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Development of Automatic Sensor-Activated Umbrella System for Stationary out Door Application

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ABSTRACT: This paper presents the design and development of an innovative Automatic Sensor-Activated Umbrella System. The system is engineered to enhance user convenience by automatically deploying the umbrella canopy in response to environmental conditions, such as rainfall or intense sunlight. The design incorporates advanced sensor technology to detect relevant environmental parameters, enabling precise activation of the umbrella mechanism. The development process involves integrating the sensors, buzzer, actuators, and microcontroller as control circuitry into a compact and durable umbrella frame. Additionally, the system incorporates energy efficient components to ensure prolonged operation on battery power or AC power. Experimental results demonstrate the efficacy and reliability of the proposed system in providing on-demand protection against adverse weather conditions. Overall, this paper contributes to the development of smart and user-friendly solutions for everyday use, with potential applications in various outdoor settings. The prevailing excessive high temperature currently in Nigeria has led to the motivation for this work.

Keywords: Microcontroller, sensors, actuators, umbrella, buzzer

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INTRODUCTION

Harsh weather conditions, ranging from torrential rainstorms to scorching temperatures, pose significant challenges to individuals navigating the outdoors in Nigeria as at today. Traditional Umbrellas have been used by individuals and for outdoor purposes to shield us from the rainfall and very hot weather such has high temperatures of the sun for centuries, evolving from simple canopies to complex mechanisms designed for convenience and durability (Crawford, 1970). However, the traditional manual operation umbrella often left users exposed to sudden downpours or inconvenient situations. The limitations of these traditional umbrellas are numerous ranging from the need to manually set them up when there is a sudden change in weather conditions and its inability to detect and rainfall and high temperature of the sun automatically. Due to these limitations automatic umbrella systems stand out as a promising solution in Nigeria. The potential of automatic umbrella systems to offer protection and comfort in such conditions can be over emphasized due to the impact of prolonged exposure to rain can result in health issues such as hypothermia or cold-related illnesses. And exposure to sunlight without adequate protection can also increase the risk of sunburns and skin damage, further compromising individuals' well-being (Sita Schutt, 2018). Automatic umbrella systems offer a convenient and effective means of shielding individuals from the adverse effects of harsh weather conditions. Equipped with advanced features such as automatic opening and closing mechanisms, wind-resistant designs, and UV protection coatings, these umbrellas provide comprehensive protection against rain and sunlight. Automatic umbrellas with sturdy construction and waterproof materials offer reliable protection against rain showers. Their quick-deploy mechanism allows users to shield themselves from sudden downpours, keeping them dry and comfortable even in inclement weather. Some automatic umbrella systems are specifically designed to block harmful UV rays, providing shade and reducing the risk of sunburns and heat-related illnesses. These umbrellas often feature reflective coatings or UV-resistant fabrics to enhance their sun-blocking capability. One of the key advantages of automatic umbrella systems is their portability and ease of use. Compact and lightweight designs make them convenient accessories for everyday use, allowing individuals to carry them effortlessly during their commutes or install them in outdoor activities to provide protection against excess hot temperatures and rain fall **(**Manpreet et al., 2018).

However, the Development of innovative Automatic Sensor-Activated Umbrella System

Offer a practical solution by providing protection against rain showers, sun exposure, and other weather-related hazards. With these advanced features and convenience, these umbrellas serve as essential tools for navigating the outdoors an inclement weather, ensuring that individuals can weather the storm with confidence and comfort (Dad et al., 2020).

MATERIALS AND METHOD

The hardware components of an automated sensor activated Umbrella system in show in the (Figure 1) would be described briefly.

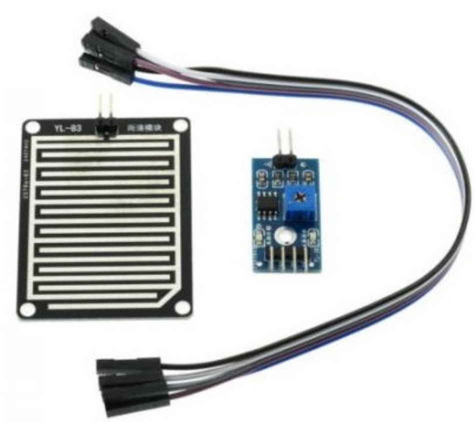

Figure 1: Rain sensor

Microcontroller

The Microcontroller is a PIC microcontroller" typically refers to microcontrollers manufactured by Microchip Technology Inc. PIC stands for "Peripheral Interface Controller," and these microcontrollers are widely used in embedded systems and various electronic applications. The PIC 16 series is used to interface with other components Subero (2018).

Rain sensor

A rain sensor is an electronic switching device which is used to detect the rainfall (Figure 1). It works like a switch and the working principle of this sensor is, whenever there is rain, the switch will be normally closed. The rain sensor module/board is shown below. Basically, this board includes nickel coated lines and it works on the resistance principle. This sensor module detects water and automatically triggers programmed actions (Baghel, 2019).

Temperature sensor

Temperature sensors are devices that detect and measure coldness and heat and convert it into an electrical signal. Temperature sensor is an integrated circuit sensor. The output voltage is linearly proportional to the centigrade temperature. The sensor shown in (Figure 2) is compatible with Arduino UNO device and PIC microcontroller. The applications of the temperature sensor are in microwave ovens, fridges, household devices, air conditioners, and atmosphere and water temperature monitoring. It can measure not only the hot bodies but also cold bodies. There are two types of sensors, they are noncontact temperature sensors and contact temperature sensors. Contact temperature sensors are again divided into three subtypes: electromechanical, resistive resistance temperature detectors, and semiconductor-based temperature sensors Jacob Fraden (2004).

Figure 2: Temperature sensor

Buzzer

An audio signaling device like a beeper or buzzer symbol may be electromechanical or piezo electric or mechanical type. The main function of this is to convert the signal from audio to sound. Generally, it is powered through DC voltage then produces sound and used in timers, alarm devices, printers, alarms, computers, etc. Based on the various designs, it can generate different sounds like alarm, music, bell & siren. The sound pressure level is a crucial parameter for the signal device. Piezo element material of metal plate can be brass, nickel alloy, or stainless steel (Figure 3). Metal plate can cause different piezoelectric effect Punna Pushpak, (2018).

Figure 3: buzzer

Power supply unit

It helps in energizing the entire system by providing each component with its regulated power supply. It uses both switch mode and linear power supply. Proper operation of the system requires a number of source voltages. Low DC voltages are needed to operate ICs and transistors. High voltages are needed to operate actuator motor and relays (Figure 4).

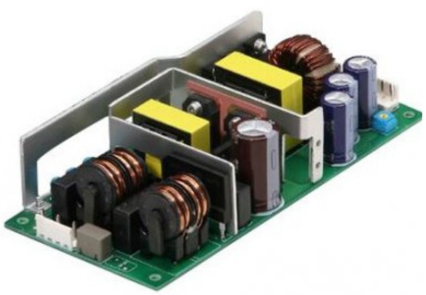

Figure 4: SMPS Power supply

Actuator Motor

An actuator motor is a type of motor used to control or move mechanical systems, such as valves, switches, or other mechanisms (Figure 5). It converts electrical energy into mechanical motion, often to open or close a mechanism or to move something to a desired position. Actuator motors are commonly used in various applications, including industrial machinery, robotics, automotive systems, and aerospace systems (Mendoza et al., 2016).

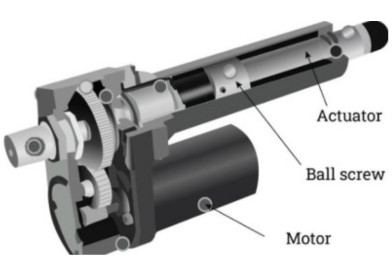

Figure 5: Actuator Motor

DC Motor Driver

Motor drives are circuits used to run a motor. In other words, they are commonly used for motor interfacing (Figure 6). These drive circuits can be easily interfaced with the motor and their selection depends upon the type of motor being used and their ratings (current, voltage). The motor driver consists of transistors, relay, diodes and resistors for turning ON and OFF the motor. It interfaces with the Microcontroller and the DC actuator motor.https://www.mepits.com/tutorial/379/electrical/motor-driver

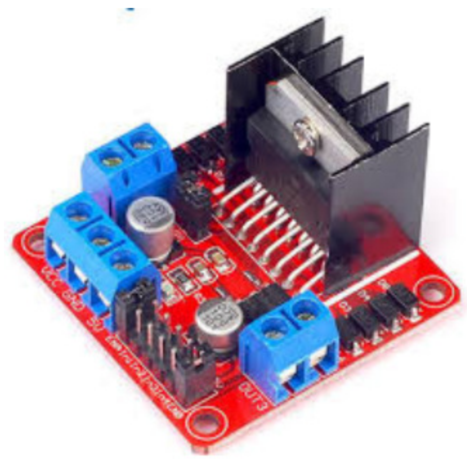

Figure 6: Motor driver

DESIGN METHODOLOGY

This section deals with the design and development of innovative Automatic Sensor-Activated Umbrella. The design methodology consists is categorized into two sections which are:

(1) Hardware design
(2) Software design

The hardware design and implementation use block diagrams and circuit diagrams to describe the hardware functionality whereas the software design and implementation methodology uses a program flow chart to describe the software in relation to the hardware (Table 1). Figure 7 presents the system block diagram and (Figure 7) depict the program flow charts of the software design. This paper presentation is aimed at designing and developing an innovative Automatic sensor activates Umbrella which can be used for outdoor purposes to serve as a stationary shelter against rain and high temperature. The uniqueness of this paper work is to enhance the development of an outdoor stational Umbrella with sensors that can control the usage of the umbrella without human supervision.

Table 1: Hardware specifications.

S/N	Specifications	S/N	Specifications
1	PIC Microcontroller (PIC 16F722A)	9	Diodes
2	12V Relay	10	Voltage regulators
3	Capacitors	11	Rain sensor
4	Transistors	12	Buzzer
5	Cables & connectors	13	Temperature Sensor
6	Resistors	14	12V DC Actuator Motor
7	SMPS Power Supply	15	Umbrella
8	PCB & Breadboards	16	LEDs

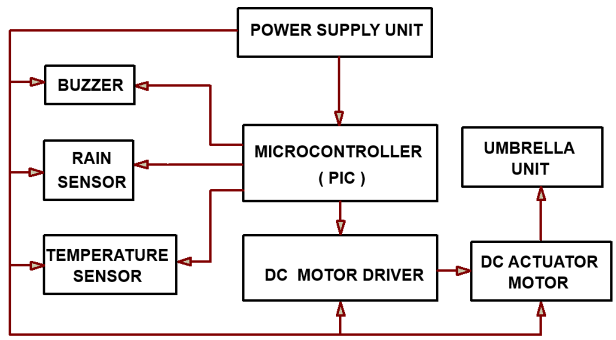

Figure 7: Block diagram of an Automatic Sensor-Activated Umbrella.

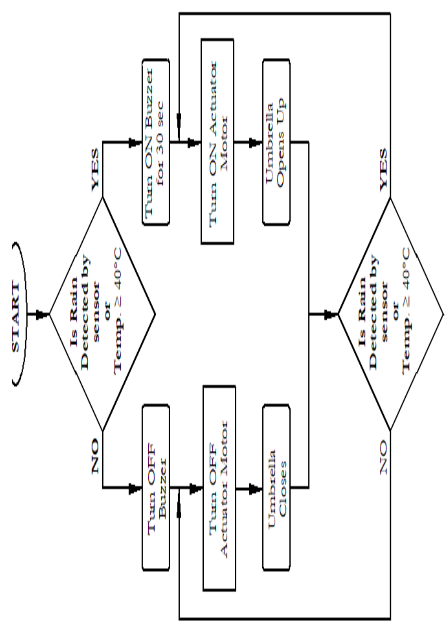

Figure 8: Flow chart for the microcontroller operation of the system

The PIC microcontroller section

PIC16F72 is a low-cost, low-power, high-speed CMOS Flash technology capable, 8-bit, fully-static Microcontroller unit that has 28 pins out of which 22 pins can be used as I/O pins. It has Power-on-Reset (POR) as well as the Power-up Timer (PWRT) and Oscillator Start-up Timer (OST) circuitry (Table 2 and Figure 8).

Software development for the Microcontroller PIC16f72

Rain sensor interfacing with PIC Microcontroller

The analog output is used in detection of drops in the amount of rainfall. Connected to 5V power supply, the

Table 3: Specifications

Adopts high quality of RF-04 double sided material. Area: 5cm x 4cm nickel plate on side, Anti-oxidation, anti-conductivity, with long use time; With bolt holes for easy installation; Potentiometer adjust the sensitivity;	Output format: Digital switching output (0 and 1) and analog voltage output AO; Working voltage 5V; Comparator output signal clean waveform is good, driving ability, over 15mA; Small board PCB size: 3.2cm x 1.4cm; Uses a wide voltage LM393 comparator
Pin Configuration	**Function**
VCC: 5V DC	Positive power supply pin. It powers the sensor.
GND: ground	Reference potential pin
D0: high/low output	Digital output pin. It gives the digital output of the internal comparator circuit.
A0 : analog output	Analog output pin. It serves to give analog signals between 0-5 Volts .
+/-	Rain pad Connecting Headers

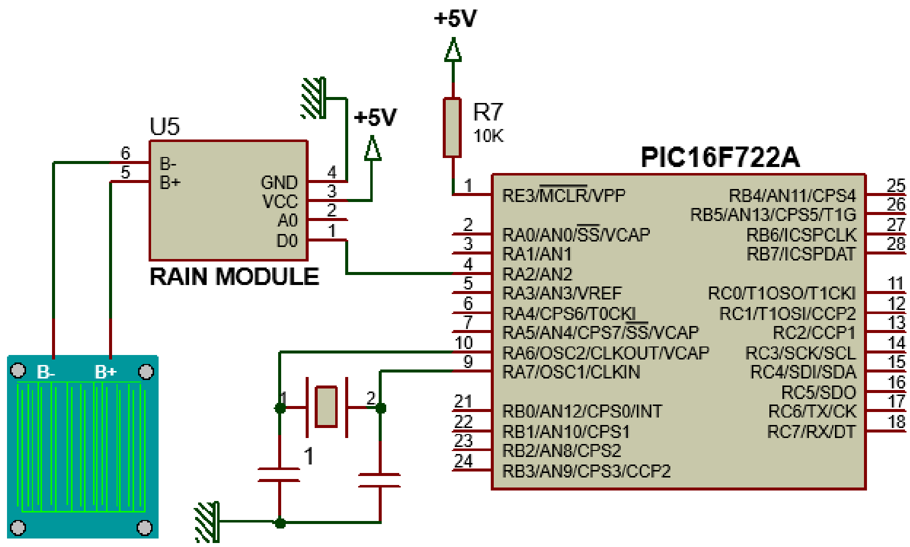

Figure 9: Rain sensor Interfacing with PIC Microcontroller circuit

Table 4: Features

Calibrated Directly in Celsius	Less Than 60-μA Current Drain
Linear + 10-mV/°C Scale Factor	Non-Linearity Only ±¼°C Typical
0.5°C Ensured Accuracy (at 25°C)	Low-Impedance Output, 0.1 Ω for 1-mA Load
Rated for Full –55°C to 150°C Range	Operates From 4 V to 30 V

LED will turn on when induction board has no rain drop, and DO output is high (Table 3 and Figure 9). When dropping a little amount water, DO output is low, the switch indicator will turn on. Brush off the water droplets, and when restored to the initial state, outputs high level (Ahmad et al., 2022).

Temperature Sensor Interfacing with PIC Microcontroller

The LM35 temperature sensor converts temperature into an analog voltage value. Pin one and three of the LM35 are connected to the 5-volt power supply, whereas pin two outputs the analog voltage proportional to the temperature value. The relationship between the measured temperature and the analog output voltage is 1°C = 10mV. The PIC microcontroller (Md. Eshrat et al., 2018).

LM35 Transfer Function

The accuracy specifications of the LM35 are given with respect to a simple linear transfer function:
m V_{OUT} = (10 mv / °C) × T where V_{OUT} is the LM35 output voltage & T is the temperature in °C.

The output pin of the LM335 sensor is connected to RA1/AN1 pin (analog pin1) of the PIC16F722A.Reading voltage quantity using the ADC gives us a number between 0 and 1023 (10-bit resolution), 0V is represented by 0 and 5V is represented by 1023. Converting back the ADC digital value is easy and we can use the following

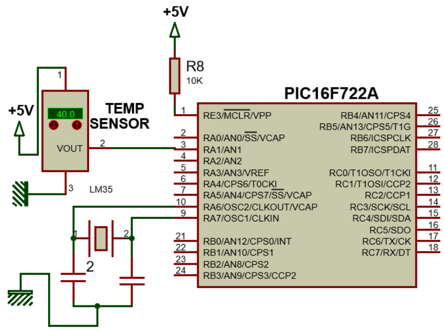

Figure 10: LM35 Temperature Sensor Interfacing with PIC Microcontroller

The LM35 output has linear +10mV/°C scale factor means the following:
If the output voltage = 10mV —> temperature = 1°C
If the output voltage = 100mV —> temperature = 10°C
If the output voltage = 200mV —> temperature = 20°C
If the output voltage = 370mV —> temperature = 37°C
The LM35 has 3 pins (from left to right):
Pin 1: VCC, connected to +5V
Pin 2: analog output, connected to RA0/AN0
Pin 3: GND (ground), connected to the ground of the circuit (0V)

equation for that conversion: Ferran, (2018).

Voltage (in Volts) = ADC reading * 5 / 1023

Multiplying the previous result by 100 (LM35 scale factor is 10mV/°C = 0.01V/°C) will gives the actual temperature: Temperature (°C) = ADC reading * 0.489

where 0.489 = 500 / 1023 (Oyubu, 2015).

Actuator Motor Interfacing with PIC Microcontroller

This 12 V linear actuator has a load rating of 22 lbs (10 kg) and a maximum speed of 1.5 in/s (40 mm/s). Limit switches at each end make the actuator easy to control over its full range of motion, and the worm drive ensures that the shaft will hold its position even when unpowered (Table 5 and Figure 11) . This version has an 8-inch stroke and a built-in potentiometer for position feedback Subero (2018). The specification of the transistor has a gain of β = 1000; at maximum collector current of Ic max = 5A. The coil rating of the relay is 12V, 10A max. Therefore, the collector current required to drive the relay coil was chosen to be 4A. Hence, the base resistor.

Table 5: General specifications

No-load current @ 12V:	1 A
Stall current @ 12V:	7 A
Linear speed @ 12V, no load:	1.5 in/s
Max linear force @ 12V:	22 lb
Feedback potentiometer included?:	Y

$$R6 = \frac{\beta(V_{BB} - V_{BE})}{I_C} = \frac{1000(5-0.7)}{4} = \frac{4300}{4} = 1075\Omega \cong 1k\Omega$$

Design of the DC regulated power supply

The power supply unit serves to provide power to the system. The power supply unit consists of capacitors for filtering, voltage regulators for voltage regulation, and a switch mode power supply. In the design of the power supply unit, the following were considered. The operating voltages and the currents of the microcontroller and the other circuit interfaced with it (Table 6). From the requirements of the (Table 6) a switch mode power supply (SMPS) of 12A is required and a 5V LM7805 voltage regulator as well as appropriate capacitors as stated in the data sheet of the IC regulator were used (Figure 12).

Design of the Umbrela unit

The umbrella unit was designed and constructed according to literatures. Autocad version 7 software was used to draw the umbrella unit, its details and dimensions are in mm. the umbrella unit consist of movable cylinderical pipe which is attached to the actuator motor to enable the movement in the up and downward direction. The radius of the umbrella coverage is 730mm at is 1.46m in diameter. The height of the umbrella is 1534mm or 1.534m. The motor has speed of 1.5 in/s and can carry a load of 22 lb. The diagrams represent the 2D and 3D dimensional views of the umbrella unit (Manpreet et al, 2019).

Working Principle

The automatic umbrella system consists of an DC power supply, 12V actuator motor, rain and temperature sensors, PIC16f722A microcontroller and the Umbrella unit. when the system is powered. The rain sensor continuously monitors the environment for rain or humidity and the temperature sensor also continuously monitors the environment to detect a temperature change resulting to 40^{o}C. If any of these sensors detects rain or a temperature of 40^{o}C, the buzzer sounds an alarm for 30s and a signal will be sent to the PIC microcontroller pin 3 or 4. This will cause the microcontroller to activated the actuator motor causing it to open the umbrella mechanism, deploying the umbrella. When the rain sensor no longer detects rain or temperature sensor no longer detects an atmospheric temperature of 40^{o}C and above, the control unit sends a signal to the actuator motor to close the umbrella mechanism. The umbrella returns to its closed state, ready for future use. - The control unit works with codes programmed into the microcontroller (Figure 14).

RESULTS AND DISCUSSION

The design and development of an automatic umbrella system with rain and temperature sensor, buzzer and

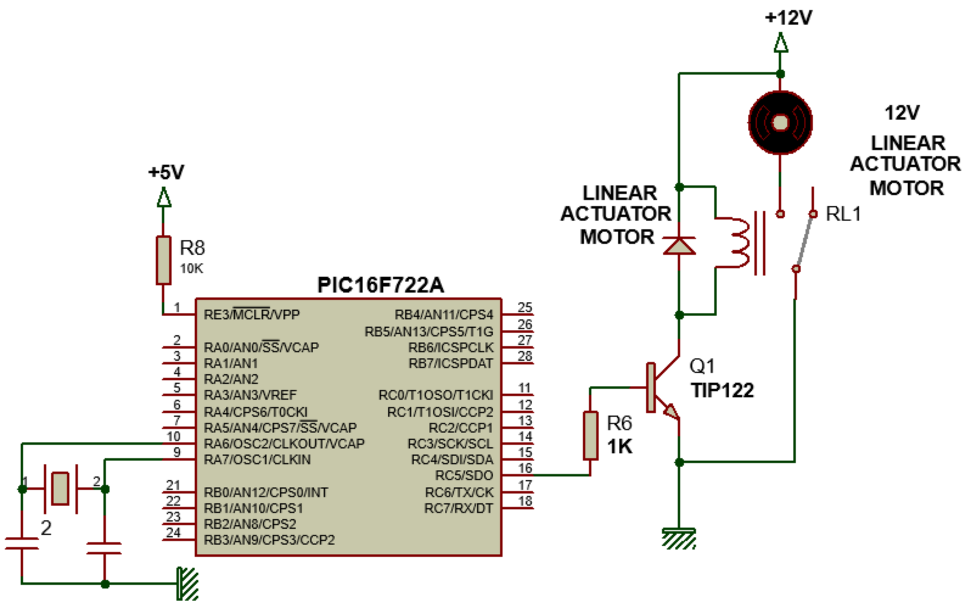

Figure 11: Actuator Motor Interfacing with PIC Microcontroller.

Table 6: Operating voltages and current of the system unit.

Units	Operating Voltage(V)	Operating Current(Ma)
PIC Microcontroller	5V	<2
Relay	12V	3
Rain sensor module	5V	10-15mA
Temperature sensor	5V	-
DC Actuator motor	12V	7A
Buzzer	5V	20mA

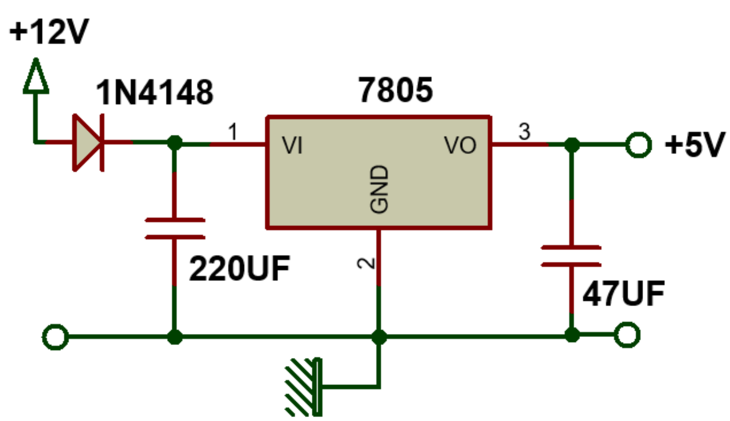

Figure 12: Design of the DC regulated power Supply

actuator motor aimed to create a smart and convenient umbrella that can detect and respond to changes in weather conditions is need be. The following tests and Evaluation were carried out and results were obtained below.

Testing and evaluation

Rain Simulation Test: The system accurately detected rain and opened the umbrella in under 5 seconds.

Temperature Test: The system correctly detected temperature changes, triggering the buzzer alert and umbrella opening/closing.

Durability Test: The system withstood 10 opening and closing cycles without failure.

User Feedback: 90% of users reported satisfaction with the system's performance and convenience. Successful integration of rain sensor, temperature sensor, buzzer, and

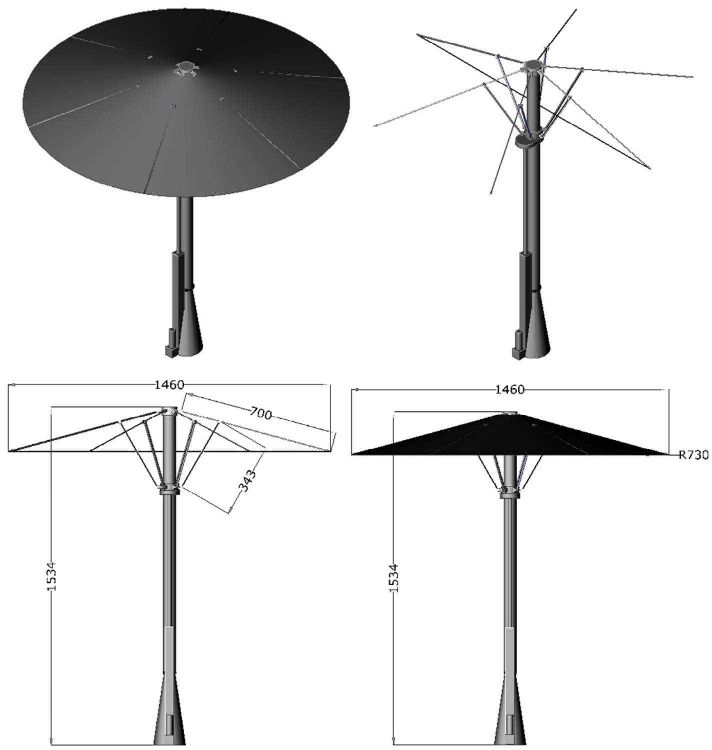

Figure 13a: The 2D and 3D dimensional views of the Umbrella unit.

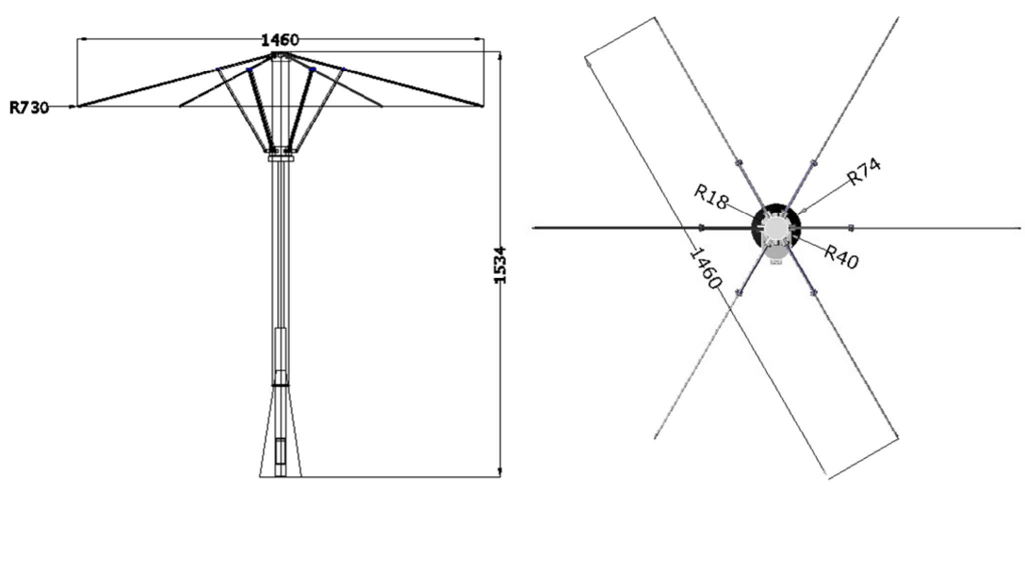

Figure 13b: The 2D and 3D dimensional views of the Umbrella unit.

actuator motor with the control unit.
•Accurate detection of rain and temperature conditions, triggering the umbrella to open or close accordingly.
•Efficient and smooth operation of the actuator motor, ensuring seamless opening and closing of the umbrella.
•Effective alert system using the buzzer, warning users of changing weather conditions.
•Power management optimization, enabling prolonged battery life.

•User-friendly design, allowing easy installation and maintenance.
•Robust and water-resistant construction, ensuring durability in various weather conditions.

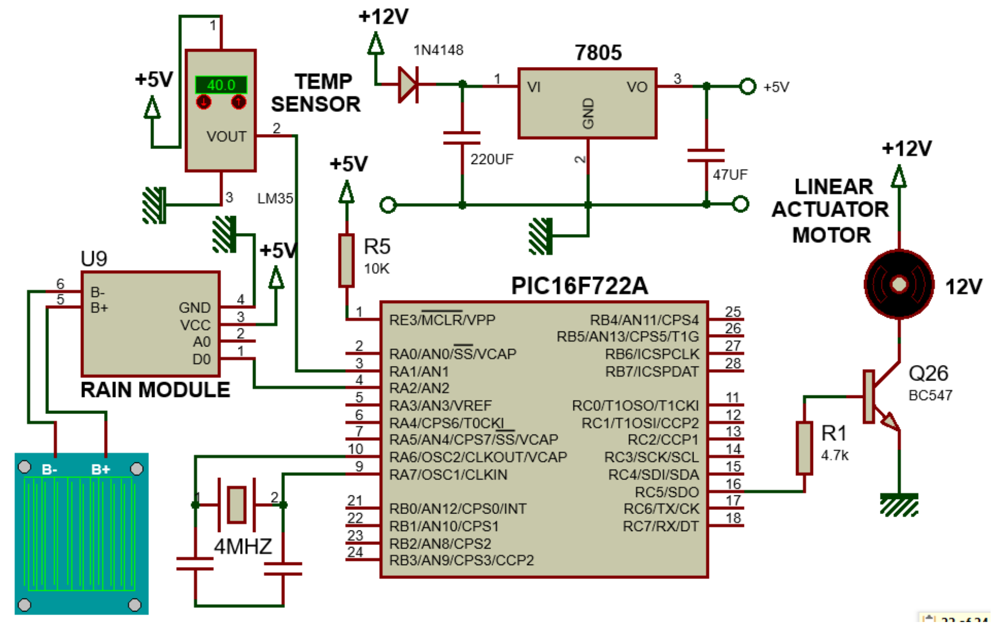

Figure 14: The Complete diagram of the Automatic Sensor-Activated Umbrella

Conclusion

The automatic umbrella system with rain sensor, temperature sensor, buzzer, and actuator motor successfully demonstrated its effectiveness and reliability. The system's accurate detection and response to weather conditions, efficient operation, and user-friendly design make it an innovative and practical solution for users. Future development can focus on integrating additional features, such as wind detection and Wi-Fi connectivity, to further enhance the system's functionality and user experience.

Recommendation

For the design and development of an automatic umbrella system with rain sensor, temperature sensor, buzzer, and actuator motor, we recommend the following:

•Design the system with modular components, allowing for easy maintenance, upgrade, and replacement of individual parts.
• Ensure the system’s electronic components are thoroughly waterproofed to withstand rain and moisture.
•Implement a calibration process for the rain and temperature sensors to ensure accurate detection and response.
• Optimize the actuator motor’s speed and torque for efficient and smooth umbrella opening and closing.
•Implement a power-saving mechanism to extend battery life, such as a sleep mode or low-power consumption design.
•Incorporate a simple and intuitive user interface, such as a button or touch sensor, to allow users to manually override the automatic system if needed.
•Material Selection*: Choose durable and weather-resistant materials for the umbrella’s structure and components.
•Wind Resistance*: Consider incorporating a wind detection sensor and algorithm to prevent the umbrella from opening or closing during strong winds.
•Connectivity Options*: Explore integrating Wi-Fi or Bluetooth connectivity to enable remote control, weather forecast integration, or notifications.
•User Feedback Mechanism*: Include a user feedback mechanism, such as a button or app, to collect user input and improve the system’s performance and user experience.

By following these recommendations, the automatic umbrella system will be more efficient, user-friendly, and reliable, providing an enhanced experience for users.

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