# SOLAR POWERED SMART IRRIGATION SYSTEM USING IOT FOR EFFICIENT WATER MANAGEMENT

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## Abstract

The Smart Solar-Powered Irrigation System leverages renewable energy and IOT technology to optimize water usage in agriculture. This system integrates solar panels, a charge controller, a battery, an Arduino microcontroller, an LCD display, moisture sensors, a DHT11 temperature and humidity sensor, a motor driver, and a water pump. Data from the sensors is transmitted to the Thing Speak cloud platform via a Wi-Fi module, enabling remote monitoring and control through a mobile application. The system ensures efficient irrigation by analyzing real-time soil moisture and environmental conditions, reducing water wastage, and maximizing crop yield. This project focuses on a Solar Irrigation and Crop Protection System designed to improve agricultural productivity and resource management. The system sourced by renewable energy from solar panels with IoT-enabled smart sensors and actuators. Using Arduino, it automates irrigation based on soil moisture and weather conditions, protects crops from wildlife using ultrasonic sensors and servo motors, and monitors environmental parameters like temperature and humidity. It includes Wi-Fi connectivity for real-time monitoring and control via a mobile app, ensuring energy-efficient and sustainable farming practices.

***Keywords: Think speak, Internet of Things, Photo Voltaic, water pumping, Arduino .***

## I. INTRODUCTION

Agriculture is a fundamental sector for sustaining human life and plays a pivotal role in the economies of developing countries. However, the sector faces increasing stress due to rapid urbanization, unpredictable climatic patterns, depleting water resources, and inefficient traditional farming practices. One of the most pressing issues is the inefficient use of water in conventional irrigation methods such as flood irrigation, where a significant portion of water is lost due to evaporation, surface runoff, and percolation beyond the root zone [1]. With over 70% of freshwater globally being consumed by the agricultural sector [2], there is an urgent need to implement intelligent irrigation practices to conserve water while ensuring high crop productivity.

To address this challenge, smart irrigation systems have emerged as a technological solution that integrates Internet of Things (IoT), microcontrollers, and renewable energy sources. These systems are capable of automating the irrigation process by monitoring soil moisture, environmental conditions, and crop water requirements in real time [3]. The use of Arduino-based microcontrollers facilitates a low-cost and programmable control system, which can read sensor data and activate irrigation mechanisms as per pre-defined thresholds. Additionally, the incorporation of wireless communication modules such as GSM, Bluetooth, or Wi-Fi (ESP8266) enables farmers to monitor and control irrigation remotely through a smartphone or web interface [4][5]. Furthermore, in rural and remote areas where access to electricity is inconsistent or unavailable, powering irrigation systems using solar energy offers a sustainable and environment-friendly alternative. Solar panels convert sunlight into electrical energy, which can be stored in batteries and used to operate sensors, microcontrollers, and water pumps. This not only reduces dependency on the grid but also ensures uninterrupted operation of the system in off-grid regions [6][7].

A number of researchers have proposed and implemented various forms of IoT-based smart irrigation systems in recent years. For instance, Jain et al. [8] designed a solar-powered smart irrigation framework using Arduino Uno, GSM module, and moisture sensors, which automatically waters the field based on sensor feedback. Similarly, Gutiérrez et al. [9] developed an automated irrigation system using a wireless sensor network and a GPRS module to monitor soil and climate conditions, significantly improving water usage efficiency. Another study by Singh et al. [10] enhanced traditional models by incorporating weather forecasting APIs, which help predict rainfall and adjust irrigation schedules accordingly. Lakshmi and Reddy [11] demonstrated that using such systems can lead to 30–50% water savings compared to manual irrigation, alongside a noticeable improvement in crop yield. Moreover, Pavithra and Srinath [12] emphasized the benefits of integrating Android-based mobile control with smart irrigation systems, providing real-time alerts and easy control to farmers. Machine learning techniques have also begun to be applied in this domain, enabling systems to learn from historical irrigation patterns and optimize water delivery [13]-[16]. Despite these advancements, most existing systems still face challenges related to cost, maintenance, and scalability in rural environments. The proposed research focuses on the design and implementation of a solar-powered smart irrigation system that combines low-cost Arduino hardware, IoT-based sensor networks, and solar energy for efficient, autonomous, and remotely accessible irrigation. This system aims to reduce manual labour, conserve water, and promote sustainable farming practices in regions where modern infrastructure is limited. The proposed work aims to design and implement a solar-powered smart irrigation system using Arduino, IoT sensors, and a web-based dashboard for remote monitoring. The system operates autonomously and provides real-time feedback to the user, ensuring optimal water usage and crop health.

## II. SYSTEM DESCRIPTION

The system integrates solar power with IOT technology to provide an intelligent irrigation solution. The solar panels power the system, reducing the reliance on non-renewable energy sources. The system uses various sensors (soil moisture, temperature, humidity) to gather real-time data, which is processed by the Arduino microcontroller. Based on the sensor data, the microcontroller controls the water pump, ensuring that crops receive the optimal amount of water. Additionally, the system sends data to the ThingSpeak cloud platform for remote monitoring and control via a mobile application, allowing farmers to manual irrigation even when away from farm.

The solar panels supply power to the system, including the Arduino, sensors, and water pump. Soil moisture, temperature, and humidity are measured using the respective sensors (Moisture Sensor, DHT11 Sensor). The collected data is sent to the Arduino microcontroller for analysis and decision-making. If soil moisture falls below a predetermined threshold, the microcontroller triggers the water pump to water the crops. The system continuously uploads data to the ThingSpeak cloud platform. Users can monitor and control the system remotely via the mobile application connected to ThingSpeak. The system continuously adjusts irrigation schedules based on real- time environmental data, ensuring efficient water usage.

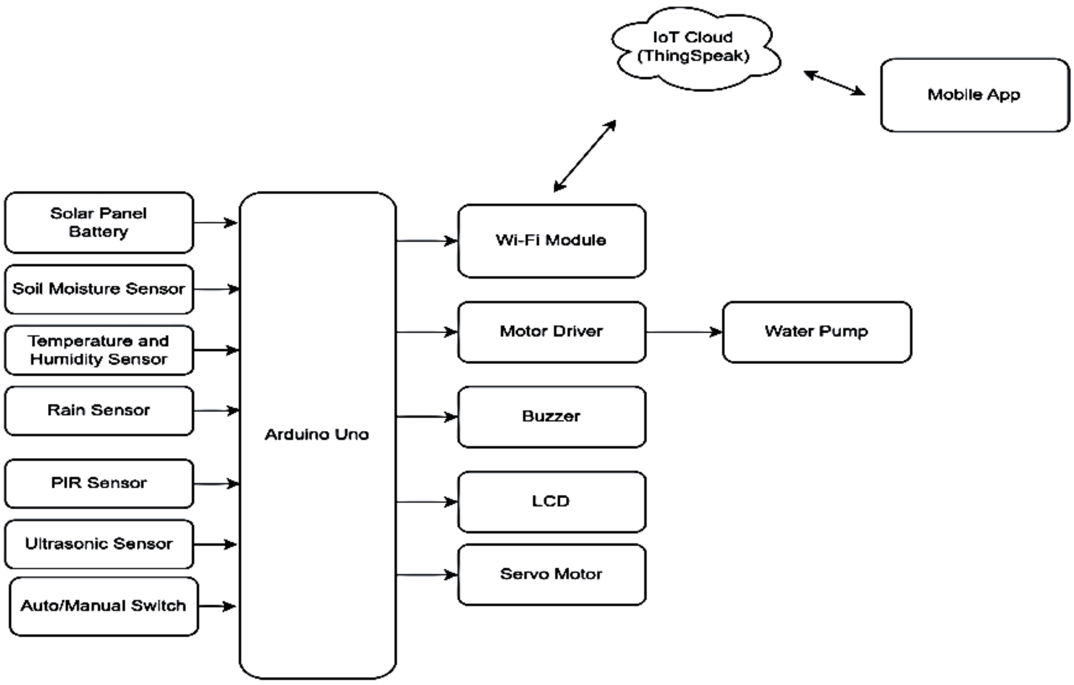


Figure 1: Block diagram of Proposed System

# III. METHODOLOGY

Solar Panel Integration: Solar panels are used to charge a battery that powers the system, ensuring that it can operate independently of external power sources.

Sensor Integration: Sensors are deployed in the soil to monitor moisture, temperature, and humidity. The Arduino microcontroller processes the data to activate the irrigation system when needed.

IOT Integration: A Wi-Fi module (e.g., ESP8266) is used to connect the system to the ThingSpeak platform, allowing for remote monitoring and control through a mobile app.

Automation Logic: The system uses pre-set thresholds for soil moisture to determine when irrigation is required, ensuring optimal watering based on real-time conditions.

# IV. Hardware Implementation

A. **Design Circuit:** Create the circuit that connects all components (solar panel, sensors, microcontroller, motor driver, etc.)

B. **Solar Panel:** Solar panels are used to convert light energy into electrical energy that electrical energy is stored in the batteries

C. **Li-ion Battery(18650) :** Lithium batteries are used in solar battery storage systems to store excess solar energy for later use.

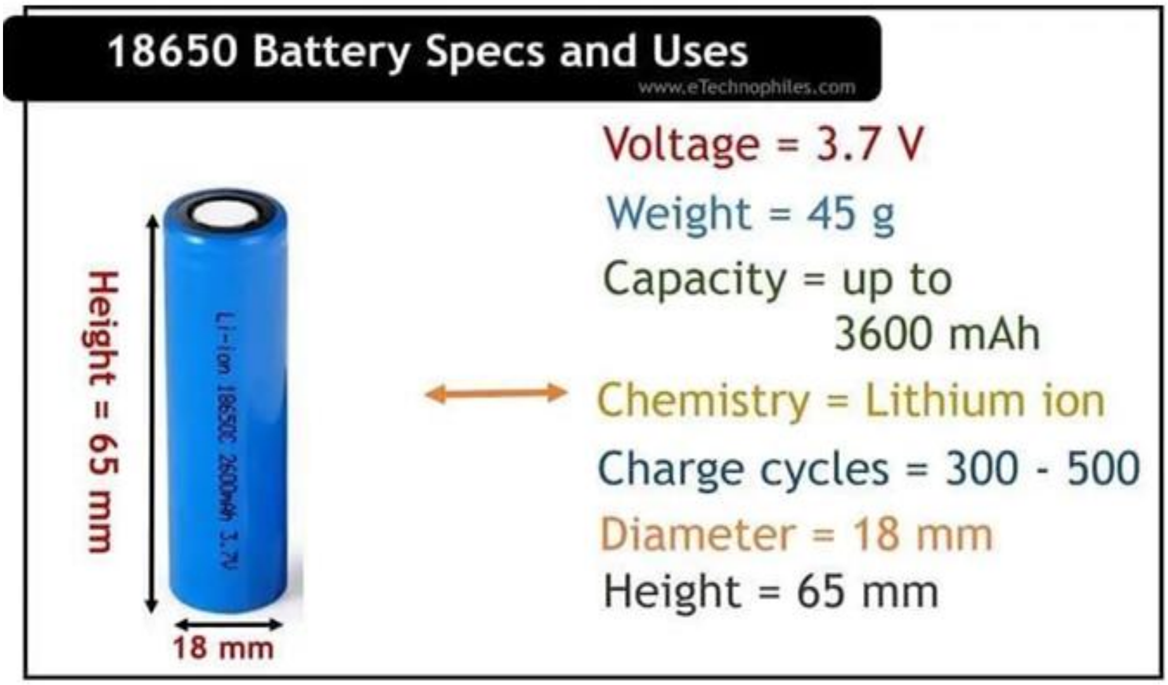


Figure 2: Lithium ion of battery specifications

### D. L298n Module Pinout Configuration:

This L298N Motor Driver Module is a high power motor driver module for driving DC and Stepper Motors. This module consists of an L298 motor driver IC and a 78M05 5V regulator. L298N Module can control up to 4 DC motors, or 2 DC motors with directional and speed control.

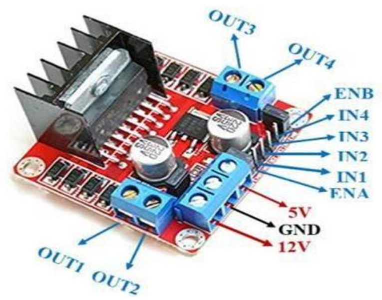


Figure 3: L298n Module

| Pin Name | Description |
|---|---|
| IN1 & IN2 | Motor A input pins Used to control the spinning direction of Motor A |
| IN3 & IN4 | Motor B input pins Used to control the spinning direction of Motor B |
| ENA | Enables PWM signal for Motor A |
| ENB | Enables PWM signal for Motor B |
| OUT1 & OUT2 | Output pins of Motor A |
| OUT3 & OUT4 | Output pins of Motor B |
| 12V | 12V input from DC power Source |
| 5V | Supplies power for the switching logic circuitry inside L298N IC |
| GND | Ground pin |

### E. Install Sensors:

In this work different sensors are used .

#### i. Soil moisture sensor:

Moisture sensor module consists of four pins i.e. VCC, GND, DO, AO. Digital out pin is connected to the output pin of LM393 comparator IC while the analog pin is connected to Moisture sensor.

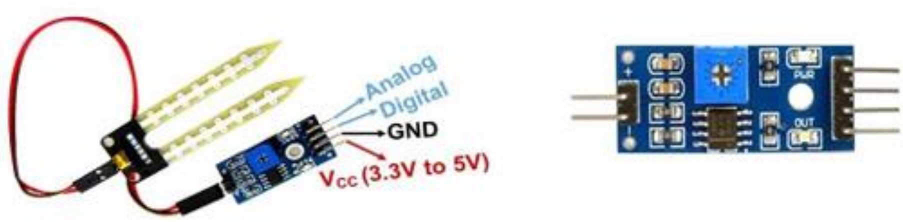


Figure 4: Soil Moisture Sensor Module

| Pin Name | Description |
|---|---|
| VCC | The Vcc pin powers the module, typically with +5V |
| GND | Power Supply Ground |
| DO | Digital Out Pin for Digital Output. |
| AO | Analog Out Pin for Analog Output |

Using a Moisture sensor module with a microcontroller is very easy. Connect the Analog/Digital Output pin of the module to the Analog/Digital pin of Microcontroller. Connect VCC and GND pins to 5V and GND pins of Microcontroller. After that insert the probe inside the soil. When there is more water presented in the soil, it will conduct more electricity that means resistance will be low and the moisture level will be high.

### ii. Ultrasonic Sensor :( HC-SR04)

The Ultrasonic transmitter transmits an ultrasonic wave, this wave travels in air and when it gets objected by any material it gets reflected back toward the sensor this reflected wave is observed by the the sensor.The current consumed by the sensor is less than 15mA and hence can be directly powered by the on board 5V pins (If available).

If the detected distance is expressed as L, the time from the emission of ultrasonic to the receipt as T, and the speed of sound as C, the detected distance can be calculated by the formula: $L = 1/2 \times T \times C$. (T is 'to-and-from' time; thus it is divided by 2.)

| Pin Name | Description |
|---|---|
| VCC | The Vcc pin powers the module, typically with +5V |
| GND | Power Supply Ground |
| Trigger | Trigger pin is an Input pin. This pin has to be kept high for 10us to initialize measurement by sending US wave. |
| Echo | Echo pin is an Output pin. This pin goes high for a period of time which will be equal to the time taken for the US wave to return back to the sensor. |

### iii. Raindrop Sensor Module:

Raindrop Sensor is a tool used for sensing rain. It consists of two modules, a rain board that detects the rain and a control module, which compares the analog value, and converts it to a digital value. The raindrop sensors can be used in the automobile sector to control the windshield wipers automatically, in the agriculture sector to sense rain and it is also used in home automation systems.

| Pin Name | Description |
|---|---|
| VCC | Connects supply voltage- 5V |
| GND | Connected to ground |
| DO | Digital Out Pin for Digital Output. |
| AO | Analog Out Pin for Analog Output |

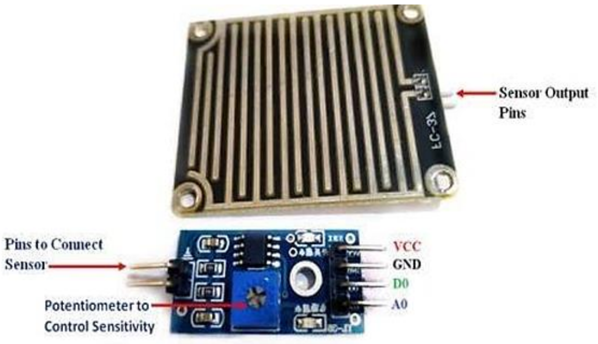


Figure 5: Rain Drop Sensor Module

### iv. Passive Infrared Sensor:

PIR Sensor Switch Can Detect the Infrared Rays released by Human Body Motion within the Detection Area (14 Meters), and Start the Load - Light Automatically. The PIR Sensor senses the motion of a body by the change in surrounding ambient temperature when a human body passes across. Then it turns on the lighting load to which it is connected. The lighting load remain on until it senses motion. Once the motion is seized it switches off the lighting load. During the night, the LUX adjustment knob allows you to adjust the luminosity based on which the lighting load will either switch on/off automatically.

| Pin Name | Description |
|---|---|
| VCC(pin3) | Connects supply voltage- 5V |
| GND(pin1) | Connected to ground |
| OUT (pin2) | digital signal 3.3V or 5V |


Figure 6: Pir Sensor

### v. DTH11(Temperature and Humidity Sensor):

It is used to keep in the soil to monitor moisture levels. The DHT11 Sensor is factory calibrated and outputs serial data and hence it is highly easy to set it up. The connection diagram for this sensor is shown below.

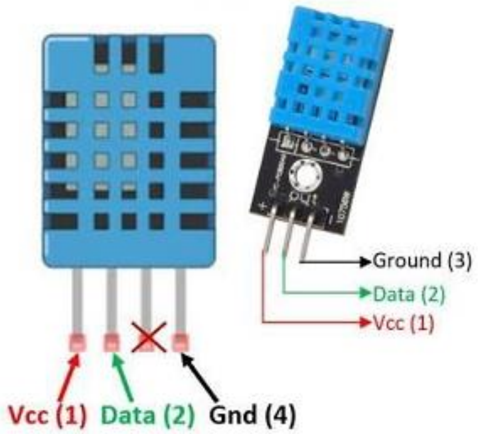


Figure 7: Temperature and Humidity Sensor

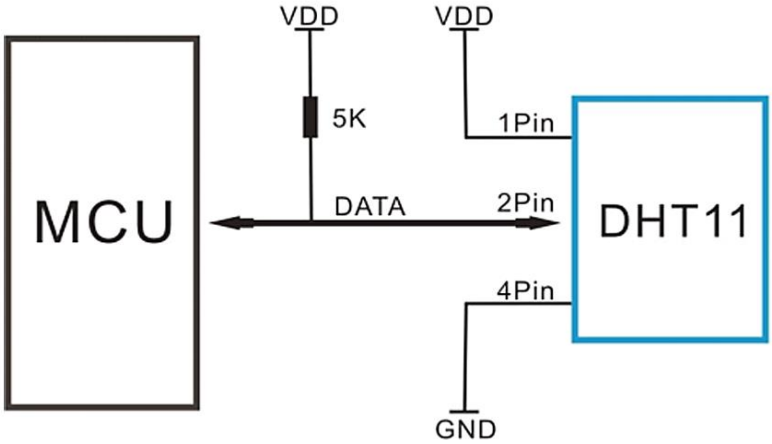


Figure 8: DHT11 connection diagram with Arduino MCU

To request the DHT11 module to send these data the I/O pin has to be momentarily made low and then held high as shown in the timing diagram below

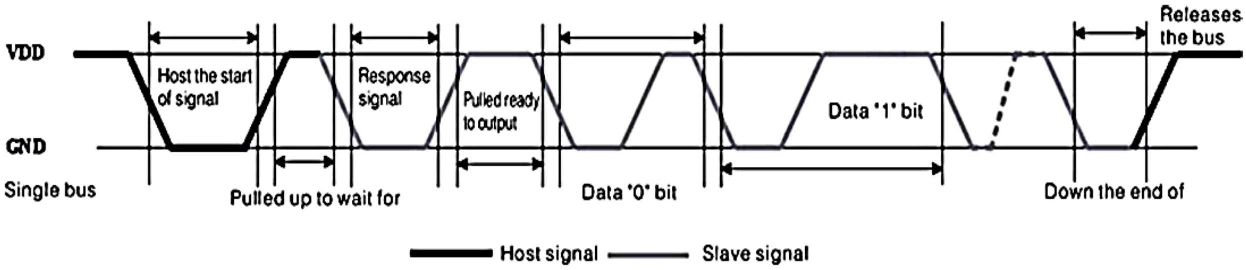


Figure 9: Timing diagram for output data of DHT11 Sensor

### F. Connect IoT Module:

Set up the Wi-Fi module to enable communication with the ThingSpeak platform. Wifi module used in this work is ESP8266 D1 Mini V2 NodeMCU Lua IoT Dev Board.

### G. Develop Software:

Program the Arduino to read sensor values, make decisions, and trigger the irrigation system.

### H. Cloud Setup:

Set up ThingSpeak to receive and display sensor data.

### I. Mobile Application:

Develop or use an existing app that allows users to view data and control the system remotely.

## V. THING SPEAK CONFIGURATION

The main aim is to create the ThingSpeak channel and get the key. Inorder to achieve this ,the procedure is explained below in step by step:

Step 1: Open ThinkSpeak cloud Platform

Step 2: Choose Channels -> My Channels -> New Channel

Step 3: Input Channel name, Field1 , then click “Save Channel”

Step 4 You will see a chat for data field1

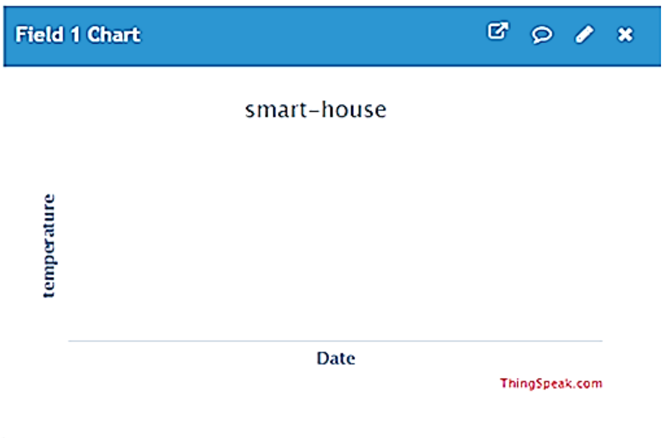


Figure 10: Chart showing Temperature data

Step 5: Open your web browser, go to https://thingspeak.com , select your channel > "API Keys" , copy the API key as follows:


Figure 11: API Key Interface


Figure 12:ThingSpeak IOT Platform

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## VI. MIT APP INVENTOR OVERVIEW

In this work, mobile app for monitoring data using MIT App Inventor. It provides a web-based "What you see is what you get" (WYSIWYG) editor for building mobile phone applications targeting the Android and iOS operating systems. It uses a block-based programming language built on Google Blockly. The MIT App Inventor user interface includes two main editors: the design editor and the blocks editor. The design editor, is a drag and drop interface to lay out the elements of the application's user interface (UI) and the blocks editor in which app inventors can visually lay out the logic of their apps using color-coded blocks that snap together to describe the program. To aid in development and testing, App Inventor provides a mobile app called the App Inventor Companion (or just "the Companion") that developers can use to test and adjust the behaviour of their apps in real time.

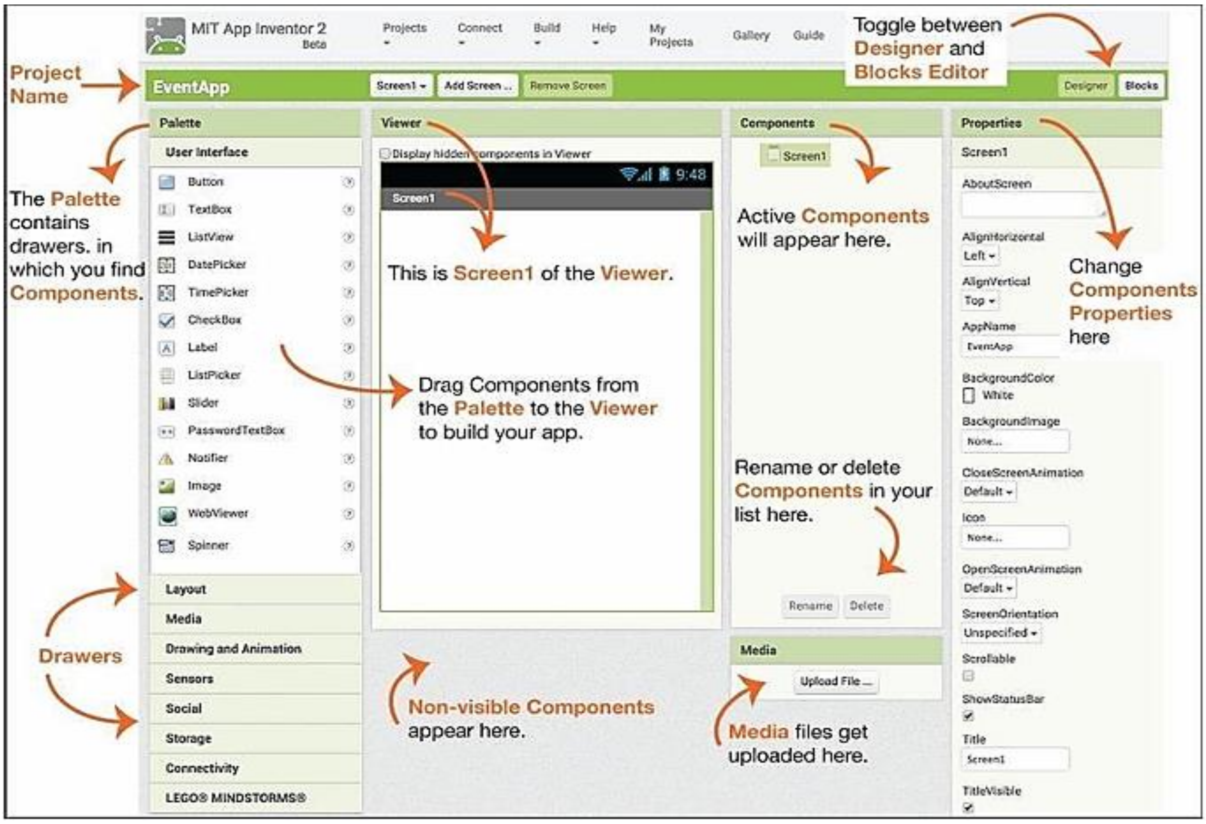



Figure 13: App Inventor's design editor.

## VII. RESULTS & DISCUSSION

The Smart Solar-Powered Irrigation System has been successfully implemented and tested in a variety of agricultural environments. The system has shown a significant reduction in water wastage by automatically regulating irrigation based on real-time data collected from soil moisture and environmental sensors. By leveraging solar power, the system operates independently of the grid, ensuring an energy-efficient solution with minimal operational costs.

**SPECIFICATIONS OF ARDUINO:**

| Parameter | Specifications |
|---|---|
| Microcontroller | ATmega328 |
| Operating Voltage | 5V |
| Input Voltage | 7-12V(recommended)<br>6-20V(limits) |
| Digital I/O Pins | 14 |
| Analog Input Pins | 6 |
| DC Current per I/O Pin | 40 mA |
| Current for 3.3V Pin | 50 mA |
| Flash Memory | 32 KB |
| SRAM | 2KB |
| EEPROM | 1 KB |

**Specifications of Sensors:**

| Parameter | Value/Description |
|---|---|
| **SOIL MOISTURE SENSOR MODULE (DHT11 Sensor):** | |
| Vcc | Power supply 3.5V to 5.5V |
| Data | Outputs both Temperature and Humidity through serial Data |
| NC | No Connection |
| Ground | Connected to the ground of the circuit |
| **ULTRASONIC SENSOR PIN CONFIGURATION(HC-RS04)** | |
| TRIG | For sending ultrasonic sound waves |
| VCC | Power supply 3.5V to 5.5V |
| GND | Connected to the ground of the circuit |
| ECHO | For Receiving ultrasonic sound waves |
| **RAINDROP SENSOR** | |
| Vcc | 5V |
| Comparator | LM393 |
| Driving ability | 15mA |
| **PASSIVE INFRARED SENSOR** | |
| Voltage | **4.8 V – 20 V** |
| Lock time | 2.5 s (default) |
| Trigger | repeat : L = disable , H = enable |
| Sensing range | <120 °, within 7 m |
| Temperature | – 15 ~ +70 °C |

**SG-90 (Servo Motor)**

| Parameter | Specifications |
|---|---|
| Operating Voltage | +5V |
| Torque | 2.5kg/cm |
| Operating speed | 0.1s/60° |

| | |
|---|---|
| Gear Type | Plastic |
| Rotation | 0°-180° |
| **Wire Number /color** | **Description** |
| 1 (Brown)<br>2 Red Ground wire<br>3 Orange | connected to the ground of system<br>Powers the motor typically +5V is used<br>PWM signal is given in through this wire to drive the motor |

**Water Pump**

| **Parameter** | **Specifications** |
|---|---|
| Maximum Water lift heigh | 40-110cm / 15.75"-43.4" |
| Operating Voltage | 2.5-6V |
| Flow rate | 80-120L/H |

**Solar Panel :**

| **Parameter** | **Specifications** |
|---|---|
| Power delivered | 1.5W |
| Voltage | 6V |
| Current | 250mA |

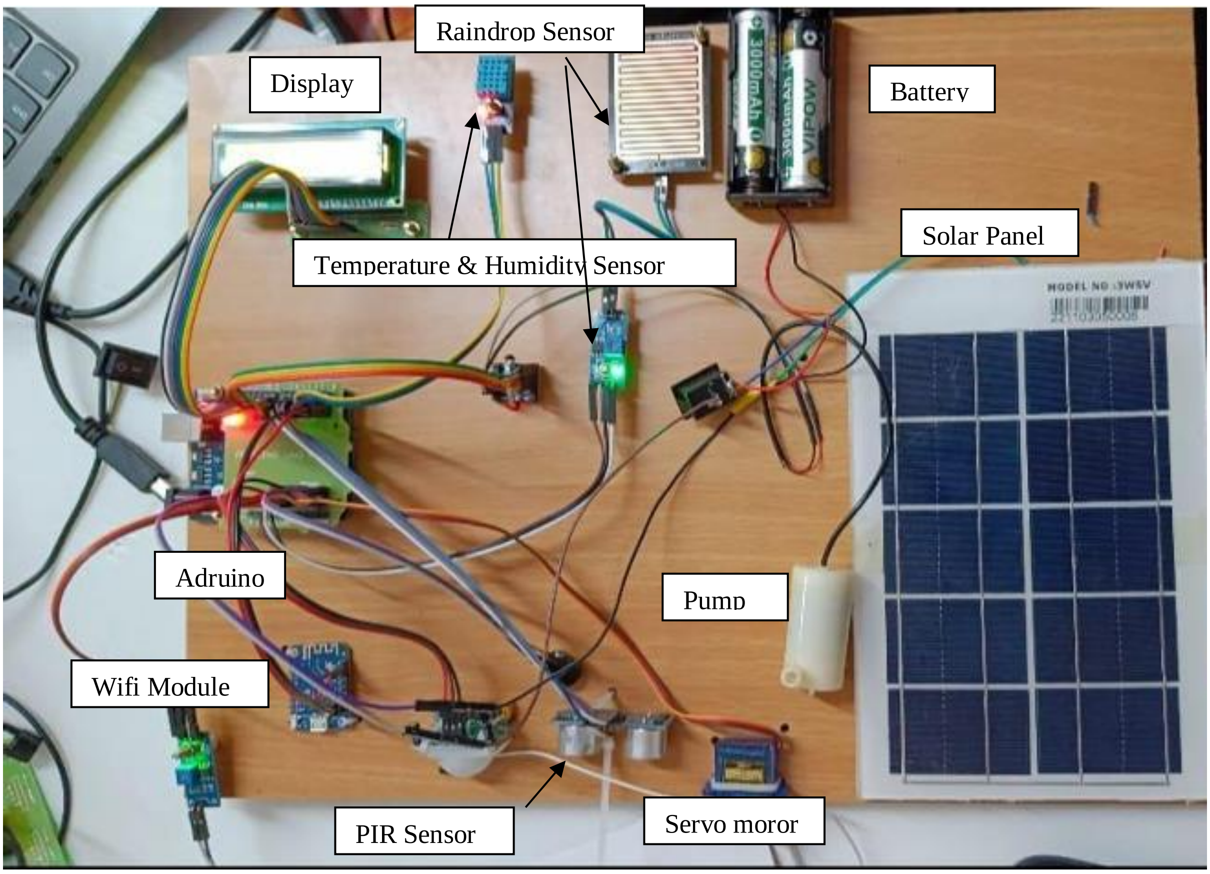
**Wifi Module:**

| **Parameter** | **Specifications** |
|---|---|
| Microcontroller | ESP8266 |
| Operating Voltage | 3.3V |
| Input Voltage | 5V (via micro USB) |
| Wi-Fi Protocol | IEEE 802.11 b/g/n |
| | |

**L298 Motor Driver**

| **Parameter** | **Specifications** |
|---|---|
| Motor Supply Voltage (Maximum) | 46V |
| Motor Supply Current (Maximum) | 2A |
| Logic Voltage | 5V |
| Driver Voltage | 5-35V |
| Driver Current | 2A |
| Logical Current | 0-36mA |
| Maximum Power (W) | 25W |

**The proposed system hard ware setup is shown in . It works efficiently as desired**




**Parameter Test Condition Sensor Reading System Response**

| Parameter | Test Condition | Sensor Reading | System Response |
|---|---|---|---|
| Soil Moisture (Dry) | Moisture < 31% | 25% | Pump turned ON automatically |
| Soil Moisture (Wet) | Moisture > 62% | 67% | Pump turned OFF |
| Temperature | 33°C | 32.8°C | Displayed on LCD and sent to cloud |
| Humidity | 60% RH | 59.5% RH | Displayed and monitored on mobile app |
| Battery Voltage | Bright sunlight | 3.7V | Battery charged; system working efficiently |
| IoT Data Upload | WiFi connected | Real-time values uploaded | Verified on Blynk/ThingSpeak |
| Solar Panel Performance | Cloudy vs Sunny | 4V (cloudy) / 6V (sunny) | Charging speed adjusted automatically |

# VIII. CONCLUSION

The Smart Solar-Powered Irrigation System represents a highly efficient, sustainable, and automated solution to modern agricultural challenges. By combining solar energy with IOT technology, it addresses two key issues in agriculture: water scarcity and inefficient irrigation. The Smart Solar-Powered Irrigation System not only enhances the efficiency of water use but also promotes environmental sustainability by reducing reliance on fossil fuels. The integration of solar power ensures that the system is energy-efficient, while the IOT technology provides real-time monitoring and control, allowing for precise water distribution based on soil conditions and weather patterns. This technology-driven approach enables farmers to optimize crop yields while minimizing water waste, making it an invaluable tool for sustainable agriculture. Ultimately, the system empowers farmers to address the growing global concerns of water conservation and energy consumption, paving the way for a more resilient and eco- friendly agricultural future. This level of automation ensures that water is delivered only when needed, improving crop health and conserving valuable water resources. As climate change continues to exacerbate environmental challenges, the Smart Solar-Powered Irrigation System is poised to play a crucial role in building a more resilient and sustainable agricultural sector. With its ability to optimize water usage and reduce energy consumption, this system represents a key innovation in the future of agriculture, offering long-term benefits for both farmers and the planet.

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