



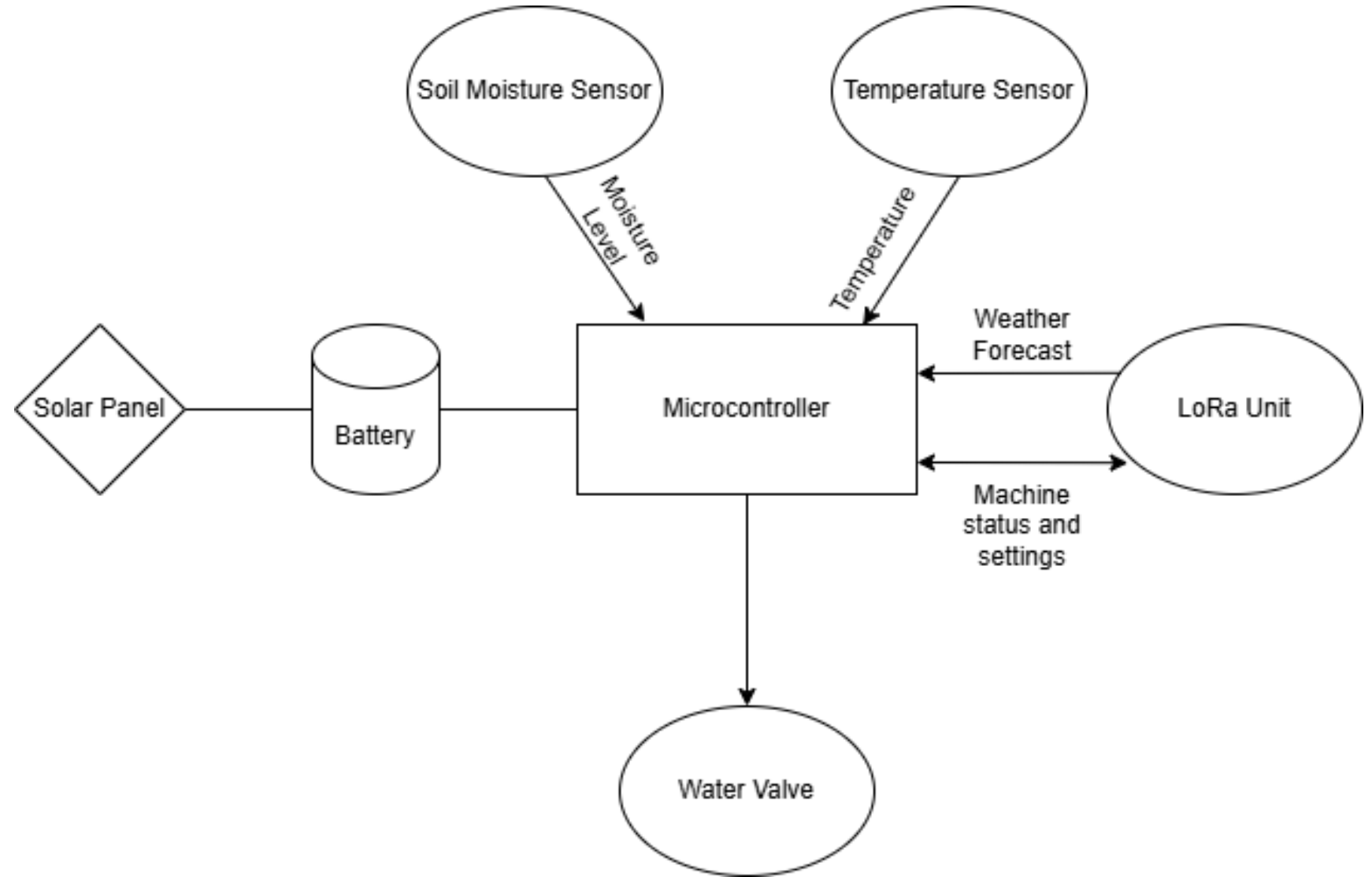
Hardware Selection

Hardware for Smart Irrigation Systems

This section elaborates on the selected hardware components for a Smart Irrigation System, detailing their specifications, justifications for use, possible alternatives, and reliable sources.



System Architecture Diagram



Capacitive Soil Moisture Sensor v1.0

Comprehensive Specifications and Benefits



Supply Voltage

- Operates between 3.3V and 5V, featuring an onboard regulator.

Analog Output

- Outputs an analog signal (0–3V) inversely proportional to soil moisture with a 10-bit resolution.

Sensing Method

- Utilizes capacitive sensing with dielectric non-contact probes for accurate readings.

Power Consumption

- Consumes 5 mA during operation and 0 μ A when switched off via GPIO pin.

Dimensions

- Compact design measuring 98mm \times 23mm \times 7mm, with a 15cm cable for easy installation.



Environmental Rating

- Rated IP66, capable of withstanding temperatures from -20°C to +70°C.

Reliability

- Accurate and reliable measurements unaffected by soil salinity or temperature variations.

Durability

- Non-corrosive probes ensure longevity even in wet soil conditions.

Low Power Draw

- Designed for low power consumption, suitable for multi-point household sensing.

Comparison with Resistive Sensor

- Alternative SEN0193 resistive sensor is cheaper but less durable and accurate.

- **Supply Voltage Range**

Operates within 3.3V–5.5V, suitable for various applications.

- **Measurement Range**

Measures temperature from -40 °C to 80 °C and humidity from 0 to 100% RH.

- **Resolution**

Offers a resolution of 0.1°C for temperature and 0.1% RH for humidity.

- **Sampling Rate**

Samples data at 0.5 Hz, providing readings every 2 seconds.

- **Power Consumption**

Consumes 1.5 mA in active mode and 50 µA in standby mode.

- **Compact Size**

Measuring only 27mm × 14mm × 13mm, it's easy to integrate.

- **Integration Objectives**

Records temperature and humidity for weather-based irrigation.

- **Accuracy**

Accuracy of ±0.5°C and ±2% RH meets agricultural requirements.

- **Ease of Integration**

Uses a single-wire protocol simplifying connections to ESP32.

- **Cost-Effectiveness**

\$5–\$10 price range makes it the best performance-to-cost option.

- **Alternate Option: DHT11**

DHT11 is cheaper but less accurate, with temperature accuracy of ±2°C.

- **Trade-Offs of DHT11**

Lower precision can lead to irrigation errors, hence not chosen.

- **Product Link**

Find more about DHT22 at SparkFun:
<https://www.sparkfun.com/products/10167>.

Temperature Sensor: DHT22 (AM2302)

Comprehensive Overview of DHT22
Specifications and Benefits

Central Microcontroller: ESP32-WROOM-32

Key features and justifications for ESP32-WROOM-32

- **Specifications Overview**

Processor: 32-bit Dual-core Xtensa LX6, 240 MHz; 520 KB SRAM.

- **Voltage Operation Range**

Operates between 2.7V–3.6V with 3.3V as the ideal, max 500 mA.

- **Communication Capabilities**

Supports Wi-Fi (802.11 b/g/n), Bluetooth 4.2/BLE, and LoRa via SPI.

- **I/O Features**

Equipped with 36 GPIO, 18-channel 12-bit ADC, 2 DACs, and more.

- **Power Usage Efficiency**

150 mA during wiki on, 20 mA normal, and 10 μ A in deep sleep.

- **Temperature Range**

Operates reliably in temperatures from -40°C to +125°C.

- **Dual-core Processing**

Allows simultaneous management of sensor data and valve control.

- **LoRa Support**

SPI capability supports LoRa transmitter and receiver functionalities.

- **Power Efficiency Goals**

Deep sleep mode aligns with energy efficiency objectives.

- **Versatile I/O Integration**

Rich I/O supports integration with sensors, relays, and more.

- **Cost-Effectiveness**

Affordable with a price range of \$5 to \$10, scalable for projects.

- **Alternative Consideration**

Arduino Uno R3 was considered but lacks wireless capability.

- **Trade-Offs of Arduino**

No LoRa support, higher power consumption, and less processing power.

- **Final Decision Rationale**

ESP32-WROOM-32 selected for its support of all project aims.

Wireless Communication Transmitter Overview

Exploring the SX1276 LoRa Module Specifications

- **Power Specifications**

Operates at 3.3V supply voltage with transmission power up to +20 dBm, ensuring effective long-range communication.

- **Frequency and Range**

Covers 868/915 MHz frequencies with a range of 1–5 km in open areas, ideal for remote monitoring.

- **Current Consumption**

Features low operating currents: 20 mA in RX mode and 120 mA in TX mode, with a minimal 0.2 μ A in sleep mode.

- **Communication Interface**

Utilizes SPI communication with 6 pins (MISO, MOSI, SCK, CS, DIO0, GND) for flexible integration.

- **Data Rate Capabilities**

Supports maximum data rates of up to 300 kbps (FSK) and 37.5 kbps (LoRa) for efficient data transmission.

- **Rationale for Use**

Chosen for its low energy consumption and high range, supporting remote field observation and data fusion.

- **Alternative Consideration**

Ak8175 was considered but rejected due to higher power consumption and expected interference issues.

- **Cost Effectiveness**

Available in an attractive price range of \$10–\$15, making it a budget-friendly option for projects.

Solenoid Valve Specifications & Benefits

Overview of Solenoid Valve and Relay System

- **Solenoid Valve Specifications**

5V DC voltage, 300 mA output, normally closed type with a 1/2" NPT brass body.

- **Pressure Range**

Operates within a pressure range of 0.02 to 0.8 MPa, ensuring versatility.

- **Quick Response Time**

Responds within 1 second, allowing for efficient water regulation.

- **Relay Specifications**

Utilizes a 5V coil and 3.3V trigger with a switching capacity of 10A at 250VAC/30VDC.

- **Safety Features**

Relay isolates solenoid from ESP32 GPIO pins, enhancing safety during operation.

- **Durability of Material**

Constructed from brass, making it suitable for outdoor applications and resistant to corrosion.

- **Power Efficiency**

Activates only during irrigation, ensuring minimal power usage.

- **Cost-Effectiveness**

Affordable components with valve priced at \$10 and relay at \$2.

- **Alternative: 12V DC Pump**

Specifications include 12V, 1A, 5L/min but are power-hungry and less accurate.

- **Decision Justification**

Selected solenoid valve due to high performance aligned with irrigation goals.

Power Consumption Estimation

Component	Voltage	Active Current	Sleep Current	Duty Cycle	Avg.
ESP32	3.3V	20mA	10µA	10%(6min/hr)	2.0
SoilMoistureSensor	3.3V	5mA	0µA	5%(3min/hr)	0.25
DHT22	3.3V	1.5 mA	50 µA	5 % (3 min/h)	0.075
LoRaSX1276(TX)	3.3V	120mA	0.2µA	1%(0.6min/hr)	1.2
SolenoidValve	5V	300mA	0mA	1%(.6min/hr)	3
Relay	5V	70mA	0mA	1%(.6min/hr)	.7
DC-DCBoostConverter	3.7V	1mA(quiescent)	0mA	100%(always on)	1
Total	-	517.5mA	-	-	8.225 mA/h

Communication and Data Flow

Component Communication

- Sensors (Soil Moisture & Temperature) → Microcontroller
 - Communication Method: Analog or Digital Signals
 - The microcontroller reads sensor values at defined intervals.
- LoRa Weather Data → Microcontroller
 - Communication Method: SPI
 - The microcontroller receives weather data from the internet through LoRa daily.
- Microcontroller → LoRa Module
 - Communication Method: SPI
 - The microcontroller sends sensor history, and various machine status and settings.
- Microcontroller → Solenoid Valves
 - Communication Method: Digital Signal
 - The microcontroller triggers the solenoid valves to regulate water flow based on ML algorithm.

Communication and Data Flow

Data Processing and Transmission

- Step 1: Sensor Data Collection
 - Soil moisture and temperature sensors continuously monitor environmental conditions.
 - The microcontroller reads and filters sensor data at regular intervals.
 - Weather data received via LoRa is incorporated to improve irrigation accuracy and efficiency.
- Step 2: Data Processing in the Microcontroller
 - The microcontroller applies an ML-based irrigation control algorithm to decide when to activate the solenoid valves.
- Step 3: Solenoid Valve Control
 - The microcontroller opens or closes the solenoid valves based on the ML algorithm's decision.
- Step 4: App/Webpage Reporting
 - The system sends status updates and historical data to an app or webpage for user monitoring.

System Integration Challenges and Solutions

Potential Integration Challenges

- **Hardware Compatibility**
 - Ensuring seamless communication between different components (e.g., sensors, LoRa module, solenoid valves, microcontroller) can be challenging due to varying voltage levels and communication protocols.
- **Power Limitations**
 - The system relies on a solar panel and battery, which may face energy shortages in prolonged low-light conditions.
- **Latency in LoRa Communication**
 - LoRa has a lower data rate compared to other wireless communication methods, which might cause slight delays in weather data retrieval and irrigation decisions.
- **Environmental Durability**
 - Components like the soil moisture sensor and solenoid valve must withstand outdoor conditions, including temperature extremes and moisture exposure.

System Integration Challenges and Solutions

Proposed Solutions

- **Ensuring Hardware Compatibility**
 - Use voltage level shifters where needed to match communication voltages between components.
 - Select components that support standard protocols like SPI, I2C, and UART to simplify integration.
- **Optimizing Power Consumption**
 - Implement low-power modes in the microcontroller and sensors to reduce energy usage during idle times.
 - Use an energy-efficient MPPT charge controller to maximize solar power harvesting.
- **Mitigating LoRa Latency**
 - Optimize data transmission intervals to balance power efficiency and timely weather updates.
 - Implement local fail-safe mechanisms, where the microcontroller can make irrigation decisions even if LoRa connection fails.
- **Enhancing Environmental Durability**
 - Use IP-rated enclosures to protect sensitive electronics from dust and water exposure.
 - Select durable components or apply corrosion-resistant coatings on sensors to prolong lifespan.