Group 8:

LetitGrow! : Autonomous Hydroponic Garden

Leandro Alepuz (**CpE**)

- Web Server Implementation
- System Assembly

Danny Nguyen (**EE**)

- PCB Design
- Hardware troubleshooting

Edwin Rivera (**EE**)

- Parts and Budget
- PCB Manufacturing

Nathan To (**CpE**)

- Software Implementation
- Sensor Troubleshooting

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Our Solution: **LetitGrow!** A smart hydroponic system

Leandro Alepuz

- ➢ **Deep Water Culture Hydroponic**

- ➢ **Automatic Plant Care**

- ➢ **Web App Integrated**

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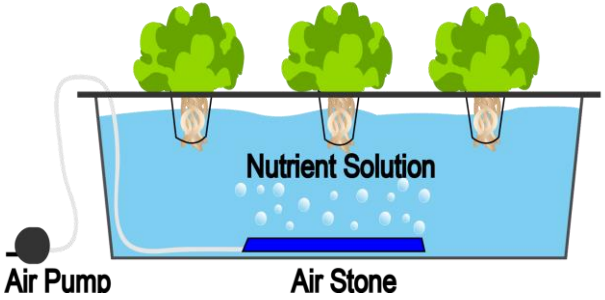
Why Deep Water Culture (DWC) Hydroponics?

Leandro Alepuz

➢ **What is it?**

Hydroponics is an agricultural technique that only uses water to grow plants, completely getting rid of soil.

DWC is a specific type of hydroponics where the roots are directly submerged in a water reservoir with oxygen and nutrients.



➢ **Advantages**

- Fast growth
- Simple setup
- Clean

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Motivations

Nathan To

- **Food Insecurity**
  - Rising temperatures due to climate change
  - Population outgrowing agricultural output

- **COVID-19**
  - Supply chain issues
  - Scarcity due to panic buyers
  - People acquiring new hobbies

- **Rising popularity of Hydroponics**
  - Uses 70% to 90% less water
  - Faster growing speed
  - Cleaner experience for indoors

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Current Solutions

Nathan To

- **Home Hydroponics**
  - For beginners
  - Small capacity
  - Automatic lights
  - Small water pump to oxygenate water
  - Cheap ($50-$80)

- **Hybriponics**
  - Vertical garden
  - Large capacity
  - Costly ($800+)
  - App connectivity

- **Farm.bot**
  - Robotic arm
  - Multiple arm tips for functionalities
  - Soil based garden
  - Scalable
  - Expert level install
  - Expensive ($1700)

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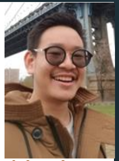
Goals and Objectives



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- **Garden Autonomy**
  - Achieve a minimal amount of time needed for plant care from the user: 2 weeks without any care needed
- **Beginner user friendly experience**
  - Require no plant maintenance experience
- **Total feedback of the plant environment**
  - Use the plant’s pH, nutrients, water level, air and water temperature data to achieve optimal plant growth
- **Monitor remotely from the web**
  - Receive data from your garden

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Requirements and Specifications

Leandro Alepuz

Requirement	Specification
Sensor Reading Frequency	30 minutes
Power self-sufficiency	Direct connection to US outlet
Water capacity for 12 plants	22 gallons
Sensor monitoring	Minimum 12 GPIO pins
Affordable cost	< $600
Accessible User Interface	Web browser monitoring

Plant Requirements

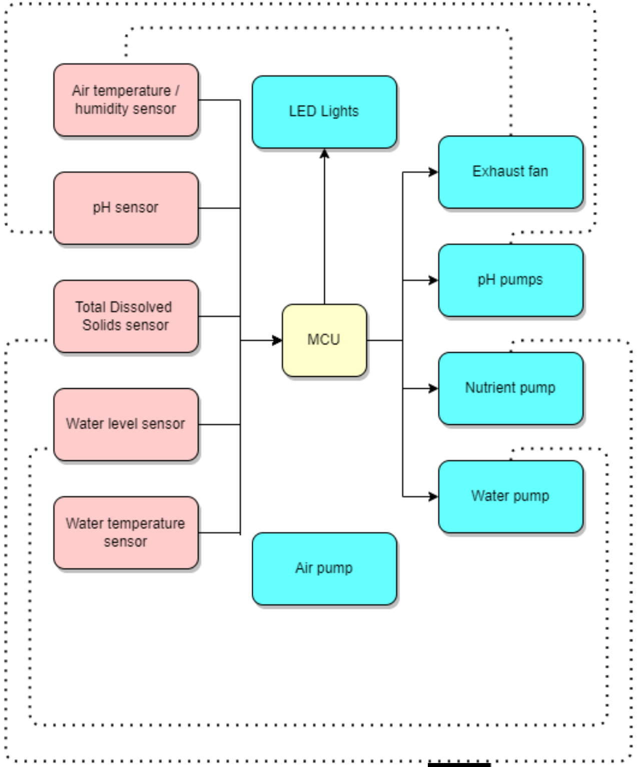
Leandro Alepuz

Plant Parameter	Specification
Water Temperature	[65-80]° F
Nutrients : Total Dissolved Solids (TDS)	[600-1000] ppm
Water pH level	[5.0 , 7.0]
Air Temperature	[60-90]° F
Humidity	[50-70]%
Light	LED Lights | 12-16 hours| Everyday

System Design Diagram

Leandro Alepuz

- ➢ **Inputs (red)**
  - Turn output components On/Off
  - Data is collected every 30 minutes under normal levels
  - If system needs calibration, data is actively sampled in a feedback loop
  - Water temperature sensor is used to calculate TDS levels.
- ➢ **Outputs (cyan)**
  - Dependent on the input sensors
  - LED lights directly controlled by MCU by regular scheduling
  - Air pump is completely independent as is always On



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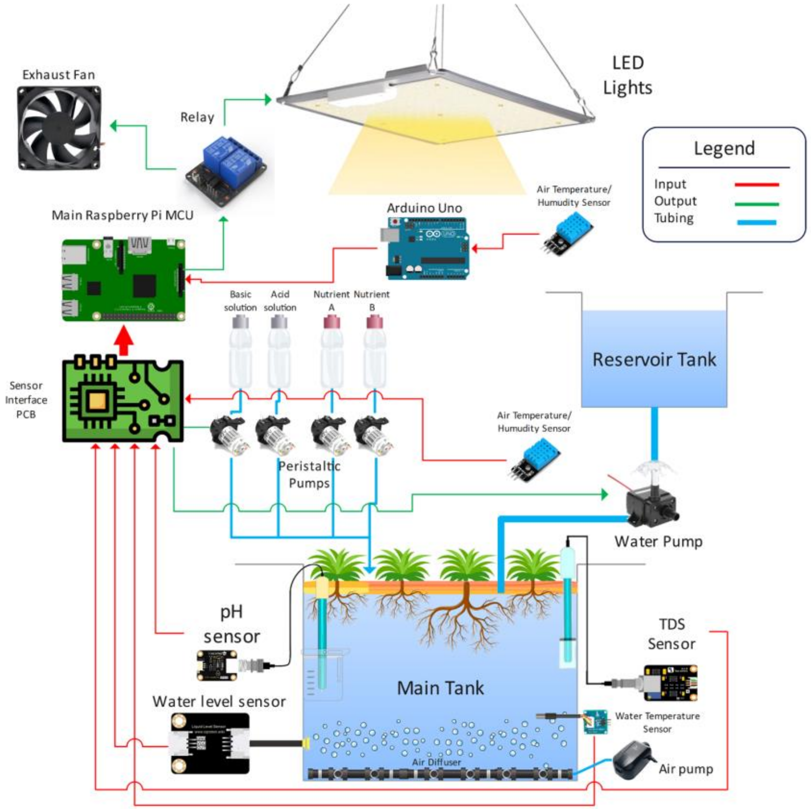
Final Design

Leandro Alepuz



- **Inputs (red)**
  - Sensor data is received and transmitted to the main MCU
  - Humidity Sensor constantly monitors
- **Output (green)**
  - 4 peristaltic pumps supply pH and Nutrients
  - Lights are automatically turned on/off
  - Exhaust fan helps regulate humidity
  - Water pump refills the main tank
- **Supply Lines (blue)**
  - Tubing connects to the main tank for pH and Nutrient delivery
  - Air pump delivers oxygen to the roots via air diffuser placed in the bottom of the tank
  - Tubes deliver water from the reservoir tank to the main tank

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Microcontroller

Edwin Rivera

Raspberry Pi 4	
Processor:	Broadcom BCM2711 Quad core Cortex-A72 1.5GHz
Memory:	8GB LPDDR4 SDRAM
Connectivity:	X4 USBs, Ethernet, Bluetooth, x2 micro HDMI, 40 pin GPIO header
Power:	5V DC via USB-C & 5V DC via GPIO header (500mA)

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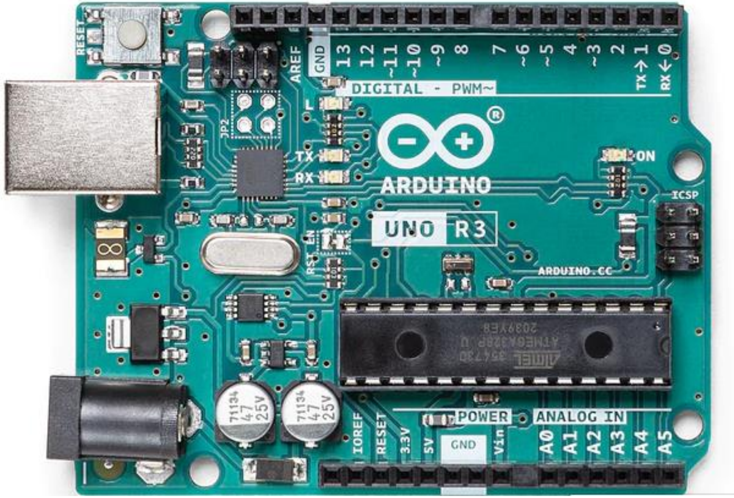
Arduino Uno

Edwin Rivera

Arduino Uno Rev3	
Processor:	Atmega328p
Memory:	32KB Flash & 2KB SRAM
Connectivity:	USB, 14 digital I/O pins, and 6 analog inputs
Power:	5V DC operating voltage and 50mA DC current



Relay Module

Edwin Rivera

4-Channel Relay Interface	
Manufacturer:	SunFounder
Driver Current:	15-20mA (Each Channel)
Max Current:	10A
Max Voltage:	250V DC ; 125V AC
Coil Voltage	5V

pH Sensor

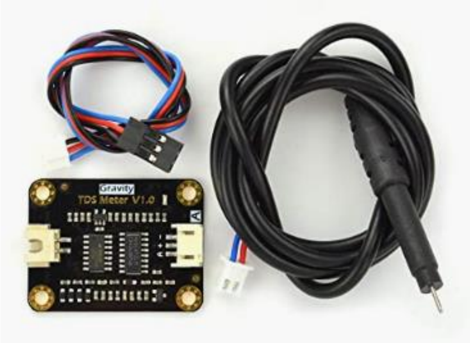
Edwin Rivera

Manufacturer:	GAOHOU
Cost:	$35.88
Measurement Range:	0pH - 14pH
Accuracy:	+/- 0.25pH
Operating Temperature:	0°C - 60°C
Size:	42 x 32 x 20mm

TDS Sensor

Edwin Rivera

Manufacturer:	Gravity
Cost:	$16.80
Measurement Range:	0ppm - 1000ppm
Accuracy:	+/- 10%
Working Voltage:	3.3~5.5V
Size:	42 x 32mm



- ❖ Challenges with calibrations

Water Level Sensor

Edwin Rivera

Manufacturer:	CQRobot
Cost:	$8.99
Working Voltage:	5V
Operating Temperature:	-25°C to 105°C
Size:	35 x 36 x 3mm

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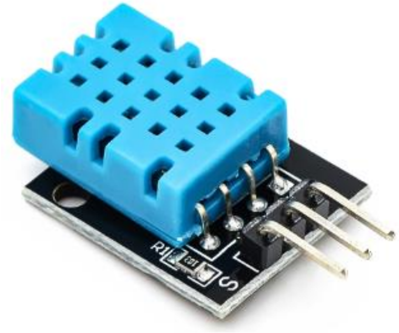
Air Temp/Humidity Sensor

Edwin Rivera

Manufacturer:	Elegoo (DHT11)
Cost:	Owned
Temperature Range:	0°C to 50°C (+/-2°)
Humidity Range:	20% - 90% RH (+/-5%)
Size:	28 x 12 x 7.2mm



- Connection to Arduino was required

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Water Temperature Sensor

Edwin Rivera

Manufacturer:	GAOHOU
Cost:	$13.99 (x2 Sensors)
Measuring Range:	-55°C to 110°C (+/-2°)
Working Voltage:	3.2 ~ 5.25V
Size:	7 x 26mm

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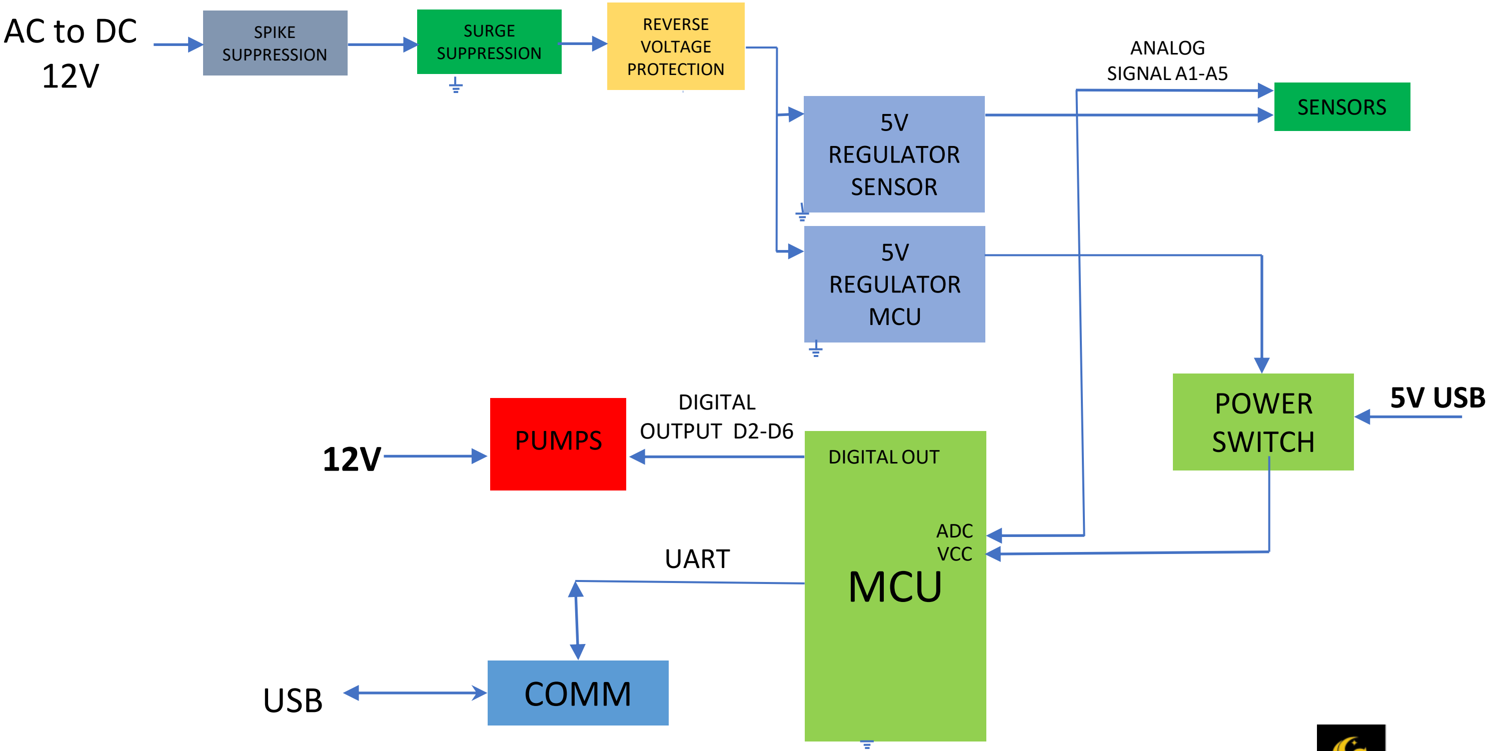
Power Block Diagram

Danny Nguyen



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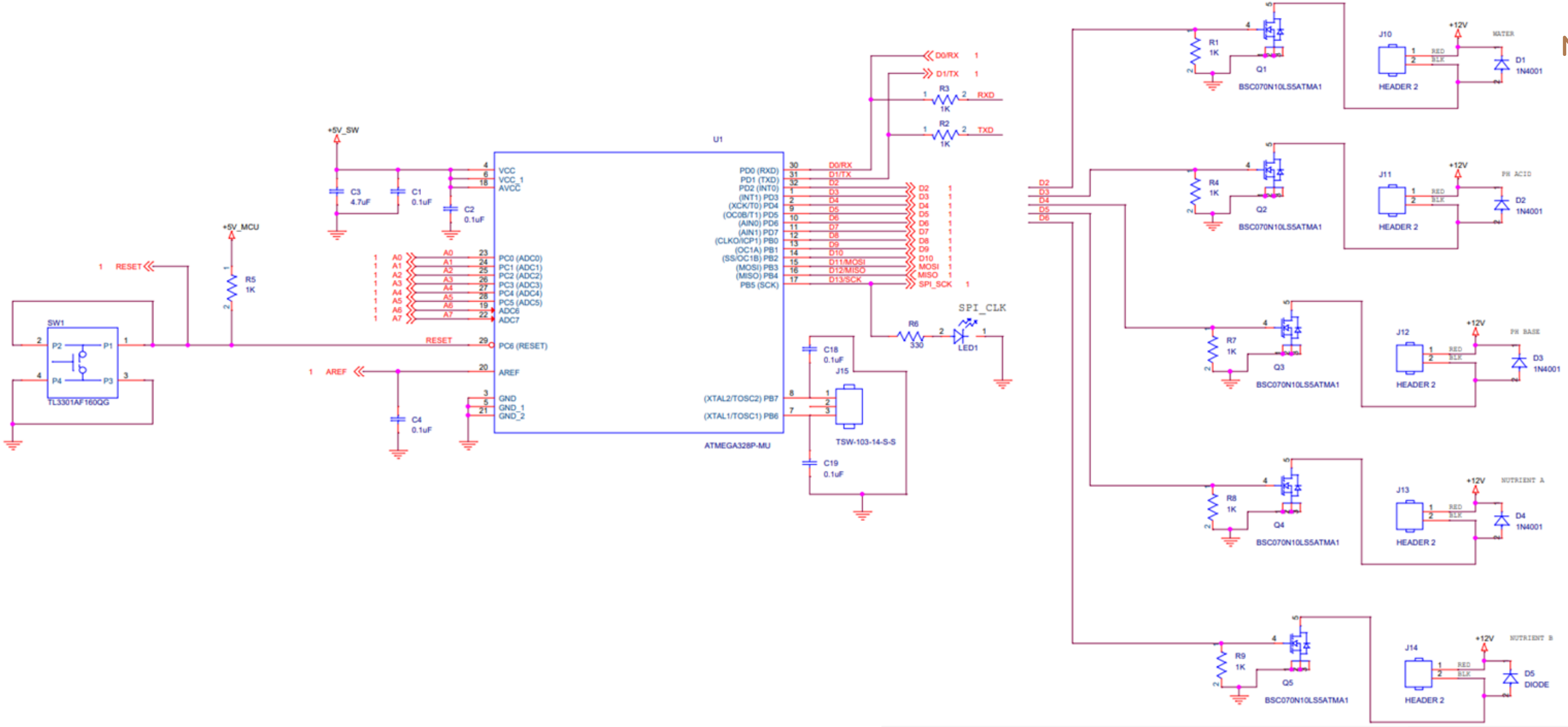
Schematics

Danny Nguyen



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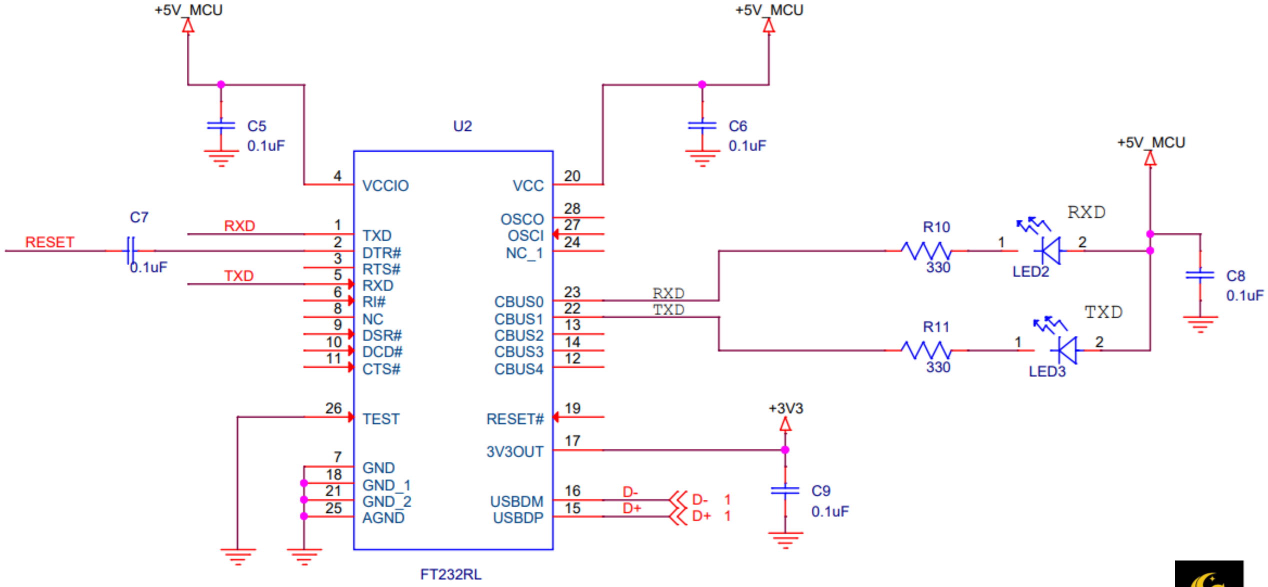
Schematics

Danny Nguyen

FT232RL/USB-UART



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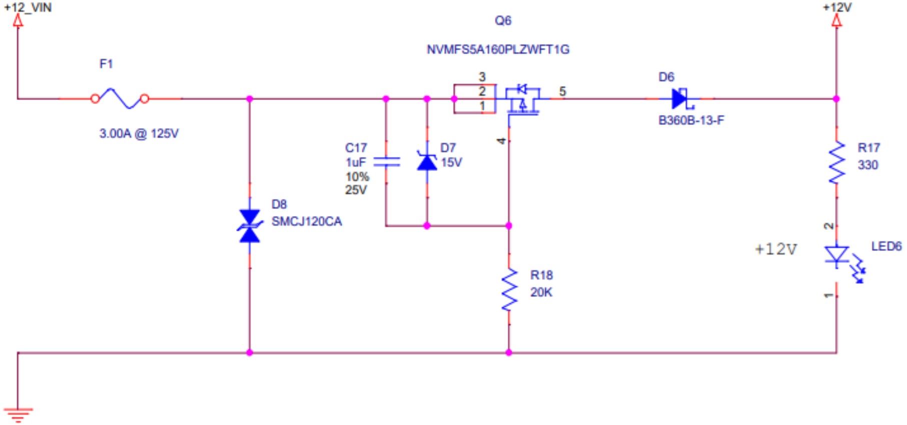
Schematics

Danny Nguyen

+12_VIN PROTECTION



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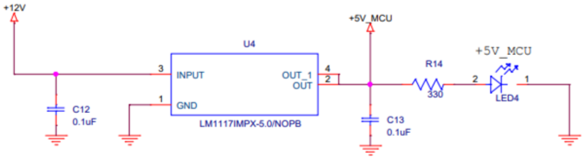
Schematics

Danny Nguyen

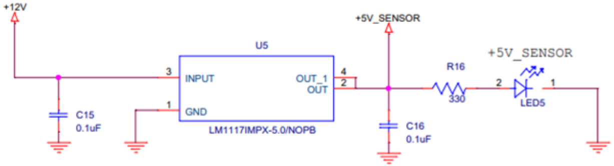
+5V LINEAR REG

SENSOR

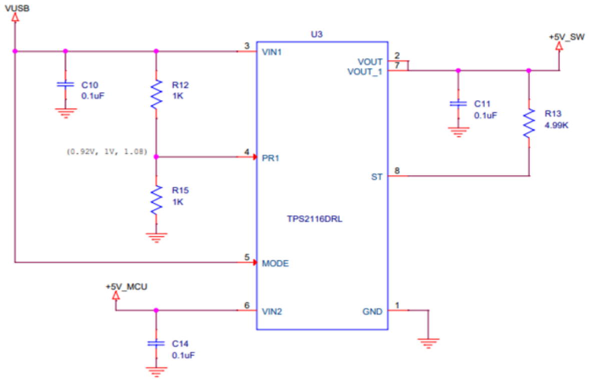


+5V LINEAR REG

MCU



POWER SWITCH



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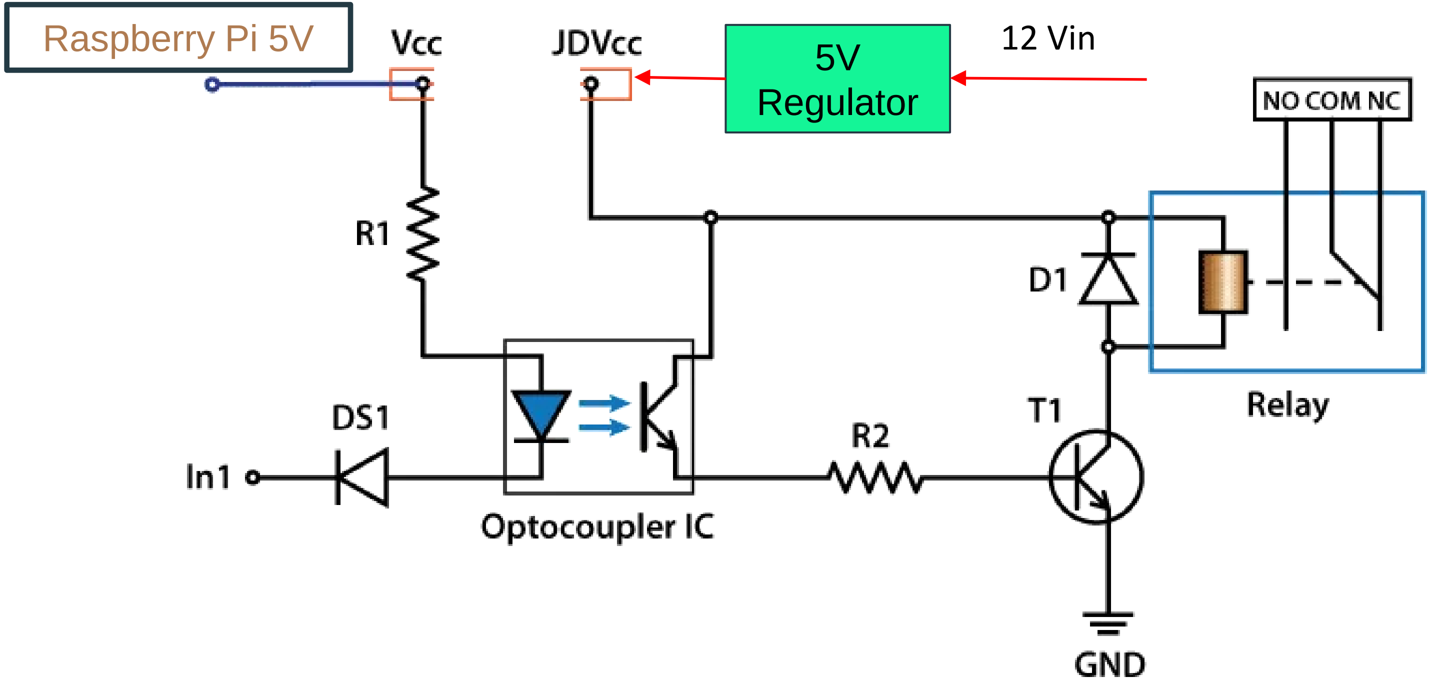
Relay Schematic

Danny Nguyen



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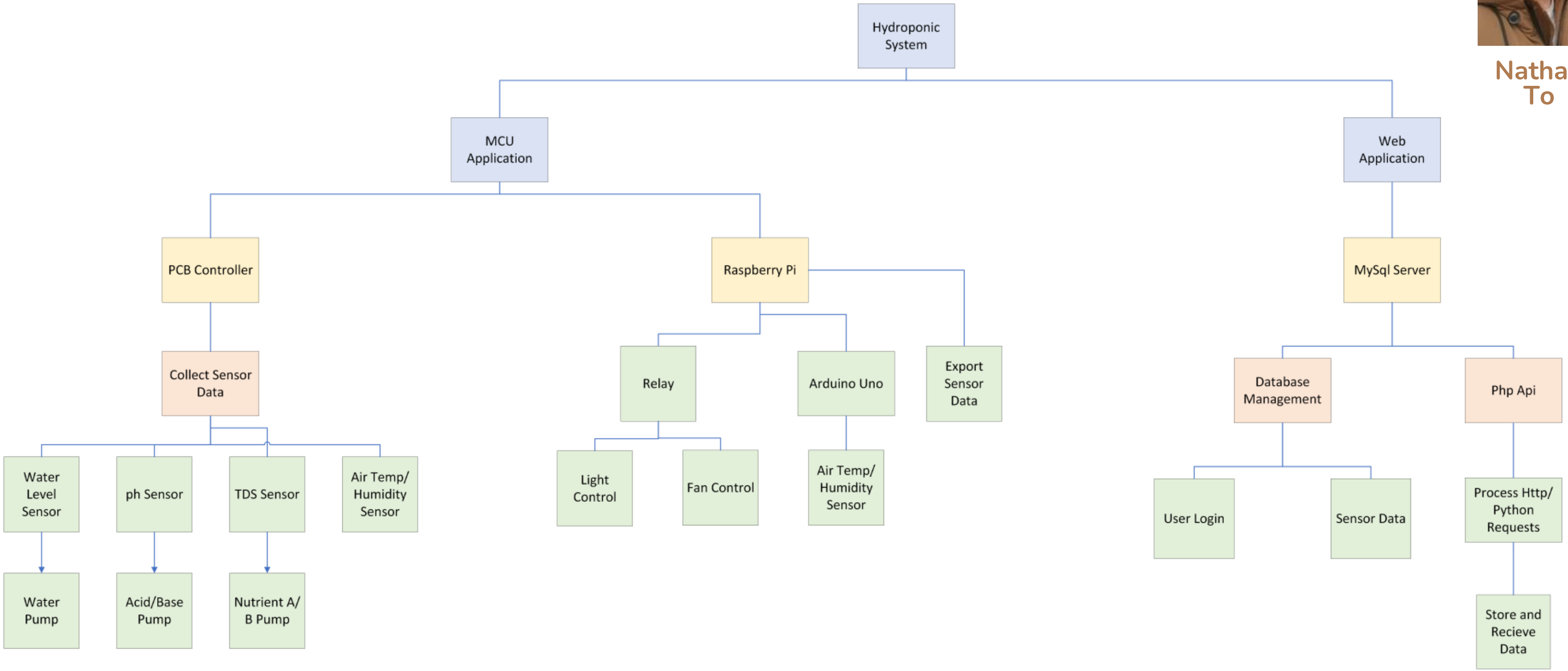
Software System Overview



Nathan To

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Defining Libraries, Pins, and Thresholds

```
// include sort library
#include <KickSort.h>

// include air/hum sensor library and initialize variables
#include "DHT.h"
#define DHTPIN A5
#define DHTTYPE DHT11
DHT dht(DHTPIN, DHTTYPE);

// include water temperature sensor library and initialize variables
#include <OneWire.h>
#include <DallasTemperature.h>
#define ONE_WIRE_BUS A4
OneWire oneWire(ONE_WIRE_BUS);
DallasTemperature sensors(&oneWire);

// initailize water level variables
int waterLevelPin=A3;// define pin A3

// A2 is A0
// must download the zip file for the library and import it from
https://wiki.dfrobot.com/Gravity__Analog_TDS_Sensor___Meter_For_Arduino_SKU__SEN0244
#include <EEPROM.h>
#include "GravityTDS.h"
#define TdsSensorPin A0
GravityTDS gravityTds;
// define tds range
float tdsLow = 600;
```

```
// define pH variables and calibration value
#include <Arduino.h>
const float m = -6.81818182;
int phPin = A1;
// define ph range
float phLow = 5;
float phHigh = 9;

// define pins for pumps
int waterPumpPin = 2;
int phAcidPumpPin = 3;
int phBasePumpPin = 4;
int nutrientAPumpPin = 5;
int nutrientBPumpPin = 6;

// define temporary pump delay
int waterPumpDelay = 5000;
int phPumpDelay = 2000;
int nutrientPumpDelay = 2000;
```

Nathan To

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Arduino Setup

Nathan To

```
void setup() {
  // put your setup code here, to run once:
  Serial.begin(9600);
  // initialize the air humidity sensor
  dht.begin();

  // initialize water temperature sensor
  sensors.begin();

  // set A3 pin as “input” for water level sensor
  pinMode(waterLevelPin,INPUT);

  // initialize tds sensor
  gravityTds.setPin(TdsSensorPin);
  gravityTds.setAref(5.0);  //reference voltage on ADC,
default 5.0V on Arduino
  gravityTds.setAdcRange(1024);  //1024 for 10bit
ADC;4096 for 12bit ADC
  gravityTds.begin();  //initialization

  // set pump pins for output
  pinMode(waterPumpPin,OUTPUT);
  pinMode(phAcidPumpPin,OUTPUT);
  pinMode(phBasePumpPin,OUTPUT);
  pinMode(nutrientAPumpPin,OUTPUT);
  pinMode(nutrientBPumpPin,OUTPUT);
}
```

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Parse ph

Nathan To

```
// function to return ph value median of ten
values
// (individual ph values can very greatly)
double getPhValue(){
  double bufferArray[10];
  int size = 10;

  // fill array with po values
  for (int i=0; i<size; i++){
    bufferArray[i] = analogRead(phPin) * 5.0 /
1024;
    delay(30);
  }
```

```
 // sort array
  KickSort<double>::insertionSort(bufferArray,
size);

  // find median
  double Po = (bufferArray[(size-1)/2] +
bufferArray[size/2])/2.0;
  // find ph value
  double phValue = 6.86 - (2.7 - Po) * m;

  return phValue;

}
```

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Print Sensor Data

Nathan To

```
// function that reads and prints sensor values for testing
void printSensorValRasp(){
  // read air humidity
  float airHumi = dht.readHumidity();
  // read air temperature as Celsius
  float airTempC = dht.readTemperature();
  // read temperature as Fahrenheit
  float airTempF = dht.readTemperature(true);

  // read in water temperature sensor
  sensors.requestTemperatures();
  float waterTempC = sensors.getTempCByIndex(0);
  float waterTempF = sensors.toFahrenheit(waterTempC);

  // read in water level sensor
  int waterLevelVal = digitalRead(waterLevelPin);// read the level
value of pin A3 and assign if to val

  // read in TDS sensor
  gravityTds.setTemperature(waterTempC);  // set the temperature and
execute temperature compensation
  gravityTds.update();  //sample and calculate
  float tdsValue = gravityTds.getTdsValue();  // then get the value
```

```
  // print sensor values for raspberry pi

  // TDS sensor
  Serial.print(tdsValue,0);
  Serial.print(" ");

  // pH Sensor
  Serial.print(getPhValue());
  Serial.print(" ");

  // Water Level Sensor
  // 0 - Indicates no liquid, 1 - Indicates probe is submerged
  Serial.print(waterLevelVal); // print the data from the sensor
  Serial.print(" ");

  // Water Temperature sensor
  Serial.print(waterTempF);
  Serial.print(" ");

  // Air/Hum sensor
  Serial.print(airHumi);
  Serial.print(" ");

  Serial.print(airTempF);
}
```

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Water Level Sensor Loop

Nathan To

```
// loop to check and raise water level
// 0 means unsubmerged 1 means submerged
void waterSensorLoop(){
  // reads in water sensor value
  int waterLevelVal = digitalRead(waterLevelPin);
  Serial.println(waterLevelVal);

  // loop while water sensor is unsubmerged
  while(waterLevelVal == 0)
  {
    // Run pump for designated amount of time
    digitalWrite(waterPumpPin, HIGH);
    delay(waterPumpDelay);
    digitalWrite(waterPumpPin, LOW);

    // wait 2 min sec
    //delay(120000);

    // wait 30 sec
    //delay(30000);

    // test delay 5 seconds
    delay(5000);

    // read new water sensor value sensor
    waterLevelVal = digitalRead(waterLevelPin);

    // read water level val to serial monitor
    Serial.println(waterLevelVal);
  }
}
```

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ph Sensor Loop

Nathan To

```
// loop to check water ph and bring water ph within threshold values
void phSensorLoop(){
  // reads in ph sensor value

  double phVal = getPhValue();

  Serial.print("ph value = ");
  Serial.println(phVal);

  // loop while water ph is not within threshold values
  while(phVal < phLow || phVal > phHigh)
  {
    // if the water ph is too acidic run base pump for designated amount of time
    if(phVal < phLow)
    {
      digitalWrite(phBasePumpPin, HIGH);
      delay(phPumpDelay);
      digitalWrite(phBasePumpPin, LOW);
    }
    // if the water ph is too basic run acid pump for designated amount of time
    if(phVal > phHigh)
    {
      digitalWrite(phAcidPumpPin, HIGH);
      delay(phPumpDelay);
      digitalWrite(phAcidPumpPin, LOW);
    }

    // wait 2 min sec
    //delay(120000);

    // wait 30 sec
    //delay(30000);

    // test delay 5 seconds
    delay(5000);

    // read new ph sensor value sensor
    phVal = getPhValue();
    Serial.print("ph value = ");
    Serial.println(phVal);
  }
}
```

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TDS Sensor Loop

```
// loop to check water tds and bring water tds within threshold values
void tdsSensorLoop(){
  // read water temptերature value and calibrate the tds sensor
  sensors.requestTemperatures();
  float waterTempC = sensors.getTempCByIndex(0);

  // set the temperature and execute temperature compensation
  // gravityTds.setTemperature(24); // manual
  gravityTds.setTemperature(waterTempC); // from water temperature sensor

  gravityTds.update();  //sample and calculate
  float tdsVal = gravityTds.getTdsValue()-100;  // then get the value

  Serial.print("TDS value: ");
  Serial.println(tdsVal);

  // loop while water tds is not within threshold values
  while(tdsVal < tdsLow)
  {
    // if the water tds is too low run nutrientA pump for designated amount of time

    digitalWrite(nutrientAPumpPin, HIGH);
    digitalWrite(nutrientBPumpPin, HIGH);
    delay(nutrientPumpDelay);
    digitalWrite(nutrientAPumpPin, LOW);
    digitalWrite(nutrientBPumpPin, LOW);

    // wait 2 min sec
    //delay(120000);

    // wait 30 sec
    //delay(30000);

    // test delay 5 sec
    delay(5000);

    // read water tempterature value and calibrate the tds sensor
    sensors.requestTemperatures();
    float waterTempC = sensors.getTempCByIndex(0);

    // set the temperature and execute temperature compensation
    // gravityTds.setTemperature(24); // manual
    gravityTds.setTemperature(waterTempC); // from water temperature sensor

    gravityTds.update();  //sample and calculate

    // read new tds sensor value sensor
    tdsVal = gravityTds.getTdsValue()-100;

    Serial.print("TDS value: ");
    Serial.println(tdsVal);
  }
}
```

Nathan To

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Final Loop

```
void loop() {

  // sensor loops
  printSensorValRasp();
  waterSensorLoop();
  phSensorLoop();
  tdsSensorLoop();


  //testing sensors and pumps
  // runAllPumps();
  // printSensorVal();
  // delay(5000);

  // 30 min test delay
  delay(1800000);

  // check sensors after an hour
  // 1 hour delay
  // delay(3600000);
}
```

Nathan To

Relay and Lights

Nathan To

```
#!/usr/bin/env python3
import serial

import RPi.GPIO as GPIO            # import RPi.GPIO module
import time
from time import sleep             # lets us have a delay
GPIO.setmode(GPIO.BCM)             # choose BCM or BOARD

# 3 controls fan
FAN_RELAY = 3
GPIO.setup(FAN_RELAY, GPIO.OUT)    # set GPIO3 as an output
GPIO.output(FAN_RELAY, 1)          # fan starts off

# 2 controls lights
LIGHT_RELAY = 2
GPIO.setup(LIGHT_RELAY, GPIO.OUT)   # set GPIO2 as an output
GPIO.output(LIGHT_RELAY, 1)         # Light starts off

# stablish communication with Arduino
if __name__ == '__main__':
  ser = serial.Serial('/dev/ttyACM0', 9600, timeout=1)
  ser.reset_input_buffer()

# set On and Off times for the light
lightOn = "8:00"
lightOff = "20:00"

# calls current time and converts to integer
def getCurTime ():
  date=time.asctime().split(' ')

  (h, m, s) = date[3].split(':')
  result = int(h) * 3600 + int(m) * 60

  return result;

# returns time to integer
def timeToInt(time):
  (h, m) = time.split(':')
  result = int(h) * 3600 + int(m) * 60

  return result;
```

```
try:
  while True:

    if(timeToInt(lightOff) > timeToInt(lightOn)):
      if (timeToInt(lightOn) <= getCurTime() < timeToInt(lightOff)):
        GPIO.output(LIGHT_RELAY, 0)         # Lights on
      else:
        GPIO.output(LIGHT_RELAY, 1)         # Lights off
    else:
      if (timeToInt(lightOff) <= getCurTime() < timeToInt(lightOn)):
        GPIO.output(LIGHT_RELAY, 1)         # Lights off
      else:
        GPIO.output(LIGHT_RELAY, 0)         # Lights on

    if ser.in_waiting > 0:
      humidity = int(ser.readline().decode('utf-8').rstrip())
      print(humidity)


      while humidity > 60:
        print("Adjusting humidity...")
        print(humidity)
        GPIO.output(FAN_RELAY, 0)
        sleep (5)
        humidity = int(ser.readline().decode('utf-8').rstrip())
        print(humidity)
        print("------------------")
      GPIO.output(FAN_RELAY, 1)

except KeyboardInterrupt:          # trap a CTRL+C keyboard interrupt
    GPIO.cleanup()                 # resets all GPIO ports used by this program
```

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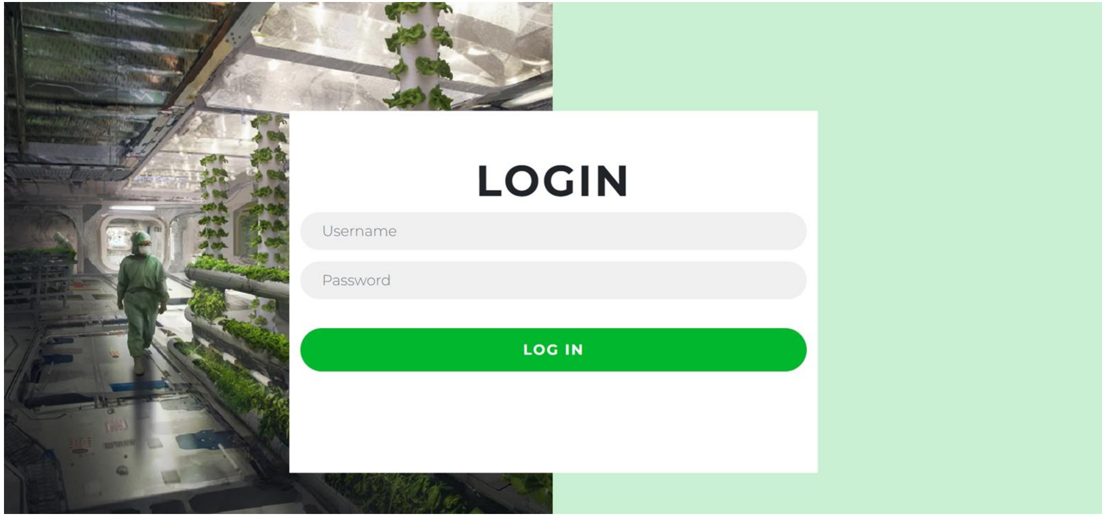
Website Application

Leandro Alepuz

- ❖ Login and user authentication
- ❖ Receive and display sensor data



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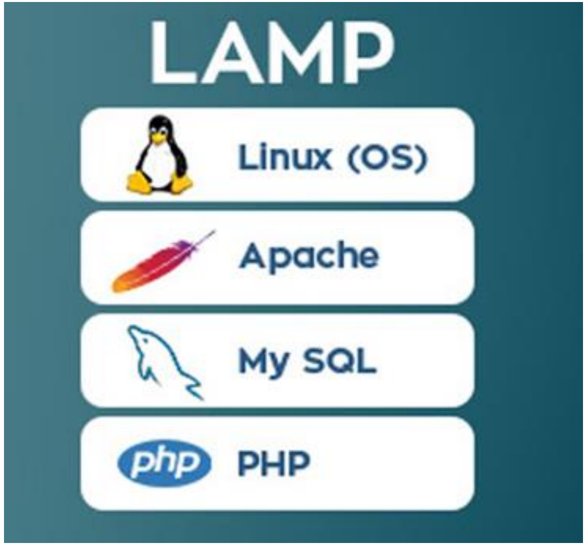
Full-stack technology used : LAMP

Leandro Alepuz



- ➢ Perfect for low-scale projects
- ➢ MySQL fits the needs for our sensor data
- ➢ Previous experience working with Linux through MobaXterm
- ➢ PHP is simple and quick for handling user authentication and display data

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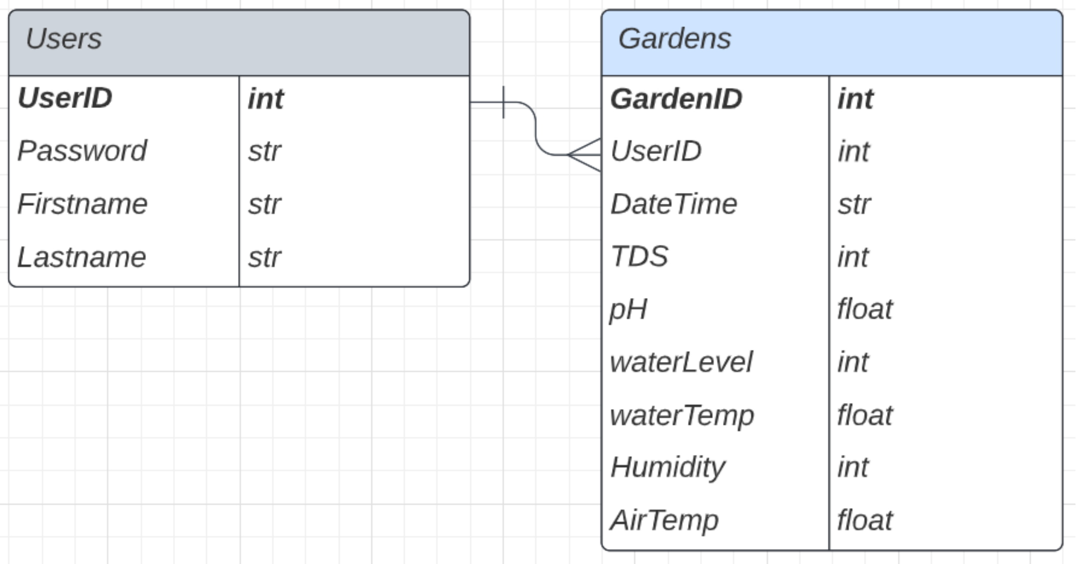
Database Structure

Leandro Alepuz



Users	
UserID	***int***
Password	*str*
Firstname	*str*
Lastname	*str*

Gardens	
GardenID	***int***
UserID	*int*
DateTime	*str*
TDS	*int*
pH	*float*
waterLevel	*int*
waterTemp	*float*
Humidity	*int*
AirTemp	*float*

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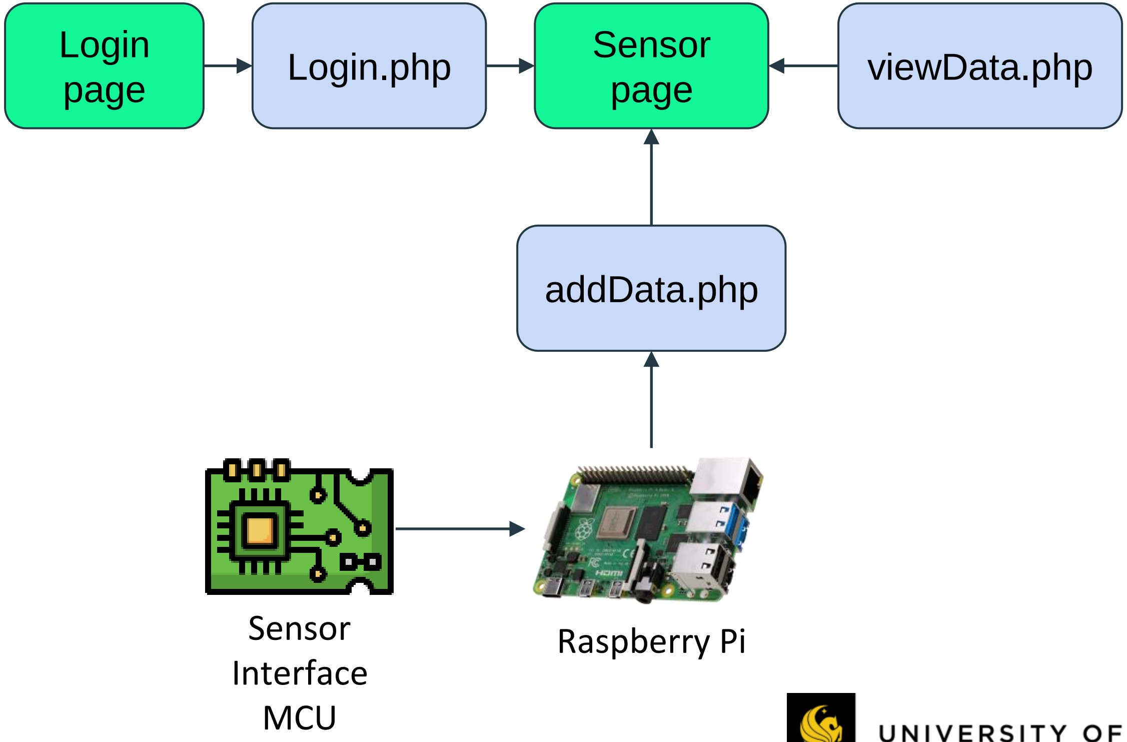
Backend Flowchart

Leandro Alepuz



Login page

Login.php

Sensor page

viewData.php

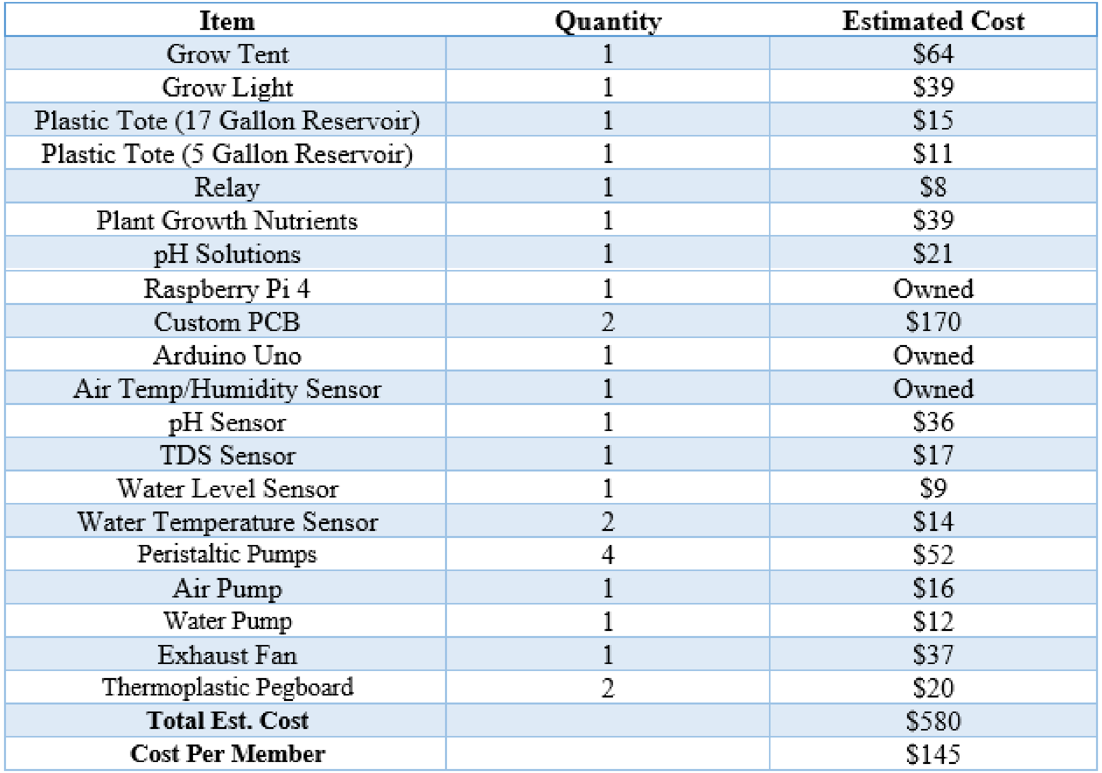
addData.php

Sensor Interface MCU

Raspberry Pi

Budget

Edwin Rivera



Item	Quantity	Estimated Cost
Grow Tent	1	$64
Grow Light	1	$39
Plastic Tote (17 Gallon Reservoir)	1	$15
Plastic Tote (5 Gallon Reservoir)	1	$11
Relay	1	$8
Plant Growth Nutrients	1	$39
pH Solutions	1	$21
Raspberry Pi 4	1	Owned
Custom PCB	2	$170
Arduino Uno	1	Owned
Air Temp/Humidity Sensor	1	Owned
pH Sensor	1	$36
TDS Sensor	1	$17
Water Level Sensor	1	$9
Water Temperature Sensor	2	$14
Peristaltic Pumps	4	$52
Air Pump	1	$16
Water Pump	1	$12
Exhaust Fan	1	$37
Thermoplastic Pegboard	2	$20
Total Est. Cost		$580
Cost Per Member		$145

- Initial estimated budget was between $700 - $800
- Largest expense attributed to the custom PCB
- Other minor components not listed are also already owned
- Total cost is approximately $580