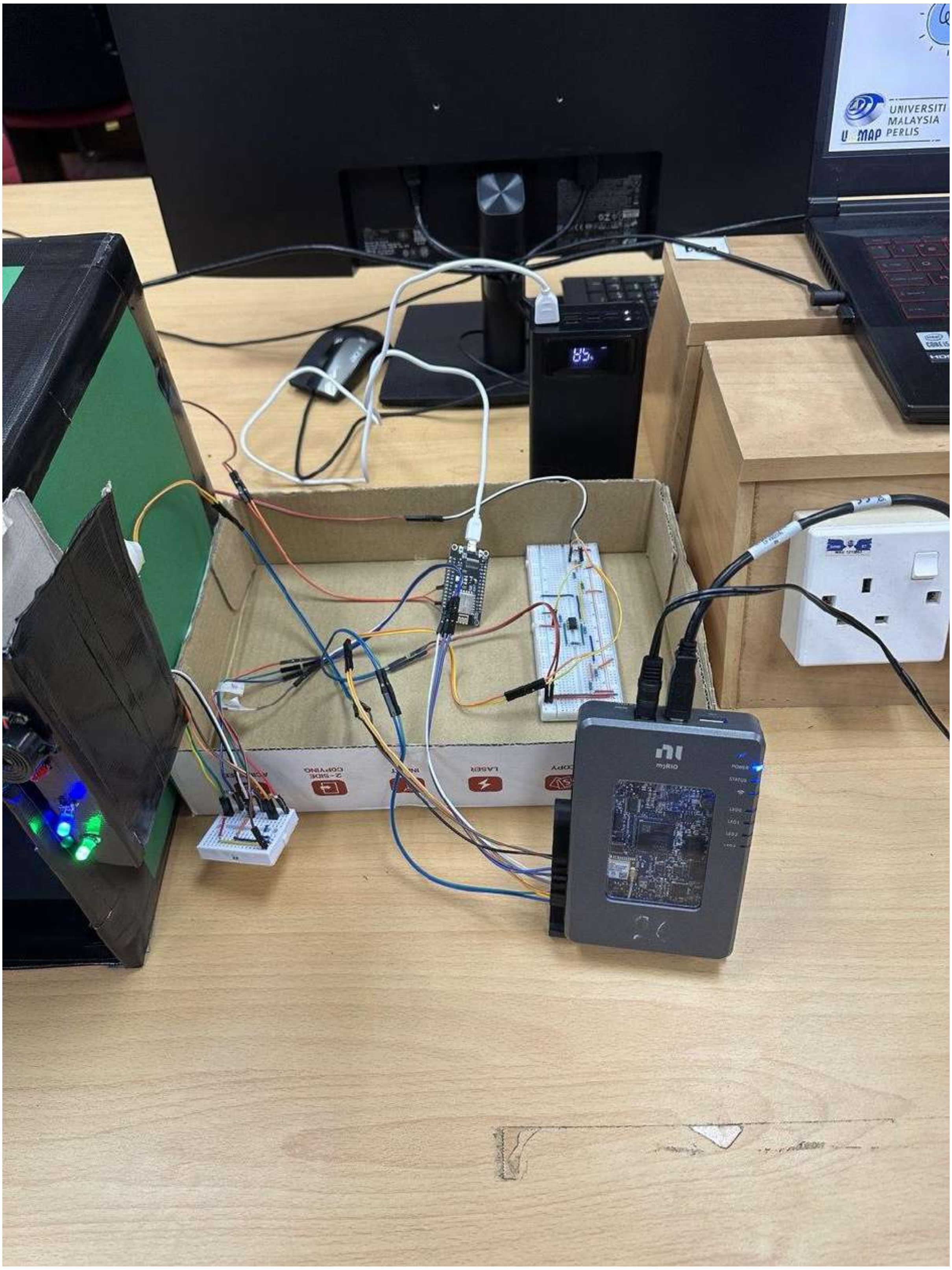
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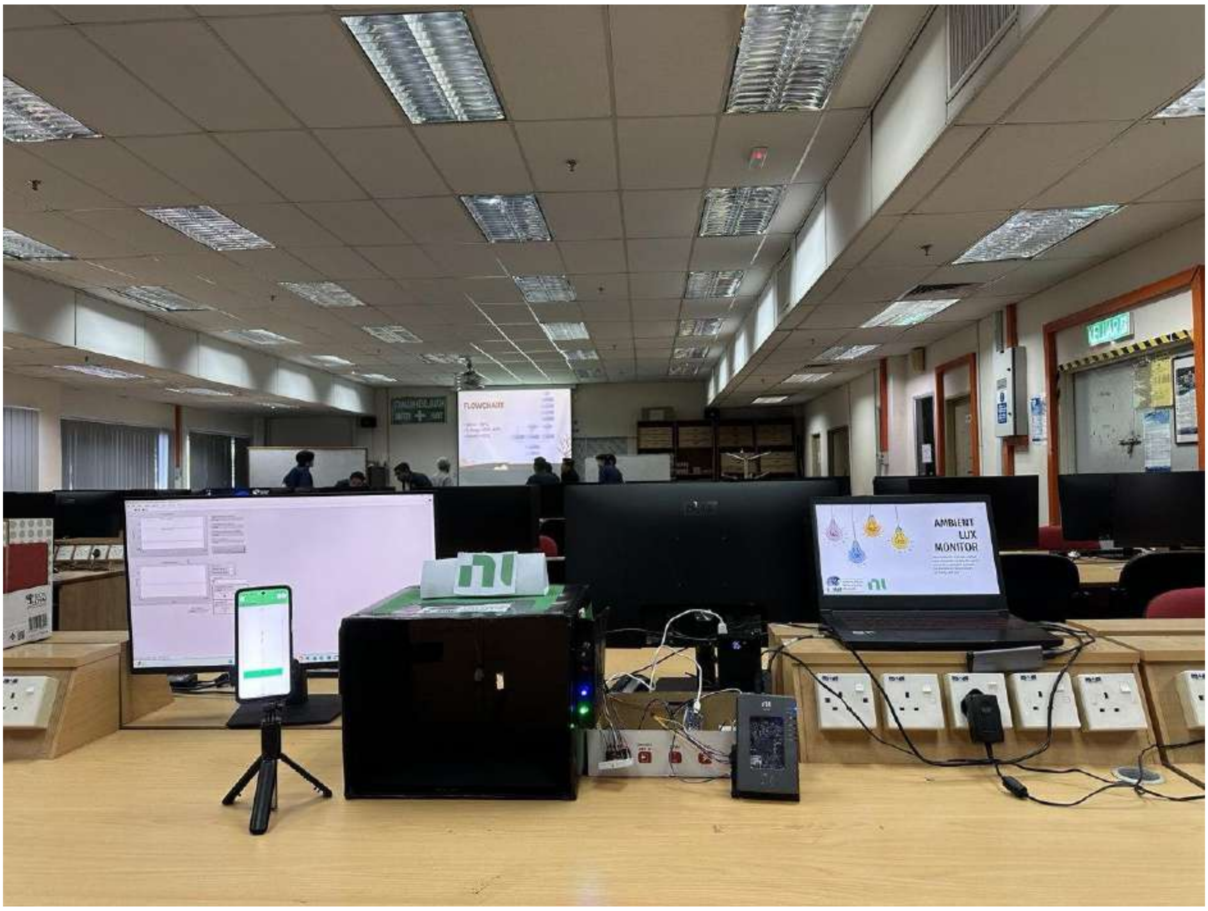
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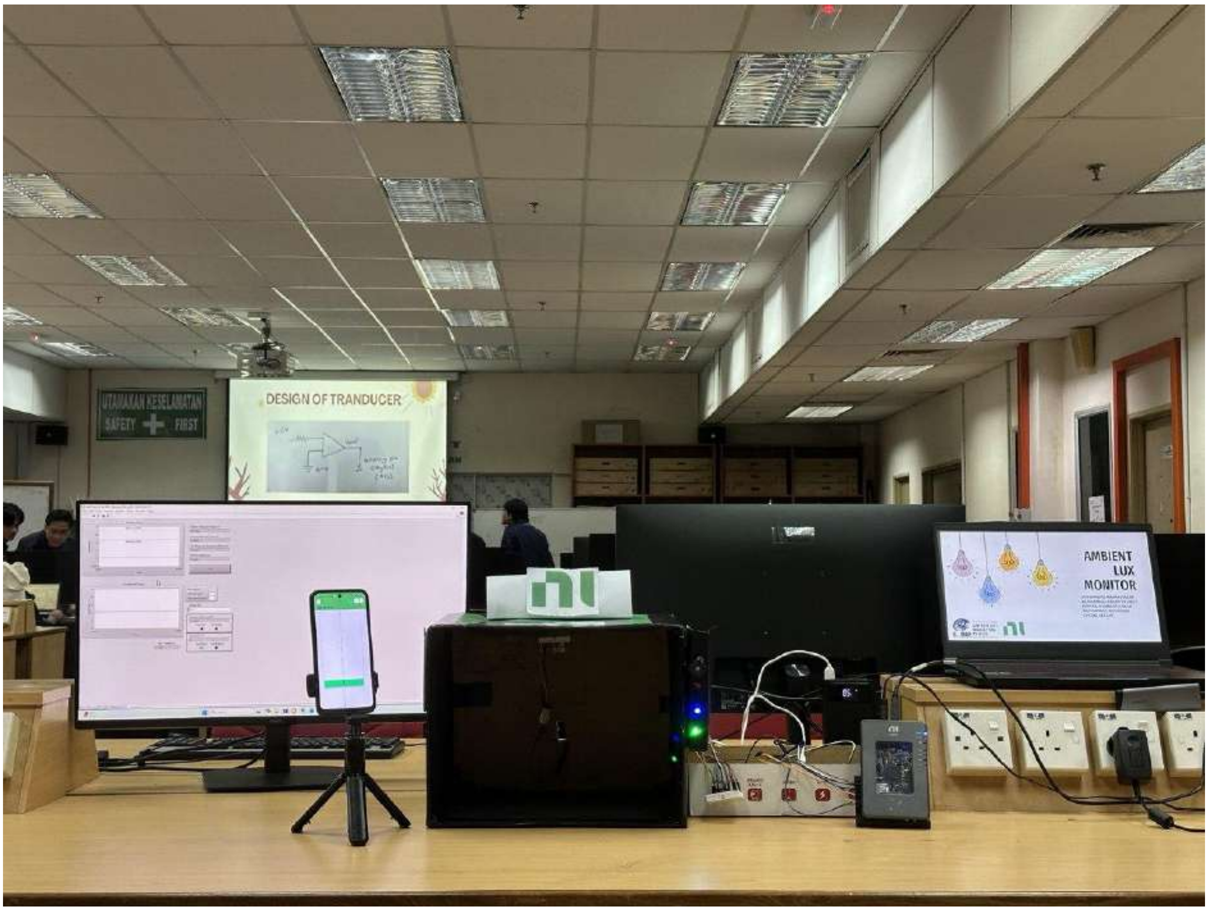
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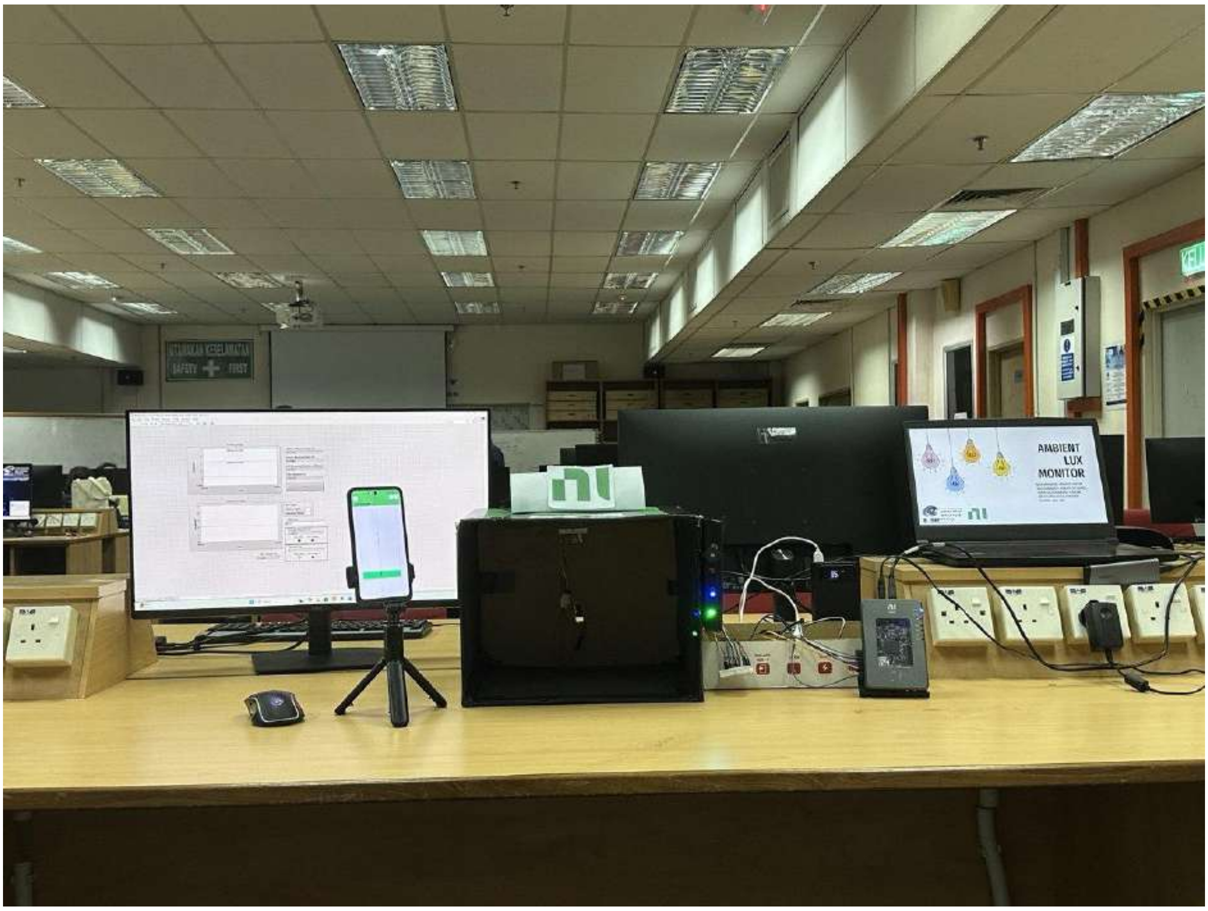
AMBIENT
LUX
MONITOR

Github: https://github.com/ConfirmDev/ambient-lux-monitor