Assignment 2

Deadline: 24th of July, 2025 at 11:59. All team members submit on teams.

Problem 1: Conceptual Questions

Answer the following questions with references and at least one figure per each question or one diagram.

- **Theoretical Assignment Questions**

1. **Explain the difference between analog and digital signals** and give two examples of each in real-life applications.
2. **Describe how a potentiometer works.** How is it used with ESP32 to provide analog input? Explain how its analog voltage is read and used in programming.
3. **What is Pulse Width Modulation (PWM)?**
    - Describe its waveform.
    - Explain how ESP32 uses PWM to control devices like LEDs or motors.
    - Include examples of duty cycle usage.
4. **Explain how an LDR (Light Dependent Resistor) works** and how its resistance changes with light. How can you use ESP32 to detect changes in light intensity using an LDR?
5. **Discuss the behavior of a push button as a digital input.**
    - What issues can occur when reading a push button?
    - Explain debouncing and how it can be implemented in code.
6. **Compare analog and PWM signals.**
    - Can PWM simulate analog output on a digital pin?
    - What are the benefits and limitations?

7. **Explain the working principle of LEDs and how they are controlled by ESP32.**
    - What is the significance of a current-limiting resistor?
    - What happens if it's omitted?
8. **How do internal ADCs (Analog to Digital Converters) in ESP32 work?**
    - How many bits of resolution does ESP32 ADC provide?
    - What is the voltage range it can read?
9. **List and describe any two real-world IoT applications** that use:
    - a potentiometer for user input
    - an LDR for environment sensing
10. **Design a simple circuit using ESP32, an LDR, and an LED** that turns the LED on when it gets dark.
    - Draw the circuit
    - Explain how the analog value from LDR is processed to control the LED.

🔷 Project 1: Potentiometer-Based LED Brightness Control

📌 Description:

Use a potentiometer as an analog input to control the brightness of an LED using PWM output from the ESP32.

🔧 Requirements:

- ESP32
- Potentiometer
- LED
- 220Ω resistor
- Breadboard and jumper wires

📦 Deliverables:

- Code that maps potentiometer value (0–4095) to PWM duty cycle (0–255)
- Circuit diagram and simulation using Wokwi
- Video or image showing the LED brightness changing with knob

🔷 Project 2: LDR-Controlled Night Light

📌 Description:

Create a system that turns on an LED when light levels go below a certain threshold using an LDR.

🔧 Requirements:

- ESP32
- LDR
- 10kΩ resistor (for voltage divider)
- LED + resistor
- Breadboard and jumper wires

📦 Deliverables:

- Analog reading and threshold logic in code
- Video demo showing LED turns on in darkness
- Circuit diagram and simulation using Wokwi

🔷 Project 3: Push Button-Activated LED Toggle

📌 Description:

Use a digital push button to toggle an LED's ON/OFF state on each press. Implement software debouncing.

🔧 Requirements:

- ESP32
- Push button
- 10kΩ resistor (pull-down)
- LED + resistor
- Breadboard and jumper wires

📦 Deliverables:

- Debounced button control logic
- LED toggling on each press
- Circuit diagram and code
- Circuit diagram and simulation using Wokwi

🔷 Project 4: Multi-Input Control System

📌 Description:

Design a small control system where:

- Potentiometer controls brightness of LED 1 (PWM)
- LDR controls LED 2 based on light threshold
- Push button toggles LED 3 ON/OFF

🔧 Requirements:

- ESP32
- 1 potentiometer
- 1 LDR
- 1 push button
- 3 LEDs + resistors
- 10kΩ resistor (for LDR and button circuits)
- Breadboard + jumper wires

📦 Deliverables:

- Complete integrated code
- Circuit diagram and simulation using Wokwi
- Demonstration video
- Code explanation (brief)

🔷 Project 5 (BONUS): Adaptive Lighting Control System using LDR, Potentiometer, and LED

📌 Description:

Build an adaptive lighting control system using ESP32, where:

- The LDR senses ambient light.
- The potentiometer adjusts the light sensitivity threshold.
- The LED brightness is dynamically adjusted via PWM based on LDR input.
- The system adapts in real-time to changes in both ambient light and user-defined thresholds.

🔧 Requirements:

- ESP32
- LDR sensor
- 10kΩ resistor (for voltage divider)
- Potentiometer
- LED
- 220Ω resistor
- Breadboard + jumper wires

🔁 How It Works:

- The LDR gives analog input on brightness.
- The potentiometer sets a sensitivity threshold (also analog).
- When the ambient light < threshold:
    - LED brightness increases proportionally using PWM.
- When ambient light > threshold:
    - LED brightness decreases or turns off.

📦 Deliverables:

- Functional adaptive control code
- Circuit diagram and simulation using Wokwi
- Serial monitor log (optional): print LDR & threshold values
- Project video or screenshots

🔷 Pretuned Project 1: Light-Controlled Transistor Switch (LDR + BJT)

📌 Description:

Use an LDR and a BJT (NPN transistor like 2N2222) to create an automatic light switch:

- LED turns on in darkness using LDR.
- No microcontroller is used — only analog components.

🔧 Requirements:

- LDR
- 10kΩ resistor
- NPN Transistor (e.g., 2N2222 or BC547)
- LED
- 220Ω resistor
- 9V battery
- Breadboard + wires

📦 Deliverables:

- Schematic of the analog circuit
- Hand-calculated threshold voltages
- Breadboard photo or LTSpice simulation (optional)
- Circuit diagram and simulation using Wokwi

🔷 Practical Potentiometer Project: LED Brightness Control (Analog Circuit Only)

📌 Project Title:

Analog LED Dimmer Using Potentiometer

🔧 Objective:

To control the brightness of an LED without using any microcontroller, just using a potentiometer in a voltage divider configuration.

⚙️ Components Required:

Component	Quantity
Potentiometer (10kΩ)	1
LED	1
Resistor (220Ω)	1
Power Supply (e.g., 5V)	1
Breadboard	1
Jumper Wires	As needed

🧠 Working Principle:

- The potentiometer acts as a voltage divider.
- Turning the knob changes the voltage at the wiper pin (middle pin).
- That voltage is sent through a current-limiting resistor to the LED.

- The LED brightness increases or decreases based on the voltage level supplied.

📦 Deliverables / What to Submit:

- Breadboard photo or video demo showing dimming effect.
- Circuit diagram and simulation
- Explanation of how the voltage across the LED changes with potentiometer rotation.