1. Components Overview

This section presents the key hardware components used in the system and their purpose.

Component	Function
ESP32 Dev Board	Central microcontroller handling sensor data, MQTT, and SMS
ADS1115	Analog-to-Digital Converter for interfacing multiple analog sensors
pH Sensor **DFRobot pH Sensor (Gravity series)**	Measures acidity/alkalinity of the pond water
Water Temp Sensor **DS18B20 (Waterproof)**	Captures water temperature
Dissolved O2 Sensor **Gravity DO Sensor (DFRobot)**	Monitors oxygen level in the water
Salinity Sensor **DFRobot Gravity Analog TDS Sensor**	Measures salt concentration in the pond
Ammonia/Nitrate/Nitrite Sensors **Industrial Ion-Selective Electrode (ISE)**	Detect chemical waste levels in the water
Water level Sensor **JSN-SR04T Waterproof Ultrasonic**	Measures water level in the pond
SIM800L GSM Module	Sends SMS alerts based on threshold conditions
Power Supply (LiPo or Buck Regulator)	Powers the ESP32 and GSM module

2. Sensor to ESP32 Connectivity

Sensors are connected to the ESP32 via both direct GPIO and the ADS1115 module for analog signals:

- **ADS1115 → ESP32 (I2C Bus)**
  - SDA → GPIO21
  - SCL → GPIO22
- **Analog Sensors → ADS1115**
  - pH → A0
  - DO → A1
  - Salinity → A2
  - Ammonia/Nitrate/Nitrite → A3
- **Digital Sensors → ESP32 Directly**
  - DS18B20 (temperature) → GPIO4
  - Ultrasonic Sensor → GPIO5 (Trig), GPIO18 (Echo)

The ESP32 reads sensor data either directly or through the ADS1115 and processes it periodically.

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3. ESP32 to Node-RED Connectivity (via MQTT)

The ESP32 communicates with Node-RED using the MQTT protocol.

- **MQTT Broker**: Hosted locally (e.g., Mosquitto) or on the cloud (e.g., HiveMQ)
- **Connection Flow**:
  1. ESP32 connects to Wi-Fi
  2. ESP32 connects to MQTT broker
  3. ESP32 publishes data to topics:
     - ponds/sensor/ph
     - ponds/sensor/temp
     - ponds/sensor/o2
     - ponds/sensor/salinity

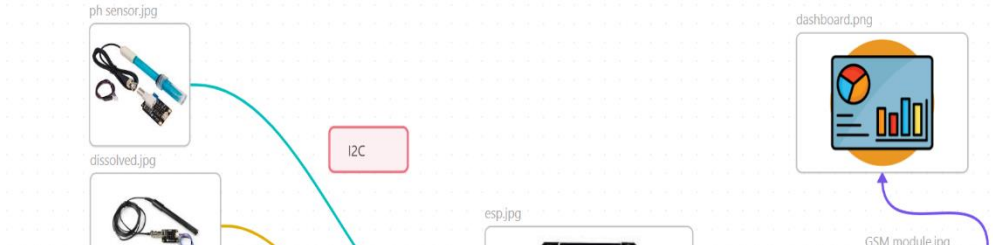
- ponds/sensor/ammonia
- ponds/sensor/waterlevel

4. Node-RED subscribes to these topics and visualizes data in a dashboard
5. Node-RED also performs threshold checks for anomaly detection

4. ESP32 to GSM Module for SMS Alerts

The GSM module (SIM800L) is used for sending SMS alerts when water parameters exceed safe limits.

- **Wiring**:
  - SIM800L TX → ESP32 RX (GPIO16)
  - SIM800L RX → ESP32 TX (GPIO17, with voltage divider)
  - SIM800L VCC → 4V power supply (not ESP32 5V)
  - GND → GND
- **Functionality**:
  1. ESP32 detects out-of-range values
  2. It formats an alert message
  3. Sends it using AT commands to the GSM module
  4. SMS is sent to the fish farmer's phone



Connectivity Diagram

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