UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Team 39

Soil Moisture Controller (Pitched Project)

ECE 445 – Spring 2023

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Introduction

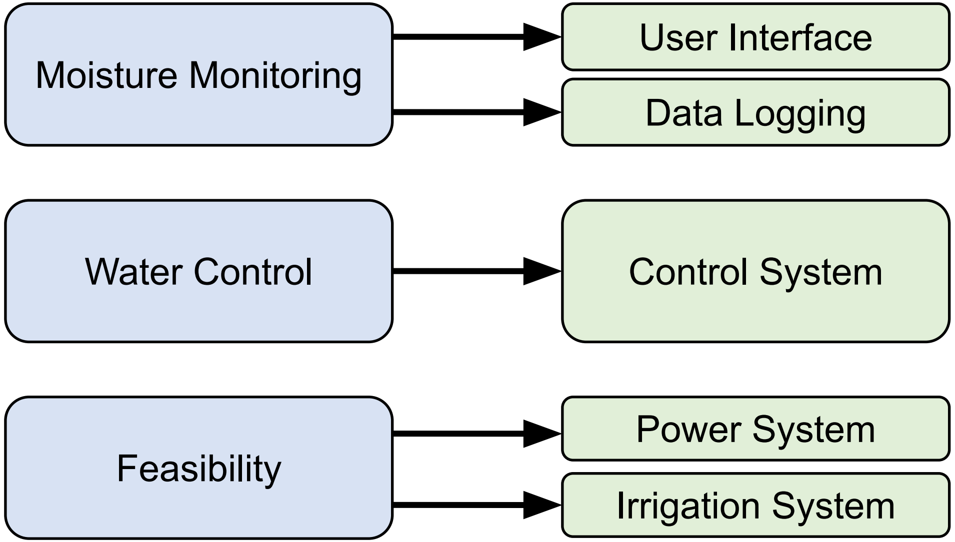
Problem
Solution
Objectives and High-Level Requirements

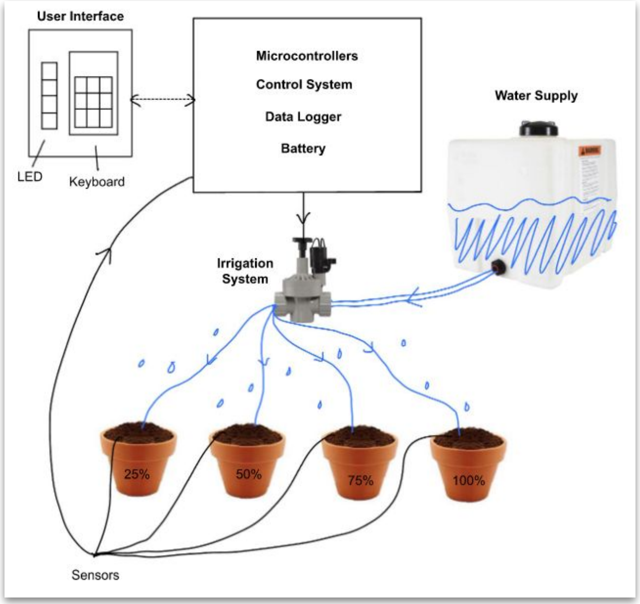
Problems faced by the U.S. Department of Agriculture (USDA)

- Biggest limiting factor for gains in agricultural productivity is the ability to **provide sufficient moisture in the soil for the growth of crops**
- Currently, the measurement of soil moisture content in pots are **performed manually** with individuals monitoring the moisture level based on **weight**, or the **use of gravimetric sensors**
- Difficult to measure **exact proportion** of increase in plant mass to change in soil moisture content

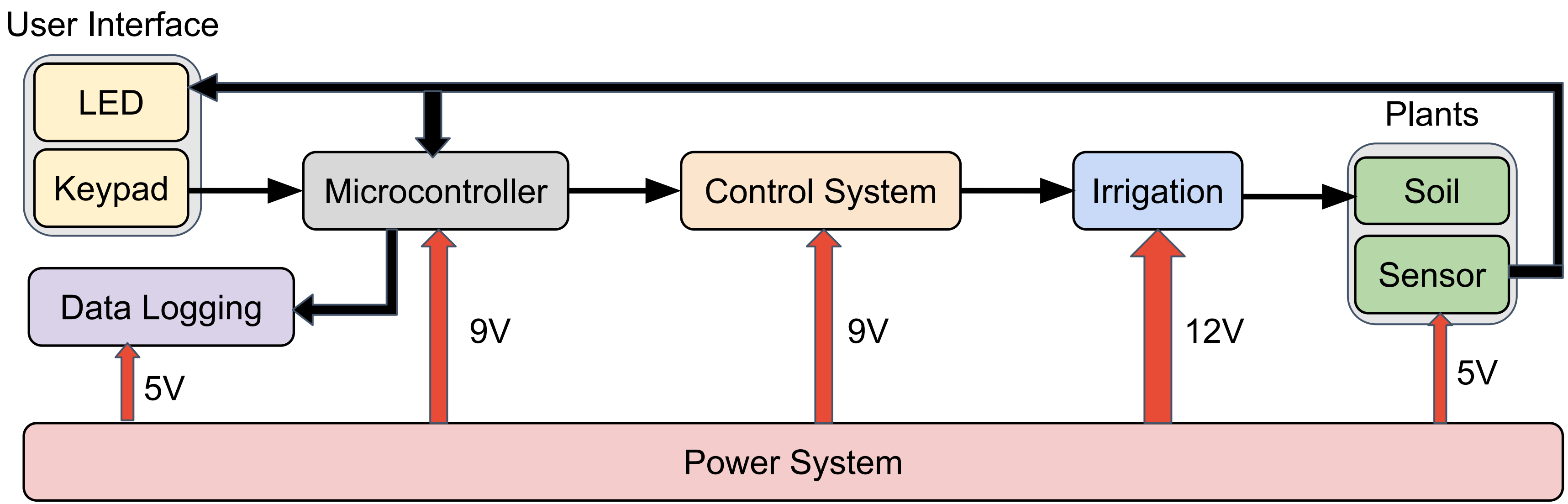
Therefore, there needs to be a **more precise method** to measure and maintain the soil moisture conditions in these pots using soil moisture sensors.

Solution


Moisture Monitoring
User Interface
Data Logging
Water Control
Control System
Feasibility
Power System
Irrigation System


User Interface
LED
Keyboard
Microcontrollers
Control System
Data Logger
Battery
Water Supply
Irrigation
System
25%
50%
75%
100%
Sensors

Block Diagram



Objectives / High Level Requirements

1. The moisture sensors should be able to **detect the current level of moisture in the soil** and the moisture level **data should be logged** on an SD card and **displayed** on an LED bar graph **every 6 hours**

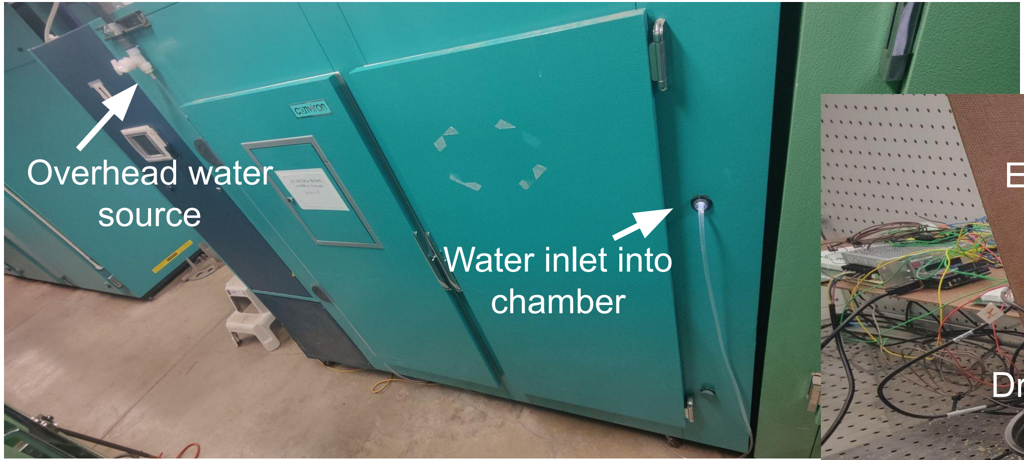
2. The system should be able to **provide irrigation** when the **moisture level falls beyond a set threshold** level as inputted using a keypad by the user

3. The system should be **scalable to four different pots** and the **moisture level maintained** at 100%, 75%, 50%, and 25% in each of the respective pots

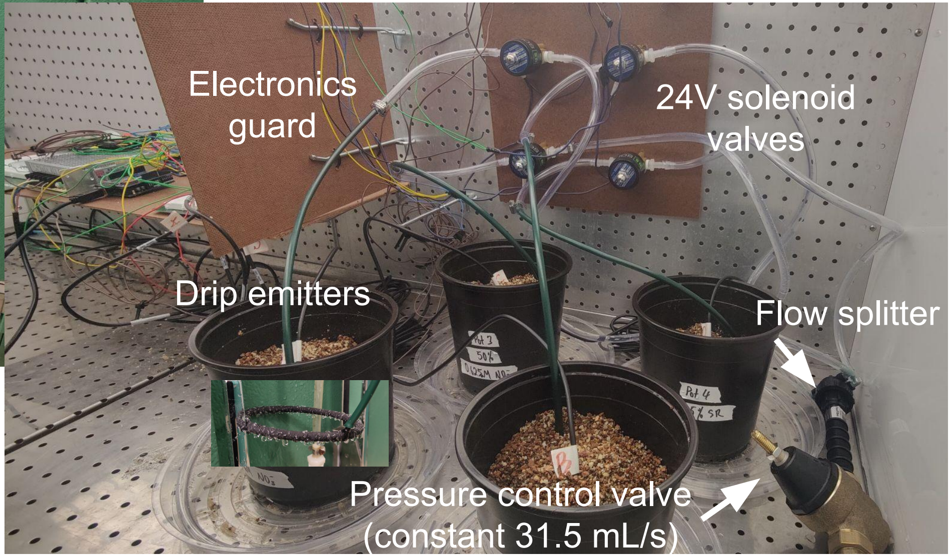
Design

Irrigation Subsystem
Data Logging Subsystem
User Interface Subsystem
Power Subsystem
Controller Subsystem
PCB Design

Irrigation Subsystem - Setup in Edward R. Madigan Laboratory



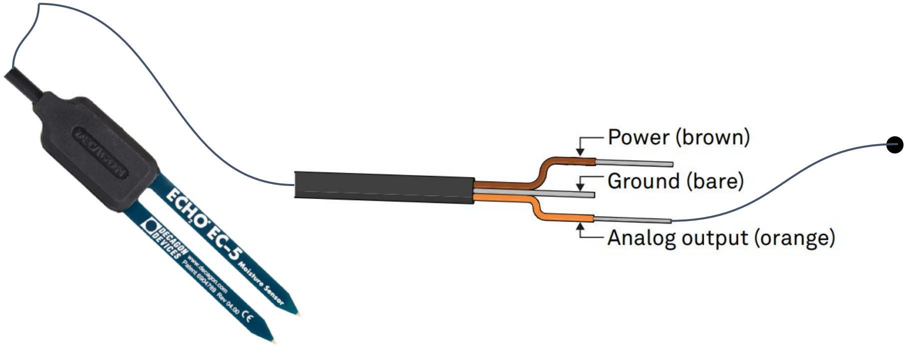
CO2 Growth Chamber



Irrigation Subsystem - Soil and ECH20 EC-5 Moisture Sensors

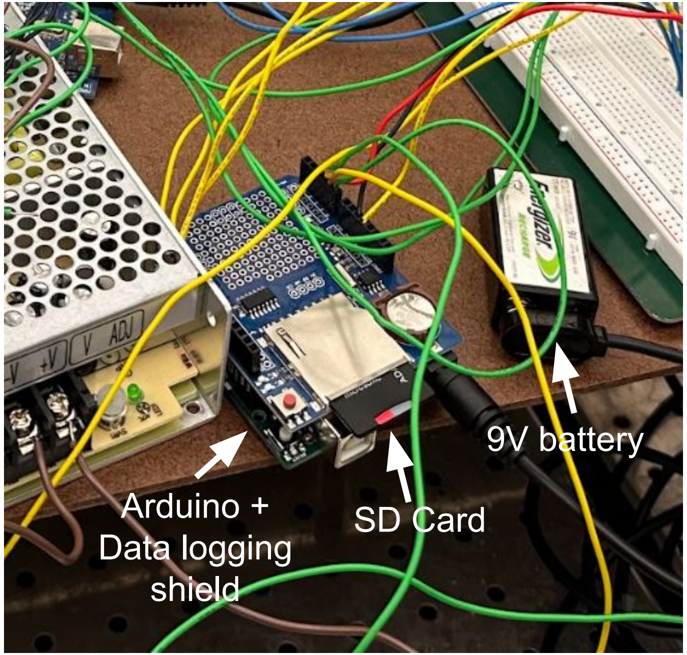
- Prepared **2 types of soil** – 5mM and 0.625mM
  - Sand/clay mixture, water flows through it relatively fast
- Created **soil specific formulas** to determine:
  - VWC → Saturation rate (SR)
  - SR → time valve should be open

```
# Lookup table to define experiment
potLookup = {'pot1': [0.625, 100],
             'pot2': [5.0, 75],
             'pot3': [0.625, 50],
             'pot4': [5.0, 25]}
```



- Output value is the **volumetric water content (VWC)**
  - Sensor produces an output voltage based on the soil's dielectric constant

Data Logging Subsystem - Overview



<u>At 12am, 6am, 12pm, 6pm:</u>

1. Check sensors and log data on SD card
2. Irrigate and wait 30 minutes for water to settle
3. Check sensors and log data again. See if a little more irrigation is necessary. If so, irrigate again.
4. Wait 5 ½ hours
5. Repeat

Data Logging Subsystem - Data Collection Examples

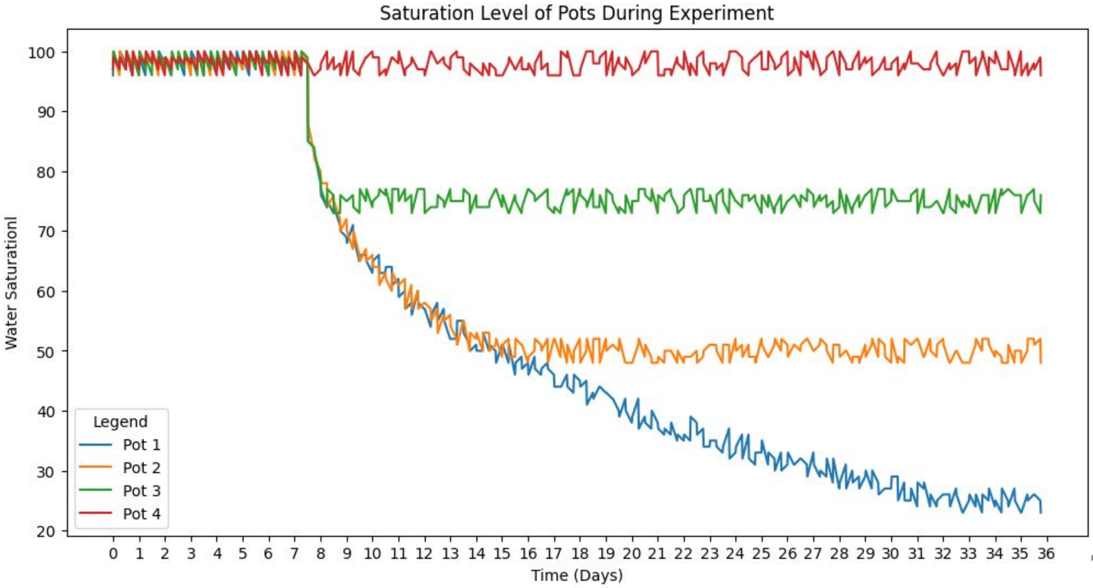
demo_data

File Edit View

```
0:0:1
4/19/2023
150, 16.98
146, 22.13
154, 22.81
144, 18.38

0:30:2
4/19/2023
294, 100.00
258, 75.15
187, 50.72
148, 25.69

6:0:2
4/19/2023
280, 81.87
236, 69.40
174, 43.42
144, 18.38

6:30:0
4/19/2023
292, 97.42
258, 74.69
187, 47.84
147, 23.93

12:0:1
4/19/2023
280, 80.80
```

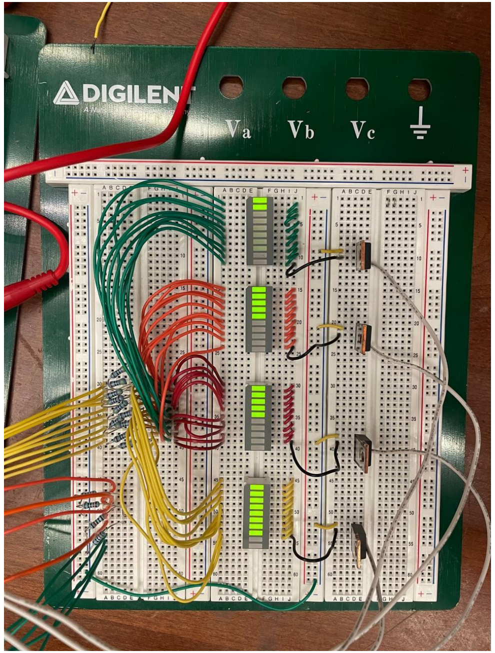
4/19/2023	4/20/2023	4/21/2023	4/22/2023	
0:00:01	0:00:00	0:00:01	0:00:02	
150, 16.98	285, 87.70	282, 84.10	280, 81.87	150 = Sensor reading, 16.98 = Saturation rate
146, 22.13	232, 69.08	239, 69.75	239, 69.75	
154, 22.81	175, 44.12	160, 30.40	160, 30.40	
144, 18.38	145, 20.28	139, 8.14	139, 8.14	
0:30:02	0:30:03	0:30:01	0:30:01	
294, 100.00	293, 98.96	294, 100.00	292, 97.42	Saturation rate should never be greater than 100%
258, 75.15	256, 74.25	258, 75.15	256, 74.25	
187, 50.72	187, 50.72	187, 50.72	187, 50.72	
148, 25.69	149, 27.39	148, 25.69	146, 22.13	
6:00:02	6:00:02	6:00:00	6:00:01	
280, 81.87	285, 87.70	280, 81.87	280, 81.87	
236, 69.40	234, 69.22	236, 69.40	237, 69.51	
174, 43.42	172, 41.92	174, 43.42	174, 43.42	
144, 18.38	144, 18.38	144, 18.38	144, 18.38	
6:30:00	6:30:01	6:30:02	6:30:00	
292, 97.42	292, 97.42	292, 97.42	293, 98.96	Example of all 4 pots being within +- 5% saturation rate after irrigation No additional irrigation is needed
258, 74.69	258, 74.69	258, 74.69	258, 74.69	
187, 47.84	172, 41.92	176, 44.81	187, 47.84	
147, 23.93	148, 25.69	147, 23.93	147, 23.93	
12:00:01	12:00:02	12:00:01	12:00:02	
280, 80.80	284, 86.46	280, 80.80	285, 87.70	
237, 69.51	241, 70.04	237, 69.51	234, 69.22	
176, 44.81	171, 41.11	176, 44.81	187, 47.84	
143, 16.44	144, 20.28	143, 16.44	144, 18.38	
12:30:00	12:30:01	12:30:00	12:30:04	
292, 97.42	293, 98.96	292, 97.42	294, 100.00	
259, 75.64	257, 74.69	259, 75.64	258, 75.15	
182, 48.34	188, 51.13	182, 48.34	187, 50.72	
146, 22.13	147, 23.93	146, 22.13	148, 25.69	
18:00:01	18:00:00	18:00:01		
284, 86.46	283, 85.26	284, 86.46		
241, 70.04	242, 70.20	241, 70.04		Example of no irrigation needed after 6 hour period
171, 41.11	154, 22.81	171, 41.11		
144, 20.28	143, 16.44	143, 16.44		
18:30:00	18:30:05	18:30:00		
293, 98.96	294, 100.00	293, 98.96		
217, 68.56	211, 68.34	259, 75.64		At next sensor reading, system will realize this pot still needs irrigating and water
188, 51.13	186, 50.30	188, 51.13		
147, 23.93	146, 22.13	147, 23.93		

SD card → Text file → CSV or Excel file



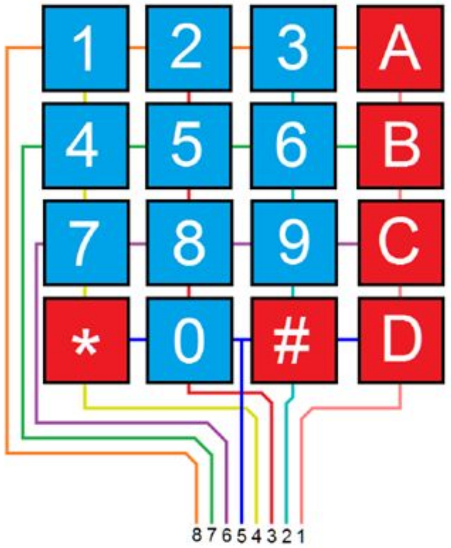
User Interface Subsystem – 10-Segment LED Bar Graph

- Shows the **soil moisture level** as detected by the sensors in each pot
- Use of **power MOSFETs** (IRF520) – consist of transistors to switch between each 10-segment LED bar graph by turning them on and off sequentially
  - If this switch were to be made very rapidly, it would allow the user to see all four 10-segment LED bar graphs together

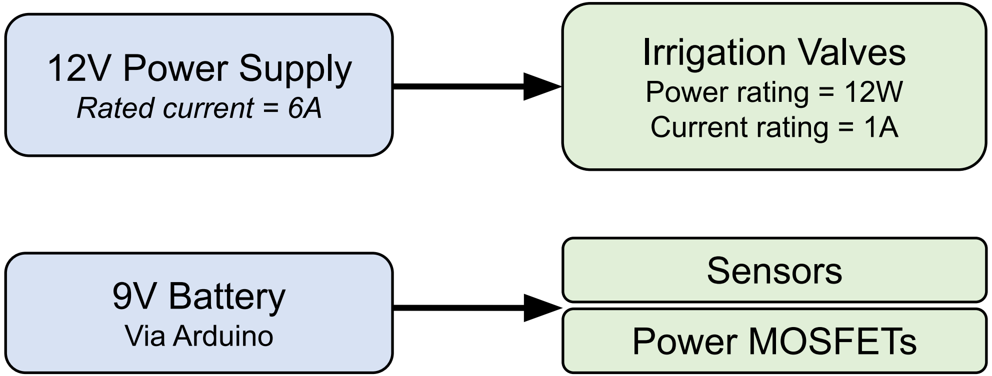


User Interface Subsystem – 4x4 Keypad

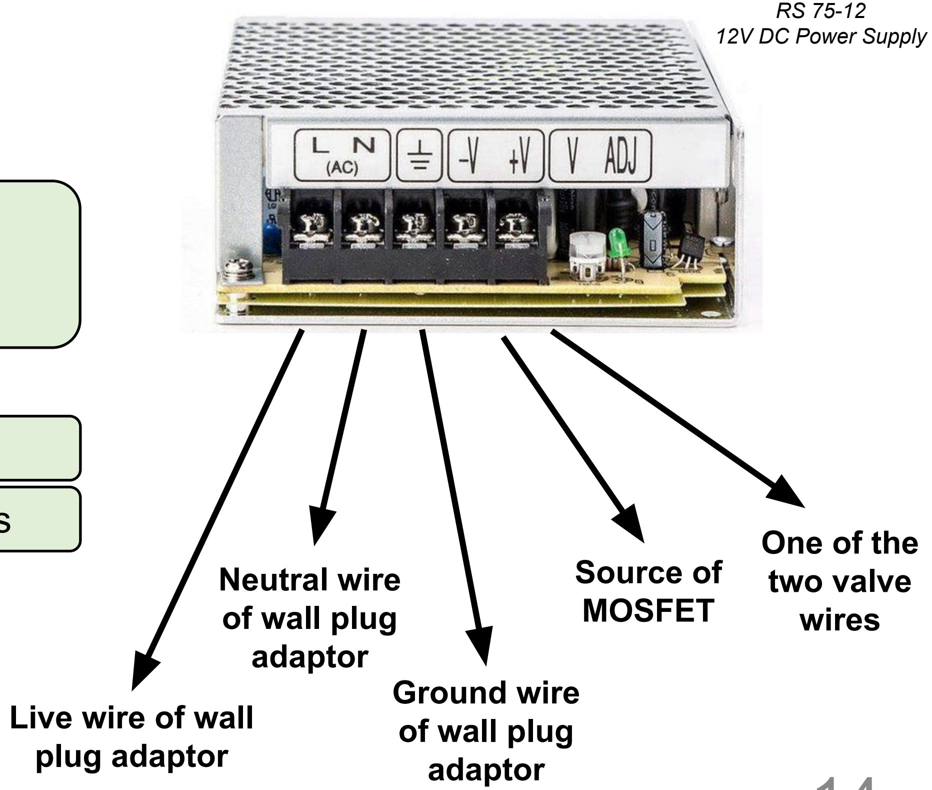
- Allow user to **input the desired soil moisture level**
  - **Compact size** of the keypad would be beneficial in a greenhouse setting
- **Pull** each of the four **columns** (pins 1-4) either **low or high** one at a time, and then **poll** the states of the four **rows** (pins 5-8)
  - Depending on the states of the columns, the microcontroller can tell which button is pressed



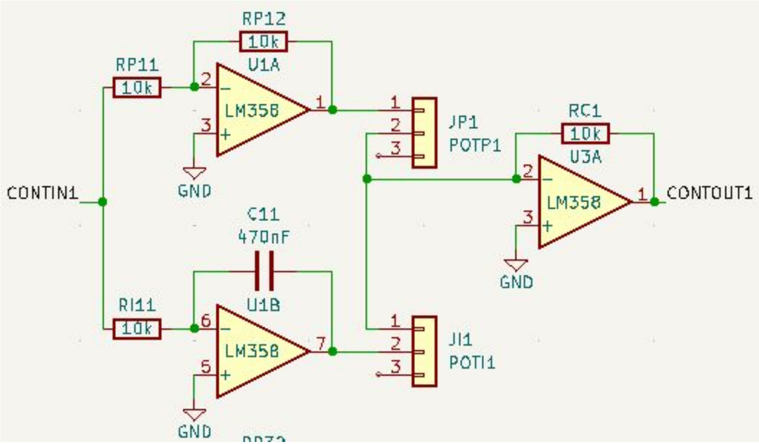
Power Subsystem



RS 75-12
12V DC Power Supply



Controller Subsystem



Proportional-Integral controller

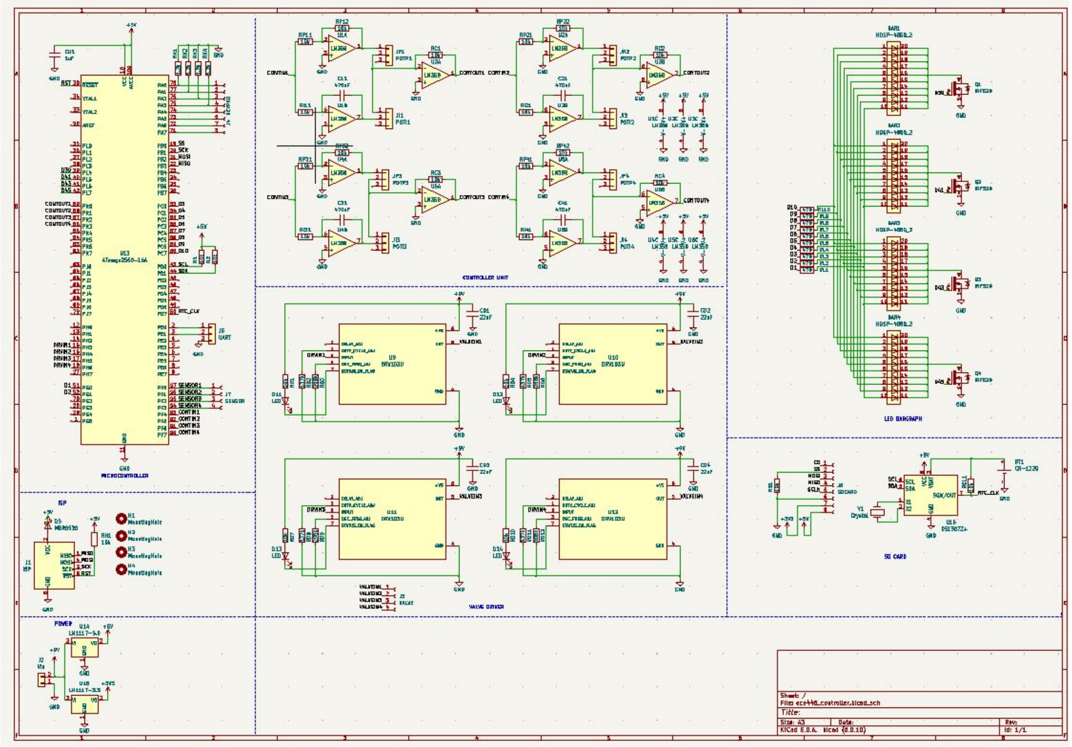
```
float SR2openTime(int potN, float SRnow) {
  if (potN >= 0 && potN < potCount) {
    float SRset = user_val[potN];
    float SRdelta = SRset - SRnow;
    if (SRdelta > 0.0) {
      // convert SR back to VWC to find water needed
      float VWCdelta = SRdelta*porosity;
      float volumeNeeded = VWCdelta*potVolume;
      float openTime = volumeNeeded/flowRate;
      return openTime; // seconds of watering needed
    }
  }
  return 0.0;
}
```

Constant rate control

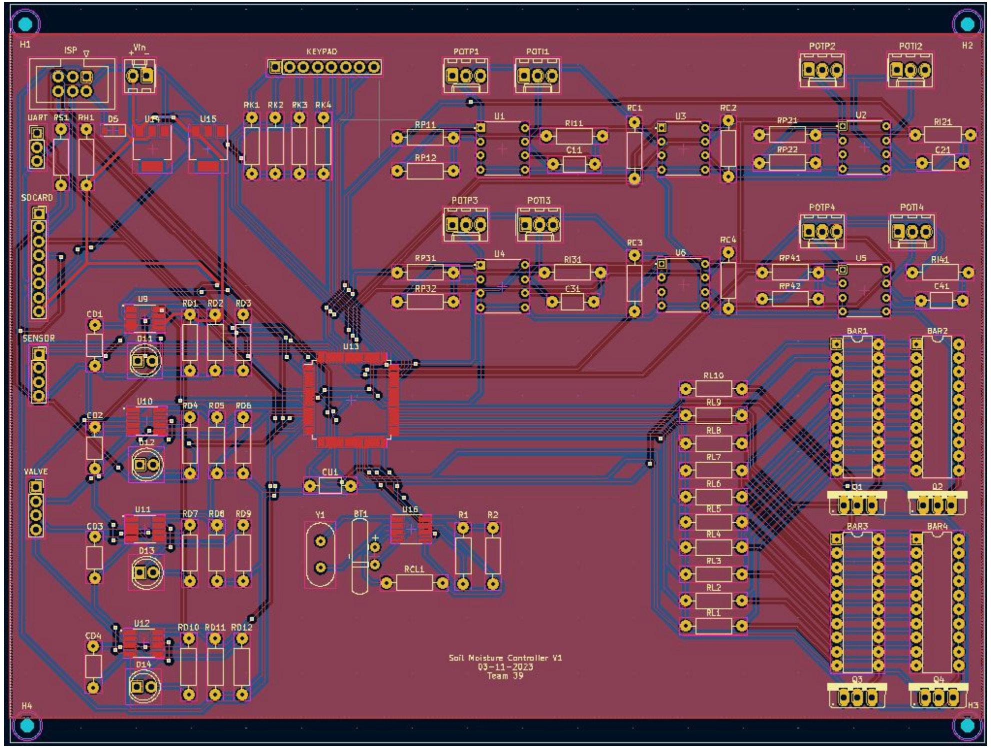
Limitations

- Each pot can only be watered for **at most four times a day**.
- The **opening time** of each valve is controlled instead of the flow rate.
- The opening time is independent of the soil concentration.

PCB Design – Schematic



PCB Design – Layout



Conclusion

Successes
Challenges
Future Work

Conclusion

Successes

Prototype is implemented and tested successfully inside the experiment's growth chamber

All high level requirements were met

Each subsystem works well with each other as expected

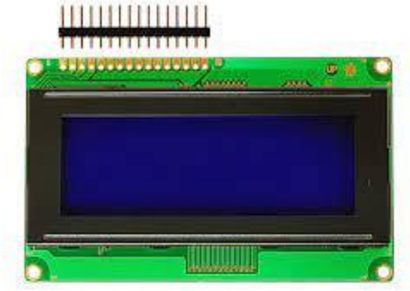
Challenges

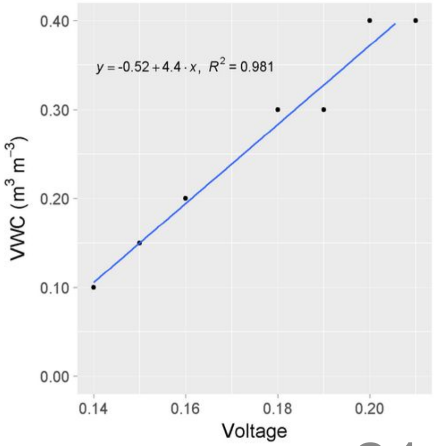
- **Changes in requirements**
  - Various changes affected the scope and design of the project entirely to fit the specific requirements
  - These changes also include restrictions onto the original design

- **Communication**
  - Different expectations and deadlines between both groups
  - Constant updates on meeting times and project issues

Future Work

- **Extension to 40 pots**
    - Current design only built for **4 different pots**
    - **Scalability** to any number of pots required – one PCB for each pot
- **User Display**
    - Comprehensive display of exact moisture level in each pot
    - **LCD screen**
- **Calibration to Different Substrate Types**
    - Current calibration curve only developed for solution with 20 mM NO3- and a solution with 5 mM NO3-
    - **Greater range of calibration curves** can be developed for various substrate types





Thank You!

Questions?

First Yingyord – phuriy2
Isabel Alviar – ialviar2
Ren Yi Ooi – rooi2

Power Supply Subsystem

RS-75-12 Power Supply

- 12V DC
- Rated Current = 6A
- https://www.meanwellusa.com/upload/pdf/RS-75/RS-75-spec.pdf

Irrigation Valves (each)

- 12W Power Rating
- 12V DC 1A Current Rating
- https://www.amazon.com/Electric-Solenoid-Normally-Solid-U-S/dp/B00APDNPXG/ref=sr_1_3?hvadid=580918680175&hvdev=c&hvlocphy=9022186&hvnetw=g&hvqmt=e&hvrand=12716180006677336 9&hvtargid=kwd-330045327273&hydadcr=26618_11681396&keywords=1%2F4+solenoid+valve+12v&qid=1680226210&sr=8-3

Arduino

- Capable of outputting 3.3V and 5V through its linear regulator

Sensors

- Minimum supply voltage of 2.5V DC at 10mA
- Maximum supply voltage of 3.6V DC at 10mA
- https://www.metergroup.com/en/meter-environment/products/ech20-ec-5-soil-moisture-sensor?sbrc=128FtFdfCwAj0hXgwQNcO-g%3D%3D%24CBeLrgD2AHEEuWT2pd8M3Q%3D%3D

MOSFETs

- Power MOSFET: IRFZ44N
- Gate threshold voltage of between 1V – 2V
- https://www.infineon.com/dgdl/irlz44npbf.pdf?fileId=5546d462533600a40153567217c32725

9V Battery (Rechargeable)

- Energizer
- Nominal Voltage = 8.4V
- Full Capacity Charge within 5 hours
- https://www.digikey.com/en/products/detail/energizer-battery-company/NH22NBP/4477695

Op-Amps

- LM358P
- Supply voltage = between 3V – 36V
- https://www.ti.com/lit/ds/symlink/lm358.pdf?HQS=dis-dk-null-digikeymode-dsf-pf-null-wwe&ts=1681900226395&ref_url=https%253A%252F%252Fwww.ti.com%252Fgeneral%252Fdocs%252Fsuppproductinfo.tsp%253FdistId%253D10%2526gotoUrl%253Dhttps%253A%252F%252Fwww.ti.com%252Flit%252Fgpn%252Flm358

Other connections

- V+ goes to one of the valve wires
- V- goes to Source of MOSFET
- The other valve wire goes to Drain of MOSFET
- Gate of MOSFET goes to Arduino

Source of MOSFET goes to ground