# REPORT OF A GROUP PROJECT TITLED
# MINI-MECHATRONICS WORKSTATION TRAINING KIT
## SUPERVISED BY DR. A.T. OYELAMI

## COURSE CODE: MTE 403
## COURSE TITLE: GROUP PROJECT


## DEPARTMENT OF MECHATRONICS ENGINEERING
## FEDERAL UNIVERSITY OF AGRICULTURE, ABEOKUTA

| GROUP MEMBERS | MATRIC NUMBER |
|---|---|
| OLADEJI EMMANUEL TIMILEYIN [GROUP LEADER] | 20222271 |
| ADENIJI SOLOMON OLUWAKAYODE | 20222223 |
| OREDIPE OLUWAGBOHUMNI ADEKUNLE | 20222283 |
| ADELEKE DANIEL OLUWASEGUN | 20202892 |
| FATUKASI OLALEKAN SAMUEL | 20322194 |
| ISMAIL BASITH OLASUBOMI | 20222255 |

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# ABSTRACT

Mechatronics Engineering is an interdisciplinary field that combines mechanical engineering, electronics, computer programming, and control systems, making hands-on practical training essential for effective learning. However, many students face difficulties in understanding key mechatronics concepts due to limited access to affordable and comprehensive training platforms. This project presents the design and implementation of a Mini Mechatronics Workstation Training Kit intended for the practical instruction of Mechatronics Engineering students.

The developed workstation is based on the Arduino UNO microcontroller and integrates five sensors—DHT11 temperature sensor, ultrasonic sensor, Hall effect sensor, light dependent resistor (LDR), and touch sensor—with corresponding actuators including DC motors, servo motors, LEDs, and buzzers. Each sensor–actuator pair is configured to demonstrate a fundamental mechatronics control concept such as environmental monitoring, distance-based control, magnetic field detection, light-based automation, and human–machine interaction. The system operates using real-time sensing and actuation, supported by a regulated power supply and relay modules where required.

To enhance its educational value, the workstation incorporates a breadboard and a spare Arduino UNO, allowing students to modify programs, test alternative connections, and perform laboratory experiments without altering the core system. Functional testing confirmed accurate sensor responses, reliable actuator control, and stable system operation. The results demonstrate that the workstation effectively simplifies complex mechatronics concepts, promotes experiential learning, and serves as a low-cost, reusable training platform suitable for academic laboratories.

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# CHAPTER ONE

# INTRODUCTION

## 1.1 Background of the Study

**1.1.1 Mechatronics Engineering** is a multidisciplinary field that integrates diverse engineering fields including Mechanical, Electronics, Computer and Control Engineering to design and develop smart automation systems such as robots, advanced manufacturing equipment, and autonomous unmanned vehicles.

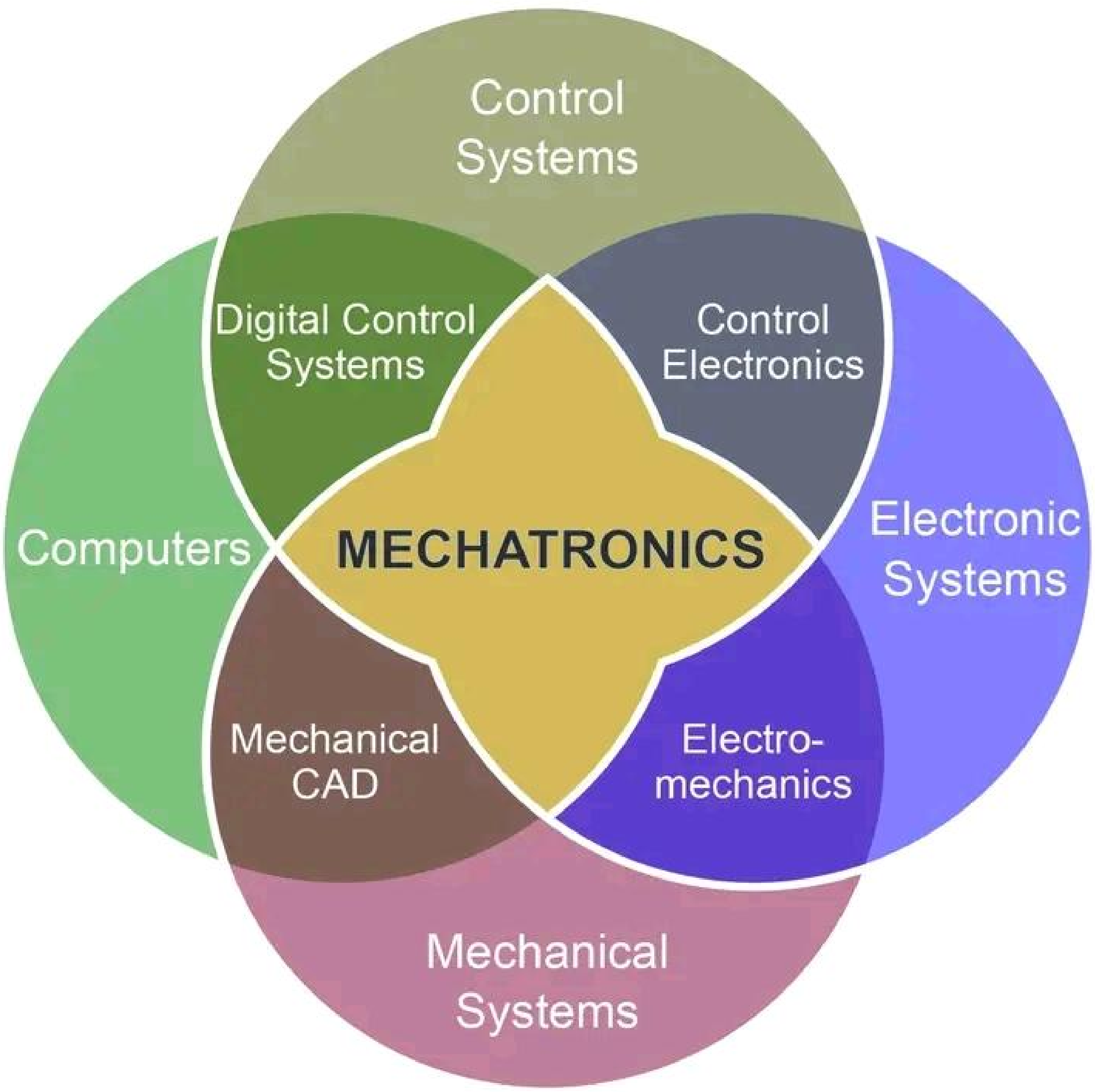


**Figure 1.1:** Chart diagram showing the fields in Mechatronics

### 1.1.2 Core Disciplines in Mechatronics Engineering

- **Mechanical Engineering**: Focuses on principles of motion, mechanics, and physical systems.
- **Electronics & Electrical Engineering**: Focuses on circuits, sensors, actuators, and power systems.
- **Computer Science**: Focuses on programming, software development, and AI.
- **Control Systems**: Focus on designing feedback loops to manage and automate system behavior.

### 1.1.3 Importance of Hands-on Training in Mechatronics Education

Mechatronics Engineering being a field that integrates many other fields, it requires a higher level of learning demands. Learning mechatronics through theories alone cannot provide students with the real life practical experiences required for a proper understanding of mechatronics systems.

Hands-on training is one of the components needed for a proper mechatronics education. It provides students with real life experiences on the concepts taught theoretically in class. This experience is essential for a proper understanding of how mechatronics systems operate and it also helps them to apply the theories taught to real life situations and problem solving.

### 1.1.4 Role of Training Kits in Engineering Laboratories

Training kits are the equipment used in the engineering laboratories to aid the hands-on practical training of the students. It plays a very vital role as it helps the students to easily grasp the practice knowledge of what is being taught.

## 1.2 Problem Statement

Students face difficulties in the understanding of some concepts taught theoretically since they are not able to link or interpret those concepts with a practical or real-life scenario. In mechatronics, the difficulties faced include:

I. **Sensor Interfacing:** Oftentimes, students do not know the process to connect physical sensors to processing systems (like microcontrollers and computers) to convert their raw physical measurements (such as light, temp, pressure) into usable digital data.

II. **Actuator Control:** Lack of knowledge in using signals and controllers (like PLCs, microcontrollers) to manage an actuator, which converts energy (electric, pneumatic, hydraulic) into mechanical motion for precise movements in systems.

III. **Microcontroller Based System:** Most students do not know how to use a microcontroller to perform a specific or dedicated task.

## 1.3 Aim and Objectives

**Aim:** To design and implement a mini-mechatronics workstation training kit for practical instruction of Mechatronics Engineering students.

**Objectives:**

1. To implement the use of different sensors and actuators in showing a typical mini Mechatronics work-station.
2. To design and develop a small scale Mechatronics training work-station.
3. To design and develop a system that can be easily used in the training of Mechatronics Engineering students.

## 1.4 Educational and Training Objectives

The project is to enable students to:

- ldentify and connect common sensors and actuators
- Understand signal flow from sensing to actuation
- Learn Arduino-based programming and control logic
- Perform laboratory experiments using the workstation

## 1.5 Scope of the Project

- Hardware design
- Software programming
- Training-oriented implementation

## 1.6 Significance of the Project

- Enhances laboratory learning
- Supports mechatronics curriculum
- Provides a low-cost teaching aid
- Encourages experimental and inquiry-based learning

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Importance of Educational Mechatronics Training Kits

Mechatronics education represents the synergistic integration of mechanical engineering, electronics, computer science, and control engineering. The rapid evolution of industrial automation and smart manufacturing has brought about the development of comprehensive training platforms that expose students to real-world mechatronic systems [1]. Educational mechatronics kits serve as crucial tools that bridge the gap between theoretical knowledge and practical application, enabling students to develop hands-on competence in sensor integration, actuator control, and microcontroller programming.

Research has demonstrated that students who engaged with physical mechatronics training platforms showed significantly better comprehension of control systems compared to those who relied solely on theoretical instruction [2]. The training kit provides an experiential learning environment where students can observe cause-and-effect relationships in real-time, enabling deeper understanding of mechatronic principles. Such platform enhance problem-solving skills and promote creativity in system design, which are essential needs for modern mechatronics engineers.

## 2.2 Sensors Used in the Workstation

The DHT11 temperature and humidity sensor is widely employed in educational settings due to its simplicity, low cost, and digital output interface. This sensor enables students to understand environmental monitoring and data acquisition principles fundamental to mechatronic systems. Hall effect sensors, such as the KY-035, provide non-contact detection capabilities essential for position sensing and rotational speed measurement in automated systems. These magnetic sensors are particularly valuable in teaching proximity detection and motor control applications.

Ultrasonic sensors, specifically the HC-SR04 module, represent a technology in distance measurement and obstacle detection [3]. The HC-SR04's straightforward interface and reliable performance make it ideal for introducing students to ranging technologies used in robotics and automation. Light Dependent Resistors (LDRs) offer an introduction to analog sensing, demonstrating how environmental light levels can be converted to electrical signals for control purposes. Touch sensors introduce students to human-machine interface concepts, enabling the development of interactive mechatronic systems.

## 2.3 Actuators Used in the Workstation

Servo motors constitute essential components in precision positioning applications, providing students with practical experience in angular control and feedback mechanisms. The integration of servo motors in educational kits allows students to understand Pulse Width Modulation (PWM) control and closed-loop systems. DC motors serve as fundamental actuators for demonstrating continuous rotational motion and speed control principles. Their simple control requirements and versatility make them ideal for teaching motor driver circuits and power electronics fundamentals [4].

Buzzers function as effective audio feedback devices in mechatronic systems, teaching students about alarm systems and user notification mechanisms. Light Emitting Diodes (LEDs) provide visual feedback and serve as introductory components for understanding electronic circuits, current flow, and digital output control. The combination of these actuators creates a comprehensive learning environment that covers the range of output devices commonly encountered in industrial mechatronic applications.

## 2.4 Microcontroller Platforms for Training

### 2.4.1 Overview of Arduino UNO

The Arduino UNO, based on the ATmega328P microcontroller, has emerged as the predominant platform for mechatronics education globally [5]. This open-source platform features 14 digital input/output pins, 6 analog inputs, and operates at 16 MHz, providing sufficient computational capability for educational projects. Its USB interface simplifies programming and communication, eliminating the need for external programmers.

### 2.4.2 Why Arduino is Suitable for Student Training

Arduino's suitability for educational environments results from multiple factors. The platform's abstraction of low-level programming complexities allows students to focus on mechatronic concepts rather than intricate microcontroller architecture [5].

## 2.5 Review of Related Training Kits

Academic institutions have developed custom training platforms tailored to specific curricula. Various universities have created mechatronics instructional workstations that integrate industrial sensors and actuators with programmable logic controllers [6]. Similarly, compact mechatronic training systems employ modular stations for sequential learning. However, many of these systems remain cost-prohibitive for widespread adoption in developing regions.

# CHAPTER THREE

# SYSTEM DESIGN AND TRAINING ARCHITECTURE

**3.1 The Mini-mechatronics workstation training kit** is a system designed to demonstrate the working principle of different sensors, the use of microcontroller in a mechatronics product and the functions of different actuators in a mechatronics system. It also incorporates an easy and simplified working environment for the students to carry out their practicals.

## 3.2 Functional Block Diagram

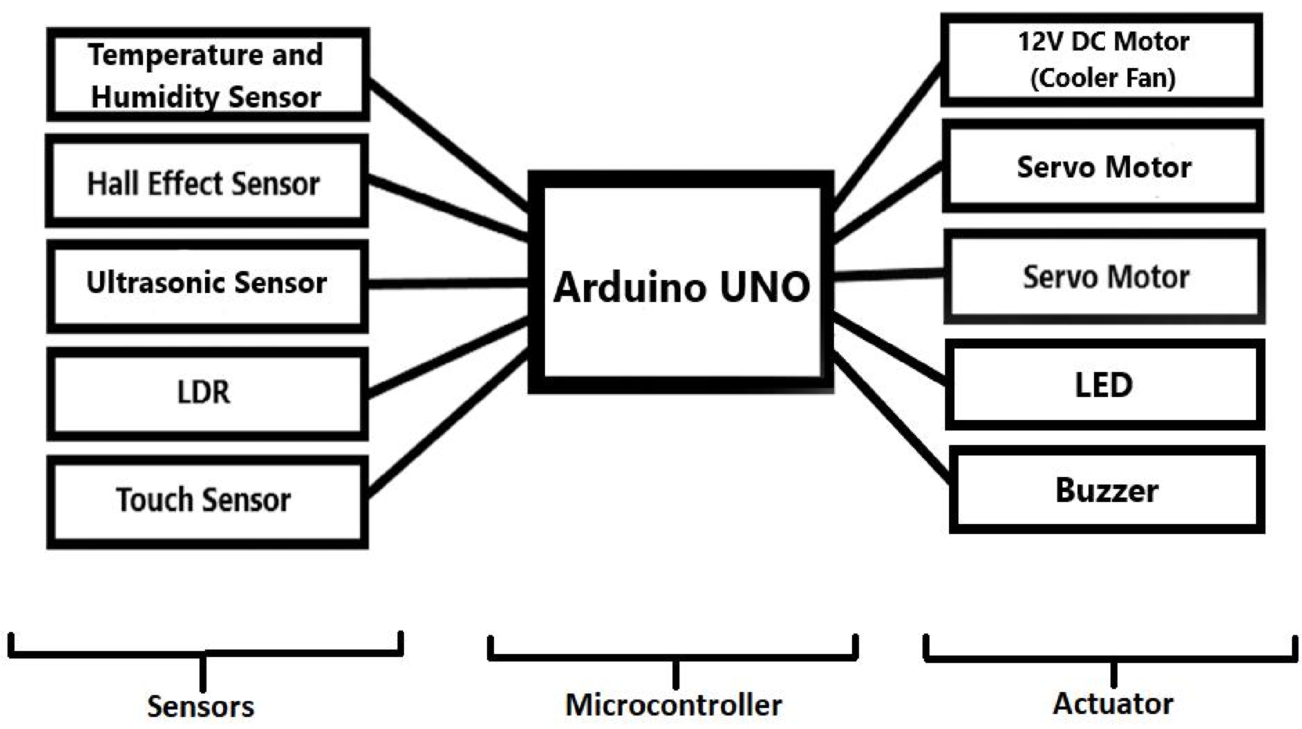


**Figure 3.1**: Functional block diagram

## 3.3 Circuit Diagram

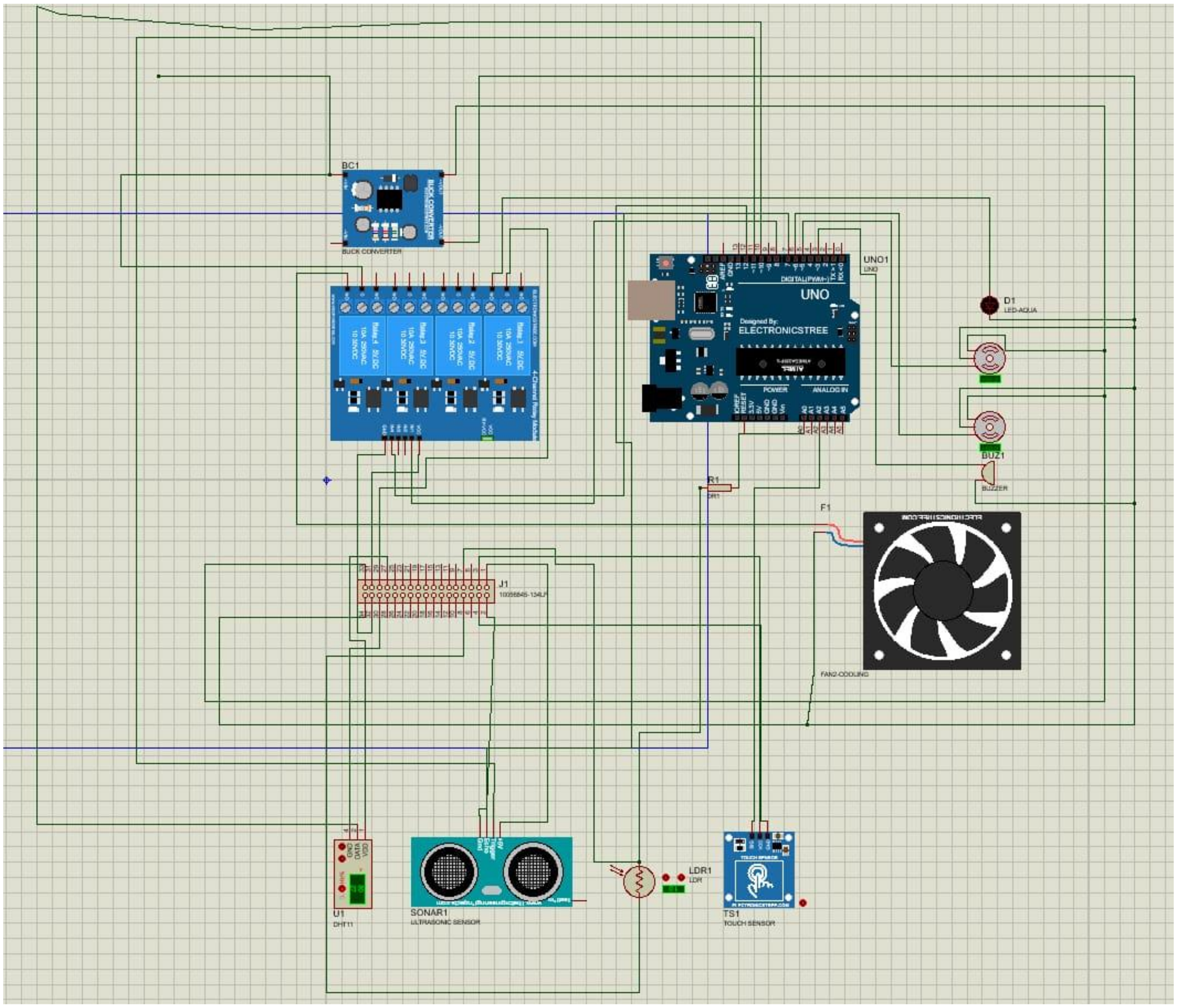


**Figure 3.2:** Circuit Diagram

## 3.4 Software Design and Control Logic

The Arduino IDE was used for the project's software. Arduino IDE (Integrated Development Environment) is a software platform used to write, compile, and upload code to Arduino microcontroller boards. It supports C/C++ programming and provides a simple interface for beginners. The IDE includes a code editor, message area, and a serial monitor for debugging. Below is the flowchart that shows the control logic of the system.

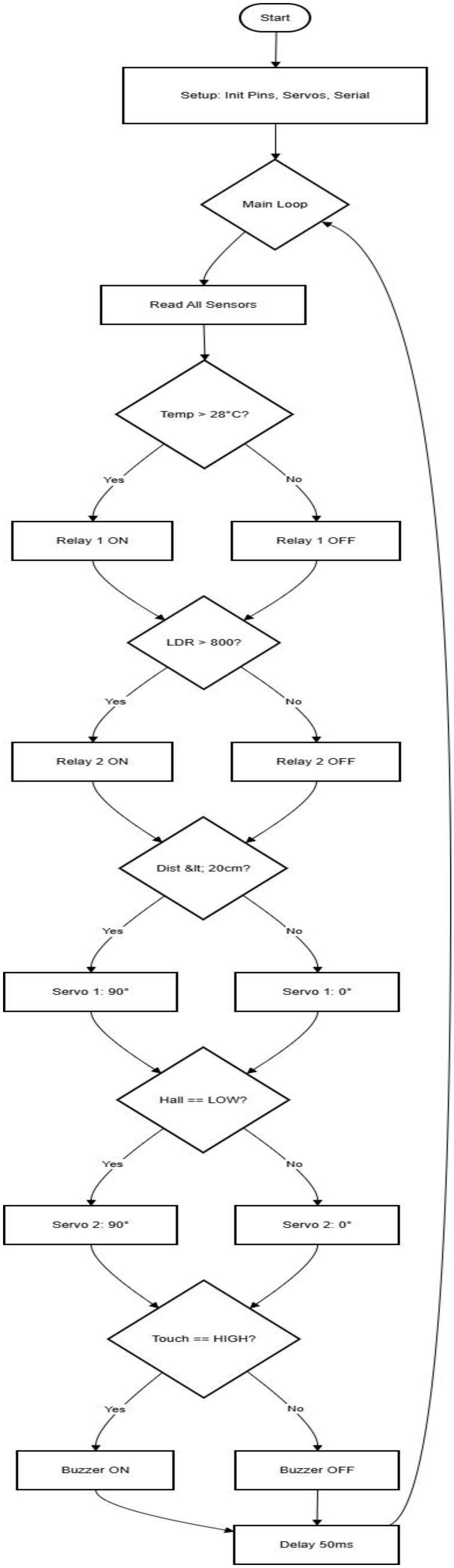


**Figure 3.3**: Flowchart of the control logic

### 3.5 Sensor-Actuator Mapping

The  table below shows a mapping of  how the sensors are use in controlling the actuator.

| Sensor | Actuator | Training Concept Demonstrated |
|---|---|---|
| LDR | LED | Analog sensing and threshold control |
| DHT11 | 12V Cooling Fan | Environmental control |
| Hall Effect | Servo Motor | Magnetic field detection |
| Ultrasonic | Servo Motor | Distance-based control |
| Touch Sensor | Buzzer | Human–machine interaction |

### 3.6 Bill of Engineering materials and Evaluation

| S/N | **Item Description** | **Unit** | **Quantity** | **Unit Rate (₦)** | **Amount (₦)** |
|---|---|---|---|---|---|
| A | **Sensors** | | | | |
| 1 | DHT11 | No | 1 | 3,500.00 | 3,500.00 |
| 2 | Hall effect sensor module | No | 1 | 4,050.00 | 4,050.00 |
| 3 | LDR | No | 2 | 700 | 1,400.00 |
| 4 | Ultrasonic Sensor | No | 1 | 5,000.00 | 5,000.00 |
| | Sub-total (Sensors) | | | | 13,950.00 |
| | | | | | |
| B | **Actuators** | | | | |
| 1 | 12v DC motor (cooler fan) | No | 1 | 2,000.00 | 2,000.00 |

| | | | | | |
|---|---|---|---|---|---|
| 2 | Buzzer module | No | 2 | 1,100.00 | 2,200.00 |
| 3 | LED | No | 1 | - | - |
| 4 | SG-90 servo | No | 2 | 5,000.00 | 10,000.00 |
| | Sub-total (Actuators) | | | | 14,200.00 |
| | | | | | |
| C | **Microcontroller & Others** | | | | |
| 1 | 12v AC to DC adapter | No | 1 | 7,000.00 | 7,000.00 |
| 2 | 5v relay module | No | 2 | 500 | 1,000.00 |
| 3 | Arduino Uno | No | 2 | 16,000.00 | 32,000.00 |
| 4 | Breadboard | No | 2 | 2,000.00 | 4,000.00 |
| 5 | Buck converter module | No | 2 | 2,200.00 | 4,400.00 |
| 6 | Female to female jumper wire | No | 2 | 2,300.00 | 4,600.00 |
| 7 | Glue gun | No | 1 | 4,900.00 | 4,900.00 |
| 8 | Hot glue and adhesive tape | Lot | 1 | 4,000.00 | 4,000.00 |
| 9 | Male to female jumper wire | No | 2 | 2,300.00 | 4,600.00 |
| 10 | Male to male jumper wire | No | 2 | 1,800.00 | 3,600.00 |
| 11 | Miscellaneous | Sum | 1 | 15,000.00 | 15,000.00 |
| 12 | Soldering iron | No | 1 | 6,500.00 | 6,500.00 |
| 13 | Soldering lead | Lot | 1 | 1,700.00 | 1,700.00 |
| 14 | Wood slab | No | 1 | 8,000.00 | 8,000.00 |
| | Sub-total (Microcontroller & Others) | | | | 101,300.00 |
| | | | | | |
| Total | **GRAND TOTAL** | | | | **₦ 129,450.00** |

# CHAPTER FOUR

# SYSTEM IMPLEMENTATION AND OPERATION

This chapter presents the practical implementation of the Mini Mechatronics Workstation Training Kit. It describes the physical construction, wiring arrangement, power distribution, sensor–actuator integration, and the operational procedure of the system. Special emphasis is placed on the training-oriented design, which allows students to actively participate in laboratory practicals by interfacing directly with the system using an Arduino Uno and breadboard.

## 4.1 Physical Construction of the Training Workstation

The workstation was constructed on a rigid wooden base platform to ensure mechanical stability and ease of demonstration. All sensors and actuators were mounted in a visible and accessible manner to enhance learning and observation during practical sessions. The system layout was carefully arranged such that:

- Sensors are positioned at one end of the base platform for easy identification
- Actuators are placed at the other end also for easy identification
- The Arduino UNO control unit is centrally located
- The breadboard and spare Arduino UNO are mounted separately for students use.

This arrangement ensures clarity in understanding the relationship between sensors, control logic, and actuators.

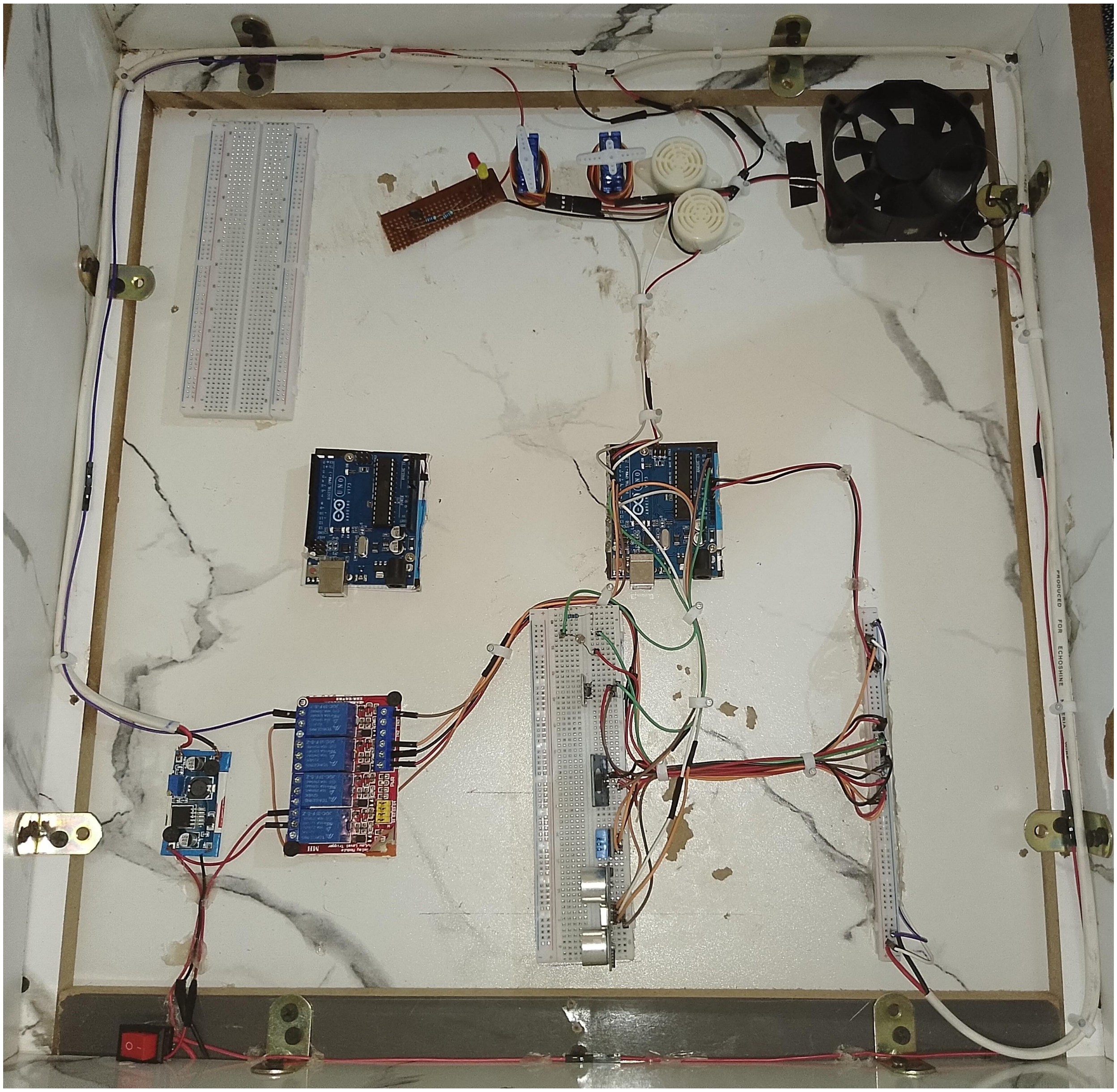

**Figure 4.1**: Picture of the project

## 4.2 Power Supply and Voltage Regulation

The system is powered using a 12V DC external power source, which serves as the main supply for the workstation. Since the Arduino UNO and most sensors operate at 5V, a buck (step-down) converter was employed to regulate the voltage from 12V to 5V.



**Figure 4.2**: 12V AC to DC power adapter



**Figure 4.3**: Buck converter module

Key features of the power system include:

- 12V supply for high-power components (fan and relay module)
- Buck converter output of stable 5V for Arduino, sensors and other actuators
- Common Buck converter output of stable 5V for Arduino, sensors and other actuators
- Ground shared across all components for signal stability

This power architecture ensures safe operation, protects sensitive components, and demonstrates real-world power management concepts to students.

### 4.3 Sensor – Actuator Integration

The training kit integrates five sensors and five corresponding output devices, each demonstrating a fundamental mechatronics control concept, that is, each sensor is paired with an actuator.

### 4.3.1 Temperature-Based Control System

**Sensor**: DHT11 Temperature Sensor  is paired with **Actuator**: DC Fan (via relay module)

When the ambient temperature exceeds a predefined threshold of 34℃, the Arduino activates the relay module, supplying 12V to the fan. This demonstrates environmental monitoring and automatic cooling control, simulating industrial temperature regulation systems.

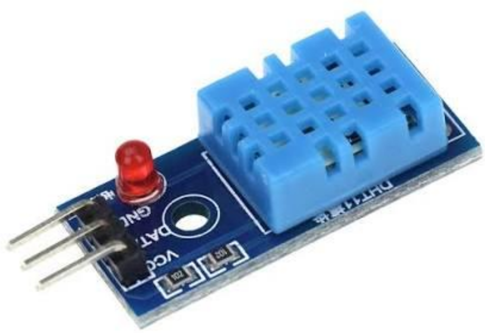

**Figure 4.4**: Temperature and humidity sensor

**Figure 4.5**: 12V DC cooler fan

### 4.3.2 Distance-Based Control System

**Sensor**: Ultrasonic Sensor is paired with **Actuator**: Servo Motor

The ultrasonic sensor measures the distance of an object in front of it. Based on the detected distance is less than 21cm, the Arduino sends a control signal to the servo motor, causing it to rotate through 180 degrees. This setup demonstrates non-contact sensing and positional control.



**Figure 4.6**: Ultrasonic sensor

**Figure 4.7**: SG-90 Servo motor

### 4.3.3 Magnetic Field Detection System

Sensor: Hall Effect Sensor is paired with Actuator: Servo Motor

When a magnetic field is detected near the Hall Effect sensor, the Arduino triggers the second servo motor, rotating it through 180 degrees. This illustrates magnetic sensing, and rotational actuation.digital triggering,

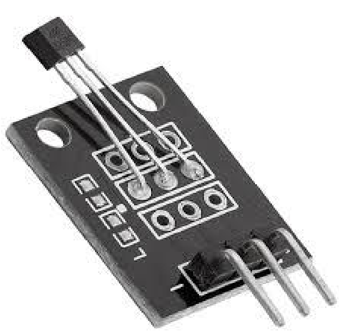


**Figure 4.8**: Hall effect sensor

**Figure 4.9**: SG-90 Servo motor

#### 4.3.4 Touch-Based Alert System

**Sensor**: Touch Sensor is paired with **Actuator**: Buzzer

Upon physical contact with the touch sensor, the buzzer is activated, producing an audible alert. This demonstrates human–machine interaction (HMI) and basic digital input–output control.


**Figure 4.10**: Touch sensor

**Figure 4.11**: Buzzer

#### 4.3.5 Light-Dependent Control System

**Sensor**: Light Dependent Resistor (LDR) is paired with **Actuator**: LED (via relay module)

The LDR senses changes in ambient light intensity. When the light level falls below a set threshold, the Arduino energizes the relay module to switch the LED ON, and switches it OFF when sufficient light is detected. This demonstrates automatic lighting control systems commonly used in smart environments.

**Figure 4:12**: LDR

**Figure 4.13**: LED

## 4.4 Training Interface Using Breadboard and Spare Arduino

To enhance its educational value, the workstation includes:

- A dedicated breadboard, an additional Arduino UNO in which students can:
- Tap into the signal, power, and ground pins of each sensor
- Reprogram the Arduino using their own control logic
- Test alternative connections without altering the main system

This design enables repeated laboratory use, experimentation, and independent learning without damaging the core workstation.


**Figure 4.14**: Arduino UNO

**Figure 4.15**: Breadboard

## 4.5 System Operation and Real-Time Response

Once power is supplied:

1. The buck converter regulates voltage to 5V
2. The Arduino UNO initializes all sensors and actuators
3. Sensor readings are continuously monitored
4. Any detected physical parameter produces an immediate corresponding actuator response

The system operates in real time, ensuring that students clearly observe cause-and-effect relationships between sensors and actuators.

## 4.6 Web-Based Project Documentation and QR Access

To further enhance the instructional value of the Mini Mechatronics Workstation Training Kit, a dedicated webpage was developed to provide supplementary information on the system architecture, design, and usage procedures. The webpage serves as a digital reference platform where students can access structured explanations, system descriptions, and operational guidance related to the workstation.

A Quick Response (QR) code linking to the webpage is affixed to the physical workstation, enabling students to conveniently scan and access the information using their mobile devices during laboratory sessions. This approach supports self-guided learning, improves accessibility to project documentation, and complements the hands-on training provided by the workstation.

**Figure 4.16**: Webpage QR scan code

# CHAPTER FIVE

# TESTING, RESULTS, AND DISCUSSION

This chapter discusses the testing procedures carried out on the Mini Mechatronics Workstation Training Kit. Each sensor and actuator was tested individually and as part of the complete system to ensure accuracy, reliability, and educational effectiveness.

## 5.1 Component-Level Testing

Each component was tested independently before full system integration.

- **DHT11 Sensor:** Correctly measured temperature changes and triggered fan activation at threshold values
- **Ultrasonic Sensor:** Accurately detected object distance and controlled servo movement
- **Hall Effect Sensor:** Reliably detected magnetic fields and activated servo rotation
- **Touch Sensor:** Instantly triggered buzzer upon contact
- **LDR:** Successfully responded to light intensity changes by switching the LED ON/OFF

## 5.2 Integrated System Testing

After individual testing, the complete system was powered and tested simultaneously. The following observations were made:

- No voltage instability was observed
- Sensors responded accurately to environmental changes
- Actuators responded instantly with minimal delay
- Relay module safely handled high-current loads

These confirmed proper system integration and safe operation.

## 5.3 Results

The workstation demonstrated:

- Fast response time
- Accurate sensor readings
- Reliable actuator control
- Clear demonstration of mechatronics principles

The system functioned continuously without overheating or component failure.

### 5.4 Educational Evaluation

From a training perspective, the workstation:

- Simplifies complex mechatronics concepts
- Encourages hands-on learning
- Supports multiple laboratory experiments
- Is easy to understand and operate by students
- The modular design allows instructors to create various practical exercises using the same platform.

## 5.5 Challenges Encountered

Some challenges encountered include:

- Limited current capacity of Arduino output pins
- Need for proper relay isolation

- Sensitivity of sensors to noise during wiring
- Difficulty in ultrasonic sensor calibration due to platform exposure

These challenges were resolved through proper grounding, relay modules, re-arrangement of our components and stable power regulation.

# CHAPTER SIX

# SUMMARY, CONCLUSION, AND RECOMMENDATIONS

## 6.1 Summary

This project successfully designed and implemented a Mini Mechatronics Workstation Training Kit using an Arduino UNO microcontroller. The system integrates five sensors and corresponding actuators to demonstrate real-time sensing, control, and actuation principles. The inclusion of a breadboard and spare Arduino enhances its instructional value, allowing students to actively participate in laboratory experiments.

## 6.2 Conclusion

The developed workstation meets its intended objective as an effective mechatronics training platform. It provides a practical and low-cost solution for teaching sensor interfacing, actuator control, power management, and system integration. The project successfully bridges the gap between theoretical knowledge and practical application, making it suitable for academic laboratories.

## 6.3 Recommendations for Future Work

To further enhance the system, the following improvements are recommended:

1. Integration of an LCD or OLED display for real-time data visualization
2. Expansion to include wireless communication (IoT) features
3. Addition of more industrial-grade sensors
4. Development of structured laboratory manuals

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